Scientific Research and Essays Vol. 6(25), pp. 5442-5456, 30 October, 2011
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE10.447
ISSN 1992-2248 ©2011 Academic Journals

Full Length Research Paper

CTM^4 model using Ishikawa diagram for quality management in design-and-build projects

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Accepted 13 July, 2010

In the demand for improved procurement methods, the design-and-build approach has become prevalent in the construction industry as a fast track strategy. However, the quality issues in design-and-build projects raise the alarm for attention. Competency of project managers in quality management of design-and-build projects may be questionable so that success is hard to achieve. This research intends to identify issues in implementing quality systems in design-and-build projects. A questionnaire survey was employed to collect data from 198 targeted project management consultant firms and construction management firms all over Malaysia. Finding shows that time constraint is the biggest obstacle in the implementation of quality system in design-and-build projects. Six root causes leading to success in design-and-build project have been identified, namely client, time, manpower, management, money, and material. The results of this study could be used as guidelines to successfully handle quality management in design-and-build construction projects in emerging economies in Asian, Africa and other developing regions.

Key words: Design-and-build, CTM^4 model, Ishikawa diagram, quality management, implementing quality system, critical success factors.

INTRODUCTION

Design-and-build system is one of the procurement systems introduced to overcome the problems associated with the traditional procurement, such as delay and over budget, while the innovative practices of the design-and-build system have been developed to cope with the growth in both private and public sectors (Chan and Yu, 2005). These innovations are referred to as reducing construction cost, shortening a tight construction programme, eliminating particular construction risks, and improving quality and durability of the finished tunnel structure (Marshall, 1999). However, Chritamara and Ogunlana (2002) argued that design-and-build procurement is imperfect due to unclear client's brief, lack of standard forms of contract, inadequate and insufficient information and coordination among parties, and late design changes. Lam et al. (2004) and Ling (2004) had identified key determinants that lead to success in design-and-build projects so that project managers would know the important variables that they must pay closer attention to, in order that their design-and-build projects can be completed within budget and schedule, to an acceptable level of quality, and to the owners' satisfaction. This study intends to focus on the project managers' point-of-views on the implementation of quality system in design-and-build projects especially using the Ishikawa diagram. The critical success factors are identified and advisable tools are suggested to achieve quality outputs in design-and-build construction projects.

QUALITY MANAGEMENT SYSTEM IMPLEMENTATION ISSUES IN DESIGN-AND-BUILD CONSTRUCTION

In the construction industry, the application of quality management concepts and tools is complicated due to its reactive nature and the complexities of the construction

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process (Kotter and Heskett, 1992; Serpell, 1999; Ling and Poh, 2008; Abdul-Aziz, 2002; Ling and Lau, 2002). Problems and constraints to integrate quality system with design-and-build construction projects are thus summarized.

Inaccurate project information

Inaccurate project information usually arose because of multiple contracts in design-and-build project and the information formed by one contractor was being used by other contractors. If the information is inaccurate, contractor who relied on the inaccurate information will precede the work wrongly. This may affect the implemented quality system as the work done is according to the wrong project information (Serpell, 1999; Ling and Lau, 2002).

Excessive change orders

In design-and-build construction, clients are not involved in the design stage or construction stage. Hence, large number of change order by clients might occur as they found the design is not meeting their satisfaction. This may be attributed to the lack of buidability of the design produced and the contractors are asked for the redesign on the production. Variation works can somehow prevent the quality system to run smoothly. It keeps on changing the quality system to suit the newly changed works (Ling and Lau, 2002).

Ineffective communication

Multiple contracts in design-and-build project, which gave rise to a large number of project participants, made the formal communication sluggish and inefficient. This will make most of the work orders not to be properly delivered among the project members and everybody may not have the same mindset while implementing quality system (Serpell, 1999; Ling and Lau, 2002).

Different quality culture among project stakeholder

Implementation of quality system in design-and-build construction is restrained by national markets where the clients, contractors and suppliers are not instilled with the same quality culture. Same quality culture is the key factor underpinning success in terms of developing the necessary commitment by all parties to any form of changes (Kotter and Heskett, 1992; Abdul-Aziz, 2002).

Different quality of material by various suppliers

In Malaysian construction industry, there are a lot of material suppliers who refer to different quality control system, that causes difficulties to assure the quality of the construction outputs in design-and-build projects (Abdul-Aziz, 2002).

Competitive bidding which emphasizes on cost

In design-and-build procurement, the client tends to tender the contractors with the lowest bid. However, the low tender bids by these contractors may not compromise with the required quality apart from the asked functionality. As a result, extra quality system implementation is needed and it imposes more cost to the project (Abdul-Aziz, 2002).

Fragmented construction industry

Generally, the construction industry comprises numerous professions. They are involved in the different phases in the construction project life cycle especially in design-and-build projects. Thus, implementation of quality system becomes more complex (Ling and Poh, 2008).

Non-standardization of construction industry

Due to the uniqueness of every construction project, it is impossible to apply universal standard or specification onto the construction product, which leads to difficulties in implementing quality system (Ling and Poh, 2008).

Time constraint

Design-and-build procurement is well known for its fast tracking benefit. Due to the short project completion times, most of the contractors are not willing to implement quality system in their works, as it takes extra time, which might drag their works behind. Moreover, contractors usually rush for a new project after the completion of previous one; and as a result they tend not to bother about the quality of their works (Serpell, 1999).

Lack of training and education in quality system

Quality system is difficult to be implemented if the project participants lack the knowledge on the quality manual and procedures. Some of the organisations find it as burden to give training and education to their staff because they have to bear the cost and the clients will not pay them extra for the expenses (Serpell, 1999).

Lack of commitment and interest

Low interest and commitment from the project members

can be an obstacle for the implementation of quality system. It will be worst if there is lack of organisation's top management leadership as they initiate the whole quality system (Serpell, 1999).

Human rejection due to extra works to implement quality system

It is norm that humans tend to reject something that implies extra works especially implementing quality system in design-and-build constructions (Serpell, 1999).

Insufficient control of projects

Implementation of quality system in design-and-build project is in vain if there is lack of control on the main parameter of the project management such as time, cost and quality (Serpell, 1999).

SUCCESS FACTORS IN DESIGN-AND-BUILD CONSTRUCTION

Success factors or positive aspects found in the cultural characteristics of the members of the construction companies can support the quality system implementation processes (Dwivedula and Bredillet, 2010). Construction project is commonly acknowledged as successful when it is completed on time, within budget, and in accordance with specifications and to stakeholders' satisfaction. Success factor is any knowledge, skill, trait, movie, attitude, value or other personal characteristics that is essential to perform the job or role and that differentiates solid from superior performance (Anand et al., 2010). More emphasis should be placed on the critical success factors so as to increase the chance of project success. The term critical success factors were first introduced by Rockart (1979). He defined critical success factors as those few key areas of activity in which favourable results are absolutely necessary to reach goals. They are the determinants that affect the success level of a construction project. A comprehensive review of the literature reveals that previous researchers pointed out various success factors in design-and-build construction.

Project characteristic

This factor concerns the features of a design-and-build project, including the project size, level of complexity and project location. In fact, the size of a project can be defined by the building cost, gross floor area, number or workers, duration of project and the value of contract (Yates, 1995; Songer and Molenaar, 1997). Project complexity can be measured by the types of physical services involved, the number of sub-contractors, resources in terms of labour, plant and materials, the level of technology and the uniqueness of project activities (Songer and Molenaar, 1997; Creswell and Clark, 2007). The smaller the project, the lesser complexity it can lead to project success. Project location can also be attributed to project characteristic and the soil condition can be measured to know the site compatibility. Good location and soil condition also serve as success factors in design-and-build project. Other important variable for this factor for design-and-build projects is the scope and definition of objectives (Yates, 1995; Songer and Molenaar, 1997). Project success rate will definitely increase if the scope and objectives are well defined. Whether the project is appealing to the contractor and whether the project provides scope for innovation by the contractor and the design teams can also affect the success level of a design-and-build project. If the project is innovative enough for the contractor to provide a better alternative, the chance of success can be higher. Hence, the attributes of project characteristics include the project size, level of complexity, project location, project scope, project objectives, appeal of the project and project scope for innovation.

Project cost

Project costs in design-and-build project consist of five areas, namely unit cost, cost growth, project intensity, availability of resources and accurate initial cost estimates. Unit cost is defined by the final project cost divided by the gross floor area. Cost growth shows how much final project cost is differed from the original contract sum. Project intensity indicates the workloads throughout the construction. Ling (2004) proposed these three performance metrics to be controlled in design-and-build project in order to achieve success. Unit cost and cost growth are better minimised to make sure the project is not overrun in term of cost. High project intensity will increase the cost due to massive front workloads and decrease the cost during the later stage. This can save a lot of cost especially for profit and overhead as well as plants rental at the end of project. Resources should always be available throughout the project's life as they are imperatives to carry out the projects (Nguyen et al., 2004). These resources refer to manpower, machineries and plants. According to Nguyen et al. (2004) the initial cost estimates must be accurate in order to ease the cost control at later stage, so as to ensure that the project is within budget.

Project time

In design-and-build project, project time can be managed

in three areas, which are construction speed, delivery speed and schedule growth (Ling, 2004). Construction speed indicates how fast the area constructed during the construction period. On the other hand, delivery speed is the overall speed, which takes into consideration the project duration from inception to the day the facility starts operation. Ling suggested maximizing the construction speed and delivery speed to ensure the project is completed within the given time frame.

Schedule growth shows how much works are lagging from actual completion date. Ling proposed to reduce the schedule growth as it will lead to higher probability of works delay.

Project quality

There are four aspects under project quality in design-and-build project, which are turnover quality, system quality, equipment quality and material quality. Projects with higher turnover quality are easy to start up and need minimum call-backs (Ling, 2004). System quality refers to the performance of building elements, interior space and environment in the project (Ling, 2004). Physical environment such as weather has an impact on project success (Beale and Freeman, 1991). Continuous fine physical environment can secure the chance to complete the project by the contractual completion date. The influence from government and politics can affect the success level of a design-and-build project (Okpala, 1991; Leung, 1999). Social environment such as influence from construction industry and social entities should also be considered as the success factor in design-and-build project (Beale and Freeman, 1991). Factors related to economics environment such as disequilibrium price and inflation should be taken into consideration (Okpala, 1991). Equipment quality indicates the performance of the equipment used in the project (Ling, 2004), while materials quality shows the performance of the material used in the project (Odeh and Battaineh, 2002).

Project work atmosphere

A pleasant and encouraging working atmosphere is beneficial to the success of a design-and-build project. How project participants look at a particular project can significantly affect their performance. For example, the contractor should be confident of the design and construction of a design-and-build project (Kok, 1995). Other team members should establish satisfaction, expectations and values from the project. A sufficient delegation of the project team decision-making authority can certainly raise their morale standards. When the project team members are psychologically fit to implement the design-and-build project, the chance of forming a consistent and well-integrated team can be increased, which is crucial to design-and-build project success (Rowlinson, 1997; Abdul-Rashid et al., 2006).

Such a project team is effective in eliminating communication problems, encouraging esteem and mutual trust (Deakin, 1999; Kok, 1995). The formation of team spirit strengthens the keenness of all parties to work as a team (Smith and Wilkins, 1996) and enhances cooperation to link interdependent functions together towards project success. Faith among the project team enables the contractor to use their own construction expertise at the greatest efficiency (Hidenori, 1995). Hence, the attributes of project work atmosphere include project team members' attitudes to the job, project team members' interaction with each other and project team members' working relationships with each other.

Project management strategies

Project management has been considered as one of the key determinants of project success (Smith and Wilkins, 1996). To draw the attention of project participants on both the project-related and company-related issues, proper communication and feedback channels should be set up in order to coordinate the large number of people. Progress and coordination meetings ought to be organised regularly to maintain the close cooperation of the design-and-build contractor with their client and design team. Variation control can also be applied to filter out unnecessary changes which could prolong the project completion date (Hidenori, 1995; Morledge et al., 2006). The contractor can be required to illustrate procedures that allow conflicts in design information to be solved in a systematic manner (Lamont, 1999). Detailed programming should also be planned to provide a rigid framework of programme dates to ensure the full integration of the design process into the overall progress (Hemlin, 1999). Indeed, the overall project programme should be properly structured and sequenced to accommodate the design process, which relies heavily on the management skills of the design-and-build contractor (Smith, 1999). The project management structure should be established to clearly define the appropriate organizational structures, roles and levels of authority (Smith and Wilkins, 1996). As a result, the performance and progress can be recorded and passed up quickly among the professionals to ensure timely decision-making and develop appropriate culture for the project team (Pearson and Skues, 1999). An effective implementation of project management actions also requires adequate systems for quality, risk, safety and more human-related conflict management at the planning stage so that project participants can have standard procedures to follow (Al-Meshekeh and Langford, 1999).

Quality assurance system such as regular monitoring and auditing of contractor's works can be introduced as one requirement of a design-and-build project to help

solve the problems of consultants' inability to supervise the work for the client (Chan and Lam, 1995; Leung, 1999). Controls were also placed on the end-users to reduce changes to project requirements (Chan, 2000).

Innovative management approaches like partnering should be employed to avoid escalation of potential problems (Chan et al., 2004; Deakin, 1999). Value engineering can be applied in some design-and-build projects to enhance value in relation to design and construction (Hidenori, 1995). As sub-contractors in design-and-build projects are normally required to provide design services, it is suggested that a team-based management structure rather than a traditional hierarchy should be adopted to make the sub-contractors aware of their importance to the overall success of the project (Beard et al., 2001). To employ good project management strategies in design-and-build project, a capable project manager is indeed very crucial (Nguyen et al., 2004). Hence, the attributes of project management strategies include communication and feedback systems, quality, safety, risk and conflict management systems, organizational structures and culture, systematic control mechanisms and the overall managerial actions in planning, organizing, leading and controlling, and last but not least the competency of project manager.

Project-related participants

The completion of a project requires input from a variety of human-related groups (Ruuska and Teigland, 2009; Munns and Bjeirmi, 1996). Project-related participants refer to the major parties to a design-and-build project, namely the client, the project team leader, contractor and design consultant, and the end-users who all contribute significantly to the success of a design-and-build project. A client can be defined as the person or firm responsible for commissioning and paying for the design and construction of a facility (Kamara et al., 2000). Clients can be classified into primary and secondary, or experienced and inexperienced (Love et al., 1998). They play a vital role in the successful outcome of the project. In design-and-build projects, the contractor develops the design according to the client's brief. The client should be able to brief his requirements in writing and be prepared to take an active role in the construction process to avoid a gap between the requirements of the client and other project team members (Kometa et al., 1995). Therefore, the level of experience of the client is critical to the success of design-and-build projects. The traditional goals of a construction project in terms of time, cost, and quality should also be stressed by the client to show its concerns and induce pressure to the project team members (Chan and Yu, 2005). The overall contribution of the client to the project is indeed necessary. The client's project team, the contractor and the design consultants are the key project participants in a design-and-build project and their respective team leaders form the main focus of this factor. They should possess all the necessary skills of a project manager, namely leading, planning, organizing and coordinating skills and perform to the greatest extent of their capability (Smith and Wilkins, 1996; Yates, 1995). They should have a clear understanding of the client's brief and be mindful to the business and cultural aspects of the company (Deakin, 1999).

As design-and-build projects require design inputs from the contractor, the team leader should first be able to develop the client's requirements by clearly formulating the intensions of the client (Leung, 1999). Indeed, all project team leaders should be devoted to the integration of specialized knowledge for a common purpose towards project success (Muller and Turner, 2010) and should have sufficient knowledge on design-and-build documentation and dissemination (Songer and Molenaar, 1996).

Apart from working within the constraints of the project itself, project team leaders should also possess certain human skills in coping with stresses, establishing good relationships among team members and inducing a harmonious working atmosphere (Smith and Wilkins, 1996). As the contractor becomes the single-point entity of a design-and-build project, he should possess the leadership skills to coordinate the various building professionals for both the design and construction works. Such team-building skills are increasingly required by the project team leaders to increase the project team's effectiveness (Hemlin, 1999). The traditional skills of an effective project team leader rests in the project or project-related aspects which are technical and social skills (Hauschildt et al., 2000).

One increasingly critical prerequisite, the adaptability to change, is also necessary to cope with constant and rapid change of technology, markets, regulations and socio-economic factors (Hemlin, 1999; Yates, 1995). Design-and-build procurement is known for time-saving with the fast-track principle. Without the coordination and support from the project team members, the success of the project can hardly be assured. One common element for the successful performance of the client and the project team leaders of the contractor and design consultants is the support from the parent company, which is a vital requirement to project success (Munns and Bjeirmi, 1996). Their commitment towards the project in providing resources and any administrative support is important. Such determination can be attributed to the size of the parent company. The authority delegated to the client and the project team leaders can also significantly affect the success of a construction project (Pitagorsky, 1998).

End-users in many cases are not the same as the client and the understanding of the needs of the end-users is also important to the success of a design-and-

build project (Deakin, 1999; Retherford, 1998). Therefore, the project team leaders should have end-users input and coordinate them in the successful implementation of a design-and-build project (Pearson and Skues, 1999). Hence, the attributes of project-related participants include client's experience, ability, emphasis on time, cost and quality, client's contribution to the project, project team leader's experience, project team leader's knowledge and skills, project team leader's commitment to time, cost and quality, project team leader's responsiveness to changes and external environment, project team leader's effectiveness to coordinate end-users, support from the parent company and end-user's ability to input.

Project procedures

Chan (1996b) analyzed project procedures under two sub-factors, namely procurement method and tendering method. In the search of success factors for design-and-build projects, the procurement form is focused on the integrated procurement system and some researchers consider the contractual issues important to the success of design-and-build projects (Akintoye, 1994). The use of the proper type of contract may increase the chances for success (Cheng et al., 2010). To procure a construction project such as hospital by design-and-build procurement, project procedure manuals were prepared to define the procedures to be adopted and define the means of ensuring adequate control so that the standard procedures, practices and systems can be observed throughout the life of the project (Pearson and Skues, 1999). Modifications were also made for design-and-build projects to strengthen the contract in design responsibilities (Chan, 2000). In fact, the focus of a contract should not be just on the choice of procurement, but the identification of risk and its equitable allocation since the clients have become increasingly concerned about the extent of risk they are exposed to (Akintoye, 1994; Chua et al., 1999).

There should be a more extensive assessment of the design quality that is backed up by a suitable form of contracts to promote quality in the design (Harris, 1999). In civil engineering and refurbishment projects, the contractor is even exposed to huge pricing risk and work uncertainty and a method statement should be drafted to provide information for the responsibilities at various stages of design and construction (Akintoye, 1994). The selection of contractors is being considered as a significant aspect in achieving project success of design-and-build projects (Chan and Yu, 2005; Deakin, 1999). In design-and-build projects, prequalification is necessary to make an initial assessment of the interested parties' suitability to undertake the works.

In prequalification of hospital projects, assessment criteria such as hospital construction experience and design-and-build experience were included (Chan, 2000). Other related issues, like the procedures and the system for tender evaluation also attract much attention (Lamont, 1999; Smith, 1999). The scoring system in tendering evaluation should also be formalized and be repeatable to avoid injustice (Molenaar et al., 1999). In the UK, a clear selection methodology with weightings assigned to the criteria is essential to procure projects by the design-and-build approach (Smith and Wilkins, 1996). Therefore, the appointment of a competent contractor can increase the chance of success. Hence, the attributes of project procedures include contractual arrangement and the tendering system.

Other success factors

Other success factors have been highlighted by Ling (2004) in her research. She suggested that by means of minimization, the administrative burden in design-and-build project can also lead to success in the project. This can be achieved by project managers in selecting capable contractor. Project manager can suggest a few number of competent contractors who have design capability, good track record for completing past projects to acceptable quality, on time and budget, have technical expertise, good health and safety capability. Not only that, the contractor needs to have high level of staffing to attend to the project so that the burden of administrative can be reduced to the minimum. Ling also proposed client's satisfaction as another project performance metric in design-and-build project, which needs to be attended by all the project members in design-and-build project. Design-and-build project is regarded as success if the client is satisfied with the overall works done. Therefore, every project team members need to fulfil every client's requirements in order to meet their satisfaction.

QUALITY CONTROL IN DESIGN-AND-BUILD CONSTRUCTION

Quality assurance is a programme covering activities necessary to provide quality in the work to meet the project requirements. On the other hand, quality control is the specific implementation of the quality assurance programme and related activities. Effective quality control reduces the possibility of changes, mistakes and omissions, which in turn results in fewer conflicts and disputes. There are few simple tools used to handle numerical data in daily quality control and improvement. One of these examples is Ishikawa Diagram. Ishikawa diagrams or cause and effect diagrams, also known as Fishbone diagrams are a measure to identify the root cause of a problem (Harris et al., 2006). An Ishikawa diagram is used in construction projects quality management to clarify the actual cause of any quality

Table 1. Issues of quality system implementation in Design-and-Build construction.

Issue of quality system implementation in design-and-build construction	
a)	Inaccurate project information
b)	Excessive change orders
c)	Ineffective communication
d)	Different quality culture among project stakeholder
e)	Different quality of material by various suppliers
f)	Competitive bidding which emphasizes on cost
g)	Fragmented construction industry
h)	Non-standardization of construction industry
i)	Time constraint
j)	Lack of training and education on quality system
k)	Lack of commitment and interest
l)	Human rejection due to extra works to implement quality system
m)	Insufficient control of projects

related problems such as delay. Thereafter, corrective actions can be implemented to rectify the matter arising. Ishikawa Diagram resembles a fishbone (hence the alternative name "Fishbone Diagram") - it has a box (the 'fish head') that contains the statement of the problem at one end of the diagram. From this box originates the main branch (the 'fish spine') of the diagram. Sticking out of this main branch are major branches that categorize the causes according to their nature. The Ishikawa Diagram is employed by a problem-solving team as a tool for collating all inputs (as to what are the causes of the problem they are addressing) systematically and graphically, with the inputs usually coming from a brainstorming session. It enables the team to focus on why the problem occurs, and not on the history or symptoms of the problem, or other topics that digress from the intent of the session. It also displays a real-time 'snap-shot' of the collective inputs of the team as it is updated.

RESEARCH METHODS AND PROCEDURES

From the review of past works, 13 issues of implementing quality system in design-and-build projects (Table 1) were identified. In addition, 44 potential success factors in design-and-build were identified from the literature (Table 2). The identified issues of implementing quality system in design-and-build projects (Table 1) and critical success factors in design-and-build projects (from Table 2) were ranked during analysis. Thus, a retrospective case study questionnaire (data collection instrument) was designed based on the factors and performance metrics uncovered from the literature review. The questionnaire was then finalized and distributed to project managers that handled design-and-build projects from start to finish in Malaysia. Several means were employed to deliver the questionnaires and to receive responses. However, the direct (face-to-face) delivery was preferred to motivate the respondents to participate and thereby improving response rate.

The survey respondents were asked to rank the issues of implementing quality system in design-and-build projects from 1 to 13. Meanwhile, to elicit the extent of significance of project success factors, the survey respondents were asked to rate against the five-point scale, from “not critical” (1) to “very critical” (5). Responses to the questionnaire were then analyzed. The analysis included ranking the issues of implementing quality system and the critical success factors in terms of degree of significance. One sample *t*-test was used to test the degree of significant of the identified success factors towards the quality success in design-and-build projects. The one sample *t*-test helps to determine whether the population mean is equal to a hypothesized value, which is the test mean. The test uses the standard deviation of the sample to estimate the population standard deviation. If the difference between the sample mean and the test mean is large relative to the variability of the sample mean, then the population mean is unlikely to be equal to the test mean. Before the test, the hypothesis must be set up, which are the null hypothesis and the alternative hypothesis. In one sample *t*-test, null hypothesis, H_0 assumes that there are no significance differences between the population mean and the sample mean. However, alternative hypothesis, H_1 assumes there is a significance difference between the population mean and the sample mean. In this study, a success factor is considered to significantly affect the quality success in design-and-build project when the significance level calculated using the Statistical Package for Social Sciences (SPSS) is less than 0.05 ($p < 0.05$).

ANALYSIS AND DISCUSSION

The questionnaire survey is sent to 198 firms of project management consultant and construction management. There are 79 individuals who responded to the questionnaire survey, which is equivalent to 39.9% of total questionnaire post. The valid data in table (???) represents the valid sample in this research which consisted of 79 respondents.

Ranking of issues of quality system implementation in design-and-build project

Based on the rank from 1 to 13, the ranking by the respondents are tabulated in Table 3, showing clearly the

Table 2. Success factors in design-and-build projects.

Success factors in Design-and-Build projects	
A.	**Project characteristic**
i.	Size
ii.	Complexity
ii.	Location
v.	Site condition information
v.	Scope
vi.	Objectives
ii.	Appeal of project
ii.	Scope for innovation
B.	**Project Cost**
i.	Unit cost
ii.	Cost growth
ii.	Project intensity
v.	Availability of resources
v.	Accurate initial cost estimates
C.	**Project Time**
i.	Construction speed
ii.	Delivery speed
ii.	Schedule growth
D.	**Project Quality**
i.	Turnover quality
ii.	System quality
ii.	Equipment quality
v.	Material quality
E.	**Project work atmosphere**
i.	Project team members' attitudes to the job
ii.	Project team members' interaction and relationship with each other
F.	**Project management strategies**
i.	Communication and feedback systems
ii.	Quality, safety, risk and conflict management
ii.	Organizational structures and culture
v.	Systematic control mechanisms
v.	Overall managerial actions in planning, organizing, leading and controlling
vi.	Competency of project manager
G.	**Project-related participants**
i.	Client's experience
ii.	Client's ability
ii.	Client's emphasis on time, cost and quality
v.	Client's contribution to the project
v.	Project team leader's experience
vi.	Project team leader's knowledge and skills
ii.	Project team leader's commitment to time, cost and quality
ii.	Project team leader's responsiveness to changes and external environment
x.	Project team leader's effectiveness to coordinate end-users

Table 2 Contd.

κ.	Support from the parent company
i.	End-user's ability to input
H.	**Project procedures**
i.	Contractual arrangement
ii.	Tendering system
I.	**Others**
i.	Administrative burden
ii.	Client's satisfaction

Table 3. Issues of implementing quality system in design-and-build project.

Issues of implementing quality system in Design-and-Build Projects	Mean	Rank
a) Inaccurate project information	7.97	11
b) Excessive change order	7.05	8
c) Ineffective communication	6.55	3
d) Different quality culture among project stakeholder	6.64	5
e) Different quality of material by various suppliers	8.28	12
f) Competitive bidding which emphasizes on cost	6.26	2
g) Fragmented construction industry	7.08	9
h) Non-standardization of construction industry	6.97	7
i) Time constraint	6.05	1
j) Lack of training and education on quality system	6.63	4
k) Lack of commitment and interest	8.39	13
l) Human rejection due to extra works to implement quality system	6.82	6
m) Insufficient control of projects	7.34	10

issues of implementing quality system in design-and-build project. The smaller the score of mean ranking, the higher rank the issue of implementing quality system in design-and-build project. The respondents tend to agree with the issues identified as hinderance of implementing quality system in design-and-build project. Most of the respondents tend to agree that time constraint is the main obstacle of implementing quality management in design-and-build project, showing a lowest score mean value of 6.05. The highest score achieved 8.39 of mean value, for the factor 'lack of commitment and interest'. With this, generally, all the factors in Table 3 are significant issues to the project managers in implementing quality system in design-and-build project. Other issues like cost of implementing quality system are also suggested by some of the respondents.

Success factors in design-and-build project

The one sample *t*-test was used to test whether the various attributes identified earlier were significant in influencing the success of design-and-build project in Malaysia. Table 4 shows the success factors in design-and-build project with their mean value, *t*-value, standard deviation and significant value. A five-point Likert scale was used to measure the attributes influence on the success of design-and-build project. In this scale, 1 represents "Not critical", 2 represents "Less Critical", 3 represents "Average", 4 represents "Critical", and 5 represents "Very Critical". To interpret the results of the *t*-test, the test significant level was compared against the level of significance, which was set at 0.05 at the 95% confidence level. It can be seen from the Table 4 that all the success factors have significant level less than 0.05, except size (0.057) and location (0.133). The decision was to reject null hypothesis, H_0 for the 41 success factors, which have significant level less than 0.05. This seems to suggest that all the 41 factors have an impact on success of design-and-build project except project size and project location.

Next, a ranking of these 41 success factors was carried out to determine the relative importance of the various success factors as perceived by the respondents.

Table 4. Results of one sample *t*-test.

Category	Success Factor	Test value = 3			
		Mean	*t*-Value	Standard deviation	Significant (2-tailed)
A) Project characteristic	Size	3.308	1.966	0.977	0.057
	Complexity	3.590	3.368	1.093	0.002
	Location	3.282	1.537	1.146	0.133
	Site condition information	3.385	2.569	0.934	0.014
	Scope	3.539	3.571	0.942	0.001
	Objectives	3.513	3.891	0.823	0.000
	Appeal of project	3.333	2.397	0.869	0.022
	Scope for innovation	3.590	4.185	0.880	0.000
B) Project cost	Unit cost	3.641	4.434	0.903	0.000
	Cost growth	3.615	3.782	1.016	0.001
	Project intensity	3.641	4.434	0.904	0.000
	Availability of resources	3.821	4.889	1.048	0.000
	Accurate initial estimates	3.974	5.154	1.181	0.000
C) Project time	Construction speed	3.821	5.438	0.942	0.000
	Delivery speed	4.026	6.676	0.959	0.000
	Schedule growth	3.821	5.141	0.997	0.000
D) Project quality	Turnover quality	3.615	5.402	0.711	0.000
	System quality	3.513	3.748	0.854	0.001
	Equipment quality	3.539	4.451	0.755	0.000
	Material quality	3.923	5.860	0.984	0.000
E) Project work atmosphere	Project team members' attitudes to the job	3.792	5.011	0.959	0.000
	Project team members' interaction and relationship with each other	3.667	4.025	1.034	0.000
F) Project management strategies	Communication and feedback systems	3.795	4.941	1.005	0.000
	Quality, safety, risk and conflict management	3.846	5.664	0.933	0.000
	Organisational structures and culture	3.667	4.793	0.869	0.000
	Systematic control mechanisms	3.692	3.835	1.128	0.000
	Overall managerial actions in planning, organizing, leading and controlling	3.821	5.010	1.023	0.000
	Competency of project manager	3.872	5.283	1.031	0.000
G) Project-related participants	Client's experience	3.615	5.141	0.747	0.000
	Client's ability	3.692	4.841	0.893	0.000
	Client's emphasis on time, cost and quality	4.231	7.797	0.986	0.000
	Client's contribution to the project	3.462	3.376	0.854	0.002
	Project team leader's experience	3.897	5.357	1.046	0.000
	Project team leader's knowledge and skills	4.000	6.245	1.000	0.000
	Project team leader's commitment to time, cost and quality	3.923	4.987	1.156	0.000
	Project team leader's responsiveness to changes and external environment	3.846	5.211	1.014	0.000
	Project team leader's effectiveness to coordinate end-users	3.692	4.198	1.030	0.000
	Support from the parent company	3.436	3.611	0.754	0.010
	End-user's ability to input	3.333	2.179	0.955	0.036
H) Project procedures	Contractual arrangement	3.821	5.997	0.854	0.000
	Tendering system	3.564	3.864	0.912	0.000
I) Others	Administrative burden	3.667	4.970	0.838	0.000
	Client's satisfaction	3.846	5.350	0.988	0.000

Table 5. Ranking of critical success factors in design-and-build project.

Critical success factor		Mean	Rank
A	Client's emphasis on time, cost and quality	4.231	1
B	Delivery speed	4.026	2
C	Project team leader's knowledge and skills	4.000	3
D	Accurate initial estimates	3.974	4
E	Material quality	3.923	5
F	Project team leader's commitment to time, cost and quality	3.923	6
G	Project team leader's experience	3.897	7
H	Competency of project manager	3.872	8
I	Quality, safety, risk and conflict management	3.846	9
J	Client's satisfaction	3.846	10
K	Project team leader's responsiveness to changes and external environment	3.846	11
L	Contractual arrangement	3.821	12
M	Construction speed	3.821	13
N	Schedule growth	3.821	14
O	Overall managerial actions in planning, organising, leading and controlling	3.821	15
P	Availability of resources	3.821	16
Q	Communication and feedback systems	3.795	17
R	Project team members' attitudes to the job	3.792	18
S	Client's ability	3.692	19
T	Project team leader's effectiveness to coordinate end-users	3.692	20

However, only the top 20 ranked success factors will be considered as the critical success factors. Table 5 ranks these critical success factors based on mean value. It shows that the three most critical success factors identified were client's emphasis on time, cost and quality (4.231); delivery speed (4.026); and project team leader's knowledge and skills (4.000). These three critical success factors also have mean rank greater than or equal to 4, which are also equivalent to "critical" on a five-point Likert scale in the questionnaire.

Using the Ishikawa method to identify critical success factors in design-and-build project

These top 20 ranked critical success factors from Table 5 will be grouped into six root causes and transferred into the Ishikawa Diagram or so called Fishbone diagram that can lead to a better quality design-and-build projects in Malaysia. The author considers that some of the critical success factors will overlap as they appeared in other groups of root cause. This model will serve as a quality control tool for the project managers to implement quality system in local design-and-build projects. The author gave the name of this model as CTM^4 after the first letter of each group's name. There are Client, Time, Manpower, Management, Money, and Material. These six items appear to be very crucial in Malaysia design-and-build projects as they were rated as most important by local project managers, which is inclusive of the top 20 ranked critical success factors in Table 5. Table 6 shows the six identified root causes with related twenty critical success factors from Table 5. Moreover, Figure 1 shows the CTM^4 model in Ishikawa diagram.

Critical success factors in design-and-build projects

By using Ishikawa Diagram, the authors have grouped the critical success factors in design-and-build projects into six main root causes, which are Client, Time, Manpower, Management, Money, and Material. Next, the authors will further discuss on how these critical success factors can be achieved and lead to success in design-and-build projects

Client

The client component grouping comprises client's concern, satisfaction and ability. This component emphasizes that successful design-and-build projects are implemented with the involvement of client. In nature of the design-and-build projects, client does not interfere in the design stage and construction stage as the design and construction responsibilities are transferred to the contractors. However, client should be able to show his or her concerns and induce pressure to the project team members by laying emphasis on the common goal of design-and-build projects in terms of time, cost and

Table 6. Root causes regarding critical success factors in design-and-build projects.

Root cause	Cause	Critical success factor
Client	Concern	A
	Satisfaction	J
	Ability	S, P
Time	Speed	A, B, M
	Commitment	F
	Scheduling	A, N, O,
Manpower	Project manager	H, P
	Team leaders	C, F, G, K, T, P
	Team members	R, P
Management	Planning, organising, leading and controlling	H, O
	Establishment of management divisions	I, L, O, Q
Money	Estimating and controlling	A, D, O, P, S
	Commitment	F
Material	Quality	A, E, J, P

Refer the critical success factor from Table 5.

quality. Client's satisfaction is also one of the important measures to ensure quality success in design-and-build projects. Thus, project team members should be able to deliver the project well to meet the client's expectation. To achieve this goal, client should assist the team members from the inception stage of the projects by briefing his or her requirements in writing with high level of clarity. Hence, misunderstanding on the project goals can be avoided and lead to zero variation orders, which can drag the project time into longer. Client's ability is also very important especially the funding. Adequate funding until project completion is obvious imperative to carry out the projects. They ensure the projects run smoothly.

Time

Time is also another prerequisite for the success of design-and-build projects. This component includes speed, commitment and scheduling. Client's emphasis on time by putting pressure on the project team members can be treated as a powerful force to push the team members to their optimum performance. This can shorten the time of the construction duration. Maximising the construction speed and delivery speed are also the other ways to accelerate the construction stage. Whenever the client imposes pressure onto the project team leaders, they should take this pressure as a thrust to delivery works on the fastest track. They have to show their commitment to the fullest before asking other team members to put in their best efforts. In fact, this is the best way to lead the other team members in real life practise. Client should also lay emphasis on the actual time frame for the whole project in the beginning of the projects. Next, it is the responsibility of the project team members to minimize the schedule growth as much as possible to mitigate delays. Controlling tools like Critical Path Method (CPM) and Project Evaluation and Review Technique (PERT) can be adopted in effective project scheduling.

Manpower

Manpower is widely recognised as an important factor for the success design-and-build projects. It reflects all the project members and affected people are strongly interested in projects such as project managers, project team leaders and other team members. It should be implied that these resource are the engine that drives the design-and-build projects into success. A competent project manager should impose not only technical and managerial skills but also leadership to guide the rest of the team members. As a team leader, one must be very capable in terms of knowledge, skills and experience. Team leaders should be very committed to the project in various aspects namely time, cost quality. At the end of the project, they should make sure the project is completed within the given time frame, budgeted cost, and acceptable level of quality. Variation order always happens in design-and-build projects and the team

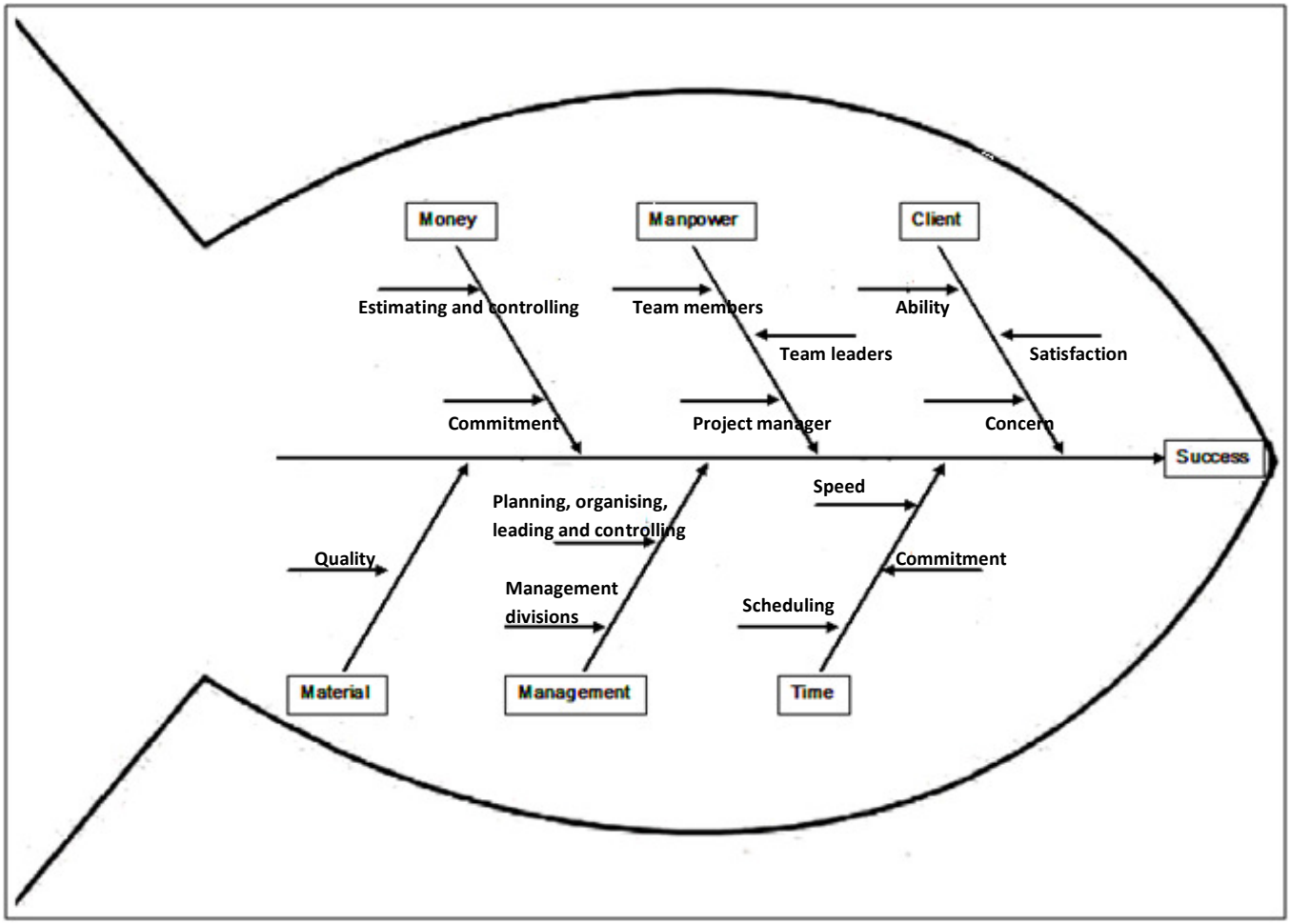

Figure 1. CTM[4] model in Ishikawa diagram based on the result of studies in critical success factors in Design-and-Buildprojects

leaders have the ability to cope with these changes and external environment. Team leaders should also take into consideration the end-users' opinion and try to integrate it into the project for better quality of output. There is no doubt that other team member's attitudes towards the job can affect the project performance. Thus, availability of these manpower resources in design-and-build projects is a must if success is to be assured.

Management

Management component plays a vital role in order to make the design-and-build project a success. It consists of most of the common managerial actions like planning, organising, leading, and controlling; and establishment of different management divisions. Planning, organising, leading and controlling are the basic principals in management strategy. It can be applied in any part of design-and-build projects to achieve the project goals and objectives. Establishment of management division will make another effective strategy in managing a design-and-build project. Each of the division set up will be in charge of that particular area of the project. These divisions could be quality division, risk division, safety division, communication division, contractual division and more. The ordinary managerial actions will be adopted in each division for better project handling.

Money

This component is undeniable the most crucial in making the whole design-and-build project run. A project can only be started when this component exists in nature and it shows the importance of its availability in the project. This component comprises budgeting and controlling as well as commitment. Client's financial ability must be very solid in funding the project. Contractual management in the project will help to budget the overall project and also choose how the project is being procured. Again in this, the basic management actions will be used for the cost budgeting and cost controlling purposes. Commitment from the project team leaders in money component is also important. They are the ones liable for the losses and expenses. The other team members work under the instructions from them. Therefore, they must manage this component wisely.

Material

Last but not the least, this component also determines the success of the projects. Quality of the material was ranked five among the other factors. If the quality of the materials meets the client's requirement, definitely the quality of the outputs will achieve a very high satisfaction from the client. Thus, in the beginning of the project, client must lay emphasis on what kind of quality is required in the specification of the projects. Next, the type of materials used will be chosen to meet the quality and client's satisfaction.

Conclusion

For the most important factors that stop the implementation of quality system in design-and-build project is the time constraint. Apart from that, client's emphasis on time, cost and quality, delivery speed and project team leader's knowledge and skills are among the critical success factors in Malaysia design-and-build project. Top 20 ranked critical success factors in design-and-build project from the questionnaire survey are presented in Ishikawa Diagram as CTM^4 model to serve as a practical advisory tool for project managers in the industry. In a nutshell, design-and-build project managers should be capable enough in suggesting appropriate contractors to the clients. Design-and-build contractors bear higher initial tendering cost and higher risk that the contractors and clients need to cooperate closely in order to realize the system. Thus, it is the project manager who works on behalf the client, serves as the medium for both the client and contractor to communicate well. Quality indeed saves cost by first time right works. No matter what is the scale of the projects, the project managers shall be serious in managing the quality of the projects and emphasizes the community welfare in long-term to ensure sustainable business environment and uphold their reputation besides ultimately generate profits. A good track record and quality management practice and additional recognition and qualification achievements by the project team members will benefit and satisfy all the stakeholder of the projects. Malaysia project managers shall continuously improve their expertise and be equipped with knowledge and skill apart from leadership to perform better in order to face the challenges of globalization and liberalization of local market.

RECOMMENDATIONS FOR FUTURE RESEARCH

Success of construction projects depends on several aspects, which may include human-related factors, project-related factors, project management-related factors and factors related to external environment. Depending on their needs, different participants in construction may have divergent interests in the project, but they must have an agreement, in principle, about project objectives and critical factors that can help to achieve those objectives. Results in this study reveal that most of the high-rated critical success factors in design-and-build project are related to project planning and control, personnel and involvement of client. In terms of practical application, project leaders can use these findings to establish critical success factors for their own construction projects in Malaysia. Project leaders can also compare these success factors with real success factors if they have already accomplished them in the past. This can prove to be a healthy knowledge management exercise and can be used as baseline for establishing and implementing performance enhancement strategy for Malaysia construction projects. Also, project managers can work out measures for improvement in order to raise the probability of success and reduce the chances of any setbacks in their own projects. With and apart from that, a few recommendations of research area are proposed:

1. Success factors for public-private partnerships project.
2. The level of quality performance in partnering projects and the concept of Public-Private Partnership (PPP) in Malaysia.
3. Correlation of organization culture and the quality management performance.
4. The efficiency and quality of outsourcing work compared to in-house expert production in construction.
5. Total innovative management in Malaysia construction industry.
6. Sustainability of integrated quality management system in construction industry.

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