IMPACT OF DESIGN CHANGES IN CONSTRUCTION PROJECT

Nurul Huda Muhamad[1], Mohammad Fadhil Mohammad[2]
Faculty of Architecture Planning & Surveying, Universiti Teknologi MARA, Seri Iskandar Campus, Seri Iskandar, 32610, Perak, Malaysia.
Faculty of Architecture Planning and Surveying, Universiti Teknologi MARA, 40450, Shah Alam, Selangor, Malaysia.

nurul885@perak.uitm.edu.my

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ABSTRACT

Design changes in construction projects are always going to happen and cannot be avoided. Design changes are the primary contributor to disruption of time and cost performance of construction projects. Previous research in this domain lacks of detail studies on systematic review on the existing literature. This paper reviewed literature published in peer-reviewed journals and conference proceedings in the construction management field and had emailed several questions to the expert in construction industry. The objectives were to recognize the causes and impacts of design changes on project performance and to provide insights for future studies in Malaysian context. The findings indicate that design changes originate mainly from the owner side are identified as important causing factors to time overruns and cost overruns. This paper proposes framework for the management of design changes in construction projects.

Keywords: *Design changes, Time overrun, Cost overrun, Project performance*

INTRODUCTION

Malaysian construction sector was projected to grow at 8.0% for 2017 and up to 10.3% for 2018 (CIDB Report, 2017). The construction sector is expected to have a sustainable demand approximately at RM170 billion for 2017 and RM180 billion for 2018 (CIDB Report, 2017). Therefore, due to the large investment involved, there is a critical need to sustain the successful delivery of construction projects. According to Chan and Lee (2014), as Malaysia aims to be a developed country by year 2020, the construction industry has since been identified as a major catalyst for the country to attain the status. As such, the construction industry is on the upswing, and projects are becoming increasingly complicated. Besides, designs are larger and more complex, leaving construction companies with very narrow margin for error.

The considerable amount of research recognized the prevalence of design changes and their resultant cumulative negative impact on project performance (Han et al., 2012; Gde Agung Yana et al., 2015; Peansupap and Cheang, 2015; Yap and Skitmore, 2017, Yap et al., 2017). However, reasons for cost and schedule increases arising from design changes are not formally studied (Chang, 2002). Chang (2002) mentioned that identifying the reasons is usually the first step when addressing a problem, and the corrective action can be taken into consideration (Chang, 2002). Questions regarding the causes of design changes remain unanswered. To date, there seems to be limited studies for summarizing what has already been presented in the literature. To fully understand the resulting problem caused by design changes, firstly their source and nature need to be understood, and why they arise. Hence, the need of a systematic review of existing literature in this domain should be amplified. Therefore, the objectives of this study were to recognize the causes and impacts of design changes on project performance and to provide insights for directing further studies in Malaysia context. It is hoped that this study can assist researchers in gaining an in-depth understanding of previous research efforts on the causes of design changes and their impact on time and cost performance in the construction projects.

OVERVIEW DESIGN CHANGES IN CONSTRUCTION PROJECT

Design changes occur when changes are made in the project design or requirements (Burati et al. 1992). Abdul-Rahman et al. (2016) defined design changes as regular additions, omissions and adjustments to both design and construction work in a construction project that occurs after the award of contract which affects the contract provisions and work conditions that make construction dynamic and unstable. Similarly, Mohamad et al. (2012) defined a design change as any change in the design or construction of a project after the contract is awarded and signed. According to Park (2002), changes in the design work that have been made by mistake can cause subsequent changes in construction. In addition, Akinsola et al. (1997) highlighted the modification or changes to design after the contract was awarded. As a result, variations were created which are likely to be a major cause of disruption, disputes, and claims.

Causes of Design Changes

Burati et al. (1992) classified the design changes into seven categories; design change/improvement, design change/construction, design change/ field, design change/owner, design change/process, design change/ fabrication, and design change/ unknown. Another study by Chang et al. (2011) found that design changes result from three categories of reasons: under owner's, designer's, and beyond control. Similarly, Peansupap and Cheang (2015) in their research, assert that classification of changes focusses on the change in construction project that occurs from several originators such as owner/client, designer, and other parties. They found the most of the important change issues leading to conflicts about project cost originate mainly from the owner's side. This corroborates Gde Agung Yana et al. (2015) and Mohamad (2012) findings that the owner is the greatest influential factors on the occurrence of the design changes. This aligns with Mohammad et al.'s (2010) claim that the owner is the major source of variation orders in construction of building projects. Similarly, in Hwang et al.'s (2014) study, they found that the client contributed most to rework. On the other hand, Yap et al. (2016) mentioned that numerous studies show that client-related changes have a significant impact on the project performance. Various causes of design changes have been identified by many researchers in different regions (Mohamad et al., 2012). Therefore, the common causes of design changes as recommended by each researcher are presented in Table 1.

Table 1: The Causes of Design Changes as Identified in Literature

	Change of requirement/specification	Addition/omission of scopes	Slow decision making	Unclear initial design brief	Lack of coordination among	Erroneous/discrepancies in design	Design omissions/incomplete	Inexperience consultant	Unforeseen ground conditions	Changes in government regulations, laws
Yap & Skitmore (2017)	√	√	√	√	√	√	√	√	√	√
Gde Agung Yana et al. (2015)	√	√	√	√	√	√	√	√	√	√
Hwang et al. (2014)	√	√	√							
Mohamad et al. (2012)	√	√		√	√	√				
Chang et al. (2011)	√	√	√		√	√	√	√	√	√
Love & Li (2000)	√			√		√	√			
Cox et al. (1999)	√						√		√	

Through the literature review, ten causes of design changes were identified and summarized in Table 1. Frequently, cited causes for design changes included: employer has changed his requirement/specification, employer's addition/omission of scopes, slow decision making, unclear initial design brief, lack of coordination among various professional

disciplines/consultants/client, erroneous/discrepancies in design documents, design omissions/incomplete drawings, inexperience consultant, unforeseen ground conditions, and changes in government regulations, laws, and policies.

The most common causes of design changes cited by previous researchers was change of requirement or specification by the client. Client's requirements often change during the course of a project for a variety of reasons (Sun and Meng, 2009). According to Hwang et al. (2014), the change of project plans or scope initiated by the client after the work is undertaken means re-doing the work based on to the new plans or scope. Every time a change was made in design, it had to be reworked by design team, which in turn affected their fee (Love and Li, 2000). On the other hand, changes in specification results in variations to the project, leading to delay and increased overall cost (Memon and Abul Hassan, 2014). Similarly, Sunday et al. (2017) found that errors related to specifications account constituted 57.6% of the total errors which led to variations in construction projects. There are many problems that are yet to be solved in the specifications of construction drawings (Sunday et al. 2017).

These causes were followed by addition or omission of scopes. This is the result of inadequate planning at the project definition stage or because of lack of involvement of the owner in the design phase (Arain et al. 2004). Changes in design are frequent in projects where construction starts before the design is finalized. For for instance, in the concurrent design and construction (Chappell and Willis, 1996; Al-Hazmi, 1987; Arain et al. 2004). Besides, design omissions may lead to loss of productivity and delay the project schedule (Al-Hazmi, 1987). Whenever a change order occurs, it needs to add, delete or modify the original plans and specifications accordingly (Arain et al. 2004).

Another common causes of design changes cited by previous researchers was erroneous or discrepancies in design and design omissions. Design complexity may cause discrepancies at project interfaces (Arain et al. 2004). An interpretation problems due to incomplete plans and specifications might create discrepancies at the design and construction interface (Al-Hazmi, 1987). According to Sung and Meng (2009), design errors and omissions can be caused by human error on the part of architects,

structural engineers, as well as building services engineers. Design errors which are not rectified during the design phase, will eventually appear in the construction phase where the impact can be more severe than at the design phase (Chappell and Willis, 1996). In addition, increased client demands for earlier project completion is another factor that has been identified as a major contributing factor to the production of incomplete and/or erroneous contract documentation (Love et al. 2004).

Other common causes of design changes cited by previous researcher was lack of coordination among consultants. Coordination is important in a multi-participant environment as in most construction projects (Al-Hazmi, 1987; Clough and Sears, 1994). A lack of coordination between parties may cause conflicts that could eventually impact the project adversely (Arain et al. 2004). For better coordination during the project, mutual respect plays a vital role because the participants consider all decisions and opinions for the betterment of the entire project (Arain et al. 2004). Besides, more coordination and cooperation between parties is required especially in the use of exotic designs and technology as to reduce discrepancies (Arain et al. 2004). Hence, a successful project delivery requires good collaboration between all parties involved (Sung and Meng, 2009).

Lastly, another common causes of design changes cited by previous researchers were slow in decision making by client, unclear initial design brief and unforeseen ground conditions. Inexperienced one-off clients are prone to causing late changes due to delays in review and approvals (Sung and Meng, 2009). According to Sung and Meng (2009), poor brief development at the start of a project often leads to a wrong understanding clients requirements and wrong assumptions on key project aspects. In addition, inadequate soil condition survey and unknown geological conditions would often result in necessary amendment to design remedial actions to building work (Sung and Meng, 20009).

The least common causes of design changes cited by previous researchers was changes in government regulations and law and inexperience consultant. Local authorities may have specific codes and regulations that need to be accommodated in the design (Arain et al. 2004). Unfamiliarity with government regulations would made the project difficult to execute (Arain et al. 2004). Codes such as environmental or labor codes were revised

periodically for compliance by the designer and contractor (Assaf and Al-Hammad, 1988, Arain et al. 2004). According to Sun and Meng (2009), change in government legislation and regulation with regards to health and safety, planning, employment, environment, taxation, etc is source of project change amy affect the smoothness of the construction.

Impact of design changes on project performance

According to Yap and Skitmore (2017), the detrimental (direct) effects of design changes on project performance are rework, schedule delay resulting in longer project duration and cost overruns from the additional resources and wastage involved. Burati et al. (1992) found that design and construction produced the greatest deviation of construction cost (direct cost). They defined deviation include changes to the requirements that result in rework, as well as products or results that do not conform to all specification requirements, but do not require rework. The findings of the study showed that the deviation was 12.4% of the total cost of a project. They suggested that the deviation caused by design changes was 78% of the total deviation, 79% of the deviation of costs and 9.5% of total construction cost for the nine industrial projects studied.

Yap and Skitmore (2017) revealed that building projects in Malaysia encounter time-cost overruns of 5-20% due to design changes. Chang et al. (2011) found that construction cost changes on average 8.5% arising from design changes. Yap et al. (2017) found that the cost rework to range from 3.1% to 6.0% of project value and schedule growth due to rework to range from 5.1% to 10.0%. Burati et al. (1992), stressed that rework costs are a significant portion of total costs. In addition, Bakhary et al. (2015) found that design changes being introduced at the post-tender stage is the main reason for claims, whileYap et al. (2017) found that an indirect effects of design changes and rework are a notable delay and disruption as well as unneccasry claim and dispute.

Furthermore, Sunday et al. (2017) found that most of the causes of variation cost are design related. This is substantiated by most literatures that are reviewed in their study. Memon and Abdul-Rahman (2014) found that change in design is one of the most important causes of variation in construction projects. They further recommended that the consultant must

focus on controlling the recurrent change in design; avoid inadequate working drawing details through systematic detailing of the design.

Table 2: Limitation of Quantum of Schedule Delay and Cost Overrun Arising from Design Changes as Identified in Literature

Sources	Country	Schedule Delay (%)	Cost Overrun (%)	Type of Projects	No of Projects / No of Respondents
Burati et al., (1992)	USA	-	12.4	Industrial	9 projects
Chang (2002)	California	69	24.8	Roadway	4 projects
Chang et al. (2011)	Taiwan	-	8.5	Highway widening, new highway, landscape bridge, sewer	7 projects
Yap & Skitmore (2017)	Malaysia	5-20	5-20	Building	338 clients, consultants & contractors

There have been several studies quantifying the magnitude of time overruns and cost overruns arising from design changes based on different type of projects, location of study and limitation of the population (see Table 2). Every construction industry has its nature, culture and regulations; these factors can change as a result of the above differences.

METHODOLOGY

This paper is part of an on-going research on the design changes in construction projects which is still at the initial stage. The research methodologies employed were literature review and preliminary study. An in-depth and critical literature review was conducted in this study. A literature review was the first phase of the research. It discusses and reviews on design changes and the impacts to project's time and cost performance. In this preliminary study, the distribution of initial questionnaires survey had been sent through email to the expert panels to narrow down the scope of the topic. In this research, the respondents' and the results were summarized

based on the initial questionnaire surveys provide evidence from the experts in evaluating the impact of design changes on construction project performances. The reason of selecting the experts' panel as the respondents during the survey is due to their experience in evaluating the impact of design changes on construction project performances. Their designation as the experts are also extended to being practitioners players who are; 1) Director of Construction Contracts Consultants who has over 22 years of experience in quantity surveying and construction contracts consultancy and a panel arbitrator and adjudicator with KLRCA (Kuala Lumpur Regional Centre for Arbitration) 2) Deputy Project Director of Construction Consortium who had worked in established niche player in the design engineering and construction industries. The exploratory questionnaire employed put forward questions examining the respondents' opinion on evaluating the impact of design changes in construction project performance.

FINDINGS AND FORMULATION OF FRAMEWORK

A framework for the management of design changes in construction projects was established by placing emphasis on indirect effects of design changes to project performance that are a notable delay and disruption. In addition, the claims and disputes are proposed (refer to Figure 1). This framework can be deployed to provide effective communication platform through predictive framework in order to understand the dynamics of design changes, the knock-on effects due to rework that cause delay and disruption and possible degradation of project time and cost performance. Therefore, practitioners can refer to the framework for clued-up decision-making at the point of design change request. Hence, the impacts can be envisaged at the early stage in order to minimize the risk of project to potential claims and disputes at the end of the project.

As aptly put by Han (2013), reworks is unnecessary effort of redoing a process or task that was incorrectly implemented the first time. Robinson-Fayek et al. (2003) found the engineering and review processes for an engineering project contributed to 68% of rework costs with 78% of this total attributable to design errors. Similar with Simpeh et al. (2015), rework can make a significant contribution to a project's cost overrun.

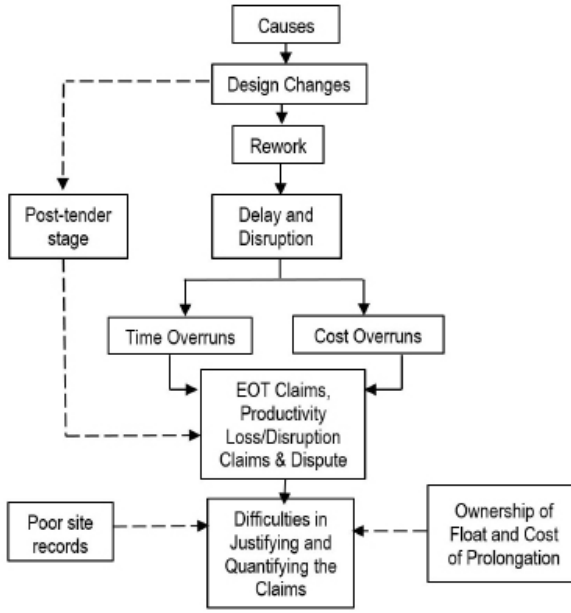

Figure 1: The Conceptual of Design Change Management Framework

According to Sun and Meng (2009), the most frequent effects of design changes were increase in project costs and delays in completion. This is in line with panel expert comment that design changes had a substantial increase of contract sum of 30% to 40% that the cost involved by delay and disruption between RM3 million to RM6 million. Another expert panel commented that the impact of design changes on variation cost estimated RM2 million for relocation of TNB (Tenaga Nasional Berhad) overhead power line to correspond with the elevated highway route and height. Therefore, both expert panels unanimously agreed that design changes is a major factor responsible to construction schedule delays and cost overruns. According to Memon et al. (2014), from the client's perspective, the respondents agreed that incomplete design at the time is the most significant factors of time overrun. In addition, Ramanathan (2012) found from the consultant's perspective, design changes is the most significant factors of cost overrun.

The term "delay" in construction contracts as often used to mean the time period during which some part of the construction project has been extended beyond what was originally planned due to unanticipated circumstances or an incident that affects the performance of a particularly activity, with or without affecting project completion (Bramble and Callahan, 2002; Assaf and Al-Hejji, 2006; Lee, 2007). In other words, delay means as an act or event that extends the time required to perform tasks under a contract (Stumpf, 2000). Normally, actual time to deliver the completed project is subject to various periods of execution, while-delay refers to delay in the actual work or services (Galloway and Nielsen, 1990).

Braimah and Ndekugri (2009) consider delay analysis as a mean of providing the justification and quantification of the time and/or cost consequences necessary to resolve the different contentions. In other words, in evaluating a delay, it is the contractor's job to explain why delays have occurred to the project and then, through a cause-and-effect analysis, the findings will show which delays are due to the responsibility of the employer, contractor, or subcontractor (Lee, 2003). Unfortunately, these delays are often left unanalysed until the end of the job, when it is already too late to mitigate their effects or avoid constructive accelerations (Finke, 1997). According to Baki (1999), in todays' litigious world the claims analysis and preparation are the keys to the success of any project particularly so whenever construction claims occur. However, delay analysis is still time consuming, and an expensive process which comprises reviewing project records, interviewing key personnel, visiting the construction site, prioritization of fact-finding and analysis requirements, determining causation, establishing a reasonable as-planned schedule, documentation of actual performance, and finally comparison and presentation of the as-planned and actual performance (Evrenosoglu, 2008).

Furthermore, when management has got an effective tool during the inception of critical path method to optimize the allocation of resources by focusing on critical and near-critical activities, the ownerships of floats on noncritical activities become a critical matter (Mohan and Al-Gahtani, 2004). Therefore, float ownership debates and contractual modifications began about a decade after critical path method-based analysis was used in claims analysis in the late 1970s (Popescu, 2009). The float means as the time assigned to an activity, which is longer than the shortest time

that is reasonably necessary to undertake that activity (Braimah, 2008). According to Galloway and Nielsen (1981), the two most common types of float are total float and free float. However, free float does not consider the total effort in terms of duration, cost, or man-hours, and thus does not necessarily lead to a fair distribution but the total float, which belongs to a path within the network, provides a number that can be distributed between the activities of the path in some rational manner (Mohan and Al-Gahtani, 2004). Moreover, total float is an indicator of an activity being critical or not by using it to know how many days are left for the activity to be critical and can significantly affect the analysis of delay claims due to its potential of changing any of the successor non-critical activities to critical or vice versa (Al-Gahtani and Mohan, 2005).

Thus, design changes are primary contributors to delay, disruption, claims and disputes. However, managing changes effectively is crucial. Most changes, if not managed properly through a formalized change management process will have considerable impact as they disrupt work and affect its orderly sequence, adversely impacting productivity and cause schedule delays and cost overruns (Anees et al. 2013). In addition, Muhamad (2016) found lack of clear, accurate/reliable and adequate contemporaneous records as the highest frequency of the problems affecting difficulty in assessing and managing of delays and extension of time claims. Han et al. (2003) concluded that design errors leading to rework and/or design changes are considered to be the primary contributor to schedule delays and cost overruns in design and construction projects. Therefore, the need to capture the dynamics of design change as well as able to access systematically the impacts in order to assess project performance is vital.

CONCLUSION

The literature review on causes and impacts of design changes and the findings on rework that cause delay and disruption led to time delays and cost overruns in construction projects was presented. This study hightlights that literature linking design changes, rework, delay, disruption and claims and disputes in construction projects is limited. However, this study found that design changes is the significant factor for time delays and cost overruns. Researchers and practitioners in construction management field will find

this study useful in understanding the causing factors of design changes and its detrimental impacts to project performance. The framework which is a noteworthy outcome from this study that stresses the importance of the adversarial effects of design changes is rework. As a result, rework leads to delay and disruption more than disrupotion claims and disputes. It gives the practitioners the ability to view the impacts of design changes to project performance before actually making the decision to implement the proposed design changes.

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