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Comparative Analysis on Design Error Risks in Design-Bid-Build and Design-Build Construction Approaches

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ABSTRACT

This study was conducted to compare design errors risk in Design-Bid-Build (DBB) (traditional) and Design-Build (DB) methods in building projects. Several construction projects under both DB and DBB method were reviewed. On most of construction projects under DB method, it was found that there were over supply of floor area due to different reasons. Also, it was found that, clients' requirements were changed during project execution, which resulted into change on schedule, contract value and project quality. It was also revealed that in most cases, designs were in accordance with the clients' requirements as submitted earlier but during construction clients requested to add some items, which resulted in change of both contract sum and period. For projects under DBB method, the results showed that during project enactment, projects experienced design errors in different ways such as change in specifications, slow decision making, unforeseen conditions and change in clients' requirements as the aspect of design errors. Approvals of changed materials and additional works were delayed in some occasions; thus, leading to contractors to slow down the construction. It was also further found that the variation in final cost, time and project quality of building construction projects due to design error aspect is more likely to occur when using DB as a delivery method than DBB. The study suggests knowledge sharing, visitation to site before designing and proper planning for design error reduction.

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INTRODUCTION

Design plays an important role in construction projects. Indeed, the design process influences the activities in subsequent phases and overall project performance. In fact, the quality of designs has direct impact on project success (Sanjay and Yadav, 2015). On the other hand, project failure occurs when the management overlook the technical issues during the design process (Williams and Johnson, 2014). In this regard, the Indian government's status report shows that, out of 951 government projects, 309 projects reported cost overruns of about 55 percent. In terms of time overrun, 474 of the projects investigated experienced delays of two to 192 months. The time and cost overruns were largely attributable to design-related factors such as delays in release and finalisation of drawings, change in scope, geological surprises and underestimation of the original costs. The same problems were found by Rwakarehe and Mfinanga (2014) on their study on the causes of time and cost overrun of road projects in Tanzania.

A project's delivery system is a key factor in enabling successful implementation of building projects. The right method may help avoid problems and be crucial in achieving project-specific goals. These goals may include quick project completion, low acquisition price, practical assignment of risk between the parties, and providing the owner the prospect of affecting the details of the design solution and the amount of self-performed work. Certain procurement methods typically apply to certain projects with variations (Turina, *et. al*., 2008).

Under the Design-Bid-Build (DBB) delivery method, the owner selects a design firm for generating contract documents consisting of project drawings (the design) and job specifications. Depending on the project size and complexity, the project drawings typically consist of seven main design disciplines: Civil, Architectural, Structural, Mechanical, Electrical, Plumbing and Telecommunications. After completion of the design, the quantities and cost estimates follow with all the costs that can appear over the project management life-cycle. As such, an accurate cost estimate method can be the difference between a successfully-executed plan and failed one. Subsequently, the project drawings become the contract documents with the construction project awarded to the lowest evaluated bidder (Fernane, 2011).

On the other hand, under the Design-Build (DB) delivery method, the owner is the one who produces joining documents created by an architect he or she has hired. These joining documents provide the basis of the design that sets forth their expectations for the design and construction of the project. Typically, these bridging documents contain requirements that enable the DB entity to create their DB proposal that is tailored to the needs and desires of the Client. This process somewhat differs from the DBB bidding process since DB entities can alter the bridging documents in addition to having more freedom to tailor the design to what that particular team believes is best for both owner and the project. These changes to the joining documents, of course, must be approved by the owner (Fernane, 2011).

As for the existing project delivery methods in Tanzania, they are usually traditionally focused; moreover, only a small number of projects apply the new or innovative methods, such as DB, design, build, finance and operate (DBFO), and Construction Management At-Fee and At-Risk. These can be considered as recent modern type developments, and not those of normal procurement processes. The DB contract between the owner and the design-builder creates a "single point of responsibility" that offers considerably more to a project owner than mere convenience and time savings whereas under the traditional delivery method, the owner is legally responsible for the contractor for the accuracy of the construction drawings and specifications that the owner's architects and engineers prepare (Lahdenpera, 2001). In fact, the DB method of procurement method has been in use in Tanzania for only a few years but is one of the most favoured project delivery methods in the engineering construction project (Ghadamsi, 2016). Moreover, DB is one of the integrated forms of procurement methods that allows the client to provide his/her requirements and needs for the specified project and signs contract with only one organisation - the contractor (Ghadamsi, 2016).

Most of the literature from other scholars reviewed indicated that, many organisations lacked methods and measures of performance as well as factors that can enhance performance. As a result, it is difficult to raise their position in the dynamic marketplace. Design errors are unavoidable in any building construction projects and can negatively affect cost, schedule and safety performance (Shamsudeen & Biodun, 2016).

Previous researches carried out by Shamsudeen and Biodun, (2016) and Love et al. (2004) concluded that the main factors that influenced the quality of building works are attributable to design such as, lack of co-ordination of design, unclear and missing documentation and poor workmanship. The findings suggest that most of the project-based errors can be avoided by having adequate knowledge coupled with better management practices. Design errors can adversely influence project performance and can contribute to failures, rework during the construction phase, time and cost overruns, accidents, and loss of life (Love and Li, 2000). A recent study in Australia estimated the design error costs from 139 projects. The mean direct and indirect costs for design errors were revealed to be 6.85 and 7.36 percent of the contract value, respectively (Lopez & Love, 2012). Although the research provides invaluable insights into the practitioners' perceptions of design errors costs, their actual costs remain relatively and largely unexplored (Lopez *et. al.*, 2010).

As a matter of fact, many researchers treat design errors as the most critical problems and have varyingly defined the term 'design errors'. Reichart (2012) contends that design errors are unavoidable failures, which result from incorrect application of information, or inaccessibility of pertinent information. 'Design errors' refer to the failures of humans to design tasks with accuracy within time limits. Depending on the required level of accuracy and time constraints, common human errors can lead to design errors. These problems can influence the quality of both the design and resultant construction. In this regard, deviation from actual values, inadequate precision and inconsistencies in measurement constitute design errors (Lopez *et. al*., 2010).

Design errors are diverse in nature and severity. The majority of structural failures and associated damage costs are due to errors in design rather than variability in construction material, strengths and structural loads. The DB and DBB acquisition process offer significantly different approaches to managing building construction projects. Even though each process results in a completed project, they take fundamentally different paths to get there.

Surprisingly, there were recurring questions facing owners regarding how best to meet their goals and needs in construction project and one important driving factor contributing to the success of the new facility is the selection of method used to deliver the facility to the owner. Design error is among of the factor contributing to cost and delays of the building projects regardless of the delivery method. DB and DBB are well known delivery method available. However, the extent on how a project delivery method selection minimizes the design error impact is not clearly addressed. Moreover, the two methods involve different procurement processes, design culture and production of information. Under the Public Procurement Regulatory Authority (PPRA), a traditional contracting scheme require the design to be procured independently under consultancy service procedures whereas the DB delivery method the design is procured under the goods, works and non-consultancy services (procurement of contractors).

In fact, traditional approaches obligate design professionals to exercise their professional judgments so as to work in the owner's best. As such, the design team would ensure that every design detail is well-communicated before the post-contract stage to reduce any variation related to design. Because there are no ties between the designer and the contractor, design professionals can exercise their judgments independent of the wishes of the contractor. The DBB option provides a wider range of design work completeness than the DB, which allows for the overlapping of activities between design and constructions phases. Apparently, under the DB scheme, there is no independent architect to oversee the process as under the DBB.

This scenario raises a question on how to minimise the design error, which has yet to be well-addressed by other scholars. As a result, it has become increasingly difficult for the owner to select the best procurement method based on design error. As such, there was a need for more research to develop useful information pertaining to design error essential for procurement method decision-making. After all, the project delivery method selection must aim to minimise the design error impact. This study, therefore, seeks to account for this design error-risk from the comparative perspective focusing on the DBB and DB methods.

MATERIALS AND METHODS

Construction Project Delivery Systems and Methods

Armstrong (2011) describes project delivery as a process by which all of the procedures and components of designing and building are organised and assembled in an agreement that results in a completed project. In other words, project delivery is the owner's approach to organising the project team that will manage the entire design and construction process. According to him, project delivery is the contractual relationships between the owner, architect/engineer (A/E), contractor(s), and management services for designing and construction. Project delivery method is the approach to implementation and utilisation in a bid to accomplish the goals of a given project, which specifically entails integrating organisational, risk allocation, assignment of responsibilities, pricing, and payment obligations (Juliana *et al.*, 2005). For any given project, there can be more than one appropriate project delivery approach, but be one most suitable approach, depending on the owner's requirements, specifications and capabilities.

The construction of a building involves Architects, Designers, Engineers, Contractors and Sub-Contractors, all working together to meet the needs of the client. These construction professionals converge for a specific construction project and then disperse once building is complete (Anyanwu, 2013).

Design Errors

Numerous definitions of error feature in normative literature. Lopez *et. al.* (2010) define error as the execution of a task that is either unnecessary or incorrectly carried out. Similarly, Bea (2003) define error as the failure of planned actions to achieve their desired goal, which occurs without some unforeseeable or chance intervention. The term 'failure' is often used interchangeably with error; however, the difference between error and failure exists. A failure is an unacceptable difference between expected and observed performance. Studies that have examined design errors in construction have often interchangeably used the terms changes, omissions, defects, quality deviations, non-conformances and failures.

As previously mentioned, design errors are responsible for almost half of all structural failures. Design errors are often related to misinterpretations, miscalculations and omissions (Lopez *et. al.*, 2010). From a construction management perspective and based on previous work by Reason and Hobbs (2003) and Lopez *et. al.* (2010), design errors are classified based on the following characteristics:

i. Skill or performance-based errors (slips) e.g., the plan is acceptable, yet the actions are not performed as planned.
ii. Rule or knowledge-based errors (mistakes), for instance the actions are performed as planned, yet the plan may not achieve the outcome intended.
iii. Intentional violations or non-compliances e.g. to industry or organisation-imposed norms and standards.

According to Fröderberg (2014), this classification relates well to how human errors in general are considered from a structural reliability point-of-view, which are errors of concept (mistakes), errors of execution (slips) and errors of intention.

Design-Bid-Build Process

The specific features of DBB system, according to Ratnasabapathy and Rameezdeen (2006), are the rigid separation of design and the construction process and lack of integration across this boundary. Under this system, client appoints an independent team of consultants on a fee-basis, who designs the project and prepares tender documentation to solicit competitive bids from contractors. The successful tenderer enters into a direct agreement with the client and carries out the work in accordance with the design and specifications under the supervision of consultants. This arrangement offers minimal input of the contractors into the design process (Lopez and Love, 2012).

The DBB method has experienced longevity because it offers several advantages. These include familiarity with the participants of the construction process, testing, refining and broad-based understanding of the contractual relationships, clear lines of authority, responsibility and liability. Moreover, owners have complete control over the design because they directly engage consultants. Still, DBB contends with some limitations such as vertical fragmentation, slow take-up of innovation, low productivity, and lack of single point responsibility (Ling and Kerh, 2004).

The acquisition planning process in a DB project includes all the personnel involved in the project from conception to completion. The pre-award personnel and the post-award personnel are an integral part of the team. The team stays together throughout project's span. Conversely, in a DBB project, the team comes together for the acquisition planning stage for the A/E contract, but may disperse in any of the phases. Personnel involved in acquisition planning may not necessarily participate in contract administration. The pre-award and post-award personnel may converge at a handshake meeting to endorse the contract action from the pre-award side to the post-award team. In a DBB project, the team that developed the RFP for the A/E contract often differs from team executing the construction contract. Figure 1 displays the DBB process but can differ from one agency to another (Turina *et. al*., 2008). Table 1 shows the advantages and disadvantages of DBB approach.

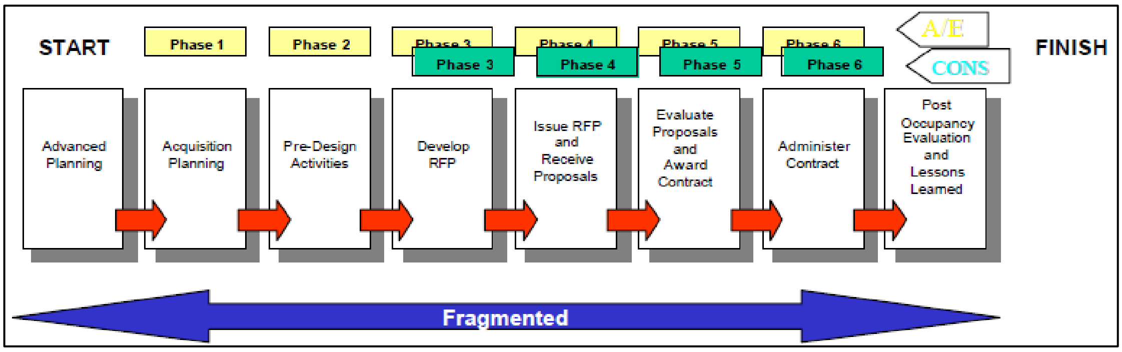

Figure: 1: The Traditional Method of DBB.

Table 1: Advantages and Disadvantages of the Design-Bid-Build Approach

Advantages	Disadvantages
i. Long history of acceptance	i. Innovation not optimized
ii. Open competition	ii. Usually cost overruns
iii. Distinct roles are clear	iii. Disputes between parties
iv. Owner flexibility	iv. Client retains most risks
v. Easy to tender	v. Usually low bid - incentive for change orders
vi. Applicable to a wide range of projects	vi. Owner responsible for errors & omissions
vii. Well established and easily understood	vii. Tends to yield base level quality
viii. Clearly defined roles for all parties	viii. Least-cost approach requires higher level of inspection by the agency
ix. Provides the lowest initial price that is responsible, competitive bidders can offer	ix. Initial low bid might not result in ultimate lowest cost or final best value
x. Extensive litigation that result in well-established legal precedents	x. Designers may have limited knowledge of the true cost and scheduling ramifications of design decisions
xi. No legal barriers in procurement and licensing	

The DBB is a project delivery system that allows the owner to separately contract with a designer and constructor. First, the owner normally contracts with the architect/engineering company for a full set of design documents. Then, based on these pre-descriptive drawings and specifications, the owner usually solicits fixed price bids from construction contractors to perform the work through a contract.

Design-Build Process

The DB project delivery system, on the other hand, is one in which the client contracts a single entity to perform both the design and construction under a single DB contract. Contractually, DB offers the client a single point of responsibility for both design and construction services. The design and construction, either partly or fully, may be performed by a single DB contractor or may be sub-contracted. Under the DB, designers work under contractors as one team; therefore, there is an absence of adversarial relationship between contractors and consultants, which is commonly found in DBB projects. Furthermore, advantages of the DB system include the transfer of risk to contractor (but not usually all the risks), competition in design, maximum overlap of design and construction, availability of construction expertise for design, early commitment to maximum price and less construction information required from the client (Ling and Kerh, 2004). Figure 2 illustrates the processes under DB approach and Table 2 shows the advantages and disadvantages of the same approach.

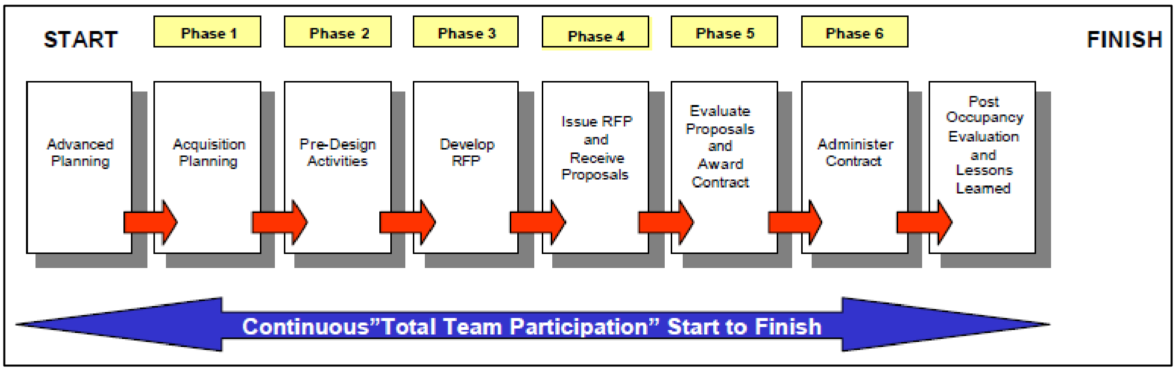

Figure 2: DB Process.

Table 2: Advantages and Disadvantages of the Design-Build Approach (Fernane, 2011)

Advantages	Disadvantages
i. Owner looks to one entity for the entire project performance. ii. The owner can obtain an early commitment to an overall project price. iii. Owner's contract administration and site representative risks and costs are reduced, since the DB Contractor is responsible for all coordination efforts. iv. Innovation and quality improvements through alternative designs and construction methods suited to the contractor's capabilities and flexibility in the selection of design, materials, and construction methods v. Cost containment by minimizing owner's exposure to design errors and omissions vi. Earlier schedule and cost certainty	i. Owner must develop and issue an early definition of the important design and performance requirements that it must have in the project. ii. Once the contract is issued, owner relinquishes control of the detailed design selection and the construction process. iii. Since the price offered by DB Contractors are typically predicated on conceptual designs or performance specifications, the awarded price is likely to be higher than in a DBB process as the DB Contractor needs to include some contingency for design development, risks and other unforeseen construction risks.

Main Characteristics of the Design-Build Procurement Model

The DB category of integrated procurement systems incorporates all of those methods of managing the design and construction of a project. These two basic elements of design and construction are integrated and become the responsibility of one organisation. Masterman (2002) defines the DB procurement method as *"an arrangement where one contracting organisation takes sole responsibility, normally on a lump sum fixed price basis, for the bespoke design and construction of a client's project."*

Design Error Causes

Since human errors are the major causes of most structural failures, extreme loads or material deficiencies are normally of secondary importance in most of the structural failures. In fact, various projects have studied the human factor in the design phase; how subjective decisions, individual knowledge and the use of advanced tools and codes affect structural safety and structural design (Pugsley, 1969; Pugsley, 1973). Indubitably, human errors in the construction process are related to, and induced by, a large variety of factors. Some are related to technological development and others to engineering climatology (Pugsley, 1969). Pioneers of structural safety and reliability, based on accidents and structural failures from the early and mid-20th century, according to Pugsley (1973), distilled a set of often outlined general but still relevant parameters of significance in accident history:

i. New or unusual materials
ii. New or unusual methods of construction
iii. New or unusual types of structure
iv. Experience and organisation of design and construction team
v. Research and development background
vi. Industrial climate
vii. Financial climate
viii. Political climate

Additionally, Brown and Yin (2014) further contend that engineers and contractors are equally culpable in contributing to structural errors; however, the severity of the errors committed by engineers tend to widely exceed those of the contractor. Implicitly, the errors engineers commit often tend to be critical and costly. The engineers' errors are mostly related to insufficient knowledge and incorrect assessment of influences whereas those of the contractors are mainly occasioned by ignorance, thoughtlessness and negligence. Brown and Yin (2014) summarised the error causes as follows:

i. Poor training and pay of field inspectors
ii. Inadequate preparation and review of contract and shop drawings
iii. Breakdown or misinterpretation of communications between the design and construction - operation communities
iv. Lack of professional design and construction experience, especially when novel structures are needed
v. Complexity of codes and specifications leading to misinterpretation and misapplication
vi. Unwarranted belief in calculations and specified extreme loads and properties
vii. Frequent personnel changes
viii. Compressed design-construction time.

For design errors alone, the comprehensive work of Lopez *et al.*, (2010) concluded that these often tend to reflect bad quality and stem from erroneous design documentation. These errors may emanate from three hierarchically different levels: personal, organisational, or project level.

Errors in the Employer's Requirements

Employer's requirements typically feature in the DB projects such as Joint Contracts Tribunal, BD 16, or on a traditional contract whereby the contractor designs discrete parts of the works. They describe the client's requirements, including the specification for the building, the scope of services required from the contractor, and accommodation of risk for unknown items. In this regard, FIDIC Conditions of Contract for Plant and DB Contract, First Edition (1999) stipulates that a contractor can suffer delay and/or incur costs as a result of an error in the employer's requirements, even when experienced particularly after failing to discover the error when scrutinising the employer's requirements under *General Design Obligations* after exercising due diligence and care. Under such circumstances, the contractor may notify the engineer. Moreover, the contractor is entitled subject the claims to:

a) An extension of time for any such delay, if completion is or will be delayed, and
b) Payment of any such cost plus reasonable profit, which shall be included in the Contract Price.

The employer's requirements is an important document as it defines the success of the outcome. The better prepared they are, the keener the price from the contractor and the less likely there could be disputes. If the employer's requirements are not properly developed, the client can incur significant additional costs, as any requirements which are not properly specified, or are changed.

Once the client has received the contractor's proposals, ensuing negotiation may help iron out any inconsistencies between the contractor's proposals and the employer's requirements. This negotiation may result in either the amendment of contractor's proposals or the employer's requirements to ensure agreement between them. This is an important part of the tender process as it is not always entirely clear which document would prevail after the contract has been sealed.

Reducing Design Error in Construction Management

A mainly project-based construction is one in which design and construction transactions within projects are mostly segregated. Due to various inherent complexities in construction projects, design changes may be deemed as inevitable in some circumstances. An array of best practices has been consolidated by interviewing leading practitioners in the industry. Palaneeswaran *et. al*. (2007) recommended some strategies for design error reduction targets which include the following:

a) Avoiding design errors, omissions and other non-conformances through appropriate design reviews, independent checking arrangements and relevant quality management systems.
b) Reducing design changes and adversarial conflicts through better briefing, enhanced stakeholder interactions and their early involvements, improved scope definitions including freezing from further changes.
c) Enhancing systematisation including improved documentation, relevant knowledge management frameworks, appropriate arrangements for information and communication.
d) Hiring suitable design team members and keeping commitment of the key personnel throughout e.g., for essential design tasks and main design management roles
e) Selecting best value business partners such as 1) knowledgeable and understanding clients; including continuous monitoring of their satisfaction levels, and 2) best possible supply chain sources e.g., sub-consultants and joint-venture partners; including continuous monitoring of outsourcing and effectively managing interface issues.
f) Benchmarking and improving through useful frameworks such as key performance indicators, structured queries, constructability reviews, and satisfaction surveys.
g) Adopting appropriate contractual safeguards and developing suitable incentive/ disincentive mechanisms.
h) Reinforcing relationships and enabling better supply chain integrations (e.g., partnering arrangements).

c) Research Design

According to Kombo and Tromp (2006), research design is the scheme, outline or plan applicable in generating answers to research problems. This research design is a conceptual structure of the research being conducted. It is the arrangement of conditions for collecting and analysing data in a manner that aims to combining relevance to the research purpose with economy in procedure. To get appropriate data on emerging innovative construction projects delivery systems the researcher intends to adapt multi-dimensional research design that involves a variety of approaches, quantitative and qualitative. In other words, the researcher adapted mixed approach. The selection of this approach is supported by Creswell and Plano (2007), who explain that mixed approach is an approach to inquiry that combines or associates both quantitative and qualitative forms. Thus, it is more than simply collecting and analysing both kinds of data; it also, involves the use both approaches in tandem so that the overall strength of a study is greater than quantitative or qualitative research.

Furthermore, the study adopted survey design because the use of the same is useful in providing answers to questions such as what, how and why. According to Yin (1997), a case study method relies on the use of and capability to integrate in converging fashion (data from multiple sources of evidence). The information may come from direct observation, archival, interviews, and documents. Also, Yin (1997) provides that this method is suitable for exploratory, descriptive or explanatory research. Data from survey facilitate generalisation of the findings (Flyvberg, 2006).

d) Area of the Study

A study area as the territory to be covered by the study. The selection of the study area is essential as it influences the usefulness of the information produced. Due to critical importance of this study, the researcher finds it is much wiser to select ongoing and completed buildings project, which are constructed under either DBB or DB project delivery method. As such, the study was carried out in Dar es Salaam city with a bountiful of projects of interests to the study.

e) Target Population, Sample Size and Selection

Targeted Population and Sample Size

The targeted population for this study was the all current high/larger building projects in Dar es salaam city. Kombo and Tromp (2006) define a population as a group of individuals, objects or items from which samples are taken for measurement. It is the entire group of persons or elements that have at least one thing in common. It is the full set of cases from which a sample is taken (Saunders, *et al.*, 2009). A population is a group comprising individuals or things or elements that fit in a certain specification. Population is basically a large group that bears characteristics of the research issue. The selected project for DB were: (i) PSSSF Commercial Complex, (ii) TBA-Magomeni Residential Apartments (iii) NHC-Mixed use development (Victoria place), (iv)NHC-Mkulima Residential Apartment (Ananasifu), and (v) CRDB Headquarters.

On the other hand, the projects selected under DBB comprised: (i) NSSF-Mzima tower, (ii) DAWASA Yetu Building, (iii) NSSF-Affordable Housing Scheme at Kigamboni Kijichi, (iv) NHC - Proposed Mixed Use Development (Morocco square), and (v) Mlimani Plaza (Sky City Malls).

Kombo and Tromp (2006) define sampling as a set of act, process or technique of selecting a suitable sample or a representative part of a population for the purpose of determining parameters of characteristics of the whole population. A sample is, therefore, a segment of population in which a researcher is interested in gaining information and drawing conclusion.

A sample of 10 constructed projects was drawn from the targeted population for the study and analysis. There are several ways of determining a sample size and so which method to use depends on various factors such as time constraints, diversity of population, population size and researcher's preference. A sample size of the stratified group for this study was calculated from Yamane (1967) equation and presented as in equation1 for projects under DBB and DB:

$$n = \frac{N}{1 + Ne^2} \quad (1)$$

where; n is the sample size, N is the population size and e are the acceptable marginal of error. For this research 10% will be the acceptable margin of error at a 90 percent level of confidence. There were 205 participants, who accounted for a rate of 95 percent of the respondents from questionnaire distributed at sites.

Data Source and Collection Techniques

Data Source

The study made use of both primary and secondary data sources. Primary data refers to information collected directly from the field. In this study, the source of this kind of data was collected from selected construction projects. On the other hand, secondary data were obtained through reviewing different sources such as reports, papers, and previous researches, about the same and/or relevant topics.

Data Collection Techniques

To collect necessary information and data for this study several techniques for data collection were employed. This is due to the fact that no single data collection technique is adequate on its own. Saunders *et al.* (2007) argues that it is usually better to link one technique with others. The following data collection techniques were employed in this study.

Questionnaire

The study used both Likert scale with the greatest of five things and closed-ended survey to gather information from test estimate. This technique helped to collect information on construction projects, level of awareness and to examine challenges faced by clients in their use of project delivery procedures and determine the project delivery methods available for construction projects in Tanzania. The questionnaire was circulated to all the respondents in the case study based on sample size. The technique applied to all construction related officers, managers and directors. Questionnaires were divided based on respondent's function at the construction site.

Interview

An interview is an important data collection technique that can be conducted in different forms and types. Such interviews could be based on different research guidelines depending on research type. There are three main types of interviews: structured, semi-structured and unstructured interviews. This research applied semi-structured interview to collect data. Semi-structured interviews consist of list of questions of which the researcher wants to get answers from the interviewees. However, the importance of this type of interview, according to Saunders *et. al.* (2000), provides an opportunity to interviewer to probe answers, and explain, or build on, interviewee responses. This data collection requires the researcher to identify interviewees and request them to answer certain questions (Kombo & Tromp, 2006). This method involves presentation of oral-verbal stimuli and reply in terms of oral-verbal responses (Augustino, 2010). This technique enables the researcher to explore extra data otherwise not easily obtainable through other methods. Furthermore, Saunders *et. al.* (2000) contended that this approach is time-saving, normally well-tested, and enables interviewer to compare collected result with other surveys. In this study, 20 respondents were interviewed including some senior officials and decision-makers to gather more information due to their vital roles and position.

Documentary Review

Saunders *et. al.* (2009) treats documents as a secondary form of data collected and stored by organisations or governments for use by externals interested in them in any relevant area to which can fit. Such data include articles, the public procurement regulations of 2013, and construction manuals (FIDIC, 1999) for conditions for plant and DB contracts. Furthermore, the study explored various project construction policies, reports, manual as well as journals providing vital information to the study.

Data Analysis and Presentation Methods

Data analysis refers to examining what has been collected in a survey or experiment and making deductions and inferences (Kombo & Tromp, 2006). Kothari (2009) further defines data analysis as the computation of certain indices or measures alongside searching for patterns of relationship that exist among the data group. For data analysis, the researcher intends to use both quantitative and qualitative data analysis techniques. To gather required information, data from the questionnaire survey was analysed by frequency and simple percentages and data, which was obtained from interview ought to be thematically, matching and comparisons analysed. Data were presented in form of text, graphs, and charts depending on the nature of data.

Furthermore, analysing the correlation between design errors aspect for project performance, researcher used correlation (test) analysis. Also, for ranking the 5-point Likert scale, the researcher applied the Relative Importance Index (RII) mainly for comparing the contribution of each variable relative to others. The RII is based on the following formula:

$$RII = \frac{5(1) + 4(2) + 3(3) + 2(4) + 1(5)}{5(1+2+3+4+5)}$$

where: 1 = number of respondents that strongly agree, 2 = number of respondents that agree, 3 = number of respondents that are neutral, 4 = number of respondents that disagree and 5 = number of respondents that strongly disagree. The factors were ranked from the highest to the lowest based on the frequency index. Nevertheless, the researcher used simple descriptive statistics such as frequencies and percentages in analysing categorical data.

DATA PRESENTATION AND ANALYSIS OF FINDINGS

Deployment of DB and DBB as Project Delivery Method

The 205 respondents' views based on their experiences with applying DB and DBB project delivery methods have been presented in Table 3.

Table 3: Respondents Experiences on applying DB and DBB Project Delivery Methods

No. of Projects		Never involved in any project	Involved in 1 - 3 projects	Involved in more than 3 projects
No of Respondents	**DB**	25	45	30
	DBB	5	26	74

Knowledge about Design Error in Building Construction Project

Respondents were asked to indicate whether they had any knowledge on design error in building construction projects and their responses from both methods of DB and DBB. Each respondent provided information based on his/her experiences with the two delivery methods regarding which one was more likely to cause more design errors.

Design Error in Construction Project

Factors Impelling Design Error in Building Construction Projects

Different respondents from construction projects under review were given different itemised factors that can lead to design error in building construction projects for them to rate. Table 4 presents the results from interviews.

Table 4: Factors for Design Error and its Ranking (n = 21)

S/N	Aspects of design error	RII	Rank
a	Unsubstantial client requirements	0.63	6
b	Financial factor	0.57	7

c	Skills factor	0.66	4
d	Material Selection	0.46	14
e	Political factor	0. 51	12
f	Technological factor	0.75	1
g	Inadequate details in drawings	0.46	14
h	Lack of knowledge	0.56	8
i	Inadequate project objectives	0.68	3
j	Design complexity	0.73	2
k	Change in schedule	0.55	9
l	Change in scope	0.57	7
m	Clients' financial problems	0.64	5
n	Change in specifications	0.5	13
o	Safety consideration and poor planning	0.68	3
p	Slow decision-making process	0.52	11
q	Noncompliance of design with government regulation	0.54	10
r	Poor design documentation	0.57	7
s	Profit maximization	0.52	11
t	Unforeseen conditions	0.55	9
u	Poor coordination among design/construction team	0.57	7

Note: The responses were not mutually exclusive

Variation in Construction Costs During Project Implementation

Since construction costs can vary during project implementation, the respondents also presented their views on cost variation. Responding, 85% of the 20 respondents agreed that there was such variation whereas the remainder were non-affirmative. Implicitly, the majority of the respondents beard testimony to the existence of variation in construction costs during project implementation. The study also determined whether the design error can cause variation in construction cost. In this regard, the respondents were even divided since 50% were positive about design error causing variation of construction cost and another 50% thought otherwise.

Design Error Aspects Based on Delivery Methods

The study aimed to determine which delivery method was associated with high effect of cost variation due to design error. The majority (70%) of the respondents associated the DB as a delivery method with high effect of cost variation due to design error whereas the minority (30%) cited the DBB method as having such an effect.

Effects of Design Errors on the Execution of Construction works for DBB and DB

Table 5 shows the RII and ranking system of the project risks caused by design error aspect on building construction project using DBB and DB as the project delivery methods.

Table 5: Design Error Risks on the Execution of Construction works for DBB and DB

S/N	Risk due to Design error Aspect	RII	Rank
	Traditional Method (DBB)		
1	Time overruns	0.89	2
2	Cost overruns	0.99	1
3	Project abandonment/failure	0.66	6
4	Client accountable for additional cost caused by design errors aspect	0.69	4
5	Designer accountable for additional cost caused by design error aspect	0.75	3
6	Contractor accountable for additional cost caused by design errors aspect	0.50	5

Design and Build (DB)			
1	Time overruns	0.86	2
2	Cost overruns	0.89	1
3	Project abandonment/failure	0.44	5
4	Client accountable for additional cost caused by design errors aspect	0.67	3
5	Designer accountable for additional cost caused by design error aspect	0.61	4
6	Contractor accountable for additional cost caused by design errors aspect	0.15	6

Design Error Effects on Case Study Projects

DB Delivery Method Projects

The particular construction projects classified under the DB method in this study were PPF/PSSSF, Victoria Palace, Magomeni Residential Apartments, the Mkulima Ananasifu Project, and CRDB Headquarters, all based in Dar es salaam. The aim was to assess the effects of the design error on these construction projects executed under the DB arrangement.

PPF/PSSSF Fund Project

Value change/cost overrun: During project execution, the contractor experienced design error as explained by the engineer from employer's Personnel team. The contractor claimed about over supply of floor area at the commercial tower due to increase of the size of columns for stability reasons, which subsequently created a domino effect by necessitating pushing at further periphery walls. As a result, the gross area also increased.

Change of scope: The PPF/PSSSF Fund project also experienced change of scope due to design error. In this regard, a report from the site reads in part: "The contractor's claim report submitted shows that technically the design team increased sizes of columns which eventually caused significant multiple effect of additional area from 2000 m^2 to 2110m^2." This development resulted into an adjustment of construction specifications, which resulted into hiking of costs, additional payment for the contractor, increased overhead expenses, completion schedule delay, reworking and demolition. In this regard, it appears important for the clients and contractor to use DB method rather than DBB to minimise unnecessary cost. Overall, PPF/PSSSF Fund project quality neither changed nor adjusted the project schedule as the following statement affirms: *"There was no change in time due to design error".*

Victoria Palace

During the project construction, the client experienced a design error which resulted into change of the project's quality and schedule. There was change in project schedule due to design error because the contractor was to rectify the design error observed.

Magomeni Residential Apartments

Magomeni residential apartments experienced challenges during the project implementation, which included financial constraints, political factors, and change of schedules. These challenges inevitably delayed the completion of the project. The client's requirement reportedly changed during project execution, hence resulted into the adjustment of the schedule, change in contract value and project quality. In this regard, questionnaire responses revealed that the design was in accordance with the client's requirements submitted earlier; however, during construction client requested to add a reception building, garbage collection cubicles, chain-link fence, and children's playground which hiked the contract sum in addition to extending contract period. Since the client's requirement is one of the aspects of design error, all these subsequent changes are classified as having been caused by design error. Also, the Project Manager specified the areas changed due to design error to the building's structure (re-bars calculation), roof treatment materials arrangement and change in material specifications. Moreover, because of financial factor, some important items within the building contract were omitted. The contract value also changed because of the change in the scope of the work as well as unforeseen conditions.

Mkulima Ananasifu Project

This project did not experience any design error during construction. However, there was change in original contract price due to additional works at the behest of the client.

CRDB Headquarters Project

This project experienced a design error during its execution. Reportedly, there was no compliance of the contractor to attain the required built-up area. Also, there was a change in project's schedule resulting from this design error. In consequence, the contractor had to rectify the design error as per notification, hence the changes in the work schedule. However, there was neither change in contract value nor change of scope due to this design error because the error was made by the designer, in this case the contractor, hence making the contractor's responsibility to rectify it.

DBB Delivery Method Construction Projects

For comparative purposes, the study also assessed particular construction projects falling under the DBB (traditional) delivery method. The projects of interest under DBB in this regard comprised NSSF Mzizima Tower, Sky City Mall, Morocco Square, Affordable Housing Scheme Phase III Project at Mtoni Kijichi and DAWASA Yetu Building.

NSSF Mzizima Tower

During its execution, the project experienced change in specifications, slowed down decision-making, unforeseen conditions, and client requirement as aspects of the design error. In this regard, the respondents attributed the change in the project's schedule to the design error: "Approvals of changed materials and additional works were delayed in some occasion, thus led to the contractor to slow down the construction". However, there was no contract value change, no change in the project's scope, and no change in the project's quality.

Sky City Mall

This project also experienced a design error as stated by the Clerk of Works: *"The change in staircase direction as a result of deviation from the plan of the section"*. Moreover, the project's schedule changed due to design error, according to the respondent. Demolition of the existing solid block wall for office partitions also rescheduled project. Furthermore, the additional floor for the penthouse changed project's schedule, as this aspect was not foreseen and required the reallocation of the already designed components. The project experienced adjustment in the contract value, which resulted from compensation due to delays in construction and the cost stemmed from the design error**.** Finally, the project's quality also changed due to the design error. As respondent pointed out, *"Details of structural design did not include notches to escalators; as a result, ramp was introduced to solve the error. This affected the quality the building to some extent"*. Implicitly, there were many grounds for making adjustments occasioned by the design error.

Morocco Square

This project did not experience any design error during the its construction.

Affordable Housing Scheme Phase III Project at Mtoni-Kijichi

This project also experienced a design error during the construction process. Reportedly, the structural drawing was slightly incongruent with the architectural drawings. This incongruity resulted into a change in contract value, though it was taken as variation to contract and paid by contingency amount. However, there was no change in the project schedule as the error had been rectified in the early stages of the works.

DAWASA Yetu Building

This project reportedly experienced changes in both schedule and contract value. Based on the information from the respondent, it was established that the change was not due to design error. Instead, the project schedule had to be adjusted due to change in the client's requirement, hence prompting the need to accommodate some requirements in the revised schedule. Similarly, the over-budget did not stem from design error. Meanwhile, the project cost overrun was caused by price adjustment, which was allowable in the contract after 18 months had elapsed. Also, the client had project cash flow problem, which delayed payments to the contractor. As one respondent further explained that payment delays resulted to loss and expense claims from the contractor. All the changes reported by the respondent can be classified as the design error effect because they are attributable to the design error aspect.

Best Delivery Method to Reduce Design Error in Building Construction Projects

This study also aimed to determine the most viable construction delivery method that can comparatively minimise design errors and variation in building construction projects. From this study, 60% of the respondents indicate that DB is likely to reduce risks of design error while 25% indicate that DBB is likely to reduce the risks. 15% had no opinion on the best method.

Correlation Graph (Test) for the Design Risks Aspect Based on Delivery Method

Based Figures 3 and 4, the correlation coefficients (R^2) are 0.6579 (66%) and 0.6426 (64%) for DBB and DB, respectively. This value of R^2 suggests the linearity correlation between the dependent variable - Design Error Aspect and independent variable - Risk due to design error Aspect shown in Table 6.

Table 6: Design Risks Aspect Based on Delivery Method

S/N	Risk due to Design error Aspect	RII	
		DBB	DB
1	Time overruns	0.89	0.86
2	Cost overruns	0.99	0.89
3	Project abandonment/failure	0.66	0.44
4	Client accountable for additional cost caused by design errors aspect	0.69	0.67
5	Designer accountable for additional cost caused by design error aspect	0.75	0.61
6	Contractor accountable for additional cost caused by design errors aspect	0.50	0.15

From the correlation test performed, the correlation coefficient, (R^2) was observed at 0.6579 for DBB delivery method as justified in Figure 3. Correlation evaluates the strength of the relationship between two quantitative variables. Regarding prediction, it emerged that the stronger relationship between the variables, the more accurate the prediction. The observed value of R^2 suggests that a moderately linear correlation exists between dependent variable *"design error cause risks in the construction projects"* and independent variable *"Occurrence of risks such as cost and time overrun"* as presented in Table 6. Impliedly, the occurrence of design error in the building construction projects causes project cost risks in construction projects. Therefore, the occurrence of design error in all building construction is a useful predictor of causes of cost overruns, delay of the projects and poor quality of project performance in construction projects.

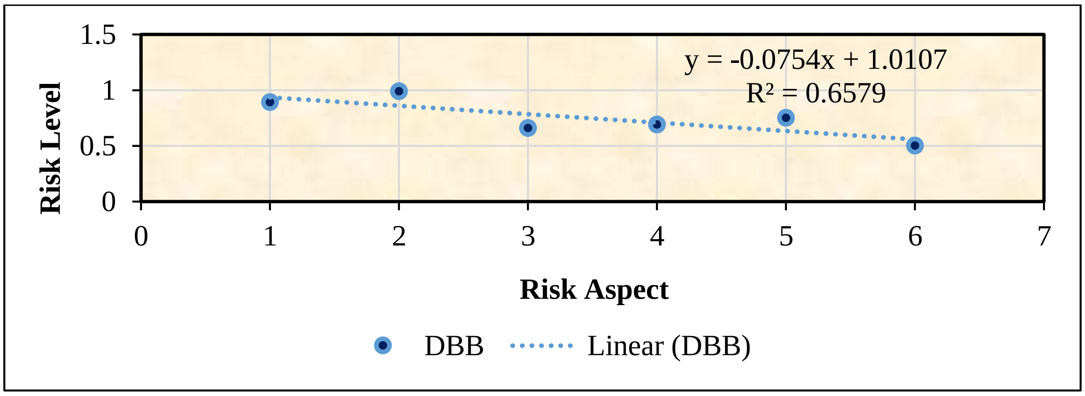

Figure 3: Correlation coefficient test for the DBB delivery method.

Risk aspect 1 = time overruns, 2 = cost overruns, 3 = project abandonment/failure, 4 = Client accountable for additional cost caused by design errors aspect, 5 = Designer accountable for additional cost caused by design error aspect and 6 = Contractor accountable for additional cost caused by design errors aspect.

Also, correlation coefficient (R^2) for DB delivery method was observed at 0.6426 as a strong positive correlation between the risk level and risk aspect as illustrated in Figure 4. In other words, the variation in the final cost, time and project quality of a building construction project due to the design error aspect was more likely to occur when using DB as a delivery method than the DBB. Moreover, the negative sign (negative slope) indicates the negative dependence between the risk level and the design error (risk) aspect. Increase of design error (risk) aspect would result on decrease in risk level and vice-versa.

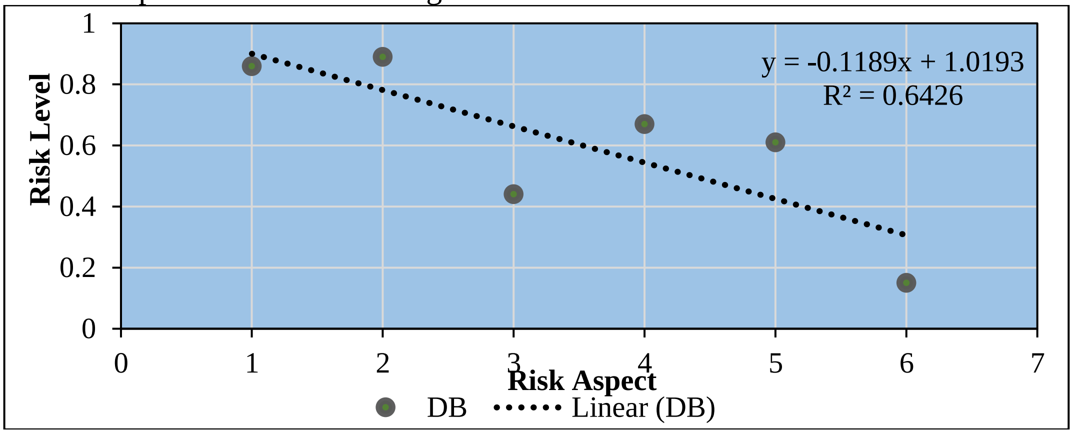

Figure 4: Correlation coefficient test for the DB delivery method.

Risk aspect 1 = time overruns, 2 = Cost overruns, 3 = Project abandonment/failure, 4 = Client accountable for additional cost caused by design errors aspect, 5 = Designer accountable for additional cost caused by design error aspect and 6 = Contractor accountable for additional cost caused by design errors aspect.

Analysis of variance, one-way ANOVA was used to carry out statistical analysis in which DBB and DB delivery methods were compared. The ANOVA determines whether there was a significant difference between the means. From the analysis, p-value was 0.620888, which is greater than the alpha p-value of 0.05 by mean of 0.620888 > 0.05. In other words, there is no statistical significance difference between DBB and DB delivery method. Impliedly, these two delivery methods have no influence on the construction projects since all method has the same context. Table 7 presents the results.

Table 7: ANOVA analysis for DBB and DB delivery methods in construction projects

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.008008	1	0.008008	0.260448	0.620888	4.964603
Within Groups	0.307483	10	0.030748			
Total	0.315492	11				

Design Error Remedial in Building Projects

The study also suggests some measures or solutions for minimising design error. These measures have been ranked from 1 - 5 (whereby 1 = no impact at all, 2 = rare impact, 3 = moderate impact, 4 = high impact, 5 = very high impact). Table 8 presents the results.

Table 8: Design error remedial in building project

S/N	Measures/ Solutions	RII	Rank
a	Visitation to site before designing	0.57	2
b	Proper planning	0.57	2
c	Contractors' representatives are important	0.57	2
d	Use of computer programs	0.55	3
e	Pay adequate attention to details	0.47	5
f	Client requirements	0.44	5
g	Construction professionals and their roles	0.48	5
h	Knowledge sharing	0.6	1
i	Professionals should have checklists from a collective building code that can be used for future projects	0.52	4

DISCUSSION OF FINDINGS

Deployment of DB and DBB as Project Delivery Methods

The 205 respondents indicated the number of their projects that had been undertaken based on either DB or DBB as project delivery methods as shown in Table 3. For the DBB, 74 respondents, which account for 36.1% reported that they had applied the delivery method and had been involved in more than three projects, 26 respondents that account for 12.7% reported 1 - 3 projects and a small fraction of 2.4% indicated that DBB had never been deployed as a delivery method. It appears the respondents were relatively new to construction project or indicated that they always employed other types of delivery method because these two are rare common. On the other hand, 45 respondents that account for 22.0% reported having applied the DB delivery method in 1-3 projects, another 30 respondents that account for 14.6% indicated having applied it in more than three projects whereas another significant minority (12.2%) said they had never applied the DB delivery method.

Delivery Method Causing More Design Error

The study compared the method likely to cause more design error than the other. Data from 20 study participants interviewed indicate diverse views on which delivery method was more likely to lead to a design error. The study found that 60% of the respondents interviewed identified the DB delivery method as the one more likely to lead to the design error whereas the remaining 40 percent went for the DBB. Each respondent provided the information based on their experiences regarding the two delivery methods.

Design Error in Construction Projects

Participants further indicated their awareness on the design error pertaining to construction projects. The aim was to evaluate the knowledge on different aspects of the design error in construction project. From the interviews held with 20 participants, 85%were aware of the design error occurrence in construction project whereas the rest of the participants were not. In other words, many participants were aware of these aspects, implying that design error was well-known to many construction stakeholders.

Factors Impelling Design Error in Building Construction Projects

20 participants were interviewed to give their views on the factors behind the design error in building construction projects. As shown in Table 4, some factors seem to be graver in occasioning error as pointed out by so many respondents than the others. In this regard, factors with high RII score were ranked first whereas responses for each factor were ranked 1 - 5 (1 = no impact at all, 2 = rare impact, 3 = moderate impact, 4 = high impact, 5 = very high impact). Technological factor trumped all the factors influencing design error with RII of 0.75 and ranked first,

followed by design complexity with RII 0.73 at number two. Even though the technological and design complexity factors seem to be crucial aspects to look on, other remaining factors should not be ignored. Most of the factors revealed in this study concurs with what was found in the research by Busby (2001), Andi & Minato (2003a), Andi & Minato (2003b), Love *et al.* (2000) and Brown and Yin (2014).

Project Schedule Changes Due to Design Errors

The change in time for completion of the project due to design errors also featured in this study. In this regard, the key informants' views indicate the factors that caused changes on schedule due to design errors based on DB methods. The respondent from the first construction project explained that there was no change in time for project completion due to design errors because DB has allowance of phase interference. The second respondents from the second construction project explained the reason caused changes on schedule due to design errors of which the Contractor had to rectify. Another respondent indicated that because of financial factors some important items within the building context were expelled out. The design was in accordance with the client requirements as submitted earlier; however, during construction the client requested to add some items, which spiked the project's contract sum and extension of contract period.

From the key informants during interviews conducted at construction sites, the respondents from the third construction project explained that DBB method caused changes in the schedule due to design errors Approval of changed materials and additional works were delayed in some occasion, which led to the contractor to slow down the construction. Another respondent indicated that demolition of the existing solid blocks wall as office partition rescheduled project. Further, additional floor of penthouse changed project schedule of which was not foreseen and reallocation of already designed components. Generally, effects on the schedule resulting in change depended on the design errors, which explains diversity in the research participants' views.

Design Errors Experienced During Project Execution

Key informant interviews held with research participants revealed different views regarding the experiences they have on design error. One respondent in fourth construction project with the DBB delivery method experience said: *"I consider the aspects of design error the project experienced design error in different ways such as change in specifications, slow decision-making process, unforeseen conditions, and change in client requirements".* Therefore, changed specifications in construction may result to increase unnecessary cost, additional payment to contractor, increase overhead expense, completion schedule delay, rework and demolition. It is important for the clients and contractor to use DB method rather than DBB so as to minimise unnecessary cost. The participants from construction project explained their views on experiences they have on design errors. For instance, on one the examined project there was change in staircase direction as a result of different direction from plan to section. Some errors were caused by structural drawings, which was slightly different with architectural drawings. On the other hand, there were also design errors whereby the contractors claimed about the oversupply of floor area at commercial tower due to the increase of the size of columns for stability reasons, which subsequently created a domino effect by necessitating pushing part further as periphery walls as a result gross area also increased. Other design errors experienced was due to the building structure, roof treatment materials arrangement and change in material specifications.

Effect of Design Error Based on Delivery Methods

The previous section has indicated variations in construction cost. As such, the assessment revealed that the delivery methods were highly subjected to these variations. The two delivery methods of DB and DBB as assessed by 20 respondents from construction field with most of them affirmed the variations linked to the design error. The few participants who indicated no variation on construction cost were not involved in responding to aspects on the delivery method that can cause variation. Only a few respondents affirmed a variation; these were the ones who indicated the delivery method most likely to cause variation in construction cost performance due to design error. Consequently, only 10 respondents provided their views on this aspect, 70% of whom identified the DBB delivery method as the one more likely to cause variation of construction cost performance due to design error whereas the remaining 30% identified the DB delivery method as the more likely causation.

Effect of Design Error on Changes in Contract Value

This study desired to assess the variation in contract value due to design error. In this regard, different views emerged from 20 respondents on this question. There were those who said that there was a variation (increase/decrease) in contract value, which is in agreement with Lopez & Love (2012) and Lopez *et al.* (2010); and some of respondents said that there was no change on contract value. A large number of the respondents (70%) of the research participants responded positively that there could be change in contract value while the other group (30%) were against and strongly said that there is no change in contract value that could be caused by design error. Since the people who indicated change in contract value outweighed the number of those who indicated otherwise, then third party come up with the agreement with a large number of respondents though that cannot ignore the other 30%.

Effects of Design Errors on the Execution of Construction Works for DBB and DB

From Table 5, cost overrun was ranked the first with the RII of 0.89 for DBB and 0.99 for DB, implying that a considerable number of the respondents strongly agreed that the design error aspect causes additional cost in building construction projects and it had a significant effect on the activities of construction works on the project. Time overrun was ranked the second with RII of 0.86 and 0.89 for DBB and DB, respectively. In other words, a considerable number of the respondents strongly agreed that the design error affected the final time schedule of a building construction project. The designer being accountable for additional cost caused by design error aspect with RII of 0.75 and 0.61 for DBB and DB respectively was ranked the third and fourth for DBB and DB respectively. Implicitly, a considerable number of the respondents agreed that design error affect brought a risk to designer of a project which also affects the activities of the construction workers. The RII is 0.69 for DBB and 0.67 for DB show that a considerable number of the respondents strongly agreed that a client was responsible for additional cost caused by the design error in construction projects. Also, it emerged, the RII of 0.50 for DBB was ranked number fifth, that is, the contractor accounted for additional cost the design errors caused whereas RII of 0.66 for DBB indicated that a project would be abandoned or fail due to due to the design error. A considerable number of the respondents agreed that the additional cost in a project due to design error led to project abandonment and had lesser effect on the activities of construction workers. Finally, Table 5 also shows the RII and its ranking of the project accounted for the abandonment of the DB with the contractor held accountable for additional cost arising from design errors in a building construction project that stood at 0.44 and 0.15

respectively. This shows that a considerable number of the respondents fairly agreed that the contractor being accountable for additional cost caused by design errors in building construction projects does not have much effect on the activities of construction works if DB is employed.

The results of the RII and ranking system of the project risks caused by the design error in building construction project using the DBB and DB as the project delivery methods gave the important information for this study. It also emerged that using DB could have significant impact on the cost overrun than using DBB. In this regard, the respondents' responses show higher percentage (99%) for use of DB and a slightly lesser one (89%) for the DBB application.

Indeed, the design error aspect tends to affect the final time schedule of a building construction project. In other words, if the project initially is not well-designed it can result in changing the time to accomplish. The increased time may be attributable to time spent on redesigning work, which has already been designed or even stop construction activities to correct the error occurred due to poor design.

Best Delivery Method to Reducing Design Error in Building Construction Projects

20 stakeholders from the construction project further provided information on the best construction delivery method that can minimise design errors and variation in the building construction projection. The design error can engineer some variation in the projected timeline for project completion. As such, this study assessed which delivery method need consideration to reduce the design error variation. The DB method was highly recommended as the best method to be considered to reduce the variation due to design error as it was evidenced by 60% of all respondents recommending this method. On other hand, 25% of all the respondents recommended traditional method while the rest 15% said that they cannot recommend any of two methods because they did not consider reducing the variation due to the design error.

Correlation Graph (Test) for the Design Risks Aspect Based on Delivery Method

From the correlation test performed, the correlation coefficient (R^2) was observed to 0.6579 for DBB delivery method as Figure 3 illustrates. Correlation evaluates the strength of relationship between two quantitative variables and also used to make prediction whereby the stronger relationship between or among variable the more accurate prediction. This value of R^2 suggests a moderately linear correlation exist between dependent variable "design error cause risks in construction projects" and independent variable *"Occurrence of risks such as cost and time overrun"* in Table 6. Impliedly, the occurrence of design error in all building construction causes cost project risks in construction projects. As such, occurrence of design error in all building construction is a useful predictor of causes of cost overruns, delay of the projects and poor quality of project performance in construction projects. Also, from Figure 4, the correlation coefficient (R^2) for DB delivery method was observed to be 0.6426 meaning that there is a correlation between the risk level and risk aspect. However, this value indicates that the variation in terms of final cost, time and project quality of a building construction project due to the design error are more likely to occur when using DBB as a delivery method than the DB. Moreover, the negative sign (negative slope) indicates the negative dependent between the risk level and the design error (risk) aspect. Increase of design error (risk) aspect could result in a decrease in the risk level and vice-versa. Also, the analysis of variance required the use of the one-way ANOVA whose statistical analysis facilitated the comparison of the DBB and DB delivery method. ANOVA determines whether there was significance difference between the means. The results indicate a p-value of 0.620888, which is greater than alpha p-value of 0.05 and a mean of 0.620888 > 0.05. In other words, there was no statistical significant difference between DBB and DB delivery methods. Implicitly, these two delivery methods do not have independently a significant bearing on the construction projects since both methods operate in the same context under similar circumstances (see Table 7).

Design Error Remedial in Building Project

Reducing or minimising design error on construction project is the key issue in ensuring that the buildings are well-maintained. In this regard, the study suggests some measures that could minimise the design error. These measures were ranked 1 - 5 (1 = no impact at all, 2 = rare impact, 3 = moderate impact, 4 = high impact, 5 = very high impact). The respondents were required to rank each measure based on their experiences and after that RII were calculated for each measure to know, which mostly minimise design error. Measure with high RII were more applied to minimise the design error that induced variation in building projects. Knowledge sharing comparatively have high RII (0.6). Even though knowledge sharing has high RII, other measures which should not be ignored. These measures include visitations to the site before designing, proper planning and others shown in Table 8. These proposed measures are in line with those suggested by Palaneeswaran *et al.* (2007)

CONCLUSIONS

It emerged that using DB could have a more significant impact on the cost overrun than using DBB. Regarding the potential of the delivery method between DBB and DB on time overrun, the RII calculated revealed that the DB had considerably low possibility of time overrun than DBB. It has also emerged in this study that the designer ought to be held responsible for errors evident in designs and ought to foot expenses for the consequences of these errors as well as some tangible/intangible ripple effects that might have been felt by other stakeholders.

The study also found that DB delivery methods accounted for more design error when applied in construction project as compared to DBB. Also, the technological factor and design complexity constituted two aspects that could potentially cause design risks in the construction project. The DB method has emerged in this study as the best method deserving consideration in reducing variations stemming from the design error.

Recommendations

Based on the findings and conclusions, the study recommends that even though some issues seem to be minor, they tend to affect construction projects. The overriding concerns raised by the respondents require addressing the following issues:

i. To prevent/reduce the occurrence of design errors on construction projects, construction stakeholders should consider the consultants' experience, adequate design reviews, awareness of changes in design standards and specifications, proper communications among project team, proper co-ordination between the project team, proper planning, inspection of projects and unclear scope of works.

ii. As material selection, technological aspects, change in schedule, change in specifications, non-compliance of design with government regulations, profit maximisation, unforeseen conditions seem to have low RII in relation to others, these aspects should not be ignored when considering aspects related to minimising design risks.

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