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Design Errors in Building Construction Projects

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Abstract - *Design errors are inevitable in the construction industry. These are unavoidable failures occurring when information is incorrectly applied or used, or the pertinent information is not accessible. 'Design errors' refers to the failures of humans to design tasks within time limits and accuracy (E.D Love, 2016). Owing to the required level of accuracy and time constraints, common human errors leads to design errors. These problems can influence the quality of both design and construction. Deviation from actual values, inadequate precision and inconsistencies in measurement are also considered as design errors (Dosumua, 2017). 'Design errors' refers to design mistakes, design omissions, and design conflicts. These mistakes can occur due to memory failures or slips due to incorrect knowledge (Ali Haghani; 2015). Many researchers consider design errors as the most critical problems in construction industry. There is need to evaluate the types and causes of design error there are in a construction project. To create an effective strategy to manage design errors, it is important to recognize the level of their impact. Design errors in different building components may have different levels of impact. The aim of this study is to identify and evaluate the impact of design errors in building construction projects and develop a framework to address them effectively.*

***Key Words*: Design errors, Errors, Rework, Cause of design error, Impact of design error.**

1. INTRODUCTION

Construction is complex and uncertain by its own nature (Dedy Farhan Fuadie, 2017). Unlike other sectors of the economy such as manufacturing, the design and production activities of construction projects are separate functions (D, 2017). That is, the design and construction of a building are two separate functions performed by different parties working independently (Juliana, Ramirez & Larkin, 2005). Design errors are unavoidable in any construction projects and can adversely affect cost, schedule and safety and project performance (Peter E.D. Love, 2014).Despite stringent rules and procedures, regulations and standards, errors still manage to propagate themselves within the design process (Peter E. D. Love, 2009).Design errors are an inevitable and important issue which have negative impact on project management efficiency and effectiveness (E.D Love, 2016). They are the important contributors to reworks, cost overruns, schedule delays, and unsafe environments which affect project performance (Yogen Sadashiv Masurkar, 2014). Different types of design drawings may have various levels of design errors due to many factors such as unclear overview of the designs, lack of coordination process, and human mistakes (Dosumu & Aigbavboa, 2018). In construction project, all the stakeholders such as owner, contractor have different interests in the design implementation. These various interests leads to design errors which can arise at any time. The occurrence of these errors can increase many difficulties in construction management (Bijen, 2003). These difficulties can lead to between 80% and 90% of the failures occurring in construction projects (Robert Lopez, 2016). Engineering failures account for as much as 10% of the total investment in new buildings and structures (Musa Shamsudeen, 2016). Importantly, these failures are not restricted to simple direct cost considerations because they are also inextricably linked to less tangible environmental and social costs (E.D Love, 2016). They can also incur more cost that adds a project's value around 14.2% (Ali Haghani, 2015).

Despite the amount of research that has addressed error causation in construction and engineering projects, the actual costs associated with design errors remain unknown because they are not formally measured by organizations (Love et al. 2009). Even at a project level. Design error costs are rarely measured, although a proclivity exists for them to manifest as change orders or claims (E.D Love, 2016). If the occurrence of design errors cannot be effectively controlled and it can greatly affect the construction process. Design errors are thus very significant and should be carefully managed to ensure the success of construction projects and to minimise difficulties in project performance.

2. NEED IDENTIFICATION

Design errors are unavoidable in any construction projects and can adversely affect cost, schedule and safety and project performance (Peter E.D. Love, 2014). Despite stringent rules and procedures, regulations and standards, errors still manage to propagate themselves within the design process (Peter E. D. Love, 2009). Even at project level design error costs are rarely measured, although a proclivity exists for them to manifest as change orders or claims (E.D Love, 2016).A large proportion of rework and non-conformance costs are also directly due to deficiencies in design and contractual documents and in the transfer of information during the design process (Peter E. D. Love, 2009).

"Avoidable errors are costing the £100bn a year construction industry £21bn annually, according the 'Get it Right Initiative (GIRI)' launched to help firms avoid construction errors." The research shows that between 10% and 25% of project costs are lost through errors. This includes direct and indirect costs plus unmeasured costs." (GIRI, 2019). On average 78% of the total numbers of contract deviations identified were design related and that these deviations made up 79% of the total deviation costs (Burati et al.2004). A national survey of Australian contractors by Tilley & McFallan in 2000 found that design documents deficiencies were directly responsible for approximately 50% of all variations, contract disputes and cost overruns (Tilley, 2005). A research by the USA's Construction Industry Institute (CII) reveals that direct costs caused by rework average 5% of total construction costs (CII 2005) (but range from 0-25%). "Avoidable errors are costing the £100bn a year construction industry £21bn annually, according the 'Get it Right Initiative (GIRI)' launched to help firms avoid construction errors." The research shows that between 10% and 25% of project costs are lost through errors. This includes direct and indirect costs plus unmeasured costs." (GIRI, 2019). Architectural error amount 60% of errors in construction project based on a survey of 250 building projects (Vachara Peansupap, 2015). One of the main reasons for claims in construction projects is the engineering design for the project errors. Claims because of architectural errors are 20 % of the contract value (ER. Hassan Mohamed Abdulnabi, 2016). As per the research done in 2019 on risk in design management in SPA, Delhi, design error and change had the second highest risk severity with respect to design management after lack of coordination.

Design errors have been the root cause of several catastrophic accidents that have resulted in the loss of life and injury of workers and members of the public. So much emphasis is placed on the issue of time and cost that quality takes a back seat (Musa Shamsudeen and Obaju Biodun .N, 2016). Due to the complex nature of the construction industry, and the variety of definitions and interpretations of error or rework, there has been little agreement as to a common classification system for recording errors and rework. This leads to uncertainty over the true scale and source of the issue. To avoid errors in construction project and to complete the project on time without excessive cost overrun due to errors, specific attention should be paid in the planning and designing phase of the project.

3. AIM

Aim is to identify and categorize Design Errors in building construction project and their cost implications and to develop a framework to address the design error in building construction project.

4. OBJECTIVE

1. To develop an understanding of Design Error in Building construction projects.
2. To identify, evaluate and prioritize design errors and their causes in the building construction project.
3. To identify the impact of design errors on a building construction project and their cost implication.
4. To develop a framework for the mitigation of design error in building construction projects.

5. RESEARCH METHODOLOGY

To address the research questions or meet the research objectives, the following research steps are proposed-
Step 1 - Desk research for collecting the data on what constitutes as design errors, their types, their causes and impact.
Step 2 –Listing of design error, their causes and impact from literature, case examples and survey.
Step 3 – Ranking of Design Error on the basis of their occurrence and identifying most occurred error and using this ranking in framework.
Step 4- Development of steps involved in framework and demonstrating it through an example.
Step 5-Validation of framework through its application on case example.

6. LITERATURE REVIEW

Errors occur in all construction projects and cannot be avoided or disregarded. When an error occur, some modifications are required to the project design and specifications (A. Fleming, 2013). In the past, several researches have been done the design error in construction industry. The main focus of the literature review is to analyse design error in building construction industry, identify the cause of design error, its impact on a building construction project and the methodologies adopted for the mitigation of error, design management and their limitations in order to develop a framework to deal with the errors.

6.1 Design Errors

An error is defined by (Webster, 2017), as "a deviation from accuracy or correctness; a mistake, as in action or procedure; an inaccuracy, as in speaking or writing." Design errors are the deviation from the plans and specification (Ali Haghani, 2015). Design error are the occurrences which were unexpected and which could not be attributed entirely to chance or circumstances (Busby, 2001). Design errors are also defined as the failure of planned actions to achieve their desired goal, where this occurs without some unforeseeable or chance intervention (E.D Love, 2016). Design error are the errors occurring when the execution of a task that is either unnecessary or incorrectly carried out (Tucker and Edmondson, 2002). A number of latent conditions reside within project systems that influence error-provoking activities to take place and, therefore, contribute to design errors occurring downstream during construction (Love et al., 2009). Deviation from actual values, inadequate precision and inconsistencies in measurement are also considered as design errors (Love et al., 2009). 7 Researchers that have examined design errors in construction have often interchangeably used the terms inadequate design, design inefficiency, design changes, omissions, defects, quality deviations, non-conformances, and failures. (Josephson et al. 2002). The term failure is often used interchangeably with error; however, a subtle difference between error and failure exists. A failure is "an unacceptable difference between expected and observed performance" (Ayininuola Olalusi, 2004). With a failure an implicit expectation, exists; whereas, in the case of an error an unforeseeable or chance intervention takes place.

The image describes that due to design error and variation there is delay in completion of work and not completed work. Figure 2: Schematic model for understanding the dynamics of design errors. (Image source: Mathematical and Computer Modelling, 2013).

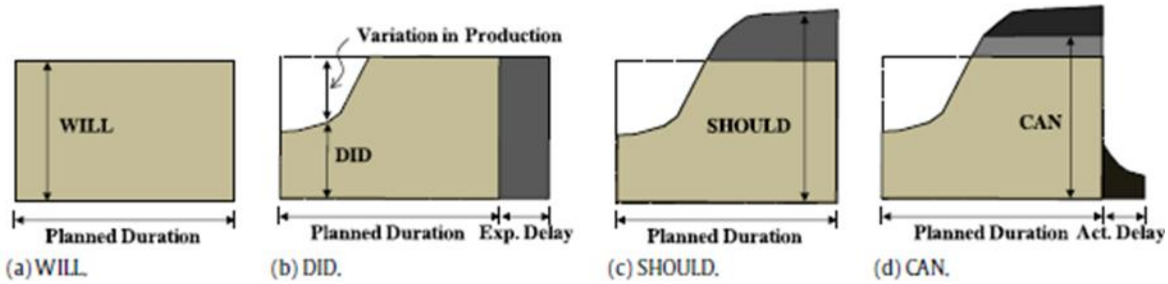

Image -1: Schematic model for understanding the dynamics of design errors.
(Image source: Mathematical and Computer Modelling, 2013)

Table -1: Definition of design errors as described in various literatures.
(Image source: Author)

SNo.	Authors	Definition of Design Error
1	John J. Anumah, Lesado Anumah	Design errors are omissions and ambiguities from drawing or specification.
2	Reason and Hobbs(cited in Robert Lopez 2018)	An outcome that essentially involves a deviation of some kind, whether it is a departure from the intended course of actions, departure from a path of actions planned toward a desired goal or deviation from the appropriate behavior at work.
3	Busby (2001)	Occurrences which were unexpected and which could not be attributed entirely to chance or circumstances.
4	Bea (cited in Atkinson 1998)	A departure from acceptable or desired practice on part of an individual that can result in unacceptable or undesired results.
5	Knocke (2000)	Any departure from correct construction including checking and supervision technical inspection; and absence of adequate instructions for maintenance and operation of the building.

6	Dedy Farhan Fuathe, Yani Rahmawati, 2017	Errors are deviations from true values, lack of precision, measurement variations due to lack of human perfection and tools.
7	Vachara Peansupapa, Rothmony Lyb (2015)	Design errors refers to the failures of humans to design tasks within time limits and accuracy.
8	Oluwaseun Sunday, Dosumua, Clinton O, Aigbavboa (2017)	Design error are defined as preventable deviations from acceptable standards of practice during the design of construction projects.
9	Love et al. (2008)	Unintended deviations from correct and acceptable practice that are avoidable.
10	Rooney, et al., (2002)	Deviation from a code of behaviour; an act involving an unintentional deviation from truth or accuracy; an act that through ignorance, deficiency.

7. Survey

A survey was carried out with the aim of ranking them in terms of their occurrence in construction project through the collected data of design error through survey and case examples. The survey consisted of 17 questions for the purpose of ranking. Design Errors were rated in terms of the frequency of their occurrence in a building construction project on a scale of 1 to 5. 1 - Rarely (Less than 5 times), 2 - Sometimes (5 - 10 times), 3 - Frequently (11 - 15 times), 4 - High (16 - 20 times), 5 - Very High (>/= 20 times).

Relative Importance Index is calculated for each of the error and ranked accordingly.

RII = Sum of weights (W1 + W2 + W3 + ……+ Wn) / A x N
Where W = weights given to each factor by the respondents and will ranges from 1 to 5
Where '1' is less significant and '5' is extremely significant. A = highest weight (i.e. 5 in this case), and N = total number of respondents.
Higher the value of RII, highest is the occurrence of that error
RII has been calculated for every design error as explained below:
Q1: For Design Changes based Error: RII = 233/5x37 = 0.991

7.1 Survey Results

Table -2: Survey Results
(Source: Author)

	Types of Design Errors	RII Value	Ranking
1	**Design Change based**: Due to frequent design changes during construction process.	0.991	1
2	**Coordination based**: Due to improper coordination between the stakeholders.	0.710	3
3	**Scope based**: Due to unclear scope of work.	0.629	7
4	**Omission based**: Due to omission of data in design drawings/documents.	0.689	4
5	**Non-conformance based**: Due to non-conformance of design with the standards.	0.557	11
6	**Skill/performance based**: Due to lack of skills of the designer.	0.548	12
7	**Drawing/Documentation based:** Due to improper documentation of shop drawings and design data.	0.642	6
8	**Process based:** Due to the software/techniques used while developing the design.	0.463	16

9	**Knowledge based:** Due to lack of knowledge of the type of project.	0.472	15
10	**Specification based:** Due to ambiguity in specifications.	0.565	10
11	**Communication Gap based:** Due to communication gap between the stakeholders.	0.617	8
12	**Violation based:** Due to Non Compliance of design with government regulation.	0.476	14
13	**Inspection based:** Due to improper inspection at different construction stages.	0.714	2
14	**Contractual condition based:** Due to discrepancy in contract clauses.	0.523	13
15	**Site Investigation based:** Due to improper site investigation data.	0.591	9
16	**Design Management based:** Due to lack of adequate design management process.	0.672	5
17	**Unforeseen conditions**: Known unknowns (due to unforeseen circumstances.	0.452	17

8. FRAMEWORK FOR ADDRESSING ERRORS IN BUILDING CONSTRUCTION PROJECTS

Framework will have all the stages of design process in a construction project and all the errors that may occur in those identified stages and their impact on time and cost and resources required to mitigate them. One can identify the impact of design error at any stage of building construction process, which has been a constraint in past literatures.

8.1 Methodology of Framework

Step 1: Identify all the stages involved in designing process of a construction project from the inception to the completion of the projects.

Step 2: Identify errors which are possible to occur at the identified stages of design process.

Step 3: Identify resources required for the design process.

Step 4: Develop a schedule of a construction project with those stages.

Step 5: Develop a schedule for a construction project and introduce all the identified errors in those stages of project.

Step 6: Analyze the impact on time and the extra time required by the resources will result in added cost for the project.

8.2 Data Inputs in the Framework

Following data will be required for the development of the framework: Stages of construction projects, Time taken by every stage of project, Resources required for the design error, Cost of the resources required for the stages, Type of errors that occurs in all those identified stages.

8.3 Outcome of the Framework

Following output will be developed from the framework: Impact of every error on the project schedule, Impact of errors of project time, Impact of errors on project cost, Delay occurred by each type of project, Time taken to rectify the errors, Resources required for rectifying an error.

8.4 Who can use the framework

Following project participants can utilize the framework: Project manager, Architect, Owner.

Detailed framework has been presented in the thesis report with detailed schedule and stages of design process. An example is presented here for demonstration of framework.

8.5 Demonstration through Case Example

Issue: Wall constructed in wrong location instead of partition wall because of absence of note.

Error type: Drafting Error

Identification Stage: First floor Brick work

Identification method: Monthly visit by architect

Table 3: Example for the Framework (Source: Author)

Construction stages (PMBOK)	Design Stages (RIBA Plan of Work 2013)	Milestone	Expected completion time	Delay In the activity	Analysis
Initiation	Strategic Definition/Need for project				
Planning	Preparation of Brief				
	Concept Design				
	Developed Design				
	Technical Design				
Execution	Construction	Site work			Indirect impact on project schedule. 65 days lag with finish to start activity for MEP Maximum impact on MEP works
Monitoring and Controlling		Civil Works	16 days	30	
		Service MEP			
		Finishing work			
		Landscape and external development			
Closing	Handover and Close Out		-	-	-

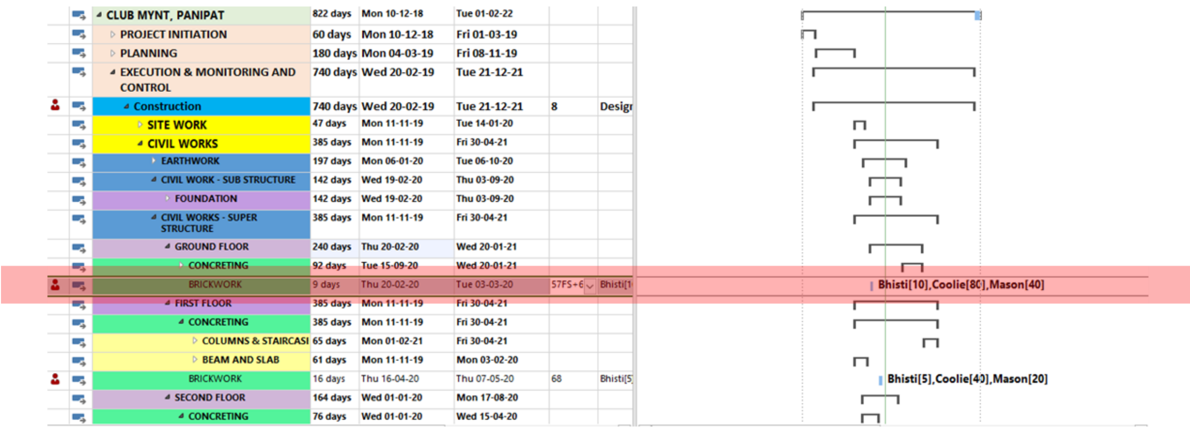

Image 2: Schedule without the application of error (Source: Author)

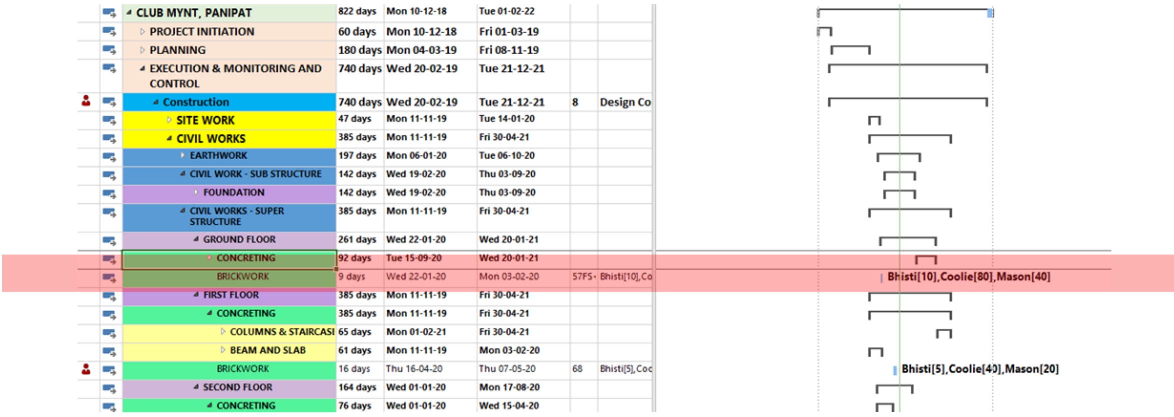

Image 3: Schedule with the application of error, 21 days delay in ground floor work. (Source: Author)

Table -4: Solution (Source: Author)

Solution:	
Time taken to rectify drafting error	12 days(Including approvals and discussions)
Time taken to demolish the wall	2 days
Rework	7 days
Total delay for this error in the activity	21 days
After adding the error, delay in Schedule of ground floor	21 days
After adding the error, delay in Schedule of project	No variation
Time required by other consultants to coordinate the drawings	14 days
Resources required to rectify the error	Architect

The total costs of design errors were calculated from the sum of the direct and indirect design error costs respondents.
Total Cost of Design Error = Direct Cost + Indirect Cost
Direct Cost: Demolition cost + Resources cost/day cost X9 + Material cost + Architects/day feesX12

9. CONCLUSION

From the application of DE in project schedule it was derived that it has both direct and indirect impact on construction project and it varies depending upon the stage of the project. During plan stage impact of error mostly result in time overrun and it has less impact on the direct cost of the project. During construction phase, civil work - MEP work has the maximum amount of impact on the time and cost of the project. With the application of framework one can calculate the cost and time impact of design error which can be utilized in future projects as well. This framework can be utilized at initial stages of construction project to reduce the impact the design error in construction project.

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