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Construction Design-Phase Errors and Their Impacts on Project Performance Case Study of Lebanese Local Applications

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Abstract: *Many are the problems that may arise through the different phases of any construction project; the "Design" is the phase considered as the roadmap to achieve the project expectation. However, design error appears to be found in all types of construction projects and can significantly degrade the project performance by generating reworks necessitating additional time, cost and resource expenditure. This paper conducts a study of the impacts of the design errors on construction project performance typically applicable to the Lebanese construction sector where majority of design firms omit design audits, reviews and verifications to maximize their fees and profits; the objective is to identify the causal factors of design errors in construction projects, and assess them with their derived relative weights in terms of project performance impact. Ranking of causes depending on respondents' opinion and agreement among raters are conducted.*

Keywords: Construction, Design Errors, Error Cost, Project Performance.

1. INTRODUCTION:

The construction industry is major player in developing countries and specifically in Lebanon. Despite this notable contribution to the economy, the Lebanese construction industry's performance still remains low. Going through the construction activities, different problems may arise, especially that the design and production are two separate functions, performed by different parties (consultants and contractors) [9].

The "Design" is a very important step in a construction process; it can be defined as a roadmap to achieve unique expectations. The design defines the plans, parameters, specifications, costs, activities, processes to achieve the objective [2]. Under such scope of design work, design error appears to be found in all types of construction projects, all of which leading to variations; Design errors can significantly degrade the project performance by generating reworks necessitating additional time, cost and resource expenditure [4].

Upon a literature review, [6,8] the three prominent sources of variation are:

- Design error and failures, accounting for around 65% of variation;
- Design changes contributing to around 30% of variation;
- And around 5% for other reasons.

From the foregoing, a strong inter-dependence between design errors and project performance (time, cost, quality) can be stated. This paper conducts a study of the impacts of the design errors on construction project performance typically applicable to the Lebanese construction sector where majority of design firms omit design audits, reviews and verifications to maximize their fees and profits; the objective is to identify the causal factors of design errors in construction projects, and assess them with their derived relative weights in terms of project performance impact. A ranking list of causes depending on respondents' opinion and agreement among raters are to be conducted.

2. THE "DESIGN" PROCESS AND ERRORS:

During the lifecycle of any construction project, the design process is considered the first step of the ladder that guides to production. The good this phase is performed, the best is the execution to be done.

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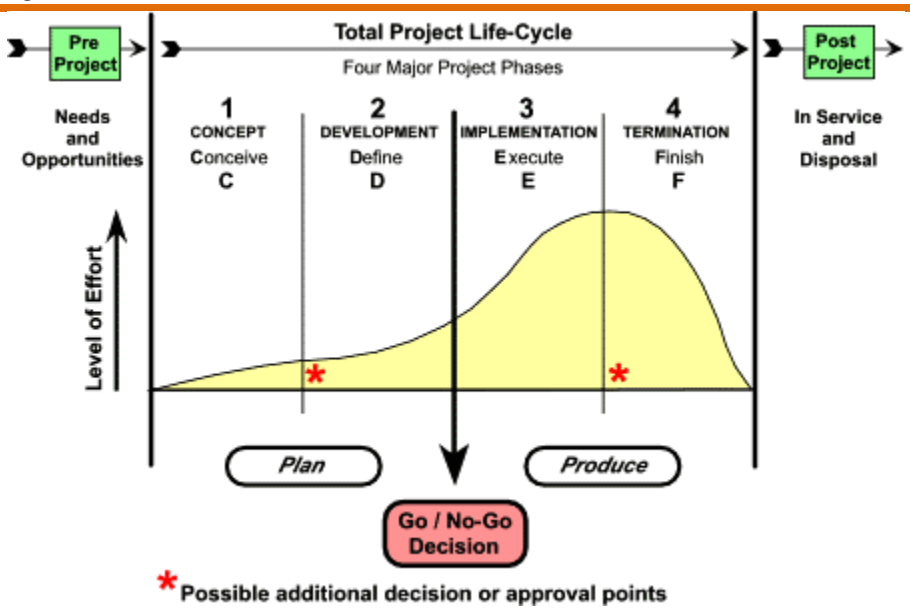

Fig. 1: Total Project Life-Cycle

The design starts up from a feasibility study, to consultancy tendering, briefing, conceptual design, detailed design ending with every aspect of the construction process with the bill of quantities and necessary specifications that guide the contractor.
With regard to the design process, errors have been adjudged to be the main source of variation, and impact on project performance. Errors are deviations from true values, lack of precision, measurement variations, etc…leading to variations. Impacts from design errors are revealed as incorrect (weak) design, unutilized facilities, addendum contract with extra cost, change in schedule and scope, poor quality work, delay in project execution time, incremental cost and timeframe, engineering failure, conflicts between stakeholders, conflicts between designers and contractors etc… [7,10]. Accordingly, and based on literature review, the researcher found that design error is a major cause of variation that negatively affects project performance, and for that reason, design error should be minimized to the barest minimum.

3. RESEARCH METHODOLOGY:

A questionnaire survey is used to elicit the attitude of respondents towards the factors causing design errors. A literature review provided the foundation of the questionnaire set-up and development. Questionnaires are delivered by the researcher to randomly selected population of the construction industry as owners,

consultants and contractors, where face-to-face interview can clarify the questions, clear doubts and make sure the questions are fully understood by the respondents before they answer the questions. Close-ended questionnaire was used for its advantages as it is easy to ask and quick to answer, they require no writing by either respondents or interviewer, the respondents were asked to use the 5-Level Likert scale to rank the importance of each item as shown in the following table.

Table 1. Likert scale ranking the importance of items

Item	Very important	Important	Medium importance	Low importance	Very Low importance
Scale	5	4	3	2	1

Sample sizing and selection:

- Consultants and contractors were selected from the listing of respectively consultant and contractor architects and engineers in the order of engineers and architects of North-Lebanon; (Our case study is limited to North Lebanon governorate).
- Owners and developers were selected from the most reputable nouns in the field of building construction, having attractive portfolio of already executed projects history.

A total number of 120 questionnaires were distributed for 50 Consultants, 40 Contractors and 30 Owners / Developers; 87 questionnaires were received back (response rate of 72.5%), with 36 from consultants (72%), 27 from contractors (67.5%), and 24 from owners (80%). Based on their practical experience in the construction filed, respondents were asked to rank the level of importance of each factor considered as basis of construction design phase error.
The statistical questionnaire results have been validated by:

- The Relative Importance Index RII methods, to determine the ranks of all factors [5]:

$$RII = \frac{\sum_{i=1}^{n} W}{A*N} \quad (1)$$

Where: W is the weight given to each factor by the respondents (1 to 5);
A is the highest weight (A=5);
N is the total number of respondents.

- Cronbach's Alpha coefficient, to measure the internal consistency of variables in the group [3]:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum_{i=0}^{n} si^2}{st^2}\right) \quad (2)$$

Where: k is the variables in concern;
Si^2 is the variance of component i for the current sample of persons;
St^2 is the variance of the observed total test scores;
n is the number of components (parameters).

- Kendall's coefficient of concordance, to measure the degree of agreement among raters**,** computed as per Legendre P. 2010 [1]:

$$W = \frac{12U - 3m^2n(n-1)^2}{m^2n\,(n-1)} \qquad U = \sum_{j=1}^{n}\left(\sum_{i=1}^{n} R_{ij}^2\right) \quad (3)$$

Where: n is the number of project success criteria;
m is the number of experts;
R_{ij} significant degree allocated for the i[th] project success criteria by the j[th] expert;
W Kendall's Coefficient of Concordance.

4. RESULTS AND DISCUSSION:

Table 1 shows the computed RIIs and the corresponding ranks as per the 3 types of respondents. Note that for each group of respondents, the Cronbach Alpha's coefficient is calculated to measure the internal consistency of variables within the corresponding group;

Table 1. Relative importance index and ranking of causes of design-phase errors

Causes for Design Phase Error	Consultants		Contractors		Owners	
	RII	Rank	RII	Rank	RII	Rank
Inexperience of the designer	0.578	12	0.556	9	0.467	11
Frequent changes in design due to owner dissatisfaction	0.561	13	0.533	10	0.633	6
Designer lacking the availability of material	0.589	11	0.511	11	0.667	5
Too little time reserved for design phase completion	0.806	3	0.711	3	0.700	3
Lack of human resources with designer	0.722	8	0.578	8	0.533	9
Poor working drawings	0.761	6	0.689	4	0.700	3
Inadequate data provided to designer	0.689	9	0.622	6	0.400	12
Lack of coordination during design	0.833	2	0.644	5	0.600	7
Contractor not involved in the design	0.789	5	0.600	7	0.567	8
change of scope of work by client	0.728	7	0.489	12	0.500	10
Lack of planning and analysis by owner at project start	0.617	10	0.444	13	0.367	13
Designer busy in too many assignments	0.806	3	0.778	2	0.833	1
Financial issues - Delayed payments	0.861	1	0.800	1	0.800	2

The results show that α = 0.754 for "Consultants", α = 0.929 for "Contractors", and α = 0.897 for "Owners". It can be obviously noted that values of Cronbach's Alpha are in the range from 0.75 to 0.93. Thereby, the questionnaire is valid and reliable.

The top 5 significant causes for the design errors are listed in table 2. The difference in the values of this table reflects the point of view of each group of respondents; the factor the most critical for a designer may not be the same for the owner or contractor. As it can be interpreted from the values of this table, the financial issues are in the main concern of the 3 groups of respondents; in fact, the ranked first, second and third factors are all related to the financial and economic issues of the project; this can be supported by the economical crisis the country is living, and its impact on the construction sector in particular.

Table 2. Top 5 Most Significant Factors Causing Errors in Design

Most Significant Factors Causing Errors in Design	Consultants		Contractors		Owners	
	RII	Rank	RII	Rank	RII	Rank
Financial issues - Delayed payments	0.861	1	0.800	1	0.800	2
Designer busy in too many assignments	0.806	3	0.778	2	0.833	1
Too little time reserved for design phase completion	0.806	3	0.711	3	0.700	3
Poor working drawings	0.761	6	0.689	4	0.700	3
Lack of coordination during design	0.833	2	0.644	5	0.600	7

As for the factors ranked in 4th and 5th positions, the author's point of view can be related to major reasons:

- One is due to the local authority regulations that allow junior engineers to be considered as consultants (with limited working experience in the design field) from a side; this may end with the lack of coordination and poor working drawings. These errors will be identified during later phases of the project life cycle (refer to Fig.1).
- And the other can be related to the fact that senior consulting engineers, with good reputation are usually over-loaded with the relatively good quality projects, and are urged to hire engineers under their firms to execute the works; the full coordination and follow up over the staff are usually time-consuming and any gap may lead to drawings' quality failures.

Degree of agreement among respondents:

The Kendall Coefficient of Concordance is used to determine the degree of agreement among the panel of experts with respect to their rankings; the calculated value of Kendall Coefficient of Concordance is W = 0.814. Accordingly, a test of hypothesis is done with:

- H_0: There is no agreement in ranking the causes of the design phase errors among the panel of experts;
- H_1: There is an agreement in ranking the causes of the design phase errors among the panel of experts;

Based on the W = 0.814 and all other parameters, the level of significance is found less than p = 0.05 (5% is the accepted level of the level of significance); Thus, the null hypothesis H0 is rejected and the alternative hypothesis H1 is accepted. There is a significant degree of agreement among all consultants, contractors and owners regarding the causes of the design phase errors affecting the performance of the construction industry in North Lebanon.

5. CONCLUSION:

With regard to the above presented study, we can summarize that the presented factors are essential parameters that causes errors in the design phase of construction project and which, by turn impact the overall performance of the project. These factors are critical in the local North Lebanese construction market and should be targeted to minimize the errors and maximize the overall performance of any construction project. The support of the local authorities as well as the Order of Engineers and Architects can be of big revenues on quality standards of the project, where the design phase is a part of. The implementation of new strategic actions and rules can limit major causes of design errors and accordingly benefit project performance. Never to forget that the stated problem should be the concern of all the participants - owners, developers, consultants, contractors, quantity surveyors and end-users - in the construction sector where their joining efforts will lead to better performance and revenue to the project.

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