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THE IMPACT OF DESIGN CHANGES IN CONSTRUCTION PROJECTS ON THE COST CHARGED BY CONSULTANT OFFICES

Abstract

In any construction project, a large number of modifications occur. The consequences of those modifications may result in additional costs due to the re-design of the project on each member of the project's stakeholders. The financial impact of modifications during the construction phase of a project on consultant offices will be explored in this study. The aim of this study is to investigate the cost of the modifications and to examine the type of relationship between the time spent on the design to accomplish the modifications and the amount of money earned in the return of the extra work done. As a wrong estimation of the additional cost may lead to an atrocious financial impact on the office and dramatic consequences. Professional interview method was used to collect data from four different Lebanese consultant offices. Eleven projects were selected in this study. These projects were categorized into three different groups based on the initial cost of the structural design. A regression model that can be used to forecast the cost of extra work for modifications based on the initial design cost was derived in this study. The outcome of this study will simplify the forecasting of cost of any modification in construction projects.

Keywords

Construction projects, cost of re-design, regression analysis

1. INTRODUCTION

Owing to a plethora of reasons, it is expected that modifications in construction projects will always happen. They cannot be avoided nor prevented. By definition, a modification in a construction project is an alteration or an adjustment of the present situation, that may require the redesigning of the project. Since there is large number of stakeholders in a construction project, the impact of project modification on each one of them can be costly. Consulting offices face a major problem when modifications are set, as modifications can cause changes in the cost and time completion of projects.

Change orders have long been an inherent part of the construction industry around the world, where construction projects suffers from variation orders (Memon *et al.*, 2014). Regardless of the cause of modifications, the redesign part of the project has a "cost impact" on each stakeholder involved in the project. Therefore, this study was carried out to investigate the cost of the modifications and to examine the type of relationship between the time spent on the design to accomplish the modifications and the amount of money earned in the return of the extra work done. Data were collected by direct communication with four consulting offices in Lebanon in order to enhance the research and make it more collaborative.

2. LITERATURE REVIEW

Many research studies dealt with the impact of design changes on cost of construction projects. Agung *et al* (2015) classified two groups as influential factors of design changes; the internal factors consist of owner, design consultant, construction management consultant, and contractor, while the external factors involve political and economic, the natural environment, advance of technology, and the third-party. Their study showed that the owner is the greatest influential factors on the occurrence of the design changes. Furthermore, Abdul-Rahman *et al.*, (2016) reported the causal factors of design changes are owner/client-related, consultant-related, contractor-related, site-related and external-related. Amusan *et al* (2017) reported similar finding stating that additional work was needed as a result of clients' request.

Nylen (1996) showed that 51% of rework comes from communication problems between the owner and designer in design stage. Chang (2002) identified three categories for cost increases for engineering design projects: under owner's control, under consultant's control, and beyond-control. Alnuaimi *et al* (2010) reported that the owner/client's additional works and modifications to design were the most important factors causing change orders. One of the most important effects of change orders on the project were found to be cost overruns. The contractor was found to be the party most benefiting from the change orders followed by the consultant. Famiyeh *et al* (2017) studied the causes of delays and cost overrun in the construction sector. Their study reported that the financial problems (delays in payments of completed works) and variations in designs were reported to be the key factors causing construction cost overruns.

Peansupap and Cheang (2015) showed the changes in construction project occurs from several originators such as owner/client, designer, and other parties. They found the most of the important change issues leading to conflicts about project cost originate mainly from the owner's side. Atout (2016) studied the causes of delays in construction projects in the Gulf regions. The study reported that the consultancy offices must coordinate and communicate with the client to make sure that project objectives are very clear and can be achieved as per the client requirements. Consultants should also advise the client about the general cost and time implications resulting from changes during the design requested by the client. Furthermore, consultancy offices should also be familiar in cultural issues to manage and control the required changes and modifications of client during design development phase and during executions well.

Yap and Skitmore (2017) revealed that building projects in Malaysia encounter time-cost overruns of 5-20% due to design changes. Chang *et al.* (2011) found that construction cost changes are from 2.1% to 21.5% and on average 8.5% arising from design changes, equivalent to the fee of a new design project. Yap *et al.* (2017) found that the cost rework to range from 3.1% to 6.0% of project value and schedule growth due to rework to range from 5.1% to 10.0%.

As shown above, previous research primarily focused on identifying the factors influencing design changes and factors causing cost overruns of construction projects. Others, attempted to find out costs for design change or rework. Given that different approaches of design change or rework costs are presented in the literature review, however, there is still a need to identify the impact of design changes/modification on the cost charged by consultant/design offices. This will enable the

development of strategies or frameworks for effective owner or consultant's management of design changes/modification in future.

3. OBJECTIVES OF THE STUDY

Four different objectives were considered in this study:

1. Dependency of cost charged for the initial design on time spent on the initial design
2. Dependency of cost charged for the modifications on the time spent on the modifications
3. Dependency of cost charged for project modifications on the cost charged on the initial design
4. Dependency of time spent on project modifications on the time spent on the initial design

To find out the answers of these objectives, standard simple regression analysis was performed using Microsoft Office Excel™ to generate a relation between independent and dependent variables, and assess the strength of this relationship.

4. DATA COLLECTION

In this research study, the selection of professionals (respondents) was limited only to engineers specialized in designing and planning in the construction industry in Lebanon.

The name of the consultancy offices and the location of the construction projects cannot be revealed due to the confidentiality agreement imposed on this study. Direct questions regarding the cost and time needed for the initial design and for the design of modification with senior design engineers were carried out as the method of data collection. Data from eleven projects were collected to explore financial impact on consultant offices due to client modification requests that resulted in changes in the structural design. The construction projects selected in this study were executed between 2017 and 2019 in various regions in Lebanon. **Table 1** presents the time needed and the related cost in US dollar (\$) for the initial design and the requested design modifications. As requested by the consultant offices, the project and its related modifications cannot be named in this study.

Table 1: Duration and cost of the initial design and the requested design modifications

Project Number	Consulting Offices	Initial design		Design modifications	
		Time (days)	Cost (\$)	Time (days)	Cost (\$)
1	A	7	1400	3	1100
2	A	285	76000	10	10000
3	A	10	10000	25	5000
4	A	20	11000	6	3100
5	B	45	15000	7	2000
6	B	60	8000	21	3000
7	B	7	3000	3	1600
8	C	120	45000	20	6000
9	C	15	7000	5	1800
10	D	210	50000	15	6000
11	D	15	3000	15	3000

5. RESULTS AND ANALYSIS

The approach used to answer the above objectives was to generate linear regression lines and estimate the slope coefficient between the dependent and the independent variables, and to test its statistical significance.

5.1 Objective 1

The following test hypotheses address this objective:

- H0: the cost charged for the initial design does not depend on the time spent on the initial design.
- H1: the cost charged for the initial design depends on the time spent on the initial design.

A linear regression test was chosen to conduct the hypothesis test. This test was carried out in order to investigate the type of relation between the time spent to accomplish the design work and the amount of money charged in return. The results of this test shows a highly significant coefficient (p-value= 0.00966) at the 5% significance level, which means that H1 hypothesis is accepted. Hence,

there is positive dependency (Slope>0) between the amount of money earned on the initial design and the time spent to complete it (Mendenhall, 2013). To visualise the dependency, the data of both values presented in Table 1 were plotted in Figure 1.

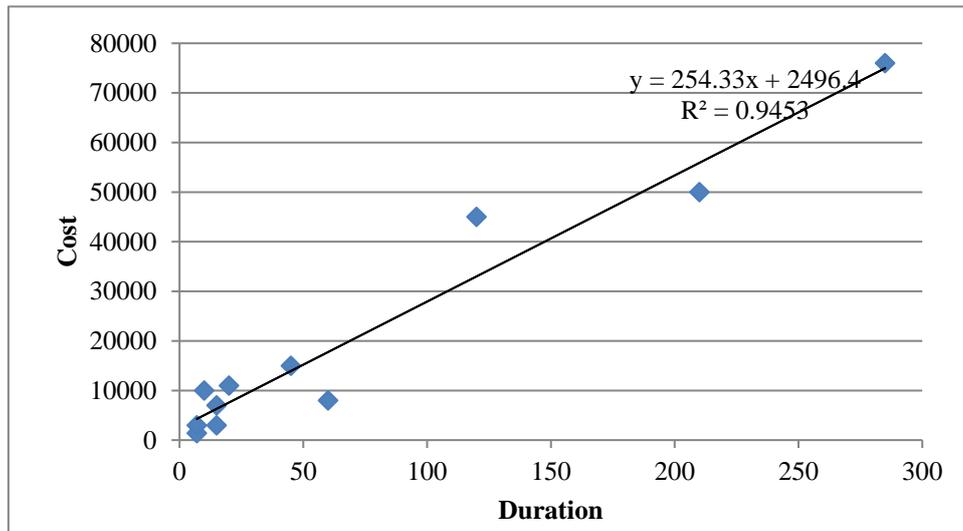


Fig.1: Cost of the initial design in \$ versus the time spent in days

Figure 1 shows that the value of the coefficient of determination R^2 (which in case of simple regression is the square of the correlation) is equal to 0.945 and it shows that the regression model can explain the relationship that the money charged on the initial design has some dependency on the time consumed on the design.

5.2 Objective 2

The following test hypotheses address this objective:

- H_0 : the cost charged for the modification does not depend on the time spent on the modification.
- H_1 : the cost charged for the modification depends on the time spent on the modification.

The results of this test using regression analysis show significant dependency relationship (p -value=0.00966) at the 5% significance level and therefore there is positive dependency (Slope>0) of the money charged on modifications on the time consumed to do these modifications. In this case, H_1 hypothesis is accepted. On the other hand, the value of R^2 for the regression model is equal to 0.186 and it shows that the regression model moderately explains the dependency relationship, as shown in Figure 2.

In contrary to the outcome of the initial design cost-time relationship (objective 1), the outcome of the modification design cost-time relationship (objective 2) shows moderate dependency between the money charged on modification design and the time spent on redesigning the project. This observation clearly indicates that there are other factors rather than time that influence the cost-time relationship of modification design of a project.

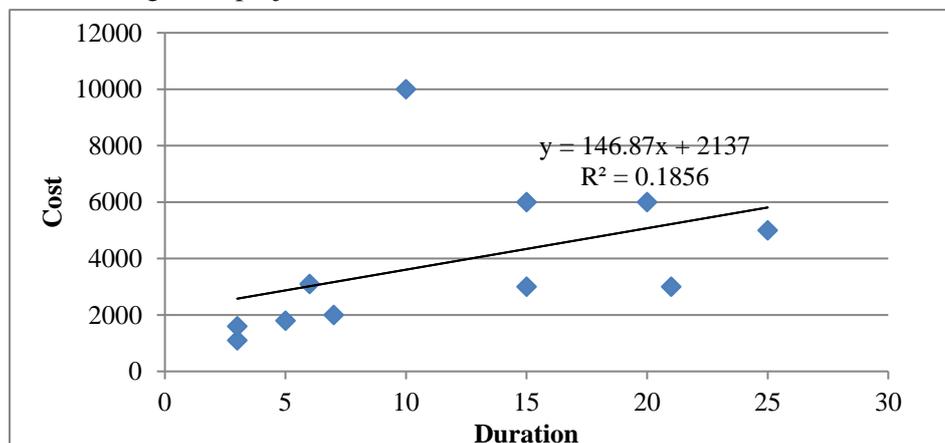


Fig.2: Cost of the modification re-design in \$ versus the time spent in days

5.3 Objective 3

The following test hypotheses address this objective:

- H0: the cost charged for the modification does not depend on the cost charged for the initial design.
- H1: the cost charged for the modification depends on the cost charged for the initial design.

Here, a simple linear regression analysis was conducted for this test and it shows that the dependency is highly significant (p -value= 0.00004) at the 5% significance level, and hence the cost charged on project modifications depends significantly on the cost charged on the initial design, and it is positively correlated (Slope>0). In this case, H1 hypothesis is accepted. In addition, Figure 3 shows that the value of R^2 for the regression model (i.e. 0.88) is high. Therefore, the correlation relationship between initial cost and cost of modification can be established.

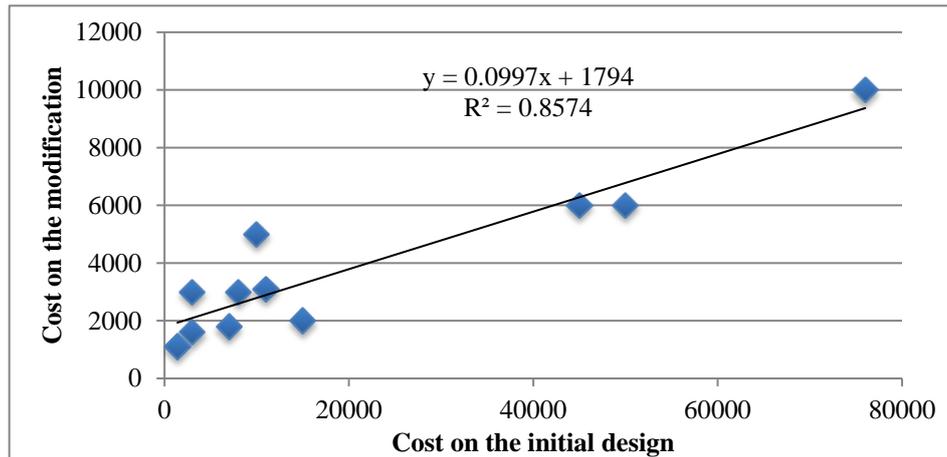


Fig.3: Cost of initial design versus cost for the modification

5.4 Objective 4

The following test hypotheses address this objective:

- H0: the time spent on project modifications does not depend on the time spent on the initial design.
- H1: the time spent on project modifications depends on the time spent on the initial design.

Here, a simple linear regression analysis was conducted for this test and it shows that the dependency is not significant (p -value = 0.60) and therefore there is no evidence that the time spent on project modifications depends on the time spent on the initial design. This can be clarified as the initial cost takes into account all the factors related to the design. It is commonly known that, the main part of the cost charged is based on the complexity of the project rather than on the time spent on the design. In this case H1 hypothesis is accepted.

The outcomes of objectives 1 and 2, showed similar relations between the time spent and the cost for the initial design and the modification. Therefore, as the initial cost takes into account all the factors related to the design, it is not surprising that factors other than time affect also the cost of modification, since both costs are closely related.

The outcomes of the four objectives in this study shed the light on the strong relationship between both costs considered, and set aside the effect of time on the cost. Furthermore, the analysis of the data collected from the eleven international projects, shows clearly that the strongest correlation in this study is the one between the cost spent on the initial design and the cost of modification (objective 3). The outcome of objective 3 can be used for further assessment to define a guideline to forecast the additional cost of any modification work for a construction project.

Hence, a further study was needed to define the type of relation between the costs. Therefore, the following test hypotheses were considered:

5.5 Objective 5

The following test hypotheses address this objective:

- H0: the percentage of cost charged for project modifications does not depend on the cost charged for the initial design.
- H1: the percentage of cost charged for project modifications depends on the cost charged for the initial design.

To highlight this dependency, the data of both values presented in Table 1 were plotted in Figure 4 and a best fit curve was obtained.

Figure 4 shows clearly that there are three different regions in the relation between the percentage of cost of modification and the initial cost of the design. Hence, analysis of variance was considered in this study to investigate the differences between the three categories based on the size of the project. These categories are as follow:

1. Category 1: project initial cost not greater than \$5000. This corresponded to an expected cost of modification between 35%-50% of the initial cost. In this study, projects 1, 7 and 11 fell in this category.

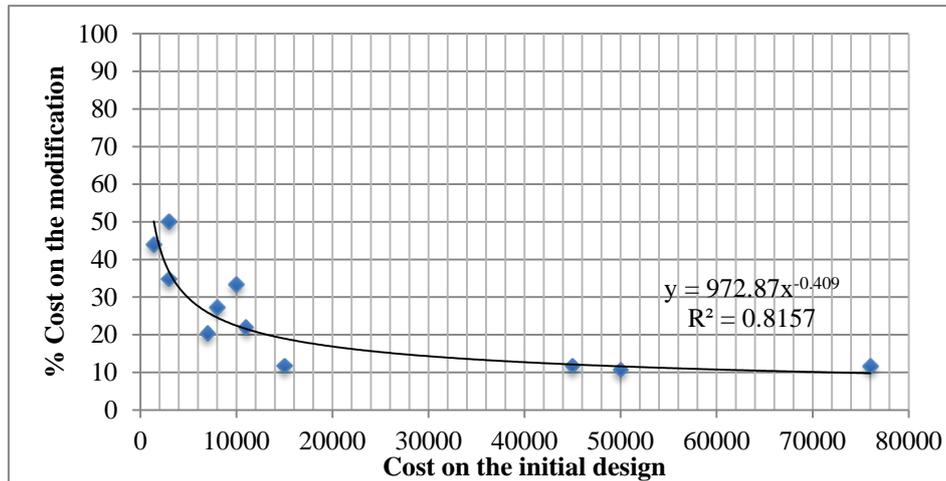


Fig.4: Percentage cost for the modification versus cost of initial design

2. Category 2: project initial cost between \$5000 and \$15000. This corresponded to an expected cost of modification between 20%-35% of the initial cost. Projects 3, 4, 5, 6, and 9 are in this category.

3. Category 3: project initial cost above \$15000. This corresponded to an expected cost of modification might be around 10% of the initial cost, and hence projects 2, 8 and 10 are in this category.

By using Analysis of Variance for this test, it was revealed that there is significant difference between the mean percentage of the cost spend on modification based on the size of the project (p-value=0.0155) at the 5% significance level.

The data collected in this study, categorized the eleven selected projects in three different groups based on the initial cost of the structural design. These groups are identified as: low cost, medium cost, and high cost designed projects. High cost projects are usually carried out on large projects; such as residential buildings, private services buildings, hospitals, public services buildings, etc. These projects are usually complex and required much more design work than other projects. Surely, this is the main contribution for the high charge by the consultancy offices. The modifications on these projects may occur, but usually, they are minor as large consortium of engineers and others were involved in the initial design. Therefore, these modifications do not have a major impact on the project design because they are not major changes. Therefore, as percentage wise of the initial design, the charges of these modifications are quite low in comparison to the other selected projects in this study.

On the other hand, small projects; such as private houses or extension on existing buildings, do not incur a significant design cost. However, any modification on these projects, which are usually required by the owner, result in re-designing the project. Even though the charges from the consultancy offices are not excessive, they are when expressed as a percentage of the initial design, significantly higher than the other selected projects in this study. The medium size projects such as small residential building or large private houses are categorized between high and low design cost projects.

6. CONCLUSIONS AND RECOMMENDATIONS

In construction projects, modifications are unavoidable. As a result, consultant offices have to handle the consequences of these modifications. The consultants must assure the continuity of the project and assess the technical consequences of the modifications on the structural design of the

project. However, the consultant offices should not neglect the additional efforts and cost incurred due to these modifications. Therefore, they should estimate carefully the cost to accomplish the additional tasks due to modifications. As a wrong estimation of the additional cost may lead to an atrocious financial impact on the office and dramatic consequences.

There was a concern regarding the sample size when this study was considered due to the confidentiality of the data collected and finding consultancy offices who are willing to provide data. Even though small size sample do not normally yield precise estimates, there is no loss of generality with small sample size as long as the data collected are interpreted carefully. Also, obtaining confidential data and official approval is easier with small size sample compared with large size sample.

The outcome of this study can be used to predict the cost of extra work for modifications based on the initial design cost. In order to predict the cost of modifications, consultant offices must allot their projects, based on the initial cost of the design, in one of the following categories:

- Category 1: project initial cost not greater than \$5000, hence, the expected cost of modification might be between 35%-50%.
- Category 2: project initial cost between \$5000 and \$15000, hence, the expected cost of modification might be between 20%-30%.
- Category 3: project initial cost above \$15000, hence, the expected cost of modification might be around 10%.

The prediction presented by this study is limited to the modifications or changes carried out during the execution of construction projects on consultancy offices. This prediction could be part of the contract signed between the consulting office and the client under the section of additional work. The method of calculation of the cost of extra work will be known by the two parts for further modifications. This step will help both parts to assure a better relation at work and clear one. Modifications in construction projects always occur, therefore owner should accept the initial design with flexibility, allowing contingency in the contract.

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