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Factors Affecting Change Orders in High-End Private Residential Projects in Lebanon

By

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Acknowledgment

Going back to the university with a full-time job, a house to maintain, and a child to take care of, was not the easiest thing to do. But it was made possible with the help and encouragement of the beautiful people I am blessed to have in my life.

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Factors Affecting Change Orders in High-End Private Residential Projects in Lebanon

Abstract

The thesis addresses the high end private residential projects in Lebanon, and discusses the reasons for projects' change orders. This research aims to determine the reasons for change orders, the party responsible for them, the factors that affect them, and finally, the mitigation measures to reduce them. From the literature review, reasons for change orders were extracted, some were modified and others were added by interviewing scholars in the construction sector, so that the reasons properly suit the project type being discussed. Statistical data among 23 completed projects in the past 10 years was the base of the study. Interviews with managers in leading construction companies in Lebanon contributes to analyzing the statistical data results, to give recommendations to handle the main reasons for change orders. A survey with professionals in the construction industry was conducted to rank the mitigation measures proposed. The final outcome of this research is a presentation of the results, that allows for extrapolating for future projects, as well as guidelines that could help determine the expected change order amounts, and direct the concerned parties to where the efforts should be exerted to minimize change orders occurrence.

Keywords: Change order reasons, Change order causes, Statistical study, High End Construction, Mitigation measures.

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Chapter One

Introduction

The Construction Industry has reached a spending value of around 12 trillion US Dollars in 2020 and was expected to grow 3% annually (De Best, 2021). The hefty amounts involved in this industry affects the global economy, which has triggered researchers and professionals to discuss numerous topics related to the financial aspects of the construction projects, in an attempt to analyze and solve frequently encountered complications.

One of the major obstacles with construction projects is going over budget. This can be due to an initial underestimation, or an additional request, scope, resources etc... along the project duration. The additional requests are referred to as Variation Orders or Change Orders. Change Orders are a common occurrence in construction projects. It involves an amendment of the original scope of work as in the contract (Memon and Abdul Rahman, 2014). A change order can be in the form of an addition, omission, or substitution. Being a major culprit behind over budget completions, change orders are the target of this study. The significance of change orders is not only the cost over budget they cause, but also their ripple effects on the overall performance of the project, which in turn affects the completion dates, gives rise to quality issues, and consequently results in additional costs.

Change orders can be initiated by the contractor, requesting an additional amount of money for work within his original scope, due to a modification or unforeseen condition, or it can be initiated by the owner/consultant, requesting new work, not previously included or mentioned in the original contract documents. The dilemma is that most often, the limits of

the scope of work might be unclear to one of the aforementioned parties, resulting in countless disputes.

The aim of this study is to identify through statistical analysis of previous projects the main causes of change orders and proposing appropriate mitigation measures that will reduce the number and cost of such change orders.

Our study addresses luxury private residential construction projects in Lebanon. By luxury, it is intended those projects that are considered expensive and of extremely high quality. The average cost for core and shell work of these projects is $3,000 per square meter. These projects are less affected by the economic conditions, in comparison with other single-family-home or multi-unit residential projects' markets that are highly susceptible to the housing loans market, and the general decline in people's purchasing power. Such projects have specific characteristics that make them different than other construction project types—mainly the fact that the owner does not seek profit out of this project, as it is their own residence. Therefore, the concept of saving in order to gain more profit is not an option or a target for the owner. But rather the main goal is to obtain the highest quality, and the desired level of luxury, with the best achievable price. In addition, extra costs cannot be compensated for from other operations such as the case with other for-profit projects. The latter might affect the owner's attitude towards requesting and/or approving change orders, as opposed to other types of projects. In addition, the cost of materials used, the complexity of the details, and desired level of aesthetics present unique considerations. The existing literature on this topic is limited, where most of the previous research work is qualitative and data is based on questionnaires from experts in the field. In addition, previous studies did not address such caliber of high-end finish construction. This study uses quantitative data that is extracted from projects' list of change orders.

This research also goes one step further in examining the reasons behind the change orders, by comparing different project factors and studying their effect on the project's percentage cost of change orders. The factors studied are: project contract type (lump sum or re-measured), project duration, project award year, and project client representative/ project management office.

This research is intended to shed the light on different aspects of change orders in high-end finish construction, mainly in Lebanon. Further studies and research could address the common or different aspects of change orders in such project types in other regions.

Chapter Two

Literature review

Several issues related to change orders have been addressed in previous studies, mostly revolving around three main topics: 1) the effects of change orders on the project outcomes, 2) the causes for change orders, and 3) the mitigation measures to reduce change orders.

The change orders' impact on a project is not limited to the direct additional cost it represents, but rather extends to—among others—the additional indirect costs to compensate for the consequent overheads and profits. Shrestha and Zeleke (2018) studied the effect of change orders on both cost and schedule overruns in school renovation projects in southern Nevada. They used questionnaires with construction managers, and included 3 main types of changes, contractor-initiated changes due to unforeseen conditions, owner-initiated changes, and design related ones. The additional cost percentage due to change orders was calculated in comparison with original project budget, and an average for all projects under study was used. The projects were divided into two groups, ones where the completion dates were met, and others where the projects extended their original agreed durations. A t-test was used to determine the variance in the means of those two groups. The results showed that the increased percentage of changes prolongs the project's completion time. A similar conclusion was established by Hansen et Al. (2020) in their case study for the GBK Aquatic Stadium Project, being one of the major complex renovation projects located in Jakarta. The study utilized data coding and correlation with work duration to arrive at their conclusions. Their data was created from site visits, documents' inspection, and interviews. Alnuaimi et Al.

(2010) listed claims and disputes, negative performance and morale of labors, and reduced work quality as additional effects for change orders on construction projects. It is worth mentioning as well that in some cases, disputes arising from project changes might lead to contract termination and loss in economy (Kaleem Ullah et Al, 2018). Memon and Abdul Rahman (2014) cited additional negative effects on construction projects caused by change orders; such as: increased project cost, delay in completion, logistic delays, slower activity progress, rework, increase unnecessary procurement, creation of non-value adding activities such as demolition, loss of productivity, as well as lower project quality. Changes can therefore be considered to massively affect the project overall performance.

Different researches and methodologies were used to extract and categorize the reasons behind change orders in construction projects. Al-Sahar (2019) considered the mismanagement of the construction projects in the Middle East to be the main reason for cost deviation. After conducting interviews with experts in the field for rating the reasons using Likert scale, he correlated the reasons collected with his suggested statement. A similar methodology was used by Adedeji et Al. (2018) who conducted a cross-sectional survey among professionals in Lagos to reach a different conclusion. Consultant related factors were found to be the highest among other change orders' initiators, with a mean item score of 0.95, and consists of alterations and modifications or newly requested ideas to the initial design. It is worth mentioning that in their study, various types of projects were combined in the survey, not a certain type of projects. Similar conclusion was presented by Suprapto and Wiguna (2020) in their qualitative study on 20 projects sample, assigning 31.5% of the total cost of change orders to design modifications. Dosumuac and Aigbavboab (2017) studied the impact of design errors on changes cost, and denoted it to be the main reason of changes. Their study was based on various project types in Nigeria, and involved interviews with experts, and a case study on 30 projects using a non-probabilistic convenience sampling technique. Their

study showed the following percentages distribution for various design errors: 53.5% for design calculations, 21.6% for wrong inadequacy description in specification, 13.2% for omission of details in specifications, 9.5% for absence of specifications, and 2.2% for dimensional error in architectural drawing. Another study on projects in Nigeria was done by Abd Majid et al. (2015) via questionnaires with professionals using Likert scale on a list of reasons for change orders. The most frequently mentioned reasons in the questionnaire were found to be: change of the original plan with 58%, followed by conflicting contract documents with 50%, and substitution of material and change in design with equal frequency of 43%. Changes for road projects in Sri Lanka was studied by Halwatura and Ranasinghe (2013), and their questionnaire results showed a different set for the top reasons for changes, ranked from the most significant: poor estimation, unforeseen site conditions, political pressure during construction stage, poor investigation, and client requests.

Noraziah and Zabidi (2019) did not present new reasons for changes, but rather collected from other researchers the main causes of change orders, which were listed and found out to be eighteen (18) main reasons: change of scope by client, Owner's financial problems, inadequate project objectives, replacement of materials or procedures, impediment to prompt decision-making process, obstinate nature of owner, change in specifications by the owner, change in design by the consultant, errors and omissions in design, conflicts among contract documents, technology changes, value engineering, lack of coordination, design complexity, inadequate working drawing details, consultant's lack of required data, poor knowledge of available materials and equipment, and ambiguous design details. The party responsible for each cause was allotted, to assign the client as the main contributor of the change orders. Their study presented a summary of the previous literature, and its conclusions were built on the same. Abidemi et Al. (2018) also listed the causes of change orders, discussed their effects, and narrowed them to the following: delay in completion schedule, increase in project

cost, dispute between owner and contractor, additional revenue for contractor, and decrease in quality of work. An additional reason for change orders—not clearly stated by other scholars—was mentioned by An and Ma (2019). In their research conducted via questionnaires regarding construction projects in China, contractor's desired profitability was denoted as the second most significant reason for changes after errors and omissions in the design. The latter presents an interesting conclusion in that change orders are correlated with other factors such as the contract conditions and the project management office / client's nature that would allow for the contractor to take advantage of any existing gaps for their own benefit. A different perspective and description of the causes of over-budgets was presented by Flyvbjerg (2011). He considers the root cause of various reasons presented by other researchers to be the underestimation of risks involved in projects by project planners, and denotes the same by optimism, and rather allocates all other reasons underneath this root cause.

It is to be noted that previous studies were conducted in different geographic locations and for various project types, which is believed to be one reason why diverse conclusions were reached. Some studies discussed causes that apply for a specific geographic area, such as: wars, extreme weather conditions, etc... Enshassi and Arain (2010) mentioned a major reason for change orders being the shortage of materials and lack of spare parts for construction projects based in the Gaza strip, where the construction industry suffers due to the special political nature of this area. Similarly, Halwatura and Ranasinghe (2013) highlighted the political pressure as one of the main reasons for changes in road projects in Sri Lanka.

The importance of classifying the reasons for changes and assigning the party that caused them is vital in determining the mitigation measures to reduce their amounts and frequency. The goal is to find the best tools that contribute to the highest reduction in change

amounts. Abuaddous et Al. (2020) suggested the use of Building Information Modelling (BIM) strategy for mitigating change orders in road projects. Their research concluded the most important factor for change orders to be the inaccurate quantity take-off, which can be enhanced by using BIM tools. Kaleem Ullah et Al. (2018) interviewed experts to recommend mitigation measures for the top causes of changes. The measures are applied for both tendering and execution phases of the project. Abidemi et Al. (2018) listed recommendations to reduce change orders and stressed on the importance of the early involvement of experts during the design planning and early construction phases to reduce ambiguities and elaborate the design.

It has been shown that several reasons for change orders can be attributed to incomplete information; whether it is related to site conditions, design issues, owner's decisions or others. A study on the cost overruns for projects by Kim et Al. (2008) used questionnaires with professionals in the field in order to allocate the risks associated with each project, based on data and experience from previous projects. The data was used for building a model that can predict cost changes on the basis of the risks involved. Czemplik (2017) presented a different concept that stresses not on the idea of minimizing the change orders, but rather on applying the earned value method to ensure that decision makers are aware of the consequences of delays resulting from performing additional requested work before issuing change orders. The drawback is that some contract types do not leave a window open for the contractor to refuse proceeding with a change order, which gets us back to the idea of trying to minimize the changes in the first place.

The varying conclusions presented by previous studies highlights the need for collecting a sample of one project type in a specific geographic region in order to properly investigate its specifics and eliminate factors that might not be applicable. In addition, they present the need for conducting a study on real projects data, instead of relying mostly on

surveys. The findings would be of great importance to clients as well as contractors dealing with the selected project type. Moreover, previous research did not address high-end finish private residential projects, which is the target of this study.

Chapter Three

Methodology

Data from twenty-three (23) actual construction projects [referred to hereafter as the dataset] was collected for this study. The data set includes high end finish projects only, started and completed within years 2010 and 2020. The projects vary in other aspects however, ranging from a total budget of less than one million dollars to projects reaching five million dollars. Some of the projects include infrastructure and structural concrete work, while others are core and shell. Various architects and interiors designed the projects. Similarly, different consultants and client representatives / project management offices were involved. However, the same contractor executed all the projects in the data set. Some of the projects had cost plus contracts, while others were lump sum; Nevertheless, design-bid-build process was the delivery system for all projects. The majority of the projects were located in the capital: Beirut, mainly in downtown and surrounding areas.

Our reference for the data has been collected from the contracting company. The list of change orders for each project was studied mainly with the assistance of the quantity surveyor responsible for issuing the change orders from the contractor's side. In addition, some information was obtained from project coordinators and project managers.

The list was studied from two aspects: the percentage of each cause for change order, which in turn leads to identifying the party responsible for the change order, and the percentage of change order by division, adopting the Construction Specification Institute's (CSI) formatting, which will be elaborated in the research program section. The classification

by division aims to gain a perspective on which type of work contributes to higher percentage of changes.

It is worth mentioning that the number of change orders is not of interest or significance in this study, but rather the amounts of change orders for the project, presented as a percentage to normalize the results within the different projects.

To explain the same, we will give an example, for a given project named X, not included in our dataset; only suggested for simplicity. The project includes change orders amounting to $100,000, and has 5 change orders for instance, for the amounts distributed below:

Change Order 1 amounting to $20,000

Change Order 2 amounting to $30,000

Change Order 3 amounting to $5,000

Change Order 4 amounting to $10,000

Change Order 5 amounting to $35,000

In our study, the change orders are represented as a percentage of the total amount of change order for this project.

Therefore, the below percentages are used instead

Change order 1: 20%

Change Order 2: 30%

Change Order 3: 5%

Change Order 4: 10%

Change Order 5: 35%

Therefore, whenever we are referring to percentage of change orders, we are using the equivalent of these calculations. The latter allows us to compare and analyze the results obtained from different projects.

3.1 Research Program

3.1.1 Classification of Change Orders by Reasons:

The classification of change orders by reason serves to answer the question: what are the main causes of change orders? Being a question addressed in several researches, with variable outcomes throughout the different studies. Moreover, each cause of change order is linked to a certain party causing the change: Owner, designer, or contractor. This classification would in turn specify which party is responsible for the highest percentage of change orders. The reasons are often referred to in the following text interchangeably as reasons, causes or categories of change orders.

The causes of change orders listed by Noraziah and Zabidi (2019) for various construction project types were used as guidelines in our classification. Some reasons were omitted, others modified, and some added to match the type of construction project types studied.

Some of the reasons omitted as deemed irrelevant, or did not match any of the existing change orders in any of the dataset projects:

- Owner's financial problems
- Inadequate project objectives
- Obstinate nature of owner

Some of the reasons added were:

- Special working conditions / hours.
- Changes for enhancement of aesthetic appearance

Table 1 shows the final list for causes of change orders, along with the party responsible for each cause. The Numbering added facilitates referring to a certain category while working on the data. However, it does not imply any significance.

Number	Causes for Change Orders	Party Responsible
1	New Work or additional scope requested by the owner	Owner
2	Change in material or specifications	Owner
3	Special Working conditions / hours	Owner
4	Samples / Mockups	Owner
5	Material acquisition scope errors	Owner
6	Change in design – new requested work	Designer
7	Change in design – abortive work	Designer
8	Changes for enhancement of aesthetic Appearance	Designer
9	Errors and omissions in design	Designer
10	Ambiguous design details	Designer
11	Conflicts among contract documents	Contractor
12	Unforeseen items or details by the contractor	Contractor
13	Upgrades or recommendations suggested by the contractor	Contractor
14	Accidents	Contractor
15	Site Requirements	Contractor
16	Change of unit rates	Contractor
17	Transportation, air freight etc..	Contractor

Table 1: Reasons for Change Orders

The contractor's project quantity surveyor identified the reason for each change order, since the quantity surveyors are responsible for the compilation, study, and submittal of the

change order from the contractor to the owner or project management office. The data was then shown as the percentage of each change order cause from the total of change orders of the project. The first classification is obtained accordingly. A sample of the results is shown in Figure 1.

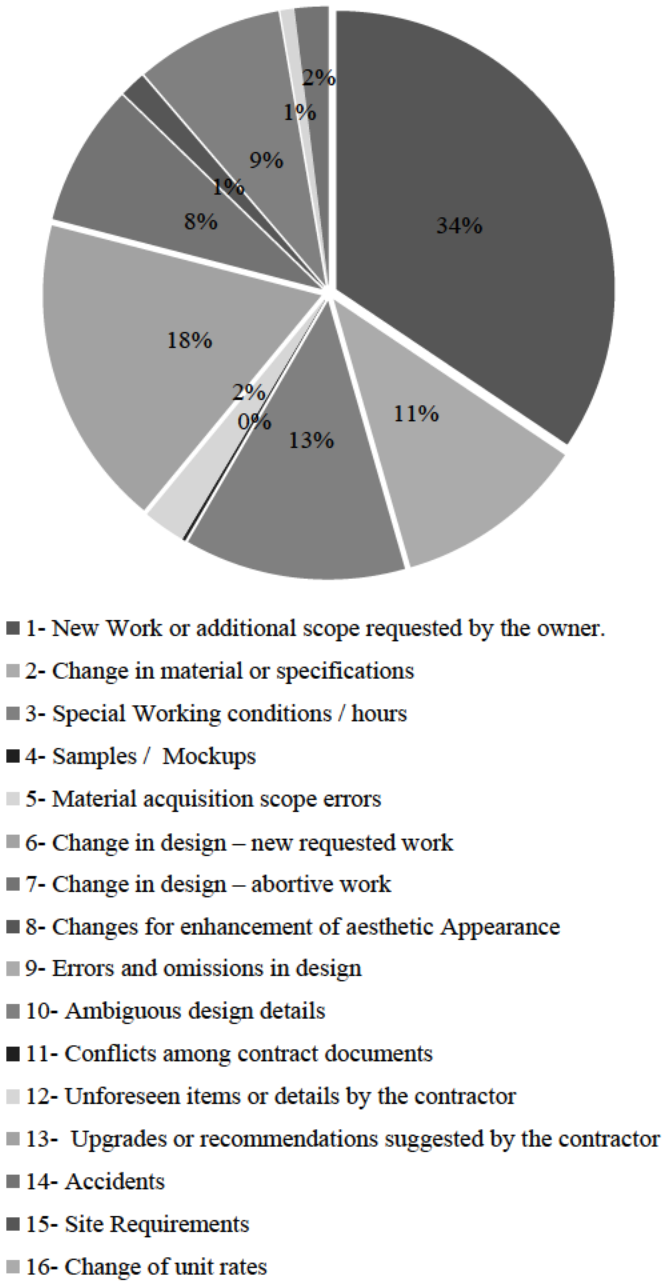

Figure 1: Reasons for Change Orders – Project Sample

3.1.2 Classification of Change Orders by Division.

The Construction Specification Institute's (CSI) Master Format allocates all work in a construction project to sixteen Major divisions (adopting the 1995 Master format Edition). In 2004 an expansion of divisions was published, but the extent of work in the related projects can be limited to the sixteen major divisions, which is why the 1995 edition will be adopted. The divisions assigned to each change order indicate the trade it belongs to. Below are the 1995 CSI divisions:

- Division 01 — General Requirement
- Division 02 — Site Construction
- Division 03 — Concrete
- Division 04 — Masonry
- Division 05 — Metals
- Division 06 — Wood and Plastics
- Division 07 — Thermal and Moisture Protection
- Division 08 — Doors and Windows
- Division 09 — Finishes
- Division 10 — Specialties
- Division 11 — Equipment
- Division 12 — Furnishings
- Division 13 — Special Construction
- Division 14 — Conveying Systems
- Division 15 — Mechanical/Plumbing
- Division 16 — Electrical
- Division 17 — Other

The classification of change orders by division allows one to track the type of work that contributes to the highest percentage of change orders. This is useful in guiding the efforts in the different project phases to minimize the occurrence of change orders. Especially due to the fact that various designers, subcontractors, and supervisors involved are different for civil, architectural, and electro mechanical work.

A sample of the results is shown in Figure 2

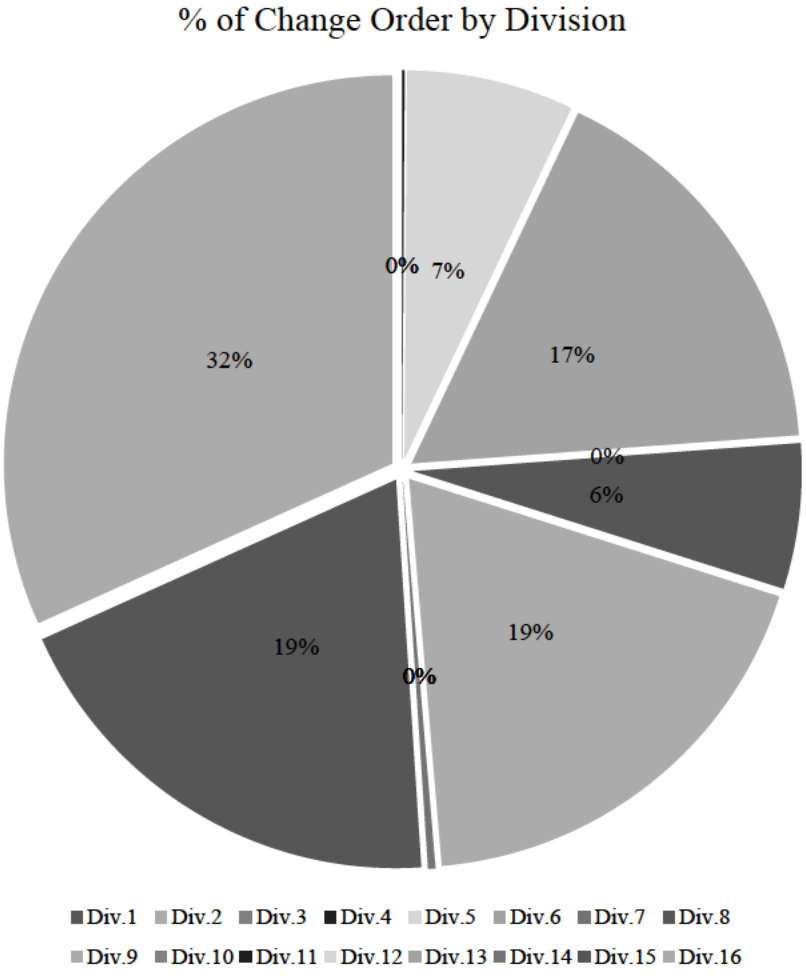

Figure 2: Percentage of Change Order by Division - Project Sample

3.1.3 Combination of the 2 classifications.

Afterwards, we combined the two above classifications into one. In Other words, for each category / reason, the percentage of change orders were assigned for each division in this category.

Figure 3 illustrates the distribution per division of all projects in category 1.

The different lines represent different projects.

The x-axis represents the division, and the y-axis represents the percent of change orders allocated in each of these divisions. Similar data plotting is represented for all other categories.

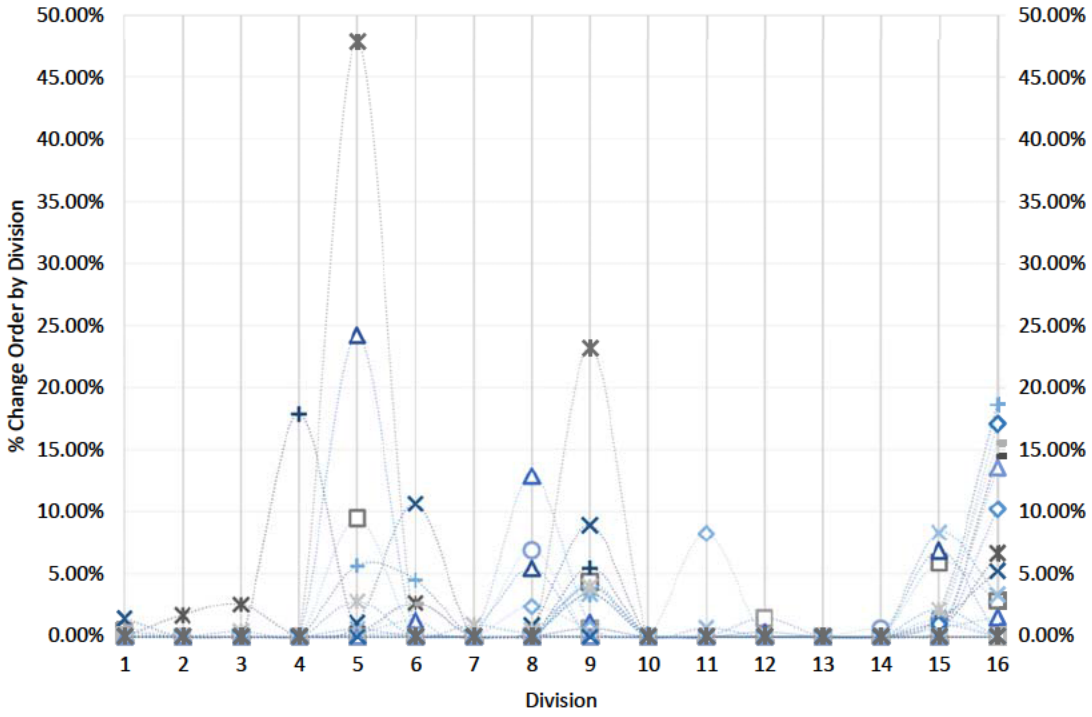

Figure 3: Percentage of Change Order by Division in Category 1

The aim of such distribution is to tackle a certain type of work represented by the division, for a category or reason of change order. Keeping in mind, that different work involves different subcontractors, designer, and consultant.

For all projects, a list including the below data was filled

- Original contract amount
- Final contract amount (excluding change orders)
- Change orders' amount
- Percentage of change order from project amount
- Contract type (lump sum or cost plus)
- Client Rep or Management office
- Project initial duration (days)
- Project actual duration (days)
- Project award year

3.2 Studied Parameters

Several parameters involved in construction projects are included. The below information is specified for each project:

3.2.1 Original and final contract amounts.

3.2.2 Change orders Amount

The aim is to get the additional percentage of change orders from the final contract amount.

3.2.3 Contract Type:

Projects are classified into two categories, projects that are cost-plus, and projects that are lump-sum to study the effect of this factor.

3.2.4 The client representative or project management office

The aim is to highlight projects with the same client representative or project management office to observe certain approaches and their effects on increasing or decreasing the percentage of change orders.

3.2.5 Project Duration:

The aim is to verify whether the project duration indicates a fluctuation in the percentage of change orders.

3.2.6 Project Award Year.

Since the sample of projects is collected from the same contractor, we aim to check if there is a certain contractor's learning curve throughout the years, or if there a reduction in change orders' percentage verifying a contractor's better awareness of errors throughout the years.

When studying the above-mentioned parameters, the change order percentage is measured form the total project amount. Their distribution per division and per reason is not related in this section. To elaborate, a change order percentage is a specific percentage of the total project amount., being for instance 10%, 20% or otherwise as calculated. As opposed to previous sections, where the distribution of the change orders was being studied with respect to their allocation in the related type of work, and the reason behind them. The change orders' total amount was considered the 100%, and this 100% was distributed among the various categories and divisions.

3.3 Procedure

Spread sheets obtained for change order lists of each project are filled with the factors previously allotted. The data is analyzed using spreadsheets.

For each of the addressed parameters, a study to identify the significance of this parameter is performed. Statistics and graphical representation are shown.

A global study on the entire data, correlating the reasons for change orders with the categories on which they occur, addressing the nature of the work done, and its detailed explanation by referring to the projects' list of change orders and their backup documents.

The purpose is to reduce the occurrence of change orders. There are two approaches to benefit from the results and analyze them.

The first method involves allocating, from our data, certain categories and divisions that are showing significant percentage of change orders, and going back to the list of change orders of projects to highlight repeated issues, to direct the efforts to reduce the change orders to a specific category and division, or a certain act that could contribute in a maximized percentage reduction.

From the outcome of method one, as well as brainstorming sessions with fellow researchers and professionals, mitigation measures addressing these issues, as well as other issues in projects were extracted.

The second method includes the extracted list of mitigation measures for change orders, presented as a survey, where professionals in the field were asked to assign the percentage of reduction in a projects' change orders, using each of the suggested mitigation measures.

The results of the second method were used to validate the ones obtained from the first method using our data.

3.4 Data Validation

As a first step, a t-test was applied on the data: the percentage of change order for projects,

The hypotheses tested:

- H_0: $\mu \leq \%10$
- H1: $\mu > \%10$

The Results obtained from our t-test are shown in table 2.

T-Test: One Sample

	% Change from project amount
Mean	16.54915599
Variance	123.8910115
Observations	23
Hypothesized Mean	10
df	22
t Stat	2.821820297
P(T<=t) one-tail	0.004965252
t Critical one-tail	1.717144374
P(T<=t) two-tail	0.009930505
t Critical two-tail	2.073873068

Table 2: One Sample T-test.

- Rejection Region: Reject H_0 if $t > 1.73$
- Test Statistic (t_0): 2.82

  Since $t_0 = 2.82 > 1.73$, we reject the null hypothesis H_0

Moreover, P-value = 0.005. Therefore, we can say that the probability for change orders of a project to be ≤ %10 of the total project amount is low (0.005 = %0.5)

Chapter Four

Results and Analysis

Several aspects of the change orders were addressed in our study. Therefore, results are presented in several combinations and by various criteria.

4.1 Reasons for Change Orders

First, the categories (reasons) for change orders are classified by the highest occurrence to the lowest occurrence as shown in table 3

Category Number	Causes for Change Orders	% Of Change Order
6	Change in design – new requested work	30.05%
1	New Work or additional scope requested by the owner	17.51%
2	Change in material or specifications	14.48%
10	Ambiguous design details	14.15%
7	Change in design – abortive work	6.56%
12	Unforeseen items or details by the contractor	6.21%
8	Changes for enhancement of aesthetic Appearance	2.86%
9	Errors and omissions in design	2.52%
16	Change of unit rates	1.31%
3	Special Working conditions / hours	1.18%
15	Site Requirements	1.04%
14	Accidents	1.04%
13	Upgrades or recommendations suggested by the contractor	0.73%
11	Conflicts among contract documents	0.13%
5	Material acquisition scope errors	0.12%
17	Transportation, air freight etc..	0.10%
4	Samples / Mockups	0.01%

Table 3: Reasons of Change Orders by highest to lowest occurrence

It has been shown that the top causes for change orders are: change in design – new requested work for 30.5% followed by new work or additional scope requested by owner for 17.51%, followed by change in material or specification for 14.48%, and ambiguous design details for 14.15%.

The above categories contribute to 76.64% of all reasons for change orders in projects. The results indicate that design modifications and clarifications contribute to 44.65%. The change in material and specifications being 14.48% is partially due to the expensive materials used in high end finish construction.

4.2 Liability of change orders

It is of great interest to highlight the party responsible for the highest contribution of change orders initiation. Each category / reason for change order was assigned the party responsible for such category.

From Table 4, it is shown that the highest contributor for change orders is the designer, initiating 56.15% of all change orders. Followed by the owner for 33.3%, followed by the contractor, for 10.55%.

The low percentage of 10.55% for change orders initiated by contractor was found low compared to designer and owner being 56.15% and 33.3% respectively. Therefore, we need to highlight that the study addresses the list of change orders submitted by the contractor to the owner. While the contractor might often cause additional costs, that are not legitimate change orders, and consequently incur the additional costs rather than submitting them as change orders. This study does not address those additional costs.

Category Number	Causes for Changes	Party Responsible for Change Order	% of Change Order	Total % for this party
1	New Work or additional scope requested by the owner	Owner	17.51%	33.30%
2	Change in material or specifications	Owner	14.48%	
3	Special Working conditions / hours	Owner	1.18%	
4	Samples / Mockups	Owner	0.01%	
5	Material acquisition scope errors	Owner	0.12%	
6	Change in design – new requested work	Designer	30.05%	56.15%
7	Change in design – abortive work	Designer	6.56%	
8	Changes for enhancement of aesthetic Appearance	Designer	2.86%	
9	Errors and omissions in design	Designer	2.52%	
10	Ambiguous design details	Designer	14.15%	
11	Conflicts among contract documents	Contractor	0.13%	10.55%
12	Unforeseen items or details by the contractor	Contractor	6.21%	
13	Upgrades or recommendations suggested by the contractor	Contractor	0.73%	
14	Accidents	Contractor	1.04%	
15	Site Requirements	Contractor	1.04%	
16	Change of unit rates	Contractor	1.31%	
17	Transportation, air freight etc..	Contractor	0.10%	

Table 4: Party Responsible for highest change order initiation

4.3 Project Management Office

The projects with the same project management office were grouped, and the average percentage of change orders for projects monitored by each office was measured. The project management offices are annotated as A, B, C, D, and E.

The results are shown in Table 5.

Project Management Office	Average % of Change Orders
A	8.98%
B	12.81%
C	19.15%
D	7.11%
E	26.41%

Table 5: Percentage of Change Orders by Project Management Office

The change in the results obtained indicates the possibility that there are certain trends or approaches adopted by some project management offices (A, B, and D) showing percentages of (8.98%, 12.81%, and 7.11%) respectively, as opposed to offices (C and E) with percentages (19.15% and 26.41%) respectively. It is worth mentioning that office D, with the least change orders (7.11%) is the oldest in the industry, and has the biggest number of employees among the other management offices. Further investigations on the above could be studied in this regard.

4.4 Project Contract Type: Lump Sum versus Cost Plus

The projects were categorized by their contract type: lump sum v/s cost plus. Projects are assigned names from A to V.

Table 6 summarizes the relevant data, and Figure 4 shows the results.

Average Change Orders for Projects with Lump Sum contracts = 12.59% while that for Cost Plus contracts = 18.17%. The same indicates a decrease in change orders for lump sum contract type.

Project	% Change Order from project amount	Contract Type
1	16.44%	Cost Plus
2	30.65%	Cost Plus
3	18.34%	Cost Plus
4	23.81%	Cost Plus
5	51.42%	Cost Plus
6	23.36%	Lump Sum
7	20.84%	Cost Plus
8	22.02%	Cost Plus
9	12.78%	Lump Sum
10	5.18%	Cost Plus
11	6.41%	Lump Sum
12	7.80%	Lump Sum
13	12.10%	Cost Plus
14	25.17%	Cost Plus
15	23.19%	Cost Plus
16	3.27 %	Cost Plus
17	4.01%	Cost Plus
18	6.26%	Cost Plus
19	9.01%	Cost Plus
20	8.85%	Cost Plus
21	23.47%	Cost Plus
22	19.15%	Cost Plus
23	7.12%	Cost Plus

Table 6: Percentage of Change Order and Contract Type

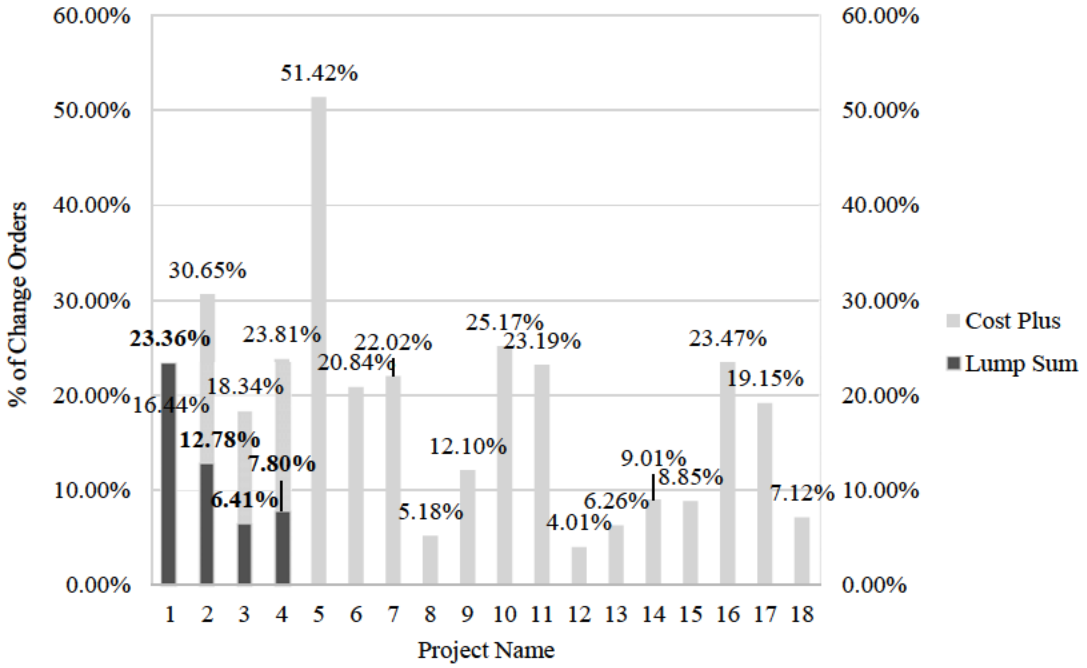

Figure 4: Percentage of Change Orders by Contract Type

4.5 Project Duration

The results obtained for percentage of change orders with respect to project duration is presented in Figure 5.

As observed in Figure 5, Projects are aligned on the x-axis from lower to higher project duration. The percentage of change orders as opposed to project duration does not show any trend. Therefore, we do not see a relation between change orders' percentage from the total contract amount and project duration.

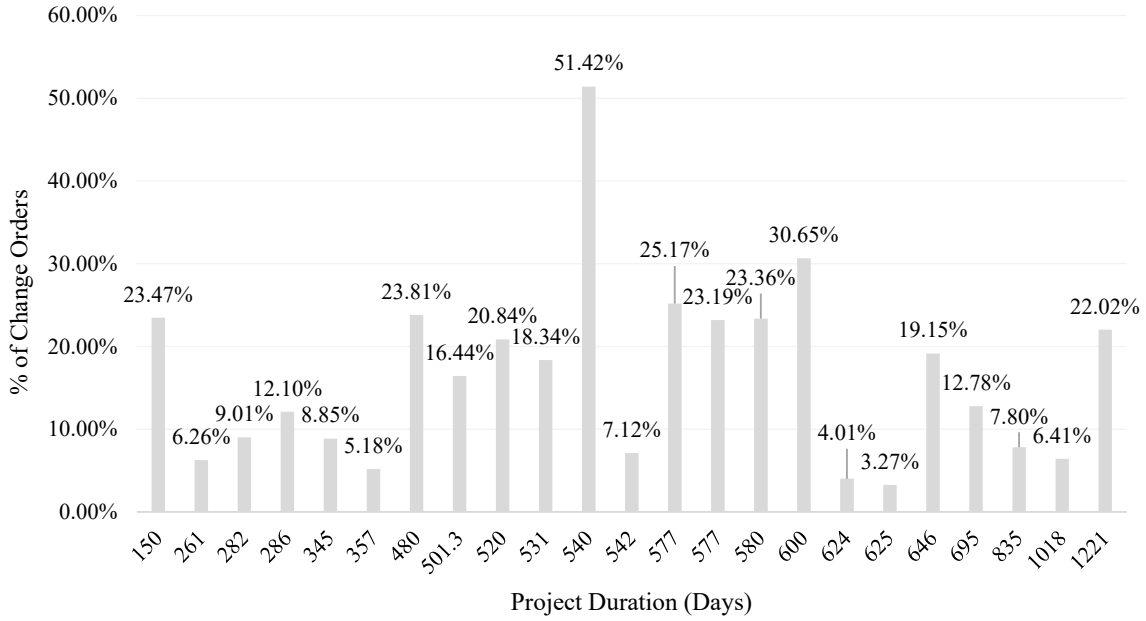

Figure 5: Percentage of Change Orders with respect to project duration.

4.6 Project Award Year

Knowing that the data sample is obtained from one contractor, the percentage of change orders per project, with respect to project award years was studied.

The results are observed in Figure 6.

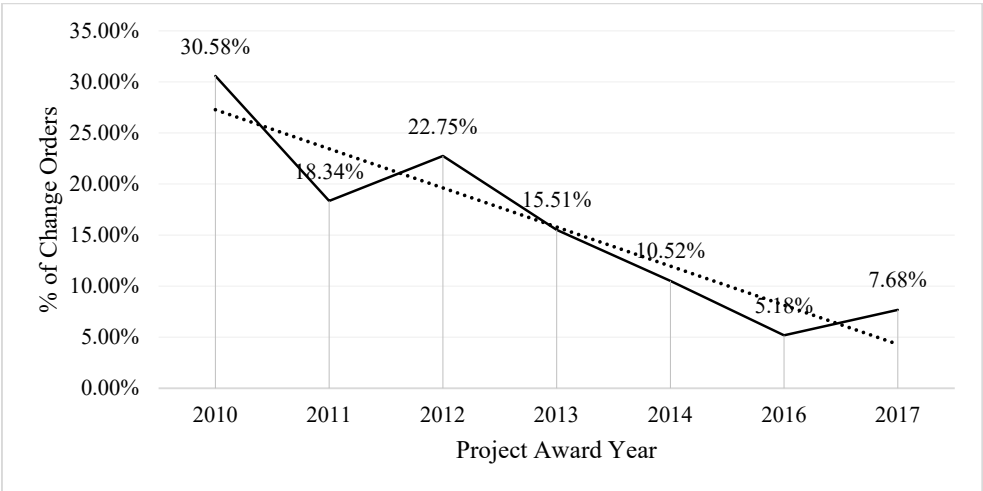

Figure 6: Percentage of Change Orders with respect to Project Award year

The percentage of change orders is generally decreasing from years 2010 to 2017.

Even though there is a slight increase from year 2011 to 2012 (from 18.34% to 22.75%), and between 2016 and 2017 (from 5.18% to 7.68%), we can still observe a global decrease, and a trendline showing an indication to a possible contractor's learning curve along the years. The same emphasizes the crucial need for hiring an experienced contractor.

4.7 All Projects' Results

Table 7 shows the percentage of change orders for one category by division.

Project No.	Div.1	Div.2	Div.3	Div.4	Div.5	Div.6	Div.7	Div.8	Div.9	Div.10	Div.11	Div.12	Div.13	Div.14	Div.15	Div.16
1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.65%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.43%	0.00%
2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	4.11%	0.14%	0.00%	0.00%	0.00%	0.00%	0.11%	10.25%
3	1.42%	0.00%	0.00%	0.00%	1.09%	10.70%	0.00%	0.91%	8.98%	0.00%	0.00%	0.00%	0.00%	0.00%	1.33%	5.26%
4	0.44%	0.00%	0.00%	0.00%	0.18%	0.22%	0.00%	0.06%	0.66%	0.00%	0.00%	1.47%	0.00%	0.00%	0.98%	0.00%
5	0.21%	0.00%	0.00%	0.00%	0.24%	1.29%	0.00%	12.93%	1.10%	0.00%	0.00%	0.37%	0.00%	0.00%	0.68%	1.54%
6	0.00%	0.00%	0.00%	0.00%	5.72%	4.54%	0.00%	0.16%	3.42%	0.00%	0.00%	0.00%	0.00%	0.00%	1.93%	18.67%
7	0.77%	0.00%	0.00%	0.00%	0.00%	2.63%	0.00%	0.00%	0.68%	0.00%	0.00%	0.39%	0.00%	0.00%	1.78%	15.55%
8	0.00%	1.70%	2.58%	0.00%	0.27%	2.70%	0.00%	0.10%	0.03%	0.02%	0.00%	0.00%	0.00%	0.00%	0.43%	6.69%
9	0.00%	0.00%	0.00%	17.89%	0.00%	0.00%	0.00%	0.00%	5.54%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	0.00%	0.00%	0.00%	0.00%	47.93%	0.00%	0.00%	0.00%	23.21%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	0.00%	0.00%	0.00%	0.00%	9.52%	0.00%	0.00%	0.00%	4.39%	0.00%	0.00%	0.00%	0.00%	0.00%	5.97%	2.85%
12	0.00%	0.00%	0.00%	0.00%	24.24%	0.00%	0.43%	5.48%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.91%	0.00%
13	0.00%	0.00%	0.00%	0.00%	0.61%	0.00%	0.00%	0.00%	3.47%	0.00%	0.70%	0.00%	0.00%	0.00%	8.38%	3.34%
14	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.43%	0.60%	0.00%	8.30%	0.00%	0.00%	0.00%	0.00%	0.00%
15	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	13.59%
17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	14.50%
18	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.34%	0.00%
20	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.01%	17.14%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
22	0.00%	0.00%	0.43%	0.00%	2.83%	0.00%	0.94%	0.53%	4.01%	0.00%	0.00%	0.00%	0.00%	0.00%	2.17%	0.00%
23	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.94%	0.00%	0.00%	0.00%	0.00%	0.00%	0.66%	0.00%	0.00%

Table 7: Percentage of Change Order for one category, by division

The data presented is for the 23 projects under study, where table 7 represents one of the 17 categories, having each division assigned the percentage of change orders in this division. Similar data is presented to all other categories. Moreover, scatter charts were created in an attempt to correlate the reasons for change orders with the divisions. Studying the spreadsheets, and graphs presented, we could observe gathering of data at some divisions in certain categories, showing that multiple projects have change orders at these divisions in these categories. On the other hand, there is a repeated assembly of data on certain divisions, in multiple categories, meaning that there are some divisions attributing to a higher contribution of change orders, despite the reason of change order.

- In the following scatter charts, each figure presents a certain category, the y-axis presents % of change order by division, the x-axis shows the divisions, and each set of points presents a different project.
- Divisions 3 and 4 (concrete and masonry) show high occurrence of change orders in this category specifically, being change in design due to abortive work. The design involved changes in block work in 30% of the projects.

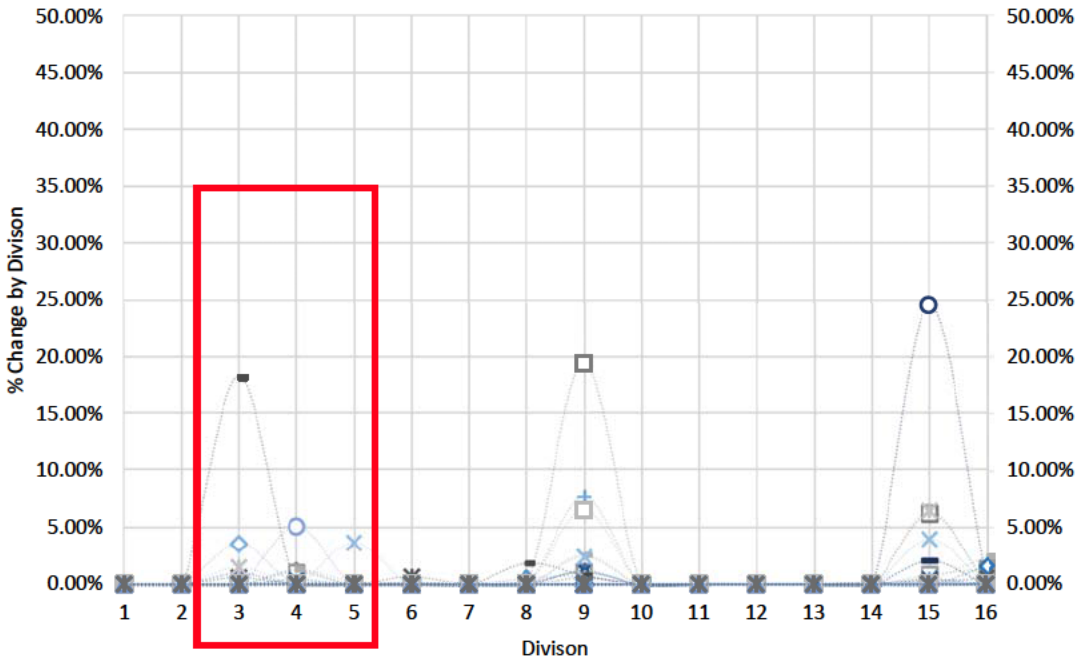

Figure 7: Change Orders by Division for Category 7 – Change in design – abortive work

- In Categories 1, 8, 10 and 12 (New Work by owner, Changes for enhancement of aesthetic Appearance, Ambiguous design details, Unforeseen items or details by the contractor), accumulation of data was shown in division 5 (metal work), noting that the items involved did not include major or structural items in metal work, but rather included stainless steel covers, frames, angles, details to cover up for a certain undesirable appearance etc...

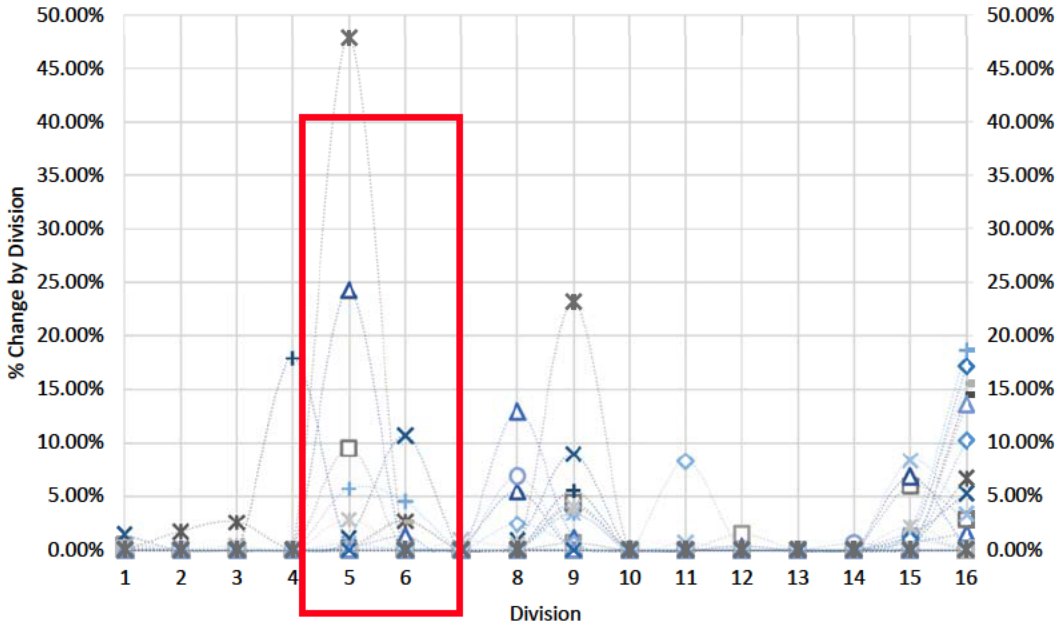

Figure 8: Change Orders by Division for Category 1 - New Work or additional scope requested by the owner

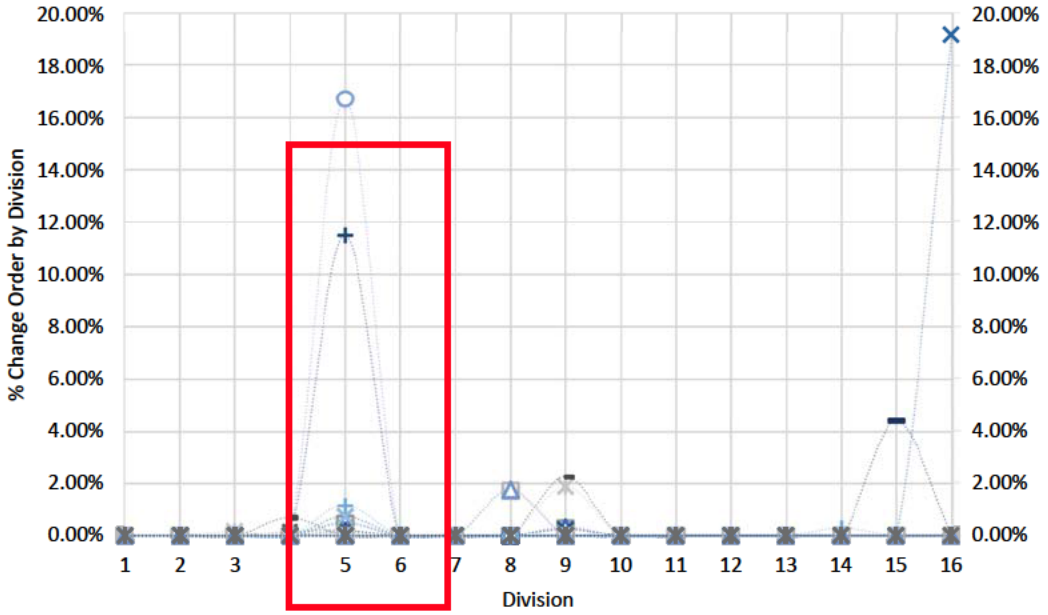

Figure 9: Change Orders by Division for Category 8 - Changes for enhancement of aesthetic Appearance

- In Categories 2, 6, and 10: (Change in material or specifications, change in design – new requested work, Ambiguous design details), division 6 (wood work) is repeatedly presented.

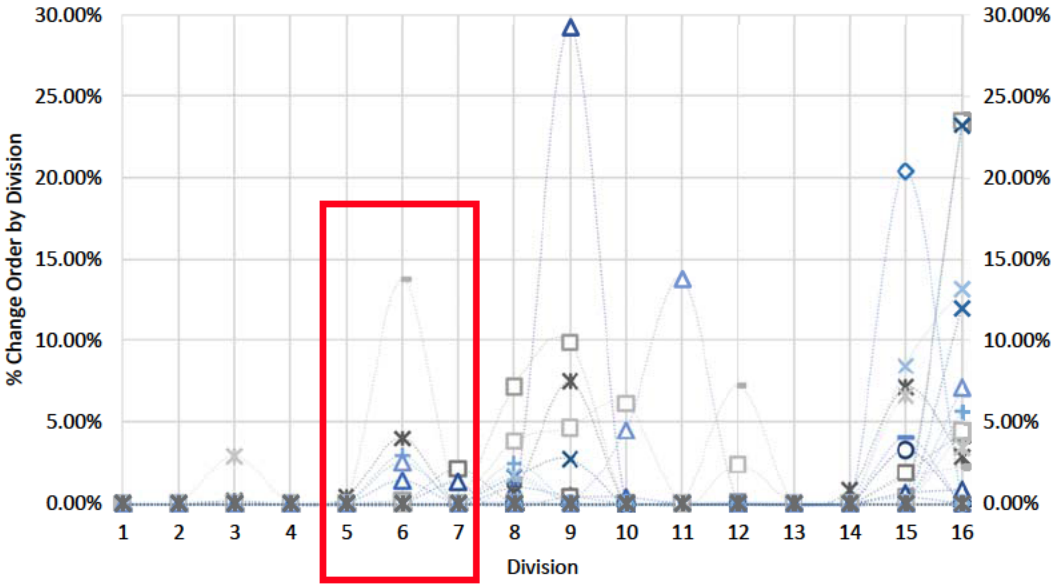

Figure 10: Change Orders by Division for Category 2 - Change in material or specifications

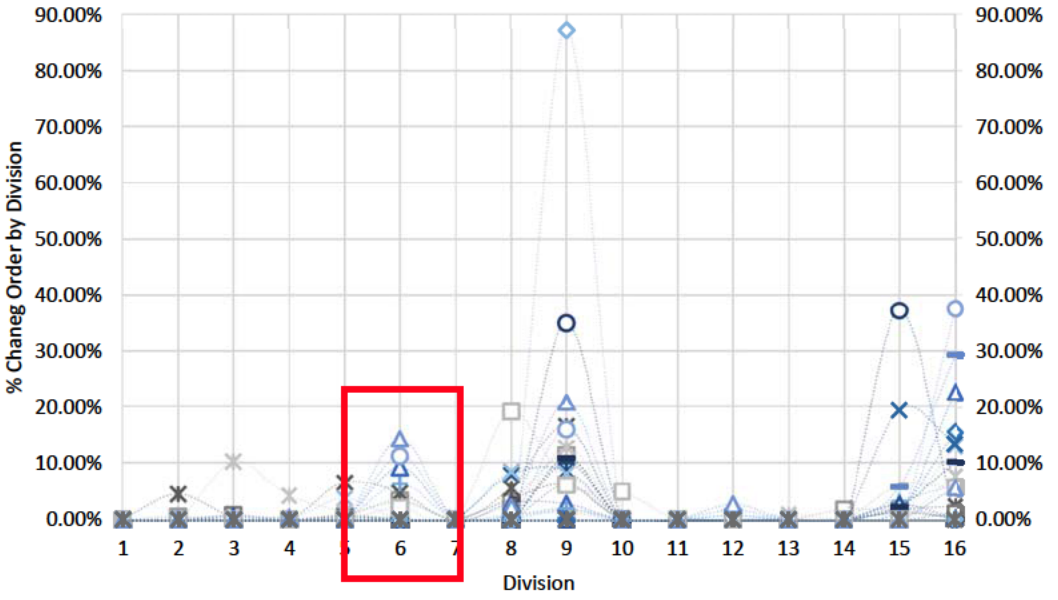

Figure 11: Change Orders by Division for Category 6 - Change in design – new requested work

The wood type selection has changed in several projects, similarly, sophisticated design details were not available since project initial phases, the changes also involved additional wood items, either new or initially supposed to be furniture purchased by the owner

then it was requested as custom made, or lack of design not showing the items in the first place. All of which resulted in change orders for wood work frequently requested in these categories

In addition to the above, it is clear that certain divisions are presented in many categories.

In specific, divisions 9,15, and 16, representing finishing, mechanical, and electrical work, are showing accumulation of data. In other words, it is clear that these types of work are contributing to bigger proportion of change orders, repeatedly in various categories.

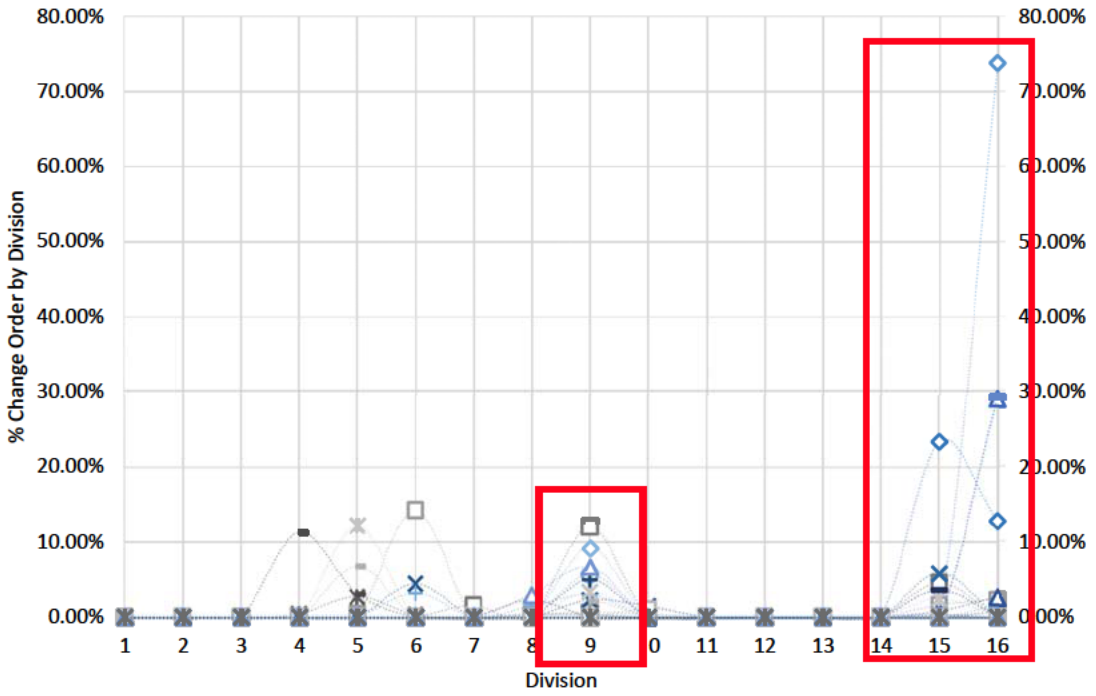

Figure 12: Change Orders by Division for Category 10 - Ambiguous design details

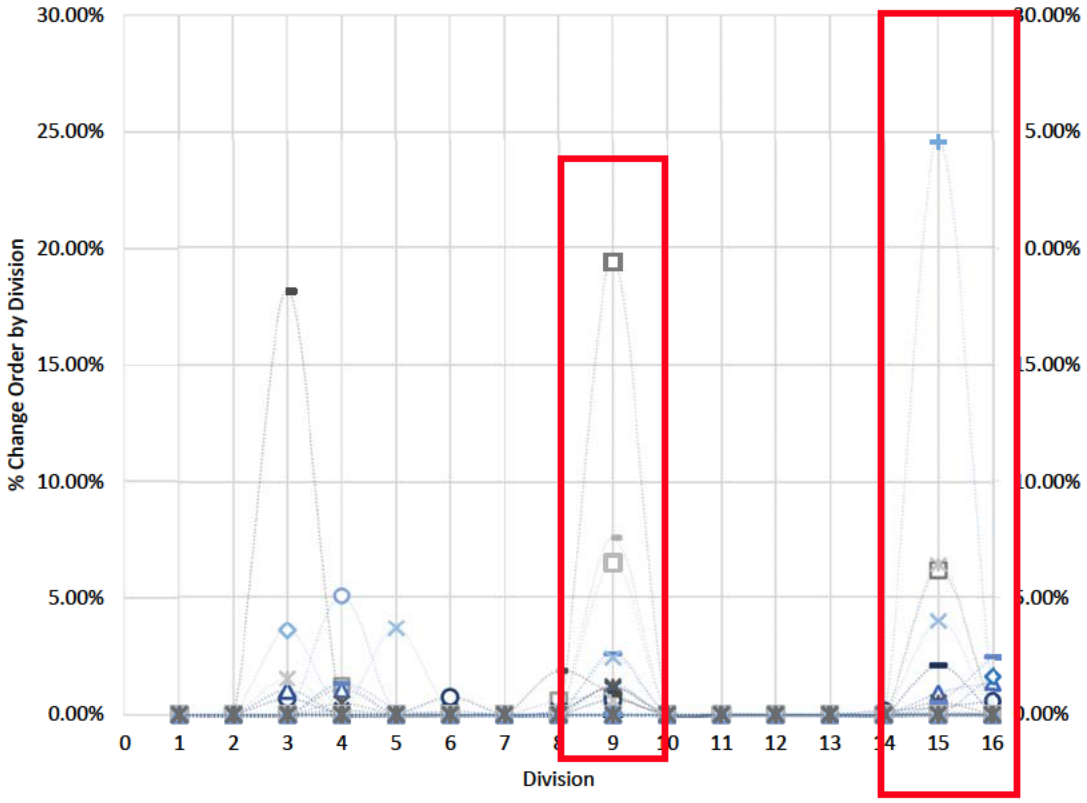

Figure 13: Change Orders by Division for Category 7 - Change in design – abortive work

Reverting back to the data to confirm the above graphically observed, it has been shown that the percentage of change order for a certain division from all change orders' percentage is the highest for division 9 (finishes) for 27.5%. followed by div. 16 and 15 (Electrical and Mechanical Work) with 25.05% and 18.66% respectively.

Therefore, and since divisions 9 (Finishes) and 15-16 (Mechanical and Electrical) show the highest appearance of data: division 9 is shown in 70% of the categories, and divisions 15-16 shown in 50% of the categories, referring to table 8, we looked for the common as well as major reasons for changes in these divisions, by going back to the lists of change orders for the projects.

	Change Orders Percentage by Division															
Project No.	Div.1	Div.2	Div.3	Div.4	Div.5	Div.6	Div.7	Div.8	Div.9	Div.10	Div.11	Div.12	Div.13	Div.14	Div.15	Div.16
1	0.00%	0.00%	0.00%	8.00%	0.00%	0.00%	0.00%	11.50%	17.83%	0.00%	0.00%	0.00%	0.00%	0.00%	49.40%	13.27%
2	0.00%	0.00%	0.00%	1.23%	0.26%	0.00%	0.00%	0.76%	8.90%	0.14%	0.00%	1.66%	0.00%	0.90%	2.11%	84.04%
3	1.42%	0.00%	0.00%	0.46%	2.21%	15.25%	0.24%	11.56%	34.25%	1.96%	0.00%	0.09%	0.00%	0.00%	3.84%	28.71%
4	0.44%	0.48%	0.00%	1.06%	2.79%	18.04%	0.00%	11.36%	28.95%	0.33%	0.00%	1.53%	0.00%	2.01%	5.62%	27.38%
5	0.21%	0.00%	0.00%	0.18%	1.80%	12.25%	0.00%	17.67%	8.89%	1.15%	0.00%	1.08%	0.00%	0.00%	3.49%	53.26%
6	0.00%	0.00%	0.00%	0.10%	6.97%	16.77%	0.00%	6.05%	18.77%	0.00%	0.00%	0.00%	0.00%	0.30%	19.30%	31.74%
7	0.77%	0.00%	0.00%	1.32%	8.90%	19.39%	0.00%	2.51%	9.82%	0.09%	0.00%	7.58%	0.00%	0.00%	24.09%	25.53%
8	2.00%	7.38%	4.62%	0.51%	11.67%	13.01%	0.01%	6.43%	28.61%	0.02%	0.00%	0.00%	0.12%	0.96%	10.16%	14.50%
9	0.00%	19.02%	18.17%	29.83%	3.58%	0.00%	0.00%	7.53%	20.98%	0.00%	0.00%	0.00%	0.00%	0.90%	0.00%	0.00%
10	0.00%	0.00%	0.00%	0.00%	59.41%	0.00%	0.00%	0.00%	40.59%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
11	0.00%	0.00%	0.76%	0.00%	12.23%	0.00%	3.55%	1.67%	53.29%	0.00%	0.00%	0.00%	0.00%	0.00%	19.36%	9.14%
12	0.00%	0.00%	3.01%	0.00%	24.45%	0.00%	2.26%	5.79%	45.81%	0.00%	0.00%	0.00%	0.00%	0.00%	15.08%	3.60%
13	0.00%	0.00%	0.00%	0.00%	8.68%	0.00%	0.00%	20.51%	19.08%	0.00%	0.70%	0.00%	0.00%	0.00%	21.45%	29.58%
14	0.25%	0.00%	0.00%	0.00%	0.00%	2.04%	0.00%	26.99%	29.73%	11.89%	8.30%	2.36%	0.00%	0.00%	3.69%	14.75%
15	0.23%	0.00%	0.00%	0.42%	0.00%	16.73%	0.00%	13.10%	27.62%	4.45%	13.79%	2.63%	0.00%	0.00%	3.59%	17.45%
16	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	41.73%	58.27%
17	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	54.44%	0.00%	0.00%	0.00%	0.00%	0.00%	35.45%	10.11%
18	0.00%	0.00%	3.58%	0.00%	0.00%	0.00%	0.00%	0.00%	96.42%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
19	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.20%	0.00%	0.00%	0.00%	0.00%	0.00%	39.16%	58.64%
20	0.00%	0.00%	0.00%	3.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	49.21%	47.05%
21	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	34.98%	0.00%	0.00%	0.00%	0.00%	0.00%	65.02%	0.00%
22	0.00%	0.00%	15.29%	4.18%	18.01%	0.00%	1.24%	1.42%	29.88%	0.00%	0.12%	0.00%	0.84%	0.00%	17.53%	11.49%
23	0.00%	0.00%	0.00%	5.07%	16.70%	11.13%	0.00%	7.44%	21.45%	0.00%	0.00%	0.00%	0.00%	0.66%	0.00%	37.56%
Average	0.23%	1.17%	1.97%	2.44%	7.72%	5.42%	0.32%	6.6%	27.50%	0.87%	1.00%	0.74%	0.04%	0.[illegible]5%	18.6%	25.05%

Table8 : Percentage of Change orders by Division

For division 9 (Finishes), the below points were identified:

- Plaster Work mostly due to fixing alignment, and due to abortive work.
- Paint due to re-work and to complicated design details not taken into account when pricing.
- Miscellaneous Finishes at the end of the project (polishing, painting work, etc.…)
- Missing or unclear Selection, causing less specified unit rates for materials.
- Missing development of detail drawings in gypsum, tiling, etc...)
- Replacing screed under tiles with terrazzo and adhesive
- Various finishes and rectifications due to design modifications
- Additional finishes (mostly gypsum work) due to MEP undeveloped initial design.
- Additional scope.
- Abortive finishing work due to revised design.

For divisions 15 and 16 (Mechanical and Electrical Work), the below points were identified:

- Coring Work due to revised design.
- Additional under floor heating area or items.
- Additional Fan Coil units.
- Additional lighting fixtures due to missing / incomplete design or selection.
- Additional sanitary fixtures due to missing / incomplete design or selection.
- Additional Systems: telephone, tata, TV, fire alarm, AV system, CCTV, speakers, audio visual equipment etc.…
- Miscellaneous system upgrades.
- Revised material selection.
- Additional requirements by owner.
- Revised design causing abortive work.
- Items not existing in original BOQ.

Addressing the repeated/major issues contributing to the highest percentage of change orders, that can potentially be reduced, we were able to assign the same into 3 major groups:

1. New scope /New design: knowing that this group is new scope or new work the owner requested, not due to ambiguities or miscoordination., the percentage of these items needed to be highlighted, in order for owners to better recognize the contribution of the various ongoing requests for additional scope of work.
2. Items that could have been foreseen and included in price (including system upgrades and missing selection).
3. Abortive work / items that could have been cancelled.

The percentages of change orders included in each of the groups is presented below:

	Group 1: New scope /New design	**Group 2:** Items that could have been foreseen and included in price (including system upgrades and missing selection).	**Group 3:** Abortive work / items that could have been cancelled
Div.9	12.75%	11.19%	0.49%
Div.15	6.68%	10.47%	0.46%
Div.16	5.79%	18.22%	0.57%
Total	**25.23%**	**39.87%**	**1.52%**

Table 9: Percentage of Major Change orders in Divisions 9, 15, and 16

Table 9 indicates significant results. As discussed earlier, change orders allocated in divisions 9, 15, and 16 constitute a total of 71.21% of all projects' change orders. A total of 66.62% of all change orders is due to repeated issues that could be tracked and addressed specifically.

The aim of this grouping is to tackle each group with a suitable mitigation measure.

It is worth mentioning, that when we discuss the need for mitigation measures of a change orders, it does not necessarily mean that the total cost of the project will be reduced, due to less amount of change orders. There are various possibilities when we say mitigation measures for change order reduction. Possibly the corresponding amount of change order will totally be eliminated, such as in the case of abortive work; whereas in other cases, the aim is to include all possible work in the initial contract amount, rather than it being submitted as change orders. Having an accurately estimated budget and scope of work, where change orders' amount is rather embedded within the initially estimated budget is a high concern for owners, as well as the contractors. Cash flows and other financial considerations highly affect the need of proper initial estimation and reduction of change orders.

From the owners' perspective:

- In the case of our type of projects, being private residences, where any additional amount is not reimbursed, as the project is not a business where the owner can increase the selling price of the units constructed to compensate for the change orders. Knowing that in the case where the project is not a private residence, most often, project units are sold before the construction process is completed. Therefore, additional change orders' amount could result in potential loss due to higher unit cost from its selling price.
- Owners might be relying on loans to fund their projects. Therefore, the correct estimation of the contract amount, that includes all owners' visions for the project is crucial for their plans. Moreover, even if the owner was not depending on a loan, when a change order is initiated by the owner, it is frequently because they assumed a certain item was already included in their project, but it turned out to be excluded. Proper scope and budget guarantee a higher customer satisfaction.

From the contractors' perspective:

- As mentioned, having a clear project scope and correct estimated budget guarantees the customer satisfaction, which is an integral aspect of a success of any business.
- High change order amounts could disrupt a contractors' cash flow, where they need to proceed with change orders and pay relevant supplier / subcontractors unexpected dues.
- The process of change orders is time and resource consuming, in terms of submitting, reviewing, and assessing change orders.

- When a scope of work is integrated within the project itself, there is more time for the contractor to properly procure the said items, properly assess the offers and select the fit subcontractor for the work. In addition, unnecessary additional costs such as transportation, air freight, testing, supervision, etc... could be eliminated.
- Moreover, a very critical aspect of change orders, is the corresponding time extension it could lead to, and its consequent indirect costs. This study is not addressing time impact; however, additional scope of work generally results in time extensions, and dealing with the complexities of allocating resources for longer period of time, triggering additional costs and loss of other opportunities for the contractor.

Having said that, among the 3 groups presented in table 8, group 3 (abortive work, amounting to 1.52% of all change orders in projects) could be entirely reduced; while the amounts of groups 2 and 3 (25.23% and 39.87%) are rather subject to complete reduction from the total project amount, or the proper estimation since early stages.

In line with the previously mentioned, and taken into account the other reasons and factors for change orders, and after consulting professionals in the field throughout brainstorming sessions and meetings, a list of mitigation measures to reduce the occurrence of change orders was extracted.

4.8 List of mitigation measures for reduction of change orders

1. Frequent inspections on site to avoid changes at later stages (daily, weekly, biweekly).
- This mitigation measure aims to detect the unwanted work the earliest possible, to reduce the volume of reworks needed, and mainly it affects the change orders due to abortive reasons.
2. Complete Coordinate design among the project’s various disciplines before work starts on site.

- The purpose is to advise spending longer time during preconstruction phase to allocate major discrepancies in design, between Architectural, Civil, Mechanical, and Electrical drawings. It is certainly impossible to finalize all coordination, but at least to avoid major problems, and start finding solutions the soonest.

3. Contractor to Include a contingency amount in their bid (can be used for items with high fluctuation in cost or are not clear in design).

- The aim is to identify to the owner that changes are inevitable, and it gives a sense of security for the owner, and more acceptance to approving change orders during project duration, as it will be partly embedded in the total budget of the project.

4. Sufficient time to be given to contractor during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity. i.e., not submitting bids unless project documents have been studied thoroughly.

- Bills of quantities are a core component of a contract, and very often, owners seem to be in a rush to start witnessing site progress. Therefore, they minimize the time given to contractors to prepare or verify bills of quantities and submit their bid price. Although sometimes extension of time to submit tender price are given; however, a predetermined sufficient time would allow better resource allocation for the contractor to properly study and include all project items in the bill of quantities.

5. Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details.

- Owners would often request the designer to start with a conceptual design, in an attempt to estimate a preliminary budget. However, such designs tend to cause contractors to submit lower prices that the actual needed to complete such jobs, based on the data in hand.

6. Following the technology and market. i.e., looking for universal systems to avoid selection or modification at a later stage. (Mainly Mechanical and Electrical Systems).

- Looking for universal systems, since MEP systems rapidly change, and often newer technologies are not directly implemented in local market, or not yet widely executed locally. This shall not hinder the owner from selecting the desired updated technologies, instead of agreeing to the available and changing at later stages.

7. Involvement of contractor technical team in early stages to highlight discrepancies / missing design.

- Contractors perceive problems from a wider vision than designers, seeking practicality and feasibility, due to their execution experience. Usually, contractors highlight issues unforeseen by the designers; therefore, their early involvement is crucial.

8. Providing multiple samples to owner prior final selection.

- The aim is to present wider variability to the owner to diminish the chances of selection changes.

9. Transparency among Owner, Designer, and Contractor, mainly revealing any data to the involved parties, to act the earliest possible.

- In an attempt to reduce the bid price, and proceed with the project, designers and contractors might neglect discrepancies or problems in design, which shall be presented later on as change orders.

10. Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades.

- Software such as Revit, identify the project as a model, not as a drawing, changes are assigned to the whole project automatically, and could be accessible to all parties working on the model. This software has numerous features, and its concept drastically differs from 2D and 3D AutoCAD drawings.

The survey respondents were 40, working as quantity surveyors, project coordinators, commercial, engineering and operation managers.

The survey results are shown in table 10.

Table 11 represents the survey results as well, but respondents are shown as percentages answering a certain option instead of number of respondents as shown in table 10.

Q.	Mitigation Measure	%0-%2	%2-%4	%4-%6	%6-%8	%8-%10
1	Frequent inspections on site to avoid changes at later stages. (Daily, weekly, biweekly)	6	13	0	13	8
2	Coordinate design among the project's various disciplines before work starts on site	0	1	13	7	19
3	Include appropriate sums as allowances in your budget for risk items.	3	9	10	8	10
4	Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity	1	5	13	12	9
5	Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details	4	6	11	11	8
6	Following the technology and market. i.e., Looking for universal systems to avoid selection or modification at a later stage. (Mainly Electrical and Mechanical systems)	6	5	10	8	11
7	Involvement of contractor technical team in early stages to highlight discrepancies and ambiguities in design.	1	3	11	17	8
8	Providing multiple samples to owner prior final selection	4	6	12	11	7
9	Transparency among Owner, Designer, and Contractor, mainly revealing any data to the involved parties, to act the earliest possible.	3	5	8	14	10
10	Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades	4	8	4	10	14

Table 10: Survey Results by Number of Respondents to each choice.

Q.	Mitigation Measure	%0-%2	%2-%4	%4-%6	%6-%8	%8-%10
1	Frequent inspections on site to avoid changes at later stages. (Daily, weekly, biweekly)	15%	33%	0%	33%	20%
2	Coordinate design among the project's various disciplines before work starts on site	0%	3%	33%	18%	48%
3	Include appropriate sums as allowances in your budget for risk items.	8%	23%	25%	20%	25%
4	Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity	3%	13%	33%	30%	23%
5	Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details	10%	15%	28%	28%	20%
6	Following the technology and market. i.e., Looking for universal systems to avoid selection or modification at a later stage. (Mainly Electrical and Mechanical systems)	15%	13%	25%	20%	28%
7	Involvement of contractor technical team in early stages to highlight discrepancies and ambiguities in design.	3%	8%	28%	43%	20%
8	Providing multiple samples to owner prior final selection	10%	15%	30%	28%	18%
9	Transparency among Owner, Designer, and Contractor, mainly revealing any data to the involved parties, to act the earliest possible.	8%	13%	20%	35%	25%
10	Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades	10%	20%	10%	25%	35%

Table 11: Survey Results by Number of Percentage of Respondents to each choice

From the survey results, we can get the total percentage reduction of change orders if all measures are diligently applied. The same is extracted as follows:

The median of each choice is considered to allow a precise number, not only a range. i.e., First choice, where percentage reduction is 0%-2%, yields a value of 1%. Similarly, choice 2 (2%-4%) yields 3%, choice 3 (4%-6%) yields 5%, choice 4 (6%-8%) yields 7%, and choice 5 (8%-10%) yields 9%.

The median is multiplied by the percentage of respondents who selected this choice.

The summation of all cells obtained gives the requested value.

The outcome is presented in table 12.

As we can observe, the total reduction for change orders, if all measures are applied, is 59.7%. The same can be compared to the results obtained from our data, as presented in table 8, yielding a total reduction of 66.62%.

Achieving the above reduction of 59.7% is possible, with the combined efforts of all concerned parties.

It is well noted that the mitigation measures have different levels of feasibility, since several factors are involved, to name a few:

- Cost.
- Feasibility.
- Practicality.
- Logistics.
- Human Innate nature

Therefore, it is practical to consider specific mitigation measures, that are more significantly effective, as per the survey results.

Q.	Mitigation Measure	1%	3%	5%	7%	9%	Sum
1	Frequent inspections on site to avoid changes at later stages. (Daily, weekly, biweekly)	0.15%	0.98%	0.00%	2.28%	1.80%	5.20%
2	Coordinate design among the project's various disciplines before work starts on site	0.00%	0.08%	1.63%	1.23%	4.28%	7.20%
3	Include appropriate sums as allowances in your budget for risk items.	0.08%	0.68%	1.25%	1.40%	2.25%	5.65%
4	Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity	0.03%	0.38%	1.63%	2.10%	2.03%	6.15%
5	Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details	0.10%	0.45%	1.38%	1.93%	1.80%	5.65%
6	Following the technology and market. i.e., Looking for universal systems to avoid selection or modification at a later stage. (Mainly Electrical and Mechanical systems)	0.15%	0.38%	1.25%	1.40%	2.48%	5.65%
7	Involvement of contractor technical team in early stages to highlight discrepancies and ambiguities in design.	0.03%	0.23%	1.38%	2.98%	1.80%	6.40%
8	Providing multiple samples to owner prior final selection	0.10%	0.45%	1.50%	1.93%	1.58%	5.55%
9	Transparency among Owner, Designer, and Contractor, mainly revealing any data to the involved parties, to act the earliest possible.	0.08%	0.38%	1.00%	2.45%	2.25%	6.15%
10	Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades	0.10%	0.60%	0.50%	1.75%	3.15%	6.10%
Total							**59.7%**

Table 12: Survey Statistical Results

From the results of table 12, we ranked the sums obtained, in decreasing order, to identify the mitigation measures with highest percentage reduction.

The results are shown in table 13.

Q.	Mitigation Measure	Sum
2	Coordinate design among the project's various disciplines before work starts on site	7.20%
7	Involvement of contractor technical team in early stages to highlight discrepancies and ambiguities in design.	6.40%
9	Transparency among Owner, Designer, and Contractor, mainly revealing any data to the involved parties, to act the earliest possible.	6.15%
4	Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity	6.15%
10	Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades	6.10%
5	Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details	5.65%
3	Include appropriate sums as allowances in your budget for risk items.	5.65%
6	Following the technology and market. i.e., Looking for universal systems to avoid selection or modification at a later stage. (Mainly Electrical and Mechanical systems)	5.65%
8	Providing multiple samples to owner prior final selection	5.55%
1	Frequent inspections on site to avoid changes at later stages. (Daily, weekly, biweekly)	5.20%

Table 13: Mitigation Measures in Decreasing Order of Effectiveness.

The two highest effective measures are numbers 2 and 7: Coordinate design among the project's various disciplines before work starts on site with 7.20% and Involvement of

contractor technical team in early stages to highlight discrepancies and ambiguities in design with 6.40%.

It is significant the both measures are related to the design drawings, and mainly design during the early or preconstruction phase.

Therefore, it is highly advisable to invest in the same, as it triggers a 13.60% reduction.

Moreover, other mitigation measures could be shared in the same aspect, stressing on the importance of the time given to elaborate not only the design, but also the bills of quantities: Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity, with 6.15%, and Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details, with 5.65%.

The Four mentioned mitigation measures are listed below:

- Coordinate design among the project's various disciplines before work starts on site
- Involvement of contractor technical team in early stages to highlight discrepancies and ambiguities in design.
- Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity.
- Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details.

The combination of these measures, requesting a certain level of accuracy and dedication facilitated by sufficient time and coordination between parties to achieve complete design, and bills of quantities, would yield a 25.4% reduction.

Regarding the remaining measures, we notice that Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades, would trigger a 6.1%, and although the BIM software are becoming a crucial requirement in the construction industry, we would not consider it as a top priority in this specific area, being the reduction of change orders for such project types. As the expertise and costs involved to implement the BIM software are high, compared to the percentage obtained, as opposed to other measures such as providing multiple samples to owner prior final selection with 5.55% reduction. Similarly, including appropriate sums as allowances in your budget for risk items, or what is often referred to as a contingency amount, tends to reduce the change orders by 5.65%.

4.9 Correlation Analysis Between Divisions

For each category independently, the correlation between the divisions was analyzed. High positive correlations from all the analysis are summarized in table 14.

Category Number	Category Name	Divisions Correlated	Correlation Coefficient	Divisions Correlated	Correlation Coefficient	Divisions Correlated	Correlation Coefficient
1	New Work or additional scope requested by the owner.	2 & 3	0.99	5 & 9	0.78		
2	Change in material or specifications	6 & 12	0.87				
3	Special Working conditions / hours	9 & 15	0.63				
4	Samples / Mockups	9 & 16	1.00				
5	Material acquisition scope errors						
6	Change in design – new requested work	3 & 4	0.76	2 & 5	0.84	6 & 12	0.56
7	Change in design – abortive work	3 & 8	0.92				
8	Changes for enhancement of aesthetic Appearance	3 & 9	0.61	4 & 9	0.72		
9	Errors and omissions in design	3 & 5	0.82	7 & 9	1.00		
10	Ambiguous design details	4 & 8	0.54	7 & 9	0.65		
11	Conflicts among contract documents	5 & 6	1.00	15 & 16	1.00		
12	Unforeseen items or details by the contractor	6 & 10	1.00	9 & 15	0.62		
13	Upgrades or recommendations suggested by the contractor						
14	Accidents	5 & 9	0.97	10 & 12	1.00		
15	Site Requirements	1 & 2	1.00	1 & 3	1.00	2 & 3	1.00
16	Change of unit rates						
17	Transportation, air freight etc..	9 & 10	0.99				

Table 14: Summary of Correlation Analysis between divisions

- For Category 1, New Work or additional scope requested by the owner:

We notice a correlation between divisions 2 and 3, being site works and concrete, with a correlation coefficient of 0.99. This could identify an additional scope being an additional zone or area requested to be built by the owner. There is also a correlation between divisions 5 and 9 being metal and finishes, with a correlation coefficient of 0.78.

- For Category 2, Change in material or specifications:

We notice a correlation between divisions 6 and 12, being wood work and furnishings, with a correleation coefficient of 0.87. The same indicates a common change in furniture specifications, reflected in material used in wood work and furnishing.

- For Category 3, Special Working conditions / hours:

We notice a correlation between divisions 9 and 15 being finishes and mechanical work with a correleation coefficient of 0.63. Basically, the labors assigned for both finishing and mechanical work were being restricted in their workig hours due to possible noises.

- For Category 4, Samples / Mockups:

We notice a correlation between divisions 9 and 16 being finishes and electrical work, with a correleation coefficient of 1.

- For Category 5, Material acquisition scope errors, no correlations exist.
- For Category 6, Change in design – new requested work:

We notice a correlation between divisions 6 and 12, being wood work and furnishing, similat to category 2, with a correlation coefficient of 0.56.

In addition, there are correlations between divisions 3 and 4 which are concrete work and masonry, with a correlation coefficient of 0.76, indicating the additional design involves new rooms or new walls. Divisions 2 and 5, being site work and metal have a correlation coefficient of 0.84.

- For Category 7, Change in design – abortive work:

We notice a correlation between divisions 3 and 8, being concrete and doors and windows, with a correlation coefficient of 0.92. The change orders related to doors and windows resulted in demolition work affecting concrete.

- For Category 8, Changes for enhancement of aesthetic Appearance:

We notice a correlation between divisions 3 and 9 being concrete and finishes, as well as 4 and 9 being masonry and finishes, with correlation coefficients of 0.61 and 0.72 respectively. Both changes in masonry and concrete seem to be related to the relevant finishes surrounding them in this category.

- For Category 9, Errors and omissions in design:

Correlations exist between between divisions 3 and 5, being concrete and metal with correlation coefficient of 0.82. As well as correlations between divisions 7 and 9 being waterproofing and finishes, with a correlation coefficient of 1.00. The latter indicates that errors and omissions in design in waterproofing details affected the related finishes above them.

- For Category 10, Ambiguous design details:

We notice correlations between divisions 7 and 9, similar to category 9, with a correlation coefficient of 0.65. In addition, there are correlations between divisions 4 and 8 being masonory and doors and windows, with correlation coefficient of 0.54. The same is due to changes affecting opening dimensions resulting in changes in both block work and doors / windows.

- For Category 11, Conflicts among contract documents:

There are correlations between divisions 5 and 6 being metal and wood work, and 15 and 16 being mechanical and electrical work, with correlation coefficients of 1.00 for both.

- For Category 12, Unforeseen items or details by the contractor:

There are correlations between divisions 6 and 10 being wood work and specialties, and 9 and 15 being finishes and mechanical work, with correlation coefficients of 1.00 and 0.62 respectively.

- For Category 13, Upgrades or recommendations suggested by the contractor, no correlations exist.
- For Category 14, Accidents:

There are correlations between divisions 5 and 9 being metal work and finsishes, and 10 and 12 specialties and furnishing, with correlation coefficients of 0.97 and 1.00 respectively.

- For Category 15, Site Requirements:

There are correlations between divisions 1 and 2, and 1 and 3 being general requirement with site work and with concrete work, as well as correleations between divisions 2 and 3 being site work and concrete work, all with correlation coefficients of 1.00. The accidents involve additional general requirement expenses, which were also correlated with site works and concrete works.

- For Category 16, Change of unit rates, no correlations exist.
- For Category 17, Transportation, air freight etc..:

Divisions 9 and 10 being finishes and specialties show correlation coefficient of 0.99. Changes in this category resulted in additional transportation costs for both finishig material and specialty items.

Figure 14 is an example of the correlations between different divisions in a certain category.

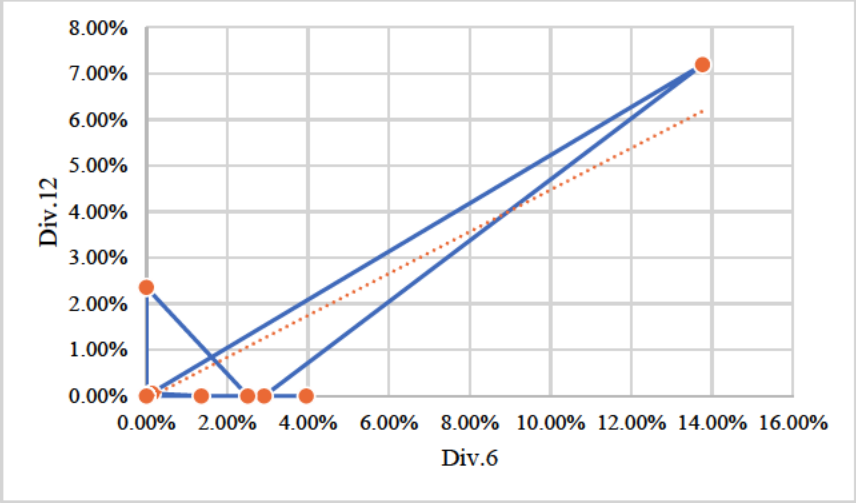

Figure 14: Correlation Analysis between divisions 6 and 12 in Category 2.

Chapter Five

Conclusion

The findings of this study are of great significance as they identify the top reasons for change orders, and identify them as shown below:

- Change in design – new requested work
- New Work or additional scope requested by the owner
- Change in material or specifications
- Ambiguous design details
- Change in design – abortive work

Moreover, it indicates that the designers contribute to the initiation of the highest percentage of change orders, being more than 50% of all change orders of projects.

In addition, several factors are studied and it has been shown that lump sum contract type projects include less amount of change orders than cost plus contract type projects. Project management office approaches are also capable of affecting the amount of change orders in a project.

Finally, the analysis of the projects' list of change orders, and brain storming with professionals in the field, has led to the identification of mitigation measures to reduce change orders. A survey was conducted to rank the obtained mitigation measures, and concluded that the most effective ones involve coordinating the design among the project's various disciplines before work starts on site, and including the contractor team on such coordination. The latter would contribute to a 13.6% reduction in change orders.

Chapter Six

Limitations

Although our study is based on data extracted from executed projects, allowing for statistical assessment, the set of data has some limitations.

6.1 Population Sample Size

- The required data for projects in construction is difficult to obtain due to company's policies, and needs detailed information and backup documents. Accordingly, a limited sample could be studied.
- The analysis of every change order in each project is a long process.

6.2 Inability to Study All Affiliated Factors

Numerous Factors might affect a projects' change orders. Only limited factors are addressed in this study.

6.3 Change Orders only are Studied, not All Additional Costs

The study involves the construction/execution change orders, any additional cost claimed by the consultant or designer to the owner is not presented in the study.

Re-measurements are not presented in the study, except when due to a modification or missing or ambiguous design. Otherwise, they are not considered as change orders.

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Appendix

Appendix A: Survey

Our research targets the Change Orders in High-End residential Projects.

The aim of this survey is to find the mitigation measures to reduce change orders, in order to allow the clients to have a more representative budget of the projects.

The results have shown that the majority of change orders (around %70) are allocated in divisions 9,15, and 16 (Finishes, Mechanical, and Electrical Work).

For the below, from your data and past experience, please indicate percent reduction in the amount of change orders for the total project, when applying each of the below mitigation measures, namely in divisions 9, 15 and 16.

A. %0 to %2
B. %2 to %4
C. %4 to %6
D. %6 to %8
E. %8 to %10

1. Frequent inspections on site to avoid changes at later stages. (Daily, weekly, biweekly)

   A B C D E

2. Coordinate design among the project's various disciplines before work starts on site

   A B C D E

3. Include appropriate sums as allowances in your budget for risk items.

A B C D E

4. Sufficient time to be given during pre-construction phase, for studying the drawings and specs and preparing a complete and coherent bill of quantity.

A B C D E

5. Owner not to accept bids based on conceptual design. Only bid based on Good comprehensive design with elaborated details

A B C D E

6. Following the technology and market. i.e., Looking for universal systems to avoid selection or modification at a later stage. (Mainly Electrical and Mechanical systems)

A B C D E

7. Involvement of contractor technical team in early stages to highlight discrepancies and ambiguities in design.

A B C D E

8. Providing multiple samples to owner prior final selection

A B C D E

9. Transparency among Owner, Designer, and Contractor, mainly revealing any data to the involved parties, to act the earliest possible.

A B C D E

10. Using Building information modelling software (BIM) such as Revit to allow better integration of the whole project and various trades

A B C D E