2-1-2015

Causes of variation orders in the Egyptian construction industry: Classification, ranking, and mitigation

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"Causes of Variation Orders in the Egyptian Construction Industry: Classification, Ranking, and Mitigation"

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B.Sc. in Construction Engineering, 2013

A thesis submitted to the School of Sciences and Engineering in partial fulfillment of the requirements for the degree of

Master of Science in Construction Engineering

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January 2016

Statement:

“Knowledge is power. Information is liberating. Education is the premise of progress, in every society, in every family.” Kofi Annan.

Acknowledgement

Thanks to almighty God for guiding me to complete this piece of work.

Special thanks go to my advisor Dr Samer Ezeldin who has always found room throughout his busy schedule to meet me and help me out through the whole process. I wouldn't forget mentioning my family, my father Dr Khaled Ezz El-Din who has always pushed me beyond the limits and didn't get a chance to see me reach this far, my mother Dr Mona Gamal El-Din whom is my source determination and motivation, and also my sister Nadin who provided me with boost in my energy and mentality. Many thanks go to everyone who has contributed to the study presented in this paper as it would have been impossible to find data to analyze without them. Finally, thanks for the support given by my extended family and, of course, my best friends.

Abstract

Variations or change orders are inevitable in any construction project. They are defined as any change that happens in the scope of the project whether this change is an additional scope of work, omission, or even alteration. This thesis presents the causes of variation orders in Egypt. The literature review divides the causes into four main categories: owner related, contractor related, consultant related, and other causes. All the identified events were surveyed in a questionnaire given to top executives in the construction field in Egypt. The survey was distributed equally on clients, consultants, and contractors. The top 10 most important causes are ranked among the opinion of each party. Another list of the least 10 important causes of variation orders is presented as well. It was found out that when adding up all the results, the most important cause of variations is that the client instructs additional work, followed by contractor using grey areas in the contract to request variations, and continuous changes in schedule. A comparison was done between Egypt, Palestine, Malaysia, and the United Kingdom. It was found it that problems related to design are mentioned directly or indirectly in every country, but there is no overall similarity when comparing all the countries against each other.

Further to data analysis, a model was created using the collected data base. This model provides the user with a scale that predicts the effect of the events triggering variations on both project cost and time. The model was validated using a case study about a large retail shopping center that was recently completed and has proven to be helpful. Finally, the research also provides a list of mitigation techniques that can help reduce the events that give rise to variations.

The list of recommendation was validated through a survey given to professionals in the industry to insure their authenticity for the thesis.

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Chapter I: Introduction

A-Background information

Egypt has various economic sectors and the construction industry definitely among the largest ones. It is a very fast growing and dynamic business. According to (World Market Intelligence, 2011) A period of time was characterized by a financial crisis and weak economies; however, the Egyptian construction industry performed strongly, growing by an annual average rate of 25% during 2008–10. Shortly after the revolution in 2011, the construction industry growth rate decreased to a growth rate of only 3% but again, it started to pick up its self after the elections and improved stability in country. Given that, Egypt is witnessing an increase in the rate of construction with the infrastructure sector constituting around 28.5% and the commercial sector constituting around 22.4% (World Market Intelligence, 2011). It can be concluded that lots of resources and money is spent on that industry which means that it has to be monitored well for sustainability. One of the most popular parameters in construction projects are the amount of variation orders generated.

Variation order or changes are a known terminology among the professionals working in the construction industry. Both the owner and the contractor are concerned about variations. The owner usually wants to receive his project on time and within the assigned budget. The contractor on the other hand is concerned about not finishing on time, or not claiming his fees arising due to variations. One can imagine the effect of a single variation on the project, let alone the effect of multiple variations on the project.

Contractors and owners are certainly concerned about the impact of the single variation; however, the composite impact of overlapping or multiple variations are of a greater concern. Hence, the more events leading to variations, the higher the risk of project cost overrun and time overrun.

B-Variation Order

A variation order is any modification in the original scope of the contract. Changes may be issued by a contractor's a claim, a designer's modification of drawings, or the owner's change in his requirements. A variation order could be as small as changing a window type to as large is omitting the construction of a building in a complex of buildings.

The variation order is formally issued to announce the modification of the contract between the contractor and the owner. It recognizes that there is a change in the assigned work without having to resort to a new contract. (Hester, Kuprenas, & Chang, 1991)

Variations could have many effects on many aspects of the project. (O'Brien, 1998) stated that variations have considerable effects on the project schedule and time. (Arain; Pheng, 2005) claimed that variations could have an adverse impact on other factors such as productivity degradation and quality degradation. Finally (CII, 1986) and (Memon, Abdul Rahman, & Abul Hasan, 2014) has stated that variations could have an effect on organizational impacts and could cause rework and demolition respectively.

A vast amount of research was done in many countries to account for the possible most recursive variations and methods to mitigate them.

C-Problem Statement

With the construction boom that is happening in the world, projects are becoming more complex and more advanced. The necessities of human needs are increasing, thus the world needs more projects in less time and with affordable costs. The higher the complexity of the project, the more chance it will not finish on time or on budget. In the literature review, the previous studies are explored to understand the most recurrent events that give rise to variations. Many studies were carried to understand the causes of variations and their risks, but few or almost none were done in Egypt. Hence, there is a gap of understanding the events that lead to variations in Egypt. Egypt is currently undergoing a heavy change in its construction context. Therefore, it is very essential to understand the events that lead to variations in construction buildings. This is important in order to produce an end product that is economic to the developer, beneficial to the society, and without scarifying the contractor's rights.

D-Research objectives

The objective of this research is to determine the most common types of events that lead to variation orders which happen during project design and construction in Egypt. By the end of the study, a ranking for the events that lead to variations will be issued, and a comparison between the client's thoughts, contractor's thought, and consultant's thoughts will be made. A guidance model using the collected data will be made which would aim to predict the severity of combined causes of variations together. In summary, the potential objectives of the research are the following:

1- Identify and rank a list of causes of variation orders on a construction project in Egypt
2- Develop a model that predicts the effect on cost & time when combining multiple events together
3- Verify the use of the model and validate it using a real example case study
4- Produce a list of recommendations to mitigate the number of events that give rise to variation orders

E-Research Methodology

1- A literature review that would allow the exploration of events that give rise to variations, their effects, and their rectification methods.

2- A survey listing the most common types of variations and their ranking from the most important to the least important by project parties e.g. client, consultant, and contractor.

3- A model that predicts the effect of combining events on cost and on time

The following diagram (Figure 1) shows a flowchart of the sequence taken in the research

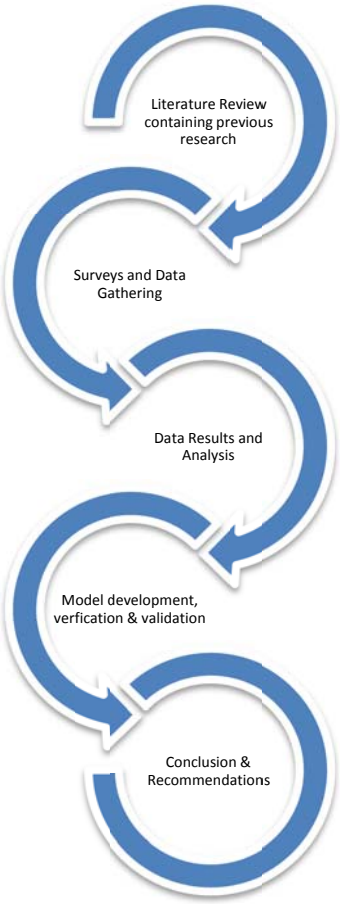

Figure 1 Research Sequence

F-Thesis Organization

This thesis is organized into six chapters which are: The introduction, the literature review, the survey, the model, the case study, and finally the conclusion.

1- Chapter I : The introduction

   The aim of chapter one is to give background information about the topic and introduce it to prove that there is a gap of research needed to be filled by the scope of work.

2- Chapter II: The literature review

   The literature review presents the efforts done by previous researchers in similar topics, a list of identified events that give rise to variations, and some of the ways used to mitigate variations.

3- Chapter III: Survey architecture & prediction model

   The survey chapter contains information about the surveying methods, number of surveys used in the study, architecture of the survey, architecture of the model, expected presentation of the data

4- Chapter IV: Data results & Analysis

   Chapter four explores the results of the study from the surveys, the analysis of those results, and commentary on them. The results are ranked by the top 10 most effective events and the least 10 effective events.

5- Chapter V: Model development, verification & validation

This chapter contains the model that was created using the data base collected in the data results and analysis chapter. An explanation for using the model is provided, and verification of the model is done by testing new random data. A final check for model validation is done by applying a real case study. The case study is used to see the effectiveness of the model and how the model will be able to help top managers to take corrective actions against the events that lead to variations.

6- Chapter VI: Conclusion, limitations, and recommendations

Conclusion chapter summarizes the research findings, presents recommendations for further studies and states limitations of the current study.

Chapter II: Literature review

A-Overview on Variations:

A change or a variation is a “Unilateral written order by a project owner directing the contractor to change contractor amount, requirements, or time. Such changes must be within the scope of the contract and in accordance with the contract's change clause to be legally implemented without the consent of the contractor” (Business Dictionary, 2015).

Another definition for variations given by (Baxendale & Schofield, 1986) is “any changes to the basis on which the contract was signed. This includes not only changes to work or matters relating to the work in accordance with the provision of the contract but also changes to the working conditions themselves”.

A third definition could be credited to (O'Brien, 1998) who has defined variations as any type of deviation from an agreed upon, well defined scope or schedule of works.

Studies were conducted to identify whether there are different types of variations in the construction industry, and Robert K. Cox has summarized them into three types which are:

- Formal change/variation: when the client or his representative issue an approved written request titled 'change order' that aims to modify the contracts conditions, expressions, strategy and specifications. However, it must be in line with the contract changes procedure (Cox, January 1997)

-Constructive change/variation: is the extra work to the contract scope of works which is executed either in accordance to verbal or implied client's instructions, as a consequence of problems that were caused by the client's intrusion. It may also be as a result of the client's representative failure to fulfil a contractual obligation. (Cox, January 1997)

-Cardinal change/variation: Occurs whenever the client requests the contractor to execute an additional scope of work outside his scope for a fixed amount (lump sum) in the original contract. This type of change/variation is also referred to as scope change which enables the contractor to pursue delay damages on contracts. (Cox, January 1997)

A vast amount of research was done in many countries to account for the possible most recursive variations and methods to mitigate them. Studies were carried across the world in both developing countries and developed countries. A developing country is a country that its gross national income per capita per year is less than or equal 12,746 USD (World bank, 2015). Egypt is a developing country with a 10,260 USD gross national income (World bank, 2015). Hence, it could be claimed that Egypt is near being developed. A collection of studies is summarized below for eight countries ranging from developing countries such as Uganda, Nigeria, and State of Palestine to mid-developed countries such as Saudi Arabia, Oman, Malaysia and ending by fully developed countries such as Singapore and the United Kingdom. A comparison between one country of each category will be done against Egypt in the data analysis chapter.

The National University in Singapore produced a journal paper named "The Potential effects of Variation Orders" on institutional buildings projects aiming to provide an in-depth analysis of the potential effects of variations in institutional building projects, which would be helpful for

building professionals in assessing and taking proactive measures for reducing the adverse impact of variations. (Arain; Pheng, 2005)

Department of civil engineering in Palestine produced a study titled “Causes of Variation Orders in Construction Projects in Gaza Strip”. The study aimed to create an understanding of the causes of variation orders that would be helpful for building professionals in assessing variation orders. The second aim of their study was also assisting professionals in taking proactive measures for reducing variation orders in construction projects. (Enshassi, Arain, & Al-Raee, 2010)

Universiti Tun Hussein Onn Malaysia, Malaysia published a paper titled “Significant Causes and Effects of Variation Orders in Construction Projects” their aim was to uncover and understand the significant causes and effects of variation orders. (Memon, Abdul Rahman, & Abul Hasan, 2014)

(Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010) Did some research on the variations topic in Oman and published a paper on the public construction projects in Oman named “Causes, Effects, Benefits, and Remedies of Change Orders on Public Construction Projects in Oman”.

(Obideyi, 2010) Wrote a dissertation about variations in Nigeria named “Major causes and effects of engineering change orders on Nigerian petroleum industry projects” where he highlighted and categorized the causes of variations into five categories which are: Project related, design related, client related, contractor related and externally related.

(Al Suliman, 2009) submitted another dissertation highlighting the impact of variations on projects during the construction phase in Saudi Arabia.

(Muhwezi, Acai, & Otim, 2014) carried out a study in Uganda to assess the factors causing delays on building construction projects. They have categorized variations according to the party that triggered the event. That means that if the variation was triggered by an event caused by the contractor, then it's a contractor related variation.

Last but not least. (Keanne, Sertyesilisik, & Ross, 2010) Produced the same preceded studies and classified the variations into owner related, contractor related, consultant related, and other in the United Kingdom.

Given the previous studies, from many countries with different back grounds, it seems that variation orders have a drastic impact on construction projects everywhere in the world. Hence, there are many studies that aim to guide engineers to mitigate the effect of variations by controlling the events that possibly give rise to them.

It is intended to apply a similar research on variations in Egypt, taking the same measurements presented from different papers across the globe. Many events that give rise to variations were identified from several papers in the literature review and they can be classified into four types of events: client related, contractor related, consultant related, and other.

B-Categorization of variations

Variations are triggered through events. That means that if a given event happens, it will most likely lead to a co-related variation to happen. Researchers have categorized variations to know which party triggers the event. Upon categorizing variations, controlling and mitigating them become easier. Categorization of variations have several forms, the following forms are some of them:

In the paper "Causes of variation orders in construction projects in Gaza strip" by (Enshassi, Arain, & Al-Raee, 2010) they have categorized variations into five main categories: Donor related factors, owner related factors, consultant related factors, contractor related factors, and other factors. The reason why they have donor related factors might be because many buildings in Gaza depends on donations as a source of finance.

(Keanne, Sertyesilisik, & Ross, 2010) have only categorized variation events into four main types where they have excluded the donor related factors from their classification. (Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010) on the other hand have categorized variation events into three main types where they have excluded other related events from their classification.

Finally, (Obideyi, 2010) has categorized variation events into five categories that can be summarized as project related, client related, design related, contractor related, and other external factors .

In this paper, variation events are categorized into four categories, the most popular form of categorization which is: client related, contractor related, consultant related, and other forms.

The number of variation order events that can be studied is limitless; however, out of these limitless choices , there are events that are common between most of the studies. In this paper, a total of 38 variations were included in the study. Those 38 variations were picked according to the most common events, and also other events that can be directly related to Egypt. The 38 variations were categorized according to the chosen method of categorization.

C- Client related events:

1- *Changes in the specification by the client*: Changes in the specifications are frequent in construction projects and that can mainly be addressed due to inadequate project objectives. Should the client decide to change the specification of his project design requirement, then this may lead to variations in the construction phase. (Keanne, Sertyesilisik, & Ross, 2010)

2- *Client instructs additional works:* This event usually happens because some-times the client might have less qualified engineers. He also might not receive discrete advice from the consultant during the pre-contract phase of the project or during feasibility study, which in turn leads to changes during the detailed design and construction. These changes are counted on the client consultants might be a part of it as well. (Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010)

3- *Obstinate nature of the client:* A building project is the result of the combined efforts of the professionals involved, which have to work at the various interfaces of a project. If the owner is stubborn or unwelcoming to work then this could cause variations at the later stages of a project. (Wang, 2000) and (Arain; Assaf; Low, 2004)

4- *Client's financial problems:* The owner's financial problems can affect project progress (Clough & Sears, 1994) and (O'Brien, 1998). This problem often leads to change in work schedules and specifications, affecting the quality of the construction. (Memon, Abdul Rahman, & Abul Hasan, 2014)

5- *Client fails to make decisions at the right time*: Prompt decision making is an important factor for project success (Sanvido, Parfitt, Guvensia, & Coyle, 1992) & (Gray & Hughes, 2001). Inability to make decisions at the right time may result in delays which in turn might cause the need for the change order due to cost increments. (Memon, Abdul Rahman, & Abul Hasan, 2014)

6- *Client's brief before the design stage is unclear or not well defined:* At the beginning of the project, usually the client issues a brief that contains his needs and expectations from the designer. The brief contains all the necessary information for the architect to issue the preliminary design drawings, if the brief wasn't clear enough, this may result in the production of a design that the client doesn't want which in turn may lead to variations.

7- *Absence of professional team members from the client's side:* All big clients have engineers that represent their business; random choosing of those engineers might lead to assigning incapable people in decision making positions which is not always in favor of the project.

8- *Unilateral decisions made by the client without proper considerations to the program:* Client's decisions sometimes might be impossible to execute given the short time notice without associating them with variations to cover those decisions.

9- *Modification of scope:* Modification of scope in the project is one of the most significant causes of variation in construction projects. Modification of scope might be to lack of the owner's knowledge in the project, lack of planning in the primary stages of the project, or

in accurate advice from the consultant in the beginning. (Memon, Abdul Rahman, & Abul Hasan, 2014)

D-Contractor related events:

1- *The contractor uses the grey areas in the contract and requests variations:* Sometimes there are certain clauses in the contract that are not clear and can be interpreted in one meaning or another. If a contract is not drafted properly, a gap is created for the contractor where he can use it for his own benefit to claim a few variations.

2- *Poor construction management by the contractor:* If the contractor is not mature enough with the construction of the project, then materials could be delayed, or lost, activities could be prolonged, and the overall planning could fail resulting in the rise of variations.

3- *Lack of contractor's involvement in the design:* Sometimes the design could possibly be designed better to facilitate the construction process, some other times the design is not constructible at first place. Lack of the contractor's involvement in the design could result in variations due to these mentioned reasons.

4- *Contractor's financial difficulties:* Construction depends heavily on labor and subcontractors. It doesn't matter that whether the main contractor was paid for his amount of work or not, yet he still needs to pay-off his wages for his labor and his sub-contractors. (Thomas & Napolitan, 1995). If a contractor faces such difficulties during the life time of the project project, variations may result and the quality and progress of the project may be affected as well. (Keanne, Sertyesilisik, & Ross, 2010)

5- *Poor workmanship*: Defective workmanship is not only harmful because it may lead to demolition, but it also means that one must re-do the work (O'Brien, 1998) . This may lead to project delay if it was a critical activity and will surely affect the cost. (Memon, Abdul Rahman, & Abul Hasan, 2014)

6- *Poor procurement process:* Procurement delays have various adverse effects on other processes in the construction cycle (Fisk, 1997). This means that if the procurement process is poor, other processes in the construction cycle will be affected; hence, variations may result. (Keanne, Sertyesilisik, & Ross, 2010)

7- *Lack of construction materials and equipment*: May leads to variations because some of the activities might depend heavily on a certain material and certain equipment. This means that if they don't exist then these activities will be omitted as they will be impossible to perform and hence, variations could rise. (Enshassi, Arain, & Al-Raee, 2010)

8- *Spare parts due to closure and siege*: Spare parts could become a major problem especially in Egypt, sometimes it takes a lot of time to bring imported parts from abroad, and it takes a while to get the permits and pay the taxes to get them on site, this might in turn affect some activities resulting in variations. (Enshassi, Arain, & Al-Raee, 2010)

E-Consultant related events:

1- *Change in the design or the specifications by the consultant:* A change in design improvement by the consultant is a norm in contemporary professional practice (Arain; Assaf; Low, 2004) Changes in design are almost inevitable and were frequent in projects where construction starts before the design is finalized (Fisk, 1997). Those changes can affect the project tremendously especially if the design was complete, and it would be hard to overcome them without variations. Changes in specifications are also frequent in the construction industry with inadequate project objectives (O'Brien, 1998). Changes in specifications might result in variations.

2- *Errors and omissions in design*: Errors and omissions in design are a significant cause of project delays (Arain; Assaf; Low, 2004) The time of error and the degree of it affects the projects and might generate variations. (Keanne, Sertyesilisik, & Ross, 2010)

3- *Conflicts between contract documents:* Conflict between contract documents can result in misinterpretation of the actual requirement of a project. All the contract documents should be in line together and don't contain any discrepancies between them in order not to leave a room for misinterpretation that can delay the project or cause variations in cost. (Memon, Abdul Rahman, & Abul Hasan, 2014)

4- *International consultant using inadequate Specification to be followed in local conditions:* If the client hires an international consultant for his project due to the experience of that consultant in a certain matter, that consultant might not be familiar with the country's conditions such as testing specifications for the project. Hence, Unfamiliarity with local conditions could lead to variations.

5- *Lack of consultant's knowledge of available Materials and equipment.*

6- *Non-availability of professional engineers to maintain the quality of consultancy services*

7- *Low consultancy fees leading to hiring less experienced designers:* The more the client pays to the firms he assigns, the most likely he will get more qualified engineers. Cutting costs and paying less money to consultants would mean that they would hire junior engineers who might not be experienced enough in crises management and decision making which would mean that the probability of variations will increase.

8- *Failure by the consultant to provide adequate and clear information in the tender documents:* As stated in the previous point, the more a client pays, the most likely he will hire a strong consultancy firm. Poor consultancy firms will not be competent enough to provide clear information in contract documents, which might lead to misinterpretation by different project parties resulting in variations.

9- *Consultant is not familiar with the regulations and construction permits:* lacking the knowledge in the country where construction project is held could interrupt the flow from one stage to another. Project interruption means schedule delay meaning more money and more variations. (Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010)

10- *Failure by the consultant to perform design and supervision effectively* (Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010)

11- *Short period for design stage:* The client might not allow for the regular design period for the sake of wanting his project to start operations as soon as possible. Short design periods provide a medium for errors which might turn into variations later.

12- *Design complexity:* Sometimes the designer/consultant issues a design that is hard to execute due to the complexity of drawings, and this perhaps justifies the importance of the early involvement of the contractor during the design stages. Contractors could be involved during design stages by choosing a certain project procurement method called Design-Build method. Complex designs might require special method statements or a different know how which usually requires more time and more money.

13- *Inadequate design:* Inadequate design can be a frequent cause of variations in construction projects (Fisk, 1997)

F-Other events:

Other events are the list of events that could rather not be affiliated to a certain party in the project, but would rather be addressed to all of them. Most of these events are not directly related to the project itself, but they have an adverse effect on it.

1- *Lack of coordination among project parties*: might lead to major variations with impact on the project (Arain; Assaf; Low, 2004) coordination is a key success tool not only in a construction project, but in any project. Bad coordination would lead to dissatisfaction of the owner from the constructed product which would lead to rework, and variations. (Keanne, Sertyesilisik, & Ross, 2010)

2- *Internal political problems between project parties:* "A lot of funds for projects were withdrawn because of political situation. The contractor is the most effected party of internal political problems" (Enshassi, Arain, & Al-Raee, 2010) take the grand Egyptian museum as an example, after the joint venture worked for a while, the funding suddenly stopped which in turn affected the survival of the project at the moment.

3- *No availability of records of similar projects:* Historical projects help designers to benchmark the cost of their proposed project to their owner. Lacking of such data might lead to false cost predictions which might lead to variations during the construction stages.

4- *Unfamiliarity with local conditions:* Familiarity with local conditions is an important factor for the successful completion of a construction project (Clough & Sears, 1994) . If the contractor or the designers are not familiar with local conditions, it would be more difficult to design an executable project, which would mean that many amendments might show up possibly leading to variations and delays to the completion of the project. (Keanne, Sertyesilisik, & Ross, 2010)

5- *Desired excessive profitability*: Variations are considered a common source of additional work for the contractor (O'Brien, 1998). Variations are additional financial reward for the contractor which means that it will be reflected on the prolongation of the project and the consultant fees. The owner will end up paying both parties more than expected. (Keanne, Sertyesilisik, & Ross, 2010)

6- *No availability of overall project planning:* Failure of planning among the project parties may lead to drastic penalties in terms of the project cost and time.

7- *Continuous change in project schedule*: A change of schedule during the project construction often results in fluctuation in resources. Changing schedules of work means that the contractor will be required to provide additional resources or remove some of his resources from site. In both scenarios, additional cost is incurred (O'Brien, 1998) and (Fisk, 1997).

8- No availability of construction method statements and procedures for project construction

G-Problems Generated Through Variations

In Any construction project time & money are usually of an extreme essence. Variations are one of the processes that prolong the end time of the project and extrapolate the value of it as well. Many authors such as (Al Suliman, 2009), (Obideyi, 2010), (Keanne, Sertyesilisik, & Ross, 2010), (Memon, Abdul Rahman, & Abul Hasan, 2014) and (Arain; Pheng, 2005) have highlighted the most recurrent problems that are generated due to rise of variations.

1- *Impact on project schedule:* variation orders affect the overall progress of the project (Assaf, Al Khalil, & Al Hazmi, 1995). Variation orders usually result in delay and time is always the equivalent of money in business. (Kumaraswamy, Miller, & Yogeswaran, 1998) Studying delay problems in construction projects of Hong Kong showed that 50% of the projects that they have surveyed were delayed because of variations. In order to overcome the delay of a project, the contractor would try to accommodate the variations by utilizing the free floats in the construction schedules. However, sometimes variations would follow on the critical path and thus could delay the whole project.

2- *Impact on project cost:* The effect on project cost is important and common in variations. Variations always have a negative impact on project cost as they are an additional cost to the project. Thus, in order to keep overall project cost the same; normally in every construction project a contingency sum is allocated to cover the expected variations. Besides, variations require a lot of paper work and reviews before they can be implemented (O'Brien, 1998). Which means that would increase the overhead expenses

for all the participants from the contractor to the consultant to even the client representative. (Memon, Abdul Rahman, & Abul Hasan, 2014)

3- *Quality degradation*: Tendency to produce variations might impact on the quality of work (Fisk, 1997).The more variations are produced, the more likely the quality of work will be affected as contractors tend to compensate for the losses by cutting costs that should not be cut to maintain the same quality.

4- *Productivity degradation*: Variations have a negative impact on labor productivity because of interruption, delays and redirection of work. These in turn can be translated into labor cost. (Hester, Kuprenas, & Chang, 1991) claimed that labor productivity was expected to be affected in cases where they were required to work overtime to compensate for schedule delays. (Arain; Pheng, 2005)

5- *Rework & demolition:* If variations occurred during the construction phase or when a phase is completed, then this will cause some demolition and rework. However, when variations happen during the design phase, they do not require any rework or demolition on construction sites but they would then lead to overheads as stated in point number two. (Memon, Abdul Rahman, & Abul Hasan, 2014)

6- *Organizational effects*: Disputes over change orders and claims are inevitable and the variation clauses are often the source of project disputes (CII, 1986)Variations could eventually affect professional relations on a construction project because they are always subject to the agreement between all the parties in the project. If the contractor and client and the consultant aren't on good terms disputes will be formed and will create further

delay. Not only they will affect the relations internally, but they can also have severe effects on each company's overall reputation. Acceleration of the work due to variations may cause poor safety conditions, may increase the likely hood of accidents, would degrade quality requirements, and thus tarnish a firm's reputation.

H-Mitigation of Events that Give Rise to Variations:

1- *Assigning a lead designer*: Lead designers/consultants act as a point of contact between all the project parties during the design stages, especially if there were many designers in the project. Big projects usually contain local consultants and international consultants usually working on different disciplines. Assigning a lead consultant will decrease the possibility of misunderstanding and errors among professionals; He will make sure that the deliverables are as accurate as possible. (Arain; Pheng, 2005)

2- *Coordinate with all design teams, review, check, & validate the design*: Continuous coordination and direct communication will eliminate design discrepancies and errors as well as omissions in design. They will also enhance the knowledge of the professionals in the project contract and documents. Thus, this would help in eliminating the variations arising because of conflicts in contract documents. (Arain; Pheng, 2005)

3- *Clarify the scope & abide by the limit of the scope:* Clear and thorough project brief would help in decreasing the frequency of variations because of the unclear scope of work for the contractor. Eventually, this may assist in developing a clear scope of work for the professionals. (Arain; Pheng, 2005)

4- *Continuous coordination & cooperation between the client representative & design team*: It is very important to coordinate between the client and the consultants in order to achieve the required design with the least wastage of time. It will also help the

consultants to figure whether they are working according to the client expectation and requirements or not. (Arain; Pheng, 2005)

5- *Assign a quantity surveying firm:* quantity surveyors have emerged and proved to be a very effective cost estimating and controlling tool. According to (Maarouf & Habib, 2010) "the quantity surveyor has traditional independent role in the team comprising client, architect, engineer and contractor combined with expertise in drafting and interpretation of contract documents will avoid disputes and ensure the effective progress of a project". Quantity surveyors will give the client accurate cost plans for the project during the design stage, they will advise on different procurement routes for the projects and will monitor the cost of the project during execution, and thus the cost of variations can be controlled better with their presence.

6- *Select an appropriate procurement route:* A procurement system (or sometimes known as delivery system) "is an organizational system that assigns specific responsibilities and authorities to people and organizations, and defines the various elements in the construction of a project" (Love, Skitmore, & Earl, 1998). Procurement systems can be classified as: traditional, design and construct, management, design-design build, and collaborative. Choosing an appropriate route according to the client resources, project characteristics, cost issues and timing is crucial in order to control the amount of variations.

7- *Apply risk management principles*: According to (Schieg, 2006) in his paper risk management in construction project management "Risk management successfully installed in the project offers the chance to gain a clear understanding of the goals, duties and contents of the service and the feasibility of the project. It provides an information basis for the quantitative data, sorted according to size, for the purpose of supporting decisions, such as e.g. The choice between costs and implementing goods or the comparison between several possible options" Hence, risk can help in mitigating variation orders.

8- *Apply value management principles*: Value management is a complete process or overarching that controls all the project stages in order to achieve the best value for money. (Rangelova & Traykova, 2014)highlight the importance of value management in construction in their paper "value management in construction project" by stating that "Value management is an integrated, organized and structured process, led by an experienced facilitator and broken down into various stages to enhance the value of a construction project, not necessarily only by cutting costs" early application of value management would organize the stages of the project in a way that could mitigate the possibility of arising of variations.

9- *Issue complete set of contract documents*: Complete contract document decrease the margin of interpretation between the parties, thus would lead to less confusion and less variations through the project lifetime. (Arain; Pheng, 2005)

10- *Early involvement of contractor before tender stage*: Sometimes, involvement of the contractor is beneficial to the project as the contractor could have some inputs in the design that could facilitate the construction process thus decrease the project duration and the project cost. The shorter the project, the less likely the frequency of variations would be. (Keanne, Sertyesilisik, & Ross, 2010). Contractors could be assigned during design stages by choosing a procurement method for the project called Design-Build method (Love, Skitmore, & Earl, 1998)

11- *PM to coordinate with the governmental body and designer abroad:* In some projects, clients like to assign foreign designers because of the nature of their project. If, for instance, the project hasn't been done in the country before, then the employer wouldn't want to take the risk of assigning a designer who is not familiar with it; instead, he would employ an expert designer for his project. Designers might not be aware of the country's rules and regulations, and hence could design something that could later be rejected by the authorities. Design rejection could lead to several variations and associates several incurred costs; hence, it is important that the project manager acts as a link between the designer and the government.

Chapter III: Survey Architecture

A collection of data is required to perform analysis on the most important events that lead to variations in the design and construction phase. In order to do that, a survey has to be made. There are several methods of surveying, but they are all centered on three techniques. (Abbott & McKinney, 2013) state in ": Understanding & applying research design" that there are three methods of surveying: Face to face interviews, phone interviewing, and questionnaires.

Face to face interviews are the best in terms on data credibility, and that is because the interviewee is in front of the interviewer, which makes sure that the interviewee will think about the question and give a valuable answer. The drawbacks of face to face interviewing are that it needs proper scheduling and it is also very time consuming. Phone interviewing is almost the same, except that you cannot tell whether the interviewee is giving an honest answer or not. The interviewee might be doing something else along with answering the questions on the phone, which might result in inaccurate results because of his distraction. The third method of surveying, and the most efficient one, is questionnaires. Questionnaires are a good option of surveying as it is very popular and almost everyone is familiar with it. Questionnaires save time and their error and reliability could be enhanced by choosing a suitable and diversified sample size (Abbott & McKinney, 2013).

Questionnaires come in two forms, either physically, or electronically. At the moment, almost every engineer required in the study would have access to the internet. Hence, it is faster and cheaper to send the questionnaire on the internet rather than sending it as a physical package. Besides, having the data online will give better opportunity in analyzing it faster. The only problem is that the longer the survey, the lower the chances you will find people to fill; besides,

the more technical the survey is, the more experienced engineers you will need to fill your survey.

A-Survey item construction:

The objective of the survey is to gather as much as useful information as possible and make use of it. The survey has to be created as simple as possible in order to avoid misinterpretation of the question by the user. The number of planned surveys for the study is two surveys. The first survey explores the percentage of the people who agree about the mitigation methods used in the thesis and it is divided into two sections, section one is gathering information about the user in a structured form. Structured questions are questions that offer the respondent a set of responses to choose from. Structured questions make data collection and analysis much simpler and they take less time to answer (Abbott & McKinney, 2013). An example of a structured question in the survey would be:

- How many years do you have of post qualification experience?

o 0-5

o 6-10

o 10-15

o 15+

This method allows you to filter the users by their experience and give more weight to the answers of the more experienced engineers. The first survey doesn't require an expert engineer to solve it, but it needs at least a firm background.

The second survey is the more challenging one. The survey is about rating of events. The user will choose a number between 1-5 to evaluate the frequency of the event that gives rise to variation. An example would be:

Rate the following based on the frequency of happening of the variation:

- Owner's request for change in the design 1 2 3 4 5

The user would then be required to give an impact for the effect of the event on project cost and time for the same statement.

The second survey will be used to rank the events from the most frequent event to the least frequent event. The comparison will be done for the client, the consultant, and the contractor. The average of all the answers from the contractor, consultant, and client will be taken to obtain the list of the most frequent events that lead to variations.

B-Choosing your sample (Statistical Sampling):

The number of samples used in the survey is important for testing the validity and the degree of confidence in the data. There will be two models of the survey, one that requires deep understanding of the field and another survey that is less complicated and more generic. Statistical sampling is concerned with the selection of a subset of individuals from within a statistical population to estimate characteristics of the whole population. As previously stated the second survey needs an extensive knowledge in the construction field; hence, if we assume that there are 1,000 Engineers holding managerial positions that are related to the cost of the project and the time of the project in Egypt in a client/contractor/consultant firm, then we need around 23 completed surveys to be able to get a 95% confidence level with 20 confidence intervals.

As for the first survey, let's assume that there are 100,000 civil engineers and architects working in Egypt, this means that we need around 79 completed surveys to be able to get a 95% confidence level with 11 confidence intervals.

Confidence level: is the margin of error, it's a plus or minus figure that states that for example if you had a confidence level of 10 and 50% of your population said "yes" as an answer for a certain question, then you can be sure that if you asked the same question to a relevant population the probability of getting a "yes" as an answer is 50-10 = 40% or 50+10 = 60%

Confidence interval: States how sure you can be of the answer and gives you an upper and lower boundary for the values obtained.

C-The Survey

As explained, the study has two surveys which will be distributed into two types of audience.

The first survey is for civil engineers and architects in the general and it is easy to fill, the second survey is for people who have more than 15+ in the construction industry and whom are working in the commercial aspect or the planning department of projects. Typically experts would be construction managers, commercial managers, senior planners and project managers.

The first survey contains two parts, the structured questions part in the beginning followed by the mitigation statements for the events that give rise to variations., it is based on a yes, no answer only; therefore, it is easy to fill.

The second survey deals with 38 events that lead to variations, and it is required from the user to give an intensity from 1-5 (5 being most intense) of the probability of seeing such an event in a project.

e.g. Errors and omissions in the design 1 2 3 4 5

If a user wishes to choose 4, then this means that he thinks that errors and omissions happen 80 percent of the time.

The user then is asked to give a rating, again from 1 to 5, for the effect of that event on cost and on time. Hence, if the user chooses 2 for cost and 5 for time then he means that he is 80% sure that errors and omissions in the design happen in the project with 40% effect on project cost and 100% effect on time.

Given the difficulty of assessing the above type of questions, the sample of experts used was chosen wisely, and that is also the required engineers must be in a senior/managerial position in a client/contractor/consultant based firm with more than 15+ years of experience in the field.

The expected outcome of the first survey is to understand the percentage of people who agree with the mitigation methods presented in the literature review. While in the second survey it is expected to rank the events and know their intensity.

D-Survey Architecture

The structured questions of the 2 surveys are going to be the same, this data is used to identify the different types of engineers in the population in order to know how reliable is your data. The questions are:

What is your field of expertise?

- Contractor
- Consultant
- Client's representative

What is the field of work of your organization?

- Buildings
- Infrastructure
- Other Please state:……..

How long is your post qualification experience?

- 5+
- 10+
- 15+

Value of executed project during the last 10 years?

- Less than 10 million USD
- Less than 50 million USD
- Less than 100 million USD
- More than 100 million USD

Which of the following best fits your role in your organization?

- Junior employee
- Senior employee
- Decision Maker

As for the technical part of the first survey, the mitigation questions are the following:

1- Coordinate with all design teams, review, check, & validate the design

2- Continuous coordination & cooperation between the client representative & design team

3- Assign a lead designer

4- Issue complete set of contract documents

5- Apply risk management principles

6- Select an appropriate procurement route

7- Apply value management principles

8- PM to coordinate with the governmental body and designer abroad

9- Assign a quantity surveying firm

10- Early involvement of contractor before tender stage

11- Clarify the scope & abide by the limit of the scope (No addition or omission)

For the technical part of the second survey 38 events were identified from the literature review and were sorted into 4 types: owner related events, contractor related events, consultant related events, and others. These events were found to be the most recurrent ones in all the previous papers. As stated before, the user will have to assign a number for every event that gives the probability, impact on cost, and impact on time. Below are the lists of events used in the survey:

1- Change in specification by owner/client
2- Client instructs additional works
3- Obstinate nature of client
4- Client's financial problems
5- Client fails to make decisions at the right time
6- Client's brief before the design stage are unclear or not well defined
7- Absence of professional team members from the client's side
8- Unilateral decisions made by the client without proper considerations to the program
9- Modification of scope
10- The contractor uses the grey areas in the contract to request variations
11- Poor construction management by contractor
12- Lack of contractor's involvement design
13- Contractor's financial difficulties
14- Poor workmanship
15- Poor procurement process
16- Lack of construction materials and equipment
17- Spare parts due to closure and siege
18- Changes in design or specs by consultant

19- Errors and omission in design

20- Conflicts between contract documents

21- International consultant using inadequate specification to be followed in local conditions

22- Lack of consultant's knowledge of available materials and equipment

23- Non availability of professional engineers to maintain the quality of consultancy services

24- Low consultancy fees leading to hiring less experienced designers

25- Failure by the consultant to provide adequate and clear information in the tender documents

26- Consultant not familiar with the regulations and construction permits

27- Failure by the consultant to perform design and supervision effectively

28- Short period for design stage

29- Design complexity

30- Inadequate design

31- Lack of coordination among project parties

32- Internal political problems between project parties

33- Non availability of records of similar projects

34- Unfamiliarity with local conditions

35- Desired excessive profitability

36- Non availability of overall project planning

37- Continuous change in project schedule

38- Non availability of construction method statements and procedures for project construction

E-Demographics of the surveys

First survey: (Survey for mitigation)

Key Jobs: Project Managers, Cost Managers, Planners, Commercial Managers	
Sample Size	80
Years of experience10+ or more	54%
Field of organization work (buildings)	81%
Value of largest executed project during last 10 years more than 100+ million USD	83%

Table 1 shows the demographics of the respondents

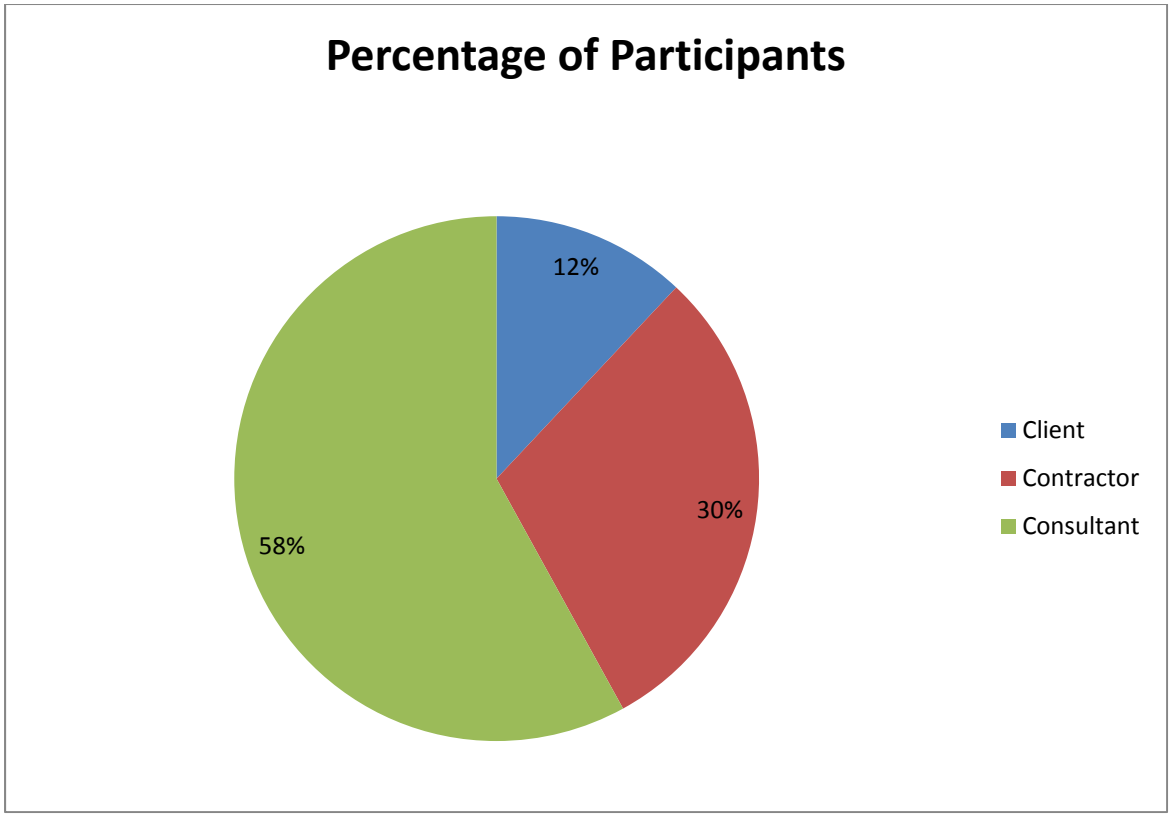

Figure 2 shows the category of participants

Table one is a presentation that shows the background of people who answered survey number 1 (the mitigation survey). The main reason behind survey number one was to test the market for its awareness against the techniques used to mitigate the number of events that leads to variations. All project parties must be aware of the mitigation techniques; hence, it was not important to target a specific age group or a specific party. The number of people who answered the survey was 80. The percentage of people who answered the survey with more than 10 years of experience constituted around 54%. That means that half of the survey was answered by experienced professionals and another half by juniors and midlevel engineers. More than 80% of participants claimed that they have worked in project areas related with buildings that had a signed off value of more than 100 million USD. The key jobs for the participants were project managers, cost managers, planners, commercial managers, quantity surveyors, contract administrators and schedulers. Figure two is a graphical representation of the category of participants used in the study. 58% of the respondents were working at a consultant firm when the survey took place; the other 42% is divided among the contractor's participants and the client's participants at 30% and 12% respectively.

Second survey: (Survey for ranking of events)

Key Jobs: Project Managers, Commercial Managers, Directors, Country managers	
Sample Size	25
Years of experience15+ or more	100 %
Field of organization work (buildings)	100 %
Value of largest executed project during last 10 years more than 100+ million USD	100 %

Table 2 shows the demographics of the respondents

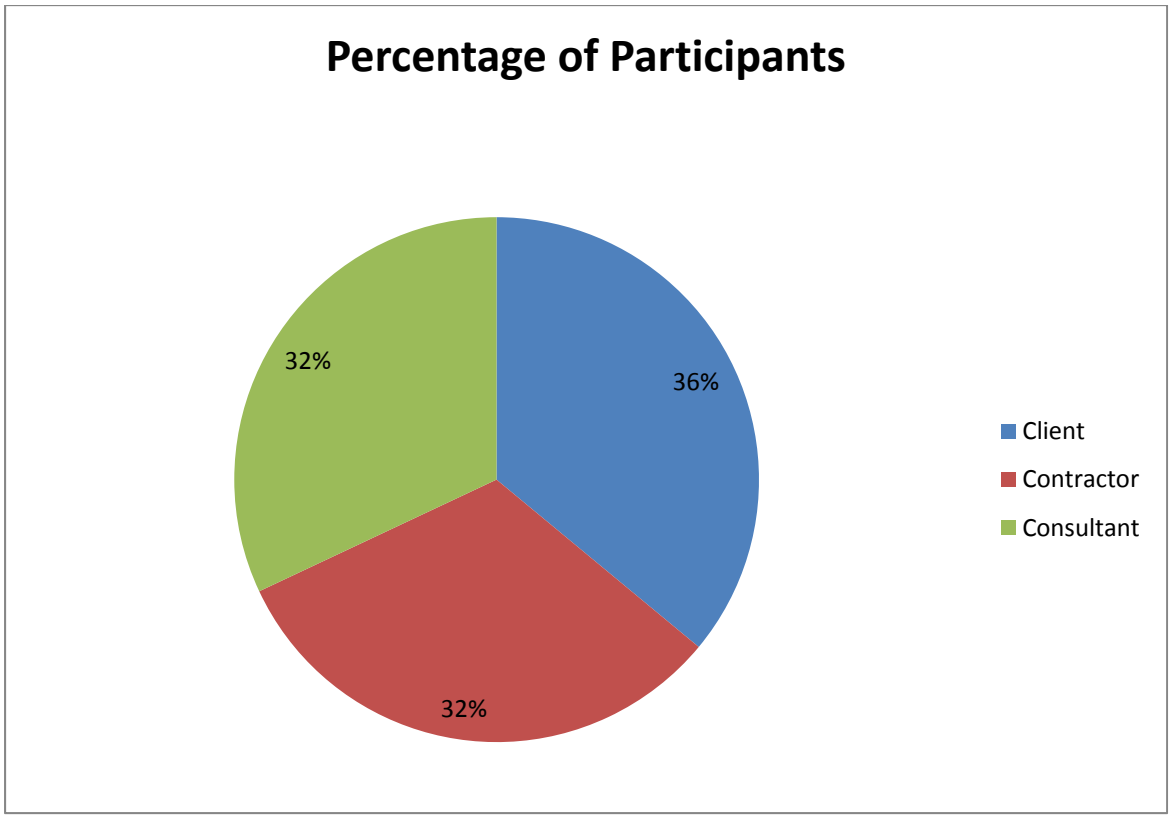

Figure 3 shows the category of participants

Table two is a presentation that shows the background of people who answered survey number 2 (the effects of events giving rise to variations). The main reason behind survey number two was to rank the top 10 most frequent events that give rise to variations. This survey was very important for the study because the amount of data that could be generated from it was limitless. The main extract of survey number two was:

1- A top 10 list for most common events that give rise to variations according to the client, the contractor, and the consultant.
2- A top 10 list for the least common events that give rise to variations according to the client, the contractor, and the consultant.
3- Probability of the effect of the event that gives rise to variation on project cost
4- Probability of the effect of the event that gives rise to variation on project time

Given the complexity of the survey, and the importance of getting reliable data, it was distributed to professionals with more than 15 years of experience in the market. Table two shows that among 25 professionals, all of them had previous experiences with building projects with a value exceeding 100 million USD. Figure three shows that the category of participants was almost equal, with the client sharing 9 surveys, and both the contractor and the consultant sharing 8 surveys each. The reason why there are equal numbers of surveys from each party is to be able to create a comparison of results between each one of them with one another.

F-Calculation of the Average Values Using Relative Importance Factor

In order to obtain the average values for the causes of variation orders, the relative importance factor method (RII) was used. The RII was adopted in many studies before to rank the events that lead to variations. The RII was adopted by (Enshassi, Arain, & Al-Raee, 2010), (Memon, Abdul Rahman, & Abul Hasan, 2014), (Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010), and also (Muhwezi, Acai, & Otim, 2014).The equation of the relative importance factor used is:

$$Score = \frac{\sum W}{H \times N} \times 100 \qquad (1)$$

The RII was adopted to determine the relative importance of the different causes of variation orders according to the responses from the various groups surveyed; contractors, consultants, and owners in the case of this research. The RII is basically an average of the values obtained and in this research it ranges from 1 (being lowest) to 5 (being highest) Where the score of a certain event as seen in equation one is:

W: summation of all the values given from the experts

H: Highest rating score, which is 5 in this case

N: The total number of respondents

G- Calculation of Cost & Time Severity

A data base was created from the surveys that were done through the experts. This data base was used to calculate the cost severity and the time severity of every event. The sum of the 38 event happening together was regarded as the worst case scenario in a given project. This means that if it is expected that if in a given project, the 38 events were satisfied then this means that there is a great danger on the project cost and a great danger on its planned finishing time as well.

The following equations were used in the model:

$$Average\ frequency\ or, Average\ cost\ impact, or\ Average\ time\ impact = \frac{\sum All\ values\ from\ the\ experts}{Total\ number\ of\ Experts} \quad (2)$$

Equation two is used to calculate the average for three parameters used in the model. The first parameter is the average frequency value for the event, the second parameter is the average cost impact of the event, and finally the third parameter is the average time impact on the event. All those parameters were previously determined by equation one.

This equation takes the scattered values from the survey respondents for a certain event, and then returns one average value to that event.

$$Cost\ score = Average\ frequency\ x\ Average\ cost\ impact \quad (3)$$

Equation three returns a cost score for the event. Cost score is calculated by multiplying the average frequency by the average cost impacts that were both previously determined by equation two.

$$Time\ score = Average\ frequency\ x\ Average\ time\ impact \quad (4)$$

The time score has exactly the same function as equation three but is used against time impact. Instead of multiplying the average frequency obtained in equation two by the average cost impact, it is multiplied by the average time impact to obtain a time score.

$$Total\ cost\ score = \sum Cost\ score \quad (5)$$

The total cost score is the summation of all the cost scores obtained by equation three for all the events. The reason behind using equation five is to obtain a maximum capped score for cost. The maximum value will be treated as the worst case scenario. That means that the total score will never be achieved unless the 38 events happen concurrently.

$$Total\ time\ score = \sum Time\ score \tag{6}$$

Total time score presented by equation six is the summation of all time scores obtained by equation four for all the events. It is also used to obtain the maximum capped score for time. The maximum value is the worst case scenario for time, which will never be achieved unless the 38 events included in the study happen concurrently.

$$Confidence\ Interval = \bar{X} \pm 1.96\ \frac{\sigma}{\sqrt{n}} \tag{7}$$

Equation 7 presents the calculation method for confidence intervals to test the upper and lower boundaries of data calculated to rank the causes where:

$\overline{X}$ = Average value of the cause

σ = Standard deviation

n = Sample size

1.96 = constant coefficient (For 95% confidence level)

Table 3 shows the scalometer used in the model to assess the degree of the cost impact and the time impact of the project expected from the events that would give rise to variations:

Scale	Low	Moderate	Important	Critical
	10%	30%	50%	70%
Effect on Project Cost	X			
Effect on Project Time	X			

Table 3 Shows the Scalometer used in the model

Let's say that the total number of events generated in a given project was 10. If the summation of numbers returned from those 10 events constitutes a value less than 30% of the value of the 38 variations combined, then the scalometer would read "Moderate". That means that the effect of those 10 events on the project cost, or the project time is moderate. The scalometer displays two results, one for the effect on project cost and the other one is for the effect on project time. The results are always indicative, meaning that the invented scale cannot be related to real effect on project cost or project time. However, on a bright side, it can help you indicate where your project might stand because of those events.

Chapter IV: Data Results & Analysis

The following results were prevailed after collecting all the distributed surveys. A total of 25 professional surveys were collected with nine surveys from the client's side, eight from the contractor's side, and eight from the consultant's side

A-Relative Importance Factor Ranking

1- Client

Top 10 important factors for client	Score	Confidence Int.
The contractor uses the grey areas in the contract to request variations	86.67	78.23-95.10
Client instructs additional works	83.33	69.70-97.06
Client fails to make decisions at the right time	80.00	70.76-89.24
Modification of scope	80.00	70.76-89.24
Short period for design stage	80.00	73.47-86.53
Lack of contractor's involvement in design	76.67	62.94-90.40
Continuous change in project schedule	76.67	64.59-88.74
Client's brief before the design stage are unclear or not well defined	73.33	68.00-78.67
Contractor's financial difficulties	73.33	62.66-84.00
Conflicts between contract documents	73.33	68.00-78.67

Table 4 shows the top 10 important factors for client

Table four shows the results of the top 10 most important factors that give rise for variations from the client's perspective. The arrangement is done using equation one which is the relative importance factor equation that was previously explained. The confidence interval gives the upper boundary and the lower boundary of the answers given by the experts. For simplicity of explanation, the score was used for comparison. Topping the client's list is the contractor uses

the grey areas in the contract to request variations. The client believes that this is the most frequent cause of variations scoring a value of 86.67 compared to a value of 83.33 for the second most frequent event which was that the client himself instructs additional works. There were three events that scored a value of 80 which are: client fails to make decisions at the right time, modification of scope, and short period for design stage. Spot six and seven were taken by lack of contractor's involvement in the design and continuous changes in project schedule were both of them scored 76.67. The difference between the most frequent event and the 10^{th} most frequent event is only 13.34 which mean that the top 10 events that give rise to variations have a relatively small margin between each other. The last three spots scored a similar score of 73.33

Surprisingly four out of the top ten most frequent events are client related which are: client's instructs additional works, client fails to make decisions at the right time, modification of scope, and client's brief before the design stage are unclear or not well defined. This means that although the client is aware that these events are among the top reasons that give rise to variations, yet he does not seem to know how to mitigate them.

Least 10 important factors for client	Score	Confidence Int.
Change in specification by owner/client	50.00	35.76-64.24
Unfamiliarity with local conditions	50.00	41.36-58.64
Non-availability of construction method statements and procedures for project construction	50.00	35.76-64.24
Absence of professional team members from the client's side	53.33	44.90-61.77
Poor construction management by contractor	53.33	44.90-61.77
Poor procurement process	53.33	48.00-58.67
Spare parts due to closure and siege	53.33	44.90-61.77
Non-availability of professional engineers to maintain the quality of consultancy services	53.33	48.00-58.67
Design complexity	53.33	48.00-58.67
Consultant not familiar with the regulations and construction permits	56.67	44.59-68.74

Table 5 shows the top 10 important factors for client

Change in specification by client is the client's thought about the least frequent event that gives rise to variation orders with a value of 50. The client might think that this is one of the least frequent events because the specifications are usually set by the designer, or the government. Unfamiliarity with local conditions and non-availability of construction method statements share the same score with the least frequent event. Six out of ten top least frequent events share a score of 53.33. The difference between the least frequent event and the 10^{th} least frequent event is only 6.67 which again means that the least 10 events that give rise to variations have a relatively small margin between each other. The client believes that consultant not familiar with the regulations and the construction permits is one of the least frequent events. This can be partly justified by noticing that most of the consultants assigned on projects in Egypt have a strong exposure to the market and government. Design complexity is among the least frequent events as Egypt is not famously known by its complex modern architecture. One can notice complex designs in the gulf countries, but he is unlikely to find that in Egypt due to its low economic power (World bank, 2015) and its recent recovery from the revolution.

2- Contractor

Top 10 important factors for contractor	Score	Confidence Int.
Client instructs additional works	85.00	70.65-99.35
Client's brief before the design stage are unclear or not well defined	82.50	73.62-91.38
Conflicts between contract documents	82.50	66.89-98.11
Lack of coordination among project parties	82.50	68.77-96.23
Poor construction management by contractor	77.50	61.89-93.11
Non-availability of professional engineers to maintain the quality of consultancy services	75.00	60.65-89.35
Poor workmanship	75.00	58.85-91.15
Contractor's financial difficulties	75.00	65.20-84.80
Continuous change in project schedule	75.00	54.38-95.62
Change in specification by owner/client	72.50	59.80-85.20

Table 6 shows the top 10 important factors for contractor

Looking at table six, the top ten most frequent events from the contractor's displacement are displayed. The Contractor believes that the owner's instruction of additional works is the most frequent event that gives rise to variations with a value of 85 which is close to the client's value of 83.33. Moving on at event number two, and three, and four, it is noticeable that they all share the same value of relative importance at 82.50. This value is not far away from the top most frequent event; however, it is important to notice that both number two and three are ranked among the client's top 10 most important events as well. The interesting part is that the contractor believes that the client usually changes the specs with a value of 72.5 placing it in number 10 of his top 10 list, where in the client it was placed among the least frequent events that give rise to variations. Poor construction management by the contractor scored 77.5 which again shows that most of the parties are aware that variations occur due to events of their own making. Non availability of professional engineers, poor workmanship,

contractor's financial difficulties and continuous changes in project schedule have all scored a value of 75.0.

Least 10 important factors for contractor	Score	Confidence Int.
Unfamiliarity with local conditions	37.50	23.77-51.23
Inadequate design	40.00	23.43-56.57
Non-availability of construction method statements and procedures for project construction	42.50	34.11-63.03
Desired excessive profitability	42.50	34.11-63.03
Spare parts due to closure and siege	47.50	29.45-65.55
International consultant using inadequate Specification to be followed in local conditions	47.50	26.63-68.37
Non-availability of overall project planning	50.00	35.45-78.83
Client's financial problems	50.00	42.59-57.41
Lack of consultant's knowledge of available Materials and equipment	50.00	39.42-60.48
Consultant not familiar with the regulations and construction permits	52.50	30.35-74.65

Table 7 shows the top 10 important factors for contractor

Table seven shows the top ten least important factors that give rise to variations from the contractor's point of view. Unfamiliarity with local conditions probably scored the lowest at 37.5 for the contractors because the survey was done in Egypt were most of the contractors are local contractors whom are based in Egypt. An interesting fact is that desired excessive profitability by the contractor was ranked among his least important events. Nevertheless, desired profitability could be linked to the event that states that the contractor uses the grey areas in the contract to request variations which was ranked among the client's top reasons. Even though most of the professionals included in this study might have worked with different parties, yet there is a tendency to see some bias in the results. Results show that whoever is doing the survey, might be a bit biased towards his entity and its nature. The difference between the least frequent event and the 10^{th} least frequent event is only 15. It is interesting that the contractor thinks that the client rarely has financial problems and that he has no desire for excessive profitability even though he is a contractor and should aim for profit. Those factors scored 50 and 42.5 respectively.

3- Consultant

Top 10 important factors for consultant	Score	Confidence Int.
Client instructs additional works	85.00	78.58-91.42
Continuous change in project schedule	80.00	69.52-90.48
The contractor uses the grey areas in the contract to request variations	80.00	65.18-94.82
Contractor's financial difficulties	77.50	65.93-89.07
Change in specification by owner/client	77.50	61.89-93.11
Lack of contractor's involvement in design	77.50	61.89-93.11
Conflicts between contract documents	75.00	65.20-84.80
Lack of coordination among project parties	75.00	62.72-87.28
Low consultancy fees leading to hiring less experienced designers	72.50	59.80-85.20
Client fails to make decisions at the right time	72.50	62.19-82.81

Table 8 shows the top 10 important factors for consultant

Last but not least, table eight shows the top ten most important factors from the consultant's point of view. It is noticeable that the consultant agrees exactly with the contractor that the most frequent event that gives rise to variations is that the client usually instructs additional works. The consultant has allocated the top factor a value of 85.0. He also agrees that there are usually conflicts between the contract documents, contractor's financial difficulties, and continuous change in the project schedule, change in the specifications by the client. He is given them values of 75.0, 77.5, 80.0 and 77.5 respectively.

The consultant also agrees with the client that the contractor uses the grey areas in the contract to request variations and have given it a score of 80. This result again, proves that whoever fills the survey is a bit biased towards his entity or his role in the company. Finally, the consultant also agreed with the client that the client fails to make decisions at the right time and gave it a score of a score of 72.5 while the client gave it 80.

Least 10 important factors for consultant	Score	Confidence Int.
Spare parts due to closure and siege	50.00	31.85-68.15
Non-availability of professional engineers to maintain the quality of consultancy services	52.50	39.80-65.20
Lack of construction materials and equipment	55.00	40.65-69.35
Consultant not familiar with the regulations and construction permits	55.00	35.75-74.25
Non-availability of records of similar projects	57.50	48.62-66.38
Internal political problems between project parties	57.50	38.70-76.30
Unfamiliarity with local conditions	57.50	52.59-67.41
Unilateral decisions made by the client without proper considerations to the program	60.00	45.18-74.82
Non-availability of construction method statements and procedures for project construction	60.00	49.52-70.48
Desired excessive profitability	60.00	52.59-67.41

Table 9 shows the top 10 important factors for consultant

Looking at the least important factors from the consultant's side shown in table nine, you would find that Spare parts due to closure and siege has scored 50, which is almost equal to the contractor's estimate of 47.5. The reason why spare parts achieved such a low score is that it is not that important in Egypt, whereas if you moved to Gaza you will find it one of their top most important factors that give rise to variations due to continuous closure of their boarders. Non availability of professional engineers scored a value of 52.5 because again, the consultant might not be aware he has this problem; and hence, would be biased to give it a small score. Lack of construction materials and equipment, consultant not familiar with regulations and construction permits have both scored a relative importance factor value of 55.0. The consultant believes that internal political problems between project parties are among the least important events with a value of 57.5. The difference between the least frequent event and the 10^{th} least frequent event is only ten points.

4- Overall Assessment

Top 10 overall important factors	Score	Confidence Int.
Client instructs additional works	84.44	77.63-91.17
The contractor uses the grey areas in the contract to request variations	78.89	72.36-86.04
Continuous change in project schedule	77.22	68.95-85.45
Conflicts between contract documents	76.94	70.67-82.93
Lack of coordination among project parties	76.94	70.67-82.93
Client's brief before the design stage are unclear or not well defined	75.28	69.68-80.72
Contractor's financial difficulties	75.28	69.23-81.17
Client fails to make decisions at the right time	72.50	65.33-80.27
Lack of contractor's involvement in design	72.22	64.01-80.79
Modification of scope	71.67	64.49-79.51

Table 10 shows the overall top 10 important factors

Table ten presents overall assessment of events. The overall assessment is the average of the contractor, client, and consultant's data. Topping the list is client's instruction of additional works which has always monopolized the top two spots among the results. It can be confidently drawn that this is the main and the most frequent cause of variations. Its average value among all the parties scored a value of 84.44. The contractor uses the grey areas in the contract to request variations took number two in the list because it was given a high score value of 78.89 from the client and from the consultant. Continuous changes in project schedule scored 77.22 while conflicts between contract documents and lack of coordination scored 76.94.

If it was to summarize the list in a nut shell, it could be said that the client doesn't always know what he wants, the data is not always complete or correct, coordination is not done effectively in Egypt and finally the contractor is a very effective member in producing variations.

Least 10 overall important factors	Score	Confidence Int.
Unfamiliarity with local conditions	48.33	39.73-57.07
Spare parts due to closure and siege	50.28	42.00-58.80
Non-availability of construction method statements and procedures for project construction	50.83	45.32-60.51
Consultant not familiar with the regulations and construction permits	54.72	44.88-64.72
Non-availability of records of similar projects	57.22	47.93-65.67
Non-availability of overall project planning	57.22	51.40-67.77
Client's financial problems	57.50	50.33-64.87
Desired excessive profitability	57.50	53.80-67.04
Lack of consultant's knowledge of available Materials and equipment	58.33	49.66-67.14
Internal political problems between project parties	59.17	50.30-68.10

Table 11 shows the top 10 overall least important factors

Table eleven shows the overall top ten least important events for all the parties. Topping the list are unfamiliarity with local conditions and spare parts due to closure and siege scoring 48.33 and 50.28 respectively. As stated before, most of the respondents were aware of the Egyptian market; hence, it is fair to state that all of them are familiar with the local conditions given that all of them had more than 15 years of experience in the field. As for the spare parts event, Egypt usually has no problem with importing goods from outside; the only problem would be paying the custom duties at the seaport or the airport. Usually, clients have enough money to finance their project or else they would have never thought of it.

All the least common factors, in the author's opinion, are a catalyst of forming variations but they are not common in the project's daily life.

B- Comparison between the top 10 important factors for all parties

#	Top 10 important factors for client	Top 10 important factors for contractor	Top 10 important factors for consultant
1	The contractor uses the grey areas in the contract to request variations	Client instructs additional works	Client instructs additional works
2	Client instructs additional works	Client's brief before the design stage are unclear or not well defined	Continuous change in project schedule
3	Client fails to make decisions at the right time	Conflicts between contract documents	The contractor uses the grey areas in the contract to request variations
4	Modification of scope	Lack of coordination among project parties	Contractor's financial difficulties
5	Short period for design stage	Poor construction management by contractor	Change in specification by owner/client
6	Lack of contractor's involvement in design	Non availability of professional engineers to maintain the quality of consultancy services	Lack of contractor's involvement in design
7	Continuous change in project schedule	Poor workmanship	Conflicts between contract documents
8	Client's brief before the design stage are unclear or not well defined	Contractor's financial difficulties	Lack of coordination among project parties
9	Contractor's financial difficulties	Continuous change in project schedule	Low consultancy fees leading to hiring less experienced designers
10	Conflicts between contract documents	Change in specification by owner/client	Client fails to make decisions at the right time

Table 12 shows a comparison of the top 10 important factors

The cells highlighted in orange in table twelve are the events that are common between all the project parties. The cells highlighted in grey are the events that are common between two parties which could be the client and the contractor, the consultant and the client, the contactor and the consultant, etc…

Looking at the overall results, it can be noticed that 4 out of 10 events are common between the client, the contractor, and the consultant with "client's instructs additional works" taking the lead by being in either spot 1 or 2.

Continuous change in project schedule scored the 7th place with the client, the 8th with the contractor and the 2nd with the consultant. Contractor's financial difficulties scored 9th with the client, 8th with the contractor and 4th with the consultant. And last but not least, conflicts between contract documents scored 10th for the client, 3rd for the contractor, and 7th for the consultant.

A number of events are common between the contractor and the consultant, or the consultant and the owner such:

1- The contractor uses the grey areas in the contract to request variations (between client and consultant).
2- Client fails to make decisions at the right time (between client and consultant)
3- Lack of the contractor's involvement in the design (between client and consultant)
4- Client's brief is unclear (between the client and the contractor)
5- Lack of coordination among project parties (between the contractor and the consultant)
6- Changes in the specifications by the client (between the contractor and the consultant).

If a conclusion can be drawn here, it could be claimed that each party is biased towards his own benefit. An example can be thrown by observing that both the client and the consultant think that "the contractor uses the grey areas to request variations" is one of the top reasons why variations are generated. Another example can be noticed is that both the contractor and the consultant think that one of the main reasons variations occur is because the tendency of the client to change project specifications.

C- Comparison of the overall results with other studies

In attempt to try using this research findings with other studies, studies carried out in Gaza, Malaysia, and the UK were used for comparing the top five reasons for triggering variations. The reason why such countries were used for comparison is because of their ranking in development. Gaza is less developed than Egypt; however, Malaysia is more developed than Egypt. The UK is the most developed country among all of them according to the (World bank, 2015). Table thirteen summarizes the results and put them in line next to each other

Rank	Gaza (Enshassi, Arain, & Al-Raee, 2010)	Egypt	Malaysia (Memon, Abdul Rahman, & Abul Hasan, 2014)	UK (Keanne, Sertyesilisik, & Ross, 2010)
1	Lack of construction materials & equipment	Client instructs additional works	Unavailability of equipment	Errors and omissions in design
2	spare parts due to closure and siege	The contractor uses the grey areas in the contract to request variations	Poor workmanship	Little involvement in design from contractor
3	Change in design by consultant	Continuous change in project schedule	Design complexity	Inadequate project objectives
4	Lack of consultant's knowledge of available materials and equipment	Conflicts between contract documents	Change in schedule	Poor design
5	Errors and omission in design	Lack of coordination among project parties	Impediment to prompt decision making process	Conflicts between contract documents

Table 13 comparison between different countries

Gaza

The top five reasons for the events that cause variations in Gaza were lack on construction materials and equipment, spare parts due to closure and siege, change in the design by the consultant, lack of consultant's knowledge of available materials and equipment, and errors and omissions in design. Event number one, two, and four could be justified due to Gaza's political conditions. No wonder why normal events that you would expect to see in the list don't make it to the top five. Event three and five are more common and can be seen in the UK top five list and could be related to Egypt by the event that states conflict between contract documents. There are no similarities between Gaza and Malaysia except for the fact that unavailability of construction equipment seems to be a popular problem there that causes variations.

Egypt

Egypt's top five events that give rise to variations as explained previously are: client instructs additional works, the contractor uses the grey areas in the contract to request variations, continuous change in project schedule, conflicts between contract documents, and lack of coordination among project parties. Egypt shares event number three with Malaysia and Event number four with the United Kingdom where event number three in Egypt ranked fourth in Malaysia and event number four in Egypt ranked fifth in the United Kingdom.

Malaysia

Malaysia's top five events that give rise to variations are: unavailability of equipment, Poor workmanship, design complexity, change in schedule, and impediment to prompt decision making process. Even though Malaysia is a country with normal and stable political conditions, yet unavailability of project equipment and poor workmanship ranks first and second in the top most frequent events. Malaysia; however, still shows similar trends in the rest of its data. Design complexity could be correlated with conflict between contract documents and lack of coordination among Egypt's top five events. Changes in project schedule ranks third in Egypt, and impediment to prompt decision making is not among Egypt's top five events; but, it ranks eighth which is still in the top ten.

United Kingdom

United Kingdom is the most developed among Palestine, Egypt, and Malaysia according to (World bank, 2015). The United Kingdom top five frequent events are errors and omissions in design, little involvement in design from contractor, inadequate project objectives, poor design, and conflicts between contract documents

Overall Assessment

It is noticeable that there are no concrete similarities between the countries next to each other. You could see a couple of events in common between two countries, but there are hardly any similarities when comparing the four countries against each other. Conflicts in contract documents did appear in the top five list between Egypt and the United Kingdom, but it didn't appear in Malaysia or Palestine. Errors and omissions in design appeared in Palestine and the UK, but didn't appear in the other two countries. However, the most frequent cause between all the countries is design related. There is no overall similarity which means that events that give rise to variations could differ from country to another. A tool is proposed in chapter five to help as an alarm against causes that lead to variations. That tool can be used in any country because it solely depends on the data that is inserted in it. Hence, it doesn't matter which variations carry how much weight because it will depend on the data supplied by the specified country of use.

D-Mitigation Methods Results

Mitigation Method	% of People Who Agree
Coordinate with all design teams, review, check , & validate the design	98%
Continuous coordination & cooperation between the client representative & design team	90%
Assign a lead designer	89%
Issue complete set of contract documents	89%
Apply risk management principles	85%
Select an appropriate procurement route	83%
Apply value management principles	80%
PM to coordinate with the governmental body and designer abroad	78%
Assign a quantity surveying firm	75%
Early involvement of contractor before tender stage	74%
Clarify the scope & abide by the limit of the scope (No addition or omission)	73%

Table 14 shows the % of people who agee upon the mitigation methods proposed

Table fourteen shows the results of the first survey with the highest agreement percentage topping the list. Survey number one was created to test the awareness of engineers and professionals in the market. The following mitigation methods were previously recommended in many studies such as (Alnuaimi, Taha, Al Mohsin, & Al Harthi, May 2010), (Arain; Pheng, 2005), (Al Suliman, 2009), and also (Obideyi, 2010).

Egyptian market awareness regarding those rectification methods is high on some statements but low on others. Coordination between all design teams scored almost a full percentage of agreement among the respondents. Continuous coordination and cooperation between the client representative and the design team comes second with 90% agreement. Assigning a lead

designer and issuance of complete drawing sets of drawings came in third scoring 89% agreement.

Starting from point number five (applying risk management principles) the percentage of agreement drops to 85%. This means that in every 100 engineer there is a probability that 15 of them are not aware that risk management is important in rectifying effects of variations. Risk management is a chain process that could be summarized in six steps: identifying project risks, analyzing risks, assessing risks, controlling risks, monitoring risks, and finally controlling goals (Schieg, 2006).

Selection of appropriate procurement route is very important; there are three famous procurement methods which are: traditional procurement method, design and build procurement, and management procurement (Davis, Love, & Baccarini, 2008). Each procurement method is suitable in accordance with the factors affecting the project such as cost, time, resources, and other external factors. A score of 83% agreement shows that the degree of awareness is not high enough to understand that procurement methods help in reducing variations.

Value management is a new applied concept in Egypt; hence, it was expected to find a low response rate. Value management is a complete process or overarching that controls all the project stages in order to achieve the best value for money (Rangelova & Traykova, 2014). If value management is properly introduced to engineers, it would score higher than 80%

PM to coordinate with the governmental body and designer abroad scored a low percentage of agreement of 78% because it is not applicable in lots of construction projects in the Egyptian market. As for quantity surveying firms, they have always been a part of the consultant's entity, the new trend in mega projects is to assign an independent quantity surveying firm.

The reason is quantity surveyors have emerged and proved to be a very effective cost estimating and controlling tool. According to (Maarouf & Habib, 2010) “the quantity surveyor has traditional independent role in the team comprising client, architect, engineer and contractor combined with expertise in drafting and interpretation of contract documents will avoid disputes and ensure the effective progress of a project”. Assigning a quantity surveying firm will definitely help in reducing the likelihood of excessive variations.

Early involvement of contractor before tender stage is very important according to the study carried in the United Kingdom by (Keanne, Sertyesilisik, & Ross, 2010). Early involvement by the contractor could help in identifying design and execution problems that might not be clear for the designer. The contractor has an extensive execution experience and can help pin point these problems early. Never the less, consultants and clients in Egypt might think that the contractor could slow the design process by suggesting excuses that would only benefit him. These thoughts are translated in the survey response, only 74% agree that the contractor early involvement is important.

Finally, clarifying the scope & abiding by the limit of the scope is thought to have scored only 73% agreement because it never happens in Egypt. Clients simply instruct additional work, and this was seen in survey number two results. Clients instruct additional works all the time and it is the top grossing reason why variations exist in Egypt. Respondents think that it doesn’t make sense that in a single project one can abide by the scope even though it was highlighted as one of the key success factors for projects by (Keanne, Sertyesilisik, & Ross, 2010).

Figure 4 is a bar chart that compares the agreement percentage for all the statements discussed previously.

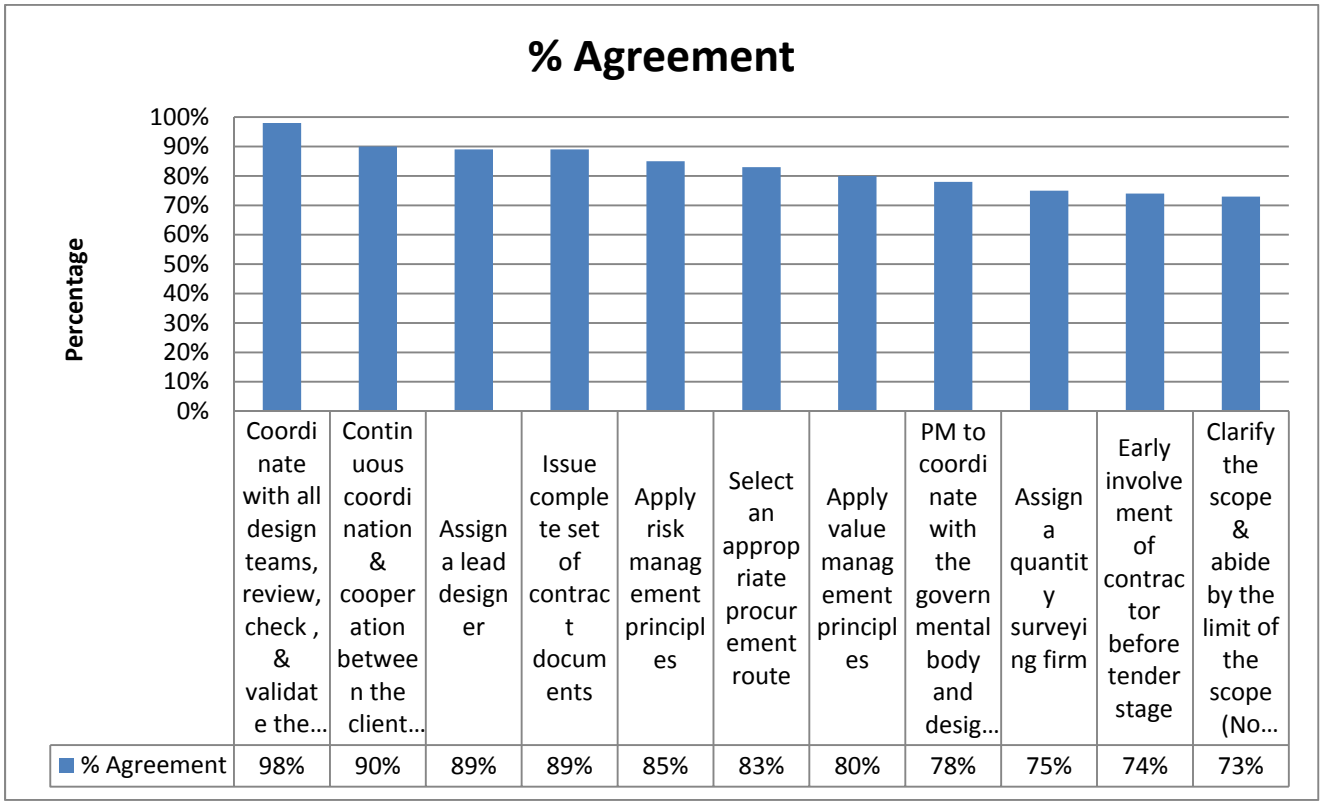

Figure 4 is a graphical representation of the respondents who agree on the mitigation methods

Chapter V: Model development, verification & validation

A- Model Development

The first step was to acquire a reliable data base that can be confidently used to advice on risk on project cost and project time. Fortunately, the database that was used to find out the top 10 most frequent events for clients, contractors, and consultants was used again in the model.

		Owner	Owner	Owner
		Frequency	Frequency	Frequency
#	Event	Survey 1	Survey 2	Survey 3
1	Change in specification by owner/client	1	4	2
2	Client instructs additional works	5	3	2
3	Obstinate nature of client	3	3	5
4	Client's financial problems	2	1	5

Table 15 shows an extract from the model database

		Owner	Owner	Owner
		eff.on.cost	eff.on.cost	eff.on.cost
#	Event	Survey 1	Survey 2	Survey 3
1	Change in specification by owner/client	1	3	3
2	Client instructs additional works	5	3	4
3	Obstinate nature of client	3	2	3
4	Client's financial problems	5	5	5

Table 16 shows an extract from the model database

		Owner	Owner	Owner
		eff.on.tim	eff.on.tim	eff.on.tim
#	Event	Survey 1	Survey 2	Survey 3
1	Change in specification by owner/client	1	3	2
2	Client instructs additional works	5	3	3
3	Obstinate nature of client	3	3	5
4	Client's financial problems	5	5	5

Table 17 shows an extract from the model database

		Owner		
#	Event	Average Frequency	Average Cost	Average time
1	Change in specification by owner/client	0.500	0.567	0.50
2	Client instructs additional works	0.833	0.767	0.73
3	Obstinate nature of client	0.700	0.533	0.63
4	Client's financial problems	0.600	0.800	0.90

Table 18 shows an extract from the model database

Table 15, 16, and 17 show the rating that the clients allocated for four randomly selected events from the data base. Table 15 shows that given the following events, the clients have allocated a rate chosen between 1 to 5 for the event frequency in their projects. Table 16 and 17 are the client's thoughts about the effect of those events, if they happened, on the project cost and project time. Table 18 is an extract of the average frequency, average effect on cost, and average effect on time. The average is then divided by 5 (the maximum value) to obtain a probability value.

#	Event	Contractor Frequency Survey 1	Contractor Frequency Survey 2	Contractor Frequency Survey 3
1	Change in specification by owner/client	5	3	2
2	Client instructs additional works	5	5	4
3	Obstinate nature of client	4	2	1
4	Client's financial problems	3	3	2

Table 19 shows an extract from the model database

#	Event	Contractor eff.on.cost Survey 1	Contractor eff.on.cost Survey 2	Contractor eff.on.cost Survey 3
1	Change in specification by owner/client	3	2	4
2	Client instructs additional works	3	5	4
3	Obstinate nature of client	5	3	2
4	Client's financial problems	5	3	2

Table 20shows an extract from the model database

#	Event	Contractor eff.on.tim Survey 1	Contractor eff.on.tim Survey 2	Contractor eff.on.tim Survey 3
1	Change in specification by owner/client	2	2	4
2	Client instructs additional works	3	5	5
3	Obstinate nature of client	5	2	3
4	Client's financial problems	5	3	5

Table 21 shows an extract from the model database

The same concept that was applied to the client was applied to the contractor as well. The selected contractors that were previously used for ranking the top 10 events that lead to variations according to the contractors were used here again. The data base was filled by the numbers between 1 to 5 to reflect the event frequency, effect on cost, and time.

		Contractor		
#	Event	Average Frequency	Average Cost	Average time
1	Change in specification by owner/client	0.73	0.70	0.65
2	Client instructs additional works	0.85	0.85	0.83
3	Obstinate nature of client	0.63	0.55	0.58
4	Client's financial problems	0.50	0.80	0.83

Table 22 shows an extract from the model database

The average frequency, average cost, and average time were calculated accordingly to get one value for frequency, for cost, and for time.

The process was repeated for the consultant, and the average parameters were obtained same as they were obtained for the client and the contractor.

		Consultant	Consultant	Consultant
		Frequency	Frequency	Frequency
#	Event	Survey 1	Survey 2	Survey 3
1	Change in specification by owner/client	3	2	3
2	Client instructs additional works	4	4	4
3	Obstinate nature of client	3	3	4
4	Client's financial problems	2	3	2

Table 23 shows an extract from the model database

		Consultant	Consultant	Consultant
		eff.on.cost	eff.on.cost	eff.on.cost
#	Event	Survey 1	Survey 2	Survey 3
1	Change in specification by owner/client	3	3	5
2	Client instructs additional works	4	3	4
3	Obstinate nature of client	3	3	2
4	Client's financial problems	4	3	2

Table 24 shows an extract from the model database

#	Event	Consultant eff.on.tim Survey 1	Consultant eff.on.tim Survey 2	Consultant eff.on.tim Survey 3
1	Change in specification by owner/client	2	1	3
2	Client instructs additional works	3	4	4
3	Obstinate nature of client	3	3	2
4	Client's financial problems	4	5	3

Table 25 shows an extract from the model database

#	Event	Consultant Average Frequency	Average Cost	Average time
1	Change in specification by owner/client	0.78	0.78	0.60
2	Client instructs additional works	0.85	0.85	0.85
3	Obstinate nature of client	0.63	0.63	0.55
4	Client's financial problems	0.63	0.63	0.85

Table 26 shows an extract from the model database

#	Event	Average Frequency	Cost	Time
1	Change in specification by owner/client	0.67	0.68	0.58
2	Client instructs additional works	0.84	0.82	0.80
3	Obstinate nature of client	0.65	0.57	0.59
4	Client's financial problems	0.58	0.74	0.86

Table 27 shows an extract from the model database

Table 27 shows the average value of the frequency, the cost effect, and the time effect for the four events that were used as an example for this demonstration. The reason why all the averages for the client, contractor, and consultant were combined is to remove any bias in the data for the model. That means that, for example, frequency of seeing event number 1 “change in specification by owner/client” will have an average value of combining the results from all parties together.

#	Event	Frequency	Effect on Cost	Effect on Time	Cost Score	Time Score
1	Change in specification by owner/client	0.67	0.68	0.58	0.45	0.39
2	Client instructs additional works	0.84	0.82	0.80	0.69	0.68
3	Obstinate nature of client	0.65	0.57	0.59	0.37	0.38
4	Client's financial problems	0.58	0.74	0.86	0.43	0.49

Table 28 shows an extract from the model database

The final step needed to complete the data base required for the model is to obtain a cost score and a time score. The cost score is multiplying the average frequency of a certain event by the average effect on cost of the same event. The time score is multiplying the average frequency of a certain event by the average effect on time of the same event. Table 28 shows the cost scores, and the time scores for the same four events that were used as a demonstration. The rest of the model is explained through what if scenario technique.

What if Scenario Using Guidance Model

The what- if scenario is what the user will experience. As explained, the model that was created based on the data collected from surveys. Currently the data base contains the client's, consultant's and contractor's thought about 38 events (four were demonstrated in the prior section) that could possibly lead to variations. The experts whom have filled those surveys allocated a frequency from 1-5 to each and every event, and an impact on cost and item for every event. The sum product of all the frequencies multiplied by all the impacts gave a sum of scores for cost and time. The sum of cost scores was used as the worst score for cost, and the sum of time scores was used as the worst score for time.

This means that on a single project, if all 38 events that give rise to variations happened, then the effect on the project cost and the project time will be maximum. If some of them happened, then there is a scale to bench mark the severity of cost and time for that specific project.

The surveys have reported a maximum summation of 16.13 for cost and a summation of 17.66 for time score. The following two tables show the scale that was created to test the severity of project and also the full data base used for benchmarking.

Scale	Low	Moderate	Important	Critical
	10%	30%	50%	50+%
Effect on Project Cost	LOW			
Effect on Project Time	MODERATE			

Table 29 Shows the readings on the Scalometer used in the model

Let's say that in a given project your total number of events that give rise to variations generated a cost score of 1.54 and a time score of 3. This means that (1.54/16.13)*100 = 9.5% and (3/17.66)*100 = 16.9% which means that the scale will read "low" effect on project cost but "moderate" effect on project time.

#	Event	Event Generator	Frequency	Effect on Cost	Effect on Time	Cost Score	Time Score
1	Change in specification by owner/client	Client	0.67	0.68	0.58	0.45	0.39
2	Client instructs additional works	Client	0.84	0.82	0.80	0.69	0.68
3	Obstinate nature of client	Client	0.65	0.57	0.59	0.37	0.38
4	Client's financial problems	Client	0.58	0.74	0.86	0.43	0.49
5	Client fails to make decisions at the right time	Client	0.73	0.68	0.85	0.49	0.62
6	Client's brief before the design stage are unclear or not well defined	Client	0.75	0.75	0.72	0.56	0.54
7	Absence of professional team members from the client's side	Client	0.64	0.64	0.71	0.41	0.46
8	Unilateral decisions made by the client without proper considerations to the program	Client	0.67	0.70	0.81	0.46	0.54
9	Modification of scope	Client	0.72	0.78	0.84	0.56	0.61
10	The contractor uses the grey areas in the contract to request variations	Contractor	0.79	0.70	0.63	0.55	0.50
11	Poor construction management by contractor	Contractor	0.65	0.62	0.80	0.40	0.52
12	Lack of contractor's involvement in design	Contractor	0.72	0.61	0.53	0.44	0.38
13	Contractor's financial difficulties	Contractor	0.75	0.64	0.89	0.48	0.67
14	Poor workmanship	Contractor	0.71	0.65	0.81	0.46	0.57
15	Poor procurement process	Contractor	0.64	0.66	0.79	0.42	0.50
16	Lack of construction materials and equipment	Contractor	0.59	0.54	0.78	0.32	0.46
17	Spare parts due to closure and siege	Contractor	0.50	0.49	0.59	0.25	0.30
18	Changes in design or specs by consultant	Consultant	0.65	0.69	0.71	0.45	0.46
19	Errors and omission in design	Consultant	0.70	0.68	0.72	0.48	0.50
20	Conflicts between contract documents	Consultant	0.77	0.70	0.75	0.54	0.57
21	International consultant using inadequate Specification to be followed in local conditions	Consultant	0.61	0.64	0.67	0.39	0.41
22	Lack of consultant's knowledge of available Materials and equipment	Consultant	0.58	0.63	0.63	0.37	0.36
23	Nonavailability of professional engineers to maintain the quality of consultancy services	Consultant	0.60	0.57	0.59	0.34	0.35
24	Low consultancy fees leading to hiring less experienced designers	Consultant	0.69	0.69	0.68	0.48	0.47
25	Failure by the consultant to provide adequate and clear information in the tender	Consultant	0.68	0.71	0.63	0.48	0.43
26	Consultant not familiar with the regulations and construction permits	Consultant	0.55	0.53	0.69	0.29	0.38
27	Failure by the consultant to perform design and supervision effectively	Consultant	0.60	0.59	0.66	0.35	0.39
28	Short period for design stage	Consultant	0.69	0.69	0.67	0.48	0.46
29	Design complexity	Consultant	0.60	0.66	0.62	0.40	0.37
30	Inadequate design	Consultant	0.62	0.76	0.81	0.47	0.50
31	Lack of coordination among project parties	Other	0.77	0.65	0.78	0.50	0.60
32	Internal political problems between project parties	Other	0.59	0.49	0.65	0.29	0.38
33	Nonavailability of records of similar projects	Other	0.57	0.55	0.48	0.32	0.27
34	Unfamiliarity with local conditions	Other	0.48	0.51	0.62	0.25	0.30
35	Desired excessive profitability	Other	0.60	0.58	0.50	0.35	0.30
36	Nonavailability of overall project planning	Other	0.60	0.61	0.80	0.36	0.48
37	Continous change in project schedule	Other	0.77	0.68	0.89	0.52	0.69
38	Nonavailability of construction method statements and procedures for project	Other	0.53	0.53	0.66	0.28	0.35
					Sum	16.13	17.66

Table 30 shows the summary of the collected database used for the model

This table shows the results from all the surveys given to 25 experts. The summation of all the cost scores and the times score are the maximum threshold.

B- Model Verification

Model verification is a process used to make sure that the model works coherently and gives results. The current model is used based on data collected in Egypt; however, it is not limited to usage in Egypt only. Events that give rise to variations could be given different weights if the survey was used in a different country, accordingly the results would differ.

The model was given to a professional with more than 25 years of experience in construction management. He was asked to delete the entire data base and to try to refill it again and see if the model will produce results. After filling in the frequency, the cost impact, and the time impact the new total cost score became 16.72 and the new total time score became 17.8

The following couple of graphs show the difference between the answers of the expert compared to the overall average obtained from the other 25 experts.

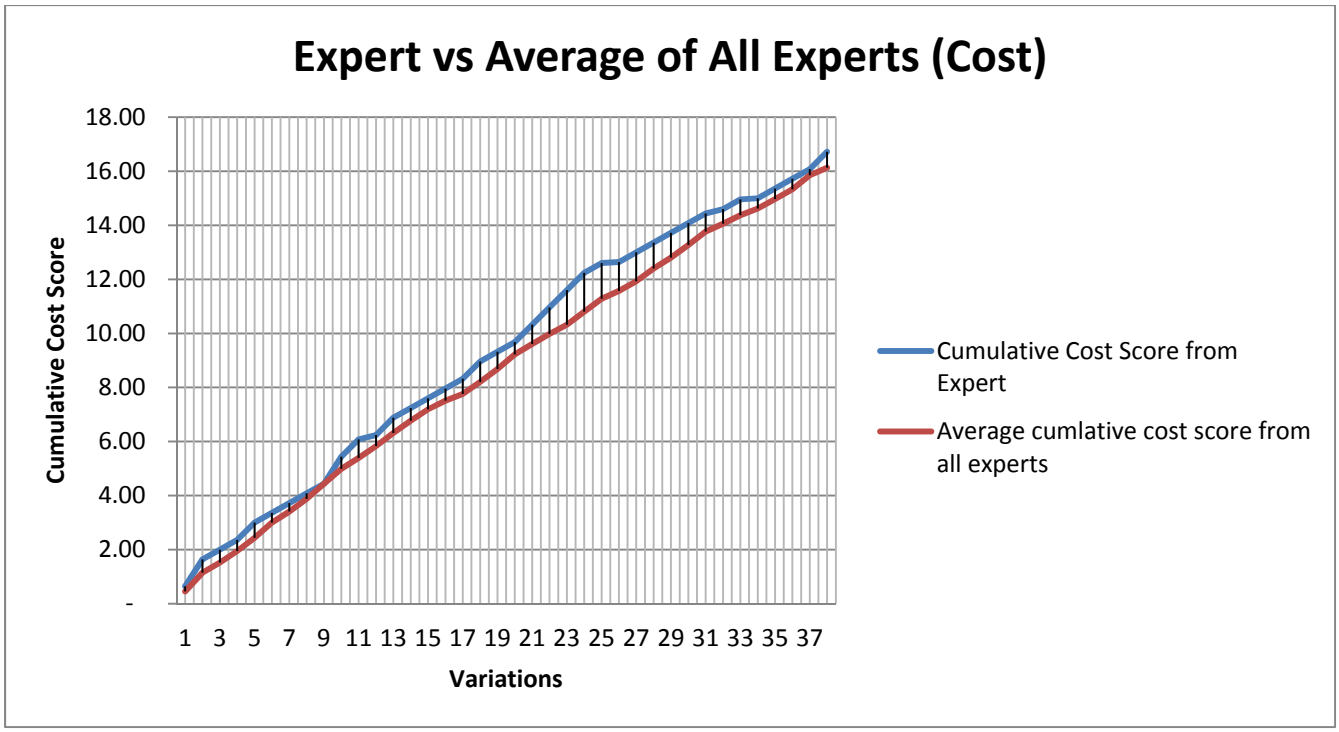

Figure 5

The x-axis presents the 38 causes of variations that are included in the study while the y-axis presents the cumulative summation of the cost score obtained from multiplying the frequency of the cause by the effect of the cause. The blue line is the curve obtained from the data given by the expert with more than 25 years of experience while the red line is the curve obtained from the 25 experts included in the survey. It is noticeable that the expert slightly over estimates the values compared to the average values obtained. The total cumulative cost score from the expert used in verification was 16.72, and the average total of the study for the cost score is 16.13. The percent over estimation is only 3% which is a reasonable marginal error.

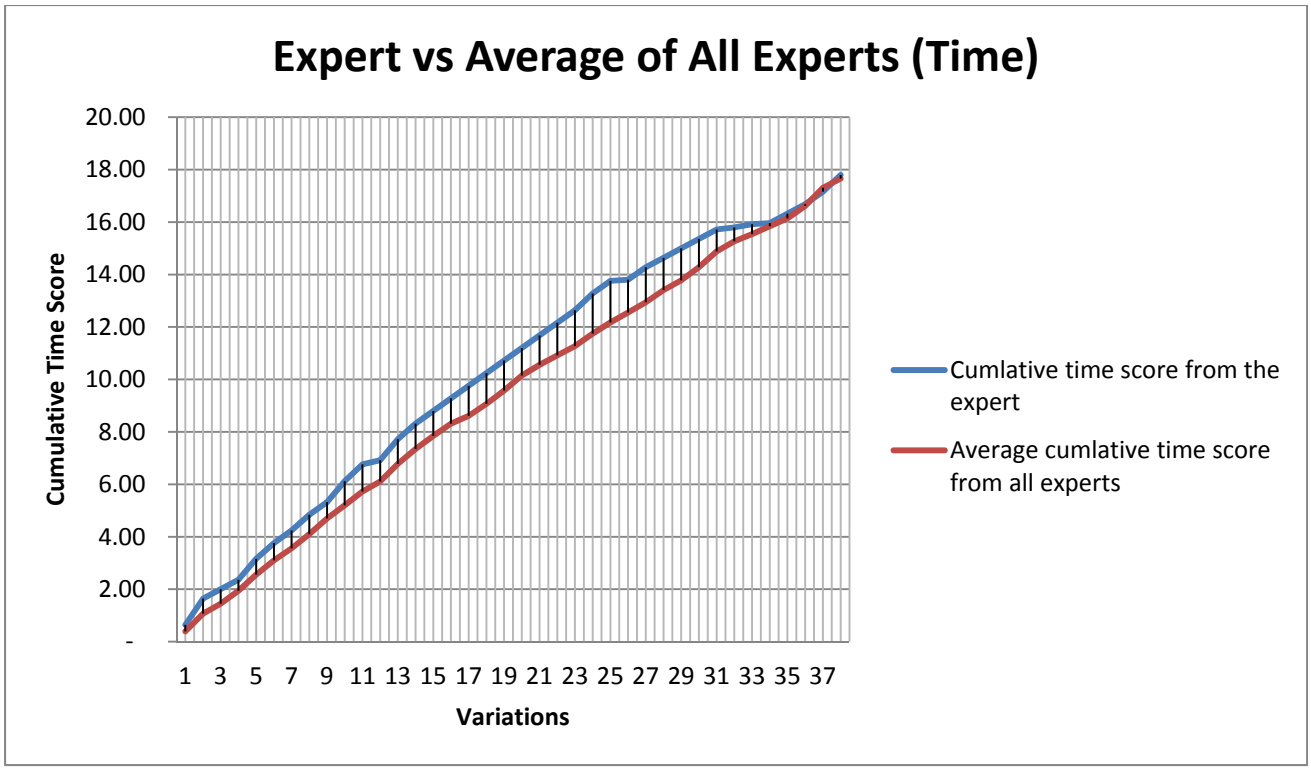

Figure 6

Figure 6 shows the same comparison between the expert and the average values of the study for the time score. The expert seemed to have larger estimated values in most of the causes for variations, but his total time score converged to a similar value in the end (17.8 vs 17.66) because he underestimated the last set of causes. The percent error for the total cumulative time score is less than 1%

The expert was asked then to think of a scenario that has happened in a project and apply it to the model. Here were his thoughts about the events that happened:

1- Changes in the specs by the client
2- Client's financial problems
3- Client fails to make decisions at the right time
4- Client's brief is unclear
5- Absence of the professional team members from the client's side
6- Poor construction management by contractor
7- Lack of contractor's involvement in the design
8- Contractor financial difficulties
9- Poor procurement process
10- Lack of construction materials and equipment
11- Conflict between contract documents

The new cost score of that combination of 11 events was 4.88 while the new time score was 5.92

#	Case / Event	Is the event satisfied? Y/N
1	Change in specification by owner/client	Y
2	Client instructs additional works	n
3	Obstinate nature of client	n
4	Client's financial problems	Y
5	Client fails to make decisions at the right time	Y
6	Client's brief before the design stage are unclear or not well defined	Y
7	Absence of professional team members from the client's side	Y
8	Unilateral decisions made by the client without proper considerations to the program	n
9	Modification of scope	n
10	The contractor uses the grey areas in the contract to request variations	n
11	Poor construction management by contractor	Y
12	Lack of contractor's involvement in designdesign	Y
13	Contractor's financial difficulties	Y
14	Poor workmanship	n
15	Poor procurement process	Y
16	Lack of construction materials and equipment	Y
17	Spare parts due to closure and siege	n
18	Changes in design or specs by consultant	n
19	Errors and omission in design	n
20	Conflicts between contract documents	Y
21	International consultant using inadequate Specification to be followed in local conditions	n
22	Lack of consultant's knowledge of available Materials and equipment	n
23	Nonavailability of professional engineers to maintain the quality of consultancy services	n
24	Low consultancy fees leading to hiring less experienced designers	n
25	Failure by the consultant to provide adequate and clear information in the tender documents	n
26	Consultant not familiar with the regulations and construction permits	n
27	Failure by the consultant to perform design and supervision effectively	n
28	Short period for design stage	n
29	Design complexity	n
30	Inadequate design	n
31	Lack of coordination among project parties	n
32	Internal political problems between project parties	n
33	Nonavailability of records of similar projects	n
34	Unfamiliarity with local conditions	n
35	Desired excessive profitability	n
36	Nonavailability of overall project planningplanning	n
37	Continous change in project schedule	n
38	Nonavailability of construction method statements and procedures for project construction	n

Table 31 shows the user interphase with the model

Here is what was displayed by the scalometer:

Effect on Project Cost	MODERATE
Effect on Project Time	IMPORTANT

Table 32 shows the results displayed by the scalometer

As stated earlier, the new total cost score in this case was 16.72 and the new time score was 17.8

The scalometer has displayed “Moderate” effect on project cost as it has compared the 4.88 (total of 11 events satisfied) to the 16.72 equivalent to 29% which is less than 30% (criterion of being moderate is that the results are less than 30%)

The scalometer; however, has displayed “important” effect on time because the combination of the chosen 11 events was 5.92 which constitutes 33% of the total time score that was 17.8

It can be concluded that whatever the data that is inputted to the model, it will be always compared to the maximum summation obtained. Hence, the more reliable data are inputted into the model, the more possible that accurate results are produced.

C- Model Validation: Case Study (Mall "X" in Cairo)

The following data is given from a popular project that was recently finished in Cairo:

- Original contract sum: 2.053 Billion Egyptian Pounds
- Modified contract sum after adding a new scope: 2.141 Billion Egyptian Pounds
- Final agreed amount: 2.85 Billion Egyptian Pounds
- Original completion date with a total of 42 month project period: February 2012
- Actual completion date: November 2013
- Number of generated variations: 380
- Amount of variations as a cost: 150 Million Egyptian Pounds

Number of events generated was 11:

- An additional scope of work was added
- Changes of the specs by the clients were done on casual basis
- Errors and omissions in the design happened
- Modifications in scope occurred
- The contractor uses the grey areas in the contract to request variations
- Lack of contractor's involvement in the design
- Conflicts between contract documents
- Lack of coordination among project parties
- Desired excessive profitability
- Non availability of overall project planning
- Continuous change in project schedule

Upon choosing those 11 events in the model the user will see the following:

#	Case / Event	Is the event satisfied? Y/N
1	Change in specification by owner/client	Y
2	Client instructs additional works	Y
3	Obstinate nature of client	n
4	Client's financial problems	n
5	Client fails to make decisions at the right time	Y
6	Client's brief before the design stage are unclear or not well defined	n
7	Absence of professional team members from the client's side	n
8	Unilateral decisions made by the client without proper considerations to the program	n
9	Modification of scope	Y
10	The contractor uses the grey areas in the contract to request variations	Y
11	Poor construction management by contractor	n
12	Lack of contractor's involvement in designdesign	Y
13	Contractor's financial difficulties	n
14	Poor workmanship	n
15	Poor procurement process	n
16	Lack of construction materials and equipment	Y
17	Spare parts due to closure and siege	Y
18	Changes in design or specs by consultant	n
19	Errors and omission in design	n
20	Conflicts between contract documents	n
21	International consultant using inadequate Specification to be followed in local conditions	n
22	Lack of consultant's knowledge of available Materials and equipment	n
23	Nonavailability of professional engineers to maintain the quality of consultancy services	n
24	Low consultancy fees leading to hiring less experienced designers	n
25	Failure by the consultant to provide adequate and clear information in the tender documents	n
26	Consultant not familiar with the regulations and construction permits	n
27	Failure by the consultant to perform design and supervision effectively	n
28	Short period for design stage	n
29	Design complexity	n
30	Inadequate design	n
31	Lack of coordination among project parties	n
32	Internal political problems between project parties	n
33	Nonavailability of records of similar projects	n
34	Unfamiliarity with local conditions	n
35	Desired excessive profitability	Y
36	Nonavailability of overall project planningplanning	Y
37	Continous change in project schedule	Y
38	Nonavailability of construction method statements and procedures for project construction	n

Table 33 shows the user interphase with the model

Only the data from the events that were applicable will be transferred to the back end of the model generated a total sum of 4.99 for the cost & 5.4 for the time which would read “important” for the cost and “important” effect on project time

Scale	Low	Moderate	Important	Critical
	10%	30%	50%	50+%
Effect on Project Cost	IMPORTANT			
Effect on Project Time	IMPORTANT			

Table 34 shows the results displayed by the scalometer

The reason why the scalometer would display “important” for both cost and time, is because the returned values from the 11 chosen events was 4.99 for the cost & 5.4 for the time which constitutes more than 30% of the total of the 38 events combined.

Looking at the mall data the amount of variations was 150 million, you would notice that it is a number that you need to account a budget for.

Amount of time lost after original completion date = 21/42 = 50% which is again very alarming.

Therefore, if the project manager from the client’s side of the mall used this model in the beginning of the project, he would have been able to know the potential effects on the project cost and the project time.

Chapter IV: Conclusion, limitations & Recommendations

A- Conclusion

Variation orders are a very important factor in construction projects. It can affect the project cost, time, quality, productivity and can have other adverse effects on organizations. Through the course of research it was found that the top 10 events that lead to variations are:

1- Client instructs additional works

2- The contractor uses the grey areas in the contract to request variations

3- Continuous change in project schedule

4- Conflicts between contract documents

5- Lack of coordination among project parties

6- Client's brief before the design stage are unclear or not well defined

7- Contractor’s financial difficulties

8- Client fails to make decisions at the right time

9- Lack of contractor's involvement in design

10- Modification of scope

And the least 10 frequent events that leads to variations were:

1- Unfamiliarity with local conditions
2- Spare parts due to closure and siege
3- Non availability of construction method statements and procedures for project construction
4- Consultant not familiar with the regulations and construction permits
5- Non availability of records of similar projects
6- Non availability of overall project planning
7- Client's financial problems
8- Desired excessive profitability
9- Lack of consultant's knowledge of available Materials and equipment
10- Internal political problems between project parties

When Egypt was compared to developing countries such as Palestine and developed countries such as Malaysia and the United Kingdom, it was found out that there are no real similarities for the events that lead to variations. Since events that give rise to variations could differ from country to another, a model was proposed in chapter five. That model can be used in any country because it solely depends on the data that is inserted in it. Hence, it doesn't matter which variations carry how much weight because it will depend on the data supplied by the specified country of use.

The use of the model created from the database can help out in alerting clients, project managers, and decision makers before the start of the project by choosing the expected events that applies to their project. The model has shown helpful results when it was validated through a case study.

There several rectification methods that could be taken to reduce the likelihood of variations, these methods are summarized below:

1- Coordinate with all design teams, review, check , & validate the design
2- Continuous coordination & cooperation between the client representative & design team
3- Assign a lead designer
4- Issue complete set of contract documents
5- Apply risk management principles
6- Select an appropriate procurement route
7- Apply value management principles
8- PM to coordinate with the governmental body and designer abroad
9- Assign a quantity surveying firm
10- Early involvement of contractor before tender stage
11- Clarify the scope & abide by the limit of the scope (No addition or omission)

B- Limitations

Throughout the course of research, there were some limitations and shortcomings

First of all, the main survey (survey number 2) which the study relies on was conducted on 25 experts only (9 clients, 8 contractors, and 8 consultants). Although the number is relatively low; it is still very hard to find suitable engineers for the study when your criteria would set 15+ years of experience and a managerial position for the credibility of the study.

Second of all, the study was done for people who worked in constructing “buildings”, it didn’t breakdown the buildings into types such as mixed use, retail, hospitality etc... Results could change according to the project type and nature; hence, there is a degree of error.

Third, the model created is only an indicative model. It doesn’t translate the actual effect on cost and time. This means that if the scalometer indicated “important” and important is translated to a 50%, then this doesn’t mean that the project cost or time would increase by 50%. It would only mean that there is a dangerous effect on cost or time. The model also treats cost and time as two separate events, but in real life they are related.

Finally, since the whole experiment was carried out by the author himself, it is unavoidable that there is a certain degree of subjectivity. It would have been objective if it had been decided by two or three researchers.

C- Recommendations for further studies

1- Include a larger amount of respondents for the study.

2- Explore more rectification methods for variations.

3- Explore a bigger number of events that gives rise to variations.

4- Create different sets of models, each model deals with projects with the same nature to increase the accuracy of results.

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Appendices

Survey number 1

I am currently undertaking a MSc. degree in Construction Engineering at the American University in Cairo (AUC). In fulfillment of this degree, it is required to do a complete research in one of the industry related topics and submit it as a thesis. The chosen topic was "Inefficiency in management of variation orders in Egypt".

I would be very thankful if you could complete the questionnaire, the questionnaire will take no longer than 3 minutes to complete. However, your cooperation is very important as the more professional surveys are completed, the more likely the study is expected to succeed with great confidence. Being said so; it will be of great help if you could also forward the link to anyone who works in the field of construction in Egypt.

- What is your field of expertise?
    1- Contractor
    2- Consultant
    3- Client representative
- What is the field of work of your organization?
    1- Buildings
    2- Infrastructure
    3- Other

- How long is your post qualification experience?

    1- 0-5

    2- 5+

    3- 10+

    4- 15+

- Value of the largest executed project during the last 10 years?

    1- Less than 10 million USD

    2- Less than 50 million USD

    3- Less than 100 million USD

    4- More than 100 million USD

In the following matrices, please choose Yes as an agreement to the statement or No to disagree

If you, for example, think that a lead designer will decrease the chances of having variations then choose Yes.

1- Assign a Lead designer (Yes – No)
2- Coordinate with all design teams, review, check , & validate the design (Yes – No)
3- Clarify the scope & abide by the limit of the scope (No addition or omission) (Yes – No)
4- Continuous coordination & cooperation between the client representative & design team (Yes – No)
5- Assign a quantity surveying firm (Yes – No)
6- Select an appropriate procurement route (Yes – No)
7- Apply risk management principles (Yes – No)
8- Apply value management principles (Yes – No)
9- Issue complete set of contract documents (Yes – No)
10- Early involvement of contractor before tender stage (Yes – No)
11- PM to coordinate with the governmental body and designer abroad (Yes – No)

Survey number 2

Please select a rating (1 being the least & 5 being the max)

#	Event	Frequency of seeing the Event					Effect of Event on cost					Effect of Event on time				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Client Related Events																
1	Change in specification by client															
2	Client instructs additional works															
3	Obstinate nature of Client															
4	Client's financial problems															
5	Client fails to make decisions at the right time															
6	Client's brief before the design stage are unclear or not well defined															
7	Absence of professional team members from the client's side															
8	Unilateral decisions made by the client without proper considerations to the program															
9	Modification of scope															
Contractor Related Events																
10	The contractor uses the grey areas in the contract and request variations															
11	Poor construction management by contractor															
12	Lack of contractor's involvement in design															
13	Contractor’s financial difficulties															
14	Poor workmanship															
15	Poor procurement process															
16	Lack of construction materials and equipment															
17	Spare parts due to closure and siege															

#	Event	Frequency of seeing the Event					Effect of Event on cost					Effect of Event on time				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Consultant Related Events																
18	Change in design or specs by consultant															
19	Errors and omission in design															
20	Conflicts between contract documents															
21	International consultant using inadequate Specification to be followed in local conditions															
22	Lack of consultant's knowledge of available Materials and equipment															
23	Nonavailability of professional engineers to maintain the quality of consultancy services															
24	Low consultancy fee leading to hiring less experienced designers															
25	Failure by the consultant to provide adequate and clear information in the tender documents															
26	Consultant not familiar with the regulations and construction permits															
27	Failure by the consultant to perform supervision effectively															
28	Short period for design stage															
29	Design complexity															
30	Inadequate design															
Other																
31	Lack of coordination among project parties															
32	Internal political problems between the project parties															
33	Nonavailability of records of similar projects															
34	Unfamiliarity with local country conditions															
35	Desired excessive profitability															
36	Nonavailability of overall project planning															
37	Continous change in the project schedule															
38	Nonavailability of construction method statements and procedures for project construction															