# A TAXONOMY FOR CAUSES OF CHANGES IN CONSTRUCTION

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
THE MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CIVIL ENGINEERING

SEPTEMBER 2012

Approval of the thesis:

**A TAXONOMY FOR CAUSES OF CHANGES IN CONSTRUCTION**

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# ABSTRACT

## A TAXONOMY FOR CAUSES OF CHANGES IN CONSTRUCTION

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September 2012, 149 pages

Change is an inevitable and inherent factor of each construction project which is a result of the nature of industry and the uniqueness of projects. Risky and unstable environment of construction industry usually triggers the potential of occurring changes during a project life cycle. Effective management of changes usually leads to increasing the project success. Change prediction and evaluation is the major step of change management process which enables the project management team to have a clear perspective of probable changes and their impacts on project. An effective prediction should be conducted based on a generic overview of likely causes and impacts of changes on projects; therefore establishing a comprehensive model of "*Change Causes"* is imperative in order to facilitate the systematic management of project change.

This thesis is based on a literature review on existing investigations and researches on project changes and their causes in construction industry and tries to develop a generic and comprehensive classification of "*Change Causes"*, from project design to construction and utilization. The proposed taxonomy is in the form of a hierarchical system to facilitate the application and extension of "*Change Causes"* categories. The taxonomy has 3 levels of categories which are identified based on their origin and independent from responsible party of change cause. Since the

changes usually occur during the whole project lifecycle, the proposed taxonomy covers all project phases from conception to construction and commissioning.

The proposed taxonomy has been validated through a survey among the construction professionals and last revisions have been conducted based on the results of validation phase.

**Keywords:** Construction Changes, Change Causes, Taxonomy

# ÖZ

## İNŞAAT SEKTÖRÜNÜN DEĞİŞİM NEDENLERİ TAKSONOMİSİ

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Değişim, sektörün doğasından ve projelerin birbirini tekrar etmeyen proje bazlı özelliğinden kaynaklanan, her inşaat projesinin özünde olan, kaçınılmaz bir faktördür. İnşaat sektörünün riskli ve değişken ortamı, genellikle proje sürecinde değişikliklerin oluşumunu tetikler. Değişikliklerin etkili olarak yönetimi, çoğunlukla proje başarısını arttırdığı hususu bilinen bir gerçektir. Değişikliklerin tahmin edilmesi ve değerlendirmesinin yapılması, değişim yönetim sürecinin önemli bir aşamasında yer alarak, proje yönetim ekibinin olası değişiklikler ve bu değişikliklerin projeye olan etkileri hakkında net öngörüler elde etmesini sağlamaktadır. Muhtemel değişikliklerin gözden geçirilmesi ve bu değişikliklerin projeye olan etkileri baz alınarak, etkili tahminler yapılmalıdır. Bu nedenle, proje değişiminin sistemli olarak yönetilmesini kolaylaştırmak için, değişiklik nedenlerinin kapsamlı bir modelinin oluşturulması oldukça önemlidir.

Bu tez çalışması, literatür taramasından elde edilen mevcut araştırmalardaki projelerin tasarım, yapım ve kullanım aşamalarından gelen veriler, inşaat sektörüne ait proje değişiklikleri ve bunların nedenleri, baz alınarak yapılmıştır. Bu çalışmayla, değişikliklerin nedenlerinin genel ve kapsamlı bir sınıflandırılması oluşturulmuştur. Önerilen sınıflandırma, değişiklik nedenleri kategorisinin uygulanmasını kolaylaştırmak için, hiyerarşik bir formda oluşturulmuştur. Sınıflandırma, değişikliklerin kökeni ve birbirinden bağımsız olma durumuna dayanılarak, üç

kategoriye ayrılmıştır. Değişiklikler, genellikle projelerin her sürecinde var olduğundan dolayı, önerilen sınıflandırma projelerin tasarım, yapım ve kullanım aşamalarının hepsinde gerekmektedir.

Önerilen sınıflandırmanın geçerliliğini denetlemek için, inşaat sektöründeki uzmanlar ile anket araştırması yapılmıştır. Bu anket araştırmasından elde edilen verilerin ve uzmanlardan gelen önerilerinin yardımıyla, önerilen sınıflandırmanın son hali oluşturulmuştur.

Anahtar Kelimeler: İnşaat sektörünün Değişiklikleri, Değişim Nedenleri, Taksonomi

Specially Dedicated to
My beloved family,
"*For your unconditional love through the years*"
and
My beloved wife
*"For her Love and patience"*

# ACKNOWLEDGEMENTS

First and foremost I offer my sincerest gratitude to my advisors, Prof. Dr. İrem Dikmen Toker, and Prof. Dr. M. Talat Birgönül, who have supported me throughout the thesis with their patience, knowledge and encouragement. I attribute the level of my Master Degree to their encouragement and effort and without them this thesis, would not have been completed or written. One simply could not wish for a better or friendlier supervisor.

Finally, I would like to thank my family; and my beloved wife, Neda for all their goodness and every single thing they have given to me.

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# CHAPTER 1

# INTRODUCTION

This chapter gives a brief introduction to the thesis topic and explains the existing problems in Construction Change Management (CCM) as well as the objective and scope of the study. Besides, the research methodology is explained during the text.

## 1.1 Background

Approximately every construction project throughout its lifecycle confronts with numerous changes which frequently bring about cost and schedule overruns quality defects along with various unfavorable impacts. Actually changes happen due to the uniqueness of each construction project as well as restricted resources available for planning such as time, money and manpower. The formal way of implementing of changes in project is by the Change Order which authorizes the contractor to execute defined changes in project. These changes are often the origin of project disputes and future claims. This makes the managing of changes in projects more critical.

As a part of "*Change Management"* process, identifying the origin and the Causes of Changes (*Change Causes*) plays a significant role in success of managing changes.

In order to clarify the origin and responsible of these changes, a comprehensive investigation on the "*Change Causes"* in construction projects is requisite.

Numerous investigations have been released in "*Change Management*" and "*Change Causes"* area. Some of them offered important empirical work; however

only a few presented an extensive and even organized review. There's also a specific level of confusion in the vocabulary used by various authors.

The Chartered Institute of Building (CIOB) investigated time and cost overruns and also disruptions as the consequences of the construction changes in the United Kingdom in the late 1970s. [1]. Based on the findings of a practice-based study, "*a Best Practice Guide on Managing Project Change*" was published by The "*Construction Industry Research and Information Association*" (CIRIA) [2]. In the early 1990s, the "*Construction Industry Institute*" (CII) of the USA arranged two research groups on "Cost and Schedule Controls" and "Project Change Management". The groups conducted a number of investigations over the impact and magnitude of changes on project cost and schedule [3] [4] and the way changes should be managed correctly [5]. As well as the attempts by all these expert organizations, researchers from the academic groups around the world have conducted numerous studies.

A comprehensive study on "*Taxonomy of Change Causes"* and "*Change Effects*" have been carried out by Sun and Meng [6] in which 101 journal papers and 6 research reports have been investigated and two "*Taxonomies for Change Causes and Change Effects*" have been developed.

## 1.2 Problem Statement

Construction works are a set of complex processes involving many uncertainties. The nature of the Construction Industry and the uniqueness of projects as well as disintegration of design and construction process, increase the probability of changes. Change refers to a deviation to the particular aspect of a project, including design and specification, schedule, cost, and so forth. Based on the relevant literature and practical experience, the "*Change Causes"* are considerably different, therefore the Change Management process would be challenging for most parties. Consequently, time and cost overruns are usually the direct results of mismanagement of changes.

According to the academic literature and practical experience, the "*Change Causes"* are significantly different which makes the act of "*Change Management*" more challenging for most construction management groups. This unfavorable condition can be relieved and even avoided, if the cycle of the "*Change Causes"* is systematically assessed and therefore recognized.

In fact, the success of a construction project depends on the capability of the project management team to deal with the changes during the project lifecycle. An effective knowledge of "*Change Causes"* and "*Change Effects"* (Impacts) is essential for successful "*Change Management"*. Within the recent years, extensive research projects have been executed in this field and numerous results have been generated.

Though "*Change Causes"* might be common knowledge in the construction industry, efficient "*Change Management"* is not as much common, specifically in huge projects. Changes can be resulted from any or even a set of causing factors. Many authors and research teams explored the causes of changes, in several projects and countries but most of them are a project-base, country-specific or case studies on responsibilities of changes; which could not be utilized as a generic model in other even similar projects. Current "*Change Causes"* classifications are characterized by considerable differences among the views of various authors and this makes the process of identification of "*Change Causes"* more difficult for professionals.

This study investigated the common "*Change Causes"* through a literature survey, and tries to put forward a general model of "*Change Causes Taxonomy"* to simplify the process of change identification in any kind of construction projects.

This study is conducted based on the current research papers through collating data from scattered resources of papers, books and reports, and then analyzing and combining them in several independent groups, which in turn led to the development of a different taxonomy of "*Change Causes"*. This taxonomy on the contrary of existing classifications, is independent from responsibility issue (responsibility-independent taxonomy); which provides a more comprehensive knowledge of "*Change Causes"*. It offers a knowledge platform for project management teams,

academic researchers and all of the construction involved parties in their current and future works in this field.

Besides, the existing taxonomy can be utilized as a framework by the construction authorities and professionals to review; evaluate and manage changes during their projects lifecycle.

## 1.3 Aim and Objectives of the Study

Change Management is really an important issue in project management. The initial step in all "*Change Management Systems*" is "*Change Identification*" which includes recognition of probable changes and the clarification of change responsibilities in project. An effective knowledge of "*Change Causes"* and change effects is a requirement for effective change management.

One of the most important challenges of "*Change Identification*" is the lack of information in the field of "*Change Causes*". Existing research activities mostly avoided to develop a generic model of "*Change Causes and Effects*" classifications because of the scattered data and investigations which are mostly project based and country-specific.

In addition, the majority of the current literatures are case studies which investigated the Causes of Changes on the base of responsibility of the change. This makes the act of "*Change Management*" more complicated because the responsibilities are usually varied from one project to another.

Also there is a great lack of extensive review papers on "*Change Causes*" and "*Change Effects*" and the existing literatures are mostly repetitive and similar rather than accomplish the defect points of the previous works. Utilization of various vocabularies to describe the same concepts in literature review is another problem of the "*Change Management*" process; which causes serious misunderstandings between professionals and leads to inaccurate imaginations of problem.

This study aims to propose a "*Taxonomy for Change Causes"*. This taxonomy is developed based on the "responsibility-independent" classification of data obtained through a comprehensive literature review on "*Change Causes"*. This would be a basis for future works on identification of probable change events in construction projects.

The proposed taxonomy of "*Change Causes"* seeks to put forward a comprehensive list of probable causes of changes in construction projects. For this purpose, the taxonomy is designed in three level of hierarchical structure in which the first two levels are including major categories of "*Change Causes"* and the third one involves Change Cases. Of course because of the numerous change events in construction, this is not asserted as a complete set of Change Cases in "Level 3" however it can be extended under the existing categories of "*Change Causes"* in "Level 1" and "Level 2". Therefore it can be utilized as a generic framework by construction professionals and research groups in Change Management process.

Since this study and the previous literatures on "*Change Causes"* are fact-based investigations, they cover the majority of causes of changes that are likely to occur in construction projects. Also the diversity of the construction projects type in existing literatures makes the "*Taxonomy of Change Causes"* more comprehensive than existing case studies. Thus the proposed Taxonomy can be utilized in several types of construction projects during all phases.

Since most of the damaging effects of changes are attributed to the poor systematic overview and early identification of project changes, then project management teams can proactively manage potential changes by using this taxonomy. The existing "*Taxonomy of Change Causes"* can be utilized as a reference model by project management experts to confirm that all important causes of change risk are distinguished.

In fact, a change is the consequence of a various factors with different level of value. Some of these factors are known as root causes; while the others are contributory causes. Some are direct and others are indirect causes and most of them are the consequence of some other causes which affects each other within a complicated

cycle. The current taxonomy tries to show the diverse factors of "*Change Causes*" but it wouldn't indicate the relation between the several causes.

## 1.4 Scope of the Study

The scope of this study can be considered in two domains:

1. *Scope of the data resources*

2. *Scope of the taxonomy application*

Scope of the resources is limited to literature review based on published research papers, books and reports and also the data achieved from the surveys conducted for validation. The diversity and extent of existing causes in literature provided a comprehensive and fact-based data base for the study.

The current taxonomy can be used as a reference model for identifying the causes of previous or probable oncoming change events. The relation and magnitude of the causes could not be detected in this taxonomy however it gives a true understanding of causes. The relation between causes and their effects on each other and also the magnitude of them can be analyzed based on the consequences of this taxonomy.

This taxonomy can be utilized by construction professionals, clients, contractors, consultants and research teams which are involved or interested in change management issue. Besides, it can be applied on any type of construction projects including infrastructure, residential, transportation and industrial projects during its lifecycle from design to operation.

## 1.5 Methodology

Most of the existing research papers on change management are fact-based and includes the majority of change factors. Accordingly, literature review and investigation is the first and fundamental part of this study. Research studies on

construction project change cover an extensive range of knowledge, including "*Change Management Systems*" and "*Change Causes*" and "*Change Effects*"; where most of them are case studies and country-specific. Therefore a considerable number of "*Change Causes"* have been listed through a comprehensive literature review.

The second part of the study was classifying and synthesizing the data collected from literature review in order to develop a "*Taxonomy for Change Causes"*. This phase of the study was more time and effort consuming because of the diversity of factors and similarities between them which made the process more complicated. Eventually, a comprehensive "*Taxonomy of Change Causes"* provided which was independent of responsibility, project type and project location.

The final part of the study was validation of the taxonomy and summarizing the results of the questionary survey. For this purpose, a questionnaire was provided that aimed to find the defect points and examine the efficiency of the existing taxonomy.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction to Construction Changes

Changes are generally inevitable in most construction project [7]. Owner needs may change during design or construction phases due to market desire and business conditions or technological developments. These changes may alter the project variables like design and specifications. Design revisions may lead to design improvements or optimizations and accordingly effect project executions. Furthermore, errors and omissions in design documents or construction defects may impose a change. All of these factors and more others necessitate changes which are cost and time consuming and normally un-welcomed by all parties. Therefore in most cases changes can be considered as the main causes of time extensions, cost overruns and quality defects at various phases of a construction project [8] [9].

The construction projects generally can be affected by extremely changing factors and unpredictable parameters. These sources originate from various sources including resources, project involved parties, contractual issues and environmental factors. As a result, the construction of projects may face variations which may trigger schedule delay and cost overruns in the project completion [10].

## 2.2 Definition of Change in Construction Industry

Changes or variations in daily life and work are normal and frequent to the extent that we have learned to manage them automatically. But the case in construction is completely different. Although the changes in projects are very common, but managing them is a serious challenge. At first, an identical assumption and

definition of change should be established. Various definitions on change and variation have been put forward by several authors.

A change is any kind of revision to or deviation from an agreed and well-defined scope and schedule of the project. Namely, change is any modification to the contractual documents and project characteristics provided to the contractor by the owner or owner's representative. This includes changes applied to designs, specifications project location and organization.

Ibbs et al, [11] declared that "*Change is normally defined as any event that results in a modification of the original scope, execution time, cost, and/or quality of work*".

Another definition by Ibbs [12] explains that "*change defines as any variation to the original project scope. It can be physical (more units of work) or less tangible (change the reporting requirements or resequence the project schedule to accommodate an earlier opening)*".

Sun and Meng [6] declared that "*in construction projects, a change refers to an alteration to design, building work, project program or other project aspects caused by modifications to preexisting conditions, assumptions or requirements*".

Antill and Woodhead [13] defined the changes as alterations, variations, deductions, extras, or omissions of work.

Hanna et al. [14] stated that "*Change is defined as any event that results in a modification of the original scope, execution time, or cost of work*".

Any additions, deletions, or other revision to project goals and scope are considered to be changes, whether they increase or decrease the project cost, schedule or quality. Change can be the responsibility of any project involved party including the owner, contractor and consultant or a third party. Frequently, uncertainties, changing environment, insufficient and untimely communication, poor integration, and growing complexity of the project provoke the risk of change [15].

Construction, as a project-based operation, is especially disposed to a high level of change for a variety of factors [16] [17]. Hence, variations are mostly inevitable in any construction project [7]. Therefore, in every construction project, a contingency value is usually assigned to consider the possible variations during the project lifecycle, by keeping the overall project cost fixed. Consequently, any regular form of construction contract provides a clear definition of change or variation with regards to specific actions and activities. Mohammad et al. [18] mentioned that according to the "Malaysian standard form of contract (PAM 98) (Persatuan Akitek Malaysia)" in clause 11, variation is defined as: "*an alteration or modification of the design, quality or quantity of the works as shown in the contract drawings and described by or referred to in the contract bills*".

The process of change implementation in project is usually complying with the procedures stipulated in the contract; by means of change (variation) orders. A change order is a written order issued by the owner to the contractor after execution of the contract, approving a change in the work or a modification in the project cost or schedule. [10]. Briefly, it can be defined as an official document which is used to modify the initial contractual agreement and considered as a part of project documents [19].

## 2.3 Type of Changes

Changes can be categorized in several ways according to the basis and the purpose of classifications. Here, the most prevalent classifications are presented. Changes in construction can be categorized based on the cause that forced them including design, construction technology, operability, external factors and so on.

Ibbs et al. [20] categorized the changes in five types; namely, "*change in scope*", "*differing site conditions*", "*delays*", "*suspensions*", and "*acceleration*".

### 2.3.1 Beneficial and Detrimental Changes

Changes can also be categorized as "*beneficial*" or "*detrimental*" (deleterious). "*Beneficial*" changes are those that really enhance project quality, reduce schedule, cost, or level of complexity in the project design or execution. A "*beneficial*" change reduces or eliminates inessential expenses from a project therefore; it optimizes the owner's benefits against the project resource input. The "*beneficial*" changes not only provide a direct, immediate and positive effect, but they also can prepare the base and conditions for oncoming activities to be managed efficiently.

"*Detrimental*" changes are those that impose unfavorable or damaging impact to the project or decrease owner benefits [7].

Generally it depends on individuals prospective whether change can be considered as a conflict or a precious action. It could be considered as "*beneficial*" change by a party but the same change might be "*detrimental*" for the other one. But actually the changes should be assessed by their effects on the project not on parties to consider them as "*beneficial*" or "*detrimental*".

The project management team should be informed to encourage and support the "*beneficial*" changes and discouraged and avoided "*detrimental*" ones. Project team should perceive that not all changes are bad whereas some of them are desirable. For instance, changes which derive from value engineering process and can reduce project cost, schedule, or complexity, should be welcomed by the project team, since these changes benefit the project.

However, "*detrimental*" changes should be minimized since they reduce owner benefit and impact the project negatively. Project management teams must perceive that "*detrimental*" changes are not always considered as "*detrimental*" until problems occur. They may arise whenever there are not sufficient or adequate solution options to the problem they present.

Obviously, the timing of a change usually defines if the change is "*detrimental*" or "*beneficial*". A change case in the early stages of a project may be beneficial, but the same change later in the project may raise the project schedule and costs.

### 2.3.2 Required and Elective Changes

Changes can also be categorized as "*required*" or "*elective*" changes. A "*required*" change is compulsory due to the limitations or acuteness of the problem and should be analyzed and processed in different way than an "*elective*" change. For instance variation on design to accord with a building code is a required change that should be executed urgently than other elective changes.

On the other hand an "*elective*" change is that management has several alternatives to modify the initial project objectives, resources, or schedule. An "*elective*" change must be authorized only if the advantages of that change significantly outbalance its expenses. In order to assess the elective changes a benefit-to-cost (B/C) ratio scale is utilized as a criteria for approving them.

### 2.3.3 Compensable, Excusable and Non-excusable Changes

Another type of change classification which is more frequent in construction contracts is based on the change compensation type named: "*compensable*", "*excusable*" and "*non-excusable*" changes.

"*Compensable*" changes are those which usually are proposed by the owner or client in reply to their needs or required changes in project. For example changes of design by client due to market demand or variations of project safety consideration due to new codes and standards are all compensable.

"*Excusable*" changes are the changes which are not the client suggestions but they are proposed by the consultant in reply to technical problems or possible document errors which were the responsibility of the consultant to predict or foresee them. For instance the execution of structure for controlling the landslides is excusable change

which would be paid to the contractor but there would not be any payment for consultant.

"*Non-excusable*" changes but are the changes completely in the responsibility of the contractor which would not be any payment for them. Construction errors or quality faults that lead to rework or demolition are examples of this kind of change. Since they are completely in the responsibility of contractor they would not be compensated.

### 2.3.4 Controllable and Uncontrollable Changes

Changes can be grouped based on their controllability namely "*controllable*" and "*uncontrollable*". "*Controllable*" changes are those which their cause sources are under the control of the contractor, like workmanship, labor productivity, clerical errors, material procurement, etc. These changes are extremely important because the contractors are usually the only responsible for them and cannot ask for extra funds for them. "*Uncontrollable*" changes include "*Change Causes"* over which the contractor has less or no effective control. Weather conditions, inflation, unforeseen ground conditions are of this type of changes.

According to Antill and Woodhead [13], delays as changes can be divided into four categories:

1. *The changes over which neither party has any control*

2. *The changes over which the client or owner has control*

3. *The changes over which the consultant or designer has control*

4. *The changes over which the contractor or subcontractor has control*

It is obvious that changes of type 1 are part of the contractor's legal financial risk, therefore, depending on contract clauses, might not be recompensed for any cost, but the project completion date should be extended to protect contractors from

liquidated problems. On the other hand it is also acceptable that for changes of type 2 and 3 the contractor should receive reasonable recompense for cost or schedule overruns, whereas for type 4 changes the contractor must endure entire responsibility of cost and time overruns.

## 2.4 Time of Change

Generally the construction process can be broken down into three general phases as follow:

1. *Project Conception,*
2. *Project Design,*
3. *Project Construction*

Project conception is the realization of a demand or desire that can be usually satisfied by a real physical composition or structure. The design phase converts the initial basic idea into a constructible spatial form that could satisfy the owner's needs and expectations in an economical and optimal manner. The construction stage produces the real physical form of design that complies with design and concept.

Frequently, the majority of project changes arise during the construction phase, at which numerous unexpected factors are associated. These changes usually occur as the project is only a means to an evolving end [21]. However, recognizing the changes in early stages of the project has more considerable, and sometimes unforeseeable, effects later on the project [22].

Changes may occur late in project due to several factors. One description is the fact that some potential discrepancies and problems are not identified until the project is far along to some extent. This is specially the case during the detailed finish trades, which often executed in the later stages of the project. Some parties, mainly the project owners who are not familiar with the construction drawings and process,

might not completely visualize the shape, size, and configuration of designed project till it is about closing to end.

Another reason behind the late changes in the project is that the involved parties may expect that arguments and conflicts could be solved in a friendly manner. Finally these kinds of disagreements might be escalated to a higher level of seriousness and formality in which a considerable amount of cost and time should be consumed to solve them. Another reason for late changes might be the owners' tendency to expand the project scope and improve the project features because of the extra funds available as the project concludes.

It is significantly beneficial to identify and consider changes in early stages of the project and manage them as soon as possible after they arise in the project. Postponing the solutions would be more costly and disruptive. [22]

Ibbs et al., [23] underlines that the changes implemented later in a project would have more disturbing impacts on project performance; specially on labor productivity, in compare with the same change executed earlier in the project.

This is confirmed by interviews of industry professionals in published papers; so most of them believe that changes implemented late in a project lead to a greater loss in labor productivity. [24]

According to a report named "Project Change Management" published by "*Construction Industry Institute (CII)*", "*the changes can be minimized if the problem is studied collectively as early as possible, since the problems can be identified and beneficial variations can be made*" [5].

## 2.5 Importance of Changes and Change Management

The construction industry has a great share in national economic growth in most countries due to the extreme connection with other economic markets such as material manufacturing and engineering services sectors. However the industry

confronts with a variety of problems which menace the profitability of investors. These challenges arise generally due to the high level of changing environment of the industry which complicates the process of managing. One of the challenging part of the management in construction industry is “changes” and “change management” in which the industry is not prepared appropriately.

Changes may arise in a project for several construction pertinent factors, like scope changes, design errors; adverse external factors etc. and affect the project during its lifecycle in different ways. Changes impact the project significantly by cost overruns, schedule delays, profit shortfalls and reducing or disrupting the labor productivity. For instance, changes in drawings or other contractual documents commonly lead to variations in contract price and/or schedule. Hsieh et al. [16], based on statistical testing, found that a 10–17% ratio of change order cost to total project cost (COR) is typical in metropolitan public works.

Changes are also one of the significant sources of disputes in construction industry and increase the possibility of contractual disputes [25]. Generally, changes provide problems to all the project involved parties so determining the responsible of the change is a challenging process which usually causes numerous difficulties in project.

The process of determining the changes’ impact and responsibility in a project is frequently subjective which leads to disputes and claims between project parties. Contractor may think that the consultant and owner effectuate the changes and so they are the responsible of the losses due to the changes. Conversely, owners may claim that probable losses are due to poor management of the contractor.

Changes, especially when they lead to prolonged conflicts and lawsuits, are costly serious challenges for project. Also, there may be numerous indirect and intangible costs imposed to the project; like delayed commissioning costs; insurance costs; lost opportunities due to projects that cannot be pursued; managing costs.

It is completely accepted in construction industry that, a project is known as a "*successful project*" if it is completed according to the budgeted cost, schedule and specified level of quality.

Generally, any investment in construction industry is known efficient and effective if only the change risk factors, which potentially have negative impacts on the project, are managed efficiently and on time. This means that, risk of changes must be identified, alleviated or even eliminated by the project management team at the right time. Therefore, team members, since most of them have been aware about the possible negative impacts of changes, must pay specific attention to efficiently deal with the changes.

Briefly, it is deduced that adequate and efficient change management can reduce negative and disruptive impacts of changes on project and in some cases it can benefit the project by improving the quality and reduce cost and schedule. To achieve an effective change management, it is obvious that a comprehensive and accurate knowledge of change and its' causal features is crucial.

## 2.6 Change Control and Change Management

In order to achieve a successful project in construction activities, all the risk factors must be managed efficiently. Change as a risk factor in construction is not an exception in this case, since the great number of construction defects, cost overruns and schedule delays arise from the changes in projects. Changes are considered as one of the most critical factors in project success. Therefore managing the change in an effective way is significantly important. By managing the changes in project lifecycle the existing change cases will be controlled efficiently and future changes will be minimized.

### 2.6.1 The Necessity of Change Control and Management

During a project lifecycle, changes can cause significant adjustments to the contract duration time, total cost, or both [26], [22] , [27]. Therefore, project management

teams need to have sufficient capabilities to handle the changes effectively in order to reduce the negative impacts on the project.

Since changes are frequent and normal in projects, it is advisable to understand that project managers encounter, embrace, adapt, and apply them to affect positively the events they face and to conceive changes as growth [28]. Kartam [29] has recommended that conflicts would be lessened when a problem has been studied and managed in early stages of the project, since the problems can be recognized and beneficial changes can be made.

Common project planning and management tools such as risk analysis can be applied to minimize the detrimental effects of change, since they give perceptions and predictions to identify potential and possible conflicts [30]. Pinto [31] has recommended that effective communication can bring about changes which can positively affect the project, since management team members can learn precious lessons from the conflict event.

Another approach which can be considered before the project commence is to contemplate through the project, utilize the tools previously explained and apply their results to prevent conflict. Development and execution of a project "*Change Management System*" prior to project initiation is an effective and positive action toward effectual management of changes. By implementing project "*Change Management System*", project involved parties would be able to reduce deleterious changes and encourage beneficial changes. Project management teams should have the proper ability to identify potential impacts of changes; so that they can minimize their undesirable impacts on the project.

Consequently, possible cost and schedule overruns in a project can be minimized when there is either a systematic approach to change efficiently or a systematic method to evaluate and compare the conflicts in corresponding projects. Furthermore, decision making is an important issue that occurs during the project life cycle and is necessary in almost each phase of the project. Since, these decisions can usually affect the current or future tasks and events; they are significantly effective on project. In order to make the process of "decision-making" effective,

project participants must have a general perception of other similar or related projects. This underlines the importance of having an effective communication and documentation system.

### 2.6.2 Change Control and Management Systems

Today the Harold Kerzner's proposed proverb is accepted as a general law in construction industry that: "*If project content is allowed to change freely, the rate of change will exceed the rate of progress*". This content is clear enough to the importance of the change control in projects. Because of the increasing competence in market, high range of construction cost and complexity of project risks, the utilization of change control and change management techniques to ensure the project success is inevitable.

Tiong [26] carried out a research on a variety of required controls applied during all phases of a project including: "*design control*", "*schedule and cost control*", "*quality control*", "*change order control*" and "*document control*". He deduced that, in order to increase the project success and profitability, a comprehensive system for change order control should be established.

According to CII publication in 1990 [3] the following procedures will facilitate the process of change control:

1. *The project objectives and owner needs should be specified early in the project and design scoping paper or the conceptual development should be clear enough. Related divisions in the owner's organization should be consulted during the process of defining project objectives.*

2. *The owner must undertake to implement change control process in project. The owner may establish a change review committee including the owner's representatives like Business Manager, Project Engineer, and Process Engineer to perform the owner's commitment of reducing change effects. These individuals should be assigned early in the project, and the responsibilities and procedures made clear to all parties.*

3. *In order to encourage change recognition, reporting, and resolution, a team work by the owner, engineer and contractor is required during the entire project lifecycle.*

4. *Freezing the design is an effective control method. Numerous owners freeze the design and terminate changes after drawings completion phase.*

5. *Each change must be justified from a cost viewpoint. Both direct and indirect cost effects of changes must be analyzed before approval for execution.*

6. *In order to prevent any delay in evaluation, approval, and execution of change, the expedient and efficient change procedures must be followed.*

7. *Owners should severely strive in the early stages of design development to lessen the possible changes during detailed design and construction phase.*

"*Project Management Body of Knowledge (PMBOK) Guide*" defines the function of scope change as concerned with:

1. *Influencing the factors which create scope changes to insure that changes are beneficial.*

2. *Determining that a change has occurred.*

3. *Managing the actual changes when and if they occur.*

"*PMBOK Guide*" also suggests that "*scope change control must be thoroughly integrated with the other control processes (time control, cost control, quality control, and others)*".

According to a systematic change control method, it is requisite to reflect all the approved changes in the project plan; as changes to the "*project scope*", "*project cost and schedule*" and the "*project resource plan*".

The main concept of any "*Change Management System*" is to predict, identify, assess, resolve, record, and learn from changes and conflicts in a way that support the overall project priorities. Learning from the faults and problems are important, since the project team members will be able to improve and implement their experience in future. By applying a systematic approach to deal with changes, the performance of project work and the chance of project success should increase.

In spite of numerous academic research literatures and practical reports, there is a great lack of knowledge about systematic approaches for project change management.

Hallock [32] recommended three logics behind the lack of comprehensive and efficient effort for systematic change management:

1. Most standard forms of contract in the construction and engineering industries do not include a provision for change management. If you asked many in the industry would point to the "Changes" provision of the contract and ask what more is required.

2. The division of authority on projects has contributed to the problem. Who is going to take the lead; the Owner, the A/E or the Contractor? When one focuses on change as a risk, the assignment of responsibility may become clearer.

3. The sheer volume of information on large projects, the duration, and multiple stakeholders has made it difficult to produce a comprehensive plan which fully defines the project requirements and manages the needs of all the stakeholders.

According to the standard of "*Project Management Body of Knowledge*" (PMBOK), the "*Integrated Change Control Process*" should be implemented from project commencement through completion. It is emphasized that change control is essential since projects rarely performed precisely according to the project plan and schedule. The project management program and other project characteristics must be

preserved by effective change managing which includes either rejecting or approving changes. Therefore if a change would be approved it should be incorporated into a revised baseline.

The "*Integrated Change Control Process*" as shown in Figure 1 includes the following change management procedures specifying the level of details through the project life cycle:

1. *Identifying that a change must be occur or has occurred.*

2. *Influencing the factors that circumvent integrated change control to ensure that only authorized changes are executed.*

3. *Reviewing and approving the requested changes.*

4. *Managing the approved changes when they occur, by regulating the flow of requested changes.*

5. *Maintaining the integrity of baselines by releasing only approved changes for incorporation into project products or services, and maintaining their related configuration and planning documentation.*

6. *Reviewing and approving all recommended corrective and preventive actions.*

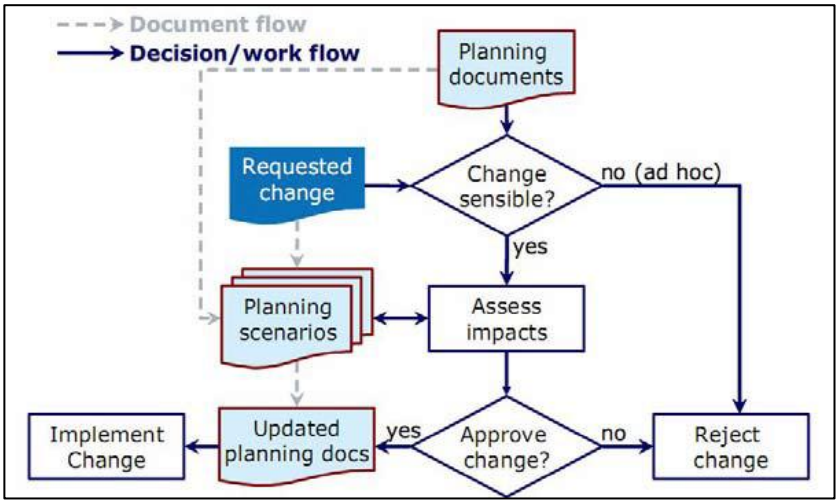


**Figure 1:** Change Control Process (PMBOK)

In 1994 the "*Construction Industry Institute*" (CII) established a "*Project Change Management Research Team*" to investigate a method to prevent or minimize the negative impacts of project change such as inflated costs, delays, claims, and litigations. They postulated that significant savings in project schedule and total execution cost are achievable in any construction project by improving the management of changes [33].

Ibbs et al. as a member of team [7] recommended a comprehensive two-level process model for change management, with principles as the base, and management processes to apply these principles. (Fig. 2):

1. *Level of starting principles*

2. *Level of management processes*

The first level includes five principles:

1. *Promote a balanced change culture;*

2. *Recognize change;*

3. *Evaluate change;*

4. *Implement change; and*

5. *Continuously improve from lessons learned.*

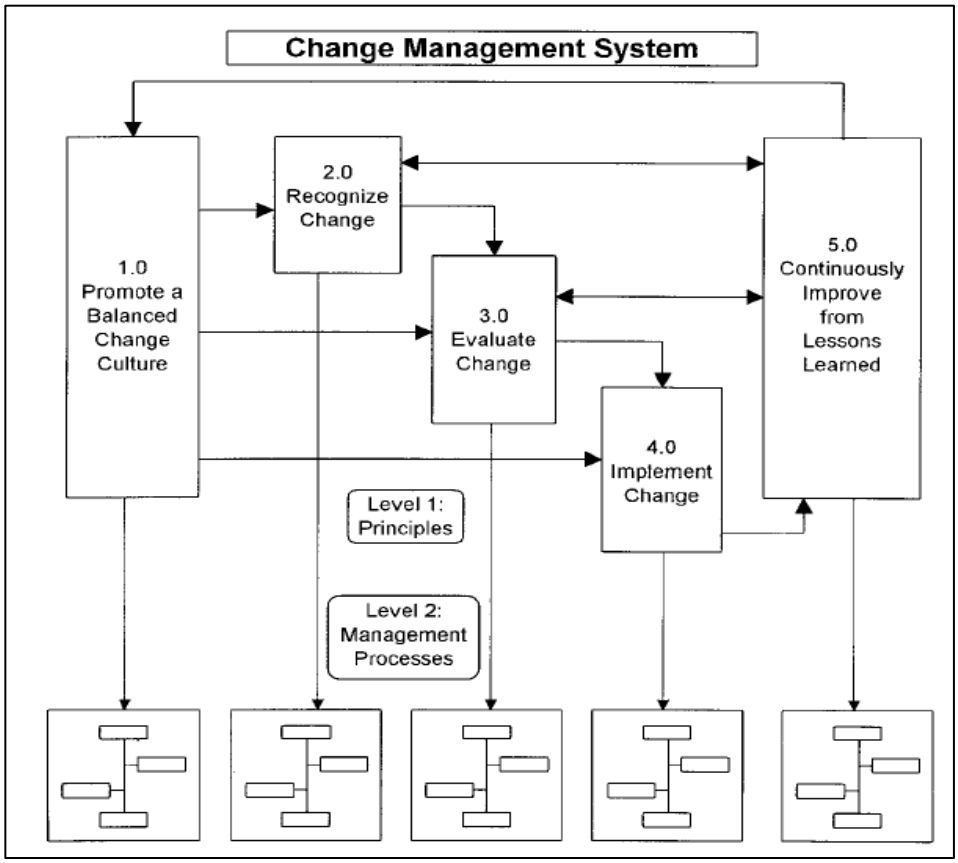


**Figure 2:** Change Management System

### 2.6.3 Promote a Balanced Change Culture:

"*Promote a balanced change culture*" is the first principle of "*Change Management System*" (CMS), in which the probable conflicts between team members will be minimized by promoting the group communication and documentation of the project objectives. Also the concept of "*beneficial*" and "*detrimental*" changes must be introduced to the project management team in order to establish a common perception about changes. Therefore, the project management team will be able to anticipate changes and prepare to handle them efficiently prior to change happens.

### 2.6.4 Recognize Change:

The team members, through an efficient communication, are encouraged to develop discussions and to discover the potential changes. Early identification of changes will facilitate managing change more effective and earlier in project life. After identification of possible changes, they should be assigned as "*required*" or "*elective*" changes. The project team should also determine the potential positive or negative effects of changes on project, and take action to reduce negative change.

### 2.6.5 Evaluate Change:

In this stage management team should evaluate the "*acceptability*" and "*implementation*" of proposed changes. In order to prevent the cost escalation due to delayed approval of change, the changes with high priority should be identified and prepare the financial resources for interim approval promptly. On the other hand, if the change is not decisive at that time, it should be considered more consciously to see whether it is necessary or not. The main reason for this reconsideration is to maximize the profitability of the project due to change and to minimize the negative impacts of change. Therefore, the unnecessary and inefficient changes should be screened in order to increase the profit.

The elective changes, which are not critical and mandatory, should be accepted only if the advantages of those changes significantly exceed their costs. The Benefit-to-Cost (B/C) ratio can be used as a guideline for authorizing of such elective changes. The later changes in the project should have a higher level of (B/C) ratio than an earlier change; since there would be unexpected impact costs in associate with late changes.

### 2.6.6 Implement Change:

The main purpose to have the "*Change Management System*" is to implement changes more efficiently. Therefore this stage is very important in the change management process. The most important issue during a change management process is that the approval of the changes should be authorized by the upper

management. Before the change is authorized, all project parties which are affected by the change must be informed about it and then it should be granted. If the management has failed to foresee and communicate with other parties about pending changes, generally they will bring about other troubles and further changes.

Besides, the process of change implementation should be monitored and controlled by project management. Monitoring implementation of changes is not only limited to monitoring the process of the implementation, but also solving the probable difficulties should be considered during the monitoring of the change implementation. The process of monitoring requires comprehensive documentation of a change to resolve disputed impacts later or to learn lessons from the change.

### 2.6.7 Continuously Improve from Lessons Learned:

The final stage of the "*Change Management System*" is to learn continuously from the faults which caused to changes. The key concept of this part is to define the main causes of change and to assess the errors which made them so the errors can be corrected in systematic way. These causes and errors should be publicly discussed between team members to ensure that every person will have the opportunity to argue about and recognize the main causes of changes.

Giving the knowledge about the causes of change to project team members is very important and effective; because the experience of change management allows them to avoid similar faults and mistakes in the future.

### 2.6.8 Recommendations for Better Change Control and Management:

1. Most construction projects have changes during their lifecycle, therefore, managers should be prepared enough to handle and deal with them. In fact, the process of change management must be started before the project construction phase; since the impacts of defects during pre-construction phase affects the project execution negatively. Therefore the implementation of effective (CMS) during all project phases and even throughout the administrative processes is significantly important.

2. Since the responsibility of implementation of (CMS) is not limited to a specific project participant, so each project participant must exert it on his own territory.

3. A great number of changes are evitable and controllable which can be prevented formerly. For instance, if the project would be awarded to a capable contractor then the risk of "poor financial resource of contractor" would be minimized. Therefore some remedies should be applied by project involved parties in order to minimize the possibility of change occurrence or even the negative effects of changes. Thus the process of change management and control will be facilitated by preventative actions.

4. An effective communication and coordination between project participants and with external parties would help the management team to eliminate the changes arising due to conflicts during project lifecycle.

Assaf and Al-Hejji [34] recommended the following points to project participants in order to minimize negative impacts of changes in construction projects:

Owners should consider the following factors:

- *Timely payments to the contractor*

- *Reducing the number of change orders during construction*

- *Reviewing and approving of design documents on time*

- *Scrutinizing and paying specific attention during project delivery phase*

Contractors should give special attention to following factors:

- *Balancing the labor quantity in compatible with task amount*

- *Attempting to increase the productivity of labor*

- *Reducing the financial and cash flow problems*

- *Giving priority for planning and scheduling*

- *Efficient site management and supervision*

Consultants should look to the following points:

- *Reviewing and approving design documents on time*

- *Having a positive flexibility in responsibilities*

- *Considering the correspondence between the cost and quality*

Finally; Architect/design engineer should focus on the following issues:

- *Producing design documents on time*

- *Trying to lessen mistakes and discrepancies in design documents*

Arain and Pheng [35] also suggested recommendations based on the research and literature review as follow:

- The project professionals should be involved during the project design phase in order to reduce the probable changes due to errors, discrepancies and omissions during the construction phase.

- The effective coordination and communication between project team members should be established in order to help to reduce and eliminate the changes arising from project design as well as variations caused by contractual conflicts and discrepancies.

- The controlling of design and detailing of the drawings should be executed by the consultants carefully; in order to reduce the changes of design during

the construction phase and also to provide the opportunity for reviewing and finalizing the design documents during the design stage.

- A brief project scope and objectives should be provided for the contractors and project team members in order to eliminate and reduce the changes arising from the unclear project scopes.

## 2.7 Change Causes

It is obvious that, change is unavoidable in most construction projects because of the uniqueness of projects and the restricted financial and time resources available for project planning.

Changes may arise in a project due to several reasons, including scope changes, design variations, or unpredictable conditions. Sun and Meng [6] declares that "Causes of change are conditions or events that either directly trigger or contribute to a change in construction projects."

Generally, any factor which leads to any kind of adjustment or variation in project initial specification, objectives, documents and scope as well as project characteristics is called change cause.

Theoretically, any distinct change has individual and appreciable reasons. However, in reality a great level of complexity and vagueness exist in the relevant conditions, indicating that, considerable effort and experience is needed for complete comprehension and analysis.

Some causes of changes in construction projects are general and common causes like design errors or scope changes; however, some causes can be country-specific or project-specific causes for instance, material shortage, prices escalation and project complexity and technology.

Some changes can be originated by project participants, like contractor experience of similar work or poor financial resources of owner and etc. however, some causes

of changes can be originated from parties from out of the project; like getting permission from municipality.

There are numerous reasons behind the changes in projects and they can be classified based on several factors. They may occur because of unknown ground, weather or site conditions as well as contractual discrepancies, administrative problems, varied market conditions and general demand and etc. All of these issues and many more cause to inevitable changes which are generally costly and undesirable by all project involved parties.

## 2.8 Change Impacts (Effects)

According to "*Longman Dictionary of Contemporary English"* "*Impact*" is defined as "the effect or influence that an event, situation etc. has on someone or something"; and according to "*Merriam-Webster Dictionary"* is defined as ''the force of impression of one thing on another''.

In construction, "*Change Impact (Effect)*" refers to direct or indirect impact of a change event on different aspects of the project. [6]. Generally, the positive or negative influence of a change event on the project which can be exerted directly or indirectly from any origins is called "*Change Impact*" or "*Change Effect*".

Changes can impact any parts of the project in a directly or indirectly manner and lead to cost or schedule overrun, reduced quality of work and etc. Usually a project is known as impacted by change if changes have a negative effect on its initial characteristics included in contract but the fact is that the impacted project is a project which change has an influence on it whether it is positive or negative. Although some projects may take advantage of changes with positive impact (positive change), but most changes have negative effect on them (negative change) and disturb the project plan and work flow, and in most cases lead to cost and time overrun.

In most construction projects, changes are the major reason of delays, cost overruns and quality defect. Changes also are the source of other numerous negative effects, such as low morale and productivity of labor, conflicts and legal disputes.

Some change effects in construction projects, like "*Change Causes*", can be country-specific or project-specific which varies from project to project and from one country to other one; however some of them are common and general impacts.

A change might have a "*single*" or a "*cumulative*" (ripple) effect on the project features. A change effect is called single effect when it has a solitary impact on a specific characteristic of project and would not affect other parts or characteristics, this kind of change effect are really hard to find. However, most of the "*Change Effects*" in construction projects are "*cumulative*" (ripple) effects which are the change which has multiple effects on project and usually affect several aspects of project.

Some effects are "*measureable*" effects like direct cost or time overruns and some others are "*unmeasureable*" in which the process of measuring is impossible or formidable and the results may be unreliable; such as moral effects of change or quality defects.

### 2.8.1 Direct Effects

A general and usual classification for change effects is to categorizing them as "*Direct*" and "*Indirect*" effects. "*Direct Effects*" are those which are the first and straight influence of project change such as cost escalation due to design or specification changes. Here the cost increase is the first and straight effect of design or specific change. "*Direct Effects*" may lead to "*Indirect or Ripple Effects*" either; in the last example the design change and the cost escalation due to this change may cause to an impact on project cash flow or may lead to claims between contractor and other parties which are the "*Indirect or Ripple Effects*" of cost increase. Additional costs and time due to the "*Direct Effects*" of the change, like change in resources or requirements, are relatively simple to estimate. Most of changes

frequently have "*Direct Effects*" on project cost, time and quality the following effects are some examples of direct effects of changes:

- *Addition or deletion of work*
- *Rework and demolition*
- *Time extension and delays*
- *Direct costs of resources and administration*
- *Quality changes*
- *Revisions on project documents*
- *Re-scheduling and re-organizing*

Some of the above mentioned effects are measurable and some are not or hardly estimated factors. The root effects of above factors are on projects' cost, time and quality, which are explained as follow.

#### 2.8.1.1 Delay

Assaf and Al-Hejji [34] described that "*in construction, delay could be defined as the time overrun either beyond completion date specified in a contract, or beyond the date that the parties agreed upon for delivery of a project*." Delay is the main variation causes of project planned schedule and is known as the most common problem of construction projects. All project participants feel and endure delay and its negative results during project lifecycle. Delay imposes financial losses to the owner due to late utilization of project and contractor burdened with delay due to higher overhead costs and possible inflation of material, equipment and manpower prices.

Apart from negative consequences of project delay it is an indicator of project success and efficiency. Completing a project on time is mostly known as the fundamental measure of project success however, the construction activities are subjected to many risk factors and variables, which result from numerous resources. These resources include internal and external, predictable and unpredictable factors which are a part of variable and unique nature of construction industry. However, it is rarely happen that a project is completed within the specified time. [34]

Many research efforts have been conducted on construction delays and numerous investigations have been executed to reduce the amount of delay in construction projects. Rwelamila and Hall [36] found that severe conflicts and disputes arise in the industry when the project completion takes much longer than stipulated in contract and mostly the majority of time extensions occur during the 'construction' phase, in which various unpredictable factors are always associated.

Since project delays is a critical factor in project success and the majority of delays normally occur due to changes and variations in project implementation of efficient change management and control system is significantly important. Chalabi and Camp [37] also suggested that efficient planning and scheduling early in the project is important in order to limit delays and cost overruns in construction projects.

Kumaraswamy et al. [38] studied claims for excusable time extension in Hong Kong’s construction projects. They found that a total of 50 percent of surveyed projects were suffered from changes-originated delays.

Assaf and Al-Hejji [34] also investigated the time performance of large construction projects in Saudi Arabia and found that around 70% of construction projects encountered time overruns. They also discovered that “change” was the most frequent source of delay recommended by all project participants.

#### 2.8.1.2 Cost Overrun

Lee [39] defined the concept of "*cost overrun"* as "*the difference between the actual and estimated costs as a percentage of the estimated cost, with all costs calculated in constant prices.*" Lee [39] also defined actual and estimated costs as follow:

1. *"Actual costs are defined as the accounted costs actually spent, as determined at the time of project completion."*

2. *"Estimated costs are defined as the budgeted or forecasted costs at the time of project approval."*

Most of the construction projects are exposed to the risk of cost overrun especially during construction phase due to the high range of financial turnover, numerous risk factors and uncertainties associated. Cost overruns are considered as a considerable financial risk to all project involved parties including contractors and owners. Generally contractors consider a financial contingency as markups to cover cost overruns during project lifecycle however when the amount of cost overruns exceed the markup margins then it could be a significant challenge for contractors. Thus the project profitability and financial attraction for contractor would be lessened and might be lead to bankruptcy or other financial difficulties which consequently affect the project negatively. Therefore, as Akinci and Fischer suggested [40] "contractors need to identify major risk sources causing cost overburdens in advance to be proactive in managing them."

Cost overruns might arise due to numerous factors including discrepancies between estimated and actual costs, construction methods, construction changes and time extension. However the considerable parts of cost overruns are time related which mostly arise from disruptions such as the effects of change and variations, and as such are a major source of claims and disputes [41]. Todays it is obvious that changes during the project lifecycle increase cost overrun due to delays and cost increases.

Ibbs et al. [20] described that the cost overrun resulted from changes is not only the direct cost of change execution derive from differences between changed and unchanged work but also there are another sources of cost which arise from the interaction between changed and unchanged work. They also [20] stated that "*The Armed Services Board of Contract Appeals* once stated that the costs of performing changed work consist of both:

1. *Those costs directly related to the accomplishment of the changed work; and*

2. *Costs arising from the interaction between the changed work and unchanged work."*

#### 2.8.1.3 Quality Changes

Quality of the project may be affected by changes due to several direct and indirect factors. When a change occurs in the project the workmanship or quality of product might be changed directly due to several factors including substitution of material or equipment, new construction method, changing execution time or season, replacing project team, etc. The influence of changes on quality could be positive or negative meaning that change may increase the quality of work or reduce it. Changes might affect the quality of workmanship indirectly; for instance changes could impact the moral of labour negatively and this may lead to low productivity and workmanship or the quality of work might be reduces due to defected cash flow.

Generally, changes have significant negative impact on the quality of work even though the main objective of the changes might be quality promotion but the negative effects of changes may weaken the positive intention of change. Thus it should be considered that the changes with the aim of quality advancement may give a converse result.

### 2.8.2 Indirect Effects

The indirect effects of changes are usually difficult to trace or analyzed but they can be observed on project performance. Several investigations have been conducted in

order to identify and evaluate the indirect effects of changes in construction projects. D. Bower [42] has investigated the indirect effects of changes in construction and expressed that they are mostly difficult to quantify. Bower [42] listed these effects as bellow:

1. *Rework and lost effort on work already done*
2. *Time lost in stopping and restarting current tasks in order to make the variation*
3. *Change in cash flow*
4. *Financing costs*
5. *Overhead costs*
6. *Inefficient use of resources*
7. *Loss of earnings*
8. *Loss of productivity*
9. *Reprogramming*
10. *Loss of rhythm*
11. *Unbalanced gangs*
12. *Acceleration*
13. *Revisions to project reports and documents*
14. *Loss of float therefore increased sensitivity to delay*

Generally it has been approved that indirect effects of changes are certainly complicated to identify and analyze systematically. Therefore, due to the high complexity of issue, the project involved parties normally avoid arguing over the cost and time effects of project changes and the related compensations. Consequently the settlement and negotiation of such issues remain to the ending period of the construction phase in which all claims and disputes have been accumulated. The uncertainty of the results in this period of time usually leads to legal disputes and considerable compensation claim by contractors and accordingly causes to take a defensive posture by owner. Consequently this may lead to polemic between project participants since the contractor is continuously forcing the client to settle the claim for further charges while usually feeling that the compensation has been inadequate. This is extremely detrimental to efficient communication and coordination between project parties and can lead to additional challenges.

D. Bower [42] stated that "*the traditional method of settling claims for indirect costs is a `horse trade' in which one party, normally the contractor, suggests a level of compensation for the variation, and then the other argues for adjustment of that amount. This method in itself would be difficult to justify if it related to individual variations, and normally it is undertaken for all of the changes at once at the end of the contract, when it is impossible to separate out the effects of any one problem*".

## 2.9 Existing Investigations on Change Causes

As it is mentioned previously "*Change Causes*" are factors that lead to a change or promote a change either directly or indirectly. The changing nature of construction industry and the diversity of uncertainty and risk associated with industry promote the complexity of field.

Through a literature review on "*Change Causes*" it can be considered that there are numerous studies on "*Change Causes*" and few investigations on change effects in construction industry. The reason behind this issue is the large and vast extent of "*Change Causes*" which include a great diversity of factors trigger changes in construction. On the other hand the extent of change effects is more limited in

compare with "*Change Causes*". The vast diversity and scope of "*Change Causes*" makes the process of classification of them more complicated therefore there is a great lack of comprehensive study on categorizing and classification of "*Change Causes*". On the other hand the existing investigations on classifications are not general and usually have been conducted based on a specific project or country and could not be implemented in other projects or locations.

There are numerous studies on "*Change Causes*" in construction projects, the existing studies have been conducted in three general methods as well as Sun and Meng [6] declared:

1. *Questionnaire surveys*

2. *Reviews of project records*

3. *Case studies*.

The questionnaire surveys generated the most extensive and complete lists of "*Change Causes*" since they covered a large number of participants than other methods did. Conversely, project records and documentation reviews as well as case studies provided a more in detailed investigation of "*Change Causes*" in a project.

Sun and Meng [6] describes that although questionnaire surveys are efficient method for collecting data from a large number of participants however; their results can be subjective and indicates a bulk and general knowledge obtained from numerous projects by respondent. Furthermore, most questionary surveys have relatively small sample sizes; therefore concluding a general and comprehensive theory or suggestion from the results of these kinds of studies must be more cautiously.

The projects records and documentations review method is more objective than questionary survey method. However, the results are directly related to the accuracy and completeness of project records which are kept. [6]

During the case study investigations, the focus and attention is on a small number of projects and the process of analyzing is more detailed and precisely. [6]

Through a comprehensive literature review on construction changes a list of "*Change Causes*" have been developed; at the rest of this section some prominent results of research efforts are given.

Arain and Pheng [43] expressed that construction changes arise for a variety of foreseeable and unforeseeable causes. They identified four origin agents of changes in construction projects including:

1. Client related changes:

   *Client related changes are the causes of changes which are initiated by project owner in order to accomplish the project objectives or to compensate the owners' defects in responsibilities*.

2. Consultant related changes:

   *These are the changes initiated directly by consultant due to project requirements or consultants' failures during project lifecycle.*

3. Contractor related changes:

   *These are the changes suggested by contractor to be exerted in project due to their necessity or in order to cover the contractors' failure in provision of project requirements.*

4. Other changes:

   *This group of changes concerns with the "Change Causes" which are not directly related to the project participants and other factors initiates them during project lifecycle.*

They also categorized the "*Change Causes*" based on above classifications; Table 1 indicates this classification:

**Table 1**: Changes Origin, Arain and Pheng [43]

| Change Origin | Change Cause |
|---|---|
| *Client Generated Changes* | *Change of scope*<br>*Change of project schedule*<br>*Owner's financial problems*<br>*Inadequate project objectives*<br>*Replacement of materials*<br>*Change in specifications* |
| *Consultant Generated Changes* | *Change in design*<br>*Errors and omissions in design*<br>*Conflicts between contract documents*<br>*Inadequate scope of work for contractor*<br>*Design complexity*<br>*Inadequate shop drawing details*<br>*Lack of consultant's knowledge of available materials and equipment* |
| *Contractor Generated Changes* | *Lack of contractor's involvement in design*<br>*Unavailability of equipment*<br>*Unavailability of skills manpower*<br>*Contractor's financial difficulties*<br>*Defective workmanship* |
| *Other Changes* | *Change in government regulations*<br>*Weather changes*<br>*Change in economic conditions*<br>*Unforeseen problems* |

Another investigation has conducted by Mohammad et al. [18] based on the "*Change Causes*" extracted through a literature review to rate the significant causes of changes in construction based on the respondents' experiences for completed projects. They listed the important causes of changes in the questionnaire as follow:

Significant causes of changes order:

1. *Change of plan by owner*
2. *Substitution of materials*
3. *Change in design by consultant*
4. *Errors and omissions in design*
5. *The scope of work for the contractor is not well defined*
6. *Conflict between contract documents*
7. *Differing site conditions*
8. *Change of plan by client*
9. *The lack of coordination between contractor and consultant*
10. *The contractor's financial difficulties*
11. *Owner's financial problems*
12. *Workmanship or material not meeting the specification*
13. *Contractor's desire to improve his financial situation*
14. *The required labour skills are not available*
15. *The required equipment and tools are not available*
16. *New government regulations*
17. *Weather conditions*

Chan and Kumaraswamy [44] conducted a survey to identify and evaluate the relative importance of the delay causes in Hong Kong construction projects. The results of the research indicated that five major delay causes were:

1. *Poor site management and supervision*
2. *Unforeseen ground conditions*
3. *Low speed of decision making involving all project teams*
4. *Client initiated variations*
5. *Necessary variations of works*

They investigated 83 delay causes, which were grouped into eight major categories as shown in Table 2:

**Table 2:** Causes of Delay, Chan and Kumaraswamy [44]

| Level 1 | Level 2 |
|---|---|
| *Project-related* | *Project characteristics*<br>*Necessary variations*<br>*Communication among the various parties*<br>*Speed of decision making involving all project teams*<br>*Ground conditions* |
| *Client-related* | *Client characteristics*<br>*Project financing*<br>*Their variations and requirements*<br>*Interim payments to contractors* |
| *Design team-related* | *Design team experience*<br>*Project design complexity*<br>*Mistakes and delays in (producing) design documents* |
| *Contractor related* | *Contractor experience in planning and controlling the projects*<br>*Site management and supervision*<br>*Degree of subcontracting*<br>*Their cash-flow* |

**Table 2:** Causes of Delay, Chan and Kumaraswamy [44] (continued)

| Level 1 | Level 2 |
|---|---|
| *Materials* | *Shortages*<br>*Materials changes*<br>*Procurement programming*<br>*Proportion of off-site prefabrication* |
| *Labor* | *Labor shortages*<br>*Low skill levels*<br>*Weak motivation*<br>*Low productivity* |
| *Plant/equipment* | *Shortages*<br>*Low efficiency*<br>*Breakdowns*<br>*Wrong selection* |
| *External factors* | *Waiting time for approval of drawings and test Samples of materials*<br>*Environmental concerns and restrictions* |

Assaf et al. [45] determined 56 major causes of delay in large building construction projects in the Eastern Province of Saudi Arabia, as presumed by the project involved parties including consultants, owners, designers and contractors . Their study included 56 causes of delays that have been classified into nine major groups as shown in Table 3:

**Table 3:** Causes of Delay, Assaf et al. [45]

| Category of Cause | Description |
|---|---|
| *Contractual Relationship* | *Include problems related to contractual relationship between the various project participants.* |
| *Financing* | *Includes contractors' financing requirements and progress payments paid by owners.* |
| *Changes* | *Include delays as a result of omissions, errors, and change of scope by owners.* |
| *Scheduling and Controlling* | *Include causes of delay due to:*<br>- *Poor planning and scheduling practices*<br>- *Lack of management expertise in project control*<br>- *Poor record keeping and maintenance* |

**Table 3:** Causes of Delay, Assaf et al. [45] (continued)

| Category of Cause | Description |
|---|---|
| *Materials* | *Include causes of delay related to:*<br>- *Shortages of material*<br>- *Materials changes*<br>- *Material delivery*<br>- *Material damage*<br>- *Manufacturing of materials* |
| *Manpower* | *Manpower includes shortages of labor, labor skill, and nationalities of laborers.* |
| *Equipment* | *Equipment includes any cause of delay related to failure, shortage, and delivery of the equipment, or the productivity or skill of the operator of the equipment.* |
| *Government Relations* | *Government relations include any delay related to permits, labor visa requirements, and government bureaucratic procedures.* |
| *Environment* | *Environment includes climatic conditions, social and cultural impact, and geological problems in Saudi Arabia.* |

The results of the investigation in ranking the causes according to their importance are as followed:

*Contractors* believed that the three most important causes of delays in construction projects were as follow:

1. *Preparation and approval of shop drawings*
2. *Delays in contractor's progress payment by owners*
3. *Design changes*

According to the *architects and engineers* view the major causes of delays were:

1. *The cash problems during construction*
2. *The relationship between subcontractors*
3. *The slow decision making process of the owner*

On the other hand, the *owners* suggested that the most significant delay factors were:

1. *The design errors*
2. *Labor shortages*
3. *Inadequate labor skills*

Assaf and Al-Hejji [34] have conducted a survey on time performance of different types of construction projects in Saudi Arabia and 73 causes of delay were identified during the research. They classified these causes in 9 major groups according to the sources of delays. Table 4 shows the list of delay causes categorized into the mentioned nine groups:

**Table 4:** Causes of Delay, Assaf et al. [34]

| Level 1 | Level 2 |
|---|---|
| *Project-related* | - *Original contract duration is too short*<br>- *Legal disputes b/w various parts*<br>- *Inadequate definition of substantial completion*<br>- *Ineffective delay penalties*<br>- *Type of construction contract (Turnkey, construction only,.)*<br>- *Type of project bidding and award (negotiation, lowest bidder* |
| *Owner- Related* | - *Delay in progress payments by owner*<br>- *Delay to furnish and deliver the site to the contractor by the owner*<br>- *Change orders by owner during construction*<br>- *Late in revising and approving design documents by owner*<br>- *Delay in approving shop drawings and sample materials*<br>- *Poor communication and coordination by owner and other parties*<br>- *Slowness in decision making process by owner*<br>- *Conflicts between joint-ownership of the project*<br>- *Unavailability of incentives for contractor for finishing ahead of schedule*<br>- *Suspension of work by owner* |

**Table 4:** Causes of Delay, Assaf et al. [34] (continued)

| Level 1 | Level 2 |
|---|---|
| *Contractor Related* | - *Difficulties in financing project by contractor*<br>- *Conflicts in sub-contractors schedule in execution of project*<br>- *Rework due to errors during construction*<br>- *Conflicts b/w contractor and other parties (consultant and owner)*<br>- *Poor site management and supervision by contractor*<br>- *Poor communication and coordination by contractor with other parties*<br>- *Ineffective planning and scheduling of project by contractor*<br>- *Improper construction methods implemented by contractor*<br>- *Delays in sub-contractors work*<br>- *Inadequate contractor's work*<br>- *Frequent change of sub-contractors because of their inefficient work*<br>- *Poor qualification of the contractor's technical staff*<br>- *Delay in site mobilization* |
| *Consultant Related* | - *Delay in performing inspection and testing by consultant*<br>- *Delay in approving major changes in the scope+ of work by consultant*<br>- *Inflexibility (rigidity) of consultant*<br>- *Poor communication/coordination between consultant and other parties*<br>- *Late in reviewing and approving design documents by consultant*<br>- *Conflicts between consultant and design engineer*<br>- *Inadequate experience of consultant* |
| *Design Related* | - *Mistakes and discrepancies in design documents*<br>- *Delays in producing design documents*<br>- *Unclear and inadequate details in drawings*<br>- *Complexity of project design*<br>- *Insufficient data collection and survey before design*<br>- *Misunderstanding of owner's requirements by design engineer*<br>- *Inadequate design-team experience*<br>- *Un-use of advanced engineering design software* |

**Table 4:** Causes of Delay, Assaf et al. [34] (continued)

| Level 1 | Level 2 |
|---|---|
| *Materials Related* | - *Shortage of construction materials in market*<br>- *Changes in material types and specifications during construction*<br>- *Delay in material delivery*<br>- *Damage of sorted material while they are needed urgently*<br>- *Delay in manufacturing special building materials*<br>- *Late procurement of materials*<br>- *Late in selection of finishing materials due to availability of many types in market* |
| *Equipment Related* | - *Equipment breakdowns*<br>- *Shortage of equipment*<br>- *Low level of equipment-operator's skill*<br>- *Low productivity and efficiency of equipment*<br>- *Lack of high-technology mechanical equipment* |
| *Labors Related* | - *Shortage of labors*<br>- *Unqualified workforce*<br>- *Nationality of labors*<br>- *Low productivity level of labors*<br>- *Personal conflicts among labors* |
| *External Related* | - *Effects of subsurface conditions (e.g., soil, high water table, etc.)*<br>- *Delay in obtaining permits from municipality*<br>- *Hot weather effect on construction activities*<br>- *Rain effect on construction activities*<br>- *Unavailability of utilities in site (such as, water, electricity, telephone, etc.)*<br>- *Effect of social and cultural factors*<br>- *Traffic control and restriction at job site*<br>- *Accident during construction*<br>- *Differing site (ground) conditions*<br>- *Changes in government regulations and laws*<br>- *Delay in providing services from utilities (such as water, electricity)*<br>- *Delay in performing final inspection and certification by a third party* |

As it mentioned previously, Akinci and Fischer [40] have categorized the causes of cost overruns into two general types, "*Controllable*" and "*Uncontrollable*" causes. They also grouped uncontrollable Causes of cost overruns in 3 general dimensions. Table 5 indicates their classification:

**Table 5:** Uncontrollable Causes of Cost Overrun, Akinci and Fischer [40]

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *Factors affecting the cost estimate* | *Estimator-Specific Factors* | - *Estimator biases* |
| | *Design and Project-Specific Factors* | - *Vagueness in Scope*<br>- *Design Complexity*<br>- *Project Size* |
| *Factors affecting the final cost* | *Construction-specific factors* | - *Unknown geological conditions*<br>- *Weather conditions*<br>- *Client generated risk factors*<br>- *Subcontractor generated risk factors* |
| | *Economic and political environment-specific factors* | - *Economic factors*<br>- *Political risk factors* |
| *Contract-specific factors* | *Type of Contract* | - *Cost-reimbursable contracts*<br>- *Fixed-price contracts* |
| | *Context of Contract* | - *Specifications*<br>- *Clauses* |

Chao et al. [46] studied the second national highway project in Taiwan as a case study and categorized the change orders into four groups based on whether their source of initiation including owner, construction design consultant, on-site construction unit, or external parties (parties which do not included in the first three groups). They classified the Causes of Changes as it is indicated in Table 6:

**Table 6:** Causes of Change in Second National Highway in Taiwan, Chao et al. [46]

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *Owner initiated changes* | *Changes owing to policy or regulations changes* | |
| | *Owner failure to provide construction sites, equipment, machinery or materials on time* | |
| | *Conflicts and disputes* | |
| | *Changes made due to modifications by other organizations* | - *To facilitate the execution of other projects and avoid construction site conflict*<br>- *Re-route the lines by utility providers*<br>- *Regulatory changes by utility providers*<br>- *Possible danger to other organizations owing to construction, or other safety concerns* |
| | *Special owner requirements* | - *Maintenance or other reasons*<br>- *Prevent casualties and ensure temporary safety*<br>- *Achieve certain milestones*<br>- *New construction techniques or materials*<br>- *Natural or artificial events* |

**Table 6:** Causes of Change in Second National Highway in Taiwan, Chao et al. [46] (continued)

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *Design consultant changes* | *Poorly executed design drawings* | |
| | *Erroneous, incomplete or inaccurate pricing documents* | |
| | *communication problems* | |
| | *Inadequate site investigation before the design period* | |
| | *insufficient Material investigation* | |
| | *Improper construction method* | |
| | *uncertainty in locating pipe positions under ground* | |
| *Changes made by the contractors* | *current site conditions* | |
| | *construction method* | |

**Table 6:** Causes of Change in Second National Highway in Taiwan, Chao et al. [46] (continued)

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *Changes with other causes* | *Geological conditions* | - *Incomplete geological survey*<br>- *Groundwater location*<br>- *Incomplete information*<br>- *Ground elevation and landform*<br>- *Differences between the original survey and on-site conditions* |
| | *Disasters* | - *Artificial disasters*<br>- *Natural disasters* |
| | *Protests* | - *Residential safety*<br>- *Environmental protection*<br>- *Business interruption* |
| | *Associated causes* | - *Previous construction delays by other contractors*<br>- *Accelerating works or changes in construction methods* |

Shing and Chang [47] investigated the causes of cost and schedule overruns in design projects by studying four case project documents and categorized them in three main groups according to Table 7 named: "*Compensable*", "*Non-excusable*" and "*Excusable*", as follows:

**Table 7:** Causes of Change in design projects, Shing and Chang [47]

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *Compensable* | *Owner's request* | - *Additional work*<br>- *Optimistic schedule*<br>- *Omissions* |
| | *Owner's failure* | - *Failure to provide information*<br>- *Incomplete or incorrect information*<br>- *Other consultants* |
| *Non-excusable* | *Consultant's failure* | - *Consultant's inability*<br>- *Underestimates or omissions*<br>- |
| *Excusable* | *Growing needs* | - |
| | *Stakeholders* | - *Agencies*<br>- *Public*<br>- *Others* |

Shing and Chang [47] described that:

It is obvious that the "*owner's request"* and "*owner's failure"* are the two major reasons frequently under the owner's control. *"Owner's request"* is a scope-related category. "*Additional work"* occurs normally after design phase starts. The *"optimistic schedule"* and *"owner omissions"* both are scope related mistakes usually made before work is started. These three factors were grouped under the "*owner's request"*.

*"Consultant's failure"* is the reason within the consultant's control; and other reasons are beyond either the owner's or consultant's control.

*"Growing needs"* relate to extra works which are not anticipated at the beginning. They can be considered as unpredicted occasions that are excusable. "*Stakeholders"* commonly include public and government agencies. "*Others"*, such as law changes or standard changes, are related to the "*stakeholder"*, so are merged under "*stakeholders"*.

If a causal factor occurs under "*Compensable"* group, the owner will compensate both cost and time. For "*Non-excusable"* factors group, the consultant will take the both cost and time. For "*Excusable"* factors group, the time will be extended, but the consultant will incur the cost of change [48].

Hsieh et al. [16] have investigated the causes of change orders in 90 metropolitan public projects in Taipei, Taiwan and categorized them in two general groups as indicated in Table 8:

**Table 8:** Causes of Changes in public projects in Taipei, Hsieh et al. [16]

| Level 1 | Level 2 |
|---|---|
| *Technical Causes* | - *Planning and design (PAD)*<br>- *Underground conditions (UGC)*<br>- *Safety considerations (SAC)*<br>- *Natural incidents (NAI)* |
| *Administrative Causes* | - *Changes of work rules/regulations (CWR),*<br>- *Changes of decision-making authority (CDA)*<br>- *Project commissioning and ownership transfer (COT)*<br>- *Neighborhood pleading (NEP)* |
| *Minor and Miscellaneous Causes (MIC)* | |

Wu et al. [17] carried out multiple-case investigations by using statistics analysis to identify change events in highway projects in Taiwan, in order to clarify the causes of construction changes.

According to the study results, the changes in highway project were identified. The "*Change Causes*" in this study have been classified into two groups: internal and external factors. The "*Change Causes*" of internal factors have been also classified into four categories considering whether they were initiated by the owner, construction design consultant, contractor, or other parties (any party except these three). The external factors included the political and economic factor, the natural environmental factor, and the third party factor. Table 9 shows their classification:

**Table 9:** Change causes classification in highway project in Taiwan, Wu et al. [17]

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *External Factors* | *Political and economic factor* | - *Legislative or policy changes*<br>- *Political pressure* |
| | *Natural environmental factor* | - *Natural disasters*<br>- *Alterations by natural or artificial events*<br>- *Geological conditions* |
| | *Third party factor* | - *Protests by local residents*<br>- *Modifications by other organizations* |
| *Internal Factors* | *Owner initiated* | - *To prevent casualties and ensure temporary safety*<br>- *Failure to provide construction sites, equipment, machinery or materials on time*<br>- *New construction techniques or materials* |
| | *Construction design-Consultant Initiated* | - *Poorly executed design drawings*<br>- *Errors, incomplete or inaccurate information in pricing document*<br>- *Inadequate communication before design*<br>- *Inadequate investigation of site before the design*<br>- *Insufficient material investigation*<br>- *Construction method*<br>- *Incomplete domestic piping management of individual organizations* |
| | *Contractor initiated* | - *Changing the construction method due to current site conditions*<br>- *New construction methods* |
| | *Other parties* | - *For maintenance or other reasons*<br>- *Artificial disasters*<br>- *Manmade disasters*<br>- *Associated causes* |

Kaming et al. [49] investigated the influencing factors of time and cost overruns in construction of high-rise projects in Indonesia. They listed the causes of delays as follow:

1. *Inclement weather*
2. *Inaccuracy of materials estimates*
3. *Inaccurate prediction of craftsmen' s production output*
4. *Inaccurate prediction of equipment production rates*
5. *Materials shortages*
6. *Equipment shortages*
7. *Skill shortages*
8. *Locational project restrictions*
9. *Inadequate planning*
10. *Poor labour productivity*
11. *Design changes*

They also described that some of these factors might cause to late project completion, whereas others might not have any impact on construction time. However, all delays usually lead to extra costs.

According to the investigation results major causes of cost overruns have been commonly identified as:

1. *Unpredictable weather*

2. *Inflationary material cost*

3. *Inaccurate materials estimates*

4. *Complexity of project*

5. *Contractor' s lack of geographical experience*

6. *Contractor' s lack of project type experience*

7. *Non-familiarity with local regulations*

They also found that the first three major influencing factors of cost overruns were:

1. *Material cost increase due to inflation*

2. *Inaccurate estimates of material*

3. *The level of project complexity*

However, the four most important causes of delays and time overruns were as follow:

1. *Design changes*

2. *Poor labour productivity*

3. *Inadequate planning*

4. *Resource shortage*

Another study has been done by Mansfield [50] in Nigeria in order to identify the major causes of cost and time overruns in Nigerian construction projects. For this purpose a questionnaire survey was conducted between project participants such as contractors, consultants and client organizations. The survey results indicated 16

major causal factors to delays and cost overruns in construction projects in Nigeria. They also identified that existing cost and time overruns in Nigerian construction industry were related to following factors:

- *Financial and payment arrangements*
- *Poor contract management*
- *Shortages in materials*
- *Inaccurate estimation*
- *Overall price fluctuations*

A quantitative analysis on construction delays have been conducted by Al-Momani [51] in Jordan. The results of the study identified that the significant causes of delays in public projects construction were attributed to following factors:

- *Designers*
- *User changes*
- *Weather conditions*
- *Site conditions*
- *Late deliveries*
- *Economic conditions*
- *Increase in quantity*

Another investigation on construction delays have been carried out by Odeh and Battaineh [52].They executed a survey between contractors and consultants of construction projects with traditional type of contracts in order to identify the major

causes of delays in this type of projects. They found that the ten major causes of delays according to contractors and consultants view point were as follow:

- *Owner interference*
- *Inadequate contractor experience*
- *Financing and payments*
- *Labor productivity*
- *Slow decision making*
- *Improper planning*
- *Subcontractors*

Odeyinka and Yusif [53] have investigated the causes of delays in building projects in Nigeria. They categorized the causes of delay in three general categories including project participants and extraneous factors as shown in Table 10:

**Table 10:** Causes of delays in building projects in Nigeria, Odeyinka and Yusif [53]

| Level 1 | Level 2 |
|---|---|
| *Client related* | - *Variation in orders*<br>- *Slow decision-making*<br>- *Cash flow problems* |
| *Contractor related* | - *Financial difficulties*<br>- *Material management problems*<br>- *Planning and scheduling problems*<br>- *Inadequate site inspection*<br>- *Equipment management problems*<br>- *Shortage of manpower* |
| *Extraneous factors* | - *Inclement weather*<br>- *Acts of nature*<br>- *Labor disputes*<br>- *Strikes* |

A study on delays in construction projects in Thailand have been carried out by Ogunlana and Promkuntong [54]. The results of the study indicated that existing problems of construction projects in Thailand as well as in developing countries could be as follow:

- *Problems due to shortages or inadequacies in industry infrastructure*
- *Problems caused by clients and consultants*
- *Problems caused by contractor's incompetence or inadequacies*

They also suggested that economy managers and construction industry associations should be concentrated on providing the required infrastructure facilities for efficient project management.

Frimpong et al. [55] also executed a research to identify and analyze the relative importance of major causes of cost and time overruns in Ghana groundwater construction projects. For this purpose, a questionnaire including 26 significant causes of delays in groundwater drilling projects were designed which had been collected by primary investigations in Ghana. According to the results of the survey conducted between owners, consultants, and contractors, the major causes of delay and cost overruns in groundwater construction projects were identified as follow:

- *Monthly payment difficulties from agencies*
- *Poor contractor management*
- *Material procurement*
- *Poor technical performance*
- *Escalation of material prices*

Another comprehensive study on both "*Change Causes*" and effects has been executed by Sun and Meng [6] in which a taxonomy for "*Change Causes*" has been developed. The taxonomy was provided in three level of a hierarchical classification as shown in Table 11:

**Table 11:** Taxonomy of Change Causes, Sun and Meng [6]

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *External Causes* | *Environmental Factors* | - *Conservation restrictions*<br>- *Weather conditions (wind, temperature, rain, etc.)*<br>- *Natural disaster (flood, earthquake, etc.)*<br>- *Geological conditions*<br>- *Unforeseen ground conditions* |
| | *Political factors* | - *Changes in government policies (environmental protection, sustainability, waste recycle, brown field use, etc.)*<br>- *Changes in legislations on employment, and working conditions*<br>- *Delays in planning permission approval* |
| | *Social factors* | - *Demography change and its impact on labour demand and supply*<br>- *Skill shortage on certain trades*<br>- *Opposition of neighboring community* |
| | *Economical factors* | - *Economic development cycle and its impact on demand*<br>- *Inflation impact on material, equipment and labour price fluctuation*<br>- *Market competition* |
| | *Technological factors* | - *New materials*<br>- *New construction methods*<br>- *Technology complexity* |
| *Organizational causes* | *Process related* | - *Organization business strategy*<br>- *Business procedures, including payment practice*<br>- *Quality Assurance procedures* |
| | *People related* | - *Competence and skills*<br>- *Culture and ethics* |
| | *Technology related* | - *IT and communication systems*<br>- *Technical supports* |

**Table 11:** Taxonomy of Change Causes, Sun and Meng [6] (continued)

| Level 1 | Level 2 | Level 3 |
|---|---|---|
| *Project internal causes* | *Client generated* | - *Requirement change and variation*<br>- *Funding change, i.e., shortage of funding*<br>- *Slow decision making*<br>- *Payment delays*<br>- *Difficulty in site acquisition* |
| | *Design consultant generated* | - *Poor, incomplete drawings*<br>- *Design changes due to poor brief, errors and omissions*<br>- *Inconsistent site conditions* |
| | *Contractor/subcontractor generated* | - *Poor project plan/schedule*<br>- *Poor site/project management skills*<br>- *Delays in appointing subcontractor*<br>- *Delay of subcontractors' work*<br>- *Poor workmanship*<br>- *Low productivity*<br>- *Poor logistic control* |
| | *Others* | - *Poor interdisciplinary communication*<br>- *Team instability, i.e., disputes, bankruptcy, etc.*<br>- *Inappropriate project organizational structure* |

As it is shown in Table 11, "level 1" of the taxonomy, has been divided into three general categories including: External causes, Organizational causes and Project internal causes. At Level 2, External causes include environmental, political, social, economical and technological factors. Organizational causes at "level 2" were divided into three groups including Process, People and Technology related factors. Internal causes were divided according to their sources: client, design consultant, contractor/subcontractor and others. All "Level 2" causes were divided into more detailed groups in "Level 3" in which the descriptions of causes were mostly self-explanatory.

Murali et al. [56] conducted a questionary survey based on Odeh and Battaineh [52] findings and identified the significant causes of delays in Malaysian construction industry. They categorized the "*Change Causes*" in eight general groups relating to:

client, contractor, consultant, material, labor, contract, contract relationship, and external factors as shown in Table 12:

**Table 12:** Categorization of Change Causes by Murali et al. [56]

| Level 1 | Level 2 |
|---|---|
| *Client Related Causes* | - *Finance and payments of completed work*<br>- *Owner interference*<br>- *Slow decision making*<br>- *Unrealistic contract duration imposed by owners* |
| *Contractor Related Causes* | - *Subcontractor*<br>- *Site management*<br>- *Construction methods*<br>- *Improper planning*<br>- *Mistakes during construction stage*<br>- *Inadequate contractor experience* |
| *Consultant Related Causes* | - *Contract management*<br>- *Preparation and approval of drawings*<br>- *Quality assurance/control*<br>- *Waiting time for approval of tests and inspection* |
| *Material Related Causes* | - *Quality of material*<br>- *Shortage in material* |
| *Labor and equipment category causes* | - *Labor supply*<br>- *Labor productivity*<br>- *Equipment availability and failure* |
| *Contract related causes* | - *Change orders*<br>- *Mistakes and discrepancies in contract document* |
| *Contract relationships related causes* | - *Major disputes and negotiations*<br>- *Inappropriate overall organizational structure linking to the project*<br>- *Lack of communication between the parties* |
| *External causes* | - *Weather condition*<br>- *Regulatory changes*<br>- *Problem with neighbors*<br>- *Unforeseen site condition* |

Alnuaimi et al. [57] studied the changes in public construction projects in Oman. According to their survey the causes of change orders in Oman were as follow:

1. *Owner instructs additional works*
2. *Owner instructs modification to design*
3. *Non-availability of construction manuals and procedures for project construction in Oman*
4. *Non-availability of engineering licensing for engineers in Oman to maintain the quality of consultancy services*
5. *Poor communication between relevant governmental units and the owner*
6. *Non-availability of overall project planning*
7. *Unrealistic design periods*
8. *Unrealistic construction schedule*
9. *Owner fails to make decisions or review documents at the right time*
10. *Low consultancy fee or less experienced designers*
11. *Non-availability of records of similar projects in Oman*
12. *Failure by the consultant to provide adequate and clear information in the tender documents*
13. *Natural growth of the project was not anticipated at the design stage*
14. *Owner's needs during the design stage are unclear or not well-defined*

15. *The contractor uses the gray areas in general conditions and request variations to the contract*

16. *Design errors*

17. *The design and construction criteria are outdated and do not suit the present construction technology*

18. *The contractor misuses variations instructions*

19. *Non-availability of qualified engineers from the owner side*

20. *Consultant not familiar with the regulations and construction permits in Oman*

21. *Unilateral decisions made by the owner without proper considerations to the contract*

22. *Consultant's supervisors do not have collective experience about construction projects in Oman*

23. *Failure by the consultant to perform design and supervision effectively*

24. *Poor project management by contractor*

They also found that the most important causes of changes were as follow:

1. *The client's additional works*

2. *Modifications to design*

3. *Non-availability of construction manuals and procedures*

Another investigation has been executed by Lee [39] on infrastructure projects in Korea. He found that three major causes for cost overruns were:

1. *Changes in project concept and design,*
2. *Addition of new facilities*
3. *Project timeline delays*

Based on the results of the research on road projects, Lee [39] identified the common causes of cost overruns as follow:

1. *Increase in capacity after the feasibility study or during construction*
2. *Adjusted supervision fees due to design changes*
3. *Cost increases due to changes in construction methods*
4. *Increases or decreases in compensation*
5. *Lane addition*
6. *Changes of a bedrock line*

For rail projects, Lee [39] described the major causes of cost overruns as:

1. *Long delays due to changes in scheme design*
2. *Track changes*
3. *The inclusion of additional stations*
4. *Adjusted supervision fees*
5. *Railroad line extensions*
6. *Compensation increases and decreases*
7. *Unexpected changes to the construction environment*

8. *Unit cost increases*

Lee [39] presented the major causes of the cost overruns in airport and port projects as follow:

1. *Runways additions*
2. *Airport terminals additions*
3. *Subsidiary facilities additions*
4. *Increase in capacity after the feasibility study or during construction*
5. *Introduction of a new system and the addition of a new embankment*

Lee [39] also categorized the causes of cost overruns in Korean infrastructure projects into four significant categories as follow:

1. *Changes in the scope of the project*
2. *Construction delays*
3. *Unreasonable estimation and adjustment of the project cost*
4. *No practical use of the earned value management system*

Moreover, Lee [39] collated the results of the study in Korean transportation projects with causes of cost overruns in Europe and North America as shown in Table 13:

**Table 13:** Cause of cost overruns in Korean infrastructure projects, Lee [39]

| Type | Korea | Europe & North America |
|---|---|---|
| *Concept changes* | *Changes of project scope (new addition, extension, capacity increase)* | - *Standards (changed requirements such as speed, road width, road type)*<br>- *Routing (changed routing)*<br>- *Norms (changed safety or building norms)* |
| *Environment* | *Unexpected changes in construction environment* | - *Environment (tighter environmental standards)*<br>- *Geotechniques (complex or extensive works on geotechniques, water or mountain)*<br>- *Archaeology (unexpected archaeological finds)* |
| *Costs* | *Irrational estimation and adjustment of project cost* | - *Expropriation costs (under estimated expropriation costs)*<br>- *Construction costs (business cycle or competitive situation)*<br>- *Calculation approach (calculation based on everything going as Planned)* |
| *Others* | *No practical use of earned value management system* | - *Complex interfaces (urban environment, link to existing infrastructure)*<br>- *New or unproven technology (limited experience base)*<br>- *Delays due to weather* |

### 2.9.1 Discussions on Existing Classifications of Change Causes:

There are lots of research efforts and investigations on "*Change Management"* and detailed studies on their causes and effects including delays, cost overruns productivity and design changes in construction projects. These studies generally can be categorized in three major groups as "case studies on specific projects",

"reviewing the completed projects and their records and documents", and also "questionnaire surveys among construction experts".

Each kind of above research methods encompasses some beneficial and detrimental points both during the research period and in results of the study. Although all of the results has a significant role in the field and provides valuable findings on "*Change Management*" in construction projects, however there are common major difficulties in utilizing their results as a generic framework in managing changes. In this point of progress in change management investigations in construction industry it is clearly tangible that there is a great lack of generic and comprehensive taxonomy of "*Change Causes*". Almost a complete list of causes have been provided due to worthy researches in the field, however gathering these causes into a complete list and in a common and general format of classification approximately have been neglected by research groups. Although few studies and efforts have been conducted in recent years to prepare such a model, but they were not generic or comprehensive enough to cover all the fields of construction industry in all times and places.

As it mentioned previously, there are some considerable restrictions in application of the results of the current studies on "*Change Causes*" as a general model to be utilized in "*Change Management*" process. These limitations of existing studies on "*Change Causes"* can be listed as follow:

1. The majority of existing studies have been conducted on completed projects by reviewing the project records and documents. This makes the results of the study to be more concentrated on specific project in specific place and time. Briefly it can be stated that most of the current investigations on change causes are project-specific as well as country-specific.

2. A great number of investigations have been executed as questionnaire surveys among construction experts. Since these surveys have been conducted based on the findings of previous studies on "*Change Causes"*, they usually encountered with considerable limitations in causes of changes and have not provided new findings. Therefore, they generally ranked the

existing causes in a specific form which are mostly subjective and significantly disparate by variations among the views of various experts.

3. Existing classifications of "*Change Causes*" are usually "*responsibility-based*" or have specific categorizing system which is mostly corresponding with the particular kinds of projects or contracts. These classifications have usually tried to clarify the responsible party for change than providing a generic model for "*Change Causes Taxonomy*".

4. There is a lack of comprehensive classifications of "*Change Causes"* which could be utilized by project experts and research groups to manage and investigate the changes in projects. Therefore the change management and investigation groups are usually have to use incomplete list of "*Change Causes"* which may be resulted in defected outcomes.

Above mentioned restrictions in utilizing the findings of existing studies on "*Change Cause*" as a generic framework in "*Change Management*" process encouraged us to investigate the causes of construction changes through a comprehensive literature review and categorize them in a generic format and in the end develop a taxonomy for causes of change in construction. This taxonomy of "*Change Causes*" will provide a common model of "*Change Causes*" for construction experts to predict, identify and manage the change factors during project lifecycle. Besides, this taxonomy will offer a generic framework for researchers to investigate the causes of changes based on a comprehensive list of causes. Also, the process of change identification during "*Change Management System*" would be facilitated and the accuracy of decisions would be ensured.

# CHAPTER 3

# DEVELOPING A GENERIC TAXONOMY FOR CHANGE CAUSES

## 3.1 Previous Studies on Classification of Change Causes

Changes in construction projects can be classified according to their causal factors or the factors that trigger them. "*Change Causes*" in construction projects can be categorized in several ways based on the intention and objective of categorizing. In this study, the most significant studies on "*Change Causes*" have been presented previously and discussed that most of the existing classifications of "*Change Causes*" were origin-based with a great focus on responsibilities. Several classifications of "*Change Causes*" have been presented by some of the authors in different ways of categorizing, depending on their purposes and objectives. Here is a brief review of previous investigations on taxonomy of "*Change Causes*":

In 1997, Chan and Kumaraswamy [44] published a research paper on "*Change Causes*" in which they grouped the causes of changes into eight main categories involving:

1. *Project related*
2. *Client-related*
3. *Design team related*
4. *Contractor-related*
5. *Materials*

6. *Labour*

7. *Plant and equipment*

8. *External factors*

Akinci and Fisher [40] also conducted an investigation on "*Change Causes*" which have been published in 1998. They grouped the "*Change Causes*" into three main categories including:

1. *Construction-specific factors*

2. *Economic and political environmental factors*

3. *Contract-specific factors*

According to their classification, *Construction-specific* factors involved change factors such as weather conditions, unknown geological conditions, client and subcontractor-generated risks. On the other hand, *Economic factors* refer to economical causes of changes like inflation and price fluctuations. *Political environmental factors* also related to government policy and regulation changes and *Contract-specific* factors include causes related to context of contract and contract types.

In 2002, Chang [47] published the results of a study executed on changes of project designs in engineering design projects; and developed a classification of "*Change Causes*" as follow:

1. *Compensable causes*

2. *Non-excusable causes*

3. *Excusable causes*

He described that *Compensable* causes were those initiated by client and generally related to requirement changes and client failures. Time and cost compensation is possible in this type of causes. *Non-excusable* causes were defined as errors and omissions occurred by design consultants. However, *Excusable causes* were defined as external factors that were generally out of the control of consultant and client.

Another classification of "*Change Causes*" was proposed by Wu et al. [17] in 2005. The taxonomy provided a hierarchical classification system in 3 levels of categories. Level 1, included "*Change Causes*" which have been divided into seven groups as follow:

1. *Political and economic factors*
2. *Natural environmental factors*
3. *Third party factors*
4. *Owner factors*
5. *Design consultant factors*
6. *Contractor factors*
7. *Others*

Each "level 1" category of causes was divided into "level 2" sub-categories also "level 2" causes was further divided into "level 3" causes in which the descriptions of change cases were more detailed and specific.

The last taxonomy of "*Change Causes*" was published by Sun and Meng [6] in 2009 based on a comprehensive literature review on "*Change Causes*". The taxonomy has been comprised of a hierarchical structure in three levels of causes. "Level 1" of the "*Change Causes*" has been divided into three categories as follow:

1. *External causes*

2. *Organizational causes*

3. *Project internal causes*

"Level 2" of the taxonomy has been divided to several sub-categories. For instance, *External causes* were consisting of five sub-categories including:

1. *Environmental factors*

2. *Political factors*

3. *Social factors*

4. *Economical factors*

5. *Technological factors*

*Internal causes* also were divided according to their sources into four major sub-categories as follow:

1. *Client*

2. *Design consultant*

3. *Contractor*

4. *Others*

All "Level 2" factors were divided into more detailed categories in "Level 3" which were generally including detailed and specific cases of "*Change Causes*". This level of the taxonomy was self-explanatory and new cases of "*Change Causes*" can be added.

### 3.1.1 Advantages and Disadvantages of Previous Classifications

Since, most of the existing taxonomies of "*Change Causes*" have been executed on specific and restricted number of projects, so they were mostly project-specific taxonomies. On the other hand, they have been concentrated on the responsible parties of changes and therefore they generally had a responsibility-related structure. Theoretically, these kinds of classifications may be useful in specific kind of construction projects with similar contract types. They can be efficient for identifying the responsibilities of changes and claim management in specific projects. Briefly, the current classifications of "*Change Causes*" may be adequately exhaustive for typical construction projects. However, they cannot be utilized as a generic model of "*Change Causes Taxonomy*" for identifying the causal factors of changes in all type of construction projects. Also, project participants may have diverse judgments on actual causes and responsible of change in practice. Therefore, there is a need for developing generic and responsibility-independent taxonomy of "*Change Causes*" to be used as a model for efficient change management in all type of construction projects.

## 3.2 The Objective of Proposed Taxonomy for Change Causes

In practice, there are a great number of change events with numerous cause factors during construction projects. It is almost impossible to create a complete list of all changes and related causes. The objective of this study is to prepare a comprehensive taxonomy for "*Change Causes*" which cover a great number of "*Change Causes*" in any type of construction projects.

## 3.3 The Process of Categorizing

For this purpose, a long list of different factors for "*Change Causes*" including about 1578 causes of changes were produced through an extensive literature review on research papers, reports and book sections. After preparing the list of change cause

from different sources, the process of reviewing and grouping them has been started. In this section of study the numerous attempts have been made to avoid iteration and to reduce the similarity of causes in order to simplify the process of classification.

Considering the objective of the study, which was providing a generic classification model for "*Change Causes*", the process of designing the taxonomy started. The principle hypothesis behind the defining a classification method was making the categories of causes independent from the responsible parties and concentrating on project essential factors such as resources, location, environment and etc. This method of grouping and categorizing would lead to create a general model of taxonomy in accordance with any type of construction projects and various contract types.

By combining the existing classifications of "*Change Causes*" and based on the results of literature review, taxonomy of "*Change Causes*" was developed. Therefore the results of literature review gathered and consolidated in a hierarchal taxonomy in three levels. The hierarchical structure of taxonomy ensures the clearance and completeness of taxonomy by minimizing any significant omissions at higher levels. The hierarchal structure also promotes the flexibility of the classification by providing the ability of adding some unforeseen causes at the lower level of the taxonomy. The proposed taxonomy is a generic model for "*Change Causes*" that can be further expanded by observing the hierarchical structure of the taxonomy.

"Level 1" of the taxonomy includes 13 categories of causes which are significantly independent and distinguished from each other including:

1. *Manpower*
2. *Material*
3. *Equipment, Tools and Machinery*
4. *Financial Issues*

5. *External Factors*

6. *Health and Safety*

7. *Project Location*

8. *Project Involved Parties (Contractor, Client, Consultant, Designer, etc.)*

9. *Project Management and Administration*

10. *Contract Management*

11. *Design and Specifications*

12. *Project Execution*

13. *Macro Factors*

In "level 2" of the taxonomy, each category of causes in level 1 is divided into equivalent and related sub-categories in which detailed categories are created in order to clarify the grouping of each category.

"Level 3" of the taxonomy is created under the each sub-categories of "level 2" which includes specific cases of related "*Change Causes*". This level is not limited to the mentioned cases of "*Change Causes*" rather, is a flexible and expandable in which new cases of "*Change Causes*" can be included according to existing hierarchal system. Table 14 indicates a brief visualization of taxonomy in level 1 and level 2. The detailed form of the taxonomy is presented in tables starting from table 15 to the end.

**Table 14:** Responsibility-independent Taxonomy of Change Causes

| | Level 1 | Level 2 |
|---|---|---|
| 1 | *Manpower* | - *Organizing and Managing*<br>- *Availability*<br>- *Competence and Skill* |
| 2 | *Material* | - *Procurement and Delivery*<br>- *Availability and Variety*<br>- *Keeping and Storage*<br>- *Quality and Specifications* |
| 3 | *Equipment, Tools and Machinery* | - *Procurement and Delivery*<br>- *Availability*<br>- *Repair & Maintenance*<br>- *Productivity & Efficiency*<br>- *Quality and Specification* |
| 4 | *Financial Issues* | - *Payments*<br>- *Financing*<br>- *Resource Costs*<br>- *Contract and Overhead Costs* |
| 5 | *External Factors* | - *Weather Conditions*<br>- *Natural/ Artificial Disasters*<br>- *Environmental Issues*<br>- *Security Issues* |
| 6 | *Health and Safety* | - *Safety Considerations*<br>- *Health Considerations* |
| 7 | *Project Location* | - *Ground Condition*<br>- *Site Conditions and Restrictions*<br>- *Accessibility and Possession* |
| 8 | *Project Involved Parties*<br>*(Contractor, Client, Consultant, Designer, etc.)* | - *Proficiency and Experience*<br>- *Needs and Expectations*<br>- *Culture and Ethic* |
| 9 | *Project Management and Administration* | - *Project and Site Management*<br>- *Supervision and Quality Management*<br>- *Scheduling, Planning and Control*<br>- *Communication and Coordination*<br>- *Organization and Bureaucracy* |
| 10 | *Contractual Document and Contract Management* | - *Project Scope and Characteristics*<br>- *Bidding and Project delivery*<br>- *Contract Administration and Documents* |
| 11 | *Design and Specifications* | - *Accuracy of Design Documents*<br>- *Changes in Design and Specifications*<br>- *Design Process*<br>- *Characteristics of Design* |
| 12 | *Project Execution* | - *Mobilization and Facilities*<br>- *Logistics and Transportation*<br>- *Construction Method and Technology*<br>- *Subcontracting*<br>- *Performance and Workmanship* |
| 13 | *Macro Factors* | - *Social factors*<br>- *Political factors*<br>- *Economic factors*<br>- *Influence of other parties (projects, organizations, etc.)*<br>- *Rules and Regulations related factors* |

## 3.4 Description of the Taxonomy

### 3.4.1 Manpower

This category of taxonomy includes cases which are related to the Manpower in construction projects such as managerial and organizational factors, availability and accessibility of Manpower in project and also the skill level and competence of the manpower. It is obvious that the quality and quantity of manpower may have a significant effect on construction projects since the majority of activities in construction industry are conducted by manpower. For instance, Murali et al. [56] found that about 20% of the construction workers in Malaysia were foreign workers whom a few of them were illegal with a relatively low level of productivity in compared with local Malaysian labors. The poor quality and productivity level of the foreign workers had negative impacts on the project progress and efficiency. In addition the deporting of illegal workers caused unavailability of labor in the construction market. Besides, the management and organization of manpower is also an important issue in projects which can lead to project changes. All of the factors related to manpower are included in this category. Table 15 shows this category in detailed:

**Table 15:** Taxonomy of Change Causes - Manpower

| **Level 1: Manpower** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Organizing and Managing** | | |
| 1 | *Poor distribution of labor* | [58], [59] |
| 2 | *Replacement of key personnel by contractor/ consultant* | [60] |
| 3 | *Excessive turnover in contractor's staff* | [61] |
| 4 | *Staffing problems (overstaffing/understaffing)* | [62], [63], [61], [64] |
| 5 | *Too much overtime for labor* | [58], [61] |
| 6 | *Severe overtime and shifts* | [65], [61] |
| 7 | *Limitation of working hours* | [66] |
| 8 | *Replacement of key personnel by owner* | [60] |

**Table 15:** Taxonomy of Change Causes – Manpower (continued)

| Level 1: Manpower | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Organizing and Managing** | | |
| 9 | *High turnover in owner's technical personnel* | [67] |
| 10 | *Absenteeism problems of labor* | [65], [68] |
| 11 | *Absence of consultant's site staff* | [69] |
| 12 | *Weak motivation and morale of labors* | [61], [44], [68] |
| 13 | *Problems due to nationality of labors* | [64], [63], [45], [34], [60] |
| **Level 2: Availability** | | |
| 1 | *Unavailability of site labors* | [70], [60], [69], [34], [45], [44], [63], [71], [55], [49], [72], [52], [64], [73], [74] |
| 2 | *Unavailability of technical professionals in the contractor's organization* | [60], [67], [75], [55], [49], [76] |
| 3 | *Unavailability of qualified/ skilled labor/craft* | [67], [75], [55], [49], [77], [78], [61], [76], [43], [18] |
| 4 | *Unavailability of local labor* | [65] |
| 5 | *Non-availability of qualified engineers from the owner side* | [57] |
| 6 | *Lack of training personnel and management support to model the construction operation* | [45], [63], [64] |
| 7 | *Unavailability of managerial and supervisory personnel* | [77] |
| 8 | *Lack of capable owner's representative* | [68], [65] |
| 9 | *Lack of contractor's administrative personnel* | [60], [76] |
| 10 | *Lack of site contractor's staff* | [69] |
| **Level 2: Competence and Skill** | | |
| 1 | *Unqualified/Inadequate experienced labor* | [69], [34], [45], [44], [63], [71], [78], [72], [68] |
| 2 | *Unskilled labor/ Low skilled manpower* | [60], [69], [58], [79], [61], [64], [65] |
| 3 | *Skill shortage on certain trades* | [6], [49] |
| 4 | *Low level of labors efficiency/ Productivity* | [60], [69], [34], [44], [63], [71], [72], [52], [61], [68], [64], [65], [73], [74] |
| 5 | *Inadequate skill of equipment-operator* | [70], [60], [34], [45], [63], [64], [73] |
| 6 | *Lack of experience of the consultant's site staff (managerial and supervisory personnel)* | [69], [76], [57] |
| 7 | *Incompetent technical staff assigned to the project / Poor qualification of the contractor's technical staff* | [73], [65], [76], [75], [34], [60] |

### 3.4.2 Material

This category includes change cause related with material including: Procurement and delivery of material, availability and variety of material, storage and keeping of material and the quality and specifications of material. The inability of project participants to provide sufficient and appropriate material usually leads to changes in construction methods or time and cost overruns.

Moreover insufficient investigation of material during design period of the project may cause to changes in material or construction method due to unavailability or inadequacy of assigned materials.

Cost inflations and unavailability of material, during the project life cycle may also impact the project negatively. Frimpong et al [55] reported that material cost escalation is one of the main five causes of project change and cost overrun in construction projects in Ghana. Similar results were found by Dalkwa and Culpin [80] and Arditi et al. [81].

Besides, poor keeping and storage of some materials like, cement, stones, bricks, and iron may cause to their damage which in turn can leads to major changes in construction such as delay, cost overruns and reworks due to quality defects.

Table 16 indicates the current category in detailed:

**Table 16:** Taxonomy of Change Causes – Material

| **Level 1: Material** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Procurement and Delivery** | | |
| 1 | *Delay in Material Delivery* | [64], [76], [73], [74], [70], [60], [69], [58], [67], [34], [45], [62], [63], [55], [72], [61], [68] |
| 2 | *Poor programming of Material Procurement* | [44] |
| 3 | *Poorly scheduled delivery of material to site* | [55], [58] |
| 4 | *Delay in manufacturing special building materials* | [73], [68], [71], [45], [34], [60] |

**Table 16:** Taxonomy of Change Causes – Material (continued)

| Level 1: Material | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Procurement and Delivery** | | |
| 5 | *Problems due to imported materials and plant items* | [79], [55], [63], [67] |
| 6 | *Late procurement of materials* | [73], [55], [34], [67], [60] |
| 7 | *Inappropriate/ Poor procurement method* | [68], [82], [55], [44] |
| 8 | *Unreliable material suppliers* | [68] |
| 9 | *Poor handling of material on site* | [61], [58] |
| 10 | *Delays/ Problems in materials or goods which are in responsibility of the owner* | [59], [66], [83], [78], [84], [75], [62] |
| **Level 2: Availability and Variety** | | |
| 1 | *Unavailability of materials on site on time* | [76], [84], [85], [55], [71], [69], [60] |
| 2 | *Late in selection of finishing materials due to availability of many types in market* | [34] |
| 3 | *Shortage of construction materials in market* | [73], [76], [64], [68], [52], [82], [77], [49], [55], [71], [63], [44], [34], [67], [69], [60], [70] |
| 4 | *poor investigations of available materials* | [43], [46], [17] |
| **Level 2: Keeping and Storage** | | |
| 1 | *Poor storage of material* | [58] |
| 2 | *Damage of sorted materials while they are needed urgently* | [74], [73], [64], [68], [63], [45], [34], [60] |
| 3 | *Unforeseen material damages* | [70] |
| **Level 2: Quality and Specifications** | | |
| 1 | *Noncompliance of material to specifications* | [70], [18] |
| 2 | *Rejected material* | [62] |
| 3 | *Poor quality of materials* | [74], [68], [61], [52], [67], [58] |
| 4 | *Changes in materials specifications* | [76], [60] |
| 5 | *Problems with new materials* | [6], [17] |
| 6 | *Changes in material types and specifications during construction* | [73], [64], [68], [71], [63], [44], [45], [34] |
| 7 | *Replacement/ Substitution of materials* | [43], [18] |

### 3.4.3 Equipment, Tools and Machinery

This category of taxonomy comprises any "*Change Causes*" related to equipment, tools and machinery of project such as: procurement and delivery, availability, repair & maintenance, productivity & efficiency and quality & specifications. For instance, the inability of project participants to prepare required equipment tools and machinery generally results in major changes in construction methods, delays or cost overruns. Defects in repair and maintenance of equipment may also lead to major stoppages in project progress and usually increase the cost of work. Poor or inadequate selection of equipment and machinery in case of the productivity rates and specifications also can cause project changes. Detailed cases of "*Change Causes*" in this category are shown in Table 17:

**Table 17:** Taxonomy of Change Causes - Equipment, Tools and Machinery

| **Level 1: Equipment, Tool and Machinery** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Procurement and Delivery** | | |
| 1 | *Insufficient/ Inadequate /Ineffective equipment used for the works* | [74], [76], [72], [78], [62], [58], [60] |
| 2 | *Equipment delivery problem* | [74], [64], [61], [72], [55], [63], [62], [45], [70] |
| 3 | *Deficiencies in equipment allocation* | [59], [68], [67] |
| 4 | *Failure to provide sufficient equipment* | [62] |
| 5 | *Delays/ Problems in equipment or tools which are in responsibility of the owner* | [59], [66], [83], [78], [84], [75], [62], [46] |
| **Level 2: Availability** | | |
| 1 | *Unavailability of equipment/ tools on site* | [74], [73], [76], [64], [68], [61], [52], [72], [82], [77], [49], [84], [55], [71], [63], [45], [34], [58], [69], [60], [70] |
| 2 | *Unavailability of equipment/ tools* | [43], [18] |
| 3 | *Shortage of construction equipment and tools in market* | [34], [69], [70], [45], [44], [63], [71], [55], [49], [82], [52], [61], [68], [64], [76], [73] |
| 4 | *Outdated equipment/ Lack of high-technology mechanical equipment* | [34], [58], [60], [63], [64], [73] |
| 5 | *Poor/ insufficient/ inaccurate investigations of available equipment* | [43], [46], [17] |

**Table 17:** Taxonomy of Change Causes - Equipment, Tools and Machinery (continued)

| Level 1: Equipment, Tool and Machinery | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Repair & Maintenance** | | |
| 1 | *maintenance problem/ Equipment breakdown/failure* | [74], [73], [76], [64], [68], [61], [52], [55], [71], [63], [44], [45], [34], [60], [70] |
| **Level 2: Productivity & Efficiency** | | |
| 1 | *Low productivity/ efficiency of equipment* | [73], [64], [68], [63], [44], [45], [34], [60] |
| **Level 2: Quality and Specification** | | |
| 1 | *Rejected equipment* | [62] |
| 2 | *Improper equipment/ Poor/Wrong selection of equipment* | [74], [68], [44], [58] |
| 3 | *Improper/ Wrong tools for materials* | [74] |

### 3.4.4 Financial Issues

Financial Issues category refers to the "*Change Causes*" related with project finance and payment issues. During the validating process of taxonomy new cases of "*Change Causes*" have been raised including: higher material costs, high range of equipment costs and high range of contract and overhead costs. Therefore according to the respondents' suggestions sub categories under this group have been created named "Resource Costs" and "Contractual and Overhead Costs".

Construction industry and accordingly construction projects demand a large amount of money and the majority of construction companies encounter considerable problems due to the heavy daily construction and overhead expenses when the payments are delayed. Work progress may be affected and project completion may be delayed due to the late payments to contractors as well as subcontractors and other parties. Late payments could cause inadequate cash flow to provide construction expenditures particularly for those parties who do not have a strong financial supports. Table 18 indicates the detailed causes of change related to financial issues:

**Table 18:** Taxonomy of Change Causes - Financial Issues

| Level 1: Financial Issues | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Payments** | | |
| 1 | *Delays in contractor's progress payments for completed works by owner* | [73], [76], [83], [64], [68], [61], [79], [72], [82], [55], [71], [63], [44], [75], [62], [45], [34], [67], [60] |
| 2 | *Problems with partial payments during construction* | [63], [64] |
| 3 | *Non-payment of contractor claim* | [60] |
| 4 | *Late payment to subcontractor by the main contractor* | [71], [76], [55] |
| 5 | *Payment delays by owner* | [65], [6], [82], [51] |
| **Level 2: Financing** | | |
| 1 | *Poor project financing by owner* | [79], [52], [44], [45] |
| 2 | *Failure/ difficulties to fund the project on time* | [62] |
| 3 | *Funding changes, i.e., shortage of funding* | [6] |
| 4 | *Financial and economic problems/ difficulties* | [86], [82], [69] |
| 5 | *Lack of finance to complete the work by the owner* | [60] |
| 6 | *Financial constraints faced by the owner* | [76] |
| 7 | *Difficulties in financing project by contractor* | [73], [65], [76], [64], [61], [72], [82], [55], [71], [63], [44], [45], [34], [67], [60], [70] |
| 8 | *Owner's/ contractor's financial problems* | [43], [18], [85], [69] |
| 9 | *Problems in cash flow management* | [72], [55], [62], [60] |
| 10 | *Contractor's financial obligations* | [61] |
| 11 | *Bankruptcy by contractor/ subcontractor or supplier* | [74], [61], [62] |
| 12 | *Subcontractor's financial difficulties* | [70] |
| 13 | *Owner's/ contractor's cash flow problem* | [72], [55], [70], [44] |
| **Level 2: Resource Costs** | | |
| 1 | *High material costs* | Project1, Project 4 |
| 2 | *High equipment and machinery costs and rent ranges* | Project 4 |
| 3 | *High range of labor costs* | Project 5 |
| **Level 2: Contract and Overhead Costs** | | |
| 1 | *High range of overhead costs (e.g. office rents, contract costs, etc.)* | Project 2 |

### 3.4.5 External Factors

External Factors refers to those causes of changes which are related to Weather conditions, Natural and artificial disasters, Environmental and Security issues. Construction works are generally exposed to climatic conditions, which vary with the project location. Unknown and inclement weather conditions potentially increase the total project time and cost by changing the production rates or damages during construction. For instance rain and snow may stop construction works or reduce the productivity of labor and machinery especially in outdoor works. Moreover, weather conditions are really difficult to predict accurately and prepare for it in advance. Subsequently, climate and weather conditions are widely cited as one of the main causes of construction delays and unscheduled changes [87] [51].

Furthermore, improper construction methods or other human factors may cause manmade damages and disasters, which are called artificial disasters and then may lead to changes due to repair works. Natural disasters like typhoons or heavy rain may also cause to damages or incidents, and repair works may then lead to project changes.

Environmental factors like pollutions, environmental protection issues may cause to changes in projects.

Besides, "security problems" relevant to project site, equipment and manpower may cause changes in project by increasing the cost and time. Table 19 presents these type of "*Change Causes*" in detailed:

**Table 19:** Taxonomy of Change Causes - External Factors

| **Level 1: External Factors** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Weather Conditions** | | |
| 1 | *Hot weather effect on construction activities* | [73], [64], [61], [63], [45], [34] |
| 2 | *Weather changes* | [43], [18], [49] |
| 3 | *Humidity effect on construction activities* | [74] |

**Table 19:** Taxonomy of Change Causes - External Factors (continued)

| Level 1: External Factors | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Weather Conditions** | | |
| 4 | *Inclement weather effect on construction activities* | [44], [49] |
| 5 | *Wind effect on construction activities* | [64], [61], [63] |
| 6 | *Rain/ snow effect on construction activities* | [74], [64], [61], [63], [45], [34] |
| 7 | *Freezing effect on construction activities* | [74], [61] |
| 8 | *Blizzards* | [88] |
| 9 | *Storms* | [88] |
| 10 | *Hurricanes* | [64], [68], [63] |
| 11 | *Tornadoes* | [89] |
| 12 | *Cyclones* | [88] |
| **Level 2: Natural and Artificial Disasters** | | |
| 1 | *Artificial/ Manmade disasters* | [46], [17] |
| 2 | *Earthquakes* | [6], [68], [89], [17] |
| 3 | *Landslides* | [88] |
| 4 | *Volcanic eruptions* | [88] |
| 5 | *Floods* | [6], [64], [68], [89], [63], [75], [62], [17] |
| 6 | *Limnic eruptions* | [88] |
| 7 | *Tsunamis* | [88] |
| 8 | *Droughts* | [88] |
| 9 | *Wildfires* | [88] |
| 10 | *Avalanches* | [88] |
| **Level 2: Environmental Issues** | | |
| 1 | *Environmental issues* | [61], [46] |
| 2 | *Environmental protection and mitigation costs* | [90] |
| 3 | *Problems due to site pollution and noise* | [65] |
| 4 | *Conservation restrictions* | [6] |
| 5 | *Environmental concerns and restrictions* | [78], [44], [74] |
| **Level 2: Security issues** | | |
| 1 | *Problems due to site security considerations* | [6] |
| 2 | *Theft/ Vandalism inside the site* | [61], [75] |

### 3.4.6 Health and Safety

This category of taxonomy is referred to "*Change Causes*" which are related to health and safety considerations of project. These issues include cases related to the safety of site or working conditions of workers and personnel as well as safety considerations of machinery. "*Change Causes*" may also come from specific health conditions in the site, such as personnel health considerations and other health restrictions. Health and safety considerations may cause to changes in construction projects by increasing the construction or overhead costs, time overruns and even design or location changes. Table 20 indicates causes of changes in this category:

**Table 20:** Taxonomy of Change Causes - Health and Safety

| **Level 1: Health and Safety** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Safety Considerations** | | |
| 1 | *Problems due to site safety considerations/Poor safety conditions* | [65], [6], [82] |
| 2 | *Accident during construction* | [73], [68], [61], [78], [85], [75], [62], [34] |
| 3 | *Unsafe practices during construction* | [61] |
| 4 | *Damage to structure* | [64], [63] |
| 5 | *Lateness in safety facilities reinforcement* | [6] |
| 6 | *Loose safety rules and regulations within the contractor's organization* | [60] |
| 7 | *Safety rules and regulations are not followed within the contractor's organization* | [76] |
| 8 | *residential safety* | [46] |
| 9 | *Work Incidents* | [47], [17] |
| **Level 2: Health Considerations** | | |
| 1 | *Epidemics* | [86], [75], [62] |
| 2 | *Pandemics* | [88] |
| 3 | *Endemics* | [88] |
| 4 | *Poisoning* | [88] |

**Table 20:** Taxonomy of Change Causes - Health and Safety (continued)

| Level 1: Health and Safety | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Health Considerations** | | |
| 5 | *Famines* | [64], [75], [62] |
| 6 | *Too high noise level* | [61] |
| 7 | *Labor injuries* | [91], [91] |

### 3.4.7 Project Location

Project Location related causes include change factors involving ground conditions, project site conditions and restrictions and also accessibility and possession of project location and site.

In numerous construction projects unknown geological conditions potentially increase the total project cost and time by extra ground works, or design changes and even by increasing the quantity of related cost items during construction. These geological conditions that are usually unknown, involve subsurface conditions, unforeseen utilities and objects, and contaminants. When projects encounter these unknown conditions, generally it would be required to stop the work in order to acquire permits and design approvals. For instance inaccurate geological surveys may cause to encounter with different soil strength from expectations and lead to changes in foundation location and depth. Insufficient landform information and ground elevation may also cause to construction changes. Groundwater location also affects the construction drainage and incomplete information about ground water can lead to changes.

Extra surveys and monitoring can be needed due to differences between the survey results and real site conditions. Moreover, the original planimetric features of project location may have been changed by natural or artificial events which in turn may cause to any change in co-ordination with the existing landscape. All of these geological cases and more can cause construction change during project lifecycle since it is sometimes hard to foresee all geological conditions until project execution

starts. The exposure of a project to unknown geological conditions mostly depends on the project type and location.

Project site restrictions like traffic problems may not let to contractor to execute the project in accordance with design and specifications and change orders may be required. These changes may include construction method and material, design and specifications and even project scope.

In some cases the accessibility of project site may be impossible or with some restrictions due to site acquisition by owner. This kind of problems during construction may lead to considerable costly changes in project such as project stoppage and location or route changes. Table 21 indicates this kind of "*Change Causes*" in detailed:

**Table 21:** Taxonomy of Change Causes - Project Location

| **Level 1: Project Location** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Ground Conditions** | | |
| 1 | *Unexpected foundation conditions encountered in the field* | [64], [63], [45], [17] |
| 2 | *Incomplete geological survey/ information* | [46] |
| 3 | *Groundwater location* | [46] |
| 4 | *Unexpected subsurface conditions (geological problems/ underground water level problems, etc.)* | [73], [64], [68], [55], [71], [63], [44], [45], [34] |
| 5 | *Unknown geological conditions* | [40], [17] |
| 6 | *Uncertainty in locating pipe positions under ground* | [46] |
| 7 | *Archaeology findings (unexpected archaeological finds)* | [39] |
| 8 | *Interferences of existing utilities* | [61], [78] |
| 9 | *Unanticipated utilities* | [61] |
| 10 | *Mistakes in soil investigation* | [64], [63], [45] |
| 11 | *Unforeseen ground conditions (rock, acid, sediment basin)* | [65], [6], [72], [82], [78], [77], [55], [69], [44] |
| 12 | *Ground elevation and landform* | [46] |
| **Level 2: Site Condition and Restrictions** | | |
| 1 | *Locational project restrictions* | [49] |

**Table 21:** Taxonomy of Change Causes - Project Location (continued)

| Level 1: Project Location | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Site Condition and Restrictions** | | |
| 2 | *Changes made by the contractor on site conditions* | [46] |
| 3 | *Differing site conditions* | [18] |
| 4 | *Differences between the original survey and on-site conditions* | [46] |
| 5 | *Unforeseen site conditions* | [59], [65], [6], [64], [61], [52], [82], [63], [34], [58], [69] |
| 6 | *Traffic control regulation and restriction at job site* | [68], [34], [73], [64] |
| 7 | *Poor site storage capacity* | [65], [61] |
| 8 | *Overcrowded work area/Congestion* | [61], [84] |
| 9 | *Poor site layout* | [65], [61], [58] |
| 10 | *Problems due to site restrictions* | [6] |
| **Level 2: Accessibility and Possession** | | |
| 1 | *Delay in site preparation and delivery* | [59], [73], [76], [83], [68], [61], [72], [85], [34], [60] |
| 2 | *Owner failure to provide construction sites on time* | [46] |
| 3 | *Expropriation costs (under estimated expropriation costs)* | [39] |
| 4 | *Difficulty in site acquisition/Failure to provide property* | [66], [6], [82], [62] |
| 5 | *Poor site access and availability/ Restricted access to the site* | [65], [83], [72], [82], [78], [75], [62] |
| 6 | *Failure of the employer over ingress and egress* | [66], [6], [82] |
| 7 | *Failure of the employer to provide right of way* | [62] |

### 3.4.8 Project Involved Parties

This category includes "*Change Causes*" related to the characteristic factors of project participants including "contractor and subcontractor", "consultant and designer", "owner and client", "project operator parties", "procurement companies" and etc. These causes include "proficiency and experience" of parties, "needs and expectations", and "culture and ethics". During the validation part of the study based on respondent's suggestions a subcategory in this section named "organizational

complexity" deleted from this part and consolidated with "Organization and Bureaucracy" category under "Project Management and Administration" group.

Inexperienced and unprofessional parties usually make excessive changes during project design and construction. These changes may arise by each project party; for instance, contractor may not have sufficient experience in similar projects, or consultant may also be unfamiliar with that kind of project as well as the owner which may not have adequate experience in specific type of construction projects. All these factors can cause significant changes and conflicts in project lifecycle.

The variable needs and expectations of parties may cause changes in construction projects during their lifecycle. These are mostly caused by variations in client's expectations; for instance, requirement updates, financial issues, demand for accelerated completion, safety considerations, market demands, etc. When requirements are changed, design solutions need to be modified accordingly. Moreover, since new construction techniques or materials are developed during long-term projects, owners may also request some variations to reduce costs or accelerate project completion.

The owner may also make changes to reach specific milestones within government stipulated timeframes. Project Commissioning is usually executed when the construction phase is close to completion. The user party, during the commissioning stage, may raise requests for changes in order to achieve its requirements for maintenance or other reasons.

The cultural and ethical factors of project participants such as opportunistic behavior, fraud, obligation or adherence to agreements can also trigger the project changes. Table 22 shows these kinds of "*Change Causes*" in detail:

**Table 22:** Taxonomy of Change Causes - Project Involved Parties

| **Level 1: Project Involved Parties** (Contractor, Client, Consultant, Designer, etc.) | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Proficiency and Experience** | | |
| 1 | *Lack of working knowledge of owner* | [69] |
| 2 | *Lack of consultant's knowledge* | [43], [46], [17] |
| 3 | *Consultant's inability* | [47] |
| 4 | *Lack of experience of owner in construction projects* | [68] |
| 5 | *Lack of proper training/ experience of contractor* | [79] |
| 6 | *Inexperienced contractor/ Poor/Inadequate contractor experience* | [65], [6], [68], [52], [72], [78], [77], [49], [71], [44], [60] |
| 7 | *Contractor's lack of geographical experience* | [49] |
| 8 | *Contractor's lack of project type experience* | [49] |
| 9 | *Non-familiarity of contractor with local regulations* | [49], [57] |
| 10 | *Lack of experience on the part of the consultant* | [73], [68], [34], [58], [69], [60] |
| 11 | *Incompetent project team* | [68] |
| 12 | *Poor knowledge of local statues* | [82] |
| 13 | *Inadequate design-team experience* | [77], [34], [44], [86], [6], [68] |
| 14 | *Insufficient training of designers* | [86] |
| **Level 2: Needs and Expectations** | | |
| 1 | *Unrealistic cost/ time /quality targets/expectations and requirements by owner* | [83], [82], [44] |
| 2 | *Contractor's desire to improve his financial situation* | [18] |
| 3 | *Unrealistic information expectations by owner* | [82] |
| 4 | *Special owner requirements (i.e. Maintenance, Safety considerations, Achieving certain Milestones)* | [46] |
| 5 | *Unclear/ not well-defined owner's needs during the design stage* | [57] |
| 6 | *Confusing and ambiguous requirements by owner* | [65] |
| 7 | *Growing needs of parties* | [47] |
| 8 | *Introduction of major changes in requirements* | [62] |
| 9 | *Changes in owner's requirements* | [86] |
| 10 | *Misunderstanding of owner's requirements by design engineer* | [68], [34] |

**Table 22:** Taxonomy of Change Causes - Project Involved Parties (continued)

| **Level 1: Project Involved Parties** (Contractor, Client, Consultant, Designer, etc.) | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Culture and Ethic** | | |
| 1 | *Non-adherence to contract conditions by owner/ contractor* | [64], [63] |
| 2 | *Misuses of variations instructions by contractor* | [57] |
| 3 | *Owner's personality and characteristics* | [71], [44] |
| 4 | *Uncooperative owner* | [64], [71], [63], [45], [60] |
| 5 | *Project fraud and corruption by contractor/ consultant* | [79], [65], [60] |
| 6 | *Opportunistic behavior of contractor* | [82] |
| 7 | *Inflexibility (rigidity) of consultant/ client* | [34], [60] |

### 3.4.9 Project Management and Administration

This category includes the factors related to "Project and Site Management", "Supervision and Quality Management", "Scheduling, Planning and Control", "Communication and Coordination" and "Organization and Bureaucracy".

Generally, construction projects management include complex operations involving the co-ordinations of numerous inter-related activities executed by various parties. The main contractor of project is responsible for planning, scheduling and managing the entire construction process on site. Poor and inefficient site management and supervision by contractors is one of the major causes of project changes and delays [16] [44]. This can be a result of inadequate experience, insufficient managerial skills or improper management structure [44] [45]. A poor site management leads to delays in responding to the problems that occur at project site and causes unfavorable impact on the entire project progress.

Poor supervision and quality control also can lead to delays and reworks during construction phase which are usually time and cost consuming changes. Inspection delays or delays in inspections can cause significant delays in project progress. Moreover, the inability of contractor or consultant in effective supervision and

control may cause to poor workmanship and considerable amount of demolition and rework.

Project planning and scheduling is generally performed at the project inception when numerous input variables are unclear and uncertain; therefore, estimations and assumptions need to be developed. Inefficient planning and scheduling which result in variations in assumptions during project execution will lead to variations in the baseline project plan. Frequent changes involve delays of start and finish time of tasks, deletion and addition of tasks, variation of resources, and etc. The optimistic and unrealistic schedule, resulting from inaccurate estimations may also cause to changes during project lifecycle. Only a project that is well planned can be well executed [56].

The construction projects generally include temporary construction, engineering and management teams. A project would be successful when a good communication and collaboration between all project participants would be developed. However, poor and inefficient communications are frequent in practice and are considered as one of the main cause of project changes and reworks [92] [93].

Any problem in communication between project parties can cause severe conflicts and disputes which are frequent source of project changes; therefore, delays and other changes may occur in the project lifecycle.

Another factor in construction change is the past experience of project parties with each other. Any type of good or bad past experience between project participants will help to reduce conflicts and misunderstandings.

The organizational structure of project parties as well as excessive bureaucracy may cause change in a project. Delays in issuance of orders and slow decision making processes are examples of organizational cause of changes. Table 23 indicates this type of "*Change Causes*" in detail:

**Table 23:** Taxonomy of Change Causes - Project Management and Administration

| Level 1: Project Management and Administration | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Project and Site Management** | | |
| 1 | *Poor site management by consultant* | [78], [70] |
| 2 | *Poor project management by contractor* | [57] |
| 3 | *Inadequate/ poor project management assistance by consultant* | [68] |
| 4 | *Lack of proper training and experience of project manager* | [79] |
| 5 | *Unsuitable leadership style of construction/project manager* | [65], [6], [77], [71] |
| 6 | *Unsuitable management structure and style of contractor* | [6], [77] |
| 7 | *Non-utilization of professional construction management* | [64] |
| 8 | *Inadequate site/project management skills/ Inadequate managerial skills* | [6], [77] |
| 9 | *Poor site management and slow site clearance* | [65], [68], [61] |
| 10 | *Poor site management by contractor* | [65], [83], [68], [61], [52], [72], [78], [77], [85], [71], [44], [62], [34], [67], [58], [69], [60], [70] |
| 11 | *Failure to utilize tools to manage the project symmetrically by contractor/project manager* | [65] |
| 12 | *Inaccurate site investigation by consultant* | [68] |
| 13 | *Poor quality of site documentation* | [82], [58] |
| 14 | *Lack of available resources/ Poor control of site resource allocation* | [59], [65], [6], [82], [77], [71], [62] |
| 15 | *Unavailability of the project management group for the project* | [71] |
| 16 | *Lack of experiences in project management process* | [64] |
| **Level 2: Supervision and Quality Management** | | |
| 1 | *Delay in performing inspection and testing by consultant* | [83], [68], [55], [34], [60] |
| 2 | *Waiting time for sample materials approval* | [82], [71], [63], [45], [60] |
| 3 | *Poor supervision by consultant* | [78], [70] |
| 4 | *Poor labor supervision* | [61] |
| 5 | *Waiting time for site inspection and approval of quality control tests or results by consultant* | [83], [61], [78], [71] |
| 6 | *Poor inspection and supervision by contractor* | [65], [83], [68], [61], [52], [72], [78], [77], [85], [71], [44], [62], [34], [67], [58], [69], [60], [70] |

**Table 23:** Taxonomy of Change Causes - Project Management and Administration (continued)

| Level 1: Project Management and Administration | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Supervision and Quality Management** | | |
| 7 | *Poor inspection and testing procedure used in project by consultant* | [64], [63], [45] |
| 8 | *Poor quality assurance and quality control by consultant* | [52] |
| 9 | *Slow response by the consultant engineer regarding testing and inspection* | [76] |
| 10 | *Inefficient quality assurance and quality control* | [74], [65], [76], [60] |
| 11 | *Long waiting time for approval of test samples and materials* | [6], [64], [82], [77], [34] |
| 12 | *Delay in performing final inspection and certification by a third party* | [68], [61], [73], [34] |
| 13 | *Failure by the consultant to perform supervision effectively* | [57] |
| **Level 2: Scheduling, Planning and Control** | | |
| 1 | *Change of project schedule* | [43] |
| 2 | *Contractor experience in planning and controlling the projects* | [44] |
| 3 | *Too optimistic schedules* | [74], [61], [47] |
| 4 | *Non-availability of overall project planning* | [57] |
| 5 | *Overestimation of the labor productivity* | [71] |
| 6 | *More work exists than planned* | [74] |
| 7 | *Ineffective planning and scheduling of project by contractor* | [34] |
| 8 | *Lack of database in estimating activity duration and resources* | [86], [64], [71], [63], [45] |
| 9 | *Inaccurate estimate of materials, labor output, equipment production rates* | [61], [72], [49] |
| 10 | *Inaccurate evaluation of projects time/duration* | [86], [79] |
| 12 | *Nonuse of appropriate software for scheduling and controlling* | [79] |
| 13 | *Contractors' planning and scheduling problems* | [70] |
| 14 | *Unrealistic project schedule/ design period* | [65], [57] |
| 15 | *Poor judgment and experience of involved people in estimating time and resources* | [64], [63], [45] |
| 16 | *Lack of experiences in project scheduling process* | [64] |
| 17 | *Inadequate early planning of the project* | [64], [72], [63], [45] |
| 18 | *Unreasonable/ unpractical initial plan* | [86] |

**Table 23:** Taxonomy of Change Causes - Project Management and Administration (continued)

| Level 1: Project Management and Administration | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Scheduling, Planning and Control** | | |
| 19 | *Poor project planning and scheduling by contractor* | [86], [73], [65], [76], [68], [61], [72], [82], [49], [55], [62], [67], [58], [60] |
| 20 | *Inefficient/ poor work breakdown structure* | [60] |
| 21 | *Problems with timelines of project information* | [64], [63] |
| 22 | *Contractor's deficiencies in planning and scheduling at preconstruction stage* | [6], [52], [77], [49], [34] |
| 23 | *Conflicts between different subcontractors' schedules in execution of project* | [73], [64], [77], [63], [45], [34] |
| 24 | *Ineffective control of the project progress by the contractor/ Inadequate progress review* | [76], [64], [55], [71], [63], [60] |
| 25 | *Poor resource allocation by contractor* | [88] |
| 26 | *Natural growth of the project was not anticipated at the design stage* | [57] |
| **Level 2: Communication and Coordination** | | |
| 1 | *Poor communication and coordination between designers* | [86], [65], [61], [82] |
| 2 | *The lack of coordination between contractor and consultant* | [18] |
| 3 | *Communication among the various parties* | [44] |
| 4 | *Insufficient communication between the owner and designer in design phase* | [64], [72] |
| 5 | *Lack of involvement of design team during construction stage* | [65] |
| 6 | *Lack of contractor's involvement in design* | [43] |
| 7 | *Conflicts between consultant and design engineer* | [68], [77], [34], [60] |
| 8 | *Poor communication and coordination by consultant with other parties* | [73], [65], [76], [64], [68], [82], [78], [77], [34], [58], [60] |
| 9 | *Failure on the part of the owner to properly coordinate multiple contractors* | [59], [83], [61], [75], [62] |
| 10 | *inadequate communication before design* | [17] |
| 11 | *Conflicts between joint-ownership of the project* | [73], [64], [68], [77], [63], [45], [34], [60] |
| 12 | *Conflicts between owner and other parties (contractor, consultant)* | [79], [77], [63], [45], [34] |
| 13 | *Poor communication between relevant governmental units and the owner* | [57] |

**Table 23:** Taxonomy of Change Causes - Project Management and Administration (continued)

| Level 1: Project Management and Administration | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Communication and Coordination** | | |
| 14 | *Poor communication and coordination by owner with other parties (construction parties and government authorities)* | [73], [65], [76], [64], [68], [72], [82], [78], [63], [45], [34], [58], [60] |
| 15 | *Lack of communication and coordination between the parties involved in construction* | [65], [64], [52], [82], [78], [84], [71], [58], [69] |
| 16 | *Poor communication and coordination by subcontractor with contractor/other parties* | [64], [72] |
| 17 | *Conflicts between contractor and other parties (consultant, owner)* | [73], [64], [79], [77], [63], [45], [34], [60] |
| 18 | *Poor communication and coordination by contractor with other parties* | [73], [65], [76], [64], [68], [72], [82], [78], [62], [34], [58], [69], [60] |
| 19 | *Poor trade coordination* | [59], [61] |
| 20 | *Contractor's failure to coordinate the work, i.e., deficient planning, scheduling, and supervision* | [75] |
| 21 | *Incomplete/ incorrect information by owner* | [47] |
| 22 | *Owner's failure to provide information* | [47] |
| 23 | *Inadequate information and supervision by the owner* | [59], [75], [62] |
| 24 | *Insufficient or ill-integrated basic project data that is needed to be provided by owner* | [86] |
| 25 | *Slow information flow between project team members* | [82], [77], [55] |
| 26 | *Insufficient or ill-integrated basic project data that is needed to be provided by contractor* | [86] |
| 27 | *Ineffective contractor head office involvement in the project* | [60] |
| 28 | *Personal conflicts among labors* | [73], [68], [77], [34], [60] |
| 29 | *Labor and management relations* | [64], [63] |
| 30 | *Unnecessary interference by the owner/ Owner's interference* | [59], [74], [94], [76], [61], [52], [75], [60] |
| 31 | *Slow information delivery between designers* | [86] |
| 32 | *Poor information dissemination/provision by consultant* | [58], [70] |
| 33 | *Subcontractor interference* | [74] |
| **Level 2: Organization and Bureaucracy** | | |
| 1 | *Delay in issuance of change orders by the owner* | [60] |

**Table 23:** Taxonomy of Change Causes - Project Management and Administration (continued)

| Level 1: Project Management and Administration | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Organization and Bureaucracy** | | |
| 2 | *Speed of decision making involving all project teams* | [44] |
| 3 | *Changes of decision-making authority* | [47] |
| 4 | *Slow decision making by designers* | [86], [72] |
| 5 | *Slow preparation of scheduling networks and revisions by consultant while construction is in progress* | [63], [45] |
| 6 | *Late preparation of interim valuation by consultant* | [70] |
| 7 | *Delay in the settlement of contractor claims by the owner* | [76], [60] |
| 8 | *Late valuation of variation works by consultant* | [70] |
| 9 | *Delayed and slow supervision in making decisions* | [55], [58], [69] |
| 10 | *Delay in the approval of contractor submissions by the consultant engineer* | [76], [82], [55], [70] |
| 11 | *Late issuance of instruction by the consultant engineer* | [83], [95], [69], [70] |
| 12 | *Slow response by the consultant engineer to contractor inquiries* | [76] |
| 13 | *Problems due to company organization of consultant* | [72], [60] |
| 14 | *Slow responses from the owner's organization* | [65] |
| 15 | *Failure to give timely orders/instructions for work by owner* | [59], [83], [95], [75], [62] |
| 16 | *Excessive bureaucracy by owner's administration* | [86], [64], [71], [63], [60] |
| 17 | *Slowness in decision making process by owner* | [73], [76], [64], [68], [61], [52], [72], [82], [55], [71], [63], [45], [34], [67], [58], [69], [60], [70] |
| 18 | *Inappropriate overall structure linking all parties in project* | [6], [77], [60] |
| 19 | *Low speed of decision making involving all project teams* | [77], [55] |
| 20 | *Low speed of decision making within each project team* | [77], [55] |
| 21 | *Lack of responsibility of project manager/ contractor* | [65] |
| 22 | *Lack of authority of contractor/project/site manager* | [67] |
| 23 | *Inadequate instructions by contractor* | [61] |
| 24 | *Lack of timely decisions and corrective actions by contractor/ project manager* | [65] |
| 25 | *Slow response by contractor/project manager* | [65] |
| 26 | *Delay in preparation of contractor submissions* | [60] |

**Table 23:** Taxonomy of Change Causes - Project Management and Administration (continued)

| Level 1: Project Management and Administration | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Organization and Bureaucracy** | | |
| 27 | *Problems due to company organization of contractor* | [72], [60] |
| 28 | *Unilateral decisions made by the owner without proper considerations to the contract* | [57] |
| 29 | *Internal company problems of contractor* | [60] |
| 30 | *Ill-defined duties and responsibilities by contractor's company organization* | [65], [67] |
| 31 | *Inadequate decision making mechanism of contractor's company organization* | [67] |
| 32 | *Delay in approving major changes in the scope of work by consultant* | [73], [68], [52], [34], [60] |
| 33 | *Large number of participants of project* | [65] |
| 34 | *Involvement of several contractors/ foreign contractors* | [65] |
| 35 | *Project commissioning and ownership transfer* | [47] |

### 3.4.10 Contract Management

This category involves "*Change Causes*" related to contract documents and contract management issues. These factors are briefly divided into three general subcategories named: "Project Scope and Characteristic", "Bidding and Project Delivery", and "Contract administration and Documents".

Project scope and characteristics have a significant effect on project changes. Project scope defines the quality and quantity of work should be performed. Scope and the objective of a project is defined and explained in contractual documents; therefore, it should be clearly stipulated in contractual documents so each party has a common understanding about it. The accuracy and clarity of project scope and objectives have a critical role in project performance. Hence, lack of proper scope definition or variations on project scope during construction, would cause significant changes in project cost and time since the accuracy level of cost estimation strongly depends on the quality of scope definition. In fact, poor scope definition has been stated to be a

major source of bad estimates which in turn leads to numerous changes in project. Furthermore, vagueness in project scope is a potential cause for future changes in project scope which generally leads to an increase in cost and time. Changes in scope usually result in addition of new activities and resources in project schedule that will increase the actual cost of the project. Besides, when the scope of a project is frequently changing, it would be hard to estimate the project duration so this generally affects the estimation of overhead costs. In general, a large number of cost overruns during the construction phase derive from scope improvement.

Project characteristics such as project size and complexity also have a significant effect on project change. The uniqueness nature of construction projects often increases the complexity of projects, which in turn increases the chances of change occurring [44] [49].

Previous studies have demonstrated that project size also can influence the change occurrence. It is difficult to identify that how project size affects the risk of change in a construction project. Both project complexity and project size should be considered together in order to determine the effect of project size on change. Past experiences show that if a project is extremely complex, like most of the huge projects, it can be expected that change will happen unless specific attention is provided by project management team.

Bidding and contract awarding process has also a significant effect on project changes. Type of project bidding and delivery system usually affects the changes in construction projects. For instance, contracts awarded on the basis of low costs are particularly prone to future changes and accordingly to disagreements between the project parties. Such conflicts can also cause claims and disruption on project progress and increase project cost and schedule.

Contract type and context as well as contract administration can also affect the project change. For example, the system used in contract for dealing with inflation, risk allocation system between parties and the efficiency of contract clauses can cause several changes during project lifecycle. Table 24 indicates this category of "*Change Causes*" in detailed:

**Table 24:** Taxonomy of Change Causes - Contract Management

| Level 1: Contract Management | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Project Scope and Characteristics** | | |
| 1 | *Technological complexity* | [6] |
| 2 | *Technical challenges* | [90] |
| 3 | *Complexity of works* | [86], [79] |
| 4 | *Risk and uncertainty associated with projects* | [79] |
| 5 | *Project characteristics* | [44] |
| 6 | *Project size* | [40] |
| 7 | *Vagueness in scope* | [40] |
| 8 | *Inadequate project objectives* | [43] |
| 9 | *Inadequate scope of work for contractor* | [43] |
| 10 | *Poor scope definition* | [86], [61], [18] |
| 11 | *Uniqueness of project* | [57] |
| **Level 2: Bidding and Project Delivery** | | |
| 1 | *Type of project bidding and award (lowest bidder, negotiation, etc.)* | [72], [55], [34], [60] |
| 2 | *Lack of clear bidding process/Exceptionally low bids* | [65], [72], [78], [84] |
| 3 | *Insufficient time for bid preparation* | [84] |
| 4 | *Lack of experiences and information preparing in price quotation* | [64] |
| 5 | *Type of construction contract/project delivery system (Turnkey, design-build, general contracting, construction only)* | [64], [34], [60], [82] |
| 7 | *Selection of inappropriate type of main construction* | [77] |
| 8 | *Inappropriate contractor or consultant selection* | [65], [82] |
| 9 | *Improper project feasibility study* | [65], [68] |
| 10 | *Improper technical study by the contractor during the bidding stage* | [76], [60] |
| 11 | *Faulty negotiations and obtaining of contracts* | [64], [82], [63], [45] |
| 12 | *Improper selection of subsequent consultants* | [86] |
| 13 | *Low consultancy fee* | [57] |
| 14 | *Owner's late contract award* | [61], [70] |

**Table 24:** Taxonomy of Change Causes - Contract Management (continued)

| Level 1: Contract Management | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Bidding and Project Delivery** | | |
| 15 | *Failure by the consultant to provide adequate and clear information in the tender documents* | [57] |
| **Level 2: Contract Administration and Documents** | | |
| 1 | *Imbalance in the risk allocation by owner* | [82], [78] |
| 2 | *Conflicts between contract documents* | [43], [18] |
| 3 | *Poor contract management by consultant/ contractor* | [52], [55], [65], [64], [72], [85], , [63] |
| 4 | *Inadequate contract administration* | [61], [82] |
| 5 | *Non-utilization of professional contractual management* | [64] |
| 6 | *Legal disputes b/w various parties* | [34] |
| 7 | *Inadequate definitions/contract clauses in contract* | [68], [34] |
| 8 | *Disagreements on contract clauses* | [67] |
| 9 | *Mistakes and discrepancies in contract documents due to owner* | [65], [64], [79], [52], [78] |
| 10 | *Gray areas in general conditions* | [57] |
| 11 | *Incomplete/erroneous contract documentation* | [82] |
| 12 | *Poor interpretation of contract clauses* | [82] |
| 13 | *Inappropriate contract form* | [82] |
| 14 | *Poor contract familiarity/Owner's contracting procedures* | [82] |
| 15 | *Contract and specification interpretation disagreement* | [79] |
| 16 | *Poor contract interpretation* | [82] |
| 17 | *Ineffective delay penalties in contract* | [64], [68], [34], [60] |
| 18 | *Unavailability of financial incentives for contractor for finishing ahead of schedule in contract* | [64], [68], [63], [45], [34], [60] |
| 19 | *Unrealistic contract duration imposed by owner* | [86], [6], [64], [52], [72], [78], [77], [71], [44], [67], [34] |
| 20 | *Contract modifications (replacement and addition of new work to the project and change in specifications)* | [64], [72], [71], [63], [69] |
| 22 | *Mistakes and discrepancies in contract documents due to contractor* | [65], [64], [79], [52], [78] |
| 23 | *Improper or wrong cost estimation* | [86], [55] |
| 24 | *Errors, incomplete or inaccurate information in pricing document* | [17] |

**Table 24:** Taxonomy of Change Causes - Contract Management (continued)

| Level 1: Contract Management | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Contract Administration and Documents** | | |
| 25 | *Inaccurate estimates - errors or omissions in quantity estimating/inaccurate bills of quantities* | [74], [6], [78] |
| 26 | *Erroneous, incomplete or inaccurate pricing documents* | [46] |
| 27 | *Underestimates or omissions by consultant* | [47] |
| 28 | *Unreasonable estimation and adjustment of the project cost* | [39] |
| 29 | *Unreasonable risk allocation by contractor* | [65] |

### 3.4.11 Design and Specifications

This category involves "*Change Causes*" related to design documents and process including: "Accuracy of Design Documents", "Changes in Design and Specifications", "Design Process" and "Characteristics of Design".

It is obvious that design changes usually happen during construction projects and mostly cause to considerable changes in projects such as cost overruns and schedule delays.

Because of various restrictions, ideal design without errors and defects is mostly improbable and unrealistic; therefore, design changes are inevitable in construction projects. Errors and omissions in design and design documents are one of the major causes of changes during the project construction phase [46] [16].

Poorly executed design drawings and inadequate investigation of site before the design period may also lead to changes in order to permit the construction to be completed, particularly where changes are required to adapt to site conditions.

Change in designs and specifications during project lifecycle may also cause significant changes. Burati et al. [8] classified the design changes into three categories according to their causal factors they described that:

1. “Design changes caused by improvement through design process (DCI). Examples are changes resulting from design reviews, technological advances or constructability reviews”.

2. “Design changes originated by Owner (DCO). Examples are scope changes”.

3. “Design changes initiated by Engineer or Consultant familiar with the process (DCP).Examples are additions of pumps, valve or instrumentation that affect the operation of the facility”.

Furthermore, changes may be caused by factors related to design process such as design software, delay in designing or approving process, lack of standards and codes and etc.

Characteristics of design like design complexity and constructability are another possible cause of changes during project lifecycle. Design complexity is defined as “the function of constructability of the design, the use of advanced technology, specialized equipment and specialized methods, and the integration of multiple disciplines” [96].

Generally, complex designs are mostly prone to change significantly during project lifecycle; because of the existing difficulties in visualizing the construction process and estimating the quantities, unit costs and production rates related to the project accurately. Detailed causes of changes in this category are indicated in Table 25:

**Table 25:** Taxonomy of Change Causes - Design and Specifications

| **Level 1: Design and Specifications** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Accuracy of Design Documents** | | |
| 1 | *Errors and omissions in design* | [43], [57] |
| 2 | *Inadequate shop drawing details* | [43] |
| 3 | *Unclear and inadequate details in drawings* | [73], [83], [68], [34] |
| 4 | *Incomplete/Defective/Poor design drawings, specifications or documents* | [59], [86], [76], [6], [83], [61], [84], [71], [75], [62], [58], [70], [46] |

**Table 25:** Taxonomy of Change Causes - Design and Specifications (continued)

| Level 1: Design and Specifications | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Accuracy of Design Documents** | | |
| 5 | *Errors and omissions in design documents and defective specifications* | [82], [83], [51], [65], [18], [46] |
| 6 | *Inaccurate design information* | [61], [82] |
| 7 | *Inaccurate design documentation* | [82] |
| 8 | *Poorly executed design drawings* | [17] |
| 9 | *Design errors made by designers* | [72], [64], [71], [63], [68] |
| 10 | *Outdated designs and specifications* | [57] |
| 11 | *Failure by the consultant to perform design effectively* | [57] |
| 12 | *Mistakes and discrepancies in design documents* | [77], [44], [6], [74], [73], [68], [34] |
| 13 | *Inconsistency between drawings and site conditions* | [6] |
| 14 | *Poor design quality – improper/ wrong /impractical design* | [72], [82], [58], [86], [65] |
| 15 | *Citation of inadequate specification* | [6], [58] |
| **Level 2: Changes in Design and Specifications** | | |
| 1 | *Change/ modifications in designs by owner* | [43], [57] |
| 2 | *Change in design by consultant* | [18] |
| 3 | *Change of plan by owner/ client* | [18] |
| 4 | *Change in specifications* | [43] |
| 5 | *Design changes in respond to site conditions* | [6], [97] |
| 6 | *Design changes due to poor brief, errors and omissions* | [6], [97] |
| 7 | *Change orders by deficiency design* | [86], [97] |
| **Level 2: Design Process** | | |
| 1 | *Insufficient data collection, survey and site investigation prior to design* | [73], [6], [68], [84], [34], [46], [17] |
| 2 | *Insufficient material/ Equipment investigation before design* | [88] |
| 3 | *Difficulties in preparation and approval of shop drawings* | [44] |
| 4 | *Involvement of several designers/ foreign designers* | [65] |
| 5 | *Disagreements on design specifications* | [86], [67] |
| 6 | *No practical use of the earned value management system* | [39] |
| 7 | *Lack of standardization in design* | [65] |

**Table 25:** Taxonomy of Change Causes - Design and Specifications (continued)

| Level 1: Design and Specifications | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Design Process** | | |
| 8 | *Non-use of advanced engineering design software* | [73], [34], [68] |
| 9 | *Delays in design information* | [6], [73], [74], [72], [68], [77], [34], [67] |
| 10 | *Late in revising and approving design documents by owner* | [73], [68], [34], [60] |
| 11 | *Slow drawing revision and distribution* | [58] |
| 12 | *Long waiting time for approval of drawings* | [59], [6], [82], [95], [77], [85], [34] |
| 13 | *Delays in producing design documents* | [34] |
| 14 | *Slow correction of design errors* | [61] |
| 15 | *Late in reviewing and approving design documents by consultant* | [68], [52], [78], [71], [63], [34], [60] |
| 16 | *Slow preparation and approval of shop drawings by consultant* | [64], [72], [95], [62], [45], [51] |
| 17 | *Failure on the part of the owner to review and approve design documents, schedules, and material on time* | [73], [61], [75], [62], [60], [57] |
| 18 | *Problems related to using of building codes in design of projects* | [63], [45], [64] |
| 19 | *Over-design increasing the overall cost* | [65] |
| **Level 2: Characteristics of Design** | | |
| 1 | *Complex interfaces (urban environment, link to existing infrastructure)* | [39] |
| 2 | *Complexity of project design* | [43], [68], [34], [44], [86] |
| 3 | *Low constructability of design* | [65] |

### 3.4.12 Project Execution

In this category of taxonomy that causes of changes which are originated from the construction of project are included. These causes have been grouped in five part including: “Mobilization and Facilities”, “Logistic and Transportation”, “Construction Method and Technology”, “Subcontracting” and also “Performance and Workmanship”.

During the project construction numerous changes may occur due to project mobilization and existing facilities; for instance delay in mobilization and providing required facilities to start the project execution or during the construction phase.

Also poor mobilization, inefficient equipment arrangement and wrong site outline could lead to changes in project.

Some changes can be originated due to problems in transportation and logistics. Inadequate logistic coordination and planning, logistic problems due to various external and internal factors can also trigger project change and leads to cost and time overruns.

Construction method and technology could also cause to considerable changes during project execution. The contractor or consultant or even project owner may have a tendency to replace the original construction method by a new technology or method. This kind of change requests may be originated for the purpose of improving project quality, profitability, safety or environmental considerations. Furthermore, the complexity of construction method or the novelty of construction technology may also cause to apply changes in project which can even reduce project cost and time but impact other project aspects negatively. The risk of change occurrence in utilization of specific construction methods and advanced technology mostly depends on the newness of the technology and its previous results and performance in actual use [98]. The contractors with previous experience in the use of specific construction method or advanced technology generally have fewer problems in this field and accordingly the probability of change would be reduced.

Nowadays, there is an increasing trend to use subcontractors in projects rather than direct labor or equipment. This tendency has generated new challenges for main contractors such as managing the subcontracting process and complexity of coordinating and controlling the work among various subcontractors. Poor subcontracting or inadequate performance of subcontractor may cause significant changes in projects. For instance delay of one subcontractor in completing a typical task can cause secondary delays by other contractors [44]. The replacement of one

subcontractor with a new one is also another problem of subcontracting system which can leads to future changes during project lifecycle.

Although subcontracting system offers several benefits, it also generates additional risk factors for general contractor; such as subcontractor's technical and financial abilities, reliability and timeliness. These risk factors can result in project changes such as time loss and cost overrun during construction.

The performance of construction team including labors and subcontractors also has a considerable effect on project changes. Inadequate performance of construction team can cause to poor workmanship, delays, reworks and demolitions which in turn may cause changes in project cost, quality and schedule. Poor performance of team members also may lead to changes in project organization by replacing some team members or adding new organizational parts to apply additional investigations which would be cost and time consuming and affects the project progress.

Poor workmanship is also more prevailing in construction projects as a common cause of unexpected project change and rework [9] [46]. The errors and defect works during the construction phase may be due to several reasons like labor skill, accident or inadequate planning. Whatever the reason of construction errors and mistakes are, the poor workmanship can have a considerable impact on project progress. The "*Change Causes*" related to this category are indicated in Table 26 in detail:

**Table 26:** Taxonomy of Change Causes -Project Execution

| **Level 1: Project Execution** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Mobilization and Facilities** | | |
| 1 | *Delay in providing services from utilities (such as water, electricity)* | [68], [73], [34] |
| 2 | *Unavailability of utilities on site (water, electricity, telephone, etc.)* | [64], [45], [63], [34] |
| 3 | *Lack of temporary facilities on site (buildings, phones, electricity, etc.)* | [65], [64] |

**Table 26:** Taxonomy of Change Causes -Project Execution (continued)

| Level 1: Project Execution | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Mobilization and Facilities** | | |
| 4 | *External work due to public agencies (roads, utilities and public services)* | [69] |
| 5 | *Difficulties in obtaining energy (electricity, fuel)* | [67] |
| 6 | *Lockout or interruption or failure of electricity or telephone service* | [95], [75] |
| 7 | *Delay in site mobilization* | [76], [62], [59], [34], [85], [73], [60], [75] |
| 8 | *Slow mobilization of equipment* | [68] |
| 9 | *Slow mobilization of labor* | [68] |
| 10 | *Slow mobilization by subcontractor* | [75], [70], [62] |
| **Level 2: Logistics and Transportation** | | |
| 1 | *Transportation problems* | [63], [67] |
| 2 | *Transportation delays beyond control* | [85], [67], [69], [64] |
| 3 | *Poor logistic control by contractor* | [6] |
| **Level 2: Construction Method and Technology** | | |
| 1 | *Problems with new construction methods* | [6], [17] |
| 2 | *Improper construction method suggested by consultant* | [37] |
| 3 | *Changing the construction method due to current site conditions* | [17] |
| 4 | *Using obsolete or outdated construction method/ technology* | [65], [68], [57] |
| 5 | *Improper construction methods/techniques implemented by contractor* | [34], [58], [60], [52], [71], [63], [64], [68], [61], [73], [65], [76], [74], [46] |
| 6 | *Problems due to proportion of off-site prefabrication* | [44] |
| **Level 2: Subcontracting** | | |
| 1 | *Unavailability of the construction group for the project* | [71] |
| 2 | *Frequent change of subcontractors (because of their inefficient work)* | [73], [64], [68], [34], [60] |
| 3 | *Poor subcontract management* | [61] |
| 4 | *Poor subcontracting (system)* | [72], [44] |
| 5 | *Lack of subcontractor's skills* | [58], [69] |
| 6 | *Lack of subcontractor's experience* | [58], [69] |
| 7 | *Unreliable subcontractors* | [68] |

**Table 26:** Taxonomy of Change Causes -Project Execution (continued)

| Level 1: Project Execution | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Subcontracting** | | |
| 8 | *Time spent to find appropriate subcontractors for each task* | [63] |
| 9 | *Degree of subcontracting* | [44] |
| **Level 2: Performance and Workmanship** | | |
| 1 | *Defective workmanship* | [43] |
| 2 | *Workmanship not meeting the specification* | [18] |
| 3 | *Delay of field survey by contractor* | [60] |
| 4 | *Delays in subcontractor's work/Delay caused by subcontractor* | [75], [34], [60], [85], [71], [44], [52], [78], [77], [74], [73], [6], [61] |
| 5 | *Accelerating works* | [46] |
| 6 | *Inadequate contractor's work* | [34], [67], [60], [59], [73] |
| 7 | *Construction mistakes and defective work* | [71], [75], [69], [52], [82], [55] |
| 8 | *Delays in construction activities* | [39] |
| 9 | *Errors committed during field construction on site* | [63], [64], [45] |
| 10 | *Rework due to errors during construction* | [85], [34], [60], [68], [61], [84], [73] |
| 11 | *Rework due to subcontractor* | [61] |
| 12 | *Problems/Delays in labor that are in responsibility of the owner* | [84], [75], [62], [66], [83], [78], [59] |
| 13 | *Rework due to defective material* | [61] |
| 14 | *Suspension of work or wrongful termination by owner* | [62], [34], [60], [64], [68], [75], [86], [73], [76], [83] |
| 15 | *Low contractor productivity* | [75], [62] |
| 16 | *Poor workmanship* | [78], [85], [62], [61], [72], [82], [59], [6] |
| 17 | *Poor performance of subcontractors and nominated suppliers* | [79], [82], [62], [65], [64] |
| 18 | *Interference with other trades (trade stacking)* | [61], [70] |
| 19 | *Inappropriate/Inadequate use (misuse) of material* | [61], [72], [78], [58] |
| 20 | *Addition/ omission of work* | [47], [57] |
| 21 | *Work imposed that is not part of the contract by owner* | [66] |
| 22 | *Excessive scope changes and constructive changed orders* | [65], [76], [83], [97], [90], [84] |
| 23 | *Change in scope of work or in construction detail* | [75], [43], [39] |

### 3.4.13 Macro Factors

"Macro Factors" involves "*Change Causes"* related with national or global variables which generally occur outside the construction industry and out of the control of project participants. They have macro effects on project and project environment. This category is divided into five groups including "Social Factors", "Political Factors", "Economic Factors", "Influence of other parties", "Rules and Regulations related Factors".

Social factors such as protests, cultural factors and civil disorders may cause to changes during a project lifecycle. Arain and Pheng [35] have investigated the institutional building projects in Singapore and found that poor knowledge about the social and cultural characteristics of Singapore joined with inexperienced owners, has resulted in inappropriate designs which lead to various changes on designs, specifications, and even contract terms.

Construction projects can also be affected by political factors like elections, foreign policies and political pressures. This would be excessive in projects with a high level of local priority and importance which are called "political projects". Most of the political projects generally do not comply with the proper execution methods and procedures due to urgent politic considerations.

In some cases projects may face changes implemented by decision making authorities during the project lifecycle due to election, politics and conflicts with higher authorities. Changes of decision-making authorities can also trigger the project change. Obviously, these changes are external and beyond the control of project involved parties.

As Ashley and Bonner [99] stated, the political risk sources for changes in construction projects are related to factors including "Nature of the firm's operation", "Regional and external factors", "Influence of power groups", "Nationalists' attitude towards the firm", "Project desirability", "Government policy".

Changes in construction projects are significantly related with economic variations like market demand, inflation rates, currency rates and tax rates. Economic factors impact the unit cost rates of construction items and bring about cost increase in the project. The impact of economic issues on the project's cost overrun varies with the project duration and also with the country in which project is executed. The effect of this factor should not be disregarded in countries with a high degree of economic instability in which the inflation rates are excessive. In studying the economic causes of changes, should not only concentrate on the economic stability of a country but also on project duration and market conditions. The longer the project duration, the greater the effect of economic factors.

Third parties including projects, companies, organizations and people can cause changes in project. These "*Change Causes"* can be as negotiations with residents concerning critical factors like safety considerations, environmental protections, business interruption and land issue which can change the project schedule, by postponing the construction activities.

Furthermore, other organizations which are affected by the project may ask to commission related works by changing the construction plans during construction in order to facilitate the construction of other projects and prevent site conflicts.

Other organizations might be concerned about probable threats of project to their own facilities and business because of construction, or may have other safety considerations. Therefore, the project owner could be asked to modify the construction methods utilized or provide specific protections. Another example of influence of other parties and organizations on project which can lead to changes is piping system of individual organizations which may be incomplete. Moreover, actual pipe locations may be different from existing plans that can lead to changes in project.

Finally, another cause of project change can be the legislation and regulation changes such as regulations in health and safety issues, employment, environment protection, taxation, etc. [100]. Public projects usually experience an extensive schedule for planning, design and construction. The longer the project's duration,

the more it is vulnerable to changes involving rules and regulations. The rules and regulations observed during design and planning period can be revised by the governing organizations later during the construction stage. Table 27 indicates the "*Change Causes"* related to macro factors in detailed:

**Table 27:** Taxonomy of Change Causes -Macro Factors

| **Level 1: Macro Factors** | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Social Factors** | | |
| 1 | *Nationalization* | [68], [75] |
| 2 | *Protests (i.e. due to business interruptions, residential interruptions)* | [46], [17] |
| 3 | *Labor dispute* | [85], [63], [70], [64], [68], [61], [74], [83] |
| 4 | *Civil Disorders* | [92], [58], [101] |
| 5 | *Theft/ Vandalism outside of the site* | [61], [75] |
| 6 | *Strikes* | [63], [75], [62], [70], [95], [90], [68], [61], [89], [74], [83], [64] |
| 7 | *Demography change and its impact on labor demand and supply* | [6] |
| 8 | *Effect of cultural factors* | [45], [63], [34] |
| 9 | *Civil commotion/disturbances* | [95], [66], [70] |
| 10 | *Social and cultural factors* | [64] |
| **Level 2: Political Factors** | | |
| 1 | *Acts of government (sovereign or contractual)* | [62] |
| 2 | *Local government pressures* | [90] |
| 3 | *Act of foreign/public enemies* | [62] |
| 4 | *Political pressures* | [6], [17] |
| 5 | *Wars* | [68], [75] |
| **Level 2: Economic Factors** | | |
| 1 | *Economic development cycle and its impact on demand* | [6] |
| 2 | *Change in economic conditions* | [43] |
| 3 | *Freight/ Economic embargoes* | [62] |
| 4 | *Inflation impact on material, equipment and labor price fluctuation* | [72], [6], [55] |

**Table 27:** Taxonomy of Change Causes -Macro Factors (continued)

| Level 1: Macro Factors | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Economic Factors** | | |
| 5 | *Market competition* | [6] |
| 6 | *Inflation/Escalation of prices* | [82], [55], [70], [65], [68], [79] |
| 7 | *Price/Financial fluctuations* | [64], [68], [90] |
| 8 | *Fluctuation of exchange rate/ currency* | [79] |
| 9 | *Unstable interest rate* | [65], [79] |
| 10 | *Poor economic conditions (inflation, currency rate, etc.)* | [69], [55] |
| 11 | *Unforeseeable financial and economic crises* | [68], [65] |
| 12 | *Prices of some materials shooting up or the constructed project being devalued* | [75] |
| 13 | *Changes in materials prices in fixed-/ unit-priced contracts* | [76], [55], [60] |
| 14 | *Government sanction* | [88] |
| 15 | *Blockage* | [88] |
| **Level 2: Influence of Other Parties *(projects, organizations, etc.)*** | | |
| 1 | *Problems due to other works on hold* | [60] |
| 2 | *Previous construction delays by other contractors* | [46] |
| 3 | *Neighborhood pleadings* | [47] |
| 4 | *Work damaged by others* | [61] |
| 5 | *Lack of cooperation from local authorities* | [65] |
| 6 | *Associated causes* | [17] |
| 7 | *Acts of another contractor in performance of a government contract* | [62] |
| 8 | *Problems with neighboring community* | [68], [52] |
| 9 | *Problems with local residents* | [6], [46] |
| 10 | *Effects of/ modifications by other organizations (i.e. Utility providers, other projects)* | [6], [46], [17] |
| 11 | *Non-cooperation from labor unions* | [65] |
| 12 | *Interference by other prime contractors working for the owner* | [62] |
| **Level 2: Rules and Regulations related factors** | | |
| 1 | *Obtaining permits/approvals from the municipality/different government authorities* | [63], [45], [34], [70], [72], [82], [71], [64], [68], [61], [59], [73], [83] |

**Table 27:** Taxonomy of Change Causes -Macro Factors (continued)

| Level 1: Macro Factors | | |
|---|---|---|
| Level 3 | | Source |
| **Level 2: Rules and Regulations related factors** | | |
| 2 | *New government regulations* | [18] |
| 3 | *Legislative or policy changes* | [17] |
| 4 | *Obtaining (working) permits for laborers* | [76], [63], [45], [73] |
| 5 | *Changes in standards/ Norms (changed requirements such as speed, road width, road type, safety norms)* | [39] |
| 6 | *Obtaining transportation permit* | [71] |
| 7 | *Building permits approval process* | [61], [82], [64], [63] |
| 8 | *Prevention of contractor's resource* | [66] |
| 9 | *Changes of work rules/regulations* | [47] |
| 10 | *Statutory actions lead to inability to obtain labor, goods or materials* | [66] |
| 11 | *Work in pursuance of a body's statutory obligations* | [66] |
| 12 | *Legal issues arising due to local government rules and regulations* | [65] |
| 13 | *Difficulties in obtaining construction licenses* | [67] |
| 14 | *Government actions and inactions regarding ordinances, construction law, and etc.* | [75] |
| 15 | *Changes in government regulations and laws* | [64], [68], [61], [73], [76], [43], [39] |
| 16 | *Worker's compensation board shutdown* | [61] |
| 17 | *Quarantine restrictions* | [62] |
| 18 | *Weak regulation and control* | [79] |
| 19 | *Government regulations* | [70] |
| 20 | *Changes in government policies (environmental protection, sustainability, waste recycle, brown field use, etc.)* | [52], [34], [69], [74], [6], [79], [39] |
| 21 | *Changes in legislations on employment, and working conditions* | [52], [34], [69], [74], [6] |
| 22 | *Changes owing to policy or regulations changes* | [46] |
| 23 | *Non-availability of construction manuals and procedures* | [57] |
| 24 | *Non-availability of engineering licensing for engineers to maintain the quality of consultancy services* | [57] |

# CHAPTER 4

# VALIDATION

## 4.1 Methodology of Validation

After the taxonomy of "*Change Causes"* was developed, based on the data collected through a comprehensive literature review, it was required to validate the results. In this section, the efficiency and applicability of the proposed taxonomy is assessed by construction professionals on various construction projects. The existing weak points are identified and attempted to resolve them as a final revision of the taxonomy. Since, one of the efficient methods of quick assessment and validation is interviewing; it is decided to conduct an interview survey among construction professionals therefore an interview form was designed; then the answers were collected and the results assessed.

## 4.2 The Objectives of the Survey

Before the interview form is designed, the objectives of the survey must be defined clearly. The objectives of the validation process are as follow:

1. *To evaluate the efficiency of the taxonomy.*

2. *To assess the applicability of the proposed taxonomy in construction projects.*

3. *Identifying the vagueness and weak points of the taxonomy and existing categories.*

4. *To evaluate the efficiency of the taxonomy for different project parties.*

Based on the above objectives the interview form was designed.

## 4.3 Designing the Interview Form

In the interview form a brief introduction and the objectives of the study were explained in order to give a summary to the respondents. The form is designed in three general parts:

**Part 1**: involves general information about respondent and the case project that would be the basis of the questions in next parts.

**Part 2**: involves questions about change events and relevant causes in the previously considered case project without giving any information about the proposed taxonomy. The aim of this part is to assess the efficiency of change identification in lack of the taxonomy and without using any systematic framework for reviewing the changes.

**Part 3**: involves questions about identifying the "*Change Causes"* occurred in the case project after reviewing the taxonomy and identifying the relative categories for each change factor in the taxonomy. Moreover, some questions about the application of taxonomy in different sectors in construction industry and existing vague points are inquired. The aims of this section are as follow:

1. To identify the efficiency of the taxonomy by comparing the results with the answers in part 2.

2. To resolve the existing vague points in the taxonomy.

3. To assess the applicability of the taxonomy in several branches of construction industry.

## 4.4 Defining the Target Community of Survey

Before interviewing with the respondents, their organizational positions, and their involved projects must have been identified. Briefly, the target community for the survey must have been defined.

In order to have a fair feedback from the industry professionals and avoid objectivity in answers, it must be considered that all project participants including contractors, consultants and owners must be included in the survey. Furthermore, in order to cover the all kinds of construction projects they should be selected from different sectors like, building, infrastructure and industrial projects.

Finally, 10 different construction-related companies and organizations including 5 contracting companies, 2 owner organizations, and 3 consultant companies were selected from Iran then, the first and second parts of the questionnaires were sent to them by E-mail. Since the survey must be conducted together with oral interview and explanation, they were asked to appoint a face to face meeting in order to answer the third part of the questionnaire.

## 4.5 Description of Projects

The selected projects in validation phase of the study are including different sectors of construction projects such as industrial, infrastructure and building projects from public and private sectors in Iran. A brief description of projects is given in the rest of the text.

***Project 1:***

The project is the complete construction of a 12,450 $m^2$ manufacturing hall of a steel profile manufacturing company in West Azerbaijan of Iran; including all structural and architectural works and the electrical and mechanical systems. Project is a private sector project with one major investor unfamiliar with construction projects. The project drawings were extremely poor and inaccurate because of the unskilled

engineering team provided by the owners' technical office to execute the structural design and calculations. The initial project time and cost were determined as 12 months and 640,000 USD. However the project was finished in 34 months and with a cost of 1,310,000 USD. The major causes of project changes were as follow:

- The frequent scope changes made by the owner during the construction phase such as adding an administrative building in 4,300 $m^2$ and also increasing the capacity of cranes and structural loading sections.

- Owners' financial problems and long waiting time for contractors' progress payments and accordingly slowing down the project progress by the contractors and subcontractors.

- Long waiting time for controlling and revising the project designs and correcting the frequent errors existing in the drawings.

- Design specification changes due to the varying needs of the owner during the construction phase which were led to demolitions and reworks during the construction and accordingly cost and time overruns.

- Other change causes were late permissions by agencies and site delivery by the owner, the extended project time caused to replace some materials with new materials in market, lack of some kinds of materials in market like cement and several types of steel profiles, late delivery of structural elements by the subcontractors and the poor experienced subcontractors.

The complete list of change events and change causes are indicated in table 29.

***Project 2:***

The project is a complete construction of a student dormitory building in 7,600 $m^2$ and 4 stories in Tehran, Iran including concrete structural system and architectural works and the electrical and mechanical systems. Project is a public sector project and the design phase was conducted by the consultant company besides, the project

supervision is also given to the same consultant company. The initial project time and cost were determined as 24 months and 2,230,000 USD. However the project was finished in 27 months and with a cost of 2,550,000 USD. The project have been started in 2008 and finished in 2010. The major causes of project changes were as follow:

- Changes in project specifications and material such as promoting the project fire protection systems specifications and replacing the PVC sewage pipes with cast iron pipes which increased the project cost and schedule.

- Changing the architectural designs due to the owners' changing needs and requirements during the construction phase.

- The project started in the spring and heavy rains delayed the project commence and some construction activities like excavation and site mobilization.

- Some errors and omissions in project details and long waiting time for revision and approving them by consultant.

- Scope addition like adding the project works, improper construction method, poor scheduling and planning, poor subcontracting and etc.

The detailed and complete list of change causes and change events are stated in table 29.

***Project 3:***

This project is the construction of an administrative building for a governmental corporation in 6,200 $m^2$ and 3 stories in downtown of Tabriz, Iran. The stipulated works which must be executed by the contractor were the execution of concrete structural system and architectural works and the electrical and mechanical systems. The project is a public sector project which the project designs and supervision was given to the same consultant company. The initial project time and cost were

determined as 24 months and 2,100,000 USD. However the project was finished in 36 months and with a cost of 4,300,000 USD. The project have been started in 2007 and finished in 2010. The main causes of project changes were as follow:

- Design and specification changes because of the change of the owners' authority, lack of materials in specific periods and poor prediction of some mechanical equipment.

- Locational restrictions and conflicts with residents and other organizations such as traffic restrictions and safety problems with residents.

- Improper site mobilization by contractor; for instance a tower crane was equipped but the concrete batching system was not provided; so the crane was not useful enough in concrete purring. Thus the concrete works were executed by track mixers and pumps which must be transported in late hours of day due to the traffic restrictions.

- High material costs and inflations in some costs which caused variations in cost estimations and specifications.

- Delay in approving and decision making by the owner and inadequate bidding and contractual documents which led to schedule delays, conflicts and discrepancies during the construction phase.

The complete and detailed list of change causes and change events are indicated in table 29.

***Project 4:***

This project is the execution of an infrastructure project for a government organization. The project was including the rehabilitation of existing water plumping networks, power networks and sewer systems and developing the existing networks and facilities in some areas and construction of new required facilities of a suburb area in West Azerbaijan, Iran. The existing facilities were be executed about

25 years before the project started and there were significant damages in system and most of the works were not measurable easily so the most of the project items were considered as lump sum prices. The project owner was a public sector and the project designs and supervision was given to a nonnative consultant company. The initial project time and cost were predicted as 18 months and 1,025,000 USD. However the project was finished in 36 months and with a cost of 2,250,000 USD. The project have been started in 2005 and finished in 2008. The main causes of project changes were as follow:

- Excessive design changes due to the project nature and high level of complexity. Since the majority of work items were not easily foreseeable, they were identified during the construction phase. These cases caused to significant cost and time overruns; for instance the damages in sewer networks were predicted about 32% whereas the actual damages after project execution were distinguished around 55% which increased the project time and cost also these changes led to challenging claims and litigations after project finished so the total project cost were increased.

- Owners' financial problems due to the reduction of project financing resources and late progress payments for contractor and accordingly late payments for subcontractors slow down the project progress.

- High equipment rents and material costs due to the exceptional and longtime works in the project increased the project overhead costs and material costs so the project cost management were considerably affected.

- Replacement of new material by the existing material in the contract specifications due to the market changes and increasing needs of owner.

- Poor consultancy and supervision by the consultant company; which were a nonnative company and the project distance from consultants' head office impacted the project technical supports and decision making process.

- Lack of skilled labour in the area, unprofessional owner and ineffective interruptions by owner authorities, new regulations and native legal restrictions such as the required permits from organizations which were not previously involved in project.

The complete and detailed list of change causes and change events are indicated in table 29.

***Project 5:***

This project is the complete construction of a hospital building project belonging to a government corporation in 13,200 $m^2$ and 6 stories in downtown of Orumiyeh, Iran. The project involved the demolition of the existing building and execution of concrete structural system and architectural works and the electrical and mechanical systems. The project is a public sector project which the project designs and supervision was given to a nonnative consultant company in Tehran. The initial project time and cost were stipulated as 30 months and 3,750,000 USD. However the project was finished in 42 months and with a cost of 6,450,000 USD. The project have been started in 2006 and finished in 2010. The main causes of project changes were as follow:

- Project location changes after the excavation and execution of sections of foundation due to the poor pre-design investigations about the local municipality regulations which caused to considerable demolition of completed works and rework of the sections of foundation.

- Owners' financial difficulties which led to project stoppage in two periods and then the cost increased because of the inflations in material and manpower costs.

- Late site delivery by the owner because of the late permits and local restrictions and safety considerations for residents. Also the late delivery of utilities; for example late electrical power supply for machineries and equipment.

- Low skilled manpower and organizational problems on the part of the owner and consultant.

- Multiple owners and differing requirements during the project execution which led to design and specification changes and project scope addition for instace, the capacity of the hospital was increased after 6 months of project commence.

- Traffic restrictions and night works and accordingly problems with residents on project night works and business interruptions.

- Late revision and correction of design errors by consultant and late decision making by the owner which caused to schedule delays.

The other cases of change causes and change events are indicated in table 29.

***Project 6:***

This project is an infrastructure project for a public organization which was including 5 kilometer road project, power networks and lightening systems in a suburb area in West Azerbaijan, Iran. The project owner was a public sector and the project designs and supervision was given to a nonnative consultant company. The project land shape was not challenging and it was a simple road project without any complex structures and works. The initial project time and cost were predicted as 16 months and 1,780,000 USD. However the project was finished in 25 months and with a cost of 2,050,000 USD. The project have been started in 2004 and finished in 2006. The main causes of project changes were as follow:

- Frequent design and specification changes because of the poor land surveys and investigations by the consultant which caused to route change in some sections. Also inadequate and improper materials identified by consultant which were not proper for that location and weather conditions. For example the asphalt type and concrete elements were changed based on the contractors' suggestions.

- Owners' financial problems and late payments for contractor which led to reduce the contractor financial resources and stoppages in progress.

- Poor and inexperienced subcontractors which caused to partly demolitions and reworks by them and also week financial abilities that caused to poor project execution in some periods because of late payments.

- Varied owners' need and expectations which caused to changes and revisions in design and cost estimates and accordingly increased the project cost and schedule delay.

- Owners' organizational problems such as owners' representative changes after elections, late decision makings and delays in order issuance.

- Economical inflations and increased cost of basic materials like tar and asphalt prices which led to additional payments to contractor and project stoppage in some periods of time.

The complete and detailed list of change causes and change events are indicated in table 29.

## 4.6 Results of the Survey

From 10 respondents for whom the interview forms were sent only 6 of them answered to inquiry and set appointment for interview. The total duration of 6 interviews was 12 hours and 40 minutes. The results of interview are as follow:

1. The distribution of the respondents according to their sector is as follow:

    a. *4 from Construction Company (contractor)*

    b. *1 from Consultant Company (Consultant)*

    c. *1 from Client Organization (Owner)*

2. Distribution of respondents experience in their field:

    a. *2 persons with 6-10 year experience.*

    b. *3 persons with more than 20 year experience.*

    c. *1 person with 16-20 year experience.*

3. Distribution of projects type:

    a. *3 building projects*

    b. *2 infrastructure project*

    c. *1 industrial project*

4. Projects ownership type distribution:

    a. *5 public sector projects*

    b. *1 private sector project*

5. Projects' initial and actual time and cost:

**Table 28:** Initial and Actual Time and Cost

| *project* | *Initial project duration (Months)* | *Actual project duration (Months)* | *Initial project cost (US $)* | *Actual project cost (US $)* |
|---|---|---|---|---|
| *1* | *12* | *34* | *640.000* | *1.310.000* |
| *2* | *24* | *27* | *2.230.000* | *2.550.000* |
| *3* | *24* | *36* | *2.100.000* | *4.300.000* |
| *4* | *18* | *36* | *1.025.000* | *2.250.000* |
| *5* | *30* | *42* | *3.750.000* | *6.450.000* |
| *6* | *16* | *25* | *1.780.000* | *2.050.000* |

According to the table above all the projects have suffered from time and cost overruns during their lifecycle.

6. Answers of questions in Part 2 (before using the taxonomy): Five most important changes and their causes during project life cycle:

**Table 29:** Summary of the Answers

| Project | Before referring the Taxonomy Part 2 | | After referring the Taxonomy Part 3 | |
|---|---|---|---|---|
| | **Change events** | **Change causes** | **Change events** | **Change causes** |
| ***1*** | *1. Design changes*<br>*2. Cost overrun*<br>*3. Time extension* | *1. Incomplete designs*<br>*2. Owners' financial problems*<br>*3. Owners' needs*<br>*4. Design errors* | *1. Changes in specifications*<br>*2. Scope changes* | *1. Delay in permits*<br>*2. Geological problems*<br>*3. Late site delivery by owner*<br>*4. Poor subcontractors*<br>*5. Lack of material in market*<br>*6. New materials*<br>*7. Late material delivery* |
| ***2*** | *1. Changes in specifications*<br>*2. Time overruns*<br>*3. Cost overruns* | *1. New material*<br>*2. Owners' need*<br>*3. Owners' financial problems*<br>*4. Weather conditions*<br>*5. Incomplete designs*<br>*6. High rent of site office and overhead costs* | *1. Scope changes*<br>*2. Change of construction method* | *1. Lack of efficient scheduling*<br>*2. Contractor organizational problems*<br>*3. Poor subcontracting*<br>*4. Lack of coordination*<br>*5. Owners expectations and quality improvement by owner*<br>*6. Material supply*<br>*7. Inefficient construction method* |

**Table 29:** Summary of the Answers (continued)

| Project | Before referring the Taxonomy Part 2 | | After referring the Taxonomy Part 3 | |
|---|---|---|---|---|
| | **Change events** | **Change causes** | **Change events** | **Change causes** |
| ***3*** | *1. Design changes*<br>*2. Cost overrun*<br>*3. Time Extension*<br>*4. Specification changes* | *1. Owners' authority change*<br>*2. High material costs*<br>*3. Lack of material*<br>*4. Inexperienced subcontractor*<br>*5. Inadequate site mobilization by contractor*<br>*6. Poor prediction of equipment types* | *1. Scope Changes*<br>*2. Construction method changes* | *1. Delay in approving designs by owner*<br>*2. Delay in decision Making by owner*<br>*3. Poor contractual documents*<br>*4. Inadequate bidding documents by owner*<br>*5. Traditional construction methods*<br>*6. Conflicts with residents*<br>*7. Delay in providing utilities*<br>*8. Site restrictions* |
| ***4*** | *1. Design change*<br>*2. Delay*<br>*3. Cost overrun*<br>*4. Scope change* | *1. Owners' financial problems*<br>*2. Delay in payments*<br>*3. Design errors*<br>*4. New material*<br>*5. High material and equipment rent costs* | *1. Change in project location and placement* | *1. Owners need*<br>*2. Delay in decision making*<br>*3. Poor consultant coordination*<br>*4. New regulations and codes*<br>*5. New materials*<br>*6. Lack of skilled labour*<br>*7. Unprofessional owners* |

**Table 29:** Summary of the Answers (continued)

| Project | Before referring the Taxonomy Part 2 | | After referring the Taxonomy Part 3 | |
|---|---|---|---|---|
| | **Change events** | **Change causes** | **Change events** | **Change causes** |
| ***5*** | *1. Location change*<br>*2. Cost Overrun*<br>*3. Time extension*<br>*4. Design change*<br>*5. Specification changes* | *1. Poor investigation of project location*<br>*2. Owners' financial problems*<br>*3. Lack of skilled labour*<br>*4. Late site delivery*<br>*5. Owners' organizational problems*<br>*6. Late payments*<br>*7. High range of labour costs* | *1. Scope change*<br>*2. Owner Change* | *1. Inadequate understanding of owners need*<br>*2. Poor site management team*<br>*3. Inadequate site investigation*<br>*4. Problems with other organizations*<br>*5. Site restrictions*<br>*6. Government pressure*<br>*7. Conflicts with consultant and contractor*<br>*8. Inexperienced consultant*<br>*9. Poor estimations of cost and quantity*<br>*10. Late permits*<br>*11. Design errors*<br>*12. Multiple owners*<br>*13. Multiple consultants*<br>*14. Multiple contractors* |
| ***6*** | *1. Design changes*<br>*2. Changes in specifications*<br>*3. Cost overruns*<br>*4. Time extension* | *1. Owners' financial problems*<br>*2. Late payments*<br>*3. Poor material specifications*<br>*4. Poor design quality*<br>*5. Inexperienced subcontractors*<br>*6. Subcontractors financial problems*<br>*7. Delay in order issuance by owner* | *1. Scope changes*<br>*2. Change in contractual documents* | *1. Owners' needs*<br>*2. Lack of scheduling and planning*<br>*3. Poor site and work investigation by consultant*<br>*4. Inadequate subcontractors workers*<br>*5. Errors in contractual documents*<br>*6. High material costs*<br>*7. Economic inflation*<br>*8. Elections and owners representative changes*<br>*9. Late revision of designs* |

As it is obviously indicated in above table, the respondents' answers after referring the taxonomy (Part 3) have been improved and more detailed cases have been identified about change events and "*Change Causes"*. This means that, reviewing the change events and "*Change Causes"* in a systematic framework which is provided by the taxonomy of "*Change Causes"* is more efficient; and the results are more detailed and accurate. This is because of the variety of "*Change Causes"* and events that may occur in a project lifecycle and identifying their causes will need to review the records and documents comprehensively. This taxonomy provides an exhaustive basis for reviewing the change events and identifying the related causes, and will lead to more efficient and reliable results in change management process.

7. The respondents' opinion about simplicity of the taxonomy and suggestions to revise the weak points and ambiguities of categories:

    a. All respondents easily found the proper category for their mentioned "*Change Causes"* except following cases:

    b. Proper categories for following cases did not found and suggested to create proper subcategories under the "*Financial Issues*" category: *"High range of labour costs*", "*high range of equipment and machinery rents*", "*excessive contract related costs*", "*high rents and overhead costs*". Therefore two subcategories created under the "*financial Issues*" named: "*Resource Costs*" which includes the costs related to all resources. And "*Contract and overhead costs*" which involve the cost items related to contract and overhead.

    c. It was hard to find a proper category for "*Multiple construction participants*" and suggested to merge the "*Organizational Complexity*" which was under the "*Project involved parties*" into "*Organization and Bureaucracy*" under "*Project Management and Administration*" since both of them includes organizational issues and it would be clear to find.

d. In order to clarify the cases related to contractual documents and project scope related factors it was suggested to rename the "*Contract Management*" category to "*Contractual Document and Contract Management*".

# CHAPTER 5

# CONCLUSION AND FUTURE WORKS

Construction Industry as an excessively unique sector is suffering from high range of risks associated with it. These risks must be managed efficiently in order to achieve a successful project. The success of a project defines as "completing the project within the scheduled time, cost and quality and during a safe construction process". One of the significant risk factors in construction industry is the risk of change which is highly appearing in all construction projects. Now this is a proverb between construction professionals that "Change is inevitable in construction project". The reasons of excessive changes in construction projects refer to the following characteristic factors of the industry including: uniqueness, dimension, varying environment, traditional methods, higher dependency to manpower, fragmented production phase, etc.

The majority of construction projects are suffering from cost and time overruns as the results of change in projects which are the main causes of claims and litigations. The negative effects of changes are significantly destructive factors in projects so dealing with changes and managing them is inevitable. Changes must be identified, evaluated and controlled during a project lifecycle in a way that positively affect the project. Changes can be converted into beneficial changes as well as the negative effects of change can be minimized by proper decisions and efficient managing.

The effective management of changes and the accuracy of reactions against the change events strongly depends on the quality of knowledge about change and its' relative causes and impacts. Poor change investigation and improper change identification process frequently result in wrong decision on changes and consequently affect the project negatively. Conversely, exact and authentic results of

change identification process generally leads to efficient decisions and positive results in change management process.

Managing changes in construction projects needs an experienced and efficient management team working through a systematic procedure. There are several "*Change Management Systems*" implemented in construction projects; in which the first and more critical step is identifying the changes and their related causes and effects. Lack of comprehensive and generic model for identifying the "*Change Events"*, "*Change Causes"* and "*Change Effects*" is a major challenge in "*Change Management"* process, since the accuracy and efficiency of future steps and decisions excessively depends on the results of this stage. Poor change identification would lead to poor and inefficient decisions in dealing with changes.

This study tried to gather the "*Change Causes"* through an exhaustive literature review and put them in a general format of taxonomy in order to be utilized in all kinds of construction projects in all countries and construction sectors. Therefore a long list of "*Change Causes"* including 1578 causal factors categorized in a taxonomy based on their origins and independent from the responsibility of their occurrence. The proposed taxonomy is developed in a hierarchical structure in 3 levels which the first two levels include general categories of change causes. First level of the taxonomy is involved 13 individual and independent categories based on project resources and characteristic factors. The second level of the taxonomy includes subcategories under the first level categories in order to provide a distinguished and clear grouping of causal factors in each level one factors. The third level of the taxonomy includes specific and unique change cases related to the level 2 subcategories. This level of the taxonomy is a flexible level which can be extended by adding new change cases.

The proposed taxonomy was assessed through a validation process on six different projects from public and private sectors in Iran which were including different types of projects as industrial, building and infrastructure projects. Then the taxonomy was revised based on the results of the survey. Also the applicability of the taxonomy was evaluated by construction professionals who were experienced in their field. The results were promising and positive reactions were obtained from all

respondents; since they really find it comprehensive and effective in reviewing the change events in their completed previous projects as well as ongoing projects.

The existing taxonomy provides a generic framework for systematically reviewing and identifying the "*Change Causes"* with the same understanding by project management team. The proposed taxonomy also can be utilized as a basis in claim management procedures to identify the exact causes of changes and accordingly the responsible party for change. Furthermore, it can be used as a data base model for change prediction systems and software.

## 5.1 Future works

Since this study provides only the initial step in systematic change identification process it is not completed yet and numerous efforts should be executed in order to accomplishment. In this taxonomy the relations between "*Change Causes"* and their internal effects are not indicated. One of the future activities can be focused on developing a method to identify the inter-relations of "*Change Causes"*.

The same taxonomy idea should be developed on change effects in order to provide the same advantages in identifying and evaluating them. Inaccurate imagine and understanding of change effects is a common challenge in construction project and can leads to various reactions to changes. Therefore developing generic change effect taxonomy would be more beneficial in managing changes.

The existing taxonomy can be utilized as a basis for identifying and analyzing the changes in different sectors and countries as well as in case studies. Ranking the change events and related causes in specific countries or construction projects is one of the most prevailing research areas in construction industry. This taxonomy provides an exhaustive list of possible changes and minimizes the subjective results in change identifications and rankings.

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# APPENDIX A

# INTERVIEW FORM

This is a survey on the Change Cause issue in Construction Industry which is aimed to validate the proposed "*Taxonomy of Change Causes*" and identify the existing limitations and blind spots of that, in order to complete it in a form which can be used by experts as a generic model to classify the Change Cause.

## OBJECTIVES OF THE STUDY

The objectives of this survey are as follows:

1. To study the main causes of changes in construction projects and investigate the practical experiences of construction experts on the causes of changes in specific projects.
2. To analyze the adequacy of the existing "*Taxonomy of Change Causes"* in identifying and classifying the causes of changes in projects.
3. To evaluate the ease of using the existing "*Taxonomy of Change Causes"*.
4. To complete and revise the existing taxonomy in a way that can be easily utilized in any kind of construction projects.

## PART 1
## GENERAL INFORMATION

***RESPONDENT INFORMATION:***

1. Type of the organization you are working in:
   - □ *Client*
   - □ *Consultant*
   - □ *Contactor*

2. Years of experience?
   - □ *1-5 years*
   - □ *6-10 years*
   - □ *11-15years*
   - □ *16-20 years*
   - □ *>20 years*

3. Please specify your current position in the organization?

***PROJECT INFORMATION:***

1. Project name:
2. Actual Project duration (Months):
3. Initial Project duration (Months):
4. Actual project cost (US $):
5. Initial project cost (US $):
6. Project type:
   - □ *Infrastructure*
   - □ *Building*
   - □ *Industrial*
   - □ *Transportation*
   - □ *Other :*
7. Project ownership:
   - □ *Public sector*
   - □ *Private sector*
8. A brief description of project:

## PART 2

## PROJECT-SPECIFIC QUESTIONS

Please answer the following questions based on your findings during the above project:

1. Identify five most important changes that are occurred in this project:
    1.
    2.
    3.
    4.
    5.
2. Identify ten most important causes of changes:
    1.
    2.
    3.
    4.
    5.
    6.
    7.
    8.
    9.
    10.

## PART 3

## PROJECT AND TAXONOMY-RELATED QUESTIONS

Now based on the same project results study the Taxonomy of Change Causes in last page and answer these questions:

1. Try to put the change causes you mentioned in question 2 in the appropriate category in existing taxonomy.

2. If there were such cases that you couldn't find appropriate categories for them please create them in "Level 1" or "Level 2" accordingly.

3. After you study the following Taxonomy, are there any change causes that have been forgotten in your mentioned causes in question 2? If yes please identify them here:

   1.
   2.
   3.
   4.
   5.
   6.
   7.
   8.
   9.
   10.

4. Do you have any suggestions in order to simplifying the existing Taxonomy in a way that it would be easier to identify the change causes category?

5. Rank the applicability of this taxonomy in following cases:

   a. Applicability and efficiency for *contractors*:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Weak | | | | Strong |

   b. Applicability and efficiency for consultants:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Weak | | | | Strong |

c. Applicability and efficiency for clients and owners:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Weak | | | | Strong |

d. Efficiency of the taxonomy during project design phase:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Weak | | | | Strong |

e. Efficiency of the taxonomy during project construction phase:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Weak | | | | Strong |

f. Efficiency of the taxonomy in planning and scheduling:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Weak | | | | Strong |

Interview duration: Minutes
Interview date:

**Table 30:** Taxonomy of Change Causes given in the interview form

| | Level 1 | Level 2 | C.C Case (q.2) |
|---|---|---|---|
| 1 | Manpower | *Organizing and Managing*<br>*Availability*<br>*Competence and Skill* | |
| 2 | Material | *Procurement and Delivery*<br>*Availability and Variety*<br>*Keeping and Storage*<br>*Quality and Specifications* | |
| 3 | Equipment, Tools and Machinery | *Procurement and Delivery*<br>*Availability*<br>*Repair & Maintenance*<br>*Productivity & Efficiency*<br>*Quality and Specification* | |
| 4 | Financial Issues | *Payments*<br>*Financing* | |
| 5 | External Factors | *Weather Conditions*<br>*Natural/ Artificial Disasters*<br>*Environmental Issues*<br>*Security Issues* | |
| 6 | Health and Safety | *Safety Considerations*<br>*Health Considerations* | |
| 7 | Project Location | *Ground Condition*<br>*Site Conditions and Restrictions*<br>*Accessibility and Possession* | |
| 8 | Project Involved Parties (Contractor, Client, Consultant, Designer, etc.) | *Proficiency and Experience*<br>*Needs and Expectations*<br>*Culture and Ethic*<br>*Organizational Complexity* | |
| 9 | Project Management and Administration | *Project and Site Management*<br>*Supervision and Quality Management*<br>*Scheduling, Planning and Control*<br>*Communication and Coordination*<br>*Organization and Bureaucracy* | |
| 10 | Contract Management | *Project Scope and Characteristics*<br>*Bidding and Project delivery*<br>*Contract Administration and Documents* | |
| 11 | Design and Specifications | *Accuracy of Design Documents*<br>*Changes in Design and Specifications*<br>*Design Process*<br>*Characteristics of Design* | |
| 12 | Project Execution | *Mobilization and Facilities*<br>*Logistics and Transportation*<br>*Construction Method and Technology*<br>*Subcontracting*<br>*Performance and Workmanship* | |
| 13 | Macro Factors | *Social factors*<br>*Political factors*<br>*Economic factors*<br>*Influence of other parties (projects, organizations, etc.)*<br>*Rules and Regulations related factors* | |