ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

IDENTIFICATION OF COST FACTORS FOR INTEGRATED ALTERNATIVE COST AND TIME ANALYSIS IN PRE-CONSTRUCTION STAGE

M.Sc. THESIS

Gülsüm Sevde BALTAŞI

Department of Civil Engineering

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

İNŞAAT ÖNCESİ SÜREÇTE ENTEGRE ALTERNATİF MALİYET VE SÜRE ANALİZİ İÇİN GEREKLİ MALİYET FAKTÖRLERİNİN BELİRLENMESİ

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HAZİRAN 2017

Gülsüm Sevde Baltaşı, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 501101158, successfully defended the thesis entitled "IDENTIFICATION OF COST FACTORS FOR INTEGRATED ALTERNATIVE COST AND TIME ANALYSIS IN PRE-CONSTRUCTION STAGE", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 5 May 2017
Date of Defense : 5 June 2017

To the 'Junior',

FOREWORD

I first would like to thank and predicate my appreciation to my thesis advisor, Assoc. Prof. Dr. Esin ERGEN PEHLEVAN for her guidance and continuous support.

Also I would like to thank Asst. Prof. Dr. Ragıp AKBAS for his worthwhile help and guidance.

Finally, I owe my sincere thank and gratitude to my beloved family, especially to my mother and father, for always supporting me and being there whenever I need.

May 2017 Gülsüm Sevde BALTAŞI

(Civil Engineer)

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ABBREVIATIONS

BIM : Building Information Modelling

CPM : Critical Path Method

TBM : Tunnel Boring Machine

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SUMMARY

As construction industry shows a rapid growth, construction companies expand their services beyond the borders of their nations. Competitiveness increases due to open markets and hence it becomes harder for construction companies to get new jobs. Minor cost differences cause a contractor to lose a bid worth millions of dollars. Hence, estimating practices and alternative project estimation formations become more important. Any action to form alternatives on project cost and time in tender and pre-construction stages, in which the project estimation is formed and finalized, can help a contractor to survive in sector. Currently, conventional alternative analysis approaches are conducted by experts in companies by considering various factors affecting cost. Decisions on which factors to be considered, however, are determined based on experts' experience and know-how. The main purpose of this thesis is to identify the cost factors for integrated alternative cost and time analysis in pre-construction stage. The three main objectives of this study are: (1) to identify cost factors that are needed when performing alternative cost and time analysis; (2) to describe conventional alternative cost and time analysis approaches; (3) to identify which factors from determined requirements are being used in conventional approaches.

The thesis is conducted through a detailed literature review and two sets of interviews. Pre-interviews were conducted with three experts while second set of interviews were conducted with eight experts. The experts were selected from three different project types; residential buildings, conventional building, and infrastructure. Pre-interviewees experience level varies as 10, 16 and 20 years. Current positions of these experts are project manager, technical office manager and managing partner respectively. Experience level of second set of interviewees varies between 10 to 22 years and their current positions are chief project controller or manager. To achieve the first objective of thesis, cost factors that are used in alternative formation are revealed with a detailed literature review. These factors are expanded with pre-interviews. Following this, second set of interviews are conducted to finalize and validate the required cost factors. In total, 34 required cost factors are found that are used in forming alternative cost and time analysis. The findings are grouped under five principal categories; equipment, crew, site access and logistics, construction process, and construction method. The factors under each principal category are discussed in detail by pointing out in which manner they form alternative project cost. Conventional alternative cost and time analysis approaches are also revealed by interviews in order to accomplish the second objective of the thesis. Experts were asked about their conventional alternative formation practices in the interviews. Finally, for the third objective of the thesis, interviewees were given

the determined factors and asked to select which factors they use among the listed ones. Cost factors used in conventional approaches for three different construction types; commercial building, residential building, and infrastructure construction are compared with the required cost factors. The results show that although some factors used in conventional alternative analysis approaches are common for all three types, there are some differences among different project types due to the characteristics of the project. Finally, to eliminate the biased and limited approach of individual expert and provide a structured approach, the need for an integrated system for alternative cost and time analysis is highlighted based on the requirements that are identified.

İNŞAAT ÖNCESİ SÜREÇTE ENTEGRE ALTERNATİF MALİYET VE SÜRE ANALİZİ İÇİN GEREKLİ MALİYET FAKTÖRLERİNİN BELİRLENMESİ

ÖZET

İnşaat sektörü son yıllarda hızlı bir büyüme göstermiş ve diğer sektörler gibi inşaat sektörü de küreselleşmenin etkisi altında kalmıştır. Ülke sınırlarının kalkması, yerel pazarların tüm ülkelerden yüklenicilere açılmasına neden olmuştur. Artan rekabet koşulları yüklenicilerin milyon dolarlık isleri çok küçük maliyet farklılıkları ile kaybetmelerine sebep olmaktadır. Bu nedenle ihale ve inşaat öncesi süreçlerde yürütülen maliyet analizi çalışmaları önem kazanmaktadır. Alternatif maliyet ve süre kalemlerinin tespit edilip proje bütçesinin alternatiflendirilmesi, yüklenicilerin sektörde tutunmalarına olanak tanımaktadır. Bu tez çalışmasında inşaat öncesi süreçte entegre alternatif maliyet ve süre analizi için gerekli olan maliyet kalemlerinin belirlenmesi amaçlanmıştır. Çalışmanın üç ana hedefi vardır; (1) alternatif maliyet ve süre analizi yapmak için gerekli faktörlerin belirlenmesi; (2) geleneksel alternatif maliyet ve süre analizi yaklaşımlarının belirlenmesi; (3) tespit edilen faktörler ile geleneksel alternatif maliyet ve süre analizi yaklaşımlarında kullanılan faktörlerin kıyaslanması neticesinde, entegre bir sistem gerekliliğinin gösterilmesi.

Tez çalışması kapmasında detaylı literatür taraması ve 2 set mülakat görüşmeleri yapılmıştır. Mülakat görüşmelerinin birinci seti ön görüşmeler olarak adlandırılmış ve üç uzman ile gerçekleştirilmiştir. İkinci seti oluşturan görüşmeler alanında uzman sekiz kişi ile yapılmıştır. Katılımcılar, tezin amaçlarına paralel olarak ticari, konut ve altyapı projeleri uzmanları arasından seçilmiştir. Ön görüşme katılımcılarının deneyim süreleri 10, 16 ve 20 yıldır. Bu katılımcıların güncel pozisyonları ise sırasıyla proje yöneticisi, teknik ofis müdürü ve yönetici ortaktır. İkinci set görüşme katılımcılarının deneyim süreleri ise 10 ila 22 yıl arasında değişmektedir. Bu katılımcıların güncel pozisyonları ise proje kontrol şefi ve yönetici olarak belirlenmiştir.

Yapılan detaylı literatür taraması ile öncelikli olarak proje bedelini etkileyen maliyet kalemleri belirlenmiştir. Daha sonra bu maliyet kalemleri, alternatif proje maliyeti oluşturabilecek kalemler olarak ayrıştırılmıştır. Bu çalışmayı takip eden ön görüşmeler ile, katılımcı görüşleri neticesinde alternatif maliyet kalemleri genişletilmiş ve gereksinimler listesi oluşturulmuştur. Oluşturulan bu liste, ikinci set mülakat görüşmelerinde katılımcılara sunulmuş ve listedeki faktörlerin doğrulaması bu görüşmeler ile yapılmıştır. Toplam 34 faktör belirlenmiş ve belirlenen bu faktörler beş ana başlık altında toplanmıştır; ekipman, ekip, saha ulaşım ve lojistik, yapım süreçleri, yapım yöntemleri. Ekipman ana başlığı altında 12 farklı alternatif maliyet kalemi belirlenmiştir. Ekip ve yapım yöntemi ana başlıklarının her birinin altında ise 6 adet faktör yer almaktadır. Saha ulaşım ve lojistiği ile yapım süreçlerinin her birinin ana başlıkları altındaki faktör sayısı ise beştir. Her bir ana başlık altındaki

faktörler detaylı şekilde incelenmiş ve bu faktörlerin nasıl alternatif proje maliyeti oluşturdukları tartışılmıştır.

Görüşmelerde katılımcılardan aynı zamanda geleneksel alternatif maliyet ve süre çalışmalarıni açıklamaları istenmiştir. Bu kapsamda, katılımcılar geleneksel alternatif maliyet çalışmalarının detaylarını iletmişler ve bu sayede çalışmanın ikinci amacı gerçekleştirilmiştir. Son olarak katılımcılar, çalışmanın ilk amacı kapsamında belirlenen maliyet kalemlerinden hangilerini geleneksel çalışma yöntemlerinde kullandıklarını belirtmişlerdir. Katılımcıların, onaylarına sunulan gereksinim faktörlerinden hangilerini güncel alternatif maliyet analizi yaklaşımlarında kullandıkları ve bu faktörlerin maliyeti nasıl etkilediği hususunda görüşleri alınmıştır. Elde edilen veriler, katılımcıların uzmanlık alanları bazlı olarak gruplanarak incelenmiştir. Buna göre, geleneksel alternatif maliyet analizi yaklaşımları konusunda elde edilen bulgular iki ticari yapı uzmanı, iki üst yapı uzmanı ve dört altyapı projeleri uzmanlarının görüşlerini yansıtmaktadır.

Elde edilen veriler göstermektedir ki, ihale ve inşaat öncesi süreçlerde yürütülen alternatif maliyet ve sure analizi çalışmaları, incelenen 3 proje tipi için de benzerlik göstermektedir. Tüm proje tipleri, ekipman secimi, sayısı ve kiralanması yahut satın alınması bazlı alternatifler oluşturmakta ve değerlendirmeler yapmaktadır. Yalnızca altyapı projelerinde, diğer iki proje tipinden farklı olarak güzergâh seçimi ve güzergâh alternatiflendirilmesi önem oluşturmaktadır. Hem altyapı hem de ticari yapı projelerinde ekip içeriği ve sayısı bazlı alternatifler oluşturulmakta ve proje bütçesi bu alternatifler baz alınarak değerlendirilmektedir. İnşaat yapım yöntemi ise, tüm proje katılımcıları tarafından güncel alternatif maliyet ve sure analizi çalışmalarında değerlendirilen bir başka unsur olarak belirtilmiştir.

Çalışmadan elde edilen bir diğer veri ise, yürütülen inşaat projesi çeşidine göre değerlendirilen alternatif maliyet analizi kalemlerinin değişiklik gösterdiğini açığa çıkarmıştır. Buna göre, ticari projelerin maliyet alternatiflendirilmesinde ele alınan ana faktörler; ekipman ve inşaat metodu ana başlıkları altında yoğunlaşmaktadır. Konut projelerinde ise ekip ana başlığı altındaki faktörlerin, alternatif maliyet analizi çalışmalarında dikkate alınmadığı açığa çıkmıştır. Bunun nedeni, konut tipi projelerde işçiliğin büyük ölçüde taşere edilmesidir. Ana yüklenici, taşere ettiği işçilik maliyetlerine dair verilerin alternatiflendirilmesini, alt yüklenicilere bırakmıştır.

Altyapı projelerinde diğer iki proje tiplerine göre daha fazla faktörün maliyet alternatiflendirilmesinde kullanıldığı görülmüştür. Bunun temel nedeni, altyapı işlerinin ticari ve konut projelerine nazaran daha karışık olmaları ve yatayda ilerlemeleri neticesinde güzergâh değişikliği alternatifi sunmasıdır. Tasarımın ihale dokümanlarında kesinleşmediği altyapı projelerinde, güzergâh ve yapım yöntemleri seçimi, ana alternatif maliyet kalemlerini oluşturmaktadır. Ekipman maliyeti, altyapı projelerinde en önemli ana maliyet kalemini oluşturmakta ve bu maliyet özellikle seçilen yapım yöntemine göre farklılık göstermektedir.

Sonuç olarak bu tez, inşaat öncesi süreçlerde entegre sistemler için alternatif maliyet ve süre analizi için gerekli olan maliyet faktörlerini belirlemiştir. Bu belirleme, detaylı bir literatür taramasına ek olarak yürütülen görüşmeler ile sağlanmıştır. Elde edilen bulgular, katılımcıların uzmanlık alanlarına paralel olarak ticari projeler, konut projeleri ve altyapı projeleri için gerekli bulguları yansıtmaktadır. Buna ek olarak, güncel alternatif maliyet analizi çalışmaları ile belirlenen faktörlerden hangilerinin geleneksel yaklaşımda kullanıldığının tespiti sağlanmıştır. Bu çalışmadan elde edilen bulgular, entegre bir maliyet analizi sistemininin geliştirilmesi için kullanılabilir.

1. INTRODUCTION

Construction industry has been showing a rapid growth and by the end of 2020, the industry is projected to reach US$10.3 trillion in all over the world (Url 1). Globalization causes local markets to be open to contractors from any country and expands construction companies' services beyond the borders of their nations (Ngowi et al, 2005). As the number of contractors increase due to open markets, number of competitors also increases. Hence, due to increased competitiveness in the industry, it becomes harder for a construction company to survive.

Challenging and limited work opportunities make it more difficult for contractors to get new jobs. Competitiveness also causes contractors to lose a bid due to minor cost differences for projects worth millions of dollars (Sattineni and Bradford, 2011). For example, four joint ventures took part in recent tender for the Canakkale Bridge project. According to the official announcements, differences among the first three tender prices were %0,295 and %1,33 respectively. This shows that less than one percent of cost differences may determine the winner for a project worth more than 10 billion TL.

In addition to competitiveness and challenges in construction industry, short durations for tender preparations also form another drawback. The time between going out to tender and tender collection is getting shorter. For instance, for Canakkale Bridge tender announcement was in 26th of October in 2016 (Url 2) and the tenders were collected in 26th of January, 2017. So even for such a large-scale and complex project that will become the longest suspension bridge with its 2023 meters main span length, tender preparation duration was just three months. Competitiveness and challenges mandate contractors to apply accurate and compatible cost calculations in short durations. Although cost practices during tendering stages is of great importance, cost calculations in tendering stage cannot be done in sufficient detail due to time limitations.

Similarly, cost calculation practices during pre-construction stages is becoming more important, since cost calculations in tendering stage is generally not conducted in detail and more information becomes available after tendering stage. Pre-construction stage is the stage commencing from the date of tender award and in this stage the project scope, schedule, and cost are defined as early as possible with the most efficient use of resources and money (Url 3). In pre-construction stage, the course of action is set by the project manager and satisfactory completion of project with all parties involved is aimed (Jackson B. J., 2010). In this stage, more information becomes available and the project schedule and project costs that were calculated in tendering stage are reviewed and modified by performing alternative cost and time analysis using this additional information. Alternative cost and time analysis at this stage is important since with the additional information provided, detailed analysis can be conducted in project cost items. Any action taken at this stage which is prior to construction start helps the construction team to act in accordance with the determined goals and objectives. To conclude, project cost and accordingly expenses that affect the project profit are determined in either tender or pre-construction stages. Since practices in these two stages affect project cost and duration, alternative cost and time analysis practices in these stages becomes vital for effective cost and time analysis.

Current practices in estimating stages have some limitations. Currently in estimating stages, contractors schedule project activities and estimate project costs using commonly available tools. In conventional approaches, company experts decide on the type, amount and duration of resources based on their past experience (Kiziltas and Akinci, 2009). Estimations are built after expert's decision on resource usage, construction method and sequence. The cost engineer or estimator estimates project costs on the basis of available data (Hendrickson, 2000). Available data covers tender documents and company database, but limited and dependent on the experience level and field of the estimator. Hence, this leads to a biased and limited analysis due to experts' know-how and area of expertise. Depending on the project size, number of evaluated cost items increases. When the construction project is large-scale and complex, it is almost impossible for an expert to evaluate all factors affecting project cost and potential cost alternatives. For example, calculation of equipment cost can be easier for a simple building project. Alternatives on equipment number and size can be formed by estimators' experience and companies past data. However, evaluating alternatives for many different factors cannot be performed easily for large-scale projects. Moreover, estimators show tendency to choose and allocate resources based on their past experiences and cannot evaluate numerous factors in order to comprise different project cost and duration. Third Airport Construction in Istanbul is an example for this. According to the recent data, 252 excavators, 57 grader, 60 tower cranes, 23 mobile cranes and 70 concrete batch plant are only some of the equipment located on the construction site (Url 4). In such a complex project, alternatives cannot be sufficiently formed for equipment quantities and locations, let alone all project resources.

Considering that estimating construction project costs is time consuming, often tedious and can be limited to expert's judgement, some tools and techniques have been developed over the years (Bryan, 1991). Estimators can use any of these tools and get benefit from it during estimating practices Yet, even in use of a construction tool, estimators still need to know about and identify which cost and time factors are needed to perform alternative analysis.

As projects get more complex and hence involve many factors that can affect the project cost and time, evaluation alternatives become harder. Since when the project is complex and it is very hard to evaluate all the alternatives with human capabilities, an integrated and structured way to perform alternative analysis becomes inevitable. In order to perform an extensive and inclusive alternative analysis, cost factors that cause different project cost and time values when changed are needed to be identified clearly. In addition to this, to be able to understand the needs of alternative cost and time analysis, estimators first should understand and see the limits of conventional alternative cost and time analysis approaches.

In current practices, estimations are built after experts decide on resource usage, construction method and sequence. These approaches limit the evaluation of possible alternatives since they are bounded by experts' knowledge and capabilities. Many alternatives depend on resources, methods and sequence, however, once these are decided, alternatives are lost. To overcome these limitations and to better evaluate resource usage and allocation for estimation, some contractors use Building Information Modelling (BIM) models which let contractors integrate the model with schedule to evaluate cash flows and see any visual conflict prior to execution.

Although this brings some advantages like resolving possible conflicts, currently used BIM-based tools do not improve on alternative evaluation during preconstruction. With the help of cost factors that are needed to perform alternative cost and time analysis, alternatives for any change in any factor can be formed and implemented into BIM-based models. By so, simulation and process model for each alternative can be formed easily and any schedule change can be implemented easier compared to hand calculations. Such a BIM-based integrated system that works as a simulation can help contractors to evaluate many alternatives in short durations and decide on the project budget and schedule that best suits them. Therefore, as the first step, the factors needed to form alternative cost and time analysis should be identified.

1.1 Motivating Case of Study

In this section, performing alternative analysis related to tunnel boring machine (TBM) in a large-scale company is explained as the motivating case of the thesis. Following the definition of TBM, TBM related cost factors that affect project cost are discussed in conformity with the thesis subject. An interview with TBM manager of a large-scale company experienced mainly in infrastructure projects was conducted to identify cost factors in TBM cost calculations (Serdar Savk, personal interview, 9 February 2017). The factors used in conventional approaches to form alternative cost analysis for TBM were revealed by this interview. By comparing the project budget effecting cost factors with the cost factors evaluated in conventional alternative analysis approaches, this motivating case highlights how conventional practices on alternative analysis are limited even for single equipment.

1.1.1 Tunnel boring machine as motivation of the study

Infrastructure is an essential element of construction industry growth. Mostly transportation related large-scale investments in infrastructure projects are the key element behind this rapid growth of the sector (Frankson, 2016). According to PricewaterhouseCoopers Capital Project and Infrastructure Spending Outlook to 2025 report, in worldwide, infrastructure spending will grow from $4 trillion per year in 2012 to more than $9 trillion per year by 2025 (PricewaterhouseCoopers, 2016).

According to the same report, about $78 trillion on infrastructure is expected to be spent globally between 2014 and 2025.

These values show the importance of infrastructure projects in construction industry. As mentioned above, investments in infrastructure are mostly based on transportation. Depending of construction methodology, tunnel boring machines (TBM) can be the most important equipment in urban transportation, mainly in subway constructions in terms of the cost percentage in project budget and time effect on project duration. A tunnel boring machine, also known as a "mole", is a machine used to excavate tunnels with a circular cross section through a variety of soil and rock strata (Figure 1.1) (Url 5).

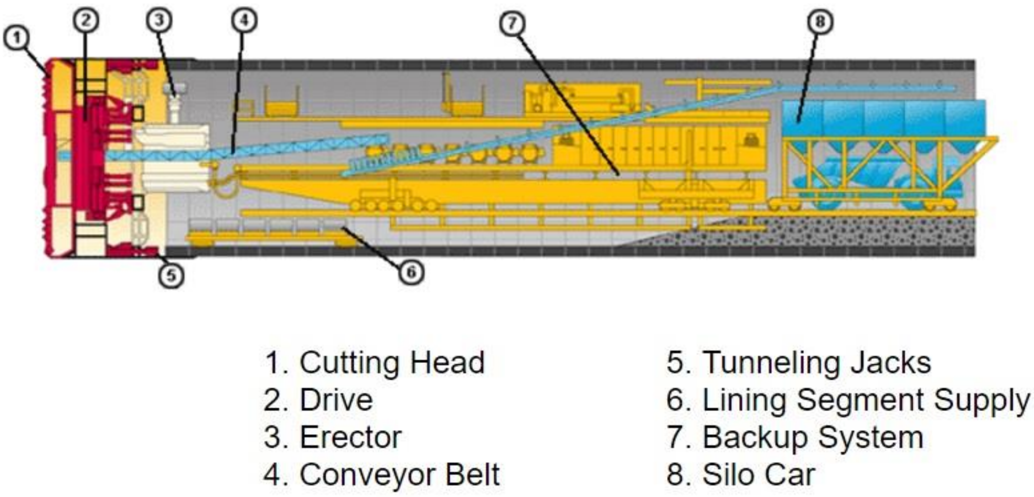

Figure 1.1 : Cross-section of a TBM machine.

In Turkey, the municipality obliges TBM use in tunnel works of metro line constructions. TBM use obligation in a project can vary between 50 to 70% of total tunnel length (Serdar Savk, personal interview, 9 February 2017). In this case study which is formed by the shared experience of a TBM expert ,who works as the TBM manager of one the biggest infrastructure company in Turkey, it has been identified that tunnel works corresponds almost 40% of all project cost for a metro construction. TBM cost holds approximately 40% of tunnel work cost which corresponds to almost 15% of overall project cost. Since TBM holds a very large percentage of overall project cost and has a high effect on project duration, accurate estimation of production rates of costs of this equipment increases the economic confidence (Cigla et al, 2001). Hence, cost calculation practices including alternatives evaluation in tunnel boring equipment plays a vital role in many infrastructure projects' budgets.

There are numerous cost factors that affect the overall TBM costs in a project. These costs are mainly the TBM itself-based costs and methodology selection based costs. TBM itself based costs can be grouped into three:

- TBM procurement and mobilization costs: these costs include the initial investment cost as procurement cost of the machine as well as transportation, mobilization/demobilization costs of it.
- Tunnel boring and assembly costs: these costs cover tunnel construction, energy supply, excavated material transportation out of tunnel, and TBM operating and maintenance costs.
- TBM station costs: TBM station is the area from where the earth waste is gathered and moved out and where the segments and injection to build the tunnel are driven in. TBM station costs include station set-up cost, injection and segment assembly costs.

Necessary calculations on these cost factors are done by evaluating the construction route, available spaces around construction area, and company data especially about productivity and cost per km for different ground conditions. Yet, all the calculations and selection of factors to evaluate are subjected to experts' personal view and judgement.

Second main cost factor of TBM is construction methodology based cost factors that can vary as:

- Platform tunnels construction methods,
- Excavated material transportation methods,
- Injection supply methods,
- In-tunnel logistic supply methods.

For example, for excavated material transportation methodology one can select conveyor system, carriage system or slurry method. When carriage system is selected, the rail laid down to the bottom of tunnel can also be used for segment launching. Hence the cost will be reduced. However, this method has a high possibility to elongate the project duration since the subway rail lay activity can only be start following demolish of the carriage system rails. To be able to start subway rail lay activity, less rails for carriage system should be used. In other to achieve this, the distance to transport excavated material out of tunnel should be shortened by moving the TBM operation station to the possible nearest location. This action will bring additional cost due to demobilization and remobilization of the station. On the other hand, when conveyor system is used, since the system is placed up of the tunnel, the subway rail laying activity can start earlier and replacement of the station will not be necessary. However, when the station is not moved, the conveyor system should be longer which will bring additional cost (Figure 1.2). When it is kept in mind that 40% of overall TBM station running cost comes from the costs of excavated material transportation, any analysis done for differentiating these costs affect severely the project total cost. As can be seen with these briefly discussed options, a wide variety of parameters that will result in different project cost and duration occurs due to the selections of any different methodology.

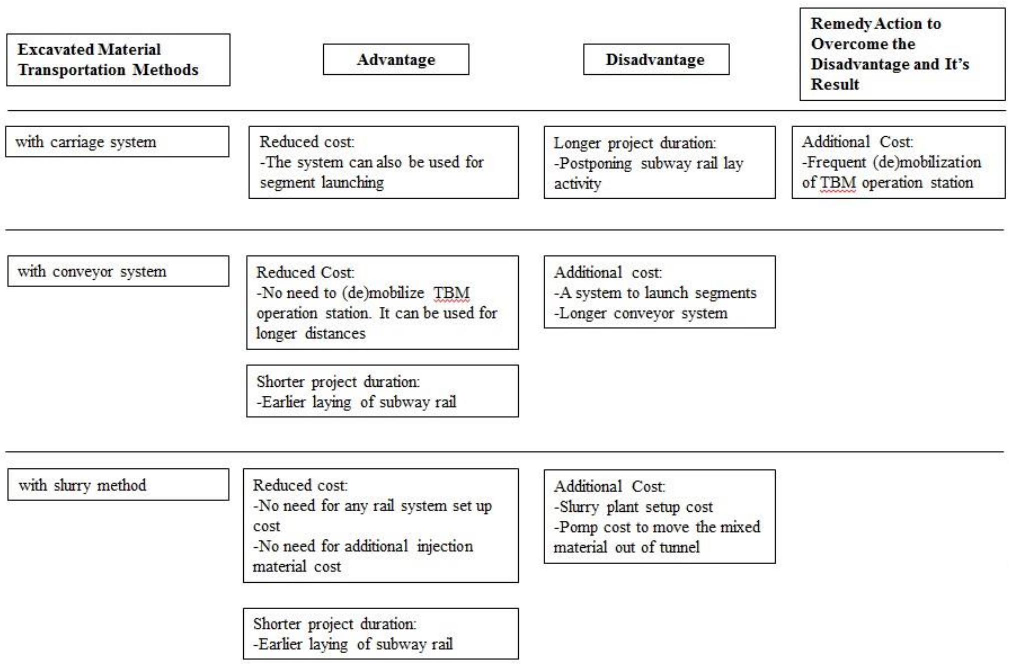

Figure 1.2 : Cost and duration effects of excavated materials transportation methods.

In this investigated case study, it was revealed that in tender and pre-construction stages, TBM based costs are mainly calculated based on company database and experts' knowledge. They can evaluate tunnel boring and assembly costs based on company's past data obtained from previous projects. Hence, for these cost factors, companies do not show tendency to perform alternative cost and time analysis. According to the expert, alternative costs can be obtained mainly by the TBM station costs and methodology based costs. TBM station costs cover the setup cost of station that includes the system for move out of earth waste from the tunnel and drive in of concrete segments and injection material inside the tunnel. This case revealed that any changes in any above mentioned factors affect the overall TBM cost drastically in a project. Since there are too many cost parameters and hence many alternatives can be formed, conventional approaches tend to evaluate very few of them selected depend on experts' and companies approaches. The cost factors cannot be evaluated in a structured form by an expert. Due to time limitations and various numbers of parameters involved, decisions on methodology selection is done not by alternative analysis results but by experts' know-how. Hence, biased and limited alternative analysis in conventional approaches cannot be overcome. This situation pointed out by TBM manager of one of the largest construction company in Turkey shows that to evaluate not only few but all the cost factors without any personal biased approach, an integrated structured alternative evaluation approach is needed.

1.2 Aim And Objectives

This thesis aims to identify the cost factors needed and used for project alternative analysis in terms of cost and time in pre-construction stage. In order to achieve this aim, the objectives are determined as follows:

(1) to identify cost factors that need to be used for performing alternative cost and time analysis,

(2) to describe how conventional alternative cost and time analysis practices are being conducted

(3) to identify which factors from identified requirements in objective (1) are considered during conventional approaches.

The first contribution of the study is the identification of the factors for performing alternative cost and time analysis. The second contribution is the description of the need for an integrated system to conduct alternative cost and time analysis by investigating the conventional practices.

1.3 Scope of Study

This study identifies the cost factors for performing alternative cost and time analysis for the construction stage during pre-construction stage. The types of projects included in the study are residential, commercial, and infrastructure projects. Only large-scale projects were considered and it is assumed that the alternative cost analysis will not consider any design changes. During tender and pre-construction stages, the design is assumed to be drawn and fixed. Therefore, this thesis focuses on the projects which have detailed design.

1.4 Methodology of Study

To achieve above objectives of the study, literature review and semi-structured interviews were conducted. Two types of interviews were conducted: pre-interviews and interviews. Pre-interviews were conducted with three experts to extend the literature review findings while eight interviews were conducted to validate the findings. In addition, conventional alternative cost and time analysis practices were obtained through the interviews. The interviewees were selected based on their expertise area and on their experience level. They were experts on tendering either at site or at the main office having minimum ten years of experience. All the pre-interviews were conducted as face-to-face interviews. Five of the interviews were also conducted as face-to-face interviews while the remaining three were performed via email.

Face-to-face interviews were selected as the methodology of this study since different than Delphi Method, the process was not iterative. In addition to this, a group communication process that aims the convergence of opinions were not aimed nor considered as a methodology. A factor was removed from the list only when all the participants were agreed on it. However, a factor was left in the list as a finding if a participant could not opine on it depending on his expertise area.

The methodology steps used in this study to achieve the objectives are given below (Figure 1.3):

To achieve the first objective, literature review was performed to identify cost items forming alternative project costs. These factors were listed under five main categories. In the pre-interviews, these factors were reviewed bythree experts from three different project types (residential, commercial, infrastructure) and modified based on their feedback. At this point, all the literature findings were agreed on by pre-interviews and additional factors obtained by pre-interviews were included as new factors. In the next step, the modified final cost factors found by literature review and extended by pre-interviews were validated by interviews which were conducted with eight interviewees from three construction types. Four of the experts were from infrastructure type while the two of the remaining is from commercial type and the other two is from residential buildings type. The interviewees were distributed the requirements list and they were asked if they agree with the list and if there are any additions or removals required.

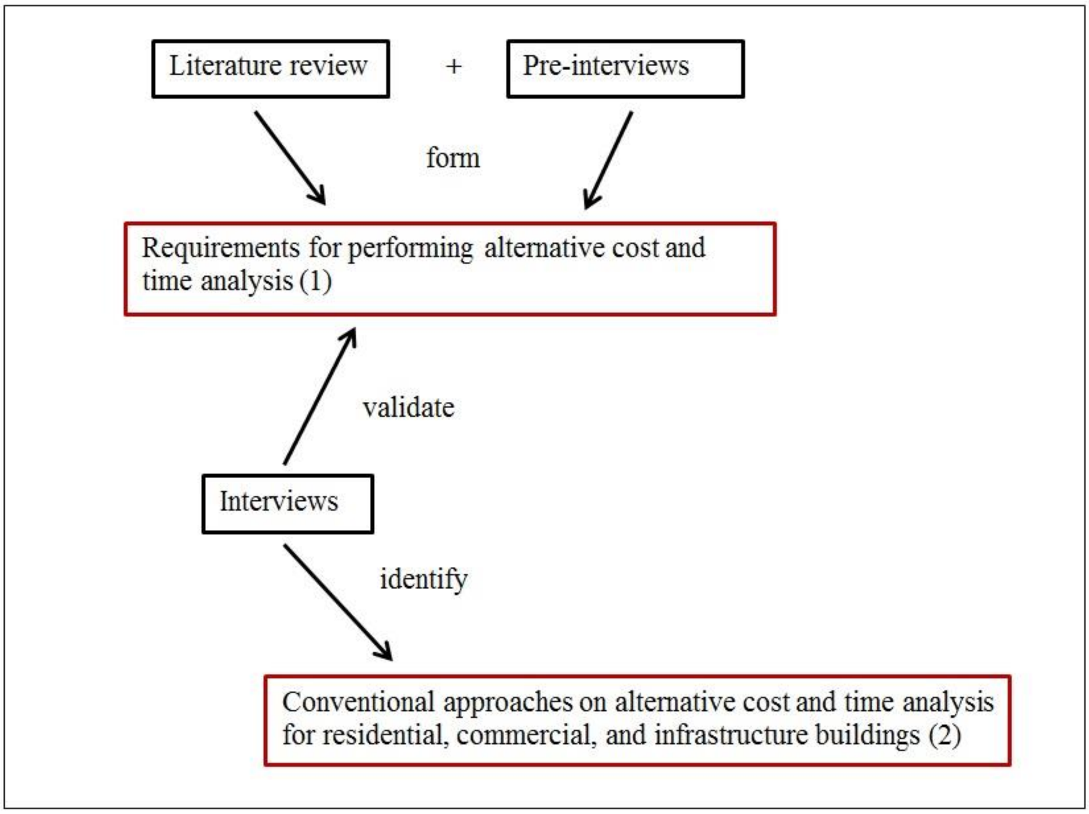

Figure 1.3 : Methodology steps for objective (1) and objective (2).

In the second part of the study, interviewees were asked about their current alternative cost analysis approaches. The obtained results were used to achieve the second objective of this thesis.

Thirdly, the results obtained from interviews and related to conventional approaches were analyzed. Factors used in conventional alternative cost and time analysis were compared with the alternative cost and time analysis requirements obtained by literature review and pre-interviews. The reasons and potential causes of differences were discussed. A future vision on needs to conduct more effective and integrated alternative cost analysis is proposed.

1.5 Organization of Thesis

In Chapter 2, background information on project cost and time, factors affecting project cost and time, and estimating practices are given. This chapter also covers the definition of alternative cost and time analysis and factors evaluated in project estimation. Research methodology with interviewees' selection criteria are presented in Chapter 3. Chapter 4 explains the findings on requirements for alternative cost and time analysis. Conventional approaches are discussed and discussions are also given in this chapter. Finally, summary of the work performed during thesis work and findings with their concluding remarks are given in Chapter 5. Contribution of the study and future work vision are also discussed in this chapter.

2. RESEARCH BACKGROUND

This chapter aims to clarify the project estimation cost factors, alternative analysis practices and their importance in literature. Accordingly, project estimation, factors affecting project estimation and alternative time and cost analysis are described in this chapter. Since the thesis focuses on requirements for alternative cost and time analysis, not the cost factors needed for estimation but needed to perform alternative project cost and time were focused on.

The chapter starts with a very brief overview on construction project and its stages. Construction stages, including pre-construction stage are described. Afterwards, project estimation types as well as its process and alternative cost and time analysis in it is clarified. Finally, cost factors that affect project estimation and cost factors that are needed to form alternative estimations are discussed.

2.1 Overview on Construction Project, Project Stages and Project Costs

2.1.1 Construction project

According to Project Management Institute (PMI), a project is defined as "a temporary endeavor undertaken to create a unique product, service or result" (PMBOK, 2013). The institute defines a project as temporary since it has a predetermined beginning and end in time. Hence, the scope and resources for a project is defined. In addition, not being a routine operation but a specific set of operations designed to accomplish a specific goal makes a project unique.

A construction project is defined as the organized many small efforts that are integrated to form a single building or structure (Sears et al.,2015). Construction projects involve processes that consist of assembling a tangible structure. A construction project differs from manufacturing projects mainly because of being a non-repetitive production for a designated client (Url 7).

2.1.2 Construction stages

Construction stages are divided into six (Figure 2.1) (Jackson, 2010):

- Design
- Pre-construction
- Procurement
- Construction
- Post-construction
- Owner occupancy

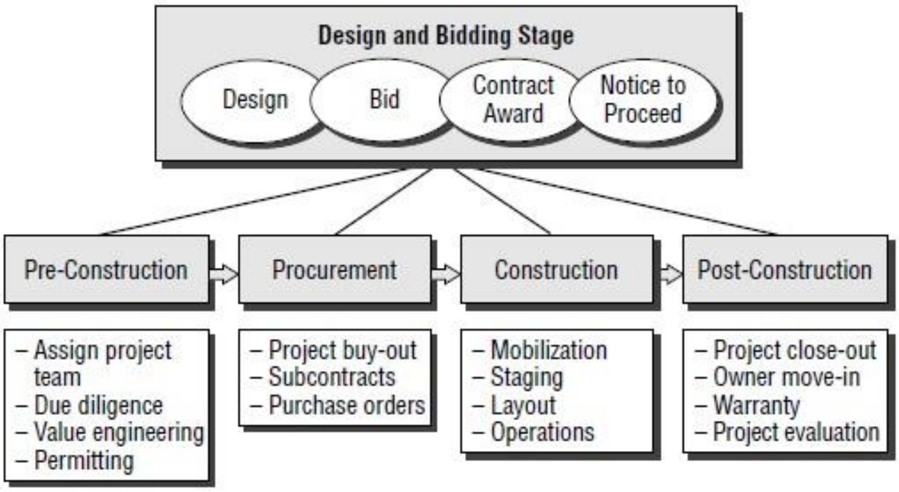

Figure 2.1 : Construction project stages (from Jackson, 2010).

Design stage is the beginning stage of every construction project. Prior to actual construction of the project, intensive works and numerous overlapping steps occur in design stage. In this stage the project is finalized in accordance with owner demand and tender documents and specifications are prepared (Barrie and Paulson, 1992).

Following the design stage, tender stage takes place as an interim stage. Tender stage is the stage in which project cost estimation is calculated in accordance with quantity take-off derived from design documents.

Pre-construction stage is a planning stage before the actual construction begins. Pre-construction stage starts with the commencement of tender award. In this stage, project cost and schedule details pass from estimators to project manager for the first time. Hence, project estimation conducted in tender stage is overviewed by the project executives, namely project manager, and necessary correction and modifications are done accordingly at this stage.

In procurement stage, the construction team buys every resource (equipment, material, labor and etc.) they need to complete the project (Bennett, 2003). The complexity of this stage depends on the project and the company. For large projects, there are more items to procure and the procurement stage is more complex.

Construction stage is the stage that starts with the execution of construction work and ends with the finish of all construction activities. This stage is the actual commencement stage where resources are used and money is spent. Decision related to construction methodology and any other cost expenses taken in pre-construction stage are applied in this stage.

Once construction is complete, the commissioning stage begins. Post-construction stage starts with the commissioning stage. Post-construction stage covers the test of all systems and equipment to ensure that the whole system works correctly and properly.

Lastly, owner occupancy starts when the owner is agreed about the final product, project, and comply with the tender documents and specifications. This stage starts when the owner accept the project and move into whilst this action starts the warranty period (Jackson, 2010).

2.1.3 Construction costs

Construction project costs are grouped under three (Larson and Gray, 2011):

- Direct costs
- Project overhead costs (direct costs)
- General and administrative overhead costs (indirect costs)

Direct costs are the costs that are chargeable to a specific work package. Labor, material, equipment, subcontracting and hand tool costs are direct costs of a project.

Project overhead costs are another direct cost type. Salaries, rents, supply and specialized machinery costs are project overhead cost items.

Indirect costs continue for the life of the project (Larson and Gray, 2011). Accordingly, any reduction in project duration means a reduction in indirect costs. General and job-specific overhead costs such as supervision, consultants, administrative and interest are called as indirect costs. Indirect costs are the organization costs indirectly linked to work packages but directly link to time of construction. Although the list of indirect costs may vary depending on project, temporary utilities, supervision, testing and inspections, job trailer expenses are the common cost items for every project.

Project overhead costs are estimated to hold approximately 5%-15% of project total direct costs whereas general overhead can be estimated to be between 2%-5% (Url 8). This shows that direct costs form the majority of total project cost. Accordingly, any action taken to improve direct cost estimation helps contractors on getting new jobs.

2.2 Project Estimating Practices

2.2.1 Project estimation

Project estimation is an educated guess of project time and cost based on available information, of probably quantities and costs of material, labor, equipment, and subcontractors to complete a project (Jackson, 2010). The costs of a facility are determined during project estimation through quantitative analysis of the work required. Quantitative analysis is conducted by using design documents to evaluate a single total project cost. The accuracy of estimation depends on the detail of input information used for estimating.

According to their accuracy level, project estimation techniques can be grouped into five (Bus. 286 Project Management, 2007):

- Expert judgement
- 3-point estimate
- Comparative estimate
- Parametric estimate
- Bottom-up estimate

The accuracy and the level of detail increase as we go through from expert judgement to bottom-up estimate. Project estimation by expert judgement is conducted by asking a subject matter project team and/or experts. 3-point estimate is a calculation based estimation approach that comes up with three numbers; realistic (most likely), best case (optimistic), and worst case (pessimistic). Comparative estimating is also known as analogous estimation. The fundamental of this approach is comparison. Actual project cost items and units are compared with similar existing or past projects based on similarities. Adjustments are applied for complexity, physical and technical differences and the project estimation is finalized. Cost estimating relationships form the basis of parametric estimation. In this type of estimation, statistical techniques are used. Relevant historical data usually at an aggregated level of detail are collected and related to the project being estimated. Bottom-up estimation is also known as detailed estimation, engineering build-up, or grass roots method. In this methodology, parametric procedures are applied for specific work packages. Bottom-up estimation methodology is a micro estimation approach that has the maximum level of detail of each cost parameter.

When cost and time is important, which is the generally the case for a contractor that has to get new jobs and survive in the industry, the cost estimation practices should be detailed as much as possible and even without detailing the cost practices, possible alternative scenarios should be evaluated for direct cost items to lower costs.

There are numerous cost factors that need to be taken into account while performing estimation. Project estimation includes estimation of design cost, drafting cost, material cost, labor cost, equipment cost, hand tool, jigs, fixtures cost, inspection cost, and overhead cost (Murugan, 2011).

Project delivery method and contract types define the responsibilities of each partner in a construction process and affect the cost estimation practices and their level of detail. Lump sum, unit price, cost plus fee and guaranteed maximum price are the types of construction contract types (Jackson, 2010). In unit price, cost plus fee and guaranteed maximum price contract types, the contractor is paid based on actual costs and a percentage of a fee amount. However, in lump sum contract types whatever the expenses of the contractor during construction, the money that is paid will be fixed. Accordingly, cost practices both in planning phase and execution phase becomes more important for lump sum contract types of projects. Project delivery methods vary as design-bid-build, design-build, construction manager contract with fee, and integrated project delivery methods. For each type of project delivery method, the responsibilities of project partners (owner, contractor, designer and construction manager) vary. Depending on the project delivery method, contractor may not be responsible for design cost. However, even if the design is provided by the owner, the contractor should estimate a budget for drafting. Basically, this cost can be calculated by multiplying the estimated draft time with draftsman salary. If drafting is subcontracted, then a bulk amount for subcontractor should be added to project estimation cost.

Material, labor, equipment, subcontracting, hand tool, jigs and fixtures costs are the main and most important costs of an estimation. As the direct costs of a project, these cost items have the most potential to go through alternative analysis that will result in different project budgets and duration.

Inspection cost is a cost obtained generally from subcontractors/vendors of a specific equipment, gauges and wages. Inspection cost of equipment is obtained by its vendor during material cost calculations and added as a given bulk amount. Accordingly, alternative formation is not considered or conducted for inspection cost.

General and job specific overhead cost, as a final estimation cost parameter, cannot be charged directly to a project. As an indirect cost, general overhead cost is estimated based on type, square meter, location, and duration and etc. information of previous project records.

Quality and accuracy of estimation depends highly on people and organization culture. Qualified and experienced estimator, good estimating method and data are the key factors for estimation quality (Adesola, 2012). Qualification and experience level of the estimator increase the quality of the estimation; however, this will not prevent the estimation to be biased. To eliminate or at least minimize the biased estimation, cost factors should be examined in detail and alternative formation practices should be free of personal choices.

Alternative analysis is the analysis of different project cost and time values by evaluating and changing all potential project factors. In alternative analysis, either the individual effect of one parameter or the overall effect of several parameters is evaluated by implementing possible different values that each parameter can take. For instance, if two tower cranes are used instead of one in a construction project, project duration will high likely be shorter due to increase number of resource. However, due to increase number of tower cranes, the direct cost accumulated by equipment will be higher while the indirect cost will be lower due to shorter duration. So, cost-time results of each alternative should be studied carefully for a better and contractor-favor estimation price. It should be kept in mind that if the design of the project is fixed and determined, material cost will not change if it depends on the estimated quantity of each material unit. The only change that can be done and forms alternatives on material cost is the use of alternative materials allowed in design documents and specifications.

2.2.2 Project estimation steps

Project estimation process should cover three components; quantities, pricing, and productivity. Pricing is determined based on quantities and project duration is calculated using productivity knowledge. As a result, these three components form the project estimate and establish the targets for project team.

Figure 2.2 shows the project estimation process step by step (Jackson, 2010). As the first step of project estimation, project plans and specifications are reviewed and understood completely. Following this step, a query list is formed by analyzing the products whose details are given in specifications. Between query list and bid strategy developments, site visits and pre-bid meetings can held. Site visits are mandatory for accurate estimation. There are some items that cannot be understood without site visit. Ground condition, site access and traffic around job site are some examples for items that are determined well with site visit. Pre-bid meetings are held by owner and/or designer. The aim of these meetings are to provide opportunity to contractors get answers of their questions related to design, specifications or project in general.

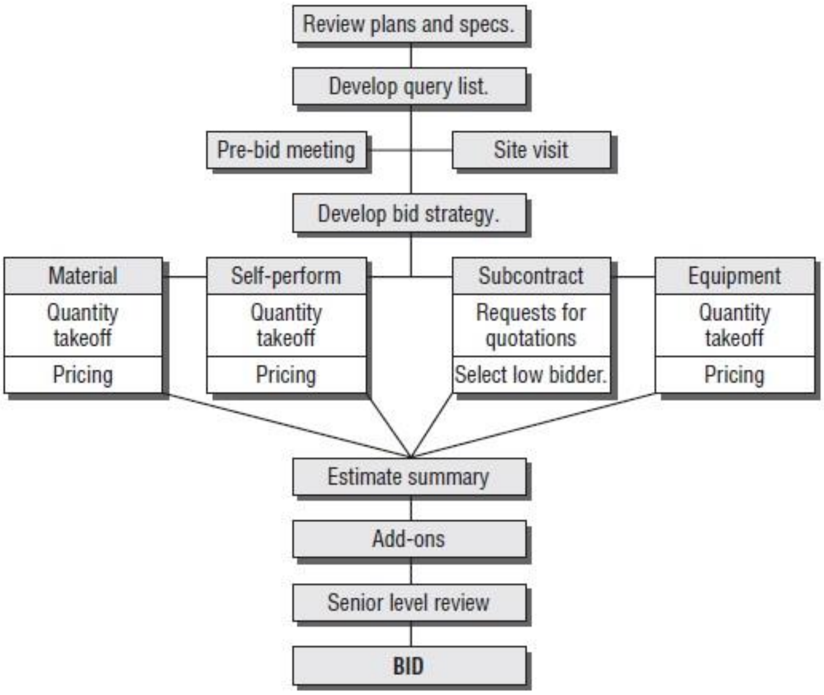

Figure 2.2 : Project estimation process (Jackson, 2010).

After all the questions are clarified and site conditions knowledge is gathered, bid strategy is developed. At this point, the main focus is given on the direct costs of the project. Hence, quantity takeoff for material, labor, and equipment is conducted. Based on quantity takeoffs, pricing of these items are done. Subcontracting cost is also calculated at this stage.

Company overheads related to all indirect expenditures are added to direct cost calculations. Administrative expenses are estimated as add-ons. As a final step, estimation is controlled by senior level review. Profit margins of the project are determined at this step by company managers or even by company board members. After all these steps, the estimation is ready for tender bid.

In traditional estimation quantity take off is handled manually whilst scheduling tools are used for construction scheduling. Hand calculation of quantity take off is time consuming and open to personal errors. Cost calculations for direct costs of a project and scheduling are calculated separately. Estimators refer to the schedule mainly for indirect cost calculations. Quantity take-off can also be done automatically when BIM based tools are used. Quantities can be easily calculated with the model of the project that is drawn according to dimensions. This reduces the time needed for material cost calculations.

2.3 Alternative Analysis in Literature

In this section of thesis, alternative analysis approaches for construction are discussed. Since any action to perform alternative analysis affects the project estimation cost and time, cost factors that affect project estimation are discussed firstly. Because the aim of this study is to identify the requirements for alternative analysis, the emphasis is given on the factors forming alternative cost analysis in the following sub-section. Literature findings on factors needed in forming alternative cost and time analysis are described.

2.3.1 Factors affecting project cost

Each construction project is unique. Even if the design of the project remains the same, project location and time, therefore prices of each direct cost factors change. There are a lot of things that are under estimating control that affects project costs significantly. Due to these reasons, factors affecting construction project should be examined in detail and project estimation practices should be handled carefully by project estimators and company managers.

The factors that might affect the pricing of a construction project can be summarized as follows (Akintoye, 2010; Jackson, 2010; Moore, 1996):

- Project size: Project size affects the project quantities, mobilization, productivity and unit material cost. As the project gets bigger, project efficiency is more likely to increase as a result the productivity increase. Moreover, unit cost of a material decreases when it is bought in bulk amounts. Hence the project size affects both the efficiency and material cost.
- Project complexity: As Jackson (2010) states, complexity and details of a project impacts productivity too. Project complexity may include type of structure, complexity of design, and scale and scope of construction.
- Buildability: Buildability of a project is affected by the extent of prefabrication and the integration of services into the construction process (Moore, 1996). Since these factors have an impact on the profitability and management of a project, the estimators should consider them carefully during estimation.

- Site location and constraints: Site location, site constraints, and time of construction have impact on productivity of both direct and indirect labors, time of an activity, and procurement and delivery of necessary materials to site. Hence, differences in any of these factors lead to different project estimations.
- Time of construction: There is always a time gap between the project award and when the construction actually starts. So, the estimators must be careful to anticipate fluctuations in prices, changes in weather conditions and availability of labor during these stretches of time.
- Clarity of specification requirements and quality of work: Clarity of specification requirements can be achieved by the data provided by owner and/or engineer. As the information provided by the owner increases, the detail level increases also. Level of data detail may affect the estimation type and process accordingly. Moreover, the required work quality is also defined by the standards and this requirement affects the material selection and activity durations.
- Project team experience: As Akintoye (2010) stated in his work, it is the estimating department's responsibility to establish the resources and cost them. Hence, project team experience affects the resource selection and costing approaches.
- Management factors: Management factors include the identification of different owner approaches and expectations and sensing accordingly.
- Market and economic conditions: Market conditions and economic conditions are interrelated with each other. And both have an impact on available resources and pricing of material and labor. In addition, supply demand law has an effect on the market condition and hence affects the mark-up percentages.
- Cash flow punctuality: Lui and Wang (2010) states that the only concern about cash flow is not its amount. Companies should also focus on cash flow timing, which is a critical issue for budget management during construction.

- Bidding strategies: The level of competition has a huge impact on construction estimation (Kim and Reinshmidit, 2010). Increases in competition level may decrease the mark-up and contingency percentages. A company may decide on to bid with lower mark-up based on bidding strategies and if it can cover the risk premium.
- Estimating processes: Estimating processes focuses on different estimation approaches and their effects on estimating accuracy. The selection of estimating approaches and also the available information can be linked to the accuracy of the early stage estimates and the estimations made when design is completed.

Most of the above mentioned factors (project complexity, project location, market conditions, etc.) are factors that are fixed for a project. In other words, although these factors affect overall project cost, they do not vary based on alternative methods that can be used in construction.. Since these factors are project-related fixed factors that cannot be used in alternative formation, estimators and managers evaluate these factors as risk items and revise contingency amount accordingly.

The cost factors that are mainly related to direct costs of a project are the ones that change based on the alternative method used and hence can be used for alternative formation. For example, based on availability and current market conditions, renting and/or owning of equipment from local market or importing them can be analyzed. Similarly, to change crew cost, alternatives on crew composition and crew local/expat ratio can be formed. Site access options are also one of the other examples of cost factors that can be changed and hence forms alternative estimations. Any alternative formed with these factors affects the project cost directly and hence forms different project estimations. Following section gives the literature findings about cost factors that might be used when forming alternative analysis.

2.3.2 Cost factors needed for alternative estimation

The research described in this section of thesis work builds on two different kinds of studies; 1) the research studies done for on-site productivity related data collection for better estimation, and 2) the research studies highlighting the requirements for BIM-based estimation tools. BIM-based estimation tools provide opportunities for early stage planning and estimation. Quantity take off of a project can be conducted with BIM-based tools in an easier and less time consuming way. In addition, they serve as a visualization tool by combining the model with project schedule (Koo and Fischer, 2000).

Categorization of the factors was done by examining the previous studies in literature. When forming the cost factors for alternative cost and time analysis, requirements are grouped under principal categories as in previous studies: equipment, crew, site access and logistics, construction process, and construction methodology (Akintoye, 2010; Kiziltas and Akinci, 2009). Equipment and crew are stated as the direct costs of a project. Equipment cost includes the purchase or rental cost, fuel oil cost, operator cost and maintenance and spare part costs. Crew cost includes the monthly wages of any labor involved in construction execution. These cost factors are important in terms of alternative analysis since they are subject to any change like the selection, composition, number, etc. Any change done in these cost factors affects the project cost and/or duration. Site access and logistics limit the usable space. Accordingly, it affects the equipment selection, number, size and so on. Construction process and construction methodology affect mainly equipment and crew related cost factors. For example, different methodologies urge the need for different construction equipment. Hence, all above principal factors affect the project budget and forms alternatives. Under each principal factor, requirements are listed in detail in Table 2.1.

Table 2.1 : Requirement factors forming alternative cost analysis.

Principal category	Factor	Author(s) and year of study
Equipment	Types and sizes of equipment	Rau 1998; Liberda et al 2003
	Number of equipment	Kiziltas and Akinci 2009
	Equipment condition	Kiziltas and Akinci 2009
	Percentage of equipment failure	Makulsawatudom and Emsley 2003; Choy and Ruwanpura, 2005
	Overtime usage of equipment	Liberda et al 2003; Choy and Ruwanpara 2005

Table 2.1 (continued): Requirement factors forming alternative cost analysis.

Principal category	Factor	Author(s) and year of study
Crew	Crew composition	Portas and AbouzRizk 1997; Ezeldin and Sharara 2006
	Availability of crew during construction	Kiziltas and Akinci 2009
	Working shift of crews	Liberda et al 2003; Choy and Ruwanpura 2005
	Skill level of crews	Russell 1993; Portas and AbouRizk 1997; Liberda et al 2003; Ezeldin and Sharara 2006
	Overtime usage of crews	Liberda et al 2003; Choy and Ruwanpara 2005
Site access and site logistics	Access to site	Kiziltas and Akinci 2009
	Existing buildings and utilities on work area	Kiziltas and Akinci 2009
	Traffic around jobsite	Kiziltas and Akinci 2009
	Weather conditions	Koehn 1985; Smith and Jolly 1985; Russell 1993; Chimwaso 2001; Liberda et al. 2003; Choy and Ruwanpura 2005; Ezeldin and Sharara 2006
Construction process	Ground condition information	Kiziltas and Akinci 2009
	Product visualization	Sacks et al. 2010
Construction method	Method visualization	Sacks et al. 2010
	Evaluation/visualization of stable workflow	Sacks et al. 2010

While identifying the productivity related requirements for estimation, researchers defined the required data either in activity level (Portas and AbuRizk, 1997; Ezeldin and Sharara, 2006) or project level (Koehn and Brown, 1985; Rau, 1988; Russell, 1993; Liberda et al., 2003; Choy and Ruwanpura, 2005; Ezeldin and Sharara, 2006; Kiziltas and Akinci, 2009). Activity level productivity related requirements describe factors that affect productivities of a set of activities. On the other hand, project level requirements describe general factors that affect the production rates in project, without giving the focus on factors specific to certain types of activities.

Activity level research studies mainly focus on excavation and concrete works. However, cost related data obtained from these studies were specific and directly related to the requirements and characteristics of work performed. As a result, from these studies, only requirement factors related to site conditions can be obtained. The majority of the requirements are obtained from project level studies. Requirements related to crew (crew composition, overtime usage of crews, skill level of crews), equipment (types and sizes of equipment, percentage of equipment failure) and site access and site logistics requirement factors are all obtained from project level studies. Crew related parameters such as crew composition and skill level of crews are stated as other requirements that form alternative project costs (Portas and AbouRizk 1997; Liberda et al., 2003; Ezeldin and Sharara 2006).

When BIM-based research studies are examined, requirements related to equipment size and type is obtained as well as construction methods i.e. mainly method visualization related requirement factors are also identified by BIM-based studies (Sacks et al., 2010).

The details of literature findings are discussed in Chapter 4 together with the interview findings. Since the requirement factors are finalized with interviews, the details of each requirement factor are given in the findings section, Section 4, with interviews' findings for coherent flow. Before this discussion, research approach and interviewees' selection criteria is detailed in the following section.

3. RESEARCH APPROACH

In this chapter, research approach including the selection criteria of interviewees is discussed.

3.1 Research Approach

This study consisted of two main steps; literature review and semi-structured interviews (Figure 3.1). Literature review was performed to identify the cost factors that are needed while performing alternative cost and time analysis and to obtain current literature on construction alternative analysis. 18 cost factors in total were identified with the literature review.

Semi-structured interview is a qualitative method that is used to gather information in a set of open questions (Drever, 1995). In semi-structured interviews, the interviewer does not strictly follow a formalized list of questions; the framework of themes is provided to the interviewer; however, the interviewer is free to add his/her opinion and thoughts. There were two types of interviews in this study; pre-interviews and interviews. Cost factors that identified in the literature review were presented to three interviewees in the pre-interviews. Three experts were agreed on the 18 cost factors found with literature review and they added 20 more cost factors that are needed to perform alternative cost and time analysis. As a result, a list with 38 cost factors was formed. The finalized cost factors were shown to the second set of interviews conducted with eight experts from three different construction fields. Interviewees were agreed on 33 of the found factors and removed 4 of them from the list. So, 33 of the factors were validated by the eight interviewees and the list was finalized with the validated factors.

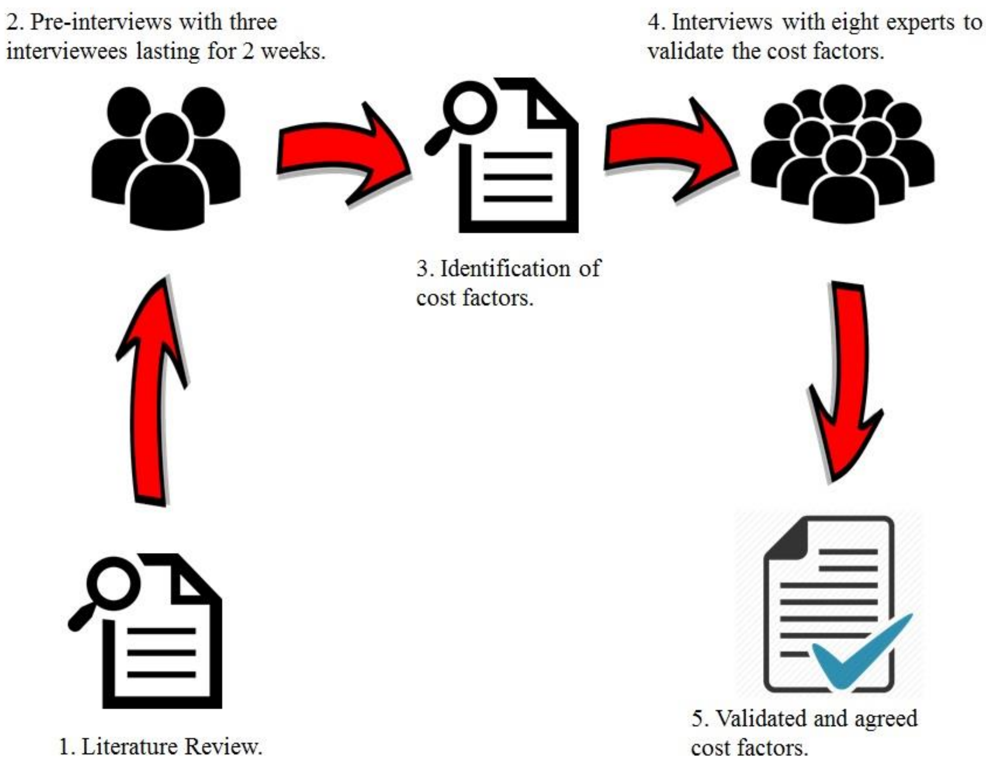

Figure 3.1 : Schematic diagram of cost factor identification.

All pre-interviews were conducted as face-to-face interviews. Five of second set of interviews were also conducted as face-to-face interviews while the remaining three were done via email. However, the interviews conducted via email were iterative; unclear parts and details were asked to interviewees and clarified.

Conventional alternative cost and time analysis approaches were also determined via these second set of interviews. Interviewees were asked about their current estimation practices and how they form alternatives during these practices. At the end of this step, interviewees were given the validated cost factors and asked to indicate which of them they use during performing alternative analysis.

3.2 Interviewees Selection Criteria

For this study, two sets of interviews were conducted; pre-interviews and interviews. Pre-interviews were conducted with three experts while interviews were conducted with eight interviewees. The selection criteria for both sets of interviewees were the same. The interviewees were selected based on these criteria;

Company characteristics: the companies that the interviewees are working for are large-scale companies. All companies are in the list of Engineering News Record (ENR) Top 250 International Contractors (Url 9).

Expertise field: while selecting the interviewees, the diversity of expertise fields have been given importance. Accordingly, the selected interviewees have experience either in building, commercial or infrastructure construction types. The interviewees have experience in complex projects and they gained their expertise in these three project types either at site or at office.

Expertise level: in this study, the minimum experience level of interviewees was determined as ten years. The experience level of interviewees varies between ten years to 22 years. Current positions of interviewees vary from chief project controller to managing partner.

Detailed information about three pre-interviewees features related to selection criteria and their current positions were tabulated below (Table 3.1).

Table 3.1 : Pre-interviewees experience in years and current position.

Expertise field of the pre-interviewer	Experience in years	Current position
Commercial buildings	10	Project manager
Infrastructure	13	Technical office manager
Residential buildings	20	Managing partner

Current positions of three pre-interviewees are project manager, technical office manager and managing partner with 10, 13, and 20 years of experience respectively.

Same selection criteria were used for determining the second set of interviewees. Four of eight interviewees from second set of interviews have expertise on infrastructure, two of them have experience on commercial buildings, while the other two gained their experience on residential building construction.

Years of experience for interviewees vary from ten to 22. Expertise area, experience in years and current positions of interviewees are tabulated in Table 3.2.

Table 3.2 : Interviewees' characteristics.

# of interviewees	Expertise area	Experience in years	Current position
1	Commercial	10	Project manager

Table 3.2 (continued) : Interviewees' characteristics.

# of interviewees	Expertise area	Experience in years	Current position
2	Commercial	15	Project manager
3	Residential	16	Planning and contracts manager
4	Residential	20	Budget and planning manager
5	Infrastructure	11	Chief project controller
6	Infrastructure	13	Technical office manager
7	Infrastructure	16	Tender manager
8	Infrastructure	22	Deputy project manager

Among all, only one of them has current position as chief project controller, and the other seven are managers that range from technical office manager, tender manager, budget and planning manager, deputy project manager, and project manager.

4. FACTORS FOR ALTERNATIVE COST AND TIME ANALYSIS

In this chapter, findings on requirements for alternative cost and time analysis are discussed in detail. Cost factors found in literature review are consolidated with the ones found with pre-interviews. The consolidated factors that are reviewed and validated by interviews conducted with eight interviewees are explained. Current approaches on alternative cost and time analysis obtained through interviews are also discussed. The factors used in conventional approaches are compared with the requirement factors found for alternative cost and time analysis. Gaps between currently used factors and required factors are also discussed in this chapter. As a final step, the need and suggestion for an integrated system is discussed.

4.1 Factors for Alternative Cost and Time Analysis

In this section, requirement factors for alternative cost and time analysis are discussed in detail and details of each item are provided.

4.1.1 Factors found from literature review

Findings from literature review on factors needed for conducting alternative cost and time analysis in tender and pre-construction stages are determined and listed in Table 2.1. As discussed in Chapter 2, the factors found by literature review are mostly on-site productivity related data factors that are used for estimation.

Literature review findings are evaluated based on whether they form an alternative project cost or not and the detail of cost factors that are needed to perform alternative analysis is given in upcoming sections.

4.1.2 Factors found by pre-interviews

Following the literature review pre-interviews with three experts were conducted. Their reviews and opinions are retrieved. Experts' suggestions different than literature review findings are added to and grouped under principal factors used for literature findings.

Pre-interview findings are merged with literature findings and a final cost factors list is formed. The factors found by pre-interviews are shown in italic in the table showing the final requirement list in the upcoming section (Table 4.1).The final list is validated by eight interviewees. The validated list shows the requirement factors agreed by each interviewee. The upcoming section shows the final requirement list and detail of each alternative forming cost factor.

4.1.3 Factors for alternative cost and time analysis

The list contains five main categories; equipment, crew, site access and logistics, construction process and construction methodology (Table 4.1). These main categories are named as principal categories. They are created in accordance with literature. The categorization of similar papers (Kiziltas and Akinci, 2009; Akintoye, 2000) which focuses on estimation cost parameters was taken into account. Based on interviewees' additional factors, the final principal categorization was formed.

It should be emphasized that these factors are the ones that affect alternative analysis, not all cost factors that are used in estimation. The selection and classification of the found factors were conducted with this purpose. The description of each factor is updated by literature and interviewees' opinion. The description of the factors found in literature is submitted to the interviewees' opinion. Their comment or addition to any description is added if there was any. For the factors that were added by interviews, the description of the factor was clarified by the interviewee and confirmed and modified in the following interviews.

Each requirement factor agreed with the interviewees is explained in detail below.

Table 4.1 : Factors for alternative cost and time analysis.

Principal category	Factor
Equipment	*Rental/owned equipment decision*
	Rental duration
	Types and sizes of equipment
	Number of equipment
	Position/location of equipment
	Equipment condition
	Equipment productivity

Table 4.1 (continued) : Factors for alternative cost and time analysis.

Principal category	Factor
	Equipment usage/idle time
	Equipment usage time per activity
	Percentage of equipment failure
	Overtime usage of equipment
	Lack of/limited access to a specific location
Crew	Crew composition
	Availability of crew used in bidding stage during construction
	Working shift of crews
	Skill level of crew
	Overtime usage of crew
	Lack of/limited access of a crew to a specific location
Site access and logistics	Access to site
	Existing buildings/utilities on work area
	Traffic around job site
	Weather conditions
Construction process	Ground condition information
	Product visualization
	Readiness of a space
	Readiness of a crew
	Readiness of an equipment
Construction method	*Method selection*
	Method visualization
	Subcontracting methodology
	Subcontracting percentage
	Starting points of construction
	Evaluation/visualization of stabile workflow

Equipment

- Rental/owned equipment decision: At the beginning of each project, following the calculation of number of equipment in need, company inventory on equipment is checked. Accordingly, based on available equipment inventory and other ongoing projects' needs, tender department decides on whether to rent equipment or to use an owned one. Since using owned equipment vs renting has different cost entries, this decision is a factor that leads to different total project cost.

- Rental duration*:* Generally, in construction sector payment for any equipment is done monthly unless the equipment is a very specific type of equipment.

For instance, in bridge deck installation process, due to dimensions and heavy load of the steel decks a very specific type of crane called floating crane, may be needed. This kind of specific equipment is rented daily and the rental payment is done based on daily usage. The decision on whether to rent the equipment for the entire duration or to rent it for a certain period when needed, taking into account the risk involved is a critical and cost effective decision. Such a decision is critical because to find and rent specific equipment when it is needed in project is a risky action since it holds the risk of delays in schedule. It can lead to alternative costs for a project.

- Types and sizes of the equipment: Construction processes involve different and complex types of equipment. For a type of work, equipment selection and use can be differentiated. In addition to this, equipment types can also be differentiated depending on the construction method. Based on different type and sizes of the equipment, rental and/or owned equipment cost may differ. So as a consequence, like in every requirement factor discussed in this study, each difference in equipment cost leads to different project estimation.

- Number of equipment*:* Equipment number decision is an important factor affecting the overall project budget. As the number of equipment available during construction increases, project duration may get shorter while project cost gets higher. As a result, a decision that best fits the tender conditions should be applied by testing possible alternatives.

- Position/location of equipment: Generally, equipment location is studied for tower cranes since it is immobile equipment in construction site. Location of tower cranes is decided based on their effective area. However, as the work progresses, the effective area may be interrupted. Hence, a relocation, which is costly, may be needed. Consequently, location of equipment should be determined and alternated to foresee the most suitable location.

- Equipment condition: This factor affects the decision on rental/owned equipment as well as the duration of use of equipment. Based on equipment condition, the estimators may decide on use duration of that equipment. Equipment condition may not be good enough to cover all activities in which it is needed. In such situation, alternatives should be applied for the remained jobs. All decisions taken in process end with different project costs.

- Equipment productivity: Based on productivity data obtained from company past projects, equipment selection are formed alternatively.
- Equipment usage/idle time: In general, any equipment is assigned for a specific time interval to the related activities. Equipment is assumed to be in use for that whole duration. However, if equipment usage/idle time can be determined for this time interval, better scheduling and arrangements can be done. These actions taken to minimize idle time of equipment use will for alternative project costs.
- Equipment usage per activity: As mentioned in above requirement factor, when equipment is assigned for a specific time interval, need of that equipment for each related activity is not taken into account. For instance, when a crane is assigned to concrete works, crane usage time is taken from the start of concrete placement activity till the end of those activities. Crane usage time for each individual concrete activity, like formwork or reinforcing replacement is not separated. Detail knowledge on equipment usage per activity can improve the equipment assignment and so resource usage.
- Percentage of equipment failure: Vendors or past project data stores provide different equipment failure percentages for equipment. These percentages are compared with other properties of the equipment by estimators and alternatives are formed.
- Overtime usage of equipment: During estimation, to avoid from overtime usage of equipment, quantity of equipment in use can be increased. However, for some specific needs, overtime usage of an equipment may cost less compared to increasing its quantity. Hence, comparison of this situation forms alternatives.
- Lack of/limited access to a specific location: During estimation, smooth workflow without any interruption is assumed. Execution of some construction activities may block or limit access of a place of an equipment. Foreseeing of such possible interruptions may result in taking into account

different methodologies and/or additional work implementation strategies that will result in alternative cost and time.

Crew

- Crew composition: Alternatives on this factor are formed by evaluating two situations; (1) how many workers a crew will consist of, and (2) local-expat ratio in a crew. Depending on different numbers and ratios, alternatives that affect labor cost in project budget are formed.
- Availability of crew used in bidding stage during construction: In construction projects, there is always a time gap between the project estimation time and project execution time. Crew assignments and related cost calculations are done by assuming that the crew will be available in actual project execution period. However, this may not be the case. This is an important factor in case of specific jobs like submerged tunnel construction or blasting works. The scheduling of special works is scheduled according to availability of specialized crew. Hence, based on restricted scheduling of these specialized works, alternative schedules are formed for other construction activities.
- Working shift of crews: This factor affects the project duration and direct labor cost. As the working shift or crews increases, project duration shortens. However, additional shifts add additional labor cost to the project. Hence, comparisons are made between alternatives to find the most suitable alternative.
- Skill level of crews: As skill level of workers increase, cost of workers will increase too while construction duration may decrease depending on increased productivity. Hence, alternatives are formed based on different skill levels of crews.
- Overtime usage of crew: Alternatives on work schedule are formed if master schedule forces crews to overtime. Comparisons are done between alternative schedules and project costs and duration as a result of each schedule alternative.

- Lack of/limited access of a crew to a specific location: As discussed under equipment principal factor, smooth workflow without any interruption is assumed during estimating. If there is an interruption that lacks or limit access of a crew to a specific location, alternatives by rescheduling or changing construction methodology are formed.

Site access and logistics

- Access to site: Site access defines the available possible route to enter in and exit from site. Depending upon site access availabilities and possibilities, construction process and sequence can differ and so alternatives on these factors can be formed. Estimators can schedule the activities alternatively based on different number of accesses to the site.
- Existing buildings/utilities on the work area: This factor is taken into account in tenders in which contractor are authorized to decide on design and route selection. Depending on existing utilities on work area, alternative routes are formed.
- Traffic around job site: This factor affects the in site and out site traffic circulation plans. According to traffic circulation plans, construction sequence and so duration may change. As a result, based on traffic around job site information, traffic circulation plans are alternated that result in alternative project costs due to schedule and sequence changes.
- Weather conditions: Some construction productions may need special material use. In such cases the interaction of these material with weather conditions are taken into account and alternatives are formed accordingly.

Construction process

- Ground condition knowledge: This factor form alternative mainly in cases in which the route selection is left to the contractor. For example, if the route is not specified, alternative route selections are applied based on ground condition knowledge. If construction site is fixed as the case in residential and commercial buildings, more information on ground condition knowledge will only result in better estimation and in taking alternative precautions to improve soil condition but will not contribute to alternative cost and time analysis.

- Product visualization: Display of status of any location at any time is a need to better plan resources, mainly work teams, equipment needs and necessary material logistics to site. Visualization of product at any time before execution of work in real helps the estimators to better evaluate any need and foreseen obstacles that may arise during execution. Alternative approaches on resources or even on methodologies can be formed in tender and pre-construction stages by being aware of the possible situation of construction at any time.
- Readiness of a space: In tendering stages, schedules are done based on stable work assumption. While scheduling the activities, any interruption is disregarded. At time of execution, all resources including crew, material and equipment are assumed at execution location and the space is assumed ready. However, this might not be the case in reality. Evaluating readiness of a space may help estimators to overcome any problem that may arise because of a non-ready space. Accordingly, activities can be rescheduled with reallocation of resources that may result in different project cost.
- Readiness of a crew: As mentioned in above factor, scheduling and resource allocation is done based on stable workflow; no interruption to work or resources. Evaluation of readiness of a crew that may be need in a specific time may result in rescheduling of construction activities based on available time of that crew.
- Readiness of equipment: Similar to evaluation of readiness of a crew case, equipment readiness may lead to rescheduling construction activities. Any action taken on schedule and resources forms alternatives and hence affect the overall project budget.

<u>Construction method</u>

- Method selection: This is one of the crucial factor affecting both project cost and time. Depending on the selected methodology, resource need changes and any change in direct cost parameters of a construction affects the project cost and schedule directly.

- Method visualization: As mentioned in above factor, method selection has a crucial impact on project cost. Visualization of the selected method may help estimators to see expected productivity and progress better. Moreover, by visualizing the method, project team members may foresee any potential problem and so act earlier. They can better evaluate the selected method and hence change it if necessary and calculate the project costs accordingly.

- Subcontracting methodology: This includes the perception and approach of company to subcontracting. Depending on the company approach and policy, company can decide on to subcontract to work to a one company, or to distribute them among many small ones. Each methodology includes different cost factors and may lead to different project budget.

- Subcontracting percentage: This defines the company's approach on how much of work will be subcontracted. Conducting the work by using company's own resources versus subcontract some percentage of work will affect the overall project time and cost. Subcontracting percentage is mainly taken into account for work force and different percentages on subcontracting work force forms different alternative project costs.

- Starting points of construction: This is an alternative forming factor especially for residential and commercial buildings. Different starting points leads in different finish time for each component of construction. Hence, the part of construction that can be turned in cash sooner may differ. In estimating stages alternatives are formed to evaluate the incomes arise from different starting points. Depending on cash flow calculation and requirement of company, best suited alternative is selected.

- Evaluation/visualization of smooth workflow: In estimating and pre-construction stages all assumption are made based on continuous workflow. To perform continuous workflow, productivity related resource needs should be identified and resource allocation should be done accordingly since any possible interruption on stability may affect the resource need and allocation. Hence, evaluation/visualization of smooth workflow may result in method or equipment or schedule changes. If the estimator can see any interruption of workflow due to resource and limited access, he can evaluate the interruption and take the necessary precautions in advance. Any change in these items change the overall project cost.

Requirements for alternative cost and time analysis are discussed in detail with emphasizing how each factor may lead to a different alternative cost of project. The factors discussed in this section are the factors found in literature, retrieved with pre-interviews and validated by eight interviewees. The detail of each factor is also discussed with and confirmed by interviewees.

4.2 Conventional Alternative Cost and Time Analysis Approaches

During second set of interviews, interviewees were asked about their typical alternative cost and time analysis approaches. To determine conventional alternative analysis methods, the interviewees were asked to explain how they make alternative analysis in current conventional forms. Then, the interviewees were given the cost factors which discussed in Section 4.1.3 and asked to point out which factors from the list they use to form alternative analysis. The interviewees are grouped based on their experience field. Answers are tabulated and discussed based on project types: residential projects, commercial projects, or infrastructure projects.

4.2.1 Conventional cost estimation and alternative analysis approaches

In this section, a general schema on how cost estimation and alternative analysis is being conducted is pointed out (Figure 4.1). The output of eight interviewees from three different construction fields is merged since the processes do not show much diversity based on the construction type. However, if there are differences in approaches for each construction type, these are pointed out.

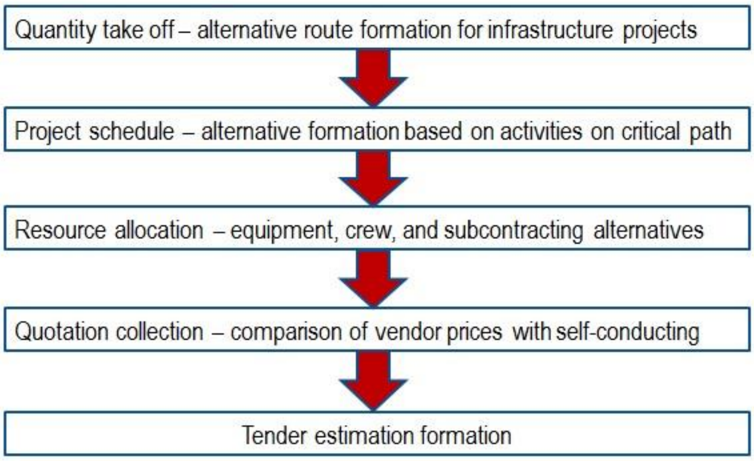

Figure 4.1 : Conventional estimation steps and alternative analysis practices.

Stages of tender estimation and alternative analysis can be summarized as follows:

- The first step of conventional cost estimation is performing quantity take-off for the project. The interviewees from residential and commercial buildings declared that in order not to lose time, they focus on the quantity of the main items such as excavation, concrete, structural steel, rebar and etc. However, the first step for infrastructure projects differs from the one in residential and commercial ones. For infrastructure projects, this step is the beginning of alternative formation. To conduct a quantity take-off for an infrastructure project, the route should be determined as much as possible. In infrastructure projects, especially in subway construction where the route is not determined precisely, the first step is to select and settle the route. In subway projects, generally tender documents provide only draft design. These projects include the overall information about the number of stations, number of storage area, and capacity of stations. However, this information could be insufficient and the design team needs to form alternative routes regarding the capacity of locations with available space provided by the owner. Accordingly, alternatives on route design are formed. Following the design route selection, quantity take off for infrastructure projects are held.

- The second step is the formation of project schedule. Since generally construction durations are predetermined in tender documents, activity durations are calculated as per calculated quantities and in accordance with companies' past project data for all project types. Following this step, schedule of the project is formed and critical path is determined. Alternative formation with second step of estimation is achieved by preparing a critical path method (CPM) based schedule and the review of critical path activities. Activities on critical path are reviewed by company managers, experts and preliminary schedule is finalized based on their comments. At this step, different alternative schedules and accordingly resource use are formed since the decision on any change in activities on critical path is possible. However, experts can form limited alternatives due to time constraints and their know-how limitations.

- After this step, resource allocation and decisions related to resource use arise. This step is conducted together with alternative formation and evaluation. Tender engineers and managers separate the activities into groups to decide which activity will be conducted by direct resources of the company and which one will be subcontracted. Residential buildings experts stated that they focus mainly on equipment resources and try different alternatives based on number, size, and types of equipment. On the other hand, both commercial buildings and infrastructure experts stated that in addition to equipment resources, they form alternatives on labor force by forming different subcontracting percentages. They form alternatives for crews holding different local/expat ratios and compare their cost with their productivity.
- Following this, quotations from suppliers/subcontractors are requested. The number of requested quotations depends on the company policy; however, quotations are generally requested at least from three different suppliers. At this stage, analysis within company related to equipment and material detail are retrieved from company databases. Quotation collection and internal company analysis till that point are conducted as part of cost estimation. After this step, sub-contracted work is compared with company-conducted work and evaluated to decide on which alternative to select. Meanwhile, resources for activities that are going to be done by direct company resources are studied by considering company inventory.

During this stage of estimation process, major risks regarding the project are identified. The most important risks related to the location of project, duration of project, characteristics of project are identified and necessary cost calculations are conducted. Depending on project delivery type, cost calculations done in previous steps are multiplied with risk coefficient calculated by experts based on their know-how. Since these risks are project-driven risks, estimators do not form alternatives for this step. However, depending on the type and effect of the risk, they increase the amount of contingency in their project estimation.

- As the final step of project estimation including alternative formation in some estimation steps, all direct and indirect cost data are compiled and evaluated to finalize project estimation. Project estimation is shared with company top managers and company management defines the final tender price by adding mark-up.

The estimation procedure given in this section is the procedure that the interviewees are shared based on their experience. Although the estimation and alternative formation procedure can change based on company characteristics and policies, the steps discussed in here still give an overall idea about conventional cost estimation and alternative evaluation approaches.

In conventional estimation process, alternatives are formed mainly on equipment type, size, and number; crew composition and subcontracting percentages are the main factors that are re-analyzed during pre-construction stages.

4.2.2 Factors used by interviewees for alternative analysis

In this section, factors used from cost factors list by interviewees for alternative analysis are discussed. The final list that was created via literature review and pre-interviews (Section 4.1) was shown to the interviewees and they were asked to select the cost factor that they use during forming alternative analysis. However, they are not restricted with the list. While interviewees can benefit from the list, they were free to add any factor that they consider while forming alternative cost analysis. The results are tabulated based on answers of each individual interviewee (Table 4.2).

Table 4.2 : Factors used in conventional alternative cost and time analysis approaches.

Cost factor	Project type							
	Commercial		Residential		Infrastructure			
	C1	C2	R1	R2	I1	I2	I3	I4
<u>Equipment</u>								
Rental/owned equipment decision	√	√	√	√	√	√	√	√
Rental duration					√		√	
Types and sizes of equipment	√	√	√	√	√	√	√	√
Number of equipment	√	√			√	√	√	
Position/location of equipment	√							
Equipment condition				√	√			√
Equipment productivity							√	
Equipment usage/idle time								
Equipment usage time per activity								
Percentage of equipment failure								√
Overtime usage of equipment								
Lack of/limited access to a specific location								

Table 4.2 (continued) : Factors used in conventional alternative cost and time analysis approaches.

Cost factor	Project type							
	Commercial		Residential		Infrastructure			
	C1	C2	R1	R2	I1	I2	I3	I4
<u>Crew</u>								
Crew composition	√	√			√	√	√	√
Availability of crew used in bidding during construction								√
Working shift of crews					√			
Skill level of crew					√	√	√	√
Overtime usage of crew								
Lack of/limited access of a crew to a specific location								
<u>Site access and logistics</u>								
Access to site		√			√		√	√
Existing buildings/utilities on work area					√		√	√
Traffic around job site					√			√
Weather conditions			√	√	√		√	√

Table 4.2 (continued) : Factors used in conventional alternative cost and time analysis approaches.

Cost factor	Project type							
	Commercial		Residential		Infrastructure			
	C1	C2	R1	R2	I1	I2	I3	I4
<u>Construction process</u>								
Ground condition information		√		√	√	√	√	√
Product visualization								
Readiness of a space								
Readiness of a crew								
Readiness of an equipment					√			
<u>Construction method</u>								
Method selection	√	√	√	√	√	√	√	√
Method visualization								
Subcontracting methodology	√	√					√	√
Subcontracting percentage	√	√					√	√
Starting point of construction				√		√		
Evaluation/visualization of stabile workflow								√

Factors that are taken into account in conventional alternative cost and time analysis approaches are detailed under each construction type; commercial, building, and infrastructure. The differences in evaluated factors in each construction type are also discussed.

Commercial Buildings

There were two interviewees from this field and they are going to be mentioned as C1 and C2. The interviewee C1 has ten years of experience while C2 has 15 and both of their current position is project manager. The interviewee C1gained his expertise mainly at construction site. While the interviewee C2 gained his experience both at office and construction site.

Under equipment category, both interviewees declared that they take into account of rental/owned equipment decision, types and sizes of equipment, and number of equipment. Interviewees stated that based on work load and duration, types, sizes, and number of equipment are determined and alternatives are compared. Following this decision, rental/owned equipment decision is taken by investigating the company inventory and local market conditions.

In addition to these factors, interviewee experienced at construction site declared that they also consider of position/location of equipment. He stated that this analysis is conducted only for tower cranes. Based on effective access area of tower crane, location alternatives are formed.

Both commercial building experts stated that the only factor that they use under crew principal factor is crew composition. They form alternatives on different local/expat percentages and try to find the optimum ratio by taking into account of tender specifications, productivity, and cost of labors from different nationalities.

In contrast to the interviewee C1, interviewee C2 declared that while forming alternative cost analysis, they also consider site access and logistics and ground condition information. The reason why these factors were selected only by one interviewee may be explained by the difference in years of experience and experience field.

Both interviewees stated that for construction method category they consider method selection, subcontracting methodology and subcontracting percentages for alternative cost and time parameters. It should be clarified that labor force is the main item that is considered for subcontracting methodology and percentages.

Residential Buildings

There were two interviewees from residential building field, R1 and R2. The interviewee R1 has 20 years of experience while interviewee R2 has 16 years of experience. R1's current position is budget and planning manager where R2's current position is planning and contracts manager. R2 gained his expertise mainly at construction site whereas R1 gained his experience both at office and construction site.

Interviewees stated that they consider types and sizes of equipment, and rent/own equipment factors under equipment category. Based on company inventory, types and rental/owned equipment alternatives are formed. R2 declared that equipment condition based alternatives are also formed. Equipment condition helps them about rental/owned equipment decision.

An important feature about conventional cost and time analysis approaches is that, crew related factors are not considered by residential building experts. This is because labor force is usually subcontracted in residential building construction in Turkey. Hence, main contractor estimators and managers do not consider crew composition, skill level of workers or working shift of crews. They are only interested in trade subcontractors' schedule and prices offered by them. Meanwhile, according to the interviewees, crew related requirement factors are considered as alternative factors by trade subcontractors and they form alternatives on different crew composition and working shifts.

Both interviewees declared that they take construction method into account while forming alternative analysis. They stated that different formwork selections in concrete construction form alternative methods and hence alternative project costs in residential building construction.

Another factor that both of residential building experts agreed on from site related factors is the weather condition. Alternative schedules are formed and evaluated based on weather conditions corresponding to some weather-effective activities.

In contrast to R1, R2 stated that he also evaluates ground condition information and starting point of construction.

Infrastructure

There were four interviewees from this field and throughout the study they are going to be referred as I1, I2, I3, and I4 who have 22, 16, 13 and 13 years of experience respectively. I1 is deputy project manager for I1, I2 is tender manager, I3 is chief project controller, and I4 is technical office manager. The interviewees I1, I3 and I4 gained their expertise at construction site. The other interviewee I2 gained his expertise at office.

As can be clearly seen from Table 4.3, factors that used in forming alternative cost and time analysis in infrastructure projects are more than the ones in commercial and residential projects. Types and sizes of equipment with rental/owned equipment decision are the cost factors taken into account by all interviewees. Unlike commercial and residential building experts, all infrastructure experts stated that they consider the skill level of workers during alternative analysis. Some special infrastructure projects need specialized workforce. If they are faced with such a need, alternatives on number of specialized labors in a crew is formed and studied. Different number of specialized worker is added to form a crew and the cost and assumed productivity of each crew is studied accordingly. This may affect the direct labor cost and so project overall cost accordingly.

The factors under site access and logistics category are also evaluated by infrastructure experts in alternative analysis. The participants stated that site access, existing building and utilities and traffic around job site affect both the route selection and methodology of construction. Weather condition is considered as an alternative factor especially for scheduling construction activities that may affect by weather.

Ground condition information is another factor that all interviewees were agreed as an alternative factor. The participants declared that based on this factor, route is alternated in projects where design is not fixed completely by owner. Method selection is stated as the most critical alternative forming factor by infrastructure experts. Depending upon method, equipment related factors which forms the major cost in infrastructure projects differ.

The factors used in conventional alternative cost and time analysis that are obtained by interviews are discussed based on construction type. The results show that factors used for alternative cost and time analysis approaches under each construction field differ slightly based on project type, expert, from where the experience is gathered and expert's experience years.

4.3 Discussions on Findings

This section focuses on the discussions of findings on conventional alternative cost and time analysis approaches and describes the need for an integrated system. Literature review and interviewees' opinions are compiled to describe conventional alternative cost and time analysis. Conventional project estimation and alternative analysis approaches discussed and the factors used in conventional approaches are compared with the ones found by literature review and interviews.

Findings in current project estimation practices reveal that during estimation, alternatives are formed and comparison is conducted only for some of possible cost parameters. Alternatives are formed mainly for equipment type and quantity selection and labor force. The alternatives are formed comparing subcontracting the work and conducting it using company resources. However, the findings show that all the alternatives are formed based on experts' know-how and can be handled up to a point. Hence, the factors chosen to perform alternative analysis do not change from project to project that result in limited alternative evaluation.

Overall, it can be said that the findings are limited to eight samples only that makes it harder to generalize. However, the findings give an overall sense that can be improved and extended with a larger sample number.

When the evaluated factors are examined in detail, Table 4.3 shows that rental/owned equipment decision, types and sizes of equipment, number of equipment, crew composition, weather conditions, and method selection are the cost parameters that are used by experts from all three construction types.

In infrastructure projects, more factors are used compared to two other types, namely commercial and residential construction. In addition to this, it is observed that interviewees having site background evaluate more factors for alternative cost and time analysis compared to the ones gained their experience mainly at site.

Although the results cannot be generalized due to limited number of participants, according to this study residential construction is the type of construction that evaluates fewer factors to form alternatives in estimating compared to the other two construction types. This is probably due to the construction characteristics of that type of buildings. Although there can be many building spread on a large area, the construction is repetitive for each building. This feature of residential building construction limits the alternative formation. According to the residential experts, site access and logistics related cost parameters are not used in alternative formation since there is no value due to above mentioned reason. However, this can be due to the location in where the interviewees gained their expertise. Both of the residential interviewees worked in project constructed in very big and crowded cities where the construction sites are generally bounded by heavy traffic and other buildings. Accordingly, the interviewees believe that there isn't so much option on forming alternatives especially on site access. Hence, the experts do not believe that project cost will not differ so much with the effort spent in and will not be worth in such short preparation durations. In addition to site access and logistics related factors, participants in this study states that subcontracting of labor force eliminates the crew related cost parameters evaluation in alternative analysis in residential buildings.

In contrast to conventional approaches in alternative formation in residential building construction, crew related subcontracting methodologies and percentages are alternative forming parameters that are used for commercial buildings. Commercial buildings require a more qualified labor force compared to residential buildings. Estimators form alternatives comparing different subcontracting methodologies such as subcontracting a work package to only one subcontractor or dividing the work into multiple smaller subcontractors. In addition to this, sometimes alternatives on different subcontracting percentages with different productivity rates of labors and with crews holding different local/expat worker ratios are formed. Consequently, these items are selected as alternative cost and time analysis parameters in commercial building budget estimations.

In infrastructure projects, more factors are used for forming alternative cost and time analysis compared to commercial and building projects. This is due to complexity of infrastructure projects. In infrastructure projects cost and time depend heavily upon the construction methodology and route selection. As these factors change, equipment costs stands as the major cost item for infrastructure projects differs significantly. Hence, alternatives are formed comparing different methodologies and routes.

In infrastructure projects, site access and logistics related factors were selected as alternative forming parameters. Only one of the interviewee, I2, didn't make any selection related to these factors. The reason behind this may be related to where the expert gained his expertise. I2 gained his experience mainly in offices. Site access and logistics related parameters are important alternative parameters for infrastructure projects since due to these factors the route of project can be revised. Access to site, existing buildings around construction site and traffic around job site are all factors that affect especially utilization of TBM station and the route of subway rails.

When findings on the parameters used in alternative analysis in conventional approaches are examined, it can be clearly concluded that current alternative analysis approaches are very limited. Time limitations as well as the limitations in human capability merge with the enormous number of factors that affects project cost. That results in limited alternative analysis capabilities.

The system should be an integrated system that helps the estimators/users to evaluate different cost parameters in all. It should provide the opportunity to evaluate many factors in all in an integrated manner while it can give the cost and time differences for any individual cost factor change. When the estimator/user change a cost variable in the system, the effects of the change should be observed in a short time. This will eliminate the time limitation driven problems that limits the alternative analysis to the evaluation of only some factors. In addition to this, when such a system is used, the biased personal approach will also be eliminated since the factors chosen for alternative formation will not be dependent on the know-how of the expert.

In order to use resource related requirement factors and analyze the alternatives, the system can be a resource-integrated BIM based simulation system.

5. CONCLUSIONS

The main goal and objectives of this study were;

(1) to identify factors that are used when performing alternative cost and time analysis,

(2) to describe conventional alternative cost and time analysis practices including cost factors that are considered,

(3) to show the necessity of an integrated system for alternative cost and time analysis practices by comparing the conventional practices with the determined requirements.

In line with its objectives, this thesis identifies the cost factors for integrated alternative cost and time analysis in pre-construction stage. The requirements identified in this study are grouped under five principal factors; equipment, crew, site access and logistics, construction process, and construction methodology. Under each principal factor, related requirement factors are detailed. To unveil the need for an integrated system for forming alternative cost and time analysis, conventional alternative analysis approaches are discussed. The factors from requirement list used in conventional alternative cost and time analysis approaches have revealed.

This thesis has reviewed the literature on cost factors forming alternative project costs and hence can be used in alternative analysis. The findings of literature review have retrieved and expanded with two sets of interviews; pre-interviews and interviews. The pre-interviews were conducted with three experts. The requirements found by literature have integrated with the ones found by pre-interviews and the finalized list has validated by second set of interviews. The second set of interviews has conducted with eight experts.

Based on literature review compiled with experts' opinion, 34 factors under five principal factors have been found. Equipment related factors hold the majority of requirement factors with 12 factors. Crew and construction methodology related factors follow the equipment related ones with six factors under each. There are five factors under site access and logistics and construction process each.

Following the requirements for alternative cost and time analysis, conventional approaches have been discussed as the second objective of this study. Conventional alternative cost and time analysis approaches have revealed by eight interviewees from three construction types; commercial, residential and infrastructure.

Rental/owned equipment decision, number of equipment, types and sizes of equipment, crew composition, weather conditions, and method selection are the major factors that are being taken into account by all interviewees from three different construction types.

The findings show that selections on which factors they use while forming alternative analysis does not change significantly between the participants in each construction type. The slight difference arises mainly from; (1) the difference in experience years of participants, and (2) the difference in where the participant gained his expertise; at site or in office.

It has been seen that more factors are taken into account in infrastructure projects than in commercial and building ones due to higher complexity of infrastructure projects. Experts form alternatives mainly in equipment related cost factors in infrastructure projects. Residential building experts have stated that crew related factors are not considered by them since labor force is subcontracted in such construction types.

5.1 Contribution of Study

Although previous studies evaluated cost factors based on their effects in estimating, but not in terms of alternative cost and time analysis. Hence, the first contribution of this study is the identification of requirements for alternative cost and time analysis. This contribution is achieved by a detail literature review and interviews.

The second contribution of this study is the reveal of conventional alternative cost and time analysis approaches in commercial, residential, and infrastructure projects. This contribution is done by conducting interviews with eight participants having experience on above mentioned construction projects. Although more factors are considered for alternative cost forming in infrastructure projects, the factors that are considered in conventional approaches are far from the list of described requirement factors. Time limitations, pre-learnt approaches that are applied by company experts can be counted as the main reasons of limited alternative formations in current estimating practices.

5.2 Future Work

For future work, studies on developing such an integrated system by using the determined requirements can be conducted. The interviews conducted for this study were limited and not comprehensive. The requirements can be widen by implementing more number of more structured and comprehensive interviews. Moreover, this study was conducted with experts who have at least 10 years of experience. Since the evaluated factors for alternative analysis can differ based on experience level, the study can be extended by including a wider change of experts with wider experience level. The requirements that commercial, residential, and infrastructure experts need whilst forming alternative cost and time analysis are determined with this study and these findings can be used as the input parameters in such an integrated system.

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