CHAPTER 1

INTRODUCTION

Construction Industry is one of the most vital economical sectors in Egypt and it has a significant contribution to the GDP “Gross Domestic Product”. It consists of two main sectors: public and private. The private construction projects’ sector grew significantly during the past decade, the private sector contribution in the construction industry share in GDP increased from 65 % in 1982 to 88% in 2011 (the ministry of economic development - report 2011) and it became the main foundation in the development of the construction industry in Egypt.

Due to such importance of this vital economic sector, ways and means of improving the construction industry in Egypt have been adopted. The interrelated nature of the varied aspects of construction implies that careful study of this industry’s inputs and their tradeoff are of utmost importance.

In this regard, one of the key factors for the construction project’s success is the reliable prediction of the project duration which is greatly affected by many uncertain but predictable factors. If a project is not completed within the stipulated period, all parties will suffer: the client will suffer because his objectives cannot be achieved, and his business goals have not met, the contractor will suffer losses due to the escalated costs, overheads, and penalties.

Reliable prediction of project duration enables the client to create a financial arrangements and cash flow plan in a proper time and can make funds available to the project. Predicting construction duration accurately and performing works on time will maximize resources’ utilization, maintain solid track records and good relations with the client, avoid the application of liquidated damages, reduce conflicts, minimize the overheads, risks which in turn enrich the country’s economy.

Therefore, just keeping the project within budget and quality level is not sufficient. Yet, accurate prediction of project duration is essential for the successful completion of the project.

Duration prediction is a dynamic process which should be performed in consecutive stages of project’s life cycle. However, it should be performed during the early stage of the project's life prior the construction stage despite the limited data available, and the sharp deadlines applied by the owner.

In the construction industry, many planning tools are used such as CPM and PERT. However, their long period for proper preparation and analysis in addition to the necessity of full details of the project, all of those are not available at the preconstruction stage. At that stage, a reliable and practical duration prediction depends on the planners' experiences and knowledge.

This research aims to identify the significant factors affecting commercial project duration in Egypt and developing a simplified model to predict commercial project duration during the tendering stage.

1.1 PROBLEM STATEMENT

Realistic project duration prediction is often overlooked by both the client and the contractor during the tendering stage.

Clients tend to impose squeezed and aggressive schedule on contractors. The consequences, however, can be troublesome if productivity, quality and safety are sacrificed in addition to the low staff morale and conflicts raise among the project's parties. Hence, a form to predict a realistic commercial project duration should be considered as part of the contract documents for the success of the project, the development of the construction industry and the country economy at large.

1.2 OBJECTIVES OF THE STUDY

The main objective of this study is to develop a model that can be used to predict commercial project duration under normal conditions in Egypt during the tendering stage in a reliable and practical way by applying the fuzzy logic technique.

Additionally, the secondary objectives are:

- To identify the factors affecting the determination of commercial project duration.
- To identify the significant factors affecting the prediction of commercial project duration models.

1.3 SCOPE OF THE RESEARCH

This research is focusing on commercial buildings executed by general contractor (Grades 1 & 2) under re-measured contracts in both the public and private sectors in Egypt.

1.4 RESEARCH METHODOLOGY

To achieve the study objectives, the following steps have been followed:

1. Review the literature to study previous researches and review various modeling methods for predicting the construction project duration and factors affecting construction duration.
2. Conduct unstructured interviews with construction experts to discuss these factors and determine the final criteria that will be used in the questionnaire of the study for the Egyptian construction industry.
3. Conduct questionnaire survey among different key players: clients, consultants and contractors for both public and private sectors to guarantee good representation of the industry.
4. Analyze the questionnaire results to determine the factors' weights and relative importance then select the most significant ones that represent the inputs of the fuzzy framework.
5. Propose fuzzy framework for predicting commercial project duration.
6. Apply the developed framework on real case studies to ensure its applicability for the construction industry in Egypt.

1.5 DISPOSITION

The thesis contains five chapters, each of which includes the following:

Chapter 1: Is a general introduction to the problem of predicting the construction project duration during the tendering stage.

Chapter 2: Presents literature review for the models of predicting the construction project duration and the factors affecting the project duration. Then it presents introduction to the fuzzy logic and its applications in civil engineering, project management and the prediction of construction project duration.

Chapter 3: Summarizes criteria used in predicting project duration of commercial buildings, the design of the questionnaire and its results.

Chapter 4: Presents the application of fuzzy logic to build the model, a discussion on the results obtained from the application of the model.

Chapter 5: Presents the conclusions, recommendations and possible future work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This literature review presents the factors affecting construction project duration and construction duration prediction models. The first part presents an introduction to the construction industry in Egypt, its importance to the country's economic growth and the growing role of the private sector in such industry. Then, the project's life cycle showing contribution of the preconstruction stage to the whole project's life is presented. Finally, the factors affecting construction project duration and the types of models for prediction are presented.

2.2 CONSTRUCTION INDUSTRY IN EGYPT

Construction industry is one of the most vital economical sectors in Egypt and it has a significant contribution to the country's GDP. It consists of two main sectors: public and private. The share of private construction projects grew significantly during the past decades as illustrated in Tables 2.1 through 2.3. The private sector contribution in the construction industry share in GDP increased from 65 % in the eightieth to 88% in 2011. Table 2.1 shows the increase in private sector share in construction industry contribution in GDP (Ministry of economic development - report 2011) and it became the main foundation in the development of the construction industry in Egypt.

Table 2.1: Percentage of private sector share in the construction industry contribution to GDP

Period / year	**% of private sector share**
1980's	65
1989/90 – 1995/96	73
1996/97 – 2000/01	58
2001/02 – 2010/11	88

Furthermore, Table 2.2 shows the increase in private sector share in construction industry investment (Ministry of economic development - report 2011).

Table 2.2: Percentage of private sector share in construction industry investment

Period / year	% of private sector share
1982/83 – 1986/87	33
1987/88 – 1991/92	51
1992/93 - 1996/97	56
1997/98 – 2001/02	68
2002/03 - 2006/07	81
2007/08 - 2010/11	83

Moreover, Table 2.3 shows the increase of the percentage of construction workforce to the whole workforce in Egypt and the increase of the percentage of private sector share in construction industry workforce (Ministry of economic development - report 2011).

Table 2.3: Percentage of construction workers to the whole workforce in Egypt and the percentage of private sector share in the construction workforce

Period / year	% of construction workers to the whole workforce	% of private sector share in construction workforce
1982/83 – 1986/87	4.50	70
1987/88 – 1991/92	5.20	75
1992/93 - 1996/97	6.00	82
1997/98 – 2001/02	7.50	88
2002/03 - 2006/07	7.80	91
2007/08 - 2010/11	8.00	93

2.3 PROJECT'S LIFE CYCLE

A project passes through several distinct phases as it matures. The life cycle includes all phases from point of inception to final termination of the project.

Major review of the entire project occurs at the end of each phase, resulting in authorization to proceed with the next phase, cancellation of the project, or repetition of a previous phase.

The preconstruction stage represents the most important part of project's life cycle. It represents the building's block and the foundation for all subsequent works which deserves a significant time and effort for the sake of project's success. Nevertheless, this stage is always overlooked and most of clients tend to rush in construction stage with immature studies. One of the most important studies at this stage is the prediction of a realistic project duration, clients tend to impose squeezed and aggressive construction project duration due to several reasons which include (but not limited to):

- Political reasons (i.e. Projects related to armed forces and nation's security, projects expecting presidential or V.I.P. visits or events, etc).
- Clients' related reasons by exerting excess pressure to market their products and get earlier profit. Moreover, from their perspective, tight schedule will be useful in case of any unforeseen conditions or potential contractor's delay, etc.

Most of consultants agree on the client's desired durations regardless their applicability and constructability, and this unrealistic duration becomes matter of fact and represents part of the contract documents.

Traditionally, almost of construction projects contracts are procured under the low bid system (William et al. 1992) where, since other decision criteria such as construction time and quality are usually specified in the bidding documents, bid price becomes the dominate or sole criterion used by the client in evaluating the contractors' proposals and awarding the contract.

In the low bid system, a contractor's bidding strategy is mainly concerned with the project cost regardless project's duration applicability so that its bid price is both competitive among all contractors and profitable to itself (Wu and Lo 2009).

The consequences will obviously arise during the construction stage which include (but not limited to):

- Potential conflicts among all project's parties.
- Cost escalation for the contractor due to working overtime, injecting additional resources, rework, etc.
- Application of liquidated damages on the contractor.
- Low staff productivity and morale due to the feeling of unreachable objectives and working in a stressful environment.
- Bad quality of deliverables.
- High potential of accidents and safety problems.

2.4 PROJECT DURATION

There are many definitions of construction project duration, however, the most appropriate one has been provided by Bhokha (1998) as follows: "The time frame given by the owner for the contractor to complete the project under normal work conditions, normal practice of construction, and based on the minimum costs. It starts when the contractor receives the instruction to proceed and ends at the completion of construction works on site. It also includes delays caused by unanticipated circumstances, e.g. alteration of works (changed conditions and change orders), extra works, and supply of materials, location, weather, and site work conditions. Major changes after the scope of work significantly are not included."

The success or failure of a construction project is typically determined by three factors: cost, quality, and time. Therefore, it is understandable that construction duration predictions often serve as benchmarks for measuring project performance (Walker 1995). To establish these benchmarks, the duration prediction is typically determined either using the client's time constraints (e.g., occupancy need) as a surrogate or by conducting a detailed analysis of the required construction (Ng et al. 2001). However, there are problems associated with these both methods.

For instance, estimates based on occupancy need may overlook actual project requirements and result in overly optimistic values. While critical need dates may be an important consideration, using them to drive construction duration predictions may be problematic and force a project into a desired, rather than realistic, time mold (Bromilow et al. 1980).

In contrast, a detailed analysis is often impractical because of either time and manpower limitations (Ng et al. 2001) or uncertainty regarding the specific tasks and materials required of the project (Khosrowshahi and Kaka 1996). Therefore, methods used to predict construction duration tend to be subjective and highly dependent on the skill, experience, and individual intuition of the project engineer (Chan and Kumaraswamy 1995).

Khosrowshahi and Kaka (1996) stated that project cost and duration estimation concept interest could be seen from the late 1960’s. In 1968, the Division of Building of Research of the Commonwealth Scientific and Industrial Research Organization in Melbourne studied on the project duration and cost by comparing the actual and estimated ones. According to results actual durations are, on average, 40% more than estimated durations.

A study on predictability of duration and cost of projects was based on over 2,700 building projects completed in the UK between 1998 and 2006. Building Cost Information Service (BCIS 2006) reported that while 40% of projects overrun their contract periods, 20% of them increase their contract costs.

Increased costs that occur during a building project will be allocated between the client and the contractor in accordance with the terms of the contract. Therefore, they may, or may not, affect the predicted cost. Time is much less flexible. Whoever is responsible for a delay, and even if financial settlement is made, the client receives his completed project later than predicted.

Accordingly, it is required to predict realistically project duration and this process is vulnerable for making mistakes.

In the construction industry, both the client and contractor want to finish the project on time for different reasons. Client wants to finish the project on time and in budget, because the finishing of construction part means that a beginning of a new long-term enterprise. Implementation cost of a project is a very important factor for the operating cost of the project. Project completion time affects the interest payable and to begin operation and to get the investment worth. (Ugur 2007).

Contractor also wants to finish the project on time not to be influenced from the factors causing increase in costs: the inflation, interest rates, and punitive sanctions of the contract. Nkado (1995) added the effect of bonus in the contract as well as financial penalty as an external pressure on construction duration.

The initial step for duration prediction is searching for the factors affecting construction durations.

2.4.1 Factors Affecting Construction Project Duration

Starting from the early 1970s, many researches identified the factors influencing construction project duration across various categories of projects. The factors found by researchers as published in literature are summarized in Appendix-A in chronological order. The researchers either studied only the factors affecting construction project duration or developed project duration prediction models by using these factors.

Chan and Kumaraswamy (2002) classified time-influencing factors into four major categories which are: project scope, project complexity, project environment; and management-related. These factors are listed in Appendix-A and presented in Figure 2.1.

Kumaraswamy and Chan (1995) investigated factors affecting construction duration in projects carried out in Hong Kong. Questionnaires were posted to 400 firms and 111 of them responded. A hierarchical chart showing the factors affecting construction project duration is given in Figure 2-2.

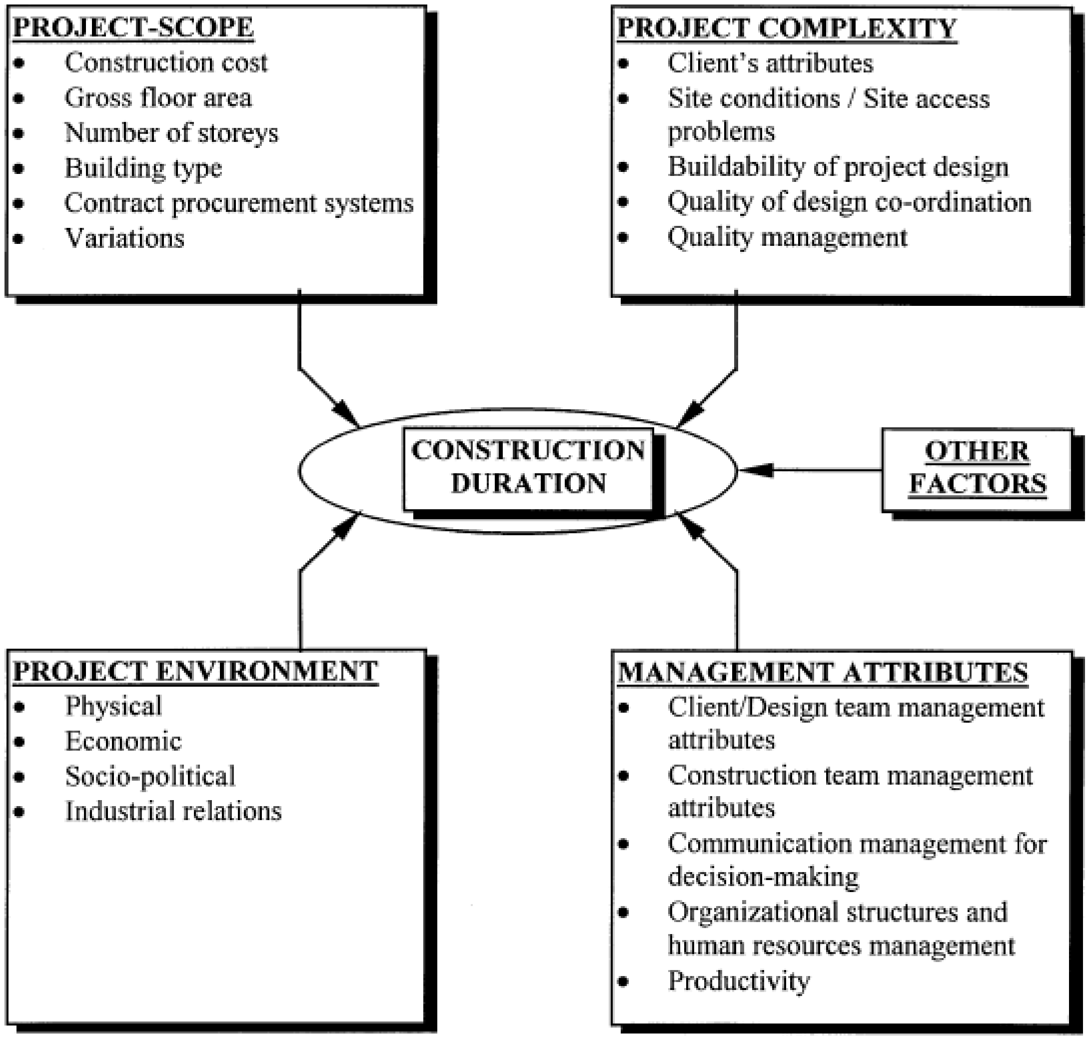


Figure 2.1: Factors affecting construction project duration (Chan and Kumaraswamy 2002)

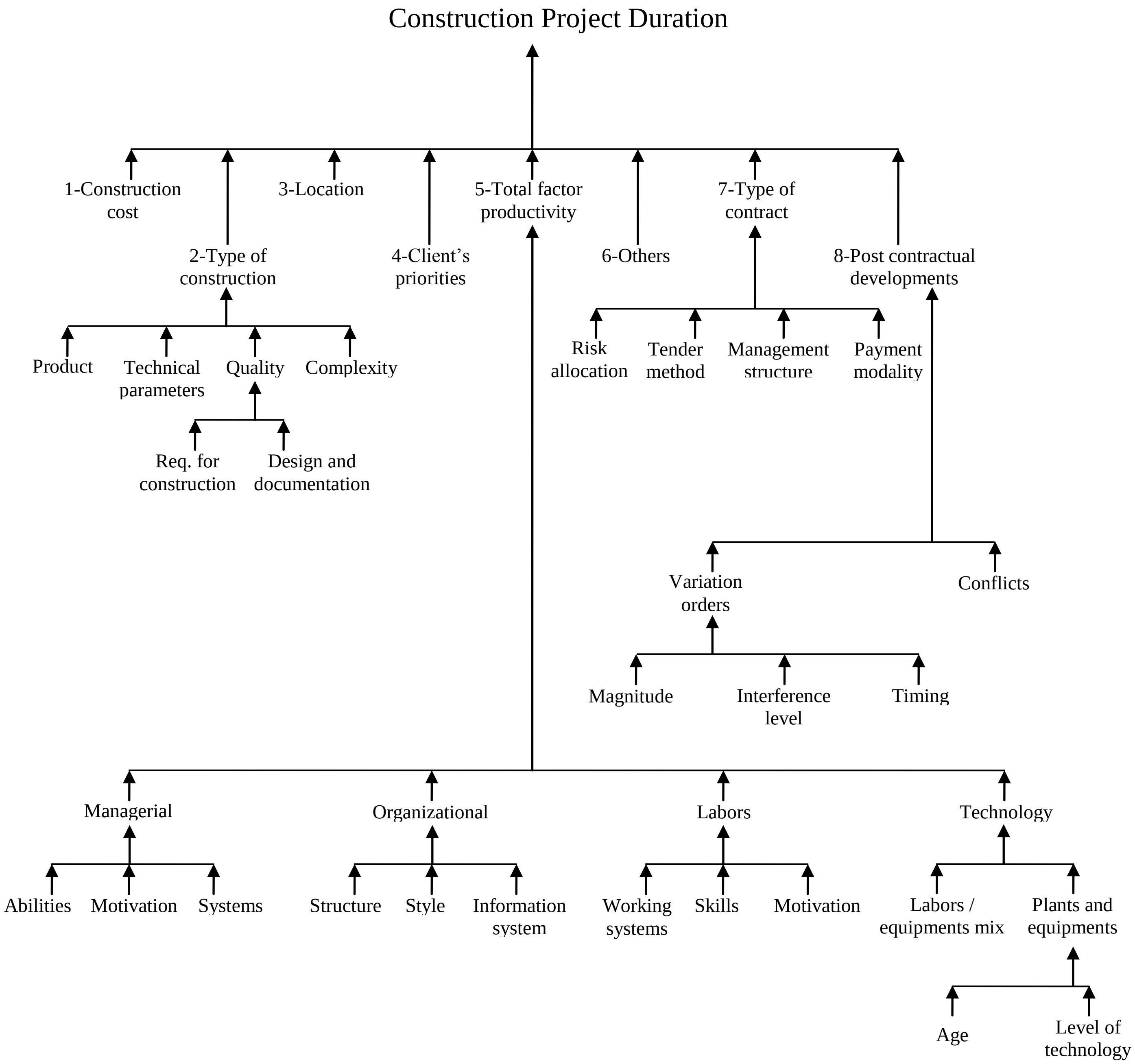


Figure 2.2: Factors affecting construction project duration (Chan and Kumaraswamy 1995)

Odabasi et al. (2009) summarized all findings in Table 2.4 under seven main headings as: cost, client related, project related, environment related, construction site related, management related factors, and other factors. They classified the time-influencing factors into seven major factor categories as shown in Table 2.4 which are:

1- Project cost.
2- Client or client representative related factors.
3- Environment related factors.
4- Construction site related factors.
5- Project related factors.
6- Management related factors.
7- Other factors.

Table 2.4: Factors affecting construction project duration (Odabasi et al. 2009)

Cost	Environment related factors	Project related factors	Management related factors
1. Project cost	**2. Weather.** **3. Economical factors (restrictions).** **4. Social factors (restrictions).** **5. Cultural factors (restrictions).** **6. Legal factors (restrictions).** **7. Politic factors (restrictions).**	**8. Factors about project team/designer/design consultants (experience, etc.).** **9. Factors about the project.** **a. Type of construction :** 1. Building type: (i.e.: Earth dam; steel framed-building, whether office, retail or other, Whether the building is purpose built or speculative New work or refurbishment of existing building). 2. Technical parameters: (i.e.: Height, floor area, spans, size of project, gross floor area, form of construction. **b. Quality of:** 1. Construction required. 2. Design and documentation (i.e.: Project information completion, Degree of standardization and mechanization, repetition of work, Project changes). **c. Complexity of:** 1. construction required . 2. constructability of project design.	**10. Managerial:** • Abilities • Leadership and motivation • Systems **11. Priorities:** • Client's priority on construction time. • Designer's (project teams) priority on construction time. **12. Organizational:** • Structure • Style • Information Systems • Flexibility in organization **13. Contract related:** **a. Type of contract** • Risk allocation (e.g., inflation, technical) • Tenderer selection method (open, prequalification, selection etc) • Management structure e.g.: traditional; design and build • Payment modalities e.g.: fixed price; cost plus **b. Post contractual developments** • Variation Orders • Orders • Conflicts **14. Coordination/Relationships** **15. Planning** **16. Construction Management** **17. Control systems** • Managerial control effectiveness • Contractor's control over site operations • Effectiveness of supervision **18. Procurement related factors** **19. Technology** **a. Resources (Labor / equipment mix)** **1. On time material delivery** **b. Labor** • Work systems • Skills • Motivation • Productivity • Labor relationships **c. Plant and equipment** • Age • Level of technology **20. Management Attributes.**
Other factors	**Construction site related factors**	**Client related factors**	
21. Financial factors. **22. General contractor related factors.** **23. Subcontractor related factors.** **24. Speed.** **25. Uncertainty.** **26. Engineering Design related factors.** **27. Experience**	**28. Construction site conditions.** **29. Geographical.** **30. Whether or not restrictions or easements exist.** **31. Availability of services.** **32. Supply of resources.** **33. Use of major equipment.** **34. Productivity on site.**	**35. Client’s experience.** **36. Type of client.** **37. Client's attributes.**	

Odabasi et al. (2009) selected the following eleven factors as the most significant ones in literature which affect construction duration. These factors were listed and explained as follows:

1. Cost
2. Cash flow
3. Productivity of on-site
4. Procurement
5. Project Related Factors
6. Technology and Methodology of Construction
7. Experience
8. Coordination
9. Weather
10. Construction site
11. The degree of completeness of design project

2.4.1.1 Cost

Although most of the literature considered the cost as an important factor, Love et al. (2005) stated that cost is a poor indicator.

Additionally, some of the literature showed that cost does not affect duration. For example, if there are two villa projects having the same design and the only difference between them is the quality of materials. Their costs will be different from each other but their construction durations will not. On the other hand, two different construction projects having different cost values may take the same time to construct. Another possibility is that two different project having same cost values may take same time to construct because of the different working productivity or experience of different construction teams. When any increase of cost occurs, construction duration does not also increase.

2.4.1.2 Cash flow

Clients make a yearly payment plan of the project by using cost and duration estimations. Payment for construction works is made to the contractor(s) at designated time intervals. If there any insufficiency of cash flow exists, it may cause long-term unfinished construction projects. If contractor is financially strong, he can continue to finish the work in the contract period by using his own finance until he receives payment. If cost estimation is wrong, investment will be insufficient and additional finance will be required. This unexpected financial problem can cause the interruptions or even stop the works.

2.4.1.3 Productivity on-site

Productivity is an important factor that affects the construction directly. Man-hours used in planning phases define the total construction duration. If the productivity of the crews decreases, it directly affects the speed of the construction works.

Chan and Kumaraswamy (1999) stated that lower productivity could contribute significantly to project delays. They listed factors affecting site productivity such as work space availability, attendance of operatives, learning, weather, labor relations, project complexity project constructability, foundation condition and effectiveness of supervision.

2.4.1.4 Procurement

Dissanayaka and Kumaraswamy (1999) pointed out the importance of procurement related factors on project duration. Both the owner and the contractor take care of procurement. Not only the materials, but also workmanship should be provided on time for the continuation of works. The aim is that the right amount of material should be available in good condition at the right time and at the right place in order to achieve good work progress. Dissanayaka and Kumaraswamy (1999) identified particular factors, which are significantly related to time and cost performance. They analyzed the relationships of procurement and non-procurement related factors with time and cost performance. The authors grouped the factors affecting project performance into two main groups as procurement related factors (work packaging, functional grouping, payment modality, selection modality and conditions of contracts) and non-procurement related factors (factors related to project, factors related to client: client representative, factors related to designer, factors related to contractor, factors related to team performance and factors related to external conditions). They found that although time over-runs affected mainly by non procurement related factors, cost over-runs were affected by both procurement and non-procurement related factors.

Although Dissanayaka and Kumaraswamy (1999) concluded that time performance was not affected by procurement related factors, there are many researches contradicting this conclusion. Sarac (1998) reported procurement factors affecting construction duration according to the percentage of effects on duration as follows:

1. Delayed procurement of materials (15.5%).
2. Material procurement being not according to specifications (6%).
3. Non-availability of requisite manpower with proper skill (4.5%).
4. Non-availability of appropriate equipment at the appropriate time (2.5%).
5. Inadequate facilities such as: (2%).
   - Supply of water, electricity, etc.
   - Sufficient housing for workers.
   - Recreational facilities.
   - Cafeteria (supply of food) near site.

2.4.1.5 Project-related factors

Project related factors are building type (hotel, hospital, villa, housing project, industrial building, etc.), design aspects (form, uniqueness, complexity of projects, etc.) and technical parameters (Area, No Floor, Structure, etc.).

Nkado (1995), Sarac (1998), Bhokha and Ogunlana (1999), and Chan and Kumaraswamy (1999-2002) pointed out the importance of building size and the height of the building (number of floors) as important factors affecting project duration. When the building size (gross floor area) increases, the construction duration will be longer. The complexity of project affects also the duration. If the level of complexity is low, the construction and the management will be easier. Actually, the complexity of the building is related to the project type. For example, construction of a market building takes shorter time than a hospital building. It is also related to using similar details in projects, because of the standardization of project, Sarac (1998).

Additionally, Love et al. (2005) stated that there is no single agreed way for defining complexity. The authors explained two handling methods for measuring the complexity. The first way is using measures such as constructability, inherent site conditions, quality of design coordination, quality management procedures, and site access. The second defines complexity to be a large project.

2.4.1.6 Technology and methodology of construction

Sarac (1998) stated that usage of new technology, machinery, and materials causes increase in production rates and high quality products by arranging times effectively and reducing lay-off times. There are three types of construction technique.

The first type is low-tech (manual technique) which is based on workmanship; most of the main work are constructed on site. Hence, labor productivity gains importance.

The second type is medium-tech (mechanized technology) which is used to decrease construction project duration or to increase the construction speed. For example, using sliding forms to reduce construction time.

The third type is high-tech (prefabricated building technique) where components of the building are produced beforehand and then erected on-site, thus, minimizing the duration.

2.4.1.7 Experience

Walker and Vines (2000) and Sarac (1998) emphasized the importance of experience on duration. Experience on similar projects reduces errors and so decreases or even totally eliminate reworks, hence reducing the total construction duration. They described the importance of client experience. Specifically, clients of commercial projects know what their requirements are, so they can give their decisions quickly because of the repetitions of their works. They also added the importance of contractor's experience. If the contractor has executed similar projects before, he is familiar with the works and does not repeat mistakes. This leads to shortening of the duration. They pointed out that the experience of team members with different parties for design, construction, or management group is valuable in reducing delays. Walker and Vines (2000) studied the factors affecting construction project duration of multi-unit housing projects in Australia. They found experience as an important factor besides management quality, environmental factors, and coordination.

2.4.1.8 Coordination

In every sector, communication between all parties has an important role for the progress of work. Especially in the construction sector, there are many parties coming together for the completion of the project, communication management is critically important between the design team, construction team and consultants, suppliers, management teams, and the client's agent. It also affects the motivation of all the employees. Nkado (1995), Chan and Kumaraswamy (1999-2002), and Walker and Vines (2000) emphasized the importance of the development of coordination between these various agencies involved in the construction for construction duration estimation.

2.4.1.9 Weather

Weather conditions determine the duration as working periods are defined according to seasonal conditions. Sarac (1998) stated that bad weather can interrupt or abort works; cause decrease in production rate and quality of works, so the work has to be done again. This kind of delays cause increase in cost since labor and equipments lay idle. Sarac (1998) also pointed out that if the weather effects are taken into consideration properly while preparing working schedule, these losses can be prevented.

2.4.1.10 Construction site

Chan and Kumaraswamy (1995), Sarac (1998) and Bhokha and Ogunlana (1999) all stated that the location of a building has a significant effect on construction project duration (i.e., availability of services, supply of resources, use of major equipment and accessibility to the site exists). Moreover, construction site conditions, (i.e., topography, ground conditions, and size of construction site) also affect the duration of construction.

Finally, no matter what construction size is, the construction site arrangement should be done in a logical way, (i.e., site offices, storage, shelter for labors, dining hall, etc. should be arranged to facilitate transportation).

2.4.1.11 Degree of completeness of project's design

Nkado (1995) and Sarac (1998) agreed that the degree of completeness and precision of project information is very important for project duration. Firstly, this can be affected from the design changes. Any changes in the original design may not be communicated to construction site. This affects construction resource program, cash flow, and material procurement program, therefore, uncertainty of projects can cause delays. Secondly, the details should be completed in project stage for the continuation of project. Finally, the project should meet with the requirement of client. Sarac (1998) explained the reasons of completion ahead of schedule, although this situation exists rarely. These summarized factors affecting construction duration are:

1. The urgency from the client's side.
2. The bonus announced by the client.
3. Higher safety factor in the allocation of time.
4. Procurement of material on or ahead of schedule.
5. Previous experience in similar projects.
6. Use of modern machinery.
7. Employment of more than the estimated number of skilled workers.
8. The number of workers employed was the same as that of estimated one, but the level of skill was higher than average.
9. The number of workers employed was less that of the estimated one, but the level of efficiency was much higher.
10. The size of the project was reduced.
11. The design and drawings were simplified before or during construction.
12. Effective coordination of different activities.
13. High motivation due to harmonious supervisor and worker relationship.

2.5 MODELING OF PREDICTING CONSTRUCTION PROJECT DURATION

Common planning and controlling tools include: Bar charts, CPM and PERT techniques. These techniques require a lot of information and a big effort (Sarac 1995). On the other hand, Helvaci (2008) pointed out that these techniques can also be used at the pre-design stages. However, accuracies of these estimates depend on the estimators' experiences.

Modeling of construction duration tries to overcome this subjectivity of the estimating process.

According to Ugur (2007), there are two widely used techniques for predicting project duration, historical data or comparing similar jobs. The other ones are consulting experts, calculation of all the durations of works separately and no duration prediction being written in the contracts.

"A high-percentage usage of duration prediction techniques can be a useful application for the minimization of the risks. All projects have their own optimal duration with their optimal cost. The prediction of duration of any construction project when the sum of direct and indirect costs is minimum, the comparison of this prediction with the contract duration and performing the project within this prediction time will be very useful application. Even the possibilities for performing an earlier date than contract date with a lower cost, calculations could be searched. By this cost of duration minimization calculations, cost-time evaluations could be done." (Ugur 2007).

Hoffman et al. (2007) searched the significant factors influencing duration by developing a regression model. The authors worked on Air Force buildings facility projects in USA, and exemplified the method used for construction duration predictions of Air Force Projects as practical method. They used benchmark techniques for duration prediction by using cost estimations of projects.

Skitmore and Thomas (2003) stated that there are two common methods for predicting construction time and cost: According to the client's available budget and time constraints and the other is the detailed analysis of activities. Construction duration predictions are made after either detailed design phase or pre-design stages. Both are required for different purposes.

Kanoglu (2003) and Akintoye and Fitzgerald (2000) classified the types of duration prediction models or techniques into four groups:

1. Experienced based models that use algorithms, heuristics, and expert systems.
2. Simulation models that use heuristics, expert models, and decision rules.
3. Parametric models that use regression, Bayesian, statistical models, and decision rules.
4. Discrete state models that use linear programming, classical optimization, PERT, and CPM.

A summary on construction duration prediction models is given in Table 2.5. It can be seen that by years, the modeling studies have increased and regression analysis method was applied more than other models.

Table 2.5: Construction project duration prediction models' development (Odabasi et al. 2009).

No.	Model	Type
1	Bromillow (1974)	Parametric (power of regression)
2	Carr (1979)	Simulation
3	Ireland (1985)	Parametric (Multiple Linear
4	Ahuja and Nandakumar (1985)	Simulation
5	Moselhi and Nicholas(1990)	Experience-based (Hybrid Expert System - (ESCHEDULER))
6	Kaka and Price (1991)	Parametric (Regression Model)
7	Nkado(1992)	Parametric (Multiple Linear
8	Wuand Hadipriono(1994)	Experience-based (Fuzzy Logic-Expert System (ADDSS))
9	Kumaraswamyand Chan(1995)	Parametric (Simple Linear Regression Analysis)
10	Chanand Kumaraswamy(1995)	Parametric (2 Simple and 1 Multiple Lin. Reg.Analysis)
11	Walker (1995)	Parametric (Multiple Linear
12	Sarac (1995)	Parametric (Linear Regression
13	Khosrowshahi and Kaka (1996)	Parametric (Multiple Linear Regression Analysis)
14	Chan and Kumaraswamy(1999)	Parametric (Multiple Linear Regression Analysis)
15	Dissanayaka and Kumaraswamy (1999)	Parametric (Multiple Linear Regression Analysis)
16	Bhokha and Ogunlana(1999)	Discrete State (Artificial Neural Network)
17	Dissanayaka and Kumaraswamy (1999)	Discrete State (Artificial Neural Network)
18	Boussabaine (2001)	Experience-based (Neurofuzzy Model)
19	Blyth, Lewisand Kaka(2001)	Parametric (Multiple Linear Regression Analysis)

Table 2.5 continued

20	Kanoglu (2003)	Experience-based (Performance
21	Skitmore and Thomas (2003)	Parametric (Regression Analysis)
22	BCIS (2004)	Parametric (Multiple Linear Regression Analysis)
23	Kumar and Reddy(2005)	Experience-based (Fuzzy Logic)
24	Love et al. (2005)	Parametric (Multiple Linear Regression Analysis)
25	Chen and Huang (2006)	Parametric (Multiple Linear Regression Analysis)
26	Hoffman and Weir (2007)	Parametric (Multiple and Simple Linear Regression Analysis) & Discrete State (ANN)
27	Helvacı (2008)	Parametric (Multiple Linear Regression Analysis)

2.5.1 Experience-Based Models

Experience-based models used heuristics, expert systems and fuzzy logic. Wu and Hadipriono (1994) developed a fuzzy-logic model for duration estimation. They classified the factors affecting project duration in their models into six main groups. These are: site condition, equipment performance, labor performance, weather conditions, material supply, and management performance.

They pointed out that project duration for construction project is determined by the estimators or the planning department based on their experiences. Uniqueness of the project is not taken into consideration in such estimations services; the authors suggest a fuzzy logic model to fill this gap.

Wu and Hadipriono (1994) tested this model on the construction of the foundations of Ohio University library building and obtained realistic results. However, in this model, which is highly influenced by the decision makers, the results may change according to the personal experience.

Kumar and Reddy (2005) developed a model using fuzzy-logic theory. The authors also emphasized the importance of projects' own characteristics for more accurate duration estimations. They developed this model to predict the project duration by incorporating the qualitative and quantitative factors using fuzzy logic approach. After analyzing the project activities, appropriate qualitative (linguistic) factors affecting each construction project duration were applied, such as, weather conditions; labor and engineer experience, productivity, type of equipment used.

2.5.2 Parametric Models

Parametric models use regression, Bayesian, statistical models, and decision rules. They are the most popular ones for forecasting construction duration. According to Morgenshtern et al. (2007), "Parametric models are the models that use historical data to identify the main factors affecting time and effort estimation."

When parametric models are studied, it is seen that regression models are used widely. Regression analysis is used to express a dependent variable (y) in terms of the independent variables x_1, x_2 … x_n for investigating the functional relationship between a dependent variable and one or more independent variables. Mathematically, regression models can be expressed by Eq. 2.1.

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \ldots + \alpha_n X_n \quad (2.1)$$

In which, Y is the dependent variable, α_0 is the regression constant, $\alpha_{1,2,3\ldots\ldots10}$ is the partial regression coefficient of $X_{1,2,3\ldots.10}$, and $X_{1,2,3\ldots..10}$ are the independent variables.

Helvaci (2008) outlined the aims of regression analysis as follows:

- To determine whether a relationship exists between the variables or not.
- To describe the relationship in terms of a mathematical equation.
- To evaluate the accuracy of prediction achieved by the regression equation.
- To evaluate the relative importance of independent variables in terms of their contribution to variation in the dependent variable.

A simple linear regression (with one independent variable), a multiple linear regression (more than one independent variable), or nonlinear regression analysis can be formed. It is found that there are two types of parametric models which are time-cost models and other parametric models as presented in the following sub-section.

2.5.2.1 Time-cost models

In Time-Cost models, duration is calculated using only the cost factor of a project. The best-known time-cost model is Bromilow's Time-Cost (BTC) model which is defined by regression formula in Eq. 2.2.

$$T = KC^B \quad (2.2)$$

In which, T is the duration of construction period from date of site possession to practical completion in working days;

K is constant describing the general level of time performance for a million of Australian dollars (AUD); and

C is final cost of building in millions of Australian dollars adjusted to cost indices;

B is constant describing how the time performance is affected by project size as measured by cost.

Bromilow et al. (1980) examined the model on 329 Australian building projects which were constructed between June 1964 to June 1967. In 1980, he re-applied the BTC model on 408 Australian building projects completed between 1970 to 1976 to find out if it still holds or not. He found this model to be still valid and applicable.

Ng et al. (2001) developed two different BTC models for 26 industrial and 67 non-industrial Australian construction projects. They stated that construction speed had improved until Bromilow by comparing K and B values of previous researches using BTC model. Ng et al. (2001) defined B as a constant that describes how the time performance was affected by project size as measured by cost. A larger value of B implies a longer construction time for larger projects. K is a constant describing the general level of time performance for one million Australian dollars project.

2.5.2.2 Other parametric models

Other parametric models have been developed by using factors affecting construction duration with or without cost variable. The Building Construction Duration Calculator (BCDC) developed by the Building Cost Information Service (BCIS) in 2004 and used by Helvaci (2008).

BCIS has investigated 1500 new building projects completed between 1998 and 2002 in the UK and used multiple linear regression analysis to estimate the construction duration. The six parameters, which were the independent variables in the regression analysis, were as follows: procurement route, contractor selection method, client type, building function, region, and value.

BCIS model uses adjusted value of cost based on the 2003-2nd quarter index. This adjusted value is calculated by location and year indices for U.K. Results obtained from these tests suggest that:

1. A clear and significant relationship exists between construction duration and total construction cost.

2. Housing projects tend to take longer than other schemes of the same value for both public and private sectors while industrial building projects are completed more quickly; non housing projects above £750,000 for private clients tend to be completed faster than those for public sector clients, although this may well reflect the amount of industrial buildings in the private sector sample.
3. The method of contractor selection does not seem to significantly influence the speed of construction.
4. Complexity and design influences the time it takes to build.
5. The analyses by location probably reflects the differing mix of projects in each region.
6. Projects tendered on a traditional lump sum basis up to £550,000 and design and build projects over £1,3 million, tend to be completed more quickly than other projects.
7. Projects between £750,000 and £10million show a consistent relationship between the log of the cost and durations. The spending rate accelerates as the cost increases at a definable rate; for smaller and larger projects, below £200,000 and above £7 million, the change in construction duration is much less marked.

Helvaci (2008) studied 17 Continuing Care Retirement Center projects constructed between 1975 and 1995 in the United States (14 different states). He studied parametric models, which are used at the early stages of projects. He formed five duration estimation models, beside one cost estimation model with these case studies. These duration estimation models are:

1) Bromilow Time-Cost (BTC) validation analysis.

2) Simple Linear Regression (SLR) analysis (with only cost).

3) Artificial Neural Network (ANN) (with only cost).

4) Multiple Linear Regression (MLR) analysis (without cost parameter).

5) ANN (without cost parameter).

In this section, second and forth models are presented. The second model is the Simple Linear Regression (SLR) analysis; in which only cost parameter was used to predict construction duration. This cost was obtained from a cost estimation model based on Multiple Linear Regression (MLR) analysis. The equation used for the simple linear regression analysis was:

$$T = \alpha_0 + \alpha_1 C \qquad (2.3)$$

In which, T is the duration, C is the detailed cost, α_0 is the regression constant, and α_1 is partial regression coefficient of detailed cost (C).

Helvaci (2008) used Percentage Error (PE) and Mean Absolute Percentage Error (MAPE) to calculate predictive accuracy. His Simple Linear Regression Analysis had a prediction performance of 14% and duration estimations were varied within an accuracy range of ± 33%.

Helvaci (2008) used Multiple Linear Regression Analysis based on six parameters (without cost parameter): 1. total building area (Area), 2. number of floors (NoF), 3. area per unit (Area/unit), 4. combined percent area of commons and health center (Per(C+H)), 5. percent area of structured parking (Per(P)) and6. type of structural frame of the building (Steel (St), Masonry (Mas), Reinforced Concrete (RC), Precast (Pre), Wood (W)).

The Multiple Linear Regression equation used was:

$$Y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \ldots + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} \qquad (2.4)$$

In which, Y is the duration (T), α_0 is the regression constant, $\alpha_{1,2,3\ldots10}$ is the partial regression coefficient of $X_{1,2,3\ldots10}$

X_1 is the Area, X_2 is the No.F, X_3 is the Area/unit, X_4 is the Per (C+H), X_5 is the Per (P), X_6 is the St multiplied by the area, X_7 is the Mas multiplied by the area, X_8 is the RC multiplied by the area, X_9 is the Pre multiplied by the area, X_{10} is the W multiplied by the area

This regression model had a prediction performance of 15.2%; while duration estimations varied within an accuracy range of ± 33%.

2.5.3 Discrete state models

Discrete state models use linear programming, classical optimization, PERT, and CPM. Bhokha and Ogunlana (1999) and Helvaci (2008) are examples of discrete state models.

Bhokha and Ogunlana (1999) applied Artificial Neural Network (ANN) to forecast the construction duration of buildings at the pre-design stage. 136 buildings (height>23m; area>10,000m^2) built between 1987-1995 in Greater Bangkok, Thailand were studied. A 3-layered back-propagation ANN consisted of 11 input nodes is used. There were two different average errors. The first one was 18.2%, resulting from 68 test samples used for validity purpose of the model. The second one was 13.6% for the 136 projects.

2.6 FUZZY SETS

Since Zadeh (1975) introduced the concept of fuzzy sets, it has been employed in numerous areas. The concept is found on the fact that some notions, though meaningful, may not be clearly defined. For example, the question whether a man is tall or not may not be easily answered by 'yes' or 'no'. Thus, the set of tall men is not clearly defined, and if we try to define it by arbitrarily setting a threshold height, above which a man is considered to be tall, we will end up with an artificial set that may contain a tall man but does not contain a slightly shorter one.

This problem can be solved using a fuzzy set to describe the notion tall men. While for a classical set, any element either belongs to the set or does not belong to it, for a fuzzy set; different elements belong to it with various strengths ranging from 0 to 1, where 0 means no membership and 1 means full membership. In other words, while a classical set A living in a universe of discourse X *(i.e.,* $A \subseteq X$*)* can be characterized by its characteristics function $X_A : X \rightarrow (0,1)$, where for $x \in X$, $X_A(x) = 1$ if $x \in A$.

In fuzzy set theory, X_A is allowed to range over the real interval [0, 1], with $X_A(x)$ describing the strength of membership of the element x in the (fuzzy) set A. In the literature of fuzzy logic the characteristics function is usually denoted by μ_A instead of X_A.

2.6.1 Fuzzy Membership Functions

In the case where X is a continuous and infinite variable, the degree of membership can be represented by a function, commonly known as membership function. Membership functions can take various shapes and forms, A is denoted by:

$$A = \left\{ \int \frac{y_A(x)}{(x)} \right\} \qquad \text{...}(2.5)$$

The numerator is the membership value in set A associated with the element of the universe indicated in the denominator.

A continuous fuzzy set has two properties: convexity and; normality. The convexity means that the membership function has only one distinct peak, while the normality ensures that at least one element in the set has a degree of membership equal to 1.0. Fuzzy sets can take various shapes, however, linear approximations such as the trapezoidal and triangular shapes are frequently used (Chen and Huang 2006). A trapezoidal fuzzy set can be represented by a four points *(a, b, c, d)*, where a and d are the lower and upper bounds, b and c are the lower and upper middle values, respectively. Also, a triangular fuzzy set considered as a special case of the trapezoidal fuzzy set with b = c, these functions are shown in Fig. (2.3). The trapezoidal membership function can be formulated as:

$$y_A(x) = \begin{cases} \dfrac{x-a}{b-a} & a < x < b \\ 1 & a \le x \le b \\ \dfrac{x-d}{c-d} & c < x < d \\ 0 & otherwise \end{cases} \qquad \text{.........(2.6)}$$

For a value of $y_A(x) = 0$ x has a null membership in fuzzy set A, and $y_A(x) = 1$ means that x has full membership. These membership functions can be determined subjectively; the closer an element to satisfy the requirements of a set, the closer its grade of membership is to 1, and vice versa.

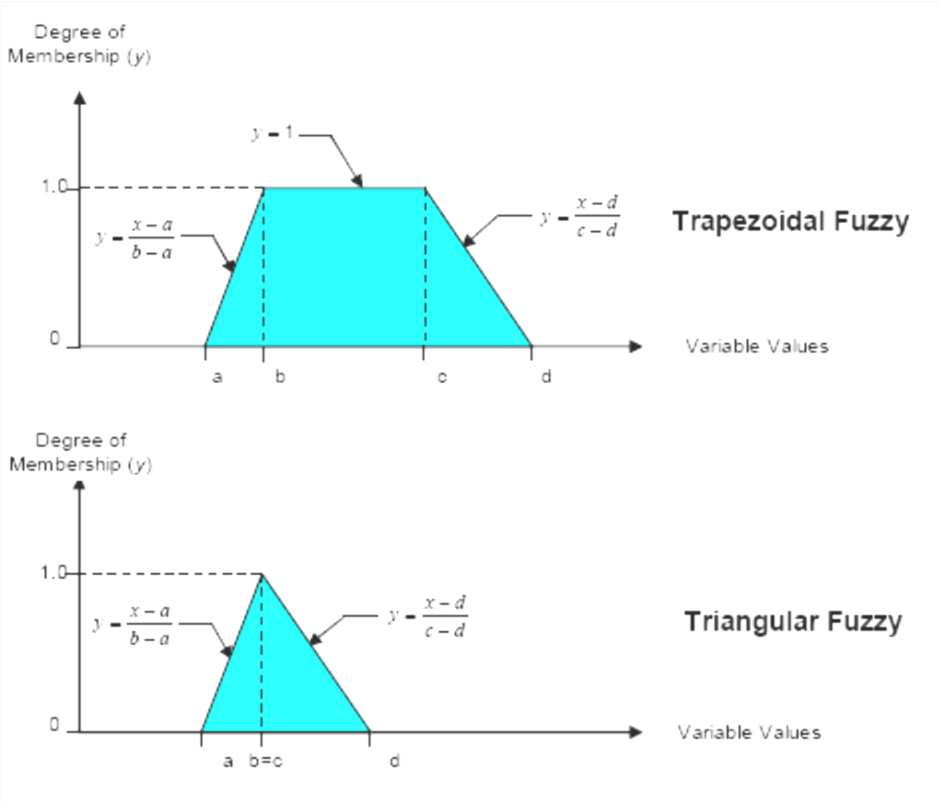


Figure 2.3: Examples of Linear Fuzzy Sets

2.6.2 Linguistic Variables

A fuzzy linguistic variable is defined as a variable the values of which are words, phrases, or sentences in a given language. For example, Quality can be considered as linguistic variable with values such as "low", "medium", or "high", while numerical variables use numbers as values. Since words are usually less precise than numbers, linguistic variables provide a method to characterize complex systems that are ill defined to be described in traditional quantitative terms (Zadeh 1975). A linguistic variable is defined by the name of a variable X and a term set T(x) of the linguistic values of X with each value being a fuzzy number defined on universe of discourse U. For example, if Quality (Q) is a linguistic variable then its term sets, are "Low," "Medium," and "High," where each term is characterized by a fuzzy set in a universe of discourse U=[0,1] (Fig.2-4).

A membership function can be established for each of these linguistic values using a certain shape on a certain range as fit for given conditions. The three functions are grouped together in the figure as a fuzzy set family for fuzzy variable Quality. Figure (2-4) shows that 3.5 as a grade of Q belongs to the linguistic variables (High, Medium, and

Low) with membership values of (0, 0.75, 0.5), respectively. Using the maximum value to find the fuzzy set that this Quality value of 3.5 belongs to the fuzzy set "Medium" with a membership value of 0.75.

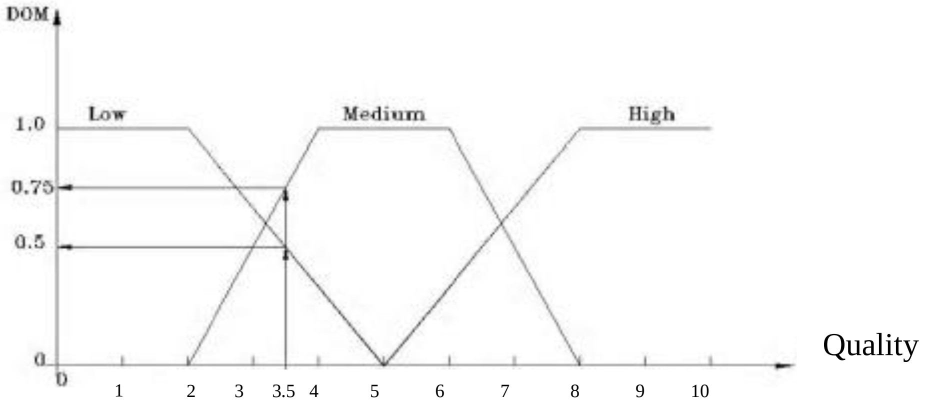


Figure 2.4: Membership Functions for Linguistic Variable "Quality"

2.6.3 Fuzzy If-Then Rules and Approximate Reasoning

Zadeh (1975) introduced the theory of approximate reasoning. This theory provides a powerful framework for reasoning in the face of imprecise and uncertain information. Central to the theory is the concept of fuzzy if-then rules, one rule may be written as (for example):

If ‘weather' is 'good', then 'the project duration' is 'short'.

Here 'the weather' is a linguistic variable and “good” is a fuzzy subset of the universe of weather ratings, which we also use 'the weather' for its name. Likewise, 'the project duration' is the name of both a linguistic variable and the universe of durations, of which 'short' is fuzzy subset.

Fuzzy rules define the value or levels of preference of a decision maker facing uncertain results. In developing fuzzy rules, a decision-maker exercises his or her subjective preference to determine the standing of various uncertain outcomes for the conditions of an operation. In general, the number of rules used in controlling a system using fuzzy control is as given in the following equation:

$R = (m)^{v}$ ………………………………………………...………………………….(2.7)

In which:

R = number of rules, m = number of membership functions, and

v = number of input variables.

Fuzzy logic for decision making is represented
by operations over fuzzy decision rules, which have the general form:

IF precondition 1 **AND** precondition 2 **AND**…………
THEN consequence 1 **AND** consequence 2 **AND** ……….

2.6.4 FUZZY SETS APPLICATIONS

The fuzzy sets and fuzzy logic has been extensively used in the construction engineering and management domain since mid 1990's. For example, selecting the winning design build proposal that best satisfies technical requirements and cost reduction (Peak et al. 1992); quantifying risk-associated activity duration under uncertainty (Ock, 1996); network scheduling (Lorterapong and Moselhi 1996); evaluating new construction technology (Chao and Skibniewski 1998); selecting the best crane type in a construction project (Hanna and Lotfallah 1999); measuring the constructability of concrete construction systems (Malek 2000); site layout planning in construction (Elbeltagi and Hegazy 2001); project performance evaluation and prediction (Fayek and Sun 2001); predicting potential cost overruns on engineering design projects (Knight and Fayek 2002); assisting contractors to estimating markup percentage (Liu and Ling 2003) and construction project monitoring and control (Oliveros and Fayek 2005).

2.7. SUMMARY AND CONCLUSION

Regression Models are related with mathematical values and very sensitive to data distribution. Therefore, if the variables are not clear, it is not possible to use regression models. (Sezgin, 2003).

Time-cost models and parametric models had close reasonably accurate estimations. The predictive accuracy of time-cost models was slightly better than parametric models. However, parametric estimations do not require cost estimation. (Helvaci, 2008).

In the study carried out by Helvaci (2008), ANN and regression analysis' predictive accuracies had no significant differences. Linear regression analyses were considered to provide an adequate and pragmatic methodology for conceptual duration estimation of construction projects.

The main advantage of the neural network models is their capability to capture the non-linear relations as well as linear relations. (Helvaci, 2008).

However, as Helvaci (2008) points out, an increase in the number of variables increases the complexity of the model. The construction industry is very complex, which contains hundreds of activities. (Bhokha and Ogunlana, 1999) Hence, Artificial Neural Network Models require trained professionals to estimate the construction duration.

Fuzzy Logic Models based on the conversion of linguistic expressions (like very good, good, fairly good) to mathematical values. It means that professionals take a role for making decisions, so it is appropriate for construction industry as compared with Regression Models and ANN's. Experience and institutions gain importance. However, if the people taking decisions are not efficient enough, it may lead to wrong decisions. (Sezgin, 2003)

CHAPTER 3

FACTORS AFFECTING PROJECT DURATION OF COMMERCIAL BUILDINGS IN EGYPT

3.1 INTRODUCTION

This chapter outlines the procedure followed to design the questionnaire and analyze its result. The procedure is divided into four steps: identifying the factors affecting the prediction of commercial project duration, designing the study questionnaire, collecting data, and finally analyzing results of the respondents that will be used to build the proposed framework in the next chapter.

3.2 METHODOLOGY

In order to identify the most significant factors that affect the prediction of commercial project duration, the following procedure was followed:

1. From the literature review, the factors that were repeated in most of previous researches have been chosen. For instance, the factors mentioned by Odabasi (2009) represented in Table (2.4), Chan and Kumaraswamy (2002) represented in Figure 2.1 and Chan and Kumaraswamy (1995) represented in Figure 2.2 were found to be the most repetitive and comprehensive factors among the previous researches.

2. Semi-structured interviews were conducted with twelve construction experts whose experience is more than 20 years to select the most important factors from the above chosen ones. In these interviews, factors were listed, combined, and finally selected to suit the construction industry in Egypt.

Furthermore, the duration estimating models concluded from the literature review were presented to the construction experts and they reach the consensus to create a new model to match the unique characteristics of the construction industry in Egypt.

3. Based on both the literature review and the semi-structured interviews, the final criteria (updated list) that were believed affecting the prediction of commercial project duration in Egypt was determined (Table 3.1) with 7 main groups including 36 factors affecting the prediction of commercial project duration in Egypt.

Table 3.1: Factors Affecting Project Duration Prediction in Egypt

Cost	**Client related factors**	**Contractor related factors**	**Consultant related factors**	**Project related factors**	**Environment related factors**	**Construction site related factors**
1. Project cost	2. Client’s experience, its representatives' capacity and qualifications.	10. Contractor's grade.	18. Consultant technical capacity.	23. Construction type (residential or administrative).	30. Economical conditions.	34. Construction site conditions.
	3. Type of client.	11. Financial capabilities.	19. Completeness and clarity of documents.	24. Complexity of the project.	31. Cultural factors.	35. Availability of services.
	4. Client's financial power and funds availability.	12. Managerial capabilities.	20. Consultant's past experience in similar projects.	25. Project's foot print.	32. Legal factors.	36. Availability of resources.
	5. Client's priorities in construction and amongst the project's objectives.	13. Project manager qualifications.	21. Consultant's past history in conflicts with contractors.	26. Project's total built up area.	33. Political factors	
	6. Required level of quality.	14. Staff and labors qualifications.	22. Speediness of replies to contractor's queries and approvals.	27. Number of stories.		
	7. Client's historical dispute records.	15. Plants and equipments.		28. Number of basements.		
	8. Speed of decision making.	16. Technical capabilities and Method of construction.		29. Floor height.		
	9. Client's tendency for changes.	17. Contractor's past experience in similar projects.				

As shown in Table 3.1, the main groups of selected factors affecting the prediction of commercial project duration are: Cost, Client related factors, Contractor related factors, Consultant related factors, Project related factors, Environment related factors, and Construction site related factors.

- Project's cost is concerned with the total cost incurred to perform the project.

- Client's related factors are concerned with:

  - Client's type either public, private or public-private partnership.
  - Client's past experience in the same field and in similar projects.
  - Client representatives' qualifications.
  - Client's financial soundness (power, stability and capability).
  - Client's priorities among the project components and project's objectives.
  - Client's desired level of quality.
  - Client's historical records in disputes with contractors in previous projects.
  - Client's speediness of decision making.
  - Client's tendency for changes.

- Contractor's related factors are concerned with:

  - Contractor's grade according to the Egyptian Federation for Construction Contractors (EFCC), the study focused on contractors with grade 1 and 2 for homogeneous results.
  - Contractor's financial stability, financial soundness and capacity which enable the contractor to proceed in project execution even if some of Client's invoices are delayed.
  - Contractor's managerial capabilities which includes but not limited to: company's organization structure, application of quality, time, cost, contract, scope, communication and risk management, etc.
  - Contractor's project manager's qualifications.
  - Contractor's staff and labors' qualification and productivity.
  - Contractor's in house plants and equipments.
  - Contractor's technical capabilities and adopt advanced methods of construction.

- Contractor’s past experience in similar projects.

- The consultant’s related factors are concerned with:

    - Consultant’s technical capabilities and his capacity to supervise complex projects.
    - The accumulative amount of the consultant’s past projects.
    - Consultant’s past records in the quality of tender documents (i.e.: completeness and clarity of tender documents).
    - Consultant’s past experience in similar projects.
    - Consultant’s past history in conflicts with the contractors.
    - Consultant’s past records in speediness of reply to the contractor’s queries and provide necessary approvals.

- Project related factors are concerned with:

    - Construction type (buildings “residential or administrative”, factories, infrastructure, etc).
    - Complexity of construction required and constructability of project design.
    - Project's foot print.
    - Project's total built up area.
    - Number of stories.
    - Number of basements.
    - Floor height.

- Environment related factors are concerned with:

    - Economical conditions.
    - Cultural factors.
    - Legal factors.
    - Political factors.

- Construction site related factors are concerned with:

- Construction site conditions (site location, access routes status, soil type, water table level, etc).
- Availability of services (i.e.: existence of utilities during construction, existence of public transportation, etc).
- Availability of resources (skilled and unskilled labors, sand and stones' quarries, batch plant and other project's resources).

3.3 Questionnaire Design

As discussed previously, factors affecting project duration estimating were identified. In order to determine the weight and relative importance of each factor, a questionnaire survey was designed and distributed among the different construction parties, namely: Clients (clients or employers), consultants (Engineers or Architects), and contractors.

3.3.1 Population and Sample Size

The size of the sample required from the population was determined based on statistical principles for this type of exploratory investigation to reflect a confidence level of 99%. The sample size was determined using the following formula (Dutta (2006):

$$N = \frac{(Z_{1-\frac{\alpha}{2}})^2 \times \sigma^2}{e^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3-1)$$

Where: *N* is the sample size, $Z_{1-\frac{\alpha}{2}}$ is the desired level of confidence (1-α),
which determines the critical Z value, σ is the standard deviation,
and *e* is the acceptable sampling error.

For this research, the 99% degree of confidence level corresponds to α = 0.01. Each of the non shaded tails has an area of α/2 = 0.005. The region is 0.5 – 0.005 = 0.495. Then, from the table of the standard normal distribution (z), an area of 0.495 corresponds to a z value of 2.58. The critical value is therefore $z_{\alpha/2}$ = 2.58, the margin of error was assumed as e = 0.25, and from the 20 samples was retakes from population, the standard deviation was calculated σ = 0.88. Accordingly, the sampling size is calculated by using Eq. (3-1) as follows:

$$N = \frac{2.58^2 \times 0.88^2}{0.25^2} = 82.48$$

Therefore, the minimum required sample is 82.48. This means that the minimum sample required is 83 from the population to reach 99% confidence level.

A number of 100 questionnaires were distributed to avoid the unreturned questionnaires and to maintain the level of confidence. 73 questionnaires are returned from the required 83, giving a response rate of approximately 88%. Selecting 73 questionnaires as the sample size and substitute this in the Equation (3-1) with a standard deviation σ = 0.92 for all the 73 respondents. Accordingly, the critical *z* value is calculated by using the Eq. (3-1) as follows:

$$Z_{1-\frac{\alpha}{2}} = \sqrt{\frac{N \times e^2}{\sigma^2}} \Rightarrow Z_{1-\frac{\alpha}{2}} = \sqrt{\frac{73 \times 0.25^2}{0.92^2}} = 2.32$$

The critical *z* value of 2.32 located between *z* = 1.96 for 95% confidence level and *z* = 2.58 for 99.7% confidence level. Therefore, the 73 responses received can be regarded as being very good and highly representative of the population since the degree confidence level has calculated by applied interpolation method to 97.32%.

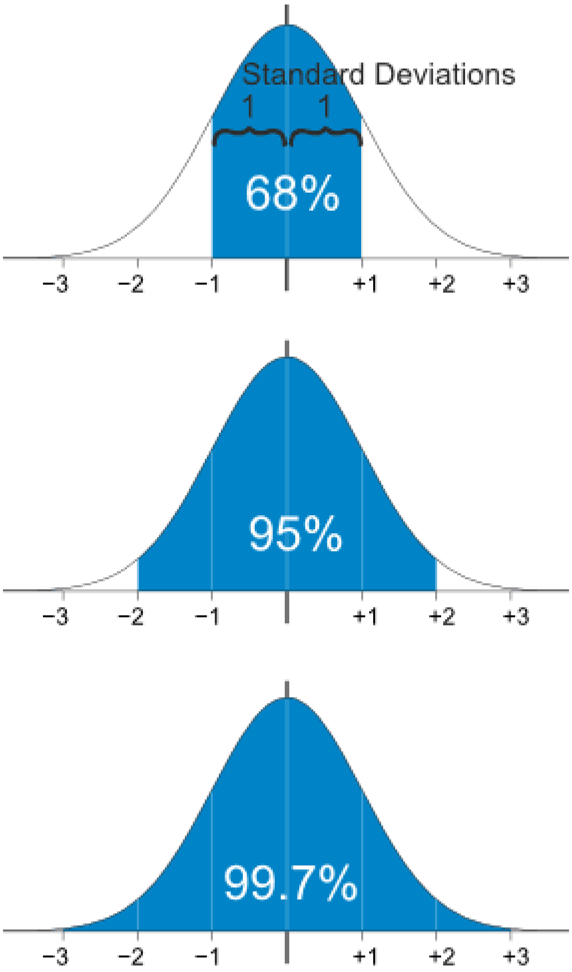


Figure 3.1: Normal distribution bell shape (probability vs. z-score)

3.3.2 Sample Formation

The questionnaire sample was selected to represent all the concerned parties of the construction industry. Accordingly, the sample consists of the decision-makers from the three groups: client, consultant, and contractor. Each group has two division : public and private. The public clients include ministries, general authorities, administrations, .. etc., while private clients include organizations, investors, .. etc.

Public consultants include governmental consultants and research centers, university research centers, .. etc., whereas private consultants include house of consultancy, different consultant offices, ..etc.

Public contractors include public sector companies that is related to the ministry of housing, trading, and industry, while private contractors include private companies, private establishments, ..etc.

The distribution of questionnaires on different construction parties is shown in Table 3.2.

Table 3.2: Questionnaire Sample Distribution

Party	Public	Private	Total
Client	10	20	30
Consultant	10	20	30
Contractor	15	25	40
Total	35	65	100

From Table (3.2), 65% of questionnaire samples were distributed among the private sector personnel to reflect the increase in the privatization governmental direction, while 35% of the questionnaire samples were distributed among the public sector personnel to assess their methodology for prediction of commercial project duration and the relative importance for each factor affecting the prediction of commercial project duration from their point of view.

3.3.3 Questionnaire Contents

The data included in the questionnaire is divided into six parts which are:

Part 1: Contains personal information (name, address, tel., organization, and email) to ease contact with each respondent.

Part 2: Contains organizational information (organization type, category, previous experience, work size, grade of the Egyptian Federation for construction contractors in case of contractors).

Part 3: Contains specific data related to the projects which have been accomplished by the respondent during the past years (project foot print, built-up area, volume, average floor area, number of stories, number of basement floors, etc).

Part 4: Is classifying the factors affecting the prediction of commercial project duration into seven main groups to give their importance degree from (0-10) where 0 means totally unimportant and 10 means extremely important.

Part 5: Is classifying each of the seven groups into second level of factors to give their degree of importance from (0-10) where 0 means totally unimportant and 10 means extremely important.

Part 6: Is developed to give opportunity to the respondents to mention his/her own criteria for prediction of commercial project duration, and any recommendations, suggestions or remarks.

3.4 Analysis of the Questionnaire Results

The distribution of the 73 survey respondents among the three main parties is shown in Table (3.3).

Table 3.3: Collected questionnaires from different parties

Party	Public	Private	Total
Client	7	17	24
Consultant	8	14	22
Contractor	11	16	27
Total	26	47	73

Table 3.4: Mean value of the questionnaire results of the main seven groups affecting prediction of commercial project duration

	Clients						Consultants						Contractors						
Part (4) :	Public	Mean	private	Mean	Total	Mean	Public	Mean	Private	Mean	Total	Mean	Public	Mean	private	Mean	Total	Mean	Mean
Main Seven groups:																			
a) Cost:	63	9	110	6.47	173	7.21	64	8	101	7.21	165	7.50	87	7.91	101	6.31	188	6.96	7.22
b) Client related factors:	59	8.43	138	8.12	197	8.21	65	8.13	121	8.64	186	8.45	88	8	140	8.75	228	8.44	8.37
c) Contractor related factors:	54	7.71	127	7.47	181	7.54	63	7.88	111	7.93	174	7.91	79	7.18	113	7.06	192	7.11	7.52
d) Consultant related factors:	50	7.14	122	7.18	172	7.17	56	7	96	6.86	152	6.91	90	8.18	128	8	218	8.07	7.38
e) Project related factors:	64	9.14	137	8.06	201	8.38	67	8.38	116	8.29	183	8.32	96	8.73	130	8.13	226	8.37	8.35
f) Environment related factors:	47	6.71	145	8.53	192	8.00	58	7.25	123	8.79	181	8.23	75	6.82	137	8.56	212	7.85	8.03
g) Construction site related factors:	57	8.14	134	7.88	191	7.96	66	8.25	113	8.06	179	8.14	95	8.64	129	8.06	224	8.30	8.13

3.4.1 General Analysis

Having a look at mean values of the survey results of the six groups: public (clients, consultants, and contractors) and private (clients, consultants, and contractors) shown in Table 3.4, the following comments are concluded:

1. Generally, the highest score factors affecting the prediction of commercial project duration are those related to the clients (item "b") and the project (item "e"), (i.e. the maximum mean value among the main seven groups for the three groups of Clients, consultants and contractors – Table 3.4), while the lowest score factors are those related to the cost in contrary to the studies reported in literature.
2. The private clients opinion tends to be more sensitive and concerned with the client's related factors (i.e. the client's objectives regarding the time constraints, construction priorities, etc) and the environmental related factors (economical and political conditions). While the public clients are more sensitive and concerned with the strict governmental procurement regulations, hence, the project's cost will be one of the highest score factors due to the limited annual budget and the inflexibility in fund's availability and redistribution. On the other hand, they selected the environmental related factors as the lowest score ones due to the weak effect of environmental changes (economical and political) on the governmental projects.
3. Consultants in general have selected the clients' related factors as the highest score ones due to the great effect of payments' regularity, speediness of decision making and tendency for changes on the completion on time, while the consultant related factors are the lowest score ones.
4. Consultants (public sector) have selected the project related factors as the highest score ones which comes in line with the clients (public sector) opinion, and they selected the consultants' related factors as the lowest score ones.
5. Consultants (private sector) have selected the environmental related factors as the highest score one which comes in line with the clients (private sector) opinion, and the consultants' as the lowest score one which comes in line with the consultants (public sector) opinion.

6. Contractors in general have selected the clients' related factors as the highest score one for the same reasons in point 3 mentioned above and the cost as the lowest score one.
7. Contractors (public sector) have selected the project related factors as the highest score one which comes in line with the clients (public sector) and consultants (public sector) opinion, and they selected the environmental related factors as the lowest score one which comes in line with the clients (public sector) opinion.
8. Contractors (private sector) have selected the clients' related factors as the highest score one, and the cost as the lowest score one.

3.4.2 Analysis of the Factors Affecting the Prediction of Project Duration For Commercial Buildings

Having the data collected and the general analysis completed, a deep analysis is carried out to calculate the weight of each factor based on the respondents weighting of the different factors.

For the purpose of the analysis of the questionnaire results, the data has been classified into six groups: Client public, Client private, consultant public, consultant private, contractor public, and contractor private.

Each group has 36 factors extracted from the literature review, and concluded from the semi structured interviews conducted with the industry experts.

In order to select the most effective factors among these 36 factors, two methods were used: Statistical Method and Criteria Weight Method.

3.4.2.1 Statistical method

SPSS (originally, Statistical Package for the Social Sciences, later modified to read Statistical Product and Service Solutions) was used for data analysis, data were expressed as Mean value and Standard Deviation for quantitative measures and both number and percentage for categorized data. The following tests were done:

1. Student *t*-test:

1.1 Student t-test is used for comparing the means of two samples (or treatments), even if they have different numbers of replicates. In simple terms, the t-test compares the actual difference between two means in relation to the variation in the data (expressed as the standard deviation of the difference between the means). It was used in this study to rank each group in descending order according to the highest mean and lowest standard deviation.

1.2 Comparison between two independent mean groups for parametric data using Student t-test. The probability of error at 0.05 and above is considered non significant, and from .05 to .01 is considered significant, while at 0.01 and below is highly significant.

2. Z - Scores:

Z - Scores tell us whether a particular score is equal to the mean, below the mean or above the mean of a bunch of scores. They can also tell us how far a particular score is away from specific reference. Is a particular score close to the mean or far away.

In this study, calculated Z - Scores were used to investigate which of the studied factors are nearer and which are out of the reference group **(the private consultant's results selected as reference group, also named the golden group, since the private consultant opinion constitute the expert and fair judgment between the Client and the contractor opinions).**

3. Pearson Correlation Coefficient:

In statistics, the Pearson product-moment correlation coefficient (sometimes referred to as the PPMCC or PCC or Pearson's r) is a measure of the correlation (linear dependence) between two variables X and Y, giving a value between +1 and −1 inclusive. It is widely used in the sciences as a measure of the strength of linear dependence between two variables. It was developed by Karl Pearson from a related idea introduced by Francis Galton in the 1880s.

In this study, Pearson correlation test was used to study the possible correlation between each sets of scores and the reference score (the consultant opinion).

Tables (3.5) through (3.10) present the ranking of the 36 factors as analyzed using student *t*-test in the six group of public (client, consultant, and contractor) and private (client, consultant, and contractor).

Student *t*- test is used as a test for comparison between 2 mean groups.

Such test is used to compare between each of the studied groups (A: client public , B: client private, C: consultant public, E: contractor public, F: contractor private) with the reference group (D: consultant private).

For instance, factor 1 (project cost) in Table (3.5) shows the comparison between group A (clients-public, number of group members n=7, mean value =8.29, standard deviation =0.756) with group D (consultants-private "reference group", number of group members n=14, mean value =8.57, standard deviation =0.514). The probability of error "p" = .391, i.e., non-significant difference in comparing the mean of factor 1 (project cost) between group A and group D.

The Z-score test results and the Figures showing how many units each factor among each group is away from the corresponding one of the reference group (D) are presented in Appendix C.

Table 3.5: Ranking of the whole criteria according to client-public group (A)

Criteria No.	Criteria description	Group notation	Mean	SD	t	p	Z	Sig.
1	Project's cost	Client Public (A)	8.29	0.756				
		Consultant Private (D)	8.57	0.514	-0.901	0.391	-0.5	NS
2	Client's experience, its representatives' capacity and qualifications.	Client Public (A)	7.43	1.134				
		Consultant Private (D)	8.71	0.611	-2.803	0.024	-2.1	S
3	Type of client.	Client Public (A)	9.29	0.488				
		Consultant Private (D)	9.36	0.633	-0.285	0.779	-0.1	NS
4	Client's financial power and funds availability.	Client Public (A)	9.43	0.535				
		Consultant Private (D)	9.29	0.611	0.55	0.591	0.2	NS
5	Client's priorities in construction and amongst the project's objectives.	Client Public (A)	9.14	0.69				
		Consultant Private (D)	8.5	0.65	2.051	0.064	1.0	NS
6	Required level of quality.	Client Public (A)	7	0.816				
		Consultant Private (D)	8	0.555	-2.921	0.017	-1.8	S
7	Client's historical dispute records.	Client Public (A)	8.14	0.69				
		Consultant Private (D)	7.86	0.663	0.906	0.383	0.4	NS
8	Speed of decision making.	Client Public (A)	9	0.577				
		Consultant Private (D)	7.21	0.802	5.839	0	2.2	HS
9	Client's tendency for changes.	Client Public (A)	8.43	0.535				
		Consultant Private (D)	8.86	0.663	-1.595	0.132	-0.6	NS
10	Contractor's grade.	Client Public (A)	8.29	0.488				
		Consultant Private (D)	8.93	0.616	-2.601	0.02	-1.0	S
11	Financial capabilities.	Client Public (A)	7.29	0.756				
		Consultant Private (D)	7.57	0.514	-0.901	0.391	-0.5	NS
12	Managerial capabilities.	Client Public (A)	8	0.816				
		Consultant Private (D)	8.21	0.699	-0.594	0.565	-0.3	NS
13	Project manager qualifications.	Client Public (A)	7	0.816				
		Consultant Private (D)	6.36	0.842	1.683	0.117	0.8	NS
14	Staff and labors qualifications.	Client Public (A)	7.14	0.69				
		Consultant Private (D)	7.14	0.663	0	1	0.0	NS
15	Plants and equipments.	Client Public (A)	8	0.577				
		Consultant Private (D)	8	0.679	0	1	0.0	NS
16	Technical capabilities and Method of construction.	Client Public (A)	8	0.816				
		Consultant Private (D)	8.5	0.519	-1.478	0.175	-1.0	NS
17	Contractor's past experience in similar projects.	Client Public (A)	8.14	0.9				
		Consultant Private (D)	8.71	0.611	-1.515	0.165	-0.9	NS

*Number of group members (n) = 7 for client public group (A) and 14 for consultant private group (D)

Table 3.5 continued

18	Consultant technical capacity.	Client Public (A)	7.71	0.756				
		Consultant Private (D)	6.86	0.663	2.55	0.027	1.3	S
19	Completeness and clarity of documents.	Client Public (A)	8.43	0.535				
		Consultant Private (D)	8.57	0.756	-0.5	0.624	-0.2	NS
20	Consultant's past experience in similar projects.	Client Public (A)	7	0.816				
		Consultant Private (D)	6.29	0.726	1.959	0.076	1.0	NS
21	Consultant's past history in conflicts with contractors.	Client Public (A)	6	0.816				
		Consultant Private (D)	5.71	0.611	0.818	0.433	0.5	NS
22	Speediness of replies to contractor's queries and approvals.	Client Public (A)	6.71	0.756				
		Consultant Private (D)	7.57	0.514	-2.704	0.025	-1.7	S
23	Construction type (residential or administrative).	Client Public (A)	8.29	0.488				
		Consultant Private (D)	7.14	0.663	4.469	0	1.7	HS
24	Complexity of the project.	Client Public (A)	9.14	0.69				
		Consultant Private (D)	9.07	0.616	0.232	0.821	0.1	NS
25	Project's foot print.	Client Public (A)	8.43	0.787				
		Consultant Private (D)	7.5	0.76	2.579	0.025	1.2	S
26	Project's total built up area.	Client Public (A)	8.86	0.69				
		Consultant Private (D)	8.64	0.745	0.653	0.525	0.3	NS
27	Number of stories.	Client Public (A)	9.43	0.787				
		Consultant Private (D)	9.21	0.699	0.61	0.554	0.3	NS
28	Number of basements.	Client Public (A)	9.29	0.488				
		Consultant Private (D)	9.14	0.77	0.517	0.612	0.2	NS
29	Floor height.	Client Public (A)	8.71	0.756				
		Consultant Private (D)	8.71	0.611	0	1	**0.0**	NS
30	Economical conditions.	Client Public (A)	9.57	0.535				
		Consultant Private (D)	9.5	0.519	0.291	0.776	0.1	NS
31	Cultural factors.	Client Public (A)	5.43	0.535				
		Consultant Private (D)	7.57	0.938	-6.657	0	-2.3	HS
32	Legal factors.	Client Public (A)	5.71	0.756				
		Consultant Private (D)	8.5	0.519	-8.771	0	**-5.4**	HS
33	Political factors.	Client Public (A)	9.71	0.488				
		Consultant Private (D)	9.43	0.646	1.131	0.275	0.4	NS
34	Construction site conditions.	Client Public (A)	9	0.816				
		Consultant Private (D)	8.86	0.77	0.385	0.707	0.2	NS
35	Availability of services.	Client Public (A)	6.86	0.69				
		Consultant Private (D)	7	0.784	-0.427	0.676	-0.2	NS
36	Availability of resources.	Client Public (A)	8.57	0.535				
		Consultant Private (D)	8.57	0.756	0	1	**0.0**	NS

Table (3.5) shows that for the Clients-public group, the most important factor is the "political factors – factor no. 33" in the environment related factors with the highest mean value while the least important one is the "cultural factor – factor no. 31" in the environment related factors with the least mean value.

Table 3.6: Ranking of the whole criteria according to client-private group (B)

Criteria No.	Criteria description	Group notation	Mean	SD	t	p	Z	Sig.
1	Project's cost	Client Private (B)	8.29	0.686				
		Consultant Private (D)	8.57	0.514	-1.286	0.209	-0.5	NS
2	Client's experience, its representatives' capacity and qualifications.	Client Private (B)	8.29	0.686				
		Consultant Private (D)	8.71	0.611	-1.802	0.082	-0.7	NS
3	Type of client.	Client Private (B)	9.35	0.606				
		Consultant Private (D)	9.36	0.633	-0.019	0.985	0.0	NS
4	Client's financial power and funds availability.	Client Private (B)	9.24	0.831				
		Consultant Private (D)	9.29	0.611	-0.194	0.847	-0.1	NS
5	Client's priorities in construction and amongst the project's objectives.	Client Private (B)	8.24	0.752				
		Consultant Private (D)	8.5	0.65	-1.05	0.302	-0.4	NS
6	Required level of quality.	Client Private (B)	7.29	0.772				
		Consultant Private (D)	8	0.555	-2.956	0.006	-1.3	HS
7	Client's historical dispute records.	Client Private (B)	7.24	0.903				
		Consultant Private (D)	7.86	0.663	-2.207	0.035	-0.9	S
8	Speed of decision making.	Client Private (B)	6.47	0.874				
		Consultant Private (D)	7.21	0.802	-2.467	0.02	-0.9	S
9	Client's tendency for changes.	Client Private (B)	8.47	0.8				
		Consultant Private (D)	8.86	0.663	-1.471	0.152	-0.6	NS
10	Contractor's grade.	Client Private (B)	8.71	0.588				
		Consultant Private (D)	8.93	0.616	-1.023	0.315	-0.4	NS
11	Financial capabilities.	Client Private (B)	7.24	0.831				
		Consultant Private (D)	7.57	0.514	-1.378	0.179	-0.6	NS
12	Managerial capabilities.	Client Private (B)	8	0.791				
		Consultant Private (D)	8.21	0.699	-0.8	0.43	-0.3	NS
13	Project manager qualifications.	Client Private (B)	6.12	0.781				
		Consultant Private (D)	6.36	0.842	-0.814	0.423	-0.3	NS
14	Staff and labors qualifications.	Client Private (B)	6.53	0.943				
		Consultant Private (D)	7.14	0.663	-2.12	0.043	-0.9	S
15	Plants and equipments.	Client Private (B)	7.53	0.874				
		Consultant Private (D)	8	0.679	-1.686	0.103	-0.7	NS
16	Technical capabilities and Method of construction.	Client Private (B)	8.12	0.697				
		Consultant Private (D)	8.5	0.519	-1.749	0.091	-0.7	NS
17	Contractor's past experience in similar projects.	Client Private (B)	8.65	0.786				
		Consultant Private (D)	8.71	0.611	-0.268	0.791	-0.1	NS

*Number of group members (n) = 17 for client private group (B) and 14 for consultant private group (D)

Table 3.6 continued

18	Consultant technical capacity.	Client Private (B)	7.41	0.712				
		Consultant Private (D)	6.86	0.663	2.241	0.033	0.8	S
19	Completeness and clarity of documents.	Client Private (B)	8.76	0.831				
		Consultant Private (D)	8.57	0.756	0.677	0.504	0.3	NS
20	Consultant's past experience in similar projects.	Client Private (B)	7.06	0.659				
		Consultant Private (D)	6.29	0.726	3.075	0.005	1.1	HS
21	Consultant's past history in conflicts with contractors.	Client Private (B)	6.41	0.795				
		Consultant Private (D)	5.71	0.611	2.76	0.01	1.1	S
22	Speediness of replies to contractor's queries and approvals.	Client Private (B)	8.06	0.659				
		Consultant Private (D)	7.57	0.514	2.314	0.028	1.0	S
23	Construction type (residential or administrative).	Client Private (B)	6.53	0.874				
		Consultant Private (D)	7.14	0.663	-2.22	0.034	-0.9	S
24	Complexity of the project.	Client Private (B)	9.06	0.748				
		Consultant Private (D)	9.07	0.616	-0.051	0.959	0.0	NS
25	Project's foot print.	Client Private (B)	7.06	0.899				
		Consultant Private (D)	7.5	0.76	-1.481	0.15	-0.6	NS
26	Project's total built up area.	Client Private (B)	8.88	0.697				
		Consultant Private (D)	8.64	0.745	0.917	0.367	0.3	NS
27	Number of stories.	Client Private (B)	9.18	0.728				
		Consultant Private (D)	9.21	0.699	-0.147	0.884	0.0	NS
28	Number of basements.	Client Private (B)	9.12	0.697				
		Consultant Private (D)	9.14	0.77	-0.095	0.925	0.0	NS
29	Floor height.	Client Private (B)	8.53	0.514				
		Consultant Private (D)	8.71	0.611	-0.899	0.377	-0.3	NS
30	Economical conditions.	Client Private (B)	9.47	0.514				
		Consultant Private (D)	9.5	0.519	-0.158	0.876	-0.1	NS
31	Cultural factors.	Client Private (B)	7.24	0.664				
		Consultant Private (D)	7.57	0.938	-1.128	0.271	-0.4	NS
32	Legal factors.	Client Private (B)	8	0.612				
		Consultant Private (D)	8.5	0.519	-2.461	0.02	-1.0	S
33	Political factors.	Client Private (B)	9.41	0.507				
		Consultant Private (D)	9.43	0.646	-0.079	0.937	0.0	NS
34	Construction site conditions.	Client Private (B)	8.94	0.748				
		Consultant Private (D)	8.86	0.77	0.306	0.762	0.1	NS
35	Availability of services.	Client Private (B)	6.35	0.702				
		Consultant Private (D)	7	0.784	-2.396	0.024	-0.8	S
36	Availability of resources.	Client Private (B)	8.18	0.883				
		Consultant Private (D)	8.57	0.756	-1.342	0.19	-0.5	NS

Table (3.6) shows that for the Clients-private group, the most important factor is the "economic conditions – factor no. 30" in the environment related factors with the highest mean value while the least important one is the "project manager qualifications – factor no. 13" in the contractor's related factors with the least mean value.

Table 3.7: Ranking of the whole criteria according to consultant-public group (C)

Criteria No.	Criteria description	Group notation	Mean	SD	t	p	Z	Sig.
1	Project's cost	Consultant Public (C)	8.38	0.518				
		Consultant Private (D)	8.57	0.514	-0.859	0.404	-0.4	NS
2	Client's experience, its representatives' capacity and qualifications.	Consultant Public (C)	6.75	0.707				
		Consultant Private (D)	8.71	0.611	-6.577	0	-3.2	HS
3	Type of client.	Consultant Public (C)	8.75	0.463				
		Consultant Private (D)	9.36	0.633	-2.579	0.019	-1.0	S
4	Client's financial power and funds availability.	Consultant Public (C)	8.88	0.641				
		Consultant Private (D)	9.29	0.611	-1.47	0.163	-0.7	NS
5	Client's priorities in construction and amongst the project's objectives.	Consultant Public (C)	7.63	0.916				
		Consultant Private (D)	8.5	0.65	-2.38	0.036	-1.3	S
6	Required level of quality.	Consultant Public (C)	7.38	0.744				
		Consultant Private (D)	8	0.555	-2.07	0.062	-1.1	NS
7	Client's historical dispute records.	Consultant Public (C)	8	0.756				
		Consultant Private (D)	7.86	0.663	0.446	0.663	0.2	NS
8	Speed of decision making.	Consultant Public (C)	8	0.756				
		Consultant Private (D)	7.21	0.802	2.294	0.036	1.0	S
9	Client's tendency for changes.	Consultant Public (C)	8.63	0.518				
		Consultant Private (D)	8.86	0.663	-0.911	0.374	-0.3	NS
10	Contractor's grade.	Consultant Public (C)	8.5	0.926				
		Consultant Private (D)	8.93	0.616	-1.17	0.268	-0.7	NS
11	Financial capabilities.	Consultant Public (C)	7.88	0.991				
		Consultant Private (D)	7.57	0.514	0.807	0.44	0.6	NS
12	Managerial capabilities.	Consultant Public (C)	8.38	0.744				
		Consultant Private (D)	8.21	0.699	0.498	0.626	0.2	NS
13	Project manager qualifications.	Consultant Public (C)	6.38	0.744				
		Consultant Private (D)	6.36	0.842	0.052	0.959	0.0	NS
14	Staff and labors qualifications.	Consultant Public (C)	7.13	0.641				
		Consultant Private (D)	7.14	0.663	-0.062	0.951	0.0	NS
15	Plants and equipments.	Consultant Public (C)	7.75	0.707				
		Consultant Private (D)	8	0.679	-0.809	0.432	-0.4	NS
16	Technical capabilities and Method of construction.	Consultant Public (C)	8.63	0.518				
		Consultant Private (D)	8.5	0.519	0.544	0.594	0.3	NS
17	Contractor's past experience in similar projects.	Consultant Public (C)	8.75	0.463				
		Consultant Private (D)	8.71	0.611	0.154	0.879	0.1	NS

*Number of group members (n) = 8 for consultant public group (C) and 14 for consultant private group (D)

Table 3.7 continued

18	Consultant technical capacity.	Consultant Public (C)	7.63	0.518				
		Consultant Private (D)	6.86	0.663	3.015	0.008	1.2	HS
19	Completeness and clarity of documents.	Consultant Public (C)	8.38	0.518				
		Consultant Private (D)	8.57	0.756	-0.721	0.48	-0.3	NS
20	Consultant's past experience in similar projects.	Consultant Public (C)	6.75	0.707				
		Consultant Private (D)	6.29	0.726	1.467	0.163	0.6	NS
21	Consultant's past history in conflicts with contractors.	Consultant Public (C)	6	0.756				
		Consultant Private (D)	5.71	0.611	0.912	0.379	0.5	NS
22	Speediness of replies to contractor's queries and approvals.	Consultant Public (C)	6.63	0.518				
		Consultant Private (D)	7.57	0.514	-4.138	0.001	-1.8	HS
23	Construction type (residential or administrative).	Consultant Public (C)	7.63	0.518				
		Consultant Private (D)	7.14	0.663	1.893	0.075	0.7	NS
24	Complexity of the project.	Consultant Public (C)	8.38	0.744				
		Consultant Private (D)	9.07	0.616	-2.244	0.044	-1.1	S
25	Project's foot print.	Consultant Public (C)	7.75	0.707				
		Consultant Private (D)	7.5	0.76	0.776	0.449	0.3	NS
26	Project's total built up area.	Consultant Public (C)	8.13	0.835				
		Consultant Private (D)	8.64	0.745	-1.455	0.169	-0.7	NS
27	Number of stories.	Consultant Public (C)	8.63	0.518				
		Consultant Private (D)	9.21	0.699	-2.253	0.037	-0.8	S
28	Number of basements.	Consultant Public (C)	8.5	0.535				
		Consultant Private (D)	9.14	0.77	-2.3	0.033	-0.8	S
29	Floor height.	Consultant Public (C)	8	0.756				
		Consultant Private (D)	8.71	0.611	-2.28	0.041	-1.2	S
30	Economical conditions.	Consultant Public (C)	9	0.756				
		Consultant Private (D)	9.5	0.519	-1.661	0.125	-1.0	NS
31	Cultural factors.	Consultant Public (C)	5.75	0.707				
		Consultant Private (D)	7.57	0.938	-5.146	0	-1.9	HS
32	Legal factors.	Consultant Public (C)	6.13	0.835				
		Consultant Private (D)	8.5	0.519	-7.285	0	-4.6	HS
33	Political factors.	Consultant Public (C)	9.13	0.641				
		Consultant Private (D)	9.43	0.646	-1.066	0.304	-0.5	NS
34	Construction site conditions.	Consultant Public (C)	8.25	0.707				
		Consultant Private (D)	8.86	0.77	-1.875	0.079	-0.8	NS
35	Availability of services.	Consultant Public (C)	7.88	0.641				
		Consultant Private (D)	7	0.784	2.834	0.011	1.1	S
36	Availability of resources.	Consultant Public (C)	7.88	0.835				
		Consultant Private (D)	8.57	0.756	-1.948	0.073	-0.9	NS

Table (3.7) shows that for the consultant-public group, the most important factor is the “political factors – factor no. 33” in the environment related factors with the highest mean value while the least important one is the “cultural factor – factor no. 31” in the environment related factors with the least mean value.

Table 3.8: Ranking of the whole criteria according to consultant-private group (D)

Criteria No.	Criteria description	Group notation	Mean	SD
1	Project's cost	Consultant Private (D)	8	0.679
			8.5	0.519
2	Client's experience, its representatives' capacity and qualifications.		9.36	0.633
			9.29	0.611
3	Type of client.		8.5	0.65
			8	0.555
4	Client's financial power and funds availability.		7.86	0.663
			8.57	0.514
5	Client's priorities in construction and amongst the project's objectives.		8.86	0.663
			8.93	0.616
6	Required level of quality.		7.57	0.514
			8.21	0.699
7	Client's historical dispute records.		6.36	0.842
			7.14	0.663
8	Speed of decision making.		7.21	0.802
			8.71	0.611
9	Client's tendency for changes.		8.71	0.611
			6.86	0.663
10	Contractor's grade.		8.57	0.756
			6.29	0.726
11	Financial capabilities.		5.71	0.611
			7.57	0.514
12	Managerial capabilities.		7.14	0.663
			9.07	0.616
13	Project manager qualifications.		7.5	0.76
			8.57	0.756
14	Staff and labors qualifications.		9.21	0.699
			9.14	0.77
15	Plants and equipments.		8.71	0.611
			9.5	0.519
16	Technical capabilities and Method of construction.		7.57	0.938
			8.5	0.519
17	Contractor's past experience in similar projects.		9.43	0.646
			8.86	0.77

*Number of group members (n) = 14 for consultant private group (D)

Table 3.8 continued

18	Consultant technical capacity.	Consultant Private (D)	7	0.784
			8.64	0.745
19	Completeness and clarity of documents.		8.38	0.518
			8.57	0.756
20	Consultant's past experience in similar projects.		6.75	0.707
			6.29	0.726
21	Consultant's past history in conflicts with contractors.		6	0.756
			5.71	0.611
22	Speediness of replies to contractor's queries and approvals.		6.63	0.518
			7.57	0.514
23	Construction type (residential or administrative).		7.63	0.518
			7.14	0.663
24	Complexity of the project.		8.38	0.744
			9.07	0.616
25	Project's foot print.		7.75	0.707
			7.5	0.76
26	Project's total built up area.		8.13	0.835
			8.64	0.745
27	Number of stories.		8.63	0.518
			9.21	0.699
28	Number of basements.		8.5	0.535
			9.14	0.77
29	Floor height.		8	0.756
			8.71	0.611
30	Economical conditions.		9	0.756
			9.5	0.519
31	Cultural factors.		5.75	0.707
			7.57	0.938
32	Legal factors.		6.13	0.835
			8.5	0.519
33	Political factors.		9.13	0.641
			9.43	0.646
34	Construction site conditions.		8.25	0.707
			8.86	0.77
35	Availability of services.		7.88	0.641
			7	0.784
36	Availability of resources.		7.88	0.835
			8.57	0.756

Table (3.8) shows that for the consultants-private group, the most important factor is the “economic conditions – factor no. 30” in the environment related factors with the highest mean value while the least important one is the “consultant's past history in conflicts with contractors – factor no. 21” in the consultant’s related factors with the least mean value.

Table 3.9: Ranking of the whole criteria according to contractor-public group (E)

Criteria No.	Criteria description	Group notation	Mean	SD	t	p	Z	Sig.
1	Project's cost	Contractor Public (E)	8.45	0.82				
		Consultant Private (D)	8.57	0.514	-0.413	0.685	-0.2	NS
2	Client's experience, its representatives' capacity and qualifications.	Contractor Public (E)	6.09	0.831				
		Consultant Private (D)	8.71	0.611	-8.769	0	-4.3	HS
3	Type of client.	Contractor Public (E)	9.09	0.701				
		Consultant Private (D)	9.36	0.633	-0.984	0.337	-0.4	NS
4	Client's financial power and funds availability.	Contractor Public (E)	9.18	0.603				
		Consultant Private (D)	9.29	0.611	-0.425	0.675	-0.2	NS
5	Client's priorities in construction and amongst the project's objectives.	Contractor Public (E)	8.91	0.701				
		Consultant Private (D)	8.5	0.65	1.495	0.15	0.6	NS
6	Required level of quality.	Contractor Public (E)	5.82	0.874				
		Consultant Private (D)	8	0.555	-7.217	0	-3.9	HS
7	Client's historical dispute records.	Contractor Public (E)	8.09	0.701				
		Consultant Private (D)	7.86	0.663	0.848	0.406	0.3	NS
8	Speed of decision making.	Contractor Public (E)	7.91	1.044				
		Consultant Private (D)	7.21	0.802	1.824	0.084	0.9	NS
9	Client's tendency for changes.	Contractor Public (E)	8.73	0.647				
		Consultant Private (D)	8.86	0.663	-0.493	0.627	-0.2	NS
10	Contractor's grade.	Contractor Public (E)	8.27	0.647				
		Consultant Private (D)	8.93	0.616	-2.571	0.018	-1.1	S
11	Financial capabilities.	Contractor Public (E)	6	0.894				
		Consultant Private (D)	7.57	0.514	-5.193	0	-3.1	HS
12	Managerial capabilities.	Contractor Public (E)	8	0.632				
		Consultant Private (D)	8.21	0.699	-0.803	0.431	-0.3	NS
13	Project manager qualifications.	Contractor Public (E)	6.45	1.036				
		Consultant Private (D)	6.36	0.842	0.253	0.803	0.1	NS
14	Staff and labors qualifications.	Contractor Public (E)	6.55	0.82				
		Consultant Private (D)	7.14	0.663	-1.964	0.064	-0.9	NS
15	Plants and equipments.	Contractor Public (E)	7.91	0.944				
		Consultant Private (D)	8	0.679	-0.269	0.791	-0.1	NS
16	Technical capabilities and Method of construction.	Contractor Public (E)	8.09	0.831				
		Consultant Private (D)	8.5	0.519	-1.428	0.173	-0.8	NS
17	Contractor's past experience in similar projects.	Contractor Public (E)	8.18	0.751				
		Consultant Private (D)	8.71	0.611	-1.907	0.072	-0.9	NS

*Number of group members (n) = 11 for contractor public group (E) and 14 for consultant private group (D)

Table 3.9 continued

18	Consultant technical capacity.	Contractor Public (E)	8.09	0.831				
		Consultant Private (D)	6.86	0.663	4.02	0.001	1.9	HS
19	Completeness and clarity of documents.	Contractor Public (E)	8.36	0.674				
		Consultant Private (D)	8.57	0.756	-0.725	0.476	-0.3	NS
20	Consultant's past experience in similar projects.	Contractor Public (E)	8	0.775				
		Consultant Private (D)	6.29	0.726	5.645	0	2.4	HS
21	Consultant's past history in conflicts with contractors.	Contractor Public (E)	8.18	0.603				
		Consultant Private (D)	5.71	0.611	10.095	0	4.0	HS
22	Speediness of replies to contractor's queries and approvals.	Contractor Public (E)	8.27	0.647				
		Consultant Private (D)	7.57	0.514	2.941	0.008	1.4	HS
23	Construction type (residential or administrative).	Contractor Public (E)	8	0.775				
		Consultant Private (D)	7.14	0.663	2.924	0.008	1.3	HS
24	Complexity of the project.	Contractor Public (E)	8.82	0.603				
		Consultant Private (D)	9.07	0.616	-1.033	0.313	-0.4	NS
25	Project's foot print.	Contractor Public (E)	8.36	0.674				
		Consultant Private (D)	7.5	0.76	3.006	0.006	1.1	HS
26	Project's total built up area.	Contractor Public (E)	8.64	0.505				
		Consultant Private (D)	8.64	0.745	-0.026	0.98	0.0	NS
27	Number of stories.	Contractor Public (E)	9	0.775				
		Consultant Private (D)	9.21	0.699	-0.716	0.482	-0.3	NS
28	Number of basements.	Contractor Public (E)	8.91	0.701				
		Consultant Private (D)	9.14	0.77	-0.792	0.436	-0.3	NS
29	Floor height.	Contractor Public (E)	8.55	0.522				
		Consultant Private (D)	8.71	0.611	-0.744	0.464	-0.3	NS
30	Economical conditions.	Contractor Public (E)	9.27	0.786				
		Consultant Private (D)	9.5	0.519	-0.828	0.42	-0.4	NS
31	Cultural factors.	Contractor Public (E)	5.55	0.688				
		Consultant Private (D)	7.57	0.938	-6.23	0	-2.2	HS
32	Legal factors.	Contractor Public (E)	5.55	0.522				
		Consultant Private (D)	8.5	0.519	-14.081	0	-5.7	HS
33	Political factors.	Contractor Public (E)	9.36	0.674				
		Consultant Private (D)	9.43	0.646	-0.243	0.81	-0.1	NS
34	Construction site conditions.	Contractor Public (E)	8.73	0.647				
		Consultant Private (D)	8.86	0.77	-0.458	0.651	-0.2	NS
35	Availability of services.	Contractor Public (E)	8.27	0.786				
		Consultant Private (D)	7	0.784	4.022	0.001	1.6	HS
36	Availability of resources.	Contractor Public (E)	8.45	0.522				
		Consultant Private (D)	8.57	0.756	-0.456	0.652	-0.2	NS

Table (3.9) shows that for the contractors-public group, the most important factor is the “political factors – factor no. 33” in the environment related factors with the highest mean value while the least important one is the “cultural factors – factor no. 31” in the environment related factors with the least mean value.

Table 3.10: Ranking of the whole criteria according to contractor-private group (F)

Criteria No.	Criteria description	Group notation	Mean	SD	t	p	Z	Sig.
1	Project's cost	Contractor Private (F)	8.75	0.683				
		Consultant Private (D)	8.57	0.514	0.815	0.422	0.4	NS
2	Client's experience, its representatives' capacity and qualifications.	Contractor Private (F)	8.25	1.065				
		Consultant Private (D)	8.71	0.611	-1.487	0.15	-0.8	NS
3	Type of client.	Contractor Private (F)	9.25	0.577				
		Consultant Private (D)	9.36	0.633	-0.482	0.634	-0.2	NS
4	Client's financial power and funds availability.	Contractor Private (F)	9.19	0.544				
		Consultant Private (D)	9.29	0.611	-0.462	0.648	-0.2	NS
5	Client's priorities in construction and amongst the project's objectives.	Contractor Private (F)	8.94	0.68				
		Consultant Private (D)	8.5	0.65	1.799	0.083	0.7	NS
6	Required level of quality.	Contractor Private (F)	7.25	1.183				
		Consultant Private (D)	8	0.555	-2.267	0.034	-1.4	S
7	Client's historical dispute records.	Contractor Private (F)	8.69	0.946				
		Consultant Private (D)	7.86	0.663	2.809	0.009	1.3	HS
8	Speed of decision making.	Contractor Private (F)	6.31	0.873				
		Consultant Private (D)	7.21	0.802	-2.948	0.006	-1.1	HS
9	Client's tendency for changes.	Contractor Private (F)	8.88	0.806				
		Consultant Private (D)	8.86	0.663	0.067	0.947	0.0	NS
10	Contractor's grade.	Contractor Private (F)	8.63	0.719				
		Consultant Private (D)	8.93	0.616	-1.246	0.223	-0.5	NS
11	Financial capabilities.	Contractor Private (F)	6.13	0.806				
		Consultant Private (D)	7.57	0.514	-5.932	0	-2.8	HS
12	Managerial capabilities.	Contractor Private (F)	7.31	0.704				
		Consultant Private (D)	8.21	0.699	-3.512	0.002	-1.3	HS
13	Project manager qualifications.	Contractor Private (F)	5.75	0.577				
		Consultant Private (D)	6.36	0.842	-2.271	0.033	-0.7	S
14	Staff and labors qualifications.	Contractor Private (F)	6.19	0.75				
		Consultant Private (D)	7.14	0.663	-3.703	0.001	-1.4	HS
15	Plants and equipments.	Contractor Private (F)	8.19	0.911				
		Consultant Private (D)	8	0.679	0.644	0.525	0.3	NS
16	Technical capabilities and Method of construction.	Contractor Private (F)	8.5	0.894				
		Consultant Private (D)	8.5	0.519	0	1	0.0	NS
17	Contractor's past experience in similar projects.	Contractor Private (F)	8.56	0.727				
		Consultant Private (D)	8.71	0.611	-0.621	0.54	-0.2	NS

*Number of group members (n) = 16 for contractor private group (F) and 14 for consultant private group (D)

Table 3.10 continued

18	Consultant technical capacity.	Contractor Private (F)	8.25	0.683				
		Consultant Private (D)	6.86	0.663	5.66	0	2.1	HS
19	Completeness and clarity of documents.	Contractor Private (F)	8.69	0.602				
		Consultant Private (D)	8.57	0.756	0.461	0.649	0.2	NS
20	Consultant's past experience in similar projects.	Contractor Private (F)	7.88	0.719				
		Consultant Private (D)	6.29	0.726	6.008	0	2.2	HS
21	Consultant's past history in conflicts with contractors.	Contractor Private (F)	7.06	0.68				
		Consultant Private (D)	5.71	0.611	5.718	0	2.2	HS
22	Speediness of replies to contractor's queries and approvals.	Contractor Private (F)	8.31	0.602				
		Consultant Private (D)	7.57	0.514	3.638	0.001	1.4	HS
23	Construction type (residential or administrative).	Contractor Private (F)	6.94	0.929				
		Consultant Private (D)	7.14	0.663	-0.703	0.488	-0.3	NS
24	Complexity of the project.	Contractor Private (F)	9	0.632				
		Consultant Private (D)	9.07	0.616	-0.313	0.757	-0.1	NS
25	Project's foot print.	Contractor Private (F)	7.38	0.806				
		Consultant Private (D)	7.5	0.76	-0.437	0.666	-0.2	NS
26	Project's total built up area.	Contractor Private (F)	8.88	0.719				
		Consultant Private (D)	8.64	0.745	0.866	0.394	0.3	NS
27	Number of stories.	Contractor Private (F)	9.13	0.806				
		Consultant Private (D)	9.21	0.699	-0.325	0.748	-0.1	NS
28	Number of basements.	Contractor Private (F)	9.06	0.68				
		Consultant Private (D)	9.14	0.77	-0.301	0.766	-0.1	NS
29	Floor height.	Contractor Private (F)	8.81	0.75				
		Consultant Private (D)	8.71	0.611	0.395	0.696	0.2	NS
30	Economical conditions.	Contractor Private (F)	9.38	0.5				
		Consultant Private (D)	9.5	0.519	-0.67	0.509	-0.2	NS
31	Cultural factors.	Contractor Private (F)	7.63	0.806				
		Consultant Private (D)	7.57	0.938	0.167	0.869	0.1	NS
32	Legal factors.	Contractor Private (F)	7.88	0.957				
		Consultant Private (D)	8.5	0.519	-2.259	0.033	-1.2	S
33	Political factors.	Contractor Private (F)	9.31	0.602				
		Consultant Private (D)	9.43	0.646	-0.507	0.617	-0.2	NS
34	Construction site conditions.	Contractor Private (F)	8.94	0.772				
		Consultant Private (D)	8.86	0.77	0.285	0.778	0.1	NS
35	Availability of services.	Contractor Private (F)	6.25	0.931				
		Consultant Private (D)	7	0.784	-2.394	0.024	-1.0	S
36	Availability of resources.	Contractor Private (F)	8.75	0.683				
		Consultant Private (D)	8.57	0.756	0.675	0.506	0.2	NS

Table (3.10) shows that for the contractors-private group, the most important factor is the “economic conditions – factor no. 30” in the environment related factors with the highest mean value while the least important one is the “project manager qualifications – factor no. 13” in the contractor’s related factors with the least mean value.

Ranking of the whole criteria for the six groups in a descending order according to their mean values is shown in Table (3.11). For each group, those factors having scores above the average value will be considered important ones.

The intersection of the important factors among all groups which are the factors having mean values above the average value in each group and included in all groups as shown in Table (3.12) results in the most important factors among the whole groups (the numbers in italic illustrated in Table 3.12), these factors’ numbers are: 33, 30, 27, 4, 3, 28, 24, 34, 26, 9, 19, 1 and 10.

Table 3.11: Ranking of the whole criteria in descending order according to the mean value for the six groups

Student t-test											
Client Public (A)		Client Private (B)		Consultant Public (C)		Consultant Private (D)		Contractor Public (E)		Contractor Private (F)	
Criteria	Mean	Criteria	Mean	Criteria	Mean	Criteria	Mean	Criteria	Mean	Criteria	Mean
33	9.71	30	9.47	33	9.13	30	9.5	33	9.36	30	9.38
30	9.57	33	9.41	30	9	33	9.43	30	9.27	33	9.31
27	9.43	3	9.35	4	8.88	3	9.36	4	9.18	3	9.25
4	9.43	4	9.24	3	8.75	4	9.29	3	9.09	4	9.19
3	9.29	27	9.18	17	8.75	27	9.21	27	9	27	9.13
28	9.29	28	9.12	9	8.63	28	9.14	5	8.91	28	9.06
5	9.14	24	9.06	16	8.63	24	9.07	28	8.91	24	9
24	9.14	34	8.94	27	8.63	10	8.93	24	8.82	5	8.94
34	9	26	8.88	28	8.5	9	8.86	9	8.73	34	8.94
8	9	19	8.76	10	8.5	34	8.86	34	8.73	26	8.88
26	8.86	10	8.71	1	8.38	2	8.71	26	8.64	9	8.88
29	8.71	17	8.65	19	8.38	17	8.71	29	8.55	29	8.81
36	8.57	29	8.53	12	8.38	29	8.71	36	8.45	1	8.75
25	8.43	9	8.47	24	8.38	26	8.64	1	8.45	36	8.75
9	8.43	2	8.29	34	8.25	1	8.57	19	8.36	19	8.69
19	8.43	1	8.29	26	8.13	19	8.57	25	8.36	7	8.69
1	8.29	5	8.24	8	8	36	8.57	10	8.27	10	8.63
10	8.29	36	8.18	7	8	16	8.5	22	8.27	17	8.56
23	8.29	16	8.12	29	8	32	8.5	35	8.27	16	8.5
17	8.14	22	8.06	35	7.88	5	8.5	21	8.18	22	8.31
7	8.14	32	8	36	7.88	12	8.21	17	8.18	18	8.25
12	8	12	8	11	7.88	6	8	7	8.09	2	8.25
16	8	15	7.53	15	7.75	15	8	16	8.09	15	8.19
15	8	18	7.41	25	7.75	7	7.86	18	8.09	20	7.88
18	7.71	6	7.29	18	7.63	11	7.57	12	8	32	7.88
2	7.43	31	7.24	23	7.63	22	7.57	20	8	31	7.63
11	7.29	11	7.24	5	7.63	31	7.57	23	8	25	7.38
14	7.14	7	7.24	6	7.38	25	7.5	15	7.91	12	7.31
6	7	20	7.06	14	7.13	8	7.21	8	7.91	6	7.25
13	7	25	7.06	2	6.75	14	7.14	14	6.55	21	7.06
20	7	23	6.53	20	6.75	23	7.14	13	6.45	23	6.94
35	6.86	14	6.53	22	6.63	35	7	2	6.09	8	6.31
22	6.71	8	6.47	13	6.38	18	6.86	11	6	35	6.25
21	6	21	6.41	32	6.13	13	6.36	6	5.82	14	6.19
32	5.71	35	6.35	21	6	20	6.29	32	5.55	11	6.13
31	5.43	13	6.12	31	5.75	21	5.71	31	5.55	13	5.75

Table 3.12: Ranking of the most effective criteria according to the six groups in descending order

	Client Public (A)	Client Private (B)	Consultant Public (C)	Consultant Private (D) "Reference group"	Contractor Public (E)	Contractor Private (F)
Criteria	*33 (NS)*	*30 (NS)*	*33 (NS)*	*30*	*33 (NS)*	*30 (NS)*
	30 (NS)	*33 (NS)*	*30 (NS)*	*33*	*30 (NS)*	*33 (NS)*
	27 (NS)	*3 (NS)*	*4 (NS)*	*3*	*4 (NS)*	*3 (NS)*
	4 (NS)	*4 (NS)*	*3 (S)*	*4*	*3 (NS)*	*4 (NS)*
	3 (NS)	*27 (NS)*	17 (NS)	*27*	*27 (NS)*	*27 (NS)*
	28 (NS)	*28 (NS)*	*9 (NS)*	*28*	5 (NS)	*28 (NS)*
	5 (NS)	*24 (NS)*	16 (NS)	*24*	*28 (NS)*	*24 (NS)*
	24 (NS)	*34 (NS)*	*27 (S)*	*10*	*24 (NS)*	5 (NS)
	34 (NS)	*26 (NS)*	*28 (S)*	*9*	*9 (NS)*	*34 (NS)*
	1(HS)	*19 (NS)*	*10 (NS)*	*34*	*34 (NS)*	*26 (NS)*
	26 (NS)	*10 (NS)*	*1 (NS)*	2	*26 (NS)*	*9 (NS)*
	29 (NS)	17 (NS)	*19 (NS)*	17	29 (NS)	29 (NS)
	36 (NS)	29 (NS)	12 (NS)	29	36 (NS)	*1 (NS)*
	25 (S)	*9 (NS)*	*24 (S)*	*26*	*1 (NS)*	36 (NS)
	9 (NS)	2 (NS)	*34 (NS)*	*1*	*19 (NS)*	*19 (NS)*
	19 (NS)	*1 (NS)*	*26 (NS)*	*19*	25 (HS)	7 (HS)
	1 (NS)	5 (NS)	1 (S)	36	*10 (S)*	*10 (NS)*
	10 (S)	36 (NS)	7 (NS)	16	22 (HS)	17 (NS)

As shown in Table (3.12), almost all the selected important factors concluded from the intersection of all groups are indicated with non significant notation (NS) which means that the results of comparing those factors with the reference group (D) shows a non significant difference, (i.e.: there is no statistically significant difference between the group in question and the reference group). If the result is significant or highly significant, then the two groups are far away from each other.

This means that the selection of group (D) as reference group was correct.

Figure (3.2) presents the results of Pearson correlation test, this is a test for searching the possible association between different groups, the highest value of r (correlation coefficient) means the stronger association between scores of the 2 groups.

		A	B	C	**D**	E
B	r	0.534				
	p	0				
	Sig.	HS				
C	r	0.644	0.48			
	p	0	0			
	Sig.	HS	HS			
D	**r**	**0.502**	**0.72**	**0.494**		
	p	**0**	**0**	**0**		
	Sig.	**HS**	**HS**	**HS**		
E	r	0.64	0.433	0.495	**0.306**	
	p	0	0	0	**0**	
	Sig.	HS	HS	HS	**HS**	
F	r	0.444	0.659	0.377	**0.582**	0.456
	p	0	0	0	**0**	0
	Sig.	HS	HS	HS	**HS**	HS

Figure 3.2: Pearson correlation test according to the six groups

The highest r with the reference group D (the private consultants results) is 0.72 with group B (the private Clients results) coming in line with expected convergence of clients / consultants opinion, and then followed by F (the private contractors results), A (the public Clients results), C (the public consultants results) and finally E (the public contractors results).

The strongest correlation (best association between the two sets of scores) is between D and B while the lowest correlation (bad association between the two sets of scores) is between D and E.

3.4.2.2 Criteria weight method

Calculated weighted score is the scoring system for each factor among each group independent for all co-variables. The weight of each criterion will be calculated as follows :

$$\text{Criterion weight} = \frac{\text{Sum of (score of each criterion * no. of respondents of similar score)}}{\text{Total no. of respondents for each category}} \quad \text{....(3.2)}$$

All studied factors for each group will be ranked according to their weighted scores.

Having six groups (client public and private, consultant public and private and contractor public and private) each set contains 36 criterion weights (for instance, Table 3.13 illustrates the calculated weight score for group (A) which refers to the Clients-public group), the calculated weight score for the other groups are attached in Appendix-D.

Table 3.13: Criteria weight scores for clients-public group (group A)

Group Group (A)	Factors	Description	Scores						Weighted Score
			5	6	7	8	9	10	
Clients – public	1	Project's cost	0	0	0	1	5	1	24.2
	2	Client's experience, its representatives' capacity and qualifications.	0	2	1	3	1	0	20.6
	3	Type of client.	0	0	0	0	5	2	25.8
	4	Client's financial power and funds availability.	0	0	0	0	4	3	26.2
	5	Client's priorities in construction and amongst the project's objectives.	0	0	0	1	4	2	25.4
	6	Required level of quality.	0	2	3	2	0	0	19.4
	7	Client's historical dispute records.	0	0	1	4	2	0	22.6
	8	Speed of decision making.	0	0	1	3	3	0	23.0
	9	Client's tendency for changes.	0	0	0	4	3	0	23.4
	10	Contractor's grade.	0	0	0	5	2	0	23.0
	11	Financial capabilities.	0	1	3	3	0	0	20.2
	12	Managerial capabilities.	0	0	2	3	2	0	22.2
	13	Project manager qualifications.	0	2	3	2	0	0	19.4
	14	Staff and labors qualifications.	0	1	4	2	0	0	19.8
	15	Plants and equipments.	0	0	1	5	1	0	22.2
	16	Technical capabilities and Method of construction.	0	0	2	3	2	0	22.2
	17	Contractor's past experience in similar projects.	0	0	2	2	3	0	22.6
	18	Consultant technical capacity.	0	0	3	3	1	0	21.4
	19	Completeness and clarity of documents.	0	0	0	4	3	0	23.4
	20	Consultant's past experience in similar projects.	0	2	3	2	0	0	19.4
	21	Consultant's past history in conflicts with contractors.	2	3	2	0	0	0	16.7
	22	Speediness of replies to contractor's queries and approvals.	0	3	3	1	0	0	18.7
	23	Construction type (residential or administrative).	0	0	0	5	2	0	23.0
	24	Complexity of the project.	0	0	0	1	4	2	25.4
	25	Project's foot print.	0	0	1	2	4	0	23.4
	26	Project's total built up area.	0	0	0	3	4	0	24.6
	27	Number of stories.	0	0	0	1	2	4	26.2
	28	Number of basements.	0	0	0	0	5	2	25.8
	29	Floor height.	0	0	0	3	3	1	25
	30	Economical conditions.	0	0	0	0	3	4	26.6
	31	Cultural factors.	4	3	0	0	0	0	15.1
	32	Legal factors.	3	3	1	0	0	0	15.9
	33	Political factors.	0	0	0	0	2	5	27.0
	34	Construction site conditions.	0	0	0	2	3	2	25.0
	35	Availability of services.	0	2	4	1	0	0	19.0
	36	Availability of resources.	0	0	0	2	4	1	23.8
	Tot		9	24	40	73	77	29	

Table 3.14: Ranking of the whole criteria according to Criteria weight method

Calculated weighted score						
Criteria	Client Public (A)	Client Private (B)	Consultant Public (C)	Consultant Private (D)	Contractor Public (E)	Contractor Private (F)
1	24.2	23.7	22.2	24.2	23.7	24.5
2	20.6	23.0	18.8	24.2	16.9	22.9
3	25.8	26.0	24.3	26.0	25.3	25.7
4	26.2	25.7	24.7	25.8	25.5	25.5
5	25.4	22.9	21.2	23.6	24.7	24.8
6	19.4	20.3	20.5	22.2	16.2	20.1
7	22.6	20.1	22.2	21.8	22.5	24.1
8	23.0	23.0	23.3	23.8	23.5	24.3
9	23.4	23.5	24.0	24.6	24.2	24.7
10	23.0	24.2	23.6	24.8	23.0	24.0
11	20.2	20.1	21.9	21.0	16.7	17.0
12	22.2	22.2	23.3	22.8	22.2	20.3
13	19.4	17.0	17.7	17.7	17.9	16.0
14	19.8	18.1	19.8	19.8	18.2	17.2
15	22.2	20.9	21.5	22.2	22.0	22.7
16	22.2	22.5	24.0	23.6	22.5	23.6
17	22.6	24.0	24.3	24.2	22.7	23.8
18	21.4	20.6	21.2	19.0	22.5	22.9
19	23.4	24.3	23.3	23.8	23.2	24.1
20	19.4	19.6	18.8	17.5	22.2	21.9
21	16.7	17.8	16.7	15.9	22.7	19.6
22	18.7	22.4	18.4	21.0	23.0	23.1
23	23.0	18.1	21.2	19.8	22.2	19.3
24	25.4	25.2	23.3	25.2	24.5	25.0
25	23.4	19.6	21.5	20.8	23.2	20.5
26	24.6	24.7	22.6	24	24	24.7
27	26.2	25.5	24.0	25.6	25.0	25.3
28	25.8	25.3	23.6	25.4	24.7	25.2
29	25	18	22.2	20	22	17.5
30	26.6	26.3	25.0	26.4	25.8	26.0
31	15.1	20.1	16.0	21.0	15.4	21.2
32	15.9	22.2	17.0	23.6	15.4	21.9
33	27.0	26.1	25.3	26.2	26.0	25.9
34	25.0	24.8	22.9	24.6	24.2	24.8
35	19.0	17.6	21.9	19.4	23.0	17.4
36	23.8	22.7	21.9	23.8	23.5	24.3

In order to define the most effective criteria (criteria with the highest weight), each group is rearranged in descending order as shown in Table (3.14) for the client, consultant, and contractor respectively. For each group, the factors with scores above the average number will be considered important ones.

The intersection of the important factors among the six groups which are the factors having mean values above the average value in each group and included in all groups will result in determining the items that exist in the six groups which will be the most effective criteria on estimating the construction project duration (the numbers in red and underline illustrated in Table 3.15). The result from intersection process is thirteen factors shown in Table (3.15) which are: 33, 30, 4, 27, 3, 28, 24, 34, 26, 1, 36, 9 and 19.

Table 3.15: Ranking of the most effective criteria in descending order according to Criteria weight method

Calculated weighted score											
Criteria	Client Public (A)	Criteria	Client Private (B)	Criteria	Consultant Public (C)	Criteria	Consultant Private (D)	Criteria	Contractor Public (E)	Criteria	Contractor Private (F)
33	27	30	26.3	33	25.3	30	26.4	33	26	30	26
30	26.6	33	26.1	30	25	33	26.2	30	25.8	33	25.9
4	26.2	3	26	4	24.7	3	26	4	25.5	3	25.7
27	26.2	4	25.7	3	24.3	4	25.8	3	25.3	4	25.5
3	25.8	27	25.5	17	24.3	27	25.6	27	25	27	25.3
28	25.8	28	25.3	9	24	28	25.4	5	24.7	28	25.2
5	25.4	24	25.2	16	24	24	25.2	28	24.7	24	25
24	25.4	34	24.8	27	24	10	24.8	24	24.5	5	24.8
29	25	26	24.7	10	23.6	9	24.6	9	24.2	34	24.8
34	25	19	24.3	28	23.6	34	24.6	34	24.2	9	24.7
26	24.6	10	24.2	8	23.3	2	24.2	26	24	26	24.7
1	24.2	17	24	12	23.3	17	24.2	1	23.7	1	24.5
36	23.8	1	23.7	19	23.3	1	24.2	8	23.5	8	24.3
9	23.4	9	23.5	24	23.3	26	24	36	23.5	36	24.3
19	23.4	2	23	34	22.9	8	23.8	19	23.2	7	24.1
25	23.4	8	23	26	22.6	19	23.8	25	23.2	19	24.1
8	23	5	22.9	29	22.2	36	23.8	10	23	10	24
10	23	36	22.7	7	22.2	5	23.6	22	23	17	23.8
23	23	16	22.5	1	22.2	16	23.6	35	23	16	23.6
7	22.6	22	22.4	11	21.9	32	23.6	17	22.7	22	23.1
17	22.6	12	22.2	36	21.9	12	22.8	21	22.7	2	22.9
12	22.2	32	22.2	35	21.9	6	22.2	7	22.5	18	22.9
15	22.2	15	20.9	15	21.5	15	22.2	16	22.5	15	22.7
16	22.2	18	20.6	25	21.5	7	21.8	18	22.5	20	21.9
18	21.4	6	20.3	5	21.2	11	21	12	22.2	32	21.9
2	20.6	7	20.1	18	21.2	22	21	20	22.2	31	21.2
11	20.2	11	20.1	23	21.2	31	21	23	22.2	25	20.5
14	19.8	31	20.1	6	20.5	25	20.8	29	22	12	20.3
6	19.4	20	19.6	14	19.8	29	20	15	22	6	20.1
13	19.4	25	19.6	2	18.8	14	19.8	14	18.2	21	19.6
20	19.4	14	18.1	20	18.8	23	19.8	13	17.9	23	19.3
35	19	23	18.1	22	18.4	35	19.4	2	16.9	29	17.5
22	18.7	29	18	13	17.7	18	19	11	16.7	35	17.4
21	16.7	21	17.8	32	17	13	17.7	6	16.2	14	17.2
32	15.9	35	17.6	21	16.7	20	17.5	31	15.4	11	17
31	15.1	13	17	31	16	21	15.9	32	15.4	13	16
Average	**22.43**	Average	**22.17**	Average	**21.78**	Average	**22.65**	Average	**22.23**	Average	**22.55**

3.5 CRITERIA FINAL SELECTION

Comparing the results from the two methods, referring to Tables (3.12) and (3.15), the twelve criteria intersected between the two tables are: (33, 30, 4, 3, 27, 28, 24, 34, 26, 1, 9 and 19), thus, these twelve criteria are considered as the most important criteria in the prediction of commercial project duration.

The twelve criteria may be grouped back to their seven main criteria, this means that when predicting the commercial project duration during the tender stage, we will consider the following :

Project's cost:

1. Project cost.

Client related factors:

3. Type of client.
4. Client's financial soundness.

9. Client's tendency for changes.

Consultant related factors:

19. Completeness and clarity of tender documents.

Project related factors:

24. Complexity of the project.

26. Project total built up area.

27. Number of stories.

28. Number of basements.

Environmental related factors:

30. Economical conditions.

33. Political conditions.

Construction site related factors:

34. Construction site conditions.

3.6 SUMMARY AND COCLUSION

The parties involved in construction process, namely: client, consultant, and contractor together selected the most important criteria in predicting commercial project duration in Egypt through questionnaire survey. After using statistical and weighting process, twelve criteria were selected and will be (under their six main groups) the input of the fuzzy model. These criteria are: project's cost, type of client, client's financial soundness, client's tendency for changes, completeness and clarity of tender documents, complexity of the project, project total built up area, number of stories, number of basements, economical conditions, political conditions and construction site conditions.

CHAPTER 4

PREDICTING PROJECT DURATION OF COMMERCIAL BUILDINGS USING FUZZY LOGIC

4.1 INTRODUCTION

Fuzzy logic technique is widely used in construction engineering and management. It contributes in solving different problems especially in decision making process to evaluate or choose between alternatives. This chapter presents the development of a fuzzy logic model to assist decision makers during the tendering stage to predict commercial project duration in building projects. Such procedure starts from determining the main features of the developed fuzzy logic inference engine, then deciding input and output variables and their membership functions, ending with the development of the fuzzy logic if-then rules. The developed model is implemented using MATLAB software.

4.2 FUZZY LOGIC SYSTEM

The reliable prediction of commercial project duration during the tendering stage is a problem due to the fuzziness of factors affecting the project duration. The decision maker may not be able to quantify a realistic project duration. However, the decision maker may be able to specify the prediction criteria in the form of linguistic expressions such as “very long”, “ long”, “medium”, “short” or “very short”. It is difficult, therefore, to accurately quantify commercial project duration.

To address this problem, a fuzzy quantifier model is developed. These developments use the concept of fuzzy set theory originated by Zadeh (1975). As mentioned in the literature, fuzzy decision making has been applied successfully in many construction management applications. The main benefit of fuzzy sets over conventional sets is that fuzzy sets provide a representation of the degree by which elements belong to a set. In predicting commercial project duration during the tendering stage, the prediction of the project’s duration is represented by a fuzzy linguistic variable.

4.2.1 Fuzzy Output Variable

The input variables are presented in both conventional sets also called crisp sets and fuzzy sets while the output linguistic variable can be represented by five fuzzy sets: “very long”, “ long”, “medium”, “short” and “very short” as shown in Fig. (4.1).

These five fuzzy sets and the range of each fuzzy set were concluded from the industry experts during the semi structured interviews and reassured from the questionnaire results. The five fuzzy sets cover the space of construction project duration estimation ranging from “very short” for “very short duration” to “very long” for “very long duration”. Furthermore, triangular and trapezoidal membership functions are the most widely used as per the literature.

For the commercial type of building projects, project durations are characterized by their high values due to the increased MEP contribution in the project and the existence of long lead items. As shown in Figure (4.1), the ranges concluded from the industry experts specialized in the commercial projects and questionnaire results to represent the commercial project duration are as follow: very short duration: for project duration less than 500 days with triangular membership function; short duration: for project duration from 250 to 750 days with triangular membership function; medium duration: for project duration from 500 to 1000 days with triangular membership function; long duration: for project duration from 750 to 1250 days with triangular membership function; and vey long duration: for project duration greater than 1000 days with triangular membership function.

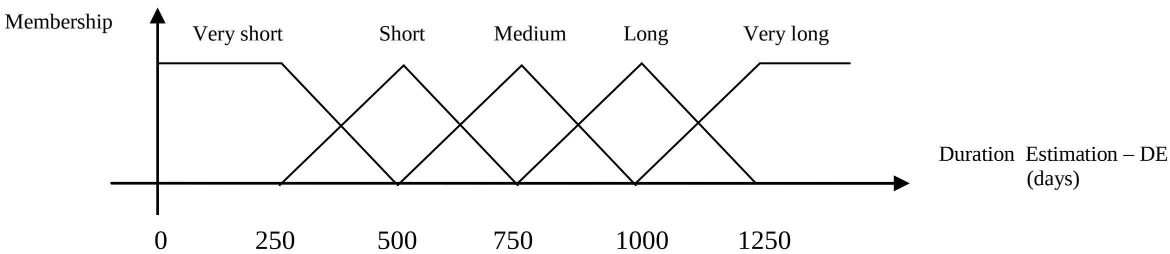


Fig. 4.1: Membership Functions of Output Variable “Duration”

4.2.2 Fuzzy Input Variables

Input variables of the fuzzy logic model were derived to represent the main criteria affecting commercial project duration in building construction in Egypt as mentioned in chapter 3 which are:

1. Project's cost.
2. Type of client.
3. Client's financial soundness.
4. Client's tendency for changes.
5. Completeness and clarity of tender documents.
6. Complexity of the project.
7. Project's built up area.
8. Number of stories.
9. Number of basements.
10. Economical conditions.
11. Political conditions.
12. Construction site conditions.

Project's cost: This criterion stands for the project's total cost which is the cost the owner will reimburse the contractor for the activities to be performed.

Type of client: This criterion stands for the client's type in terms of public, private sector, or public private partnership (PPP).

Client's financial soundness: This criterion stands for the financial stability and financial power of the client at the time of the project. It could be measured through providing evidences of cash retained for the project, credit rating, bank references, past financial disputes, pending or threatened litigations affect the client's financial position, turnover history, financial statements in terms of: liquidity (stands for how liquid is the firm, it refers to the firm's ability to meet maturing obligations and to convert assets into cash), ratio analysis, etc.

Client's tendency for changes: This criterion stands for the client's tendency for changes. It could be measured by assessing the percentage of the client's previous projects extended due to his direct change orders in accordance with the total number of previous projects.

Completeness and clarity of tender documents: This criterion stands for the completeness and clarity of contract documents. It could be measured through historical records of the consultant's previous projects extended due to the incompleteness, in clarity, or ambiguity of the contract documents issued by the consultant in accordance with the total number of previous projects.

Complexity of the project: This criterion stands for the project's untraditional shape and/or design result in untraditional method of construction and materials use. It could be measured through assessing the contract documents in terms of: irregular architectural plans, elevations, constructability of structural system, types of materials used and their availability, untraditional specifications, etc.

Project built up area: This criterion stands for the summation of the gross floor area of all floors.

Number of stories: This criterion stands for how many stories the project has (above ground level).

Number of basements: This criterion stands for the number of basements floors.

Economical conditions: This criterion stands for the status of the country's economical position at a specific period of time. It could be measured through the use of stock exchange data, governmental publications, statistics including the unemployment rates, GDP information, among other metrics.

Political conditions: This criterion stands for the country's political power and stability (internal and external). It could be measured by solid relations with neighbor and foreign countries, the existence of powerful political structure resulted from virtuous elections, solid social structure through uniform distribution of country's wealth, absence of corruption, patronage, injustice, unfairness and subdual aspects

Construction site conditions: This criterion stands for the suitability of site for the project. It could be measured by the soil type through the preliminary soil investigation report, the underground water table, access routes, sufficiency of mobilization area, applicable laws, regulations and permits.

These criteria represent the inputs for the proposed commercial project duration estimating model. The decision makers will evaluate project duration by these criteria giving them either linguistic or numeric values. For the linguistic case, after the selection of the appropriate choice (low, medium and high) as shown in Fig. 4.2, the selected one will turn into a numeric value equal to the midpoint of the range. For the numeric value it will be entered as absolute value. The score of the first criterion, namely project cost, will be entered as a numeric value, the three criteria, namely, client's type, client's financial soundness, and client's tendency for changes will be averaged to be one number representing the client's characteristics. The score of the fifth criterion, namely the consultant's historical records will be representing the tender documents' completeness and clarity. The scores of the sixth, seventh, eighth and ninth criteria, namely project's complexity, total built up area, number of stories and number of basements, will be averaged to be one number representing the project's characteristics. The score of the tenth and eleventh criteria, namely economical and political conditions, will be averaged to be one number representing the environmental conditions. The score of the twelfth criterion, namely the site conditions, will be representing the construction site suitability.

In order to simplify the proposed fuzzy logic model, these twelve criteria are grouped into six main criteria as follow:

1- Project's cost (PC): including the total project cost.
2- Client's characteristics (CC): including: the client's type, financial soundness, and tendency for changes.
3- Tender documents completeness and clarity (TC): including: past historical records for the consultant's quality of documents.
4- Project's characteristics (PC): including: project's complexity, total built up area, number of stories and number of basements.
5- Environmental conditions (EC): including: economical and political conditions.
6- Construction site suitability (CS): including: construction site conditions.

Table (4.1) shows the main criteria, criteria and the way of measurement and their associated scores.

	0 → 10		
	Low	Medium	High
1. Project's cost			
1.1 Project's cost in million Egyptian pounds	>20	10:30	0:20
2. Client's Characteristics			
2.1 Client's Type	Public	Public/Private	Private
2.2 Financial Soundness	Poor	Good	V.Good
2.3 Tendency for Changes	75 – 100 %	25 – 75 %	0 – 25 %
3. Tender documents' Completeness and clarity			
3.1 Consultant's Historical records	75 – 100 %	25 – 75 %	0 – 25 %
4. Project's Characteristics			
4.1 Project's Complexity	75 – 100 %	25 – 75 %	0 – 25 %
4.2 Total built up area (m^2)	(> 75k)	(5-75k)	(< 5k)
4.3 Number of Stories	(> 10)	(5-10)	(< 5)
4.4 Number of Basements	(> 3)	(1-3)	(0)
5. Environmental Conditions			
5.1 Economical conditions	0 – 25 %	25 – 75 %	75 – 100 %
5.2 Political conditions	0 – 25 %	25 – 75 %	75 – 100 %
6. Construction site Suitability			
6.1 Site conditions	0 – 25 %	25 – 75 %	75 – 100 %

Fig. 4.2: Input variables values' and their associate scale

Table 4.1: Criteria measure and scores

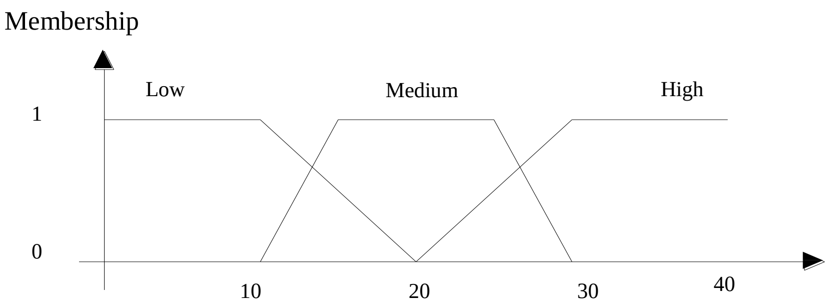
Main Criteria	Criteria	How to Measure	Choices	Score
Project's cost	Project's cost	Total project cost (estimated cost in million L.E.)	(> 20) – (10-30) – (< 20)	0-10
Client's Characteristics	Client's Type	Identifying the Type of the Client.	Public – Public/Private Partnership - Private	0 - 10
	Financial Soundness	Bank References, Credit References, Past financial failures, Pending or threatened litigations affect the client's financial position, Liquidity (% of Retained Cash for Project to Total Project Value).	Poor – Good – Very Good	0 - 10
	Tendency for Changes	% of Client's previous projects extended due to the his variations	(75-100) - (25-75) - (0-25)%	0 - 10
Tender documents completeness and clarity.	Consultant's historical records	% of Consultant's previous projects extended due to the ambiguity, incompleteness, and contradiction of contract documents.	(75-100) - (25-75) - (0-25)%	0 - 10
Project's Characteristics	Project's Complexity	Design's complexity, structure's constructability, Method of construction, utilization of irregular materials.	(75-100) - (25-75) - (0-25)%	0 – 10
	Project's BUA	Identifying the total project area in m2.	(> 75K) – (5-75K) – (< 5K)	0 – 10
	Number of stories	Identifying the number of stories (excluding the basements).	(> 10) – (5-10) – (< 5)	0 – 10
	Number of basements	Identifying the number of basements.	(> 3) – (1-3) – (0)	0 - 10
Environmental conditions	Economical conditions	% of economic growth, inflation rate, unemployment, increase in foreign currencies, decrease in expenditures balance, increase in governmental expenditures in construction projects.	(0-25) – (25-75) – (75-100)%	0 – 10
	Political conditions	Political internal and external stability, absence of any aspect of troubles like: wars, rebellion, terrorism, sabotage, revolutions, riot, commotions, disorders, etc.	(0-25) – (25-75) – (75-100)%	0 – 10
Construction site suitability	Site conditions	Site location, ease of transportation, Access roads, soil type, underground water level, Sufficiency of mobilization area, applicable laws and regulations, etc.	(0-25) – (25-75) – (75-100)%	0 – 10

Figures (4.3) through (4.10) represent the membership functions of the six inputs. Each of them has three fuzzy sets: low, medium, and high. Their universe of discourse will be from 0 to 10.

1. ***<u>Project's cost (CO):</u>***

As shown in Figure (4.3), the following points were concluded from the industry experts during the semi structured interviews and from the questionnaire results:

- The projects' contract amount ranging from 0 to 20 million Egyptian pounds will be considered with low cost.
- The projects' contract amount ranging from 10 to 30 million Egyptian pounds will be considered with medium cost.
- The projects' contract amount ranging from 20 to 40 million Egyptian pounds and above will be considered with high cost.



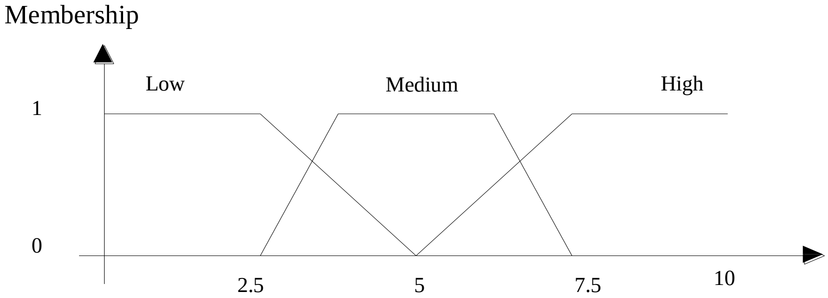
Project's cost in million Egyptian pounds - CO

Fig. 4.3 Input variable "Project's cost - CO"

2. ***<u>Client's characteristics (CC):</u>***

As shown in Figure (4.4), the following points were concluded from the industry experts during the semi structured interviews and from the questionnaire results:

- The scores ranging from 0 to 5 will be considered with low significance.
- The scores ranging from 2.5 to 7.5 will be considered with medium significance.
- The scores ranging from 5 to 10 will be considered with high significance.



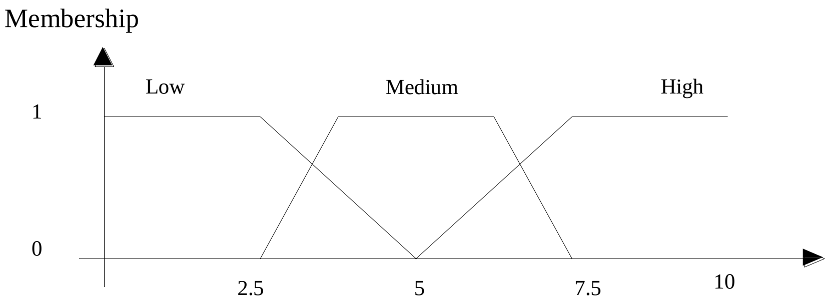
Client's characteristics - CC

Fig. 4.4 Input variable "Client's characteristics - CC"

3. ***Tender documents completeness and clarity (TC):***

As shown in Figure (4.5), the following points were concluded:

- The scores ranging from 0 to 5 will be considered with low significance.
- The scores ranging from 2.5 to 7.5 will be considered with medium significance.
- The scores ranging from 5 to 10 will be considered with high significance.



Tender documents' completeness and clarity - TC

Fig. 4.5 Input variable "Tender documents' completeness and clarity - TC"

4. ***Project's Characteristics (PC):***

As shown in Figure (4.6), the following points were concluded:

- The scores ranging from 0 to 5 will be considered with low significance.
- The scores ranging from 2.5 to 7.5 will be considered with medium significance.
- The scores ranging from 5 to 10 will be considered with high significance.

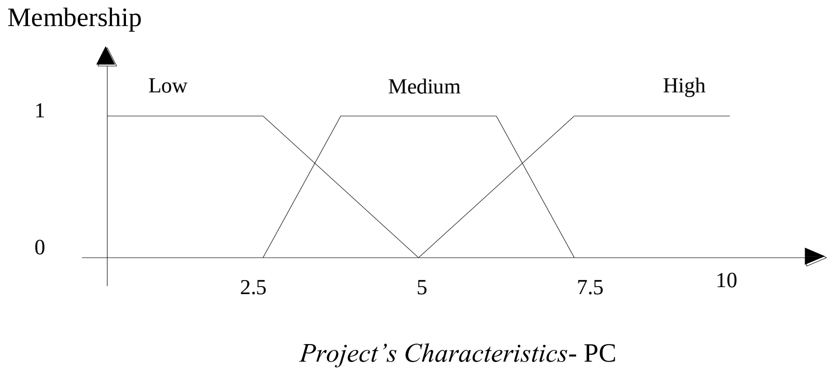


Fig. 4.6 Input variable "Project's characteristics - PC"

5. ***Environmental conditions (EC):***

As shown in Figure (4.7), the following points were concluded:

- The scores ranging from 0 to 5 will be considered with low significance.
- The scores ranging from 2.5 to 7.5 will be considered with medium significance.
- The scores ranging from 5 to 10 will be considered with high significance.

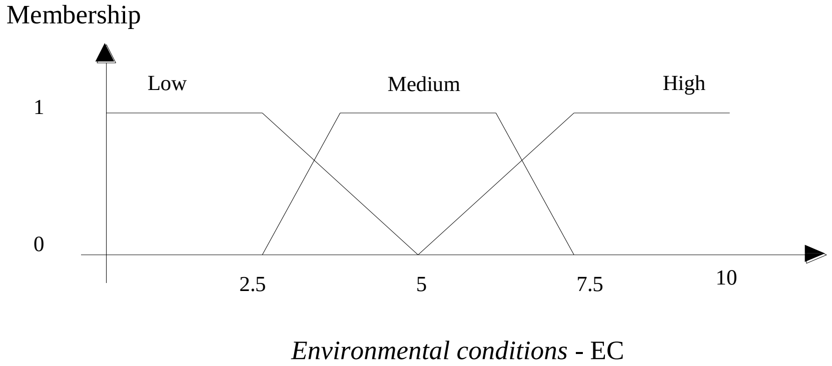


Fig. 4.7 Input variable "Environmental conditions - EC"

6. ***Construction site suitability (CS):***

As shown in Figure (4.8), the following points were concluded:

- The scores ranging from 0 to 5 will be considered with low significance.
- The scores ranging from 2.5 to 7.5 will be considered with medium significance.
- The scores ranging from 5 to 10 will be considered with high significance.

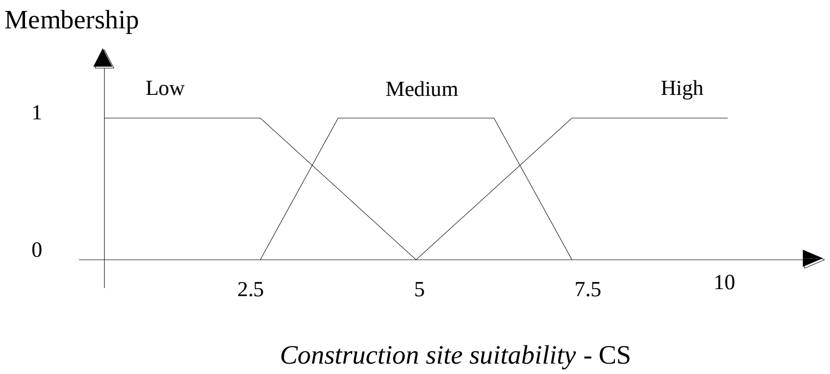


Fig. 4.8 Input variable "Construction site suitability - CS"

4.2.3 Fuzzy Decision Rules

So far, "commercial project duration prediction" desired to be determined is governed by six fuzzy variables: project's cost, client's characteristics, tender documents completeness and clarity, project's characteristics, environmental conditions and construction site suitability. Fuzzy rules define the value or levels of a decision-maker facing uncertain results. In general, the number of rules used in controlling a system using fuzzy control is given Eq. 4.1:

$R = (m)^v$ ……………………………………………………..……………….(4.1)

where R= number of rules

m = number of membership functions

v = number of input variables

For the current study: m = 3 and v = 6 then: $R = (3)^6 = 729$ rules.

It means that there are 729 different combinations of preconditions that affect the prediction of commercial project duration. These preconditions have to be stored in the form of if-then rules (called fuzzy rules) along with the decision maker's preference in their associated project's duration estimation.

To form these rules, the three inputs score (low, medium and high) will have values of 1, 2, and 3 respectively. Gathering the values of each rule will result in values ranging from 6 to 18 as shown in Table 4.2. The semi structured interviews conducted with the industry experts and the questionnaire results concluded the output linguistic variable corresponding to each range as follow:

- Very long project duration for the range of 6:7,
- Long project duration for the range of 8:10,
- Medium project duration for the range of 11:13,
- Short project duration for the range of 14:16 and
- Very Short project duration for the range of 17:18.

Examples of formation of rules are presented in Table (4.2).

As shown in Table (4.2), rule number 1 concluded from the semi structured interviews with the industry experts and the questionnaire results states that: If the project's cost is high, the client's characteristics is low, the contract documents' completeness and clarity is low, the project's characteristics is low, the environmental conditions is low, the construction site suitability is low, then, the project duration is very long.

While rule number 729 in Table (4.2) states that: If the project's cost is low, the client's characteristics is high, the contract documents' completeness and clarity is high, the project's characteristics is high, the environmental conditions is high, the construction site suitability is high, then, the project duration is very short.

Table 4.2: Fuzzy Rules formation

Rule	CO	CC	TC	PC	EC	CS	Project Duration
1	1	1	1	1	1	1	6
2	1	1	1	1	1	2	7
3	1	1	1	1	1	3	8
4	1	1	1	1	2	1	7
5	1	1	1	1	2	2	8
6	1	1	1	1	2	3	9
7	1	1	1	1	3	1	8
8	1	1	1	1	3	2	9
9	1	1	1	1	3	3	10
10	1	1	1	2	1	1	7
11	1	1	1	2	1	2	8
12	1	1	1	2	1	3	9
13	1	1	1	2	2	1	8
14	1	1	1	2	2	2	9
15	1	1	1	2	2	3	10
16	1	1	1	2	3	1	9
17	1	1	1	2	3	2	10
18	1	1	1	2	3	3	11
19	1	1	1	3	1	1	8
20	1	1	1	3	1	2	9
21	1	1	1	3	1	3	10
22	1	1	1	3	2	1	9
23	1	1	1	3	2	2	10
24	1	1	1	3	2	3	11
25	1	1	1	3	3	1	10
26	1	1	1	3	3	2	11

Table 4.2 Cont., Fuzzy Rules Formation

Rule	CO	CC	TC	PC	EC	CS	Project Duration
703	3	3	3	1	1	1	12
704	3	3	3	1	1	2	13
705	3	3	3	1	1	3	14
706	3	3	3	1	2	1	13
707	3	3	3	1	2	2	14
708	3	3	3	1	2	3	15
709	3	3	3	1	3	1	14
710	3	3	3	1	3	2	15
711	3	3	3	1	3	3	16
712	3	3	3	2	1	1	13
713	3	3	3	2	1	2	14
714	3	3	3	2	1	3	15
715	3	3	3	2	2	1	14
716	3	3	3	2	2	2	15
717	3	3	3	2	2	3	16
718	3	3	3	2	3	1	15
719	3	3	3	2	3	2	16
720	3	3	3	2	3	3	17
721	3	3	3	3	1	1	14
722	3	3	3	3	1	2	15
723	3	3	3	3	1	3	16
724	3	3	3	3	2	1	15
725	3	3	3	3	2	2	16
726	3	3	3	3	2	3	17
727	3	3	3	3	3	1	16
728	3	3	3	3	3	2	17
729	3	3	3	3	3	3	18

4-2-4 Firing Strength of Fuzzy Decision Rules

In the inference sub-process, the firing strength of each fuzzy rule is calculated. This is based on the degree to which the input elements meet the preconditions of a rule, which is measured by the fetched membership values from the fuzzy set concerned. The firing strength of a rule determines how much its consequence can be applied to the output value. The output membership function of a rule is clipped off at a height corresponding to the firing strength of that rule.

$F_i = \min (M_1 * M_2 * M_3 * M_4 * M_5 * M_6)$ ………………..………………………...(4.2)

Where:

F_i = strength of rule number *i*

M_1, M_2, M_3, M_4, M_5 and M_6 represent the memberships of the input variables: project's cost, client's characteristics, tender documents completeness and clarity, project's characteristics, environmental conditions and construction site suitability in the precondition fuzzy sets of rule *i*. Variable F_i represents the firing strength of rule *i*; $0 \leq F_i \leq 1$.

4.3 A FUZZY LOGIC MODEL FOR PREDICTING PROJECT DURATION

There are a variety of software tools that significantly expedite the design of Fuzzy Logic System (FLS). Most of software tools provide extensive debugging and optimization features that make designing a fuzzy logic system an interesting job. The commercial software, MATLAB R 2010b, Version 7.11 Fuzzy Logic Tool Box has been used to process the fuzzy logic inference system.

The software allows users to enter data using two methods; either editing a code using MATLAB file editor, or using the fuzzy logic graphical user interface (GUI) to build the model directly from the screen. Users also have the ability to use both methods to facilitate their work.

The basic steps to build a fuzzy logic model can be summarized as follow:

1. Assign the problem.

2. Determine the number of input and output variables according to problem criteria.

3. Determine number of fuzzy decision rules from equation (4.1).

4. Assign the linguistic variables.

5. Assign number and shape of the membership functions.

6. Build the input and output variables using the methods of file editor and GUI.

7. Assign the defuzzification method,in this study we used the Center of Area method (COA).

8. Write the fuzzy decision rules.

9. Calculate the firing strength of each rule using equation (4.2).

10. Enter input numerical values for the problem in the input dialogue box.

11. Now the inference engine will run and defuzzification will be done.

12. The final problem solution is now done, and the deffuzified crisp output will be printed out on each output.

4.4 PROPOSED FORM FOR PREDICTING COMMERCIAL PROJECT DURATION

In order to enable the practitioner to predict commercial project duration, a commercial project duration prediction form was designed so that it will be distributed within the tender documents, filled by all concerned parties “client, consultant, and contractor and then the consultant (or the project manager) will assess the collected forms to determine the realistic project duration.

4.5 GRAPHICAL USER INTERFACE (GUI)

To facilitate the use of the system, a Graphical User Interface (GUI) was developed to help decision makers during the tendering stage while using the framework.

The GUI screen is of simple form. The decision maker will utilize the data concluded from the “commercial project duration prediction forms” distributed amongst the tender documents (Appendix E).

After the user finish filling the project's duration prediction input variables, he will click "Evaluate" button to determine the expected project duration in days within acceptable limits.

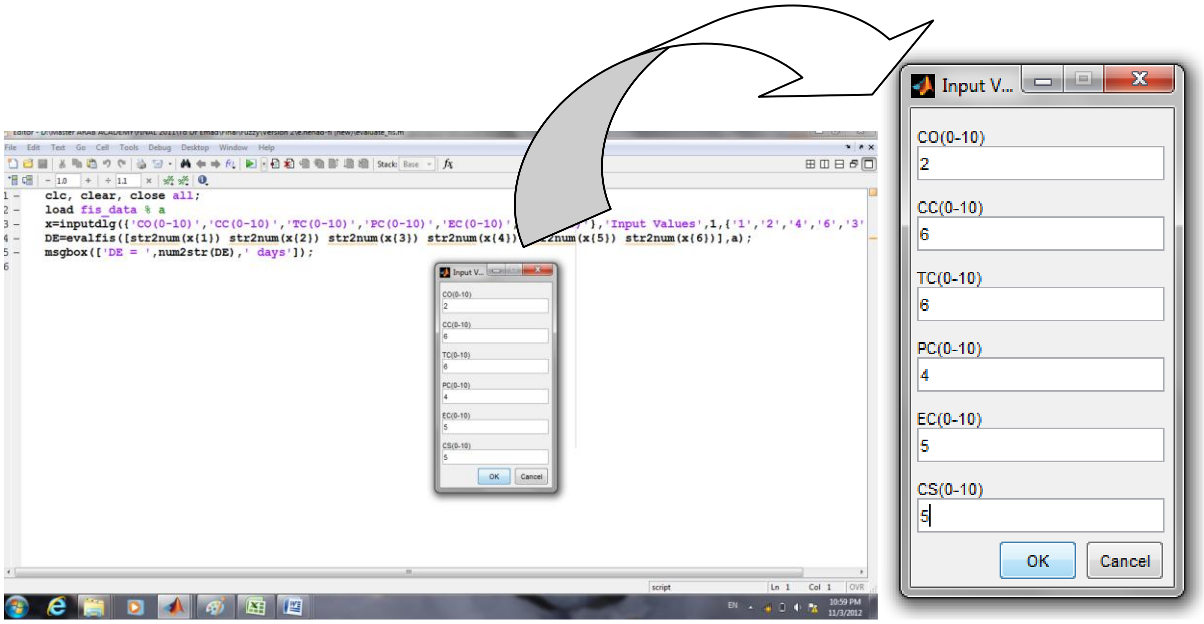


Fig. 4.9 Graphical user interface – input variables

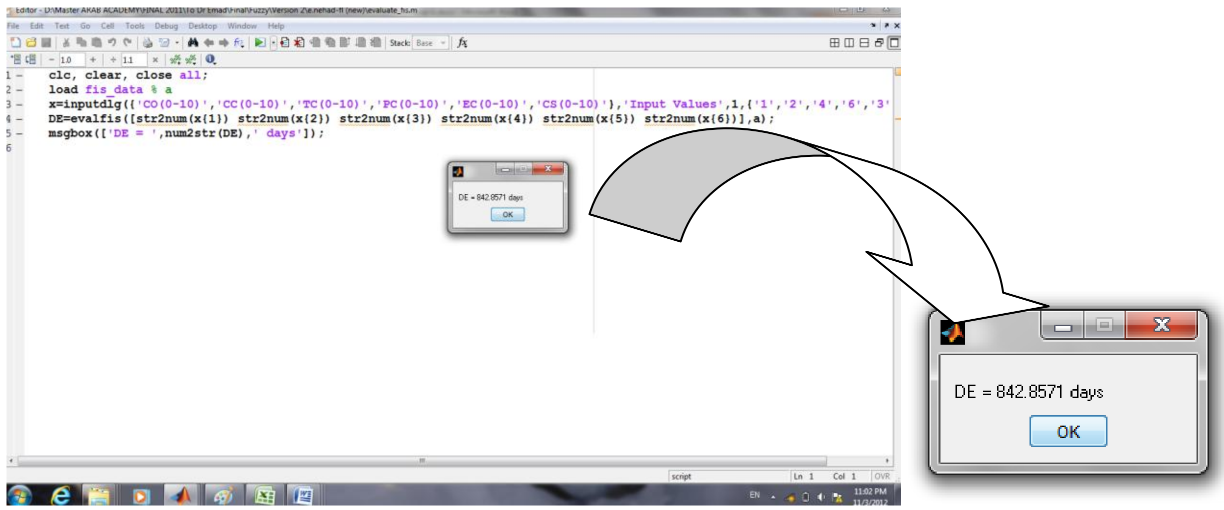


Fig. 4.10 Graphical user interface – output variable

4.6 MODEL VALIDATION

In order to test the validity of the proposed fuzzy logic model, two illustrative case studies are presented. The case studies are presented for predicting the duration of construction projects in Egypt. The examples under study present the cases of administrative building projects in Egypt.

4.6.1 Case Study # 1:

A construction of an administrative building at Smart Village in 6 October city consists of 4 typical floors, 3 basement floors, total built-up area is 18,000 m^2, the project is owned by a private bank. The main consultant is one of the most reputable one in Egypt, the contractor is ranked as one of the best 10 contractors in Egypt (Grade 1 according to Egyptian Federation for Construction Contractor) and has been selected through fair limited tendering process.

The project has been commenced in February, 2009 and has been handed over in July, 2010 (almost 540 calendar days). The project original contract price was LE 85 Million and the final contract amount is L.E. 90 Million.

Firstly, processing these data to the proposed project prediction form (Appendix E), applying the results in Table 4.1 and Fig. 4.2 as follow:

- Project cost:
  - The project cost is LE 90 million, this value exists in the low category (Table 4.1 and Fig. 4.2) and the corresponding score is 2.
- Client's characteristics:
  - The client's type is private sector. This type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 8.
  - The client's financial soundness is strong, this type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 8.
  - The client's tendency for changes is low since no recorded previous projects' extensions due to the bank's requests, this type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 9.

The average of the client's characteristics variables is 8.33

- Tender documents completeness and clarity:

- The consultant is ranked as one of the best ten consultants in Egypt and has no previous records for projects extended due to the documents ambiguity and incompleteness, this type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 7.

- Project's characteristics:
    - The project's complexity is high, this type exists in the low category (Table 4.1 and Fig. 4.2) and the corresponding score is 3.
    - The project's built up area is moderate, this type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.
    - The number of stories (4) is moderate, this type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.
    - The number of basements (3) is high, this type exists in the low category (Table 4.1 and Fig. 4.2) and the corresponding score is 3.

The average of the project's characteristics variables is 4.

- Environmental conditions:
    - The economical conditions is moderate, this type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.
    - The political conditions is moderate, this type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.

The average of the environmental conditions variables is 5.

- Construction site suitability:
    - The site conditions is good since the project exists in suburb location (6^{th}. Of October) apart from the congested areas, construction materials exist near the site, good access routes, sufficient mobilization areas and availability of resources, this type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 8.

Processing these data to the proposed model, evaluating the project duration, we get PD (Project Duration) is 595 days with a percentage of error of 10%.

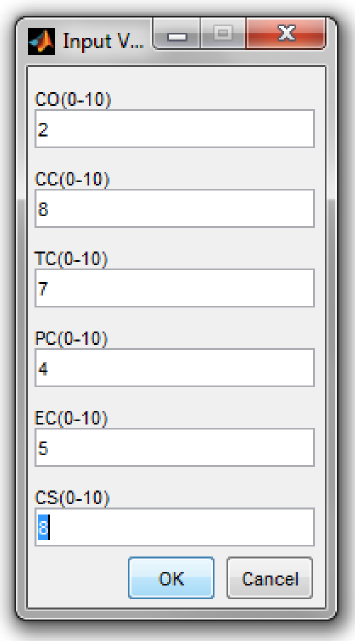


Fig. 4.11 Graphical user interface for case study # 1 – input variables

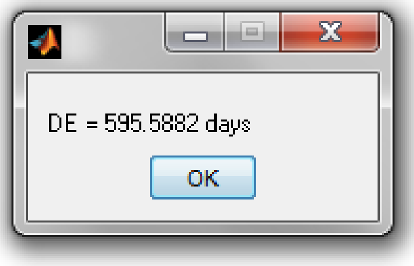


Fig. 4.12 Graphical user interface for case study # 1 – output variable

4.6.2 Case Study # 2:

A construction of an administrative building at New Cairo City consists of 4 typical floors, 2 basement floors, total built-up area is 24,000 m^2, the project is owned by a private petroleum company. The main consultant is one of the most reputable one in Egypt, the contractor is ranked as one of the best 10 contractors in Egypt (Grade 1 according to Egyptian Federation for Construction Contractor) and has been selected through fair limited tendering process.

The project has been commenced in January, 2009 and has been handed over in January, 2011 (almost 730 calendar days). The project original contract price was LE 120 Million and the final contract amount is LE 135 Million.

Firstly, processing these data to the proposed project prediction form (Appendix F), applying the results in Table 4.1 and Fig. 4.2 as follow:

- Project cost:
  - Project cost is LE 135 million, this value exists in the low category (Table 4.1 and Fig. 4.2) and the corresponding score is 2.
- Client's characteristics:
  - Client's type is private sector. This type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 7.
  - Client's financial soundness is strong, this type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 7.
  - Client's tendency for changes is high since this company has two past records of projects' extended due to the company's change requests, this type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 4.

The average of the client's characteristics variables is 6.

- Tender documents completeness and clarity:
  - The consultant is ranked as one of the best ten consultants in Egypt and has no previous records for projects extended due to the documents ambiguity and incompleteness. This type exists in the high category (Table 4.1 and Fig. 4.2) and the corresponding score is 6.

- Project's characteristics:
  - Project's complexity is high. This type exists in the low category (Table 4.1 and Fig. 4.2) and the corresponding score is 3.
  - Project's built up area is moderate, this type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.
  - Number of stories (4) is moderate. This type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.
  - Number of basements (2) is moderate. This type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.

The average of the project's characteristics variables is 4.

- Environmental conditions:
  - Economical conditions is moderate. This type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.
  - Political conditions is moderate. This type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.

The average of the environmental conditions variables is 5.

- Construction site suitability:
  - Site conditions is moderate since the project exists in downtown (new Cairo) close to the congested areas, construction materials exist near the site, good access routes, insufficient mobilization areas and availability of resources. This type exists in the medium category (Table 4.1 and Fig. 4.2) and the corresponding score is 5.

Processing these data to the proposed model, evaluating the project duration, we get PD (Project Duration) is 842 days with a percentage of error of 15%.

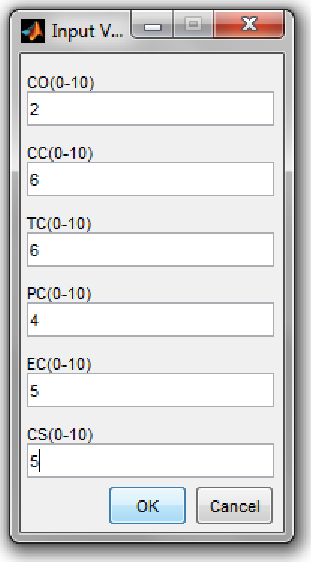


Fig. 4.13 Graphical user interface for case study # 2 – input variables

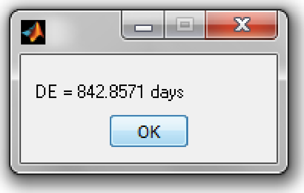


Fig. 4.14 Graphical user interface for case study # 2 – output variable

4.7 RESULTS VALIDATION

Having the model tested through the two case studies, it was necessary to check decision makers' opinion about the model. To accomplish this, the results have been presented to twelve Decision Makers. Structured interviews were conducted with them to introduce the model, explain its main features and how they are going to use. Then, each of them was given the opportunity to try the model and evaluate the project duration in his previous projects and after that evaluate the model.

4.7.1 Questionnaire Form

The questionnaire consists of two main parts: first part contains six evaluating criteria each of them has to be given a score from 1 to 4, where 1 represents poor, 2 represents good, 3 represents very good, and 4 represents excellent and the second part to provide any suggestions.

4.7.2 Questionnaire Results

The average of the twelve questionnaires results (first part) are presented in Table (4.3).

Table 4.3: Results of Model Validation

Criteria	Average
Ease of model use	3.25
Model design	2.92
Technical evaluation criteria	2.42
Range of the inputs	2.67
Results demonstration	3.50
Overall performance	3.00
AVERAGE	2.96

The average of the given scores is 2.96 out of 4.00, giving 74.00 % which could be considered acceptable.

Second part of the questionnaire shows that there is a significant need to enhance the existing model, increase the number of inputs to reflect the actual conditions as possible, study deeply each of the projects' type (administrative, residential, factories, infrastructure, etc) and develop a separate model for each.

4.8 SUMMARY AND CONCLUSION

The developed fuzzy model consists of six input variables: project's cost, client's characteristics (including client's type, client's financial soundness and client's tendency for changes), tender documents completeness and clarity, project's characteristics (including complexity of the project, total built up area, number of stories and number of basements), environmental conditions (including economical conditions and political conditions) and construction site suitability (including construction site conditions), one output variable: expected project duration, and 729 firing rules. To facilitate the use of the said model a fuzzy logic graphical user interface (GUI) was developed so that the user can deal easily with the model. A construction project's duration estimating form was designed so that it will be distributed with the tender documents, filled by all concerned parties "Owner, Consultant, and Contractor and then assessed by the project's consultant (or project manager) to get the most realistic project's duration

To test the developed model, two case studies were analyzed using the proposed model, the run of the model for the first project gave 90% accuracy level with 10% error, while the run of the model for the second project gave 85% accuracy level with 15% error which are acceptable levels. After that it was necessary to check the validity of the model, a questionnaire was distributed to the Decision Makers who assure its validity by about 75%.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 INTRODUCTION

This chapter presents the main contribution of the study, the major conclusions from the results obtained in the study, and recommendations for future work.

5.2 CONTRIBUTION

The main contribution of this study is the development of a fuzzy decision framework to be used for predicting a realistic project duration for commercial projects in Egypt during the tendering stage. Fuzzy logic technique was used to develop that framework. Different criteria affect the project duration were identified through literature review, then the suitable criteria was determined to suit the Egyptian construction industry.

The study had fulfilled its objectives – mentioned in section 1.2 – that were to:

- Identify the factors involved in the determination of commercial project duration.
- Identify the significant factors involved in commercial project duration prediction models.
- Develop a model that can be used to predict commercial project duration within acceptable limits during the tendering stage in a reliable and practical way by applying the fuzzy logic technique.

5.3 CONCLUSIONS

The following conclusions may be drawn from this study:

1. The most effective criteria that should be used to predict commercial project duration in Egypt are: project's cost, type of client, client's financial

soundness, client's tendency for changes, completeness and clarity of tender documents, complexity of the project, project total built up area, number of stories, number of basements, economical conditions, political conditions and construction site conditions.

2. Generally, the factors with the highest score affecting commercial project duration prediction are those related to the client and the project, while the least score factors are those related to the cost in contrary to the studies reported in the literature.
3. There were no significant difference between the project's parties opinion (owner public, owner private, consultant public, contractor public, contractor private) with the reference group (consultant private), hence, the consultant opinion will be the governing reference in predicting the project duration.
4. A fuzzy logic model for predicting commercial project duration in Egypt during the tendering stage, it consists of six input variables: project's cost, client's characteristics (including client's type, client's financial soundness and client's tendency for changes), tender documents completeness and clarity, project's characteristics (including complexity of the project, project built up area, number of stories and number of basements), environmental conditions (including economical conditions and political conditions) and construction site suitability (including construction site conditions), one output variable: expected project duration, and 729 firing rules. To facilitate the use of the said model a fuzzy logic graphical user interface (GUI) was developed so that the user can deal easily with the model.
5. A commercial project duration prediction form was designed so that it will be distributed with the tender documents, filled by all concerned parties "client, consultant, and contractor and then collected and evaluated by the consultant (or project manager if exist) who will include the predicted project duration in the contract documents.
6. In order to test the model and to verify its generalization use, two illustrative case studies were applied to the model successfully. Model validation was achieved using a questionnaire to decision makers.

5.4 RECOMMENDATIONS FOR FUTURE WORK

5.4.1 General Recommendations

For the benefit of all project's parties, and to maintain the project's cost, quality and safety within acceptable limit, we strongly recommend the following:

1. Tendering stage should include a sufficient period for the proper prediction of the project duration.

2. Project duration prediction form should be distributed within the tendering documents, filled by all project's parties, then collected, evaluated, processed by the fuzzy logic model and fixed by the consultant who will include the realistic project duration in the contract documents.

5.4.2 Recommendations for Future Work

1. Expanding the areas of fuzzy logic application to include all types of projects (infrastructure, residential, civil, etc) for each type of owners, consultants and contractors. Each should have its own model created from wide range of similar projects, and then, the model should be trained by the AI applications for accurate results.

2. Expanding the areas of fuzzy logic application to include all types of contract.

3. Expanding the area of fuzzy logic application to include risk and change orders contingencies.

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APPENDICES

APPENDIX (A)

TABLE A.1: FACTORS AFFECTING CONSTRUCTION PROJECT DURATION

S.No.	Author	Year	Factors	
1	Baldwin	1971	1	Weather
			2	Labor supply
			3	Subcontractors
2	Sadashiv	1979	1	The height of building
			2	Project complexity
			3	Location of building
			4	Resources
3	Sidewell	1982	1	Environmental factors
			2	Client's experience
			3	Project organization model
			4	Type of client
			5	Managerial effectiveness
			6	Project complexity
4	Ferguson	1983	1	The factors affecting site productivity
5	Legard	1983	1	The size of the project
6	Grant	1984	1	Management
			2	Leadership
7	Ahuja and Nandakumar	1984		Factors that ultimately affect site productivity
			1	Work space availability
			2	Attendance of operatives
			3	Learning curve
			4	Weather
			5	Labor relations
			6	Project complexity
			7	Foundation condition
			8	Effectiveness of supervision
8	Singh	1984		A. Physical
			1	Form of construction
			2	Size of project
			3	Number of stories
			4	Existence of basements

Table A.1 - continued

				B. Managerial
			1	Contractual system
			2	Tendering procedure
			3	Management efficiency
			4	Development of coordination among the concerned
9	Bennett	1985		
			1	Size
			2	Repetition
			3	Complexity
			4	Speed
			5	Uncertainty
10	Ireland	1985		Managerial
			1	Construction planning during design
			2	Coordination across the design-construction interface
			3	Variations
			4	Project's complexity
			5	Number of stories
			6	Extent of industrial disputes
11	Russel and McGowan	1987		
			1	Knowledge of subcontractors work
			2	The nature of relationships among the general contractor
			3	Subcontractor and client's agent
12	Ashworth	1988		
			1	Construction technology advance
			2	Complexity of projects
13	Gordon	1988		
			1	Construction site efficiency
			2	Building constructability
			3	Management and productivity
			4	Subcontractors' experience
			5	Relationship between subcontractors and client
14	NEDO	1988		
			1	The building's use
			2	Whether the building is purpose built or speculative
			3	Whether the project is new work or refurbishment of
			4	The client
			5	Quality of design

Table A.1 - continued

			6	Contractor's control over the operations
			7	Integration of subcontractors into the process of design
15	Chaung - Chlang	1989		A. Project related factors
			1	Lack of project information
			2	Work plan
			3	Construction site problems
			4	Define the project finish date
			5	Contract conditions
				B. Environment related factors
			1	Economic and commercial factors
			2	Socio-cultural factors
			3	Legal-politic factors
				C. Management related factors
			1	Leadership, communication and motivation sufficiency
			2	Organization flexibility
			3	Insufficient management systems
			4	Control systems
			5	Financial factors
16	Turesoy	1989		Groups with the most important factors
				A. Management related factors
			1	"Preparing effective work plan"
				B. Environment related factors
			1	"Weather"
				C. Project related factors
			1	"Project team experience"
				D. Resource usage related factors
			1	"On time material delivery"
17	Brensen	1990		
			1	There was a slight association between type of client or type of project and construction time performance
			2	Insignificant association was found between contract type and construction time performance
			3	New work was built quicker than refurbishment projects
18	Walker	1990		
			1	Scope of work
			2	Complexity of design
			3	Buildability
			4	Client/design/construction team relationship

Table A.1

			5	Organization structure
			6	Speed of decision making
			7	Industrial relationship environment
19	Nkado	1991		6 main categories (28 factors)
			1	Client related factors
			2	Designers and design consultants
			3	Type of contract
			4	Project conditions
			5	Management related factors
			6	External factors
20	Naoum	1991		Important factors
			1	Project cost
			2	Procurement method
			3	Designer experience
21	Callahan	1992		
			1	The height of building
			2	Project complexity
			3	The building location
22	Raymond	1994		The first ten factors (28 factors)
			1	Work completion sequence by client
			2	Construction work plans by contractor
			3	Form of construction
			4	Project team priorities about construction duration
			5	Building complexity
			6	Assessment of client's construction duration priority
			7	Construction site conditions
			8	Project constructability
			9	Suitability of management team
			10	Project information completion
23	Sarac	1995		A. Project related factors
			1	Characteristics' and complexity of project
			2	Degree of standardization and repletion of work
			3	The end product defines the duration of production with
			4	Conditions of contract provide important information for
				B. Environment related factors
			1	The geographic status of the site
			2	The accessibility to the site

Table A.1

			3	Weather
			4	The cultural characteristics
			5	The working traditions and styles of people on site affect
				C. Management related factors
			1	Experience of high level managers involved in time planning increase the probability of obtaining the ideal
			2	Planning of construction time, using the best programming methods, using past experiences in estimating the duration of work packages increase the
			3	Degree of experiences, power of decision-makers, decrease in variation of work packages increase the
			4	Subcontractors
24	Nkado	1995		
			1	Client's specified sequence of completion
			2	Contractor's programming actions
			3	Form of construction
			4	Client's priority on construction time
			5	Designer's priority on construction time
			6	Project complexity
			7	Location
			8	Constructability of design
			9	Availability of construction management team
			10	Timeliness of the project information and documents
25	Walker	1995		
			1	Construction management effectiveness
			2	The sophistication of the client and client's representative
			3	Design team effectiveness in communicating with construction management and client's representatives
			4	A small number of factors describing project scope and
26	Chan and	1995		
			1	Construction cost/value
			2	Type of construction
			a.	Product (earth dam, steel str, etc)
			b.	Technical parameters (height, floor area, span, etc)
			c.	Quality
				i. Of construction required
				ii. Of design and documentation
			d.	Complexity

Table A.1

			3	Location
			4	Client's priorities
			a.	Managerial
				i. Abilities
				ii. Motivation
				iii. Systems
			b.	Organizational
				i. Structure
				ii. Style
				iii. Information systems
			c.	Labors
				i. Work systems
				ii. Skills
				iii. Motivation
			d.	Technology
				i. Labors/equipments mix
				ii. Plant/equipments (age, level of
			5	Total factor productivity
			6	Others
			7	Type of contract
			a.	Risk allocation
			b.	Tenderer selection method
			c.	Management structure
			d.	Payment modalities
			8	Post contractual developments
			a.	Variation orders
				i. Magnitude
				ii. Interference level
				iii. Timing
			b.	Orders
			c.	Conflicts
27	Kaming	1997		Factors causing delays
			1	Weather
			2	Lack of resources
			3	Experience
			4	Project changes
			5	Labors productivity

Table A.1

			6	Local legal restrictions
			7	Insufficient work programs
28	Karsh D	1998		
			1	Factors about client/client's representative
			2	Factors about project team
			3	Factors about general contractor
			4	Factors about subcontractors
			5	Factors about coordination of construction teams
			6	Factors about the project
			7	Factors about the construction equipment and material
			8	Factors about the environment
			9	Factors about the contract
			10	Other factors
29	Dissanayaka ve	1999		Factors affecting project performance
			1	Procurement related factors
			2	Non procurement related factors
30	Mulholland ve Christian	1999		Sources of risks affecting schedule
			1	Engineering design related factors
			2	Project management related factors
			3	Site construction related factors
			4	Procurement related factors
31	Walker and Vines	2000		4 main categories (22 factors)
			1	Management quality
			2	Coordination
			3	The degree of experience and expertise for the same type
			4	Environmental factors
32	Chan and	2002		A. Project scope
			1	Construction cost
			2	Gross floor area
			3	Number of stories
			4	Building type
			5	Contract procurement systems
			6	Variations
				B. Project complexity
			1	Client's attributes
			2	Site conditions/site access problems
			3	Constructability of project design

Table A.1

			4	Quality of design coordination
			5	Quality management
				C. Project environment
			1	Physical
			2	Economic
			3	Social-political
			4	Industrial relations
				D. Management attributes
			1	Client/design team management attributes
			2	Construction team management attributes
			3	Communication management for decision making
			4	Organization structures and human resources management
			5	Productivity
				E. Other factors

APPENDIX (B)

Table B.1: Types of Duration Prediction Models found in literature

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
A. EXPERIENCE-BASED MODELS **Algorithms** **Heuristics** **Expert system programming**							
1.	**Moselhi, O. and Nicholas, M.J., Hybrid Expert System for construction Planning and Scheduling, Journal of Construction Engineering and Management, Vol.116, No. 2, p.221-238, 1990. (Canada)**	**Hybrid Expert System- EXPERT CONSTRUCTION SCHEDULER (ESCHEDULER)**	**to develop a prototype hybrid expert system for construction planning and scheduling by integrating available computing methods with expert system technology.**		**(Montreal-Canada) The building is a two-story warehouse with structural steel framing, and it was divided into 14 activities.**	**It includes 4 main databases:** **(1)WEATHER-based on ten-year historical climatologically data for the city of Montreal** **(2) HOLIDAY** **(3) LISTACT-the list of activities, codes, durations, activity definitions and relationships-2 modules; activity translator ve joblogic helper** **(4)PROJREC-duration modifier module** **(5) management performance**	**By using softwares, PROMIS and FORTRAN.etc, A system developed to modify the activities which don't have a sequential relation or don't affect each other, Factor affecting construction durations effects on activities were analyzed as "less", "middle", "high".**
2.	**Wu, R. W. and Hadlpriono, F.C., Fuzzy Modus Ponens Deduction Technique for Construction Scheduling, Journal of Construction Engineering and Management, Vol. 120, No.1, p. 162-179, 1994. (USA).**	**FUZZY LOGIC-Expert System (ADDSS-Activity Duration Decision Support System)**	**To develop more realistic duration estimation modeling system.**		**The foundation part of library construction project in Ohio University**	**(1) site condition** **(2) equipment performance** **(3) labor performance** **(4) weather conditions** **(5) Material supply** **(6) management performance**	**Trigonometric calculation methods were used for the main steps in the model , CA-Sper Project software integration were provided.**
3.	**Boussabalne, A.H., Neurofuzzy Modeling of Construction Projects' Duration I: Principles, Engineering, Construction and Architectural Management, Vol. 8, No.2, p.104-113, 2001, (UK).**	**NEUROFUZZY MODELLING**					

Table B.1 - continued

	Boussabaine, A.H., Neurofuzzy Modeling of Construction Projects' Duration II; Application, Engineering, Construction and Architectural Management, Vol. 8, No. 2, p. 114-129, 2001. (UK).	**NEUROFUZZY MODELLING**			**230 building projects**	**(1) Selection of the tending method (2) Number of tenders (3) Type of contract (4) Fluctuation in prices (5) Available space in the project site (6) Access to the project site (7) Slope of the project site (8) Ground conditions (9) Type if frame (10)Type of frame (11)Number of stories (12)Area (m2) (13)Tender price (contract sum)**	**Neurofuzzy models are fundamentally different from neural and expert systems. Neurofuzzy systems have the following characteristics: 1. Automatically extract the consequents and the antecedents of a set of fuzzy rules from the original input/output data sets. 2.Automatically train and change the shape of membership functions according to data patterns 3. The number of neurons are determined from the number of membership functions on each input variable. 4. Training and optimization periods are shorter. 5. Allows the inclusion of knowledge and expertise in choosing system topology 6. Leads to a model which can be easily understood. Model is reasonably accurate (R=0,76).**
4.	**Konglu, A., Integrated System for Duration Estimation in Design/Build Projects and Organizations, Engineering, Construction and Architectural, Management, Vol. 10, No.4, p. 272-282,2003. (Turkey).**	**PERFORMANCE BASED DURATION ESTIMATION MODEL-Expert System Intehrated System (SPIDER)**	**to explain the implementation of an experience-based computational model for project duration estimation which is integrated with an automation system developed for design/build firms**		**Türkiye**		

Table B.1 – continued

	Sezgin, Y., Tasarim/Yapm Organizasyonlaricin proje Gerçeldesme Süresinin Tahminine Yönelk Bir Bütunlesk Model Önerisi, M.S. Dissertation, Department of Architecture, Istanbul Technical University, Turkey, 2003. Turkey).	**PERFORMANCE BASED DURATION ESTIMATION MODEL-Expert System Intehrated System (SPIDER)**	**to develop an experience-based computational model for project duration estimation which is integrated with an automation system developed for design/build firms by taking into consideration the mentioned concerns**		**Türkiye**		
5.	**Kumar, V.S.S, and Reddy, G.C.S., Fuzzy Logic Approach to Forecast Project Duration in Construction Projects, Construction Research Congress, 2005.**	**FUZZY LOGIC**	**To estimate the project parameters by incorporating the qualitative and quantitative factors using fuzzy logic approach.**		**A prestressed concrete sleeper factory, India**		**(1) The applicability of fuzzy set theory to project duration estimation has been vindicate by comparison of its results of conventional techniques. (2) The advantage of the model is that it is not sensitive to small variations in the membership values but it is sensitive to the choice of fuzzy relation between the consequences and duration of an activity (3) This model can incorporate all intangible and subjective values into the analysis.**

Table B.1 Continued

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
B.	**SIMULATGION** **Heuristics** **Expert Models** **Decision Rules**						
1.	**R.I. Carr, Simulation of construction project duration, J. Constr. Div., ASCE 105 2 (1969), pp. 117-127.**						
2.	**Ahuja HN, Nandakumar V., Simulation model to forecast project completion time, J. Construction Eng Management 1985, 111 (4), (325-42).**						
	PARAMETRIC **Regression** **Statistical Models** **Decision Rules**						
1.	**Bromilow, F.J. (1974), Measurement and scheduling of construction time and cost performance in the building industry, The Chartered Builder, 10, 57. (Australia)**	**Regression Model-Power of Regression-** $T=KC^B$		**Pre-design stage**	**Australia 329 Building Projects**	**Cost**	
	Bromilow, F.J. Hinds, M.F., and Moody, N.F., AIQS Suvrey of Building Contract Time Performances, Building Economics, VOl. 19, p. 79-82, 1980. (Australia)	**Regression Model-Power of Regression-** $T=KC^B$		**Pre-design stage**	**Australia 408 Building Projects**	**Cost**	

Table B.1 - continued

2.	**Ireland, V., The Role of Managerial Actions in the Cost, Time and Quality Performance of High-Rise Commercial Building Projects, Construction Management and Economics, Vol. 3, p. 59-87, 1985. (Australia)**	**Multiple Linear Regression Analysis**	**An analysis of the effect of managerial actions on the objectives of reducing time, reducing cost and increasing quality were undertaken.**	**Pre-design stage**	**Australia 25 high rise office Buildings (1970s)**	**(1) COMPINDX (Complexity of form of construction) (2) CPDD (Construction Planning During Design) (3) AREA (4) DIPT (Disputes per unit of time) (5) DCOORD2(Design Construction Interface Coordination) (6) NoS (7) CVPC (Contract Variation per unit of Bld Cost)**	**to reduce time; (1) increased CPDD (construction planning during design). (2) reduced CONTVAR (variation to the contract) (3) reduced No Storey (4) reduced COMPINDX (complexity of form of construction). (5) increased DCOORD2 (design construction interface coordination) (6) reduced DIPT (disputes per unit of time coordination) ** R^2 were used**
3.	**Kaka, A. and Price A.D.F., Relationship between Value and Duration of Construction Projects, Construction Management and Economics, Vol. 9, p. 383-400, 1991. (UK)**	**Regression Model**	**To make comparisons with classifying the data into set of factors and analyzing them to see the effect of each factor on construction duration.**		**UK 661 building projects And 140 roadwork (1984-1989)**	**(1) type of client (public, private) (2) type of project (building, civil engineering) (3) type of tender (open competition, select competition, negotiated competition) (4) form of tender (fixed price tender, fixed adjusted tender)**	**(1) the types of tender has no effect on the duration. (all the others influenced) (2) Construction durations of projects with adjusted price contracts generally took longer than projects with fixed price contracts. (3) Construction durations of public buildings were shown to be longer than that of private buildings. (4) Construction duration durations of building projects took generally longer than that for civil engineering projects of similar value.**

Table B.1 - continued

4.	**Nkado, R.N., Construction Time Information System for The Building Industry, Construction Management and Economics, Vol. 10, p. 489-509, 1992. (UK).**	**Multiple Linear Regression Analysis**	**To prioritize factors which are taken into consideration by accomplished contractors in planning the construction time of buildings**	**Pre-design stage**	**29 commercial, privately funded blds**	**(1) Gross floor area (GFA) (m2) (2) Height from ground to eaves levels (m) (3) Type of cladding (prefabricated panels, curtain wall, brick). (4) Number of floors excluding basement floor (5) Location (London, elsewhere) (6) Type of structural frame (concrete, steel, other) (7) Storey height (8) Approximate volume of bld (m3)**	**The model can be used for estimating construction durations and producing outline construction plan of buildings in the early design stages, as the models provided reasonably accurate results…A significant degree of consistency in ranking "time influencing factors" was found. The most important factors are apparently those which can readily be identified or deduced from project information and whose impact on construction time can generally be assessed explicitly by mathematical and judgmental analyses. ** Tested with other 3 office blds' dta.**
5.	**Kumaraswamy, M. M. and Chan, D.W.M. Determinates of Construction Duration, Engineering, Construction Management and Economics, Vol. 13, 209-217, 1995. (Hong Kong)**	**Simple Linear Regression Analysis**	**The first phase of an investigation; to search factors affecting construction project duration.**	**Pre-design stage**		**Floor Area**	**(1) There is significant relationship between duration and Floor Area (2) Public Buildings' durations are lower than private ones in Hong Kong. (3) Public or private, There ise no difference in UK (4) Private buildings are more efficient in Austrralia.**

Table B.1 Continued

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
PARAMETRIC **Regression** **Statistical Models** **Decision Rules**							
6.	Chan, D.W.M. and Kuimaraswamy, M.M., A Study of the Factors Affecting Construction Durations in Hong Kong, Construction Management and Economics, Vol. 13, p. 319-333, 1995. (Hong Kong)	(1)Simple Linear Regression Analysis - 2 simple linear regression model (duration with GFA and duration with NoF) (2)A Multiple linear regression model (duration with cost and GFA)	The second phases of an investigation: 2 main objectives: (1) (1) to explore and compare the empirical relationships between duration and cost; duration and total gross floor area; duration and total number of storeys; and any other significantly related variables in representative samples within different categories of projects completed during 1990-1993 in Hon Kong. (2) The second was to determine the main causes of delays, if any, in these projects.	Pre-design stage	Hong Kong 111 projects (1990-1993)	Focused on project scope variables such as (Macro Variables); (1) Cost (2) Floor Area (3) Number of Floors	(1) There is a significant relationship between duration with GFA and cost. (2) Besides Macro variables, Micro variables affecting productivity (plant utilization-efficiency of site labourers) affects duration also. (a) Plant utilization levels such as tower cranes and truckmixers. (b) A comparison of the average productivity of different concrete placing methods such as pump and cane and skp; (c) The activity analysis profiles of construction workers such as formwork riggers, steel bar benders, steel-fixers and concretors on site. ** tested and confirmed
7.	Chan, D.W.M. and Kuimaraswamy, M.M., A Study of the Factors Affecting Construction Durations in Hong Kong, Construction Management and Economics, Vol. 13, p. 351-362, 1999. (Hong Kong)	Multiple Linear Regression Analysis	to derive benchmark measures of standard norms for overall construction duration by modeling the primary work packages of the building construction projects	Pre-design stage	Hong Kong 56 housing projects Standard "Harmony" type (1990 – 1996)	(1) Actual Construction Cost (2) Total Volume of Building (3) Type of Housing Scheme (rental/purchase) (4) Presence/Absence of precast facades (5) Ratio of Total GFA (m^2 to the number of storeys).	Reliable model (The model was applied 9 new building data, and results also compared with planners' estimations, (R^2, the significance level of variables)

Table B.1 - continued

	Chan, A.P.C. and Chan, D.W.M., Developing a Benchmark Model for project construction Time performance in Hon Kong, Building and Environment, Vol. 39, p. 339-349, 2004.						
	Chan, A.P.C. and Chan, D.W.M. , Benchmarking project construction time performance- The case of Hon Kong, Project Management-Impresario of the Construction Industry Symposium, 2002.						
8.	**Walker, D.H.T., An Investigation into Construction time performance, construction Management and Economics, Vol,. 13, p. 263-274, 1995. (Australia).**	**Multiple Linear Regression Analysis**	**To contribute to the study of CTP improvement by identifying factors that influence CTP and demonstrating how this knowledge may be applied within the context of continuous performance improvement and adoption of best practice.. a systematic method for CTP has been developed (for developing, a duration estimation model was developed also).**	**Post contract stage**	**Australia 33 construction projects (1987-1993)**	**(1) Building construction costs (2) Additional period/construction duration ratio (3) Work type (new, refurbishment, fit out etc.) (4) Client/Client representative' objectives about quality (5) Client representative' effectiveness on construction management. (6) Use of information technology (7) Communication (between architect/engineer and contractor)**	**(1) This model couldn't be used at predesign stage. (2) Construction Management (CM) team performance was found as the most important factor for construction time performance (CTP). (3) Representative management effectiveness was also found as an important factor for CTP. (1) p-values < 0,05 (All varlables) (2) R2 value= o,9987.**
	Karsli, E.D., Insaat Suresini Etldeyen Faktonler ve insaat Suresi Tahmin Modeleri, M.S. Dissertation, Department of Archituecture, Istanbul Technical University, Turkey, 1998, (Turkey).	**Walker's Model was chosen to apply as the most appropriate model for Turkey.**	**(1) to search factors affecting construction duration. (2) to search models for estimating construction duration. (3) to chose the most appropriate model to apply in Turkiya.**				**(1) Australia and Turkey has really different Construction Time Performance. (2) Total Floor Area, contract type are not parameters. (3) Financial flow does not considered for corporations especially. (4) All countries should develop their own models (local models), because of all the places has their own characteristics, and they should have their I.S.**

Table B.1 Continued

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
PARAMETRIC **Regression** **Statistical Models** **Decision Rules**							
9.	**Saraç, S., A Time Information System for the construction Industry, M.S. Dissertation, Department of Architecture, Istanbul Technical University, Turkey, 1995. (Turkey).**	**Lineer Regression Analysis**	**To establish a time information system for time planning of a project at early design from minimal information**	**Pre-design stage**	**Turkey** **33 projects of Turkish Ministry of Public Works and Resettlement (school and housing projects)**	**(1) Function of a project (Nominal)** **(2) Type of structural frame (Nominal)** **(3) Location (Nominal)** **(4) Accessibility to site (Nominal)** **(5) Type of cladding (Nominal)** **(6) Atrium existence (Nominal)** **(7) Intensity of services (Nominal)** **(8) Number of storeys (Ratio)** **(9) Height from ground to eaves level (Ratio)** **(10)Area of ground floor (Ratio)** **(11)Gross Floor Area (Ratio)** **(12)Approxiamte volume of excavation (Ratio)**	**There is a relationship between the durations of the main work groups and project variables that can be easily assessed at the early design stages. A very simple and easy to be used model.**
10.	**Khosrowshahi, F. and Kaka, A.P., Estimation of Project Total Cost and Duration for Housing projects in the U.K., Building and Environment, Vol. 31, p. 373-383, 1996. (UK)**	**Multiple Linear Regression Analysis**	**(1) a fast, cheap and easy production of a forecast** **(2) to identify the moist influential variables and quantify their influence**	**Pre-design stage**	**UK** **54 housing projects**	**(1) No of units** **(2) Project operation** **(3) project sub-type** **(4) abnormality** **(5) start month** **(6) horizontal access**	**Two separate simply applied models. Adjusted R2 (%92,7).**
11.	**Chan, D.W.M. and Kumaraswamy, M.N., Forecasting Construction Durations for public Housing projects: A Hong Kong Perspective, Building and Environment, Vol. 34, p. 633-646, 1999. (Hong Kong).**	**Multiple Linear Regression Analysis**	**To generate standard for overall completion periods of public housing blocks by modeling the durations of the primary work packages**		**Hong Kong** **15 standard housing blocks New Cruciform type**	**(1) No storeys** **(2) GFA** **(3) Ratio of GFA to Area of ground floor plan** **(4) Ratio of Area of external cladding to GFA** **(5) Type of foundations used** **(6) Information flows between architect engineer and contractor** **(7) Ground conditions for construction** **(8) Labour productivity**	

Table B.1 - continued

12.	**Dissanayaka, S.M. and Kuimaraswamy, M.M. Evaluation of Factors Affecting Time and Cost Performance in Building Projects, Building and Environment, Vol. 34, p. 31-42, 1999. (Hong Kong)**	**Multiple Linear Regression Analysis**	**To identify the relative strengths of the linkages between procurement sub-systems any other relevant variables and project outcomes in Hong Kong based building projects.**		**Hon Kong 32 Building projects**	**(1) procurement related (2) non-procurement related factors**	**Procurement sub systems variables are less significant than the non-procurement related variables in predicting time and cost performance levels on Hong Kong building projects.**
13.	**Dissanayaka, S.M. and Kumaraswamy, M.M. , Evaluation of Factors Affecting Time and Cost performance in Hong Kong Building projects, Engineering, Construction and Architectural Management, Vol 6, No. 3 p. 287-298, 1999. (Hong Kong).**	**Multiple Linear Regression Analysis**	**1. to identify and groups particular factors (variables) which are significantly related to time and cost performance; 2. to analyze the relationships of procurement and non-procurement related factors with time and cost performance; 3. to develop time and cost over-run models using critical factors influencing time and cost performance.**		**Hong Kong**	**(1) procurement related factors a) work packaging b) functional grouping c) payment modality d) selection modality e) conditions of contracts (2) non-procurement related factors a) factors related to project. b) factors related to clinician representative c) factors related to designer d) factors related to contractor e) factors related to team performance f) factors related to external conditions.**	**(1)time over-runs appear to be greatly influenced by non-procurement related factors, apart from indirect influences (on design and construction complexity and variation levels) arising from the selection of the design team; (2) cost over –run appear to be greatly influenced by both procurement and non-procurement related factors; (3) the payment modality procurement sub-system appears to influence cost over-runs; (4)Artificial neural networks (in addition to multiple linear regression) are useful in forecasting time and cost escalations; and it is also useful to examine patterns of differences in the average time and cost over-runs, between groups of projects that have used different procurement systems.**

Table B.1 Continued

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
PARAMETRIC Regression Statistical Models Decision Rules							
14.	Skitmore, R.M. and Thomas Ng, S., Forecast Models for Actual Construction Time and Cost, Building and Environment, Vol. 38, No. 8, p. 1075-1083, 2003. (Australia & Hong Kong)	Regression Model (A forward cross validation regression analysis + standard cross validation regression analysis)	To develop several models for actual construction time and cost prediction	Post contract stage	Australia 93 construction projects	(1) client sector (2) contractor selection method (3) contractual arrangement (4) project type (5) contract period (6) contract sum	(1) The errors in predicted actual construction time become smaller as the contract period increases. (2) In contract, the errors in predicted actual construction cost are virtually the same for large and small projects. (3) The actual construction time for industrial project is the longest when compared with residential, educational and recreational projects (4) significant savings in actual construction time can be achieved when negotiated tender and design and build contract are used instead of the traditional open tending and lump sum contract approaches.

Table B.1 - continued

15.	**BCIS, Guide to Building Construction Duration, MFK Chitern Press, England, 2004. (UK-London)**	**Multiple Linear Regression Analysis- (least squares linear regression)**	**This guide presents and analyses on the "actual time" taken to construct buildings. It provides an aid to clients and their consultants in estimating or benchmarking the construction duration the construction duration at the earliest stages of future projects.**	**Pre-design stage**	**UK BCIS databases 1500new build building projects (1998-2002)**	**(1) procurement route (2) contractor selection method (3) client type (4) building function (5) region (6) value (2nd quarter 2003-UK mean location; location and year indexes were used) "Log Contract Sum Squared" dependent variable: "the square root of construction duration"**	**(1) A clear and significant relationship between construction duration and total construction cost. (2) Housing projects tend to take longer than other schemes of the same value for both public and private sectors, while industrial building projects are completed more quickly; non housing projects above ₤750.000 for private clients tend to be completed faster that those for public sector clients, although this may well reflect the amount of industrial buildings in the private sector sample. (3) The method of contractor selection does not seem to significantly influence the speed of construction. (4) Complexity old design influences the time it takes to build. (5) The analyses by location probably reflects the differing mix of projects in each region. (6) Projects let on a traditional lump sum basis up to ₤ 1,3 million, tend to be completed more quickly than projects.**

Table B.1 - continued

16.	**Blyh, K., Lewis, J. and Kaka, A., Predicting Project and Activity Duration for Buildings in the UK, COBRA 2001 Conference Papers. (England)**	**Multiple Linear Regression Analysis**	**To be able to reliably predict overall project and activity duration for the sample of UK buildings, based upon a number of qualitative and quantitative project chjaractgeristics.**	**Pre-design stage**	**UK 56 building projects**	**21 PRE-DETERMINDE PROJECT CHARACTERISTICS 8 non-interval variables: (1) project function (1-11) (2) location (1-8) (3) type of procurement (1-4) (4) main frame (1-5) (5) site access (1-5) (6) service intensity (1-3) (7) presence of atrium (1-2) (8) cladding type; 13 Interval variables: (1) storeys above ground (2) height above ground (3) ground floor area (4) GFA (5) excavation area (6) average storey height (7) volume of building (8) ratio of floor area to ground floor area (9) average floor area per storey (10) average volume of storey (11) depth of foundations (12) ratio of height of building to depth of foundations (13) actual durations weeks**	**One can rapidly produce an outline construction programmer at the early stages of design from limited project information. The 85% minimum reliability for activity duration, coupled with the 93% for overall duration, contractors could provide an objective basis for the evaluation of stipulated completion times, as implied by the client.**

Table B.1 Continued

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
	PARAMETRIC **Regression** **Statistical Models** **Decision Rules**						
17.	Love, P.E.D., Tse, R. Y.C. and Edwards, D.J., Time- Cost Relationships in Australian building construction Projects, journal of Construction Engineering and Management, Vol. 131, op. 187-194, 2005. Australia, Hong kong and U.K.	Multiple Linear Regression Analysis (Weighted least squares)	To examine the project time and cost relationship by using project scope factors	Pre-design stage	Australia 126 construction Projects	The final model have 2 variables: (1) GFA (2) NoF Project scope factors: (1) Project type (1. new build-2. refurbishment/renovation-3.fdit out - 4.new build/ refurbishment) (1) project type (1. new build-2. refurbishment/ renovation-3.fit out- 4.new build/refurbishment) (2) procurement method (3) tender type (4) gross floor area (GFA) (5) Number of storeys	(1)GFA and number of storeys are key determinants of time performance in projects. (2) Cost is a poor indicator of time performance (it is not possible to know the eact cost before the work done) (3)New build projects experienced poor project time performance than the others (4) When GFA decrease or NoF increase; Speed decreases. (5) Labour wages are related with Speed of construction and Materials is related with GFA (6) BTC is applicable with reasonably judgments especially early phases.

Table B.1 - continued

18.	**Chen, W.T. and Huang, Y., Approximately Predicting the cost and Duration of School Reconstruction Projects in Taiwan, Construction Management and Economics, Vol. 24, p. 1231- 1239, 2006. (Taiwan)**	**Multiple Linear Regression Analysis- for only DURATION estimation.**	**To find the relationships between floor area, cost and duration of the reconstruction projects and to build simple estimation models to estimate the cost and duration of reconstruction projects in order to assist the decision making process in the early disaster recovery planning phase.**	**Pre-design stage**	**Central Taiwan 132 school Reconstruction projects**	**(1) Cost (2) Duration (3) Floor Area**	**(1) Data were collected from reconstruction of school projects, after the earthquake (Chi-Chi Earthquake) in Central Taiwan, cost ve duration estimations were done by using Regression and ANN Models. (2) Floor Area was the most essential variable for COST estimations (3) Cost and Floor Area were the essential variables for DURATION Estimations (4) ANN Models results were better than Regression Analysis Results.**
19.	**Hoffman, G.J., Jr., A.E.T., Webb, T.S. and Weir, J.D, Estimating performance Time for construction Projects, Journal of Management in Engineering, Vol. 23,p.193-199, 2007, (USA).**	**Multiple Linear Regression Analysis**	**To gain insight into the significant factors impacting duration by developing a regression model.**	**Pre-design stage**	**USA 856 Air Force Buildings Facility projects (1988-2004)**	**(1) Cost (2) ACC-Air Combad Command (3) AETC-Air Education Training Command (4) AFSCO-Air force special operations Command (5) Northwestern COE Region (6) in-house design' construction agent**	**(1) MLR analysis is better to provide acceptable predictions (2) There was a significant relationships between cost and duration in BTC ve MLR Models**

Table B.1 - continued

20.	**Helvaci, A., Comparison of Parametric Models for Conceptual Duration Estimation of Balding Projects, M. Sc. Dissertation, Department of Civil Engineering, Middle East Technical University, Turkey, 2008. (Turkey)**	**(1) BTC validation (2) Simple Linear Regression (only with cost and duration) (3) ANN (with only cost and duration) (4) MLR (without cost) (5) ANN (without cost) ** Cost Model were done with MLR for cost used in models.**	**To developed and compare reasonably accurate and practical methodologies for conceptual duration estimation of building projects. * To develop a parametric model for conceptual cost estimation since cost estimates are also required in the assessment of prediction performances of the time-cost models. * To test the time-cost model proposed by Bromilow (1974) * To develop time-cost models (models where cost is used to estimate the duration of the projects). * To develop parametric models for conceptual duration estimation * To compare all the models developed in terms of their predictive abilities.)**	**At the early stages of projects.**	**USA 17 Building projects (CCRC-continuing care retirement community) (1975-1995)**	**(1) Total building area (Area) (2) Number of floors (NoF) (3) Area per unit (Area/unit) (4) Combined percent area of commons and health center (Per(C + H)) (5) Percent area of structured parking (Per (P)) (6) Type of structural frame of the building (Steel (St), masonry (Mas), reinforced concrete (RC), precast (pre), wood (W))**	*** Modeling approach is an alternative method to current intuitive planning approach for early stages of the projects with reasonably accuracies. * Time-cost models and parametric models had close reasonably accurate estimations. Time-cost models' predictive accuracy was slightly better than parametric models. However, parametric estimations don't require cost estimation. * Ann and regression analysis predictive accuracies and no significant differences. Therefore, had no significant differences. Therefore, Helvaci stated linear regression analysis provides an adequate and pragmatic methodology for duration estimation of construction projects". * 13-15% precitive accuracy was achieved with 17 cases at conceptual phase.**

Table B.1 Continued

No	Name of the article	Type of Modeling (According to Fitzgerald Classification)	Why did they do this study?	When?	Case study	Variables	Results
	DISCRETE STATE (Other) Linear programming Classical Optimization Network						
1.	**B hokha, S. and Ogunlana, S.O., Application of Artifical Neural Network to Forecast construction Duration of Buildings at the predesign Stage, Engineering, Construction and Architectural Management, Vol. 6, No. 2, p. 133-144, 1999. (Thailand)**	**ANN-Artifical Neural Network (3 layered back-prorogation (BP) network consisting of 11 input nodes)**	**To apply of Ann to forecast the construction duration of buildings at the predesign stage**		**Greater Bangkok-Thailand 136 blds (h>23m; A>10.000m2) (1986\7-1995)**	**(1) building function (two nodes) (2) structural system (two nodes) (3) functional area (one node) (4) height index (one node) (5) complexity of foundation works (one node) (6) exterior finishing (two nodes) (7) decorating quality (one node) (8) site accessibility (one node)**	
2.	**Disannayaka, S. M. and Kumaraswamy, M.M., Evaluation of Factors Affecting Time and cost Performance in Hong Kong Building projects, Engineering, Construction and Architectural Management, Vol. 6, No. 3 p. 287-298, 1999.**	**ANN**					

Table B.1 - continued

3.	**Helvaci, A., Comparison of Parametric Models for Conceptual Duration Estimation of Building Projects, M. S. Dissertation, Department of Civil Engineering, Middle East Technical University, Turkey, 2008. (Turkey).**	**(1) BTC validation (2) Simple Linear Regression (Only with cost and duration) (3) ANN (with only cost and duration) (4) MLR (without cost) (5) ANN (without cost) ** Cost Model were done with MLR for cost used in models.**	**To develop and compare reasonably accurate and practical methodologies for conceptual duration estimation of building projects. * To develop a parametric model for conceptual cost estimation since cost estimates are also required in the assessment of prediction performances of the time-cost models. * To test the time-cost model proposed by Bromllow (1974) * To develop time-cost models (models where cost is used to estimate the duration of the projects). * To develop parametric models for conceptual duration estimation * To compare all the models developed in terms of their predictive abilities).**		**USA 17building projects (CCRC-continuing care retirement community) (1975-1995)**	**(1) total building area (Area) (2) Number of floors (NoF) (3) Area per unit (Area/unit) (4) Combined percent area of commons and health center (Per (C+H)) (5) Percent area of structured parking (Per (P)) (6) Type of structural frame of the building (Steel (St), masonry (Mas), reinforced concrete (RC), precast (Pre), wood (W)).**	*** Modeling approach is an alternative methods to current intuitive planning approach for early stages of the projects with reasonably accuracies. * Time-cost models and parametric models had close reasonably accurate estimations. Time-cost models' predictive accuracy was slightly better than parametric models. However, parametric estimations don't require cost estimation. *Ann and regression analysis' predictive accuracies had no significant differences. Therefore, Helvaci stated "linear regression analysis provides an adequate and pragmatic methodology for duration estimation of construction projects". * 13-15% precitive accuracy was achieved with 17 cases at conceptual phases.**

APPENDIX (C)
STATISTICAL ANALYSIS
Table C.1: Z - Scores for Client-Public Group (A) relative to Group (D)

	Gr A:		**Gr D:**		
	Mean	SD	Mean	SD	**Z-Score**
X1	9	0.577	7.21	0.802	2.2
X2	7.43	1.134	8.71	0.611	-2.1
X3	9.29	0.488	9.36	0.633	-0.1
X4	9.43	0.535	9.29	0.611	0.2
X5	9.14	0.69	8.5	0.65	1.0
X6	7	0.816	8	0.555	-1.8
X7	8.14	0.69	7.86	0.663	0.4
X8	8.29	0.756	8.57	0.514	-0.5
X9	8.43	0.535	8.86	0.663	-0.6
X10	8.29	0.488	8.93	0.616	-1.0
X11	7.29	0.756	7.57	0.514	-0.5
X12	8	0.816	8.21	0.699	-0.3
X13	7	0.816	6.36	0.842	0.8
X14	7.14	0.69	7.14	0.663	**0.0**
X15	8	0.577	8	0.679	**0.0**
X16	8	0.816	8.5	0.519	-1.0
X17	8.14	0.9	8.71	0.611	-0.9
X18	7.71	0.756	6.86	0.663	1.3
X19	8.43	0.535	8.57	0.756	-0.2
X20	7	0.816	6.29	0.726	1.0
X21	6	0.816	5.71	0.611	0.5
X22	6.71	0.756	7.57	0.514	-1.7
X23	8.29	0.488	7.14	0.663	1.7
X24	9.14	0.69	9.07	0.616	0.1
X25	8.43	0.787	7.5	0.76	1.2
X26	8.57	0.535	8.57	0.756	**0.0**
X27	9.43	0.787	9.21	0.699	0.3
X28	9.29	0.488	9.14	0.77	0.2
X29	8.71	0.756	8.71	0.611	**0.0**
X30	9.57	0.535	9.5	0.519	0.1
X31	5.43	0.535	7.57	0.938	-2.3
X32	5.71	0.756	8.5	0.519	**-5.4**
X33	9.71	0.488	9.43	0.646	0.4
X34	9	0.816	8.86	0.77	0.2
X35	6.86	0.69	7	0.784	-0.2
X36	8.86	0.69	8.64	0.745	0.3

Table C.2: Z - Scores for Client-Private Group (B) relative to Group (D)

	Gr B:		**Gr D:**		
	Mean	SD	Mean	SD	**Z-Score**
X1	6.47	0.874	7.21	0.802	-0.9
X2	8.29	0.686	8.71	0.611	-0.7
X3	9.35	0.606	9.36	0.633	0.0
X4	9.24	0.831	9.29	0.611	-0.1
X5	8.24	0.752	8.5	0.65	-0.4
X6	7.29	0.772	8	0.555	-1.3
X7	7.24	0.903	7.86	0.663	-0.9
X8	8.29	0.686	8.57	0.514	-0.5
X9	8.47	0.8	8.86	0.663	-0.6
X10	8.71	0.588	8.93	0.616	-0.4
X11	7.24	0.831	7.57	0.514	-0.6
X12	8	0.791	8.21	0.699	-0.3
X13	6.12	0.781	6.36	0.842	-0.3
X14	6.53	0.943	7.14	0.663	-0.9
X15	7.53	0.874	8	0.679	-0.7
X16	8.12	0.697	8.5	0.519	-0.7
X17	8.65	0.786	8.71	0.611	-0.1
X18	7.41	0.712	6.86	0.663	0.8
X19	8.76	0.831	8.57	0.756	0.3
X20	7.06	0.659	6.29	0.726	1.1
X21	6.41	0.795	5.71	0.611	1.1
X22	8.06	0.659	7.57	0.514	1.0
X23	6.53	0.874	7.14	0.663	-0.9
X24	9.06	0.748	9.07	0.616	0.0
X25	7.06	0.899	7.5	0.76	-0.6
X26	8.18	0.883	8.57	0.756	-0.5
X27	9.18	0.728	9.21	0.699	0.0
X28	9.12	0.697	9.14	0.77	0.0
X29	8.53	0.514	8.71	0.611	-0.3
X30	9.47	0.514	9.5	0.519	-0.1
X31	7.24	0.664	7.57	0.938	-0.4
X32	8	0.612	8.5	0.519	-1.0
X33	9.41	0.507	9.43	0.646	0.0
X34	8.94	0.748	8.86	0.77	0.1
X35	6.35	0.702	7	0.784	-0.8
X36	8.88	0.697	8.64	0.745	0.3

Table C.3: Z - Scores for Consultant-Public Group (C) relative to Group (D)

	Gr C:		**Gr D:**		
	Mean	SD	Mean	SD	**Z-Score**
X1	8	0.756	7.21	0.802	1.0
X2	6.75	0.707	8.71	0.611	-3.2
X3	8.75	0.463	9.36	0.633	-1.0
X4	8.87	0.641	9.29	0.611	-0.7
X5	7.63	0.916	8.5	0.65	-1.3
X6	7.38	0.744	8	0.555	-1.1
X7	8	0.756	7.86	0.663	0.2
X8	8.38	0.518	8.57	0.514	-0.4
X9	8.63	0.518	8.86	0.663	-0.3
X10	8.5	0.926	8.93	0.616	-0.7
X11	7.88	0.991	7.57	0.514	0.6
X12	8.38	0.744	8.21	0.699	0.2
X13	6.38	0.744	6.36	0.842	0.0
X14	7.13	0.641	7.14	0.663	0.0
X15	7.75	0.707	8	0.679	-0.4
X16	8.63	0.518	8.5	0.519	0.3
X17	8.75	0.463	8.71	0.611	0.1
X18	7.63	0.518	6.86	0.663	1.2
X19	8.38	0.518	8.57	0.756	-0.3
X20	6.75	0.707	6.29	0.726	0.6
X21	6	0.756	5.71	0.611	0.5
X22	6.63	0.518	7.57	0.514	-1.8
X23	7.63	0.518	7.14	0.663	0.7
X24	8.38	0.744	9.07	0.616	-1.1
X25	7.75	0.707	7.5	0.76	0.3
X26	7.88	0.835	8.57	0.756	-0.9
X27	8.63	0.518	9.21	0.699	-0.8
X28	8.5	0.535	9.14	0.77	-0.8
X29	8	0.756	8.71	0.611	-1.2
X30	9	0.756	9.5	0.519	-1.0
X31	5.75	0.707	7.57	0.938	-1.9
X32	6.13	0.835	8.5	0.519	-4.6
X33	9.13	0.641	9.43	0.646	-0.5
X34	8.25	0.707	8.86	0.77	-0.8
X35	7.88	0.641	7	0.784	1.1
X36	8.13	0.835	8.64	0.745	-0.7

Table C.4: Z - Scores for Contractor-Public Group (E) relative to Group (D)

	Gr E:		**Gr D:**		
	Mean	SD	Mean	SD	**Z-Score**
X1	7.91	1.044	7.21	0.802	0.9
X2	6.09	0.831	8.71	0.611	-4.3
X3	9.09	0.701	9.36	0.633	-0.4
X4	9.18	0.603	9.29	0.611	-0.2
X5	8.91	0.701	8.5	0.65	0.6
X6	5.82	0.874	8	0.555	-3.9
X7	8.09	0.701	7.86	0.663	0.3
X8	8.45	0.82	8.57	0.514	-0.2
X9	8.73	0.647	8.86	0.663	-0.2
X10	8.27	0.647	8.93	0.616	-1.1
X11	6	0.894	7.57	0.514	-3.1
X12	8	0.632	8.21	0.699	-0.3
X13	6.45	1.036	6.36	0.842	0.1
X14	6.55	0.82	7.14	0.663	-0.9
X15	7.91	0.944	8	0.679	-0.1
X16	8.09	0.831	8.5	0.519	-0.8
X17	8.18	0.751	8.71	0.611	-0.9
X18	8.09	0.831	6.86	0.663	1.9
X19	8.36	0.674	8.57	0.756	-0.3
X20	8	0.775	6.29	0.726	2.4
X21	8.18	0.603	5.71	0.611	4.0
X22	8.27	0.647	7.57	0.514	1.4
X23	8	0.775	7.14	0.663	1.3
X24	8.82	0.603	9.07	0.616	-0.4
X25	8.36	0.674	7.5	0.76	1.1
X26	8.45	0.522	8.57	0.756	-0.2
X27	9	0.775	9.21	0.699	-0.3
X28	8.91	0.701	9.14	0.77	-0.3
X29	8.55	0.522	8.71	0.611	-0.3
X30	9.27	0.786	9.5	0.519	-0.4
X31	5.55	0.688	7.57	0.938	-2.2
X32	5.55	0.522	8.5	0.519	-5.7
X33	9.36	0.674	9.43	0.646	-0.1
X34	8.73	0.647	8.86	0.77	-0.2
X35	8.27	0.786	7	0.784	1.6
X36	8.64	0.505	8.64	0.745	0.0

Table C.5: Z - Scores for Contractor-Private Group (F) relative to Group (D)

	Gr F:		**Gr D:**		
	Mean	SD	Mean	SD	**Z-Score**
X1	6.31	0.873	7.21	0.802	-1.1
X2	8.25	1.065	8.71	0.611	-0.8
X3	9.25	0.577	9.36	0.633	-0.2
X4	9.19	0.544	9.29	0.611	-0.2
X5	8.94	0.68	8.5	0.65	0.7
X6	7.25	1.183	8	0.555	-1.4
X7	8.69	0.946	7.86	0.663	1.3
X8	8.75	0.683	8.57	0.514	0.4
X9	8.88	0.806	8.86	0.663	0.0
X10	8.63	0.719	8.93	0.616	-0.5
X11	6.13	0.806	7.57	0.514	-2.8
X12	7.31	0.704	8.21	0.699	-1.3
X13	5.75	0.577	6.36	0.842	-0.7
X14	6.19	0.75	7.14	0.663	-1.4
X15	8.19	0.911	8	0.679	0.3
X16	8.5	0.894	8.5	0.519	0.0
X17	8.56	0.727	8.71	0.611	-0.2
X18	8.25	0.683	6.86	0.663	2.1
X19	8.69	0.602	8.57	0.756	0.2
X20	7.88	0.719	6.29	0.726	2.2
X21	7.06	0.68	5.71	0.611	2.2
X22	8.31	0.602	7.57	0.514	1.4
X23	6.94	0.929	7.14	0.663	-0.3
X24	9	0.632	9.07	0.616	-0.1
X25	7.38	0.806	7.5	0.76	-0.2
X26	8.75	0.683	8.57	0.756	0.2
X27	9.13	0.806	9.21	0.699	-0.1
X28	9.06	0.68	9.14	0.77	-0.1
X29	8.81	0.75	8.71	0.611	0.2
X30	9.38	0.5	9.5	0.519	-0.2
X31	7.63	0.806	7.57	0.938	0.1
X32	7.88	0.957	8.5	0.519	-1.2
X33	9.31	0.602	9.43	0.646	-0.2
X34	8.94	0.772	8.86	0.77	0.1
X35	6.25	0.931	7	0.784	-1.0
X36	8.88	0.719	8.64	0.745	0.3

Criteria notation descriptions

Criteria No.	Criteria description	Criteria No.	Criteria description
X1	Project's cost	X18	Consultant technical capacity.
X2	Client’s experience, its representatives' capacity and qualifications.	X19	Completeness and clarity of documents.
X3	Type of client.	X20	Consultant's past experience in similar projects.
X4	Client's financial power and funds availability.	X21	Consultant's past history in conflicts with contractors.
X5	Client's priorities in construction and amongst the project's objectives.	X22	Speediness of replies to contractor's queries and approvals.
X6	Required level of quality.	X23	Construction type (residential or administrative).
X7	Client's historical dispute records.	X24	Complexity of the project.
X8	Speed of decision making.	X25	Project's foot print.
X9	Client's tendency for changes.	X26	Project's total built up area.
X10	Contractor's grade.	X27	Number of stories.
X11	Financial capabilities.	X28	Number of basements.
X12	Managerial capabilities.	X29	Floor height.
X13	Project manager qualifications.	X30	Economical conditions.
X14	Staff and labors qualifications.	X31	Cultural factors.
X15	Plants and equipments.	X32	Legal factors.
X16	Technical capabilities and Method of construction.	X33	Political factors.
X17	Contractor's past experience in similar projects.	X34	Construction site conditions.
		X35	Availability of services.
		X36	Availability of resources.

APPENDIX (D)
STATISTICAL ANALYSIS

Table D.1: Calculated Weight Score Method for Client-Public Group (A)

Factor	5	6	7	8	9	10	Weighted Score
1	0	0	0	3	3	1	24.2
2	0	2	1	3	1	0	20.6
3	0	0	0	0	5	2	25.8
4	0	0	0	0	4	3	26.2
5	0	0	0	1	4	2	25.4
6	0	2	3	2	0	0	19.4
7	0	0	1	4	2	0	22.6
8	0	0	1	3	3	0	23.0
9	0	0	0	4	3	0	23.4
10	0	0	0	5	2	0	23.0
11	0	1	3	3	0	0	20.2
12	0	0	2	3	2	0	22.2
13	0	2	3	2	0	0	19.4
14	0	1	4	2	0	0	19.8
15	0	0	1	5	1	0	22.2
16	0	0	2	3	2	0	22.2
17	0	0	2	2	3	0	22.6
18	0	0	3	3	1	0	21.4
19	0	0	0	4	3	0	23.4
20	0	2	3	2	0	0	19.4
21	2	3	2	0	0	0	16.7
22	0	3	3	1	0	0	18.7
23	0	0	0	5	2	0	23.0
24	0	0	0	1	4	2	25.4
25	0	0	1	2	4	0	23.4
26	0	0	0	2	4	1	24.6
27	0	0	0	1	2	4	26.2
28	0	0	0	0	5	2	25.8
29	0	0	0	1	5	1	25.0
30	0	0	0	0	3	4	26.6
31	4	3	0	0	0	0	15.1
32	3	3	1	0	0	0	15.9
33	0	0	0	0	2	5	27.0
34	0	0	0	2	3	2	25.0
35	0	2	4	1	0	0	19.0
36	0	0	0	3	4	0	23.8
Tot	9	24	40	73	77	29	

Table D.2: Calculated Weight Score Method for Client-Private Group (B)

Factors	5	6	7	8	9	10	Weighted Score
1	0	0	0	8	9	0	23.7
2	0	0	2	8	7	0	23.0
3	0	0	0	1	9	7	26.0
4	0	0	0	4	5	8	25.7
5	0	0	3	7	7	0	22.9
6	0	2	9	5	1	0	20.3
7	0	4	6	6	1	0	20.1
8	0	0	2	8	7	0	23.0
9	0	0	2	6	8	1	23.5
10	0	0	0	6	10	1	24.2
11	0	3	8	5	1	0	20.1
12	0	0	5	7	5	0	22.2
13	3	10	3	1	0	0	17.0
14	3	4	8	2	0	0	18.1
15	0	2	6	7	2	0	20.9
16	0	0	3	9	5	0	22.5
17	0	0	1	6	8	2	24.0
18	0	2	6	9	0	0	20.6
19	0	0	1	5	8	3	24.3
20	0	3	10	4	0	0	19.6
21	2	7	7	1	0	0	17.8
22	0	0	3	10	4	0	22.4
23	2	6	7	2	0	0	18.1
24	0	0	0	4	8	5	25.2
25	0	5	7	4	1	0	19.6
26	0	0	0	5	9	3	24.7
27	0	0	0	3	8	6	25.5
28	0	0	0	3	9	5	25.3
29	2	7	6	2	0	0	18.0
30	0	0	0	0	9	8	26.3
31	0	2	9	6	0	0	20.1
32	0	0	3	11	3	0	22.2
33	0	0	0	0	10	7	26.1
34	0	0	0	5	8	4	24.8
35	2	7	8	0	0	0	17.6
36	0	0	4	7	5	1	22.7
Tot	14	64	129	177	167	61	

Table D.3: Calculated Weight Score Method for Consultant-Public Group (C)

Factors	5	6	7	8	9	10	Weighted Score
1	0	0	2	4	2	0	22.2
2	0	3	4	1	0	0	18.8
3	0	0	0	2	6	0	24.3
4	0	0	0	2	5	1	24.7
5	0	1	2	4	1	0	21.2
6	0	1	3	4	0	0	20.5
7	0	0	2	4	2	0	22.2
8	0	0	0	5	3	0	23.3
9	0	0	0	3	5	0	24.0
10	0	0	1	3	3	1	23.6
11	0	1	1	4	2	0	21.9
12	0	0	1	3	4	0	23.3
13	1	3	4	0	0	0	17.7
14	0	1	5	2	0	0	19.8
15	0	0	3	4	1	0	21.5
16	0	0	0	3	5	0	24.0
17	0	0	0	2	6	0	24.3
18	0	0	3	5	0	0	21.2
19	0	0	0	5	3	0	23.3
20	0	3	4	1	0	0	18.8
21	2	4	2	0	0	0	16.7
22	0	3	5	0	0	0	18.4
23	0	0	3	5	0	0	21.2
24	0	0	1	3	4	0	23.3
25	0	0	3	4	1	0	21.5
26	0	0	2	3	3	0	22.6
27	0	0	0	3	5	0	24.0
28	0	0	0	4	4	0	23.6
29	0	0	2	4	2	0	22.2
30	0	0	0	2	4	2	25.0
31	3	4	1	0	0	0	16.0
32	2	3	3	0	0	0	17.0
33	0	0	0	1	5	2	25.3
34	0	0	1	4	3	0	22.9
35	0	0	2	5	1	0	21.9
36	0	1	0	6	1	0	21.9
Tot	8	28	60	105	81	6	

Table D.4: Calculated Weight Score Method for Consultant-Private Group (D)

Factors	5	6	7	8	9	10	Weighted Score
1	0	0	0	5	8	1	24.2
2	0	0	0	5	8	1	24.2
3	0	0	0	1	7	6	26.0
4	0	0	0	1	8	5	25.8
5	0	0	1	5	8	0	23.6
6	0	0	2	10	2	0	22.2
7	0	0	4	8	2	0	21.8
8	0	0	0	6	8	0	23.8
9	0	0	0	4	8	2	24.6
10	0	0	0	3	9	2	24.8
11	0	0	6	8	0	0	21.0
12	0	0	2	7	5	0	22.8
13	2	6	5	1	0	0	17.7
14	0	2	8	4	0	0	19.8
15	0	0	3	8	3	0	22.2
16	0	0	0	7	7	0	23.6
17	0	0	0	5	8	1	24.2
18	0	4	8	2	0	0	19.0
19	0	0	1	5	7	1	23.8
20	2	6	6	0	0	0	17.5
21	5	8	1	0	0	0	15.9
22	0	0	6	8	0	0	21.0
23	0	2	8	4	0	0	19.8
24	0	0	0	2	9	3	25.2
25	0	1	6	6	1	0	20.8
26	0	0	1	4	8	1	24.0
27	0	0	0	2	7	5	25.6
28	0	0	0	3	6	5	25.4
29	0	3	5	6	0	0	20.0
30	0	0	0	0	7	7	26.4
31	0	2	4	6	2	0	21.0
32	0	0	0	7	7	0	23.6
33	0	0	0	1	6	7	26.2
34	0	0	0	5	6	3	24.6
35	0	4	6	4	0	0	19.4
36	0	0	1	5	7	1	23.8
Tot	9	38	84	158	164	51	

Table D.5: Calculated Weight Score Method for Contractor-Public Group (E)

Factors	5	6	7	8	9	10	Weighted Score
1	0	0	0	5	6	0	23.7
2	3	4	4	0	0	0	16.9
3	0	0	0	2	6	3	25.3
4	0	0	0	1	7	3	25.5
5	0	0	0	3	6	2	24.7
6	5	3	3	0	0	0	16.2
7	0	0	2	6	3	0	22.5
8	0	0	1	5	4	1	23.5
9	0	0	0	4	6	1	24.2
10	0	0	1	6	4	0	23.0
11	4	3	4	0	0	0	16.7
12	0	0	2	7	2	0	22.2
13	2	4	3	2	0	0	17.9
14	1	4	5	1	0	0	18.2
15	0	1	2	5	3	0	22.0
16	0	0	3	4	4	0	22.5
17	0	0	2	5	4	0	22.7
18	0	0	3	4	4	0	22.5
19	0	0	1	5	5	0	23.2
20	0	0	3	5	3	0	22.2
21	0	0	1	7	3	0	22.7
22	0	0	1	6	4	0	23.0
23	0	0	3	5	3	0	22.2
24	0	0	0	3	7	1	24.5
25	0	0	1	5	5	0	23.2
26	0	0	0	4	7	0	24.0
27	0	0	0	3	5	3	25.0
28	0	0	0	3	6	2	24.7
29	0	1	3	3	4	0	22.0
30	0	0	0	2	4	5	25.8
31	6	4	1	0	0	0	15.4
32	5	6	0	0	0	0	15.4
33	0	0	0	1	5	5	26.0
34	0	0	0	4	6	1	24.2
35	0	0	2	4	5	0	23.0
36	0	0	0	6	5	0	23.5
Tot	26	30	51	126	136	27	

Table D.6: Calculated Weight Score Method for Contractor-Private Group (F)

Factors	5	6	7	8	9	10	Weighted Score
1	0	0	0	6	7	3	24.5
2	0	1	3	4	7	1	22.9
3	0	0	0	1	10	5	25.7
4	0	0	0	1	11	4	25.5
5	0	0	0	4	9	3	24.8
6	2	2	3	8	1	0	20.1
7	0	0	1	7	4	4	24.1
8	0	0	0	6	8	2	24.3
9	0	0	1	3	9	3	24.7
10	0	0	1	5	9	1	24.0
11	4	6	6	0	0	0	17.0
12	0	2	7	7	0	0	20.3
13	5	10	1	0	0	0	16.0
14	3	7	6	0	0	0	17.2
15	0	0	4	6	5	1	22.7
16	0	0	2	6	6	2	23.6
17	0	0	1	6	8	1	23.8
18	0	0	2	8	6	0	22.9
19	0	0	0	6	9	1	24.1
20	0	0	5	8	3	0	21.9
21	0	3	9	4	0	0	19.6
22	0	0	1	9	6	0	23.1
23	1	4	6	5	0	0	19.3
24	0	0	0	3	10	3	25.0
25	0	2	7	6	1	0	20.5
26	0	0	0	5	8	3	24.7
27	0	0	0	4	6	6	25.3
28	0	0	0	3	9	4	25.2
29	3	6	6	1	0	0	17.5
30	0	0	0	0	10	6	26.0
31	0	1	6	7	2	0	21.2
32	0	2	2	8	4	0	21.9
33	0	0	0	1	9	6	25.9
34	0	0	0	5	7	4	24.8
35	4	5	6	1	0	0	17.4
36	0	0	0	6	8	2	24.3
Tot	22	51	86	160	192	65	

APPENDIX (E)

PROPOSED PROJECT DURATION PREDICTION FORM FOR COMMERCIAL BUILDINGS

Project title and location

Owner name

Consultant name

Contractor name

Date

---

1. Project's cost

L.E. …………….million

2. Client's Characteristics

2.1 Client's Type

Public Sector---

Private Sector ---

Public/Private Partnership--

2.2 Financial Soundness

Bank references --

Financial statement --

Credit rating --

Bank arrangement --

Liquidity (Retained cash for the project) ---

Total project value --

% of retained cash ---

Evidences of cash retained for the project ---

Past financial disputes---

Pending or threatened litigations affect the client's financial position -----------------------

----

2.3 Tendency for Changes

Total number of client's previous projects---

Number of projects extended due to the client's variations-----------------------------------

% of extended projects due to client's direct variation orders--------------------------------

3. Completeness and clarity of Tender documents

Total number of consultant's previous projects--

Number of consultant's previous projects extended due to the incompleteness, in clarity, or ambiguity of the contract documents --

----

% of consultant's previous projects extended due to the incompleteness, in clarity, or ambiguity of the contract documents issued by him---

----

4. Project's Characteristics

4.1 Project's complexity

Project's normality (i.e. Number of previous similar projects executed by the party)---

----

Project's design is untraditional ---

Project's constructability is untraditional (irregular method of construction) ---------------

----

Utilization of untraditional materials for construction--

4.2 Number of stories

Number of stories (above ground level) --

4.3 Number of basements

Number of basement floors ---
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5. Environmental Conditions

5.1 Economical conditions

% of Economical growth --

% of Inflation rate --

% of unemployment---

% of increase in foreign currency reserve--

% of decrease in expenditures balance --

% of increase in foreign trade balance (export – import)------------------------------------
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% of increase in governmental expenditures dedicated for infrastructure projects
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5.2 Political conditions

Country's political stability (absence of any aspect of troubles like: wars, rebellion, terrorism, sabotage, revolutions, riot, commotions, disorders, etc ------------------------

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Existence of solid external relations with the other countries -----------------------------

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Existence of solid internal political structure---

Existence of solid internal social structure--

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6. Construction site Suitability

6.1 Construction site conditions

Project location ---

Existence of transportation---

Access roads --

Soil type ---

Under ground water table---

Availability of mobilization area---

Applicable laws, regulations, permits and authorizations procedures -----------------------

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6.2 Availability of resources

There is a concrete batch plant near the site location --

There are sand and stone quarries near the site location ------------------------------------

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There are skilled and unskilled labors near the site location --------------------------------

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The local and imported materials and supplies are easy to deliver to site on their due dates---