Utilizing Soft Computing Methods in Analyzing Build-Operate-Transfer (BOT) Contracts

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

PhD
in
Civil Engineering

Eastern Mediterranean University
September 2015
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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ABSTRACT

An objective Build-Operate-Transfer (BOT) contract evaluation at the conceptual stage, in countries facing budget constraints, will lead to undertaking projects which are anticipated to be viable in the future. An objective analysis of various risk variables and their impact on a BOT project's future outcome requires study and integration of many likely scenarios into the contract terms, which is complicated and time-consuming. If the process of examining the financial parameters and uncertainties of a BOT project could be automated, this would be a milestone in objective decision-making from various stakeholders' points of view. A soft computing model would let the user analyze many probable scenarios more accurately.

In this study two soft computing methods, artificial neural network (ANN) and gene expression programming (GEP) are applied onto two distinct BOT case studies to illustrate automation of their assessment processes.

First a case study of BOT model on dormitory projects in Cyprus is analyzed. An ANN model with correlation coefficient of 0.9064 is developed to model the relationship between important project parameters and risk variables. Significant factors, used in ANN model development, were extracted from sensitivity analysis and Monte Carlo simulation results obtained from conventional spreadsheet data. The resulting consensus based on this model would yield to fair contractual agreements for both the government and the concession company.

Second financial viability of undertaking a BOT contract for sewer and water projects in California, USA is analyzed. Furthermore by aid of sensitivity analysis, risk parameters are identified. Sensitivity analysis results demonstrated that project construction cost factor determines the financial viability of undertaking a BOT contract. Therefore, reliable construction cost prediction, based on limited information, at early stages of the project planning phase is crucial for development of an objective BOT agreement. This study utilized gene expression programming (GEP) which is a derivative of genetic algorithm (GA) and genetic programming (GP), and developed a prediction model with correlation coefficient of 0.8467 for estimating the construction cost of water and sewer rehabilitation/replacement projects.

Contribution of this thesis to knowledge is by exploiting ANN model's capability to incorporate many scenarios, we developed an automated tool to define concession terms considering potential risks; and by utilizing GEP model 's ability to create an explicit equation, we developed a formula for a project construction cost prediction to help improve objective financial appraisal of a BOT project.

Author keywords: Public-Private-Partnership; Build-Operate-Transfer; Monte Carlo simulation; Contracts; Cost Estimation; Artificial Neural Network; Gene Expression programming; Dormitory Projects; Water and Sewer Replacement/Rehabilitation Projects.

ÖZ

Bütçe kısıtlamalarıyla karşı karşıya ülkelerde objektif Yap-İşlet-Devret (YİD) sözleşmelerinin kavramsal aşamada değerlendirilmesi, gelecekde positive degerli projelerin uygulamasina yol açacaktır. Çeşitli risk değişkenleri ve YİD projenin gelecek, sonuclarin üzerindeki etkileri objektif bir analiz yapmak karmaşık ve zaman alıcıdır; çünkü sözleşme şartları içine birçok muhtemel senaryolar entegrasyonunu gerektirir. YİD projenin mali parametreleri ve çeşitli belirsizliklerin incelenme süreci otomatik olursa, bu yaklaşım birçok paydaşların objektif belirleme açısından bir dönüm noktası olabilir. Soft Computing modelleri kullanıcıya daha çok senaryoları analiz etmesine izin verdiyi icin, objective karar vermesine yol vermekdedir. Bu çalışmada iki Soft Computing yöntemleri, Yapay Sinir Ağları (ANN) ve Gen tabir programlama (GEP), projelerin etkili parametrelerini belirlemek için, uygulanmiştir.

İlk Kıbrıs'ta yurt projelerinde YİD modelinin bir vaka çalışması analiz edildi. 0.9064 korelasyon katsayısı ile bir YİD modeli önemli proje parametrelerinin ve risk değişkenler arasındaki ilişkiyi modellemek için geliştirildi. YİD modelinde kullanılan önemli faktörler, Hassasiyet analizi ve Monte Carlo simülasyonun konvansiyonel elektronik tablo verilerinin uzerine yapilan sonuçlara dayanarak geliştirilmiştir. Bu modele dayalı ortaya çıkan uzlaşma, hükümet ve imtiyaz şirketine adil sözleşme ortami doğuracaktir.

Bu araştimada, bir de Kaliforniya ABD kanalizasyon ve su projeleri için YİD sözleşmesinin finansal kapasitesi analiz edildi. Ayrıca hassasiyet analizi yardımıyla, risk parametreleri belirlenmiştir. Hassasiyet analizi sonuçları YİD projenin inşaat maliyetinin mali geliri belirleyen factor oldugunu göstermiştir. Bu nedenle, proje planlama aşamasının sınırlı bilgiye dayalı, güvenilir inşaat maliyet tahmini, objektif bir YİD sözleşmesi gelişimi için çok önemlidir. Bu çalışmada kullanılan Gen tabir programlama (GEP) model sonucunda su ve kanalizasyon rehabilitasyonu / değiştirme projelerinin inşaat maliyetini tahmin etmek için 0.8467 korelasyon katsayısı ile tahmin modeli geliştirmiştir.

Bu tezin bilgiye katkisi, birçok senaryolari dahil etmekle, ANN modelin yeteneğini kullanarak, potansiyel riskleri göz önüne alarak, sözleşme terimleri tanımlamak için otomatik bir araç geliştirdi; ve basit bir denklem oluşturmakla GEP modelin yeteneğini kullanarak, bir YİD projenin mali değerlendirmeye yardımcı olmak üzere inşaat maliyet tahmini için bir formül geliştirdi.

Anahtar Kelimeler: Kamu-Özel-Ortaklığı; Yap-İşlet-Devret (YİD); Monte Carlo simülasyonu; Sözleşmeler; Maliyet Tahmini; Yapay Sinir Ağları (ANN); Gen tabir programlama (GEP); Yurt Projeleri; Su ve Kanalizasyon Yedek / Rehabilitasyon Projeleri.

ACKNOWLEDGMENTS

I would like to thank my PhD supervisor, Professor Dr. Tahir Çelik for supporting me on this journey. I have learned from him to be professional, curious, persistent and enthusiastic about pursuing a dream.

I will forever remain thankful to Professor Dr. Glenn Jenkins for expanding my horizon, providing opportunities for my career growth and teaching useful tools and techniques which formed the core of my research.

I am also very grateful to Dr. Amir H. Gandomi for his help and scientific advice. Without his help I would not have been able to succeed.

I thank Dr. Iman Aghayan for his suggestions and helping me form this research.

I also am thankful to the members of my PhD committee, Professor Drs Talat Birgönül, Atilla Dikbaş, Ibrahim Yitmen, Mehmedali Egemen for their time, helpful advice and suggestions in general.

I thank EMU and especially Civil Engineering department staff for being helpful, and friendly. Their lifelong friendships mean a lot to me.

I thank Bijan Shakiba for helping me obtain necessary data for my dissertation.

I thank Ortiz Corporation family for their supports and being a home away from home.

I thank all my dear friends for providing support and friendship and rooting for me throughout these past years.

I am grateful to my aunt Rana who has always been present and supportive in every aspect of my life.

I deeply thank my mother, father, and brother. My caring parents have sacrificed their lives for my brother and me; and provided insight, unconditional love and support. I would not have made it this far without them. My brother is my best friend and has always made me feel like I am home again. I thank him for always being there for me.

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INTRODUCTION TO RESEARCH

1.1 Introduction

In recent years, awareness of the sustainability aspects of infrastructure projects has been increasing around the world. Making infrastructure projects technologically aware and adaptable to changes while meeting user needs normally increases total project cost (ASHRAE, 2006).

‘Infrastructure’ is defined as the basic physical and organizational structures and facilities necessary for the operation of a society. Infrastructures are basic services to industry and households. They are key inputs into the economy and crucial inputs into economic growth. However, what is ‘basic’, ‘key’ and ‘crucial’ differs based on timing and each country’s needs.

Motorways, tunnels, bridges, government office accommodation, hospitals, schools, prisons, social housing, waste management systems, etc, are among infrastructure facilities (Grimsey & Lewis, 2004).

In case of inadequate public funds and the scarce financing opportunities with economies under transition, a public-private partnership (PPP) offers a better means to achieve sustainability goals (Akintoye, et al., 2003) (Grimsey & Lewis, 2004). Furthermore, private sector may perform better and undertake the pertinent risks more successfully. Typically, government prefers to establish a long-term partnership to motivate the contractor to accelerate the construction phase and to consider the whole project life cycle to reduce energy consumption, minimize waste, and decrease operating and maintenance costs. This approach prevents the contractor from reducing short-term construction cost at the expense of long-term value (Grimsey & Lewis, 2004) (Yang, et al., 2007).

One of the most popular PPP options is the Build-Operate-Transfer agreement (BOT), which is based on a defined concession method, which uses private-sector resources to design, build, finance, refurbish, operate, and maintain infrastructure facilities (Grimsey & Lewis, 2004). Government may keep ownership of the facility for the duration of the concession or gain it when the construction phase is complete, or when concession period is over at no cost and free of liens; the government will run the facility after the handover (Grimsey & Lewis, 2004) (Xenidis & Angelides, 2005). In exchange, the concessionaire will recoup its capital investment from operating revenue during the concession period (Zhang & Kumaraswamy, 2001).

Because several stakeholders are party to BOT projects and a long period of time may be required to complete the contract, many uncertainties and risks threaten the performance of BOT agreements (Shen & Wu, 2005); thus a defined and stable legal and regulatory environment is absolutely necessary (Yuan, et al., 2010). In PPP projects, uncertainty or stipulating renegotiation options in contracts may create serious problems, such as opportunistic bidding policies to increase the probability of winning the bid (Chen, et al., 2012). The acceptance of a renegotiation petition is equivalent to a possible claim. Jeopardizing public resources by expecting the government to bail out a troubled project company is out of the question, especially in cases of cost overruns or unexpected operating costs due to unqualified management (Ho, 2006).Therefore, it is of crucial importance to allocate risk objectively and to identify concession terms in a clear and mutually acceptable manner. To obtain consensus during a contract negotiation phase, various combinations of concession terms must be evaluated and many probable scenarios must be studied. This typically involves repeated recalculation of conventional financial analysis, which is a time-consuming and complex method. If the process of evaluating the financial parameters and uncertainties of a BOT project could be automated, this would be a milestone in objective decision-making from various stakeholders' point of views.

Statistical soft computing models based on machine learning have been vastly implemented to solve a vast spectrum of optimization, classification or prediction problems in different science and engineering applications (Gandomi & Alavi, 2009) (Yaghouby, et al., 2010) (Yaghouby, et al., 2012) (Azamathulla & Ahmad, 2013) (Najafzadeh & Azamathulla, 2015) (Gandomi, et al., 2014). One of such models that could be used to automate the decision making scenario is the artificial neural network (ANN) (Jin & Zhang, 2011) (Sodikov, 2005). ANN models have been particularly successful in developing nonlinear data relationships and in enhancing estimates to make more related data available (Emsley, et al., 2002).

ANNs are renowned pattern recognition systems that are able to learn from experience. ANNs are vastly implemented in cost estimating of building and infrastructure projects (Tatari & Kucukvar, 2011). The ANN approach has been widely used to predict costs in various disciplines where data can be obtained, especially in construction projects (Baalousha & Çelik, 2011) (Kim, et al., 2004) (Gunaydin & Dogan, 2004) (Fazly, et al., 2014). ANN models are capable of learning and simulating elaborate applications (Weckman, et al., 2010). Applications of artificial intelligence and statistical techniques in different fields of applications are carefully reviewed by various researchers. These reviews show that artificial neural networks outperform regression models when used for classification and prediction (Paliwal & Kumar, 2009) (Kim, et al., 2004) (Yaghouby, et al., 2009) (Gandomi & Alavi, 2009) (Alavi & Gandomi, 2011) (Hasanzadehshooiili, et al., 2012).

In this research, a neural network model was used to develop a model that formulates the relationship between the project's important parameters or risk variables. These were extracted by conducting sensitivity analysis and Monte Carlo simulation on conventional spreadsheet data to reach a fair consensus to the government as well as to the concession company. This technique was used on data obtained from six actual BOT dormitory projects in Cyprus as a case study to demonstrate the procedure.

Genetic algorithm (GA) is another machine learning tool, and one of the robust optimization approaches and a search algorithm which imitates the process of natural selection in the concept of evolution (Gandomi & Alavi, 2011). GA is considered to be efficiently applicable to vast spectrum of different engineering problems (Milani & Milani, 2008).

John Koza (Koza, 1992) is the first scientist who introduced application of Genetic Programming (GP) to the realm of solving complex problems. GP is a derivative of GA. In GP, population of computer programs are bred, meaning each individual in GP is a computer program where in GA, the population is a set of individual mathematical objects (binary strings) (Banzhaf, et al., 1998). GP is a nonlinear structured alternative to fixed length solutions (Ferreira, 2006). GP borrows Darwin's theory of evolution, expressed as "survival of the fittest". Population of computer programs (individuals) continues reproducing with each other till the best individuals will survive and finally evolve to perform well in the specified scenario (Walker, 2001).

GP's ability to develop simple prediction equations with no need to considering an existing relationship is its main superiority over the conventional statistical and ANN techniques (Gandomi, et al., 2012). When the analyst creates an equation, applicability and validity of the model is more discernible since an equation can check with common sense especially in the case of proposals requiring acquisition of management and owner approval (Smith & Mason, 2010).

A new variant of GP is Gene expression programming (GEP) which was introduced by Ferreira. The GEP is able to evolve computer programs of different sizes and shapes. GEP is extremely adaptable and supersedes the existing evolutionary techniques (Ferreira, 2001). Several scientists applied GEP to construction and civil engineering realm (Alavi & Gandomi, 2011) (Gandomi, et al., 2011).

This study utilizes the GEP technique to develop a predictive model for cost estimation of water and sewer utility rehabilitation and replacement infrastructure projects to our best knowledge for the first time (Shahrara, et al., 2015. [Forthcoming]). The developed model considers readily available variables with substantial impact on the cost of the projects. Sensitivity analysis technique and professionals' experience were employed to determine the contributions of the qualitative factors and quantifiable parameters affecting the cost estimate.

1.2 Problem Statement and Research Justification

Although professional insight and experience play very important roles in making decisions about implementing PPP arrangements, an extensive and realistic evaluation of the future circumstances is necessary to convince the parties to undertake BOT type of procurement. Some earlier researchers had developed automated mechanisms in contract negotiating procedures. However, in these studies, either extensive risk allocation was not carried out (Ngee, et al., 1997), or the information on probable combinations of risk variables was inadequate (Shen & Wu, 2005). Some other researchers have used misleading decision-making criteria (Ng, et al., 2007). On the other hand, carrying out an objective project risk analysis requires a tool to help incorporate many probable scenarios into the determination of concession terms. This research is an attempt to introduce new tools into the realm of risk analysis to be able to expand the horizon of the decision maker by creating models to evaluate various probable scenarios that may occur in the future.

1.3 Research Question, Aim and Objectives

This research will attempt to answer to the question posed below:

How to improve examination of viability of undertaking BOT contracts in infrastructure development?

The aim of this research is to introduce methods to improve examination of viability of undertaking BOT contracts in infrastructure development. For this purpose, the following research objectives were fulfilled:

- Describe various PPP arrangements and incentives of undertaking them.

- Elaborate on BOT contracts in particular; basic characteristics of a viable BOT arrangement; its goals; its main participants and their roles.
- Provide typical steps of establishing, evaluating, procurement, and implementation of a BOT arrangement.
- Carry out examination of viability of a BOT project, by illustrating on two various case studies, by undertaking financial analysis and risk analysis.
- Based on the circumstances of a unique project, show and validate how soft computing methods can be employed to bring some level of certainty to prediction of the project's critical variables to help avoid many future risks, come up with appropriate solutions and mitigation plans, and be able to set well-founded and unbiased contractual agreements beforehand.
- By exploiting ANN model's capability to incorporate many scenarios, develop an automated tool to define concession terms considering potential risks.
- By utilizing GEP model‘s ability to create an explicit equation, develop a formula for construction cost prediction to help improve objective financial appraisal of a BOT project.

1.4 Scope of the Research

The scope of this study was to answer to the questions below:

- What are the steps and criteria to undertake a BOT project?
- What are the criteria to make a BOT successful?
- How to conduct investment appraisal for a BOT project?
- Is the project financially attractive?
- What are the risks involved and how to allocate them?

- How can we improve project appraisal by applying soft computing methods to be able to predict certain risky variable more accurately.

By taking steps to answer to the questions above, in one BOT case study, we developed one automated tool to define a BOT project's concession terms which takes potential project risks into consideration. And in another BOT case study , we developed an explicit formula for construction cost prediction. By usage of the results obtained from the mentioned developed prediction models, reliable financial appraisal of BOT projects would be possible.

1.5 Research Methodology

The thesis proceeds from reviewing PPP arrangements to the data requirements for a BOT evaluation, and at last to the analysis and management of uncertainties encountered by project stakeholders. For this purpose:

- An extensive literature review is furnished. Considerable literature from various sources such as relevant books, previous researches and academic studies, many completed PPP projects around the world, etc. were reviewed to obtain more information concerning the PPP arrangements especially BOT approach in infrastructure projects. The principles and methodology set forth in Glenn Jenkin et al.'s book (Jenkins, et al., 2011) provided valuable foundation of this research.
- Two illustrative case studies were used to demonstrate the proposed methodology in this thesis. Data related to these two case studies were collected from relevant government entities or management headquarters.

- In order to gain insight about infrastructure projects, BOT arrangement's impacts on the project outcome, its performance, and its achievements were scrutinized.
- Interviews were conducted with specialists who work at the government agencies, contracting companies; or individuals who are at the managerial board of operating facilities under BOT.
- Financial analysis models were developed using collected data.
- Financial cash flow statements of the projects were developed to generate expected stream of financial revenue, financial expenditures, and the difference between the two which gives net cash flow of the project during the project's life. Potential viability of the project can be determined when the financial cash flow statement of the project is complete. Several stakeholders are involved in a project whose concern is their own benefit, therefore separate financial cash flow statements need to be computed for each of these stakeholders.
- In order to adapt financial analysis to cover project uncertainties, risk analysis was conducted to determine the key risk variables.
- Depending on the circumstances of a project and based on the results of the projects' financial appraisal, two soft computing methods namely artificial neural network (ANN) and gene expression programming (GEP) are used to develop prediction models to help improve a project's evaluation. The developed ANN model is able to specify the BOT project's concession terms considering the potential project risks. The GEP model offers a simple formula to predict the construction cost of the project more accurately. These

two soft computing tools will help the professionals make decisions about BOT schemes more realistically by investing less time and effort.

- At the end, the measures are introduced to show how to allocate the identified risks to the parties who can better handle the risks.

1.6 Research Novelty and Contribution

This research attempted to introduce a framework for developing methods to improve assessment and evaluation of BOT infrastructure projects. Due to the capability of ANN model and GEP formulation to incorporate many more scenarios into the generated model, this research developed automated methods to improve objective prediction of risk variables. The ANN model could identify relationships between the project's concession terms and important parameters, and help create an accurate decision-making model, including an extensive risk analysis. GEP model with the capability of generating a formula for prediction of construction cost of a project can give the decision maker better insight and sense of reliability to the project's investment appraisal. To the best of our knowledge none of these soft computing methods have been used before to predict project risk variables (Shahrara, et al., 2015. [Forthcoming]) (Shahrara, et al., 2015. [Forthcoming]).

1.7 Guides to Thesis

This thesis consists of 8 chapters. Chapter 2 describes what PPP is, why it is implemented, what the characteristics of an effective PPP are, what the incentives of undertaking PPP are, how to examine applicability of a PPP approach on a certain project, on which public sectors PPP responds more successfully and why, and what the types of PPP are.

Chapter 3 explains what BOT arrangement is and how it was introduced first, what are the basic elements of a BOT arrangement, what are the types of the project which can be delivered through BOT, what are the initiatives behind selecting BOT, what are BOT goals, what are the typical arrangements and the types of payments on a BOT, common misconceptions about BOT, who are the primary participants, typical steps in establishing, evaluating, procurement and implementation of a BOT, financing methods, types of contractual arrangements in a BOT approach.

Chapter 4 provides an overall methodology used on this thesis. It will describe the steps taken to conduct the BOT projects' appraisal, how to conduct financial analysis, sensitivity analysis and the risk analysis. At last it will give a brief introduction about soft computing models which will be used to develop models for prediction of the project risk variables.

Chapter 5 gives a summary of different risk classifications that have been found in the literature. It touches upon typical risk response strategies as well.

Chapter 6 illustrates usage of a neural network model on BOT dormitory projects in Cyprus to exhibit developing a model that formulates the relationship between the project's important parameters or risk variables. This chapter provides the readers with the steps of project appraisal by building financial model, conducting sensitivity analysis and Monte Carlo simulation on conventional spreadsheet data, selection of input variables for ANN model, and ANN model details.

Chapter 7 illustrates how viability of undertaking a BOT project should be evaluated. For this purpose a case study of BOT approach in utility projects in California USA is examined. Then it shows how a GEP model would help improve accuracy of the project appraisal by developing a formula to be able to predict the most risky variable, which in this case study was construction cost of the project in this case study, more accurately at the conceptual stage.

Chapter 8 provides the conclusions drawn from this study, and recommendations for future studies.

The flowchart displayed in Figure 1.1 is a summary of the content of this thesis; and the steps of preparing a BOT contract proposed in this study.

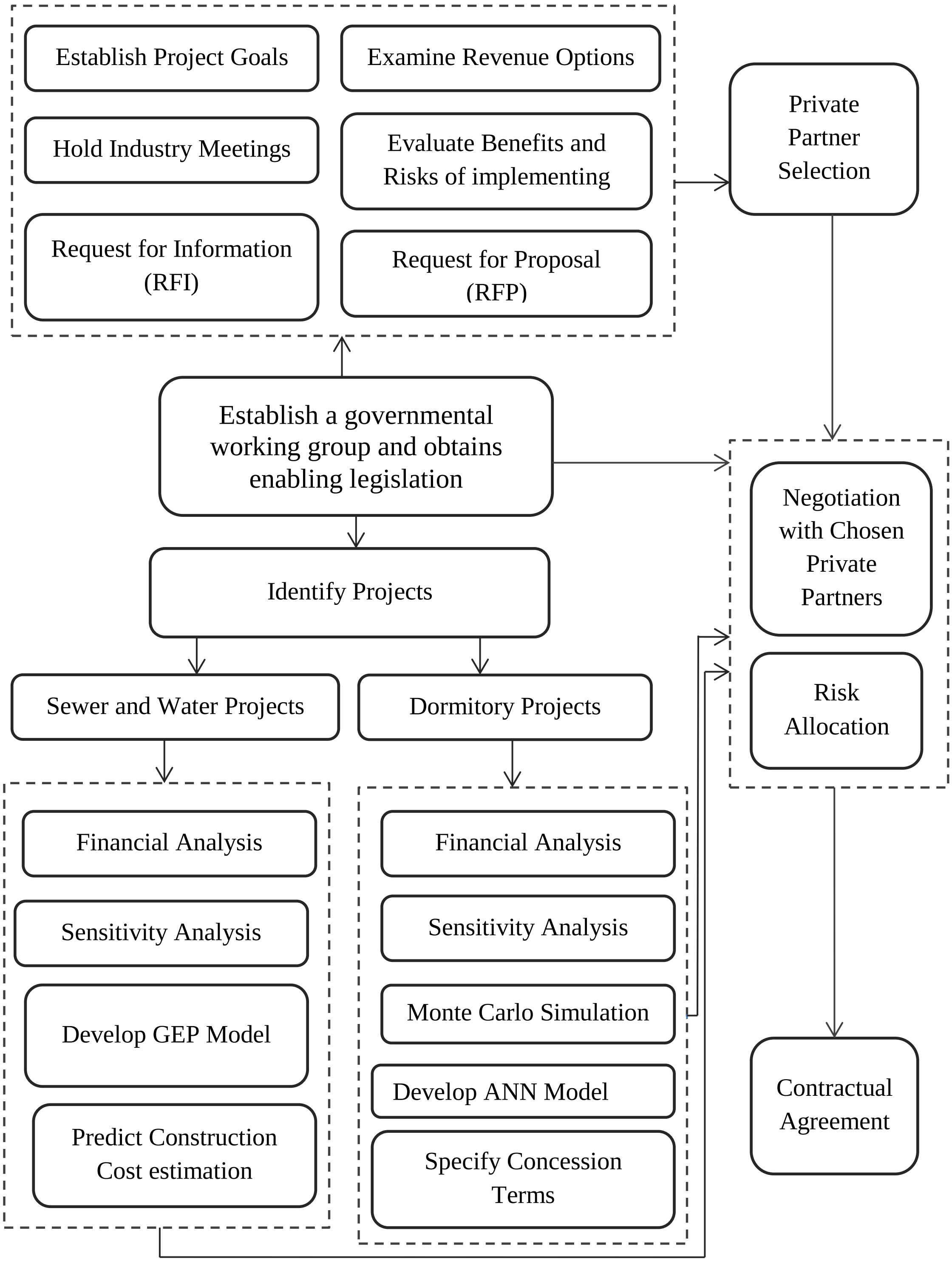


Figure 1.1: Steps of preparing BOT contracts

Chapter 2

PUBLIC PRIVATE PARTNERSHIPS

2.1 Introduction

In recent years, it has been observed that infrastructure development programs led by governments have not been successful. Furthermore, economic data analysis of twenty two countries over a decade depicted that higher amount of debt decreases the economic growth of the country and results in reduction in Gross Domestic Product (GDP) which is a measure of the economic wellbeing of a country (Reinhart, et al., 2012). Considering its existing debt, the government needs to take measures to decrease funding the country's major programs to be able to reduce accumulation of debt (Boccia, 2013). The necessity of reducing the impact of infrastructure investments on government budgets has introduced private capital markets for infrastructure funding purposes (Grimsey & Lewis, 2004). Furthermore, Public private Partnerships have been implemented realizing the importance of designing an environmentally sustainable building as well as its monetary value during the life of the building with consideration of whole-of-life cycle costing.

Familiar examples of PPPs are toll roads, rail roads, bridges, tunnels, water and wastewater facilities, hospitals, schools, prisons, fire and police. There is a misunderstanding about PPP projects that the private sector will only be financing a public infrastructure. However, financing is just one component. Public sector is acquiring a stream of services under specified terms and conditions.

Such arrangements have obvious virtues from economic point of view. Charging users for use of an infrastructure relates the revenue directly to the use of the facility, resulting in more effective and less political decisions. In other words, it will prevent excess or inefficient use (Grimsey & Lewis, 2004).

In effective PPPs the public and the private sectors each have particular potentials in undertaking certain activities. The government may invest capital obtained from tax revenue; or transfer land, property or facilities; or make similar improvements that support the partnership. The government also may organize and prioritize infrastructure projects; create civil obligations, environmental alertness, regional information, and political support. The private sector exploits its skills to manage, operate, and bring innovation to improve the development. Depending on the contract, the private partner may invest capital as well (Grimsey & Lewis, 2004).

The partnership should be structured in a way to allot risks to the parties who will be able to manage those risks well. This way the project costs will be optimized while performance will definitely be improved (Asian Development Bank, 2008).

The objective of this chapter is to present the nature of PPP arrangements. In this respect this chapter will outline the incentives of undertaking PPPs. It will depict how to examine applicability of PPP in a certain project; why undertaking PPP on some types of project are not successful; and how to examine success of undertaking PPP in a certain project,

2.2 Incentives to undertake PPPs

There are strong incentives to undertake a PPP in various situations such as:

- National Governments realize that they don’t have sufficient resources to develop necessary infrastructure for their country’s well-being.
- Technological advances and need to develop financially, economically and environmentally sustainable projects necessitate developing costly infrastructures adaptable to changes.
- PPPs are respected as better means to allocate risks of developing infrastructures.
- PPPs are regarded more effective than a full privatization infrastructure because government can control the private sector’s authority not to misuse the gained power (Sapte, 1997).
- The investment cost of the project will not be assumed under the government’s balance sheet and consequently credit rating of the country and its ability to absorb foreign resources will improve.
- Under traditional models of infrastructure development, a project’s design and its construction specifications may lack sensitivity to life-cycle costs of the project, because private sector’s profit is not dependent on operation and maintenance of the facility. But in a concession model, since the private partner acquires its profit through operating the facility, it would not sacrifice quality for lower initial investment cost; it would rather optimize life-cycle costs of the project by reducing operation and maintenance costs of the facility (US Department of Transportation, 2010). Innovative cost-saving measures are about collective impacts of many small changes rather than an impressive architectural design. (e.g. allowing access space for easier maintenance purposes) (Drucker, 1984).

- When operation revenue is the major source of repaying the debt, bankers also have motivations to ensure that services of required quality are supplied on time (Grimsey & Lewis, 2004).
- There are arguments that public sector can borrow money in less cost than the private sector, because risk of default seems to be more important than the quality of returns. Assessing quality of investment return will show that no risk-free funding is possible for the government. If bankers lend fund to the government under any circumstances with lower borrowing rates, it doesn't mean that borrowers are sure that the project outcome is successful; it is because the government will acquire money to repay debt by raising tax and diverting the risk to the tax payers. This residual risk forced on taxpayers is a cost, which must be included in any cost–benefit analysis. If this residual risk were taken into account, it would be verified that the real cost of government borrowing would be the same as the private sector, where the prime risks of the projects were the same (Key, 1993) (Klein, 1997).

2.3 Examine Applicability of PPP approach

If government assumes full engagement to PPP concept; and efficient PPP management is carried out, then three main issues must be examined before making any decision to undertake an infrastructure project as a PPP (Grimsey & Lewis, 2004):

Capacity: objective assessment of private sector's capability of undertaking the infrastructure project according to public interest.

Motivation: objective determination of project's risks and profit to anticipate private sector's willingness to undertake the project and whether the banks and financial markets will foster the proposal.

Value for money: considering that the cheapest proposal is not the most cost-effective proposal, a clear demonstration, on a whole life cycle basis, should present that PPP will be the best means to carry out the project. A balance between cost, quality and performance should be struck. Value for money is improved in a competitive environment that encourages bidders to introduce novel solutions in their design and service commitment by the appropriate transfer of risk.

2.3.1 PPP's Success in Different Public Sectors

PPP arrangements can be applied on new infrastructure development projects as well as existing infrastructure projects. PPP may involve construction of new facilities, or expansion and rehabilitation of existing facilities. Sometime the goal of PPP arrangement might be only refinancing of a facility in financial trouble.

Green public private partnership, called Green Fields, integrates design, construction, financing, operations and maintenance engagements in a long-term partnership scheme to provide financial incentive for the private party to accelerate the construction phase and to consider the whole project life cycle to reduce energy consumption, minimize waste, and decrease operating and maintenance costs. This approach prevents the Contractor from reducing short-term construction cost at the expense of long-term value (Grimsey & Lewis, 2004) (Yang, et al., 2007). PPPs on which private sector leases an existing public facility with an up-front payment, that does not contain construction, expansion, or rehabilitation of the facility, are called brownfields, and those of which that involve construction, rehabilitation or expansion of an existing facility are called Hybrid projects (US Department of Transportation, 2010).

It has been observed that some types of projects would not be successful with PPPs especially in the absence of legal legislation or in the emerging markets; or projects with certain political risks (Sapte, 1997). PPP has been more successful in road, water and wastewater projects rather than school and health care. In the latter the core and ancillary services are segmented. In such cases:

- In the knowledge of not being responsible for operation and maintenance of the facility, the private contractor is only concerned about the construction cost and consequently is not willing to bring innovations into design to achieve reasonable efficiency gains in operation and maintenance services of the infrastructure projects.
- Private sponsors must deal with a number of entities such as local education and school council with different regulations and expectations.
- Schooling and health care are highly charged political areas which create a volatile situation.
- But yet considering the fact that public funding is unable to afford advances in medical technology or development in education sector, undertaking PPP would be rewarding if it can offer cost savings and efficiency (Allen, 2001).

2.3.2 Prior Analyses to examine success of Undertaking PPP

In order to examine success of undertaking PPP, first, risk-adjusted cost of delivering a certain need under traditional procurement is estimated, which is known as Public Sector Comparator (PSC); and, second, a comparison of this estimate as a criterion with the cost of accommodating the certain need under a PPP scheme is carried out.

PSC should be unbiased when compared to the private sector proposal. Therefore, PSC should take into account all applicable charges like government taxes, levies or cost of insurance may be payable by the private sector (Grimsey & Lewis, 2004).

In developing a financial model of the project, project cash flow should be discounted to estimate the net present value of the forecast cash flow. There are two methods of discounting cash flow. The commonly used method is to make risk adjustments in the discount rate by adding a risk margin to an appropriate risk-free rate. The other approach is to include risk in the cash flow and use a risk-free discount rate for cash flow forecasts. The latter seems not applicable because it doesn’t create reward for bearing the risk since it eliminates the risk at no cost by diversifying the risk. Furthermore collecting sufficient relevant and objective market data to price risk as a cash flow is fairly difficult.

To undertake an unbiased comparison between PPP and PSC, the same discount rate should not be used for the both, because this way excessive reliance will be placed on public procurement. For public sector, cash flow displays the cost of constructing the facility; however on a PPP, in order to give value to the private sector provision, a discount rate is used that includes an investment for the public sector, but is a revenue factor for the private entity. Overall, revenues are more risky than cost, especially when the revenues are dependent on providing services with certain quality. In such a situation, usage of a higher discount rate for the public sector procurement will lead to an unbiased comparison. Otherwise, private provision would seem less efficient due to overestimating the public procurement (Grout, 2003). It is also necessary to evaluate future uncertainties under both options.

The impacts of technological changes, changes in interests, shifting from the planned amount of investment, and international changes on the investment gains should be analyzed.

Any PPP proposal should undergo risk analysis to examine impacts of assumptions about risk allocation on the value for money.

It’s undeniable fact that professional judgment, skill and experience play substantial role in implementing PPP versus public procurement, because the PSC and the private sector proposal will have a marginal difference.

PSC provides an objective value-for-money test against the bids when all quantifiable risks are priced realistically (MacDonald, 2002).

In order to conduct an analysis to examine viability of an infrastructure project, there should be adequate number of similar past projects to permit forming reliable probability distributions for project variables.

Some PPP projects such as public utilities, schools and accommodation may be simulated in satisfactory numbers, but for many other projects this is not possible; especially if PPPs are utilized for delivering complex, original and unique projects (Grimsey & Lewis, 2004).

Four key aspects of successful PPP project implementation are: defined goals, right procurement process application, quality bid acquisition, and finally if the final arrangement does not make sense, it should be nulled and re-tendered (National Audit Office, 2001) (Grimsey & Lewis, 2004).

2.4 Types of PPP

Public and Private sectors can come together to perform a project under various schemes, models and contracts such as:

2.4.1 Traditional type of project development

The public sector designs and bids the project. Private construction firms submit their sealed proposals to undertake the construction of the facility. The lowest bidder will be awarded a contract to perform the construction of the facility. The public sector is obligated to finance, operate and maintain the project (US Department of Transportation, 2010).

2.4.2 Leases/Affermage Contracts

Public sector enters into a contract with a private entity to which is awarded the right to operate and maintain the facility. The public sector in each case remains accountable for financing and managing investment in the facility.

In the case of a lease, the rental payment to the public sector is fixed regardless of the amount of tariff collection. Therefore, the operator takes a risk to get reimbursed for operating costs. In the case of affermage, the operator gets reimbursed for operating cost and an insured amount of mark up; and the public sector takes the risk to retrieve its investment through the collected tariff (World Bank, 2014).

2.4.3 Joint Ventures

The private sector and the public sector establish a partnership with a joint share ownership structure to finance, and operate a facility (Grimsey & Lewis, 2004). Depending on the government’s intentions, the proportion of share ownership will vary. The government may wish to remove the project off balance sheet, or would like to stay in position of authority (World Bank, 2014).

2.4.4 Operations or management contracts

Management contracts are task specific contracts for a short period (two to five years). Basically the private sector does not take any risk on the level of tariff collection; and gets paid a fixed fee.

If the management contract is performance-based, the operator may take some risks such as risk of asset condition and replacement of components and equipment (World Bank, 2014).

2.4.5 Cooperative arrangements

To achieve the goal of poverty reduction, government may arrange more informal partnerships with private sector .This way government involves the private sector in modernizing and transforming the public facilities to provide efficient, reliable and affordable socio-economic services (Grimsey & Lewis, 2004) (World Bank, 2014).

2.4.6 Concession Contracts

Public private partnerships are concession-based approaches and various engagements are on the basis of fixed-term concession concept. Three main components of a concession based PPP are: concession objective, a payment structure, and the length of the concession contract. Each component is designated by the public agency that executes the PPP concession (US Department of Transportation, 2010). Some of concession-based contracts are explained below:

- Build-Operate-Transfer agreement (BOT) is based on defined concession terms which the private party combines different resources to design, develop, finance, refurbish, operate, and maintain infrastructure facilities

(Grimsey & Lewis, 2004). Government may retain ownership of the facility during the concession period, or obtain it when the construction stage is completed, or at the end of the concession period at no cost and free of liens; the government will run the facility after the handover (Grimsey & Lewis, 2004) (Xenidis & Angelides, 2005). The concessionaire will recoup its capital investment from collecting operating revenue throughout the concession period (Zhang & Kumaraswamy, 2001).

- Build-Own-Operate (BOO) arrangements in which the private sector provides funds and builds an infrastructure facility and operates the facility till the end of the life of the facility. The ownership of the facility will always remain with the private sector.
- Build-Transfer-Operate (BTO) arrangements in which after construction, all the legal rights are passed on to the government. Later, the private corporation leases the built and serviceable facility from the government to undertake operating it through which collects operating revenue to repay the project debt and to earn a plausible profit on investment. During the operation phase, regardless of the government's formal ownership, full financial responsibility of the facility remains with the private sector. In some countries such as the US, this agreement is advantageous; because government-owned projects are covered under sovereign immunity laws which protect the private party from uninsurable risk during operations (Grimsey & Lewis, 2004). Table 2.1 contains a summary of PPP types by risks and activities assumed by private partners (US Department of Transportation, 2010).

Table 2.1: PPP types by private partners' risks and activities

Project Type	Risks/Activities assumed by the Private Partner						
	Design	Build	Finance	Operate	Maintain	Ownership Concession	Ownership in perpetuity
Traditional Bid-Build		×					
Design-Build	×	×					
Design-Build-Finance	×	×	×				
Build-Operate-Transfer	×	×	×	×	×	×	
Build-Own-Operate	×	×	×	×	×		×
Leasing (Affermage)				×	×		
Joint Ventures	×	×	×	×	×		×
Management Contracts				×			

Generally, the purpose of public and private collaboration is to bring added value to the economy of the host country. In the past, many infrastructure developments around the world were hindered by bureaucracy, political agendas, shortage of funds and poor management which were the direct consequence of purely public approach to the infrastructure development. World Bank (1994) reported that Public sector infrastructure developments were generally unsuccessful and inefficient in many countries (World Bank, 1994). This overall failure gave way to emergence of BOT type arrangements in various infrastructure projects.

As mentioned in this chapter, PPP procurement and specifically BOT has various advantages for the host government; besides it helps free enterprise to flourish also.

In BOT arrangements, by introducing private sector's investments, budget limitations are eliminated; and consequently government's capacity to develop required infrastructure are enhanced. Competitive environment of BOT procurement brings about creativity, reduced cost and higher quality; thus innovative approaches find grounds to be executed. Private sector's skill, technology, experience and expertise are employed to implement the project remarkably. Incentive of acquiring revenue makes the private party put the facility into operations as soon as possible; therefore it accelerates project completion. The most important advantage of BOT arrangement is the risk sharing notion which transfers the risks to the parties who are best able to manage the risks.

This chapter attempted to help the readers realize that PPP arrangements can be good vehicles for the countries' economic improvement. The following chapter will discuss BOT arrangement in detail.

Chapter 3

BUILD OPERATE TRANSFER CONTRACTS

3.1 Introduction

Build-Operate-Transfer (BOT) concept was first introduced by Turkey's late Prime Minister, Turgut Özal in the early 1980s and was known as Özal's formula; however the concept was identified earlier, when in Hong Kong in mid-1950's, a privatized cross harbor tunnel was first proposed (Merna & Njiru, 2002). As mentioned before, BOT is an agreement that entrusts the design, financing, operation and maintenance of a facility to a concessionaire for a determined concession period. Operational and construction risks are endured by the concessionaire. The management and formal ownership of the facility will be returned to the public entity at the end of the concession period.

BOT concessions are often observed to bring innovation, sustainability and diversity together while enabling the public sector to carry out its necessary objectives.

Under a BOT agreement, the parties engage themselves to contribute and cooperate more efficiently, and employ appropriate strategies to assess and manage risks objectively. The public sector brings political and regulatory stability; and is able to exercise authority on assets such as land, property, and the right-of-way, which brings to the development process. The private sector contributes with outside capital and technical expertise; and has an incentive of producing an efficient outcome at the lowest cost in the shortest time span (Grimsey & Lewis, 2004).

The projects to be delivered through BOT include: transport (road, rail, ports, airports, bridges, tunnels), water resources (hydro plants, irrigation, sewage treatment, pipelines), tourism (facility development), health (hospitals), accommodation facilities (courts, police stations), educational facilities (schools, dormitories, museums, libraries), correctional facilities (prisons and detention centers), arts, sport and recreational facilities, convention centers, government office accommodation, and social housing. However, the decision made about whether or not any of these services should be delivered by means of a PPP/BOT, depends on: the best project model that delivers the best value for money; the public interest's satisfaction of the project outcome; and that the proposed service is not a kind of service which must be delivered only by the government to its citizens (Grimsey & Lewis, 2004). Generally in the procurement method examination, which compares private sector provision of infrastructure services under a PPP/BOT arrangement with public sector provision, the expectation is based on a better value-for-money for private sector provision.

By alluding to Adam Smith principle, economic liberals believe that government should undertake only what cannot be done in the market; doing otherwise will impede free enterprise development. In this context, there remain a few services that absolutely have to be delivered by the government which consist of activities that revenue cannot be obtained due to being 'non-excludable and 'non-rival' (e.g. external defense); and those where the cost of collecting the revenue would exceed the revenue (e.g. parks and playgrounds). Non-rival goods/services are those whose cost of providing to an additional consumer is zero. Non-excludable goods/services are those which non-paying consumers cannot be prevented from accessing it (Grimsey & Lewis, 2004).

As mentioned in the previous chapter, main characteristics of a successful BOT project are: clearly outlined goals; proper procurement process application; high-quality bids acquisition; and making sure that in case the final agreement does not seem right, it should be annulled and re-tendered (Grimsey & Lewis, 2004).

In continuation of the previous chapter, which touched upon various types of Public Private Partnership (PPP), this chapter will elaborate on BOT type of PPP. The structure and participants of such a contract, and their organizational commitment to the partnership will be introduced. Basic elements of BOT procurement, its goals and the incentives of undertaking it will be indicated. Private sector's typical remuneration methods are discussed, the characteristics that lead to a successful BOT implementation will be listed, and common misconceptions about BOT arrangements will be mentioned, each party's participation in the partnership in the forms of skill, knowledge, fund, property, authority, reputation, etc. will be scrutinized; the typical steps of establishing, evaluating and tendering a BOT project will be explained; and the different methods and sources of financing will be discussed.

3.2 Basic Elements of a BOT

Basic elements of a concession based BOT contracting arrangement are mentioned below:

- The Public sector determines the functions of delivered project output, specifies characteristics and performance criteria over a long-term life cycle of the project (typically 15-30 years) without conditioning the means of the project delivery; and puts restrictions on operating standards and pricing.

- Payments are made upon asset delivery and its full serviceability; and relevant payments will be reduced if the deliverable is not compliant with specified standards.
- The private sector decides about the ways of delivering the service, owns and operates the facility during the concession period therefore bears the design risk, in reference to the serviceability and standard of the delivered asset and gains the merit of competent ownership.
- The public sector supplies no capital during the construction stage, and the private sector is obliged to undertake the risk of cost overruns, delays, etc.
- The public sector delegates control of the asset to the private sector to deliver the service; and while enduring the subsequent risks, the private sector collects the rewards of effective operation (US Department of Transportation, 2010) (Zhang & Kumaraswamy, 2001) .
- The private sector transfers the facility's ownership to the public sector (with or without payment) at the end of the concession period (Grimsey & Lewis, 2004) .

3.3 Initiatives of BOT

BOT has a simple attraction because it integrates private and public resources into infrastructure development. Many ambitious and innovative entrepreneurs would be interested in financing of construction and operation of an infrastructure. However, pure private approach is vulnerable to many risks such as: demand risk; changes in technology, regulation, and unorganized development of facilities (e.g. duplication of routes, railway, etc.). On the other hand, pure public developments often are unsuccessful as well because of the facts such as: bureaucracy; political meddling and interference; inadequate funds; tax and spend policy applications, which make the tax payers bear the burden; unsatisfactory management, operation and maintenance of the facilities.

A BOT approach successfully brings the private and public approaches to infrastructure development by exploiting private sector's novelty and market insight while bestowing main planning, coordination and authoritative supervision of the infrastructure projects upon public entities. These initiatives are often stimulated by the need for investment, an interest to operational risk transfer, and by the goal of improved serviceability (Grimsey & Lewis, 2004).

In order to create incentives for the private sector to undertake an infrastructure project and bear the associated risks, the arrangements should clearly spell out each party's responsibilities; and in order to be protected from various political and country risks, the private sector needs to receive credibility (Grimsey & Lewis, 2004).

3.4 BOT Goals

Under a BOT agreement public and private sector become one team; and commit to achieve the following objectives:

- improve government's operation system by introducing market practices into the public services;
- encourage and support involvement of private sector operators and their financial commitments;

- let the private equity increase up-front financing, or make greater total debt capacity available through private sector credibility;
- expand the number of participants in benefiting from the outcome;
- allow for financial risks to be transferred from public to private investors;
- create fundamental positive changes in public services and administrative procedures;
- allow for authority sharing arrangements;
- cultivate cooperation and trust in lieu of competitive relations and command-and-control regulations;
- create incentives for long-term investment returns, better asset management; and
- create a playground to share benefits of employing knowledge, or enduring responsibility and risk (Grimsey & Lewis, 2004).

3.5 BOT Compensation

Public agencies may reimburse the private sector for the project implementation activities by the following options:

3.5.1 Project Revenues and Toll (from Project to Private Sector)

The private sector may be granted the right to compensate, for its performance in a public-private concession, by collecting project revenues. By agreeing on this type of reimbursement, the private sector agrees to bear the risk of less than expected revenue which may result in default on debt repayment or equity return. However, depending on the degree of deficit, the public sector can share the revenue risk, for instance, by agreeing to secure a certain amount of gross revenue or return on equity investment; or to extend the concession period at no cost. In return, the public sector may bargain a percentage of future revenues of which exceed a certain level (US Department of Transportation, 2010).

3.5.2 Availability Payments and Performance Payments

Depending on availability and serviceability of the facility, the public sector compensates the private sector, by milestone payments, for its activities. Milestone payments are adjusted by considering fulfilment of specified performance level for constructing, operating and maintaining the facility. Availability payment can be decreased or even canceled, if serviceability and performance specifications are not fulfilled. Because availability payments are nothing to do with user fees, then the public sector will require obtaining a form of revenue such as toll/tariff (US Department of Transportation, 2010).

3.5.3 Shadow Tolls

In a shadow toll concession, the private concessionaire receives a certain amount of fee from the public sector for each user of the facility. Although shadow toll model provides strong motivations for on-time and on-budget completion, and quality performance, it creates a motive to increase traffic, while the public sector's overall goal might be to reduce mass congestion (US Department of Transportation, 2010).

3.6 Basic Characteristics of a Viable BOT

A BOT partnership becomes successful when the parties are open, innovative, willing to share the risks, willing to share the profits, and diligent to solve conflicts.

A BOT requires: a financially profitable project, a responsive and cooperative host government, private partners, interested sponsors, and a consortium of experienced and skilled professionals.

At the outset, government has to carry out a realistic evaluation and avoid encouraging underbidding. Also sponsors are to be cautioned against relying on future refinancing at more favorable rates; because this option generally is possible only when the project arrives at a lower risk stage. If the risk during the life of the project remained at high levels, the private party would have to default or breach the contract and abandon the project. Having contingency plan for feasible resolutions for any risk is necessary. A successful contract management endeavors to resolve issues to keep the contract in operation for the benefit of both parties, not to search for conditions to breach it (Grimsey & Lewis, 2004).

Large projects (typically $500 million or greater in cost) make BOT arrangements more viable because while they may exceed public sector's financial capacity, their higher profit potential may justify undertaking the project (Grimsey & Lewis, 2004). Because concession projects require longer consideration of possible risks, both parties generally prefer projects that already have established strong support and will receive required political approvals (US Department of Transportation, 2010).

3.7 Common Misconceptions

There are some common misconceptions that BOT projects and generally PPP arrangements:

- **are a source of revenue:** concession projects do not generate revenue, they require it. Concessionaires expect a reasonable return on their investment.
- **mean privatization:** contrary to privatization which involves absolute sale of the facility to the private sector, ownership of concession projects almost always remains with the government.

- **are a fit for every project:** a project is not suitable for BOT arrangements if it would not generate adequate revenue.
- **are free to come into being:** the public sector will have to make money and time investments to gain potential benefits of a BOT model.
- **are guaranteed to succeed:** every project, regardless of selected model, has risks. In a BOT model, the public sector allocates the risk to the party best able to manage it. In the case of unforeseen risks, the project may not be successful (US Department of Transportation, 2010).

3.8 Primary Participants and Their Roles

3.8.1 Public Sector

On a BOT project, the host government is responsible for determining the project objectives, specifying the priorities, executing the procurement plan, quality control check, and making sure that the public interest is secured. The host government should provide supports such as land provision, and bureaucratic support; and be prepared to take over in case of project defaults (Levy, 1996).

In general, PPPs involve multiple levels of government to participate and approve the project such as (US Department of Transportation, 2010):

3.8.1.1 State Legislatures

State legislatures establish enabling legislation to specify which projects will be considered as concession projects, to determine concession terms and to introduce how the project will be selected.

3.8.1.2 Governors

The Governor obtains the required legal authority from State Legislature to implement the project or program. The Governor collaborates with other public entities such as regional governments, cities, or counties to perform the project.

3.8.1.3 Public Sector Project Sponsor

State authority or a local government can sponsor BOT concessions. Considering the defined legislative frameworks, the public sponsor establishes guidelines, sets objectives, outsources the project, negotiates, and is held accountable for errors. If the state authority is the sponsor, it should consult with the city or county which the project is happening within its jurisdiction.

3.8.1.4 Public Sector Advisors

Public sector may outsource consultants and advisors to help evaluate conceptual plans of a BOT, and negotiate the concession.

3.8.2 Private Sector

3.8.2.1 Concession Company or Concessionaire

The concession company or concessionaire is a combination of several firms with special skills and expertise such as construction company, engineering company, financing institutions and other entities which altogether constitute a Special Purpose Vehicle (SPV) to implement: the concession, mobilize required funds, and negotiate contracts with the public sector (US Department of Transportation, 2010).

3.8.2.2 Equity Investors

Acquiring capital from concession company’s partners is a strategic equity investment because it gives the partners strong incentive to complete the project with required quality. Investment banks, private investors, public and private pension funds can contribute to equity investment as well.

3.8.2.3 Commercial Lenders

Banks can provide debt capital to the concessionaire. These loans typically have higher interest and often require that the concessionaire refinance them during the life of the concession.

3.8.2.4 Bondholders

Concessionaires can also borrow funds from individual investors and institutions that purchase bonds in the capital markets.

3.9. Typical Steps in Establishing a BOT

3.9.1. Establish a Working Group and Obtain Enabling Legislation

The government agency, who is going to be the project's sponsor, starts to consider and analyze implementing a BOT arrangement. They might do it in house or hire consultants to develop a program. The project's public sponsor should obtain enabling legislation as well.

3.9.2. Identify Projects

The public agency either, formulates the projects and invites the private sector to compete on them; or accepts private sector's proposal of a project on which innovations can be applied; and then public sector solicits competitive proposals from the firms other than the original proposer also (US Department of Transportation, 2010).

3.10 Typical Steps in Evaluating a potential BOT

3.10.1 Establish Project Goals

After selecting a potential BOT project, the public sector identifies: the key goals, the required construction activities, risks involved; and sets the operational and performance indicators.

3.10.2 Hold Industry Meetings

Industry meetings help the public sector collect private industry's inputs about project implementation, risks, and potential obstacles on project delivery. Industry meetings introduce possible innovations that might be used on the identified BOT project.

3.10.3 Examine Revenue Options

The public sector identifies the users and beneficiaries and conducts analysis about the users' willingness to pay. The public sponsor should examine the possible revenue options, possible grants and other potential sources.

3.10.4 Evaluate Benefits and Risks of implementing the project under BOT

Public sector conducts risk analysis to make sure that private sector's involvement would add value financially and economically. Public sponsor conducts a project appraisal considering the identified revenue sources. After examining the revenues and potential project risks, the public sector will create a comparator by assessing its capacity to complete the project under traditional methods without private sector's engagement.

3.11 BOT Procurement Steps

3.11.1 Request for Information (RFI) or Request for Qualifications (RFQ)

After the host government decides to proceed with BOT structure, the first procurement document will be released that contains information about the project and public sector's objectives, and requests for information (RFI) or qualifications (RFQ) from interested concessionaires. After reviewing the RFIs and RFQs, the public sector eliminates concessionaires with no qualifications to undertake the concession well.

3.11.2 Request for Proposal (RFP)

After potential bidders are short listed at RFI stage and lessons learned from RFI stage are incorporated to the bid documents, host government develops a draft contract which is a part of a detailed procurement agreement in order to provide the basic project outlines, specify performance standards for the facility, spell out concession terms, and indicate how revenue will be shared. Having the project agreement ready, the host government invites the short listed consortiums to submit their competitive bid proposals. Interested consortiums will conduct their own project appraisal and submit their confidential bids on the basis of the bid documents. Bidders are required to display their financial and technical capabilities required to complete the concession; they are required to submit bonds, deposits or guarantees, or to prove their creditworthiness.

3.11.3 Private Partner Selection

The host government will select the bidder that satisfies the project criteria and the public goals. It's worth mentioning that cost is only one of considerations in choosing the successful bidder. Technical, managerial and risk handling capabilities, and experience are very influential in selecting the prospective concessionaire.

3.11.4 Negotiation with Chosen Partner

The selected best bidder will prepare detailed documentation and enter into the negotiations. When all the details, specifications and concession terms are agreed, the concession agreement is signed by both parties.

3.12 BOT Implementation Steps

3.12.1 Financing

Since the financing of the project will essentially be at the Concessionaire's risk, the Concessionaire will seek maximum freedom to arrange it. Government on the other hand would like to make sure that the financing criteria are outlined in the concession agreement. The concessionaire assembles equity and funds by fulfilling all lenders' requirements and obtaining legally binding agreements, the process of which is called financial closure (Grimsey & Lewis, 2004).

Grimsey and Luis (2004) reported that the following factors are important to achieve a reliable financial closure: precise objectives, public entity's engagement to the process, practical reimbursement structure, suitable regulations and specifications, an impartial contract, profitable outcome, a clear procurement process, available historical data, competitive bidding environment, organized negotiation phases (Grimsey & Lewis, 2004).

Potential sources of finance include equity, mezzanine finance, bond issues, development finance institutions, project leasing, export credits and derivative products (Sapte, 1997) which will be elaborated on the following section:

3.12.1.1 Equity

Construction and operation companies who will be undertaking the project are typically the equity investors. Sometimes other entities might contribute equity such as the government, the general public and financial institutions (Sapte, 1997). Equity investors have a strong incentive to ensure that the performance standards are met since they would like to gain a positive return on their investment; therefore the host government's precondition to grant a concession to a concessionaire is that the concessionaire must fund a BOT project at least in part by equity. Equity is the lowest ranking form of capital; because attending to other creditors' claims have priority over equity investors'; and the time of receiving and the amount of dividends or other distributions can be restricted by the contract. This puts the equity investors in great risks if the project is unsuccessful, and the revenue is not guaranteed by the government by some means such as tariff mechanism, etc.; hence they typically seek a much higher rate of return from the project delivery. In case the government is securing the revenue, a limit can be set for shareholders' maximum rate of return. If market risks are anticipated, the lenders require the private sponsors to invest a greater percentage of project outlay by means of equity; however larger amount of investment in the form of equity costs the host government more, so a right balance should be struck between the equity and other forms of investments (Sapte, 1997).

3.12.1.1.1 Clawback Agreements

Clawback Agreements can also be categorized as equity investment (or subordinated loan). A clawback agreement obligates the project sponsors to contribute cash to the project if they receive cash dividends or any tax benefits related to the projects (Finnerty, 2013).

3.12.1.2 Mezzanine Finance

Mezzanine finance is a credit enhancement mechanism which is a subordinated debt that can be categorized as both debt and equity that bears a degree of risks more than senior debt but less than equity. Debt service obligations of senior debts should be met prior to any other forms of project investment, while mezzanine finance has a lower priority of claim to cash flow and assets than senior debts, but higher than equity. Types of mezzanine financing are (Grimsey & Lewis, 2004):

3.12.1.2.1 Convertible Debt

Convertible debt can be exchanged for specified amount of another related security.

3.12.1.2.2 Preferred Equity

Preferred equity, compare to common equity, entitles the preferred shareholders to receive their fixed dividends first.

3.12.1.2.3 Equity Warrants

Equity warrants, as a security, entitle the holder to buy a stock at the certain fixed price for a period of time.

Mezzanine can be obtained from venture capital providers, investment trusts, and insurance companies. While this subordinate debt gives confidence to the lenders, it has the advantages to the sponsors such as less equity contribution to the project, opportunity to earn a reasonable rate of return without taking full risk of acquiring the equity (Sapte, 1997).

3.12.1.3 Bond Issues

Bonds are cheaper source of debt investments used by companies, or governmental entities to raise money and finance a variety of projects. Bond holder is an investor who loans funds to the project for a defined period of time at a variable or fixed interest rate. Bonds have less extensive contractual agreements; they are tradable instruments. However, having single upfront subscription, bonds are less flexible in comparison with syndicated loans which may provide staged payments. Bondholders generally do not have industry expertise and tend to have passive interest in their bond investment; this fact restricts the project sponsors from making changes in the nature of the project (Sapte, 1997).

3.12.1.4 Commercial Funding

A number of commercial banks often forms a syndicate to finance the infrastructure projects with complexity and unknown risks. Each of the syndicate banks defines the same lending terms and conditions with the same priority of debt. Commercial banks finance the project through the credit facilities below (Finnerty, 2013):

- Long term loans which have a structured amortization profile with a fixed or floating interest rate. Debt service obligations, unlike equity, have the highest priority of the invested funds (World Bank, 2014).
- Revolving credit which is an arrangement made between bank and the project concessionaire to borrow funds on a short term basis to meet temporary cash shortfalls. Bank that issue a revolving line of credit, charges an initiation fee to start the loan and sets a maximum cap for the amount of loan borrowed. When the borrower draws on the credit, the bank charges monthly interest rate on the outstanding balance. Often borrower's assets, or accounts receivable, or inventory are used as collateral to secure the debt repayment.
- Standby letter of credit which is a guarantee of payment issued by a bank on behalf of a client as a sign of good faith in business and the client's credit quality. Standby letter of credit is needed when a client applies for Commercial Paper. Commercial Paper is a debt type of credit which is unsecured (meaning without use of collateral and for a limited time, and is issued by a corporation. Commercial Paper is generally used for redeeming a current liability (which is a debt that should be paid within a year), financing of accounts receivable or inventories.
- Bridge loan which is a short-term loan with relatively high interest rates supported by collateral which by providing an instant cash flow enables the borrower to redeem current debts as soon as possible.

3.12.1.5 Project Leasing

Lease contracts introduce new sources of project finance where the project's usage is given to a second party for a specified period; the second party, who leases the facility (the lessee), has the right to collect charges from the customers over the specified time period, and is obliged to pay rental fee to the lessor for the facility usage. Leasing has the benefits below:

- it reduces the cost of financing ;
- having gained a trading income, the lessor enjoys financial benefits of tax allowances;
- improved cash flow ensures viability of the project;
- robust cash flow makes project lenders trust on fulfillment of debt service obligations;
- lease contracts transfer commercial risk to the lessee. They create incentives for the lessee to support more clients, reduce operating cost to be able to increase revenue, and undertake regular maintenance to postpone renewal.

3.12.1.6 Export Credits

Export Credit Agency (ECA) is a government body founded to promote and support exports in the country of its own. Basically, ECA protects the exporter and its financier against payment defaults by buyers of the outcome of the project. ECA supports export which creates an incentive for competitive market. It increases the employment in the home economy. It can help in diplomatic matters by improving political relationship with a country. ECA may provide credits in circumstances below:

- It may provide buyers with credits when the exporter enters into an agreement with the buyer at the outset of the project.
- If the project sponsors are in a loan agreement with commercial banks as well, ECA may refinance the commercial banks' funding after a period.

- ECA may provide interest rate subsidies in cases of floating interest rates on the loans, where ECA makes up any shortfall between the requested interest rate by the commercial lenders and the interest rate payable by the project sponsor; similarly ECA takes the excess of the agreed interest rate over the banks' rate.
- ECA provides performance bonds on behalf of the seller.
- It provides investment insurance against the losses of overseas investments.

3.12.1.7 Development Finance Institutions

Development Finance Institutions (DFIs) are multinational entities that are not tied to the interest of any one country or a government. They ought to promote export markets for national industries. DFI's involvement is not supposed to take the role of commercial lenders. They have a catalyst effect whose involvement may convince the governments, commercial lenders, and local investors of undertaking a promising project. Having ties with their member countries, they contribute to political robustness of project host country. They will be able to exercise influence over the decisions of a host government.

3.12.1.8 Derivative Products

The ability to fix the prices of raw materials and finished products will create steadiness on the project cash flow. A future contract, which suggests a fixed price for delivery of a quantity and quality of a product at a specified future date, is a typical method of hedging commodity risks. Concurrently, the lenders or the host government often require the project's private sponsors to enter in interest rate or currency hedging arrangements as well.

3.13 Contractual Arrangements

Involvement of many parties with different interests makes BOT project very complex. Extensive risk allocation within a contractual framework is vital to a project's success; therefore establishment of strong contractual arrangements in a BOT project promises financial viability of a project (Finnerty, 2013). Generally speaking, contracts are long term commercial agreements to protect the interests of the project sponsors. They allocate the probable risks associated with the projects. Contract documents are structured and negotiated (Sapte, 1997). Typical contracts in a BOT arrangement are: concession arrangement; consortium arrangement; construction contract; operation and maintenance contract; construction subcontracts; supply contracts and off-take contracts. Figure 3.1 is a flowchart of a BOT typical contractual structure (World Bank, 2014) (Sapte, 1997).

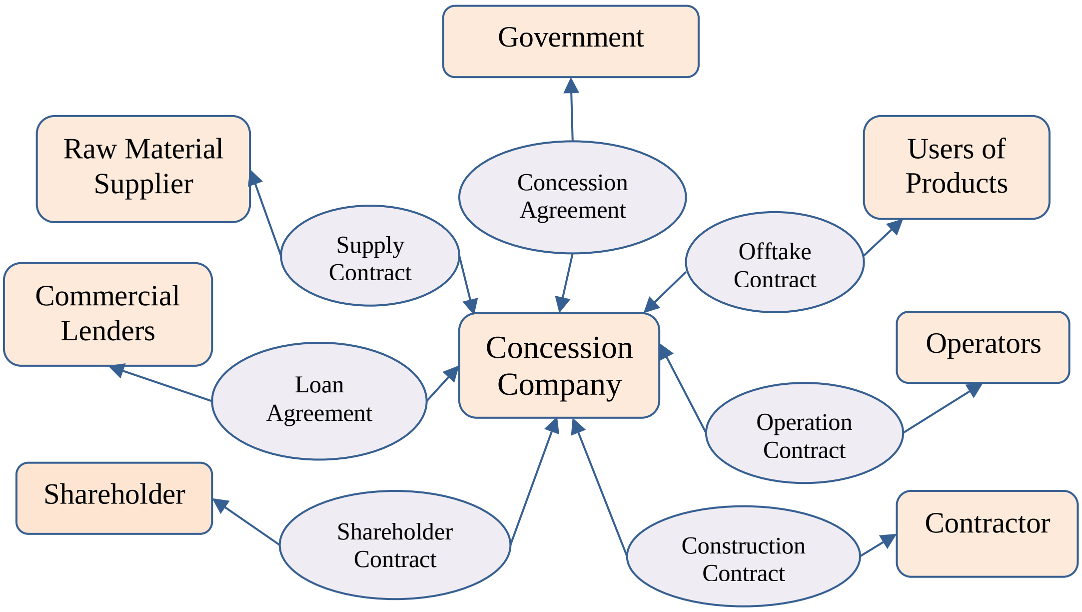


Figure 3.1: Typical contractual structure of a BOT project

3.13.1 Concession Arrangement

The given rights and responsibilities to the private sponsors by the government, to finance, design, construct, operate and maintain a BOT project are called concession. The contract which regulates these rights and obligations is called a concession contract. A precise concession contract contains specifications below:

- Basically concessionaire will seek a clear, enforceable right to implement the project. However, the public sector, who has granted the concession, will want to insure that the facility will be constructed, operated and maintained to agreed standards.
- If the public entity is going to facilitate the project by any means such as site acquisition, obtaining permit, licenses and consents, these authorizations need to be identified and guaranteed in concession contract.
- Concession agreement should reflect risk allocation and risk sharing terms between the two sectors.
- Commercial incentives which attract the private sector is mentioned in the concession agreement.
- The public entity will stipulate the regulations and the extent of control over the project.
- The concession agreement will have to promote financial viability of the project for lenders, investors and guarantors during the concession term.
- The concession agreement will contain standards for design and construction, public entity's rights to inspect and approve the facility, government's certain powers and rights over financing, performance standards, and public entity's right over operation stage, maintenance standards, rights of access and

inspection, government's control over user charges, intervention circumstances in the case of an emergency, force majeure clauses, termination rights, breach of contract cases, transfer of the assets to the government, the terms for dispute resolution, insurance requirements, liability terms, environmental requirements, confidentiality, etc.

3.13.2 Consortium Arrangement

Having common interests of promoting and financing a large infrastructure project, its private sponsors such as construction company, suppliers, future operators and maybe purchaser of the outcome establish a consortium or joint venture to bid for the project. Naturally each member of the consortium has different interests and obligations which need to be defined at the outset. The provisions below may be addressed in a consortium agreement:

- the role of each party and their undertaking;
- each party's commitment to different phases of project development;
- potential liability protections;
- rapid and effective decision making provisions;
- risk allocation and risk sharing plans;
- cost and value measurement frameworks;
- termination and withdrawal terms; and
- confidentiality terms

3.13.3 Construction Contract

Construction phase of a BOT project incurs a large amount of project's outlay; its timely completion would help earlier revenue generation; and its quality will impact the whole life cycle of the developed infrastructure. Lenders of the projects are always concerned about construction cost overruns. Contractors always should have acceptable reasons for any delay in project delivery or cost overrun due to unforeseen conditions.

Drafting and negotiation of a construction contract are major tasks in a successful BOT concession. Construction contracts will contain provisions such as (Sapte, 1997):

- liquidated damages provision for failure to deliver the project on the agreed completion date;
- scope of the design and construction in detail through project specifications;
- detailed and comprehensive scope of warranties following completion related to design, construction, and compliance with laws;
- degree of control over the contractor's performance; and right to inspect and test the works;
- risk allocation provision;
- liability terms for breach of contract;
- security for contractor's performance such as retention, bonds, insurance arrangements, and completion guarantee;
- payment methods; etc.

3.13.4 Operation and Maintenance (O&M) Contract

It is to the advantage of the project that the operator becomes one of the project sponsors; this way the success of the project is directly linked to its own performance. The operation and maintenance (O&M) agreement is carried out when commissioning and testing procedure of the facility/ project outcome starts.

Commissioning is carried out to verify if the project outcome functions according to its design objectives or specifications. The O&M agreements often contain clauses about (Sapte, 1997):

- detailed specifications on the replacement of failed equipment and details of improvements to the facility;
- the methods of payments such as fixed price, cost plus fee, or performance based fees (bonus/penalty mechanism) by taking inflation rate changes into account;
- liquidated damages for failure to perform;
- liability provisions;
- warranties;
- insurance;
- acquisition of operating permits;
- budget allocation terms;
- inspection rights;
- safety provision;
- emergency repair plans;
- operating manuals upkeep;
- routine maintenance schedules;
- transfer of intellectual property rights; and
- termination provisions.

3.13.5 Supply Contracts

Supply agreements are utilized to commit the suppliers to provide minimum amount of raw material for a specific time. In order to keep up supply consistency, bonuses can be proposed or in case of supply interruption, penalties can be imposed. Including terms regarding minimum acceptable quality of supply is also necessary (Jenkins, et al., 2011).

3.13.6 Off-take Contracts

Off-take contracts are exercised to withstand market risks to make sure that the project will survive and be able to make sufficient and robust revenues to service its debt. There are two market risks, either the risk of inadequate volume selling which is called volume risk, or a low market price risk which is called price risk. Off-take contracts often convince lenders of the project's viability. Various forms of sales contracts are:

- Take- and-pay contract: under take-and-pay contract, the project's end-users are bound to buy a certain amount of the project's deliverable on an agreed price basis when it is available even if they don't need it. This contract does not bind the customers to pay in case the project is not able to distribute the outcome; therefore pay-and –take contract does not protect lenders in case the project is not able to meet its performance requirements or is subject to interruption (Jenkins, et al., 2011). It is recommended to rather use take-and –pay contract as a supply agreement to secure delivery of raw materials to the project (Yescombe, 2014).
- Take-or-pay contract: take-or-pay contract obliges the purchaser to pay for a certain amount of the product regardless of its availability. Cash payments are usually credited against charges for future deliveries (Finnerty, 2013).

- Hell or high water arrangement: Hell or high water arrangement is an extreme variation of take-or-pay contract which binds the purchaser to pay even in the event of force majeure stoppage or disruption (Jenkins, et al., 2011).
- Throughput and cash deficiency agreement: are typically used in a pipeline projects which requires the oil companies to deliver enough product by the pipeline in a defined time period to generate enough cash revenues for debt service obligations and operating expenses. On the other hand, bound by cash deficiency agreement, the shipping companies promise to provide funds in advance if the pipeline is not able to fulfill its obligations for any reason (Jenkins, et al., 2011) (Finnerty, 2013). Later in the future the advance funds will be settled in a fashion that does not suspend debt service obligations.
- Cost-of-service contract: Cost-of-service contract trades the project's output for a proportionate payment of the project's incurred cost. This type of contract is a type of hell-or-high-water contract which obligates the parties to pay even if the project outcome is not delivered. This protects the project's lenders against increase in operating expenses and changes in tax laws.
- Tolling agreement: Tolling agreement is used in projects like processing of raw materials where the project company accepts to process raw material for the provider by charging them for each input. In tolling contracts used in energy sector, the toller orders the company to convert one form of fuel into another form of fuel. The fee which the toller pays typically corresponds to its equivalent share of the total operating expenses which includes debt obligations related to this project.
- Step-Up Provisions: Step-Up contracts are utilized when there are multiple purchasers of the output which obligates the purchasers to increase their

associated contribution in case one of the purchasers goes into default (Finnerty, 2013).

As mentioned in the previous chapter, many unsuccessful implementations of purely public infrastructure developments around the world gave rise to employment of BOT procurement methods. Although BOT procurement has proved to be a successful means to promote economic growth of a country, some countries' public agencies, such as the United States, are not willing to implement BOT in their infrastructure development projects. As Jones et al. (2004) (Jones, et al., 2004) depicted, in the United States, by the result of inadequate funds, infrastructure is being underinvested which is becoming a threat to their national economy and living standards. Economic vitality of a nation is dependent on the country's infrastructure development. The countries with immediate need of large amount of investments on the infrastructure projects can make use of successful delivery options such as BOT (Algarni, et al., 2007). This chapter can be considered as guidance to implement BOT. It was written to clarify what BOT is; and to summarize how it works.

With the financial hardships all over the world and the dire need to expand and improve public facilities and services, governments are strongly encouraged to evaluate undertaking BOT procurement in infrastructure development. The remaining chapters of this thesis will illustrate how to evaluate viability of undertaking a BOT contract.

Chapter 4

METHODOLOGY

4.1 Introduction

Undertaking a life cycle cost-benefit analysis of an investment project is necessary to enable a decision maker to appraise or evaluate the whole life of the project objectively, with the hopes of stopping a bad project from being implemented and preventing a good project from being rejected (Jenkins, et al., 2011). The word "appraise" refers to making a decision whether to allocate the resources to the project or not; and the word "evaluate' refers to analyzing the project performance (Brown & Campbell, 2003). In a public-private partnership (PPP), parties attempt to invest on the projects which are expected to provide benefits over the life of the project; and the marginal opportunities foregone by making such investments, known as the opportunity cost of the project, for the private sector, government and all other stakeholders should be the same (Brealey & Cooper, 1997).

Cost benefit analysis starts with financial analysis where the financial benefits are compared with the corresponding costs during the project's life span. This study employs Jenkins et al. (Jenkins, et al., 2011)'s methodology for cash flow development and investment project evaluation from various points of view.

In reality the values of the project's key variables in the future are uncertain due to many peculiarities that may be encountered over the life of the project. Unlike reality, project financial cash flow is built based on deterministic values with 100% occurrence certainty. In order to bring reality to project investment appraisal, and examine the possible uncertainties, sensitivity analysis is conducted to identify the critical project variables; and then risk analysis is conducted based on probabilistic values of the project's input variables. Once uncertainty is taken into account and risk is understood, appropriate measures or contractual arrangements are employed to lower the riskiness of the project's returns and mitigate the overall risk of the project. If some level of certainty can be brought to prediction of the project's critical variables, this would help to take appropriate measures, and set well-founded and unbiased contractual agreements. For this purpose, on this study, two soft computing methods namely, artificial neural network (ANN) and gene expression programming (GEP) are employed to establish automated processes for more accurate prediction of the financial parameters and uncertainties of a BOT project. Two distinct real life case studies will be used in this dissertation to illustrate the proposed procedures of the research approach. First a case study of BOT model on dormitory projects in Cyprus is analyzed; and an ANN model is developed to model the relationship between important project parameters and risk variables. Second financial viability of undertaking a BOT contract for Sewer and Water Projects in California, USA is analyzed; and then GEP, an extension of genetic algorithm (GA) and genetic programming (GP) is employed to develop a prediction model for estimating the construction cost of water and sewer rehabilitation/replacement projects.

4.2 Financial Analysis

Financial analysis is a method to organize a project's relevant financial flows such as project outlays, receipts, and expenditures in comprehensive details on a yearly basis based on the discounted cash flow approach during the project life time. In order to build a financial model, first the sources of project investment and the contribution amount of equity holder versus debt are specified. The project's construction cost, labor requirements and average wages for the employees are determined as well. Market demands are analyzed to identify who the prospective customers/users are; what the customers' willingness to pay would be; and what the possibilities of growth in the price of the end product or service would be. Using all the findings above, per Jenkins et al. (Jenkins, et al., 2011)'s methodology, the table of parameters for financial model is prepared in Microsoft Excel. In order to build cash flow statement from lenders point of view as well as concessionaire point of view in real values, inflation and exchange rates over the life cycle of the project are determined; investment, operation and maintenance costs are developed; revenues are calculated; loan repayment profile are established; income statement are factored in; and the appropriate residual value is included in the end year. By application of certain investment criteria such as ADSCR (Annual Debt Service Capacity Ratio), LLCR (Loan Life Capacity Ratio), NPV (Net Present Value) and IRR (Internal rate of Return) and by conducting the sensitivity analysis on the model, financial profitability or viability of the project is evaluated (Jenkins, 2004) (Jenkins, et al., 2011).

The ADSCR (Annual Debt Service Capacity Ratio) is a factor used by the bankers which determines if a project will be able to cover its operating expenses as well as meeting its debt servicing obligations. ADSCR is the ratio of the annual net cash flow of the project over the amount of debt repayment due. It is computed on a year to year basis as below:

$ADSCR_t = [ANCF_t / (\text{Annual Debt Repayment}_t)]$

where $ANCF_t$ is annual net cash flow of the project before financing for period t, and Annual

Debt Repayment_t is the summation of annual interest expenses and principal repayment due in the specific period t of the loan repayment period (Jenkins, et al., 2011).

Bankers use the LLCR (Loan Life Capacity Ratio) to examine availability of sufficient cash the entire project for bridge-financing for one or more certain time spans when there is not comfortable amount of cash flow to redeem the debt. LLCR is $PV_{(\text{ANCF t to end year of debt})}$ (the present value of annual net cash flows) over $PV_{(\text{Annual Debt Repayment t to end year of debt})}$ (the loan repayments' present value from the current period t to the end period of loan repayment) (Jenkins, et al., 2011):

$$LLCR_t = PV_{(\text{ANCF t to end year of debt})} / PV_{(\text{Annual Debt Repayment t to end year of debt})}$$

The Net Present Value (NPV) is a trustable criterion for evaluation of a project's financial viability. NPV is the sum of the present values of the project's net cash flows over the project's lifetime. In a project appraisal from equity holder's point of view, discount rate is the cost of investing the equity on the project by which an alternative earning of the equity is foregone because it is not being invested in its alternative use anymore. NPV equal to zero means that the investors can expect to earn a rate of return equal to the used discount rate in the project appraisal while recovering their investment. A positive NPV implies that the capital investors can surmise that they will earn a rate of return higher that discount rate while recovering their investment. With a negative NPV, the investors are losing their real net worth. It is doubtful that private sector would undertake a project with a negative NPV except for diplomatic and strategic grounds. Another criterion for financial evaluation of a project is Internal Rate of Return (IRR) which is equal to project discount rate where NPV is equal to zero; therefore in order to calculate the IRR, the net benefit of the project is set at zero (Jenkins, et al., 2011).

4.3 Sensitivity Analysis

Sensitivity carries out a clear and adjustable procedure by varying the parameters randomly one at a time to observe the impact of changes on the outcome. A number of increasing changes are made for each parameter one at a time and the project outcome is calculated every time recording the amount of shift from its baseline (Jenkins, et al., 2011).

To perform sensitivity analysis or what if analysis on Excel spreadsheet following actions will be taken:

- Forming a deterministic model in the Excel spreadsheet based on finding about the project.
- Identifying the variables which seem to have a significant impact on the outcome of the projects (and can be easily assessed in the conceptual stage).
- Selecting a most probable range for mentioned variables with the mean on the most probable assumed values.
- Computing the effect of various compounds of variables on the total cost of the projects (Rogers & Duffy, 2012).

4.4 Risk Analysis

The financial analysis is conducted based on deterministic values of project variables. Never the less, considering the lengthy concession period, the project variables such as inflation rate, interest rate, cost of project implementation and end price of the outcome are subject to many uncertainties. Executing a risk analysis, to examine the project under different probable future scenarios, would be of great assistance in objective evaluation of the project (Jenkins, et al., 2011). Indeed, concessionaire and the government would like to avoid undertaking a “bad” project and capture the opportunity of implementing a “good” project. Once the risks of undertaking the project are thoroughly scrutinized, it might be possible to mitigate significant risks through contractual agreements so that undertaking a potentially successful project can be realized (Jenkins, et al., 2011).

On this study risk analysis is conducted through Monte Carlo simulation using Crystal Ball™ Software to examine viability of undertaking the project. The methods of choosing risk variables related to project data and assigning them a probability distribution are discussed on the following sections.

4.4.1 Monte Carlo Simulation

Determination of the possible variability of a project’s return due to many uncertainties in a concession project is conducive to examine the impacts on key stakeholders.

Monte Carlo simulation can help understand magnitude and nature of the variability of the project’s outcome. Monte Carlo simulation is a computerized risk analysis methodology which generates possible project scenarios by randomly selecting input values from the defined probability distributions of risk variables. It is an amplified alternative for sensitivity and scenario analysis which are recognized to have some limitations. In Sensitivity analysis no correlation is defined between the variables, thus neglecting the probable impact of a variable change on other variables. Although likely range of values for each variable is examined in sensitivity analysis, since no probability distribution is attributed to the values, it's not possible to examine the probability of occurrence of certain values. In Scenario analysis although correlation between variables can be defined, variables cannot be associated with probability distributions. Besides, the generated scenarios are discreet rather than being continuous which in some cases may not respect all the possible situations that can happen (Jenkins, 2010).

Monte Carlo simulation is executed on an Excel spreadsheet using the Chart FX Crystal Ball 7.3 computer-based software to carry out risk analysis. Customized Monte Carlo Simulation software enables the computer to select random values in the range of specified probability distributions with certain defined correlation between variables to generate random project scenarios and a series of possible project outcomes. This procedure is repeated 10,000 times, resulting in a probability distribution of outcomes.

4.4.2 Risk Analysis Process

4.4.2.1 Identify Risk Variables and pertinent probability distributions

Risk variables, the impacts of which are considerable on the outcome criteria, are identified using sensitivity analysis (Jenkins, et al., 2011). Subsequent to identification of risk variables, based on expert input and available historical data, suitable probability distribution and probable range of values are attributed to each risk variable. Correlation between variables should be specified as well. The reason of conducting risk analysis on the risk variables (extracted from sensitivity analysis) is to decrease the level of complexity and forestall wasting limited resources (Jenkins, et al., 2011). The risk variables with the most critical effect on the outcome of the project are acquired from sensitivity analysis of the conventional spreadsheet using MS Excel 2007.

4.4.2.2 Conduct Monte Carlo Simulation

After identifying the risky variables, associating them with probability distributions, and specifying correlation between certain variables, the model outcomes which the computer program is adjusted to monitor during the simulation, should be selected. After specifying the number of simulation runs (typically 10,000), the simulation is ready to run. Each run displays a probable future scenario base on specified probability distributions and defined correlations between variables (Jenkins, et al., 2011).

4.5 Soft Computing Methods

Soft Computing tools are prevalently used in complex real world problems. Soft computing tools are called soft because they don’t offer 100% accurate solution to the problem. They use uncertainty, approximation and limited information to reach firm solutions. A soft computing tool simply helps infer the answer from past examples and learn from experience (Chaturvedi, 2008). It is a derivative of computational intelligence methodology based on information processing characteristics of biological systems. It utilizes various statistical, probabilistic and optimization tools to learn from experience and previous examples, and use that prior training to categorize new data, depict the trends, and predict new probable patterns. Soft computing techniques are able to model complex, unknown, noisy and nonlinear relationships (Mitchell, 1997).

Neural Networks and Genetic Algorithms are the two of soft computing techniques (Mitchell, 1997). Usage of these techniques in engineering disciplines has offered the possibility of simple and quick analysis of the problems. The Artificial Neural Network (ANN) is based on the human brain's functioning; they are able to model complex relationships. Genetic algorithm (GA) is a robust optimization approach which borrows the theory of natural selection and biological evolution. Genetic programming (GP) is a derivative of GA with the solutions in the form of computer programs.

The ability to develop simplified prediction equations is the major advantage of GP over ANN techniques.

In the following chapters, each of these soft computing methods will be employed in various ways to propose simplified and easy solutions to analyzing BOT contracts. Two case studies will be used to illustrate modelling the relationship between the project risk variables based on historical data to be able to examine viability of undertaking a BOT project. Soft computing model formulations will identify possible combinations of projects' influential variables. On each model, depending on the case study, first those parameters that substantially affected the variability of the proposed project outcome would be identified as uncertain and risky variables. Second with employment of expert judgment and certain defined criteria, the models' input and output variables will be selected to generate pertinent prediction models.

The important objective of a soft computing approach is to find solutions that perform well not only on the cases used for establishing the model but also on cases of new unseen sets of data. Therefore after generating the models, the performance of each model is validated by using the untrained data which were not engaged in building the models. The magnitude of errors between prediction models and their corresponding data will be determined also to give some insight to performance of the proposed models. The steps of developing GP and ANN models will be explained in detail on the following chapters.

Chapter 5

ANN MODELS IN ANALYZING BOT

5.1 Introduction

In recent years, awareness of the sustainability aspects of infrastructure projects has been increasing around the world. Making infrastructure projects technologically aware and adaptable to changes while meeting user needs normally increases total project cost (ASHRAE, 2006). In some cases, government cannot afford the investment cost, but a public-private partnership (PPP) offers a better means to achieve the goal (Akintoye, et al., 2003) (Grimsey & Lewis, 2004). Typically, government prefers to establish a long-term partnership to motivate the contractor to accelerate the construction phase and to consider the whole project life cycle to reduce energy consumption, minimize waste, and decrease operating and maintenance costs. This approach prevents the contractor from reducing short-term construction cost at the expense of long-term value (Grimsey & Lewis, 2004) (Yang & Su, 2007).

The PPP type of agreement can be used in various sectors, including education, healthcare, transportation (parking facilities, airports, railroad facilities, trains, roads, and bridges), custodial infrastructure (detention facilities, courthouses), public buildings, water and wastewater utilities, defense installations, and IT facilities (Akintoye, 2009). One of the most popular PPP options is the Build-Operate-Transfer agreement (BOT), which takes a concession-based approach and utilizes private-sector resources to design, build, fund, renovate, operate, and maintain infrastructure facilities (Grimsey & Lewis, 2004). Government may own the facility from the outset, or may obtain the ownership at the construction completion stage or at the end of the concession period. After handover, operation of the facility will be resumed by the government (Grimsey & Lewis, 2004) (Xenidis & Angelides, 2005). The concessionaire will obtain a return on its investment from collecting operating revenue during the concession period (Zhang & Kumaraswamy, 2001).

BOT-type agreements are used in projects that require huge amounts of investment. Therefore determining the concession period and terms is of crucial importance to a successful agreement. According to Ng et al. (2007) (Ng, et al., 2007), entitling the concessionaire to increase tolls or tariffs to guarantee its own minimum revenue in the case of lower-than-expected project revenue (which is probable with a short concession period) would be repellent to users. On the other hand, a long concession period may well include the period of peak project serviceability, leaving no incentive for the government to continue operating the project after the handover. Therefore, the key to a successful PPP project implementation is a clear and mutually acceptable definition of concession terms (Liou & Huang, 2008).Yang et al. (2007) (Yang, et al., 2007) proposed a model based on game theory and drew attention to the undeniable influence of project construction cost on concession terms. Their model did not specify toll/tariff rates or other fundamental parameters which define decision-making boundaries for the host government.

Ng et al. (2007) (Ng, et al., 2007) was another researcher who applied fuzzy set theory to a simulation model to examine various project scenarios and to achieve maximum Internal Rate of Return (IRR), minimum tariff regime, and minimum concession period simultaneously as an optimal scenario. IRR has certain drawbacks as a decision-making criterion, and because Net present Value (NPV) is more objective, it is logical to perform project appraisal on both criteria to avoid misleading judgments (Jenkins, et al., 2011).

To obtain consensus during a contract negotiation phase, various combinations of concession terms must be evaluated. This typically involves repeated recalculation of conventional financial analysis spreadsheets, which is a time-consuming and complex process. To alleviate this problem, Ngee et al. (1997) (Ngee, et al., 1997) developed an automated mechanism to expedite the negotiation process between the government and the concessionaire. Using multiple linear regression analysis, they obtained a predictive equation with a set of 35 inputs that linked the tariff and the concession period to the IRR as the chosen project performance indicator. It was assumed that the two parties had reached an agreement about all other parameters, although no risk allocation was considered.

Because several stakeholders are party to BOT projects and a long period of time may be required to complete the contract, many uncertainties and risks threaten the performance of BOT agreements (Shen & Wu, 2005) thus a specified and robust legal and authoritative framework is absolutely necessary (Yuan, et al., 2010). In PPP projects, uncertainty or stipulating renegotiation options in contracts may create serious problems, such as opportunistic bidding policies to increase the probability of winning the bid (Chen, et al., 2012). The acceptance of a renegotiation petition is equivalent to a possible claim. Jeopardizing public resources by expecting the government to bail out a troubled project company is out of the question, especially in cases of cost overruns or unexpected operating costs due to unqualified management (Ho, 2006).Therefore, it is of crucial importance to allocate risk objectively and to identify concession terms in a clear and mutually acceptable manner. Shen et al. (2002) (Shen, et al., 2002) proposed a deterministic model for defining a suitable concession period which strikes a balance among the financial expectations of the various parties concerned. Subsequently, Shen et al. (2005) (Shen & Wu, 2005) modified their previous model by incorporating project risks. The concession period was determined according to the risk and the confidence level in future NPV estimates, but the BOT concession model (BOTCcM) did not reveal the probabilistic combined risk variables which led to the choice of a specific concession period.

As mentioned in chapter 4, Monte Carlo simulation is a computerized risk analysis methodology which generates possible project scenarios by using input values which are selected randomly from identified probability distributions of risk variables. Malini (1999) (Malini, 1999) developed a model incorporating a Monte Carlo simulation technique to perform risk analysis for a BOT project. Policy parameters and macroeconomic indicators were provided as deterministic input variables. Liou et al. (2008) (Liou & Huang, 2008) used Monte Carlo simulation to incorporate project risk and generated 60 input variables for multiple regression analysis to examine the influence of tariffs, concession periods, and borrowing interest rates on NPV as the project evaluation indicator. To incorporate a plausible and extensive risk analysis into a BOT project evaluation, it would be helpful to integrate many more scenarios into the determination of concession terms and to perform an objective analysis of various risk variables and their influence.

Statistical soft computing models based on machine learning have been widely used to address a wide range of optimization, classification or prediction problems in different science and engineering applications (Gandomi & Alavi, 2009) (Yaghouby, et al., 2010) (Yaghouby, et al., 2012) (Azamathulla & Ahmad, 2013) (Najafzadeh & Azamathulla, 2015) (Gandomi, et al., 2014). One of such models that could be used to automate the decision making scenario is the artificial neural network (ANN) (Jin & Zhang, 2011) (Sodikov, 2005). ANN models have been particularly successful in developing nonlinear data relationships and in enhancing estimates to make more related data available (Emsley, et al., 2002).

The ANN approach has been widely used to predict costs in various disciplines where data can be obtained, especially in construction projects (Kim, et al., 2004) (Gunaydin & Dogan, 2004) (Tatari & Kucukvar, 2011) (Fazly, et al., 2014). ANN models are capable of learning and simulating elaborate applications (Weckman, et al., 2010). Various studies have demonstrated that ANN models provide more accurate estimates than traditional statistical models (Yaghouby, et al., 2009) (Gandomi & Alavi, 2009) (Alavi & Gandomi, 2011) (Hasanzadehshooiili, et al., 2012).

In this chapter, a neural network model was used to develop a model that formulates the relationship between the project’s important parameters or risk variables. These were extracted by conducting sensitivity analysis and Monte Carlo simulation on conventional spreadsheet data to reach a fair consensus to the government as well as to the concession company. This technique was used on data obtained from six actual BOT dormitory projects in Cyprus as a case study to demonstrate the procedure.

5.2 Significance of research

It is undeniable fact that professional judgment, skill, and experience play substantial role in implementing PPP versus public procurement because the difference between the two may be relatively narrow. To provide a meaningful value-for-money to convince the parties to undertake BOT type of procurement, an extensive and realistic examination of impacts of all quantifiable risks, costs and profits on each other must be included. In order to conduct an analysis to examine viability of an infrastructure project, there should be adequate number of similar past projects to allow forming reliable probability distributions.

Reaching a consensus in contract negotiation requires considering various combinations of concession terms. This typically involves repeated recalculation of conventional financial analysis spreadsheets, which is complex and time-consuming. Earlier studies had developed an automated mechanism and claimed benefits in contract negotiating procedures. However, in these studies, either risk allocation was not considered (Ngee, et al., 1997), or inadequate information was given on probable combinations of risk variables (Shen & Wu, 2005). Some researchers have used internal rate of return (IRR) as a decision-making criterion (Ng, et al., 2007); although, net present value (NPV) is a more objective criterion, and project appraisal using both criteria helps to avoid misleading judgments. IRR is the rate of return which the investors earn when the project's NPV is equal to zero meaning that the investors would recover their investment (Jenkins, et al., 2011). However IRR is not a reliable investment criterion. IRR is the root of a mathematical equation which may not have one unique result for internal rate of return. On the other hand, in selection between mutually exclusive projects with different sizes of investment, different length of life and different timing, IRR does not take into account these differences (Jenkins, et al., 2011).

Previous studies focused attention on project construction cost among the concession terms (Yang, et al., 2007), but in addition, a model should present toll/tariff rates or other fundamental parameters which define decision-making boundaries for the host government.

Incorporating extensive risk analysis into a BOT project evaluation requires a tool to help integrate many probable scenarios into the determination of concession terms and to perform an objective analysis of various risk variables and their influence. With the help of an ANN model, this research attempted to incorporate as many scenarios as could be generated. Both NPV and IRR were considered to ensure the most unbiased results. The ANN model could identify relationships between input variables and help create an accurate decision-making model, including an extensive risk analysis. The results of this study show that by defining specific concession terms (favorable to both parties), it is possible to estimate an appropriate value of price/student/year using the ANN method. Therefore, an approach is proposed by this research to develop a model that formulates the relationship between project's important parameters or risk variables by utilizing ANN model's capabilities to help professionals examine viability of undertaking a BOT type project.

5.3 Methodology

Conventional financial analysis spreadsheets are computed in MS Excel 2007 using actual data. After examining the impact of changing the concession period on the project performance indicators (IRR and NPV), several concession periods with substantial impacts are chosen to compute cash flows. Conventional spreadsheets are calculated to perform cash flow analysis for selected concession periods.

The risk variables with the most crucial impact on the project outcome are identified from sensitivity analysis. Those parameters that substantially affected the variability of the proposed project outcomes would be identified as uncertain and risky variables.

Next, Monte Carlo simulation is performed on the conventional spreadsheets to conduct risk analysis. The probability distributions and the likely ranges of risk variables (identified by sensitivity analysis) would be assumed according to historical observations. Monte Carlo analysis software is capable of selecting random values of uncertain/risk variables in a range of specified probability distributions, generating random scenarios and a series of possible project outcomes. This procedure is basically repeated 10,000 times, yielding a probability distribution of outcomes. The expected project outcomes or risk forecasts are expressed as NPV and IRR.

With consideration of eligible ranges for NPV and IRR, generated random scenarios in Monte Carlo simulation are used to draw data inputs for the ANN model. This information is fed into the ANN model to create an automated prediction model that could provide accurate results to reach unanimous decision criteria which would satisfy the requirements of all parties simultaneously. In the following section, a demonstration of this procedure on data from six actual BOT dormitory projects in Cyprus will be described.

5.4 Case Study

Turkey and Northern Cyprus are among the countries that have embraced the BOT model to provide necessary investments. The economy of Northern Cyprus is highly dependent on the education sector, which is expected to expand in the coming years. In 2011, Northern Cyprus received $400 million in revenues from this sector (Ocakoglu, 2011), and therefore investment in student accommodations has gained great importance.

Six university dormitories built in Northern Cyprus under BOT agreements with different concession terms were chosen as a case study. The authors obtained actual data related to the dormitory projects. Due to data confidentiality reasons, author is not able to exhibit the prepared financial spreadsheets. All nominal values were converted to real values according to actual inflation rates published by the government. Information about the dormitories is shown in Table 5.1.

Table 5.1: Information about the dormitories

Dormitory	Total Area (m^2)	Number of Rooms	Number of Beds	Construction Period	Construction cost in end year($)
1	3500	66	204	1989–1990	522,575.00
2	4300	66	220	1990–1991	693,383.00
3	7412	125	253	1989–1990	1,106,665.00
4	4992	192	352	2005	1,557,216.00
5	3339	72	312	2006	1,346,688.00
6	1182	40	80	1989–1990	500,000.00

5.5 Preparing conventional spreadsheets

Conventional financial analysis spreadsheets for the six dormitories were computed in MS Excel 2007 using actual data. After analyzing the impact of different concession periods on the project performance indicators (IRR and NPV), it was decided to compute cash flows for four concession periods with substantial impact on the project performance indicators: 15, 20, 25, and 30 years. Overall, 24 conventional spreadsheets were computed for cash flow analysis of these concession periods. This meant that some of the calculations had to be projected into future years. Up to 2012, all the information in the spreadsheets is actual data which were acquired from the head office of each dormitory. Data for future years were calculated according to the observed trend of changes in previous years (Shahrara, et al., 2015. [Forthcoming]).

5.5.1 Parameters and Assumptions

The following assumptions and parameters form the base case of the financial model for each dormitory:

Student demand and annual rate per student: Historical data of student demand on dormitories in Cyprus for the past ten years shows a growth of 2% each year. The average occupancy rate on service time and annual rate per student for each dormitory is reported as shown on table 5.2.

Table 5.2: Dormitories' occupancy rates and annual incomes per student

Dormitory	Occupancy rate (%)	Annual rate per student ($)
1	90	1400
2	90	1650
3	86	1200
4	80	1800
5	90	2000
6	75	2000

Energy, operation and maintenance costs: Energy cost is comprised of electricity, water and gas consumption costs. The energy costs from the first year that the dormitory was put into service till 2012 were obtained from the head of the dormitories. After 2012 the energy costs were assumed to increase by the cost growths presented on table 5.3.

The operating and maintenance costs include the wages to the employed staff, annual maintenance and cleaning cost, major maintenance which is comprised of external painting, interior painting and room furniture and room floor renovation. Table 5.3 is the summary of energy, operation and maintenance costs for all dormitories. All dormitories have been operated with the same operating company; therefore all the reported operation and maintenance costs were consistent for all of them.

Inflation rate: The inflation rates from 1999 to 2012 are displayed in table 6.4; and from 2012 ahead was assumed to be constant as 3.8%. Domestic inflation rate from 2012 till the end of the project life time was assumed to be 6.3%. Table 5.4 presents Turkey's domestic (TL) and the United States' ($) yearly inflation rates. DI and USI stand for domestic Inflation rate and US inflation rates respectively.

Table 5.3: Energy, operation and maintenance costs

		Cost ($)	Cost Growths (%)
Energy Costs			
Electricity			3%
Water			2%
Gas			3%
Operation and Maintenance Costs			
Wages			
Managers		150,000	14%
Labor		45,000	
Maintenance Cost			
Annual Maintenance		82000	8%
Cleaning		40,000	5%
Major Maintenance			
External Painting	Every 5 years	12,000	10%
Interior Painting	Every 3 Years	10,000	5%
Room furniture	Every 3 Years	12,000	5%
Room floor maintenance	Every 10 Years	14000	5%

Table 5.4: Inflation rates (1999-2013)

Year	1990	91	95	00	01	04	05	06	07	08	09	10	11	12
DI (%)	60	65	120	65	40	9.3	8.2	9.8	8.7	10.4	6.3	8.7	6.3	6.3
USI (%)	5	6	2.7	3.4	2.8	2.5	2.3	2.5	2.9	3.8	-0.3	1.4	2.0	2.0

5.6 Monte Carlo simulation and sensitivity analysis

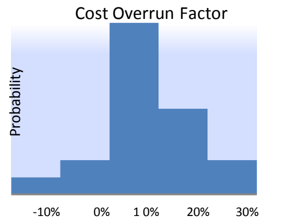
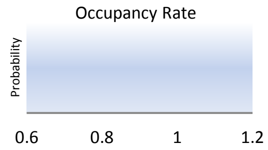
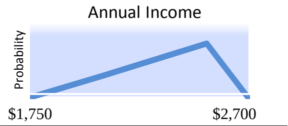
Monte Carlo simulation was performed on the 24 spreadsheets using the Chart FX Crystal Ball 7.3 computer-based software to carry out risk analysis. The risk variables with the most critical effect on the project outcome were acquired from sensitivity analysis of the conventional spreadsheets using MS Excel 2007.

Sensitivity carries out a clear and adjustable procedure by varying the parameters randomly one at a time to observe the impact of changes on the outcome. The project parameters are changed incrementally one at a time, and each time the impact of parameter change on the project outcome is calculated to record the degree of shift from the baseline scenario (Jenkins, et al., 2011). Variables that their variation could impact the projects' outcome largely will be chosen as input variables to Monte Carlo Simulation. In this study, three parameters substantially affected the variability of the proposed project outcomes and were identified as uncertain and risky variables: cost overrun factor, occupancy rate, and price/year/student. The probability distributions and the likely ranges of the selected risk variables were assumed based on the past movements of values of the variables and on expert opinion; and are presented in Table 5.5. According to reported historical observations in the region, a step distribution was assigned for capital expenditure cost overrun factors. As the distribution reflects, it had been recorded that there was a 50% probability that at the end of the project, the actual capital expenditures would go beyond the estimated costs at the conceptual stage by zero to %10. For occupancy rate, a normal distribution was assigned with mean of 90% and standard deviation of 9%. As per dormitories released yearly prices, a triangular distribution was assigned for the dollar amount of renting a bed per year per student with a range from $1750.00 to $2,700.00 with $2000.00 as the most likely price per student per year.

Customized Monte Carlo Simulation software enabled the computer to select random values in the range of specified probability distributions to generate random project scenarios and a series of possible project outcomes.

This procedure was repeated 10,000 times, resulting in a probability distribution of outcomes. The expected project outcomes or risk forecasts were expressed as NPV and IRR values. As an example, a single forecast for one of the university dormitories with a specific concession period is shown in Figure 5.1. The results obtained for the project's NPV at discount rate of 8% after 10,000 trials indicate that the mean NPV is $611,169.63 with a standard deviation of $3,647.13. The IRR simulation also yielded positive results. The range for the IRR was from -1.62% to 28.55% with a standard deviation of 0.04% from the base case IRR of 11.43%, the mean IRR obtained from the simulation was 14.10%.

Table 5.5: Risk variables and probability distribution

Capital Expenditure Cost Overrun Factors (%) (Step Distribution)		Min / Max / Prob. -20% / -10% / 0.05 -10% / 0% / 0.10 0% / 10% / 0.50 10% / 20% / 0.25 20% / 30% / 0.10
Occupancy Rate (%) (Normal Distribution)		Mean 90% Std. Dev. 9%
Price/Year /Student ($) (Triangular Distribution)		Minimum $1,750.0 Likeliest $2,000.0 Maximum $2,700.0

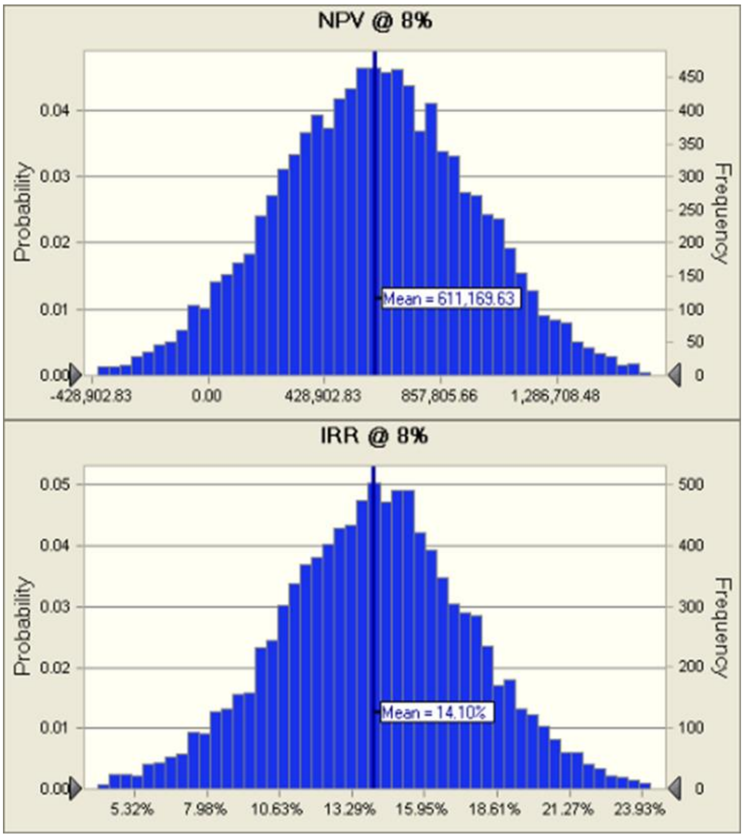


Figure 5.1: Example of frequency probability distributions of NPV and IRR

6.7 Sampling procedures

On the basis of random project scenarios generated considering eligible ranges for NPV and IRR along with other parameters that seemed important from a decision maker point of view, eight input values (capital expenditure cost overrun factor, occupancy rate, NPV, IRR, total dormitory area, number of rooms, number of beds, and concession period) were selected as input variables. Price/year/student ($) was used as the output variable.

1871 different scenarios associated with actual BOT dormitory projects for universities in Cyprus were generated. This information was fed into the ANN model to create a model that could automate the negotiation process for BOT-type dormitory projects and that could determine the optimal price/year/student according to unanimous decision criteria which would satisfy the requirements of all parties simultaneously.

The conditions defined to extract data as input values for the ANN model are:

- The eligible ranges for IRR (greater than the discount rate (8%)) and NPV (greater than zero) were obtained from the Monte Carlo simulation.
- The eligible range for risk variables mentioned above were probability distributions extracted from historical observations. Figure 5.2 portrays the procedure to draw data for ANN model.

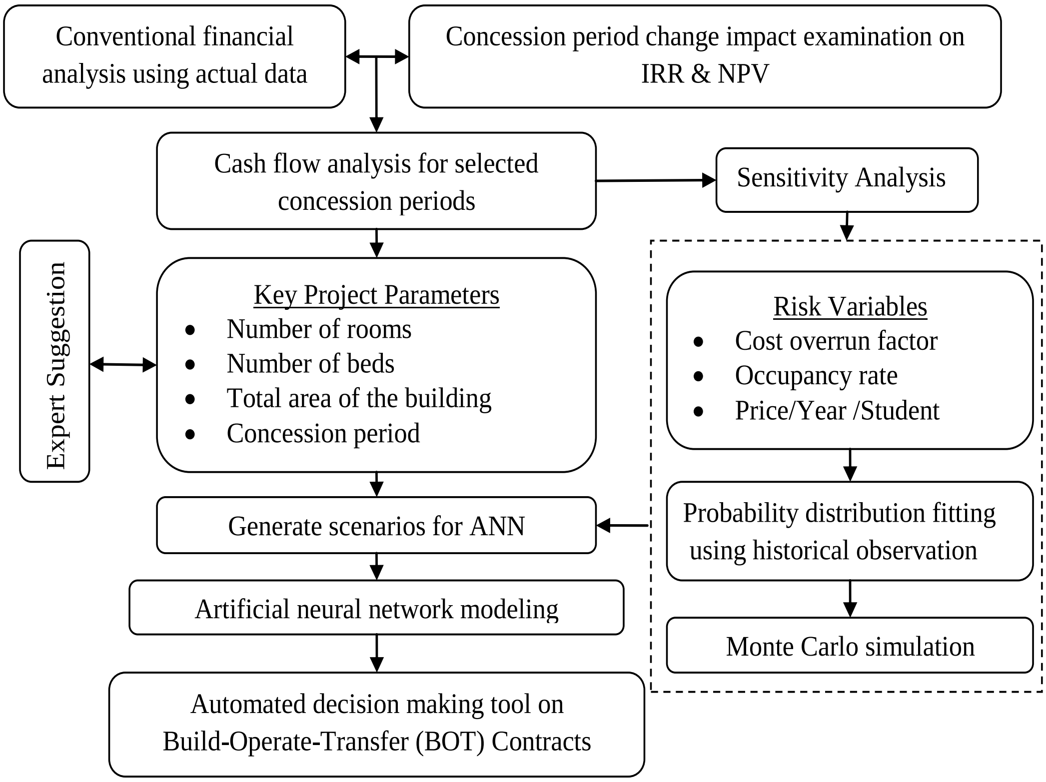


Figure 5.2: Sampling procedure for ANN model

5.8 Artificial neural network

Neural network models are comprised of simple computational units structured into layers and interwoven by a system of connections. ANN is developed in three layers; an input layer, hidden layer(s), and an output layer. The number of hidden layers changes according to the application (Dikmen & Sonmez, 2011).The output layer receives the input and signals flow from the input layer through the hidden layers which are between the output and input layers (Apanaviciene & Juodis, 2003). Each layer consists of several neurons, which are interconnected by sets of correlation weights. The input layer’s neurons receive their activation from the environment, while the activation levels of neurons in the hidden and output layers are computed as a function of the activation levels of the neurons feeding into them. The information which is received as inputs will be transferred to the hidden layer, and produce an output with the transfer function. Additionally, the learning processing (or training) is formed by adjusting the weight of interconnectivity neurons. The training data set is continuously looped through the network and after every predefined number of iterations, the test set data is passed through the evolved network to generate an output. Then the error of each neuron is calculated. The training is stopped as the error fall to a lower value than the target value. The total error is evaluated by adding up all the errors for each individual neuron and then for each pattern in turn to give a total error. The network keeps training until the total errors falls to some pre-determined low target value and then it stops. Once the network has been fully trained, the test set which is different than the training set is used to check the validation networks (Baalousha & Çelik, 2011).

In this study 1780 data sets (80% of the data) were used to train the ANN model, while the remaining data sets were used as test data. A two-layer feedforward network with sigmoid hidden neurons and linear output neurons was found to fit multidimensional mapping problems sufficiently well, given consistent data and enough neurons in the hidden layer. The network was trained using the Levenberg-Marquardt backpropagation algorithm unless there was not enough memory, in which case scaled conjugate-gradient backpropagation was used. The ANN model was built with a hidden layer and dataset using the 8-20-1 architecture, which contains eight nodes in the input layer, 20 nodes in the hidden layer, and one node in the output layer. Figure 6.3 displays the designed ANN architecture with eight input values (capital expenditure cost overrun factor, occupancy rate, NPV, IRR, total dormitory area, number of rooms, number of beds, and concession period) and one output value of Price/year/student ($) . MathWorks MATLAB R2010b, ANN Toolbox software was used for the analysis. The data sets were divided into three groups: training data, cross-validation data, and a test data set according to the following percentages:

1. Training set – 80%

2. Cross-validation – 10%

3. Test set – 10%.

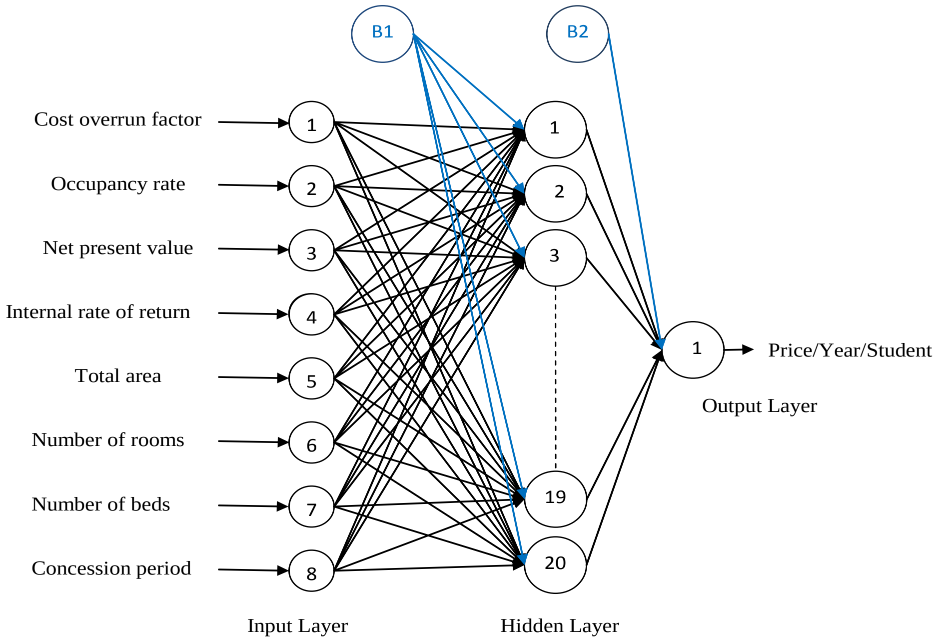


Figure 5.3: Artificial neural network architecture

5.9 Results and discussion

Table 5.6 shows an example of the training data which were used to train the network by determining values for the parameters (weights). On table 5.6 P/Y/S stands for price per year per student. Cross-validation was used to monitor the capability of the neural network to build generalized outputs and to eliminate data memorization risk. Finally, test data were used to validate the quality of the chosen ANN model. Scarce or overly simple training data produce large training and testing errors, resulting in underfitting. Complex and ambiguous models constructed using noisy or corrupted training data create low training errors, but their testing errors cannot be ignored. Stopping criteria and weight resetting were used to cope with under- and overfitting problems (Sodikov, 2005) (Smith & Mason, 1997). A comparison of training and testing data was performed as illustrated in Fig. 5.4 and showed a close fit between predicted and measured values. The three axes represent training, validation, and testing data. The dashed line in each dimension represents a perfect relationship between outputs and targets, the solid line represents the best-fit linear regression line, and the R-value indicates the strength of the relationship. In this study, the training data achieved a good fit, and the validation and test results also yielded R-values greater than 0.9. Training was stopped after the validation error increased for six iterations, which occurred at iteration 32.

Figure 5.5 shows a plot of the training, validation, and test errors. In this example, the results can be viewed as reasonable because of the following considerations:

- The final mean squared error is small.
- The test set and validation set errors have similar characteristics.
- No significant overfitting has occurred by iteration 26 (when the best validation performance occurs).

Table 5.6: Example of training data set

			Input					
Cost overrun factor (%)	Occupancy rate (%)	NPV	IRR (%)	area (m^2)	No. rooms	No. beds	CP (years)	P/Y/S ($)
-20	95	230000	10.4	7412	125	253	25	1750
0	100	244760	11.0	4992	192	352	20	1950
10	90	437100	15.6	3339	72	312	30	2000
-10	85	90470	10.3	4300	66	200	15	2200

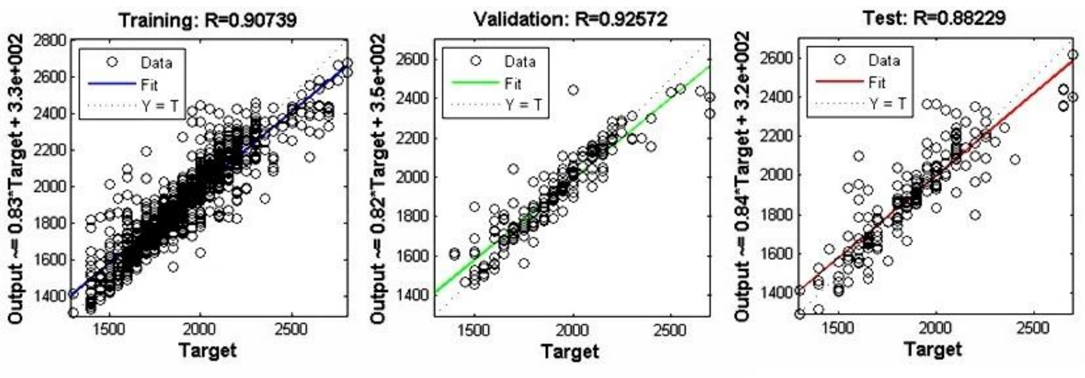


Figure 5.4: Training, validation, and test data.

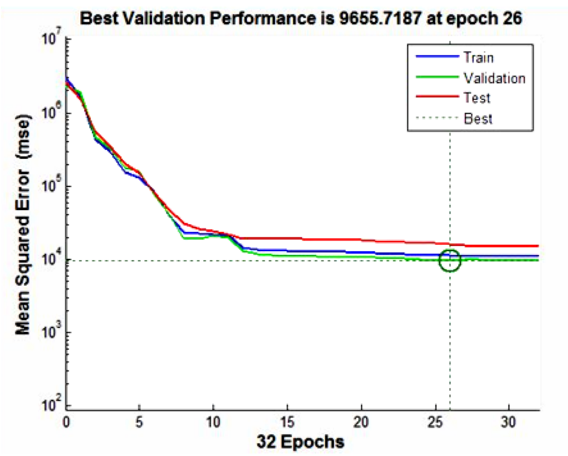


Figure 5.5: Training, validation, and test root mean squared error values

In addition, examples of test data for different price-estimation status values were also calculated as illustrated in Figure 5.6 By projecting each input value against its output value, the accuracy of using ANN as a comprehensive price estimation tool can be evaluated. Note that the trends in the graphs reflect all eight input values simultaneously, not just the projected input value. By using these link weights from a trained ANN, the price/year/student can be estimated. The errors and correlations for the whole data sets are presented on table 5.7. This study can be reproduced and applied to other projects as well.

Table 5.7: Errors and correlations

RMSE	MAE	R	ρ
108.0841	71.287	0.9064	0.029477

RMSE: root mean square error
MAE: mean absolute error
R: correlation coefficient
ρ: performance index (Gandomi & Roke, 2013)

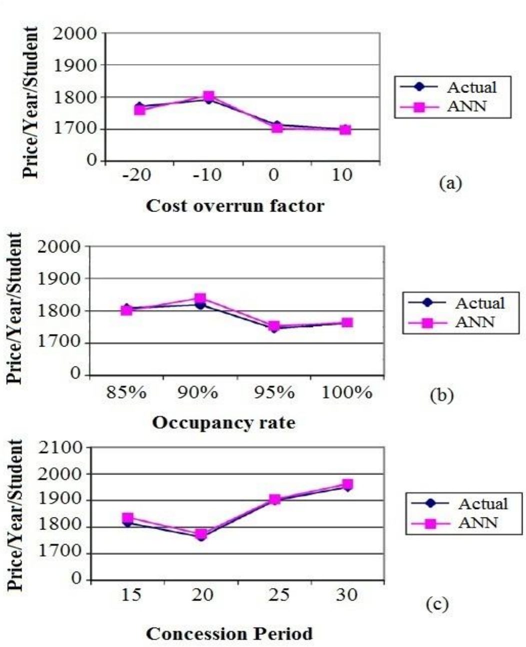


Figure 5.6: Test data for evaluating price/year/student

5.7 Conclusions

The results of this study show that by defining specific concession terms (favorable to both parties), it is possible to estimate an appropriate value of price/student/year using the ANN method. Using actual data for dormitories in Cyprus helped demonstrate how to incorporate risk attributes and relevant parameters into the model formulation process to identify possible combinations of financial terms in a BOT project. On the basis of actual cash flow statements for six university dormitory construction projects and considering 15-, 20-, 25-, and 30-year concession periods for each, 24 conventional spreadsheets were prepared to NPV and internal rate of return (IRR) as project performance indicators for the various concession periods. With incorporating data sets drawn from Monte Carlo simulation and several important parameters on all the spreadsheets, 1871 random scenarios were produced, and each scenario with a selected set of eight input variables (capital expenditure cost overrun factor, occupancy rate, NPV, IRR, total dormitory area, number of rooms, number of beds, and concession period) was fed into the ANN. The ANN approach succeeded in automating the negotiation process for a BOT-type contract by taking into account project risks and uncertainties along with several important parameters to build an unbiased and accurate pricing structure for BOT-type projects.

Chapter 6

GEP MODELS IN ANALYZING BOT

6.1 Introduction

Recurrent incidents of sewer overflows into rivers and streams as well as water main breaks in the cities manifest that there is a dire need for upgrading aging and deteriorating drinking water and wastewater infrastructures in the USA. In fiscal year 2012, the U.S. Environmental Protection Agency (EPA) financed the Clean Water program $1.5 billion and the Drinking Water program $918 million. EPA furnishes funds to states of USA that provides local communities with low- or no-interest loans to invest on treatment plants, sewer and water distribution pipelines projects and other similar infrastructure. EPA estimated funding requirements of almost $335 billion for drinking water infrastructure and $298 billion for wastewater infrastructure (Gómez, 2013).

A study in the water industries by Hassanein and Khalifa (2007) reported that private sector outperformed its public counterpart in the US and UK (Hassanein & Khalifa, 2007) .

Imminent water shortages in the State of California, County of San Diego and frequent disruptions of service due to water main breaks alarmed the authorities to address the urgent need to reduce water loss and minimize water service interruptions. Most of the existing old cast iron (CI) mains have reached to the end of their predicted service life which necessitates their immediate replacement to halt water main breakage and water leakage (San Diego County Grand Jury, 2013).

The State of California Department of Public Health has mandated that cities replace at least 10 miles of CI pipe per year, with the goal of eliminating all CI pipe by 2017 (San Diego County Grand Jury, 2013).

This study proposes application of Build- Operate-Transfer (BOT) type of Public-Private-Partnership (PPP) to help overcome existing financial and operational shortfalls of water and sewer distribution services. If the generated revenue suffices to pay for the costs and fulfill financial obligations, then private capital would help replace the old distribution services consequently decrease water interruptions due to break and curb the leakage, expand the coverage so that poorer households can get healthier and cheaper water versus expensive private vendors. Private sector management would help remedy the problems of operation by applying effective operational practices such as optimal levels of staffing, and 'user pays' pricing method to save water (Grimsey & Lewis, 2004).

This chapter will provide a brief history of sewer and water distribution systems in the City of San Diego. It will also provide the necessary technical information about the sewer and water replacement/rehabilitation project considered in the study. Financial analysis and risk analysis will be conducted as well. Due to the outcome of sensitivity analysis, usage of a soft computing model is introduced to improve the appraisal of undertaking a BOT project at the conceptual stage.

6.2 Proposed Project

Lack of investment on the operation of water system, low operating efficiencies, high staffing levels, poor capital structure, low revenue collection, and a high level of unaccounted-for-water reflecting leakages and losses, as well as the inability to bill and collect payments need to be addressed in delivering water to communities. Objective of this study is to propose a type of PPP to use private sector skills and capital to distribute improved water services although it is essential that public sector commit to the project throughout the PPP transaction process.

We will analyze financial viability of design, construction, finance, operation and maintenance of 10 miles of water and sewer main replacement/ rehabilitation project taken place in one year in 2012 and put into operation promptly after one year. A concession period of 30 years will be attributed to the project on Built-Operate – Transfer (BOT) basis between the concessionaire and the City of San Diego.

6.2.1 Population Data

In 2010 San Diego Association of Governments' (SANDAG) released the 2050 Regional Growth Forecast from 2010 to 2035 in 5 year increments presented in table 6.1. It's been predicted that the population will increase from around 1.3 million to almost 1.7 million in 2035 (SANDAG, 2010)

Table 6.1: City of San Diego present and future demographics

	2010	2015	2020	2025	2030	2035
City of San Diego population	1,376,173	1,459,351	1,542,528	1,615,891	1,689,254	1,756,621
City population not served by the water system	51,868	53,811	58,542	61,105	63,501	68,668
Service area population	1,324,305	1,405,540	1,483,986	1,554,786	1,625,753	1,687,954

6.2.2 Housing Data

SANDAG is predicting a 23 percent housing growth rate on residential category during years 2000 to 2030 and consequently an increase in water consumption is expected. The residential category comprises of single family and multifamily dwelling units. The single family units are expected to have an increase of 5 percent by 2030, whereas, multi-family units will have a dramatic increase of 47 percent (SANDAG, 2010).

Another factor used in water consumption prediction is housing density which refers to occupied housing units per associated acres for single family and multi-family dwelling units. Housing density is expected to decrease by 4 percent for single family and increase by 24 percent for multi-family units from 2000 through 2030. Table 6.2 demonstrates SANDAG's regional growth forecast for the City of San Diego where Household Income derived from SANDAG data of number of housing units by income range (City of San Diego Public Utilities, 2010).

6.2.3 Employment Data

In order to determine non-residential water demand, San Diego's future employment is studied under the following categories: Military; Civilian; Agriculture; Construction; Manufacturing; Transportation, Communication and Utilities; Wholesale Trade; Retail Trade; Finance, Insurance and Real Estate; Services; and Self Employed and Domestics. On Table 6.2 SANDAG has listed the Civilian category as the largest category (City of San Diego Public Utilities, 2010) .

6.2.4 Median Household Income

Median household income refers to consumer's ability to pay for their water usage. Table 6.3 displays data provided by SANDAG for the years of 2000 to 2030, in five-year increments anticipating a 36 percent increase in household income to occur by 2030.

6.2.5 Water Use

The City of San Diego has utilized an econometric model to consolidate SANDAG data sets to produce projected water demands. Tables 6.4 presents the City's actual water use which shows a decline due to economic conditions, water use limitations due to drought, increased water costs and conversion of potable water system customers to the recycled water system.

Table 6.5 displays projected water demands till 2035 and table 6.6 shows the water demand for the low income household with less than 80 percent median income. The acronym (AFY) stands for Acre-feet per year.

Table 6.2: City of San Diego's regional growth forecast

Years	2000	2005	2010	2015	2020	2025	2030	Growth Rate
Total Occupied Housing Units	450,634	475,156	498,617	518,357	531,694	559,648	579,788	23%
Single Family	256,676	265,692	269,181	273,652	275,599	277,703	276,523	5%
Multi-family	193,958	209,464	229,436	244,705	256,094	281,945	303,265	47%
Housing Density								
Single Family	7.13	6.87	6.77	6.75	6.71	6.71	6.71	-4%
Multi-family	19.26	19.71	20.83	21.42	21.98	23.26	24.32	24%
Total Employment	775,624	817,876	864,052	907,562	929,916	949,802	973,937	20%
Military	34,365	34,365	34,365	34,365	34,365	34,365	34,365	0%
Civilian	741,259	783,511	829,686	873,196	895,550	915,437	939,571	21%
Agriculture	1,763	1,703	1,681	1,672	1,616	1,623	1,623	-5%
Construction	24,725	28,366	27,971	28,011	28,104	26,530	26,931	-3%
Manufacturing	74,098	66,669	67,479	67,566	67,594	67,791	68,028	0%
Transp., Commun. & Util.	36,204	36,944	39,755	41,707	42,511	43,906	45,873	25%
Wholesale trade	28,760	28,854	31,932	34,747	35,745	37,094	38,459	33%
Retail trade	110,000	117,091	120,692	126,139	128,884	131,819	134,215	16%
Finance, Insurance, Real Estate	48,492	51,956	57,400	61,821	64,210	66,102	67,744	32%
Services	257,585	276,567	297,152	319,791	330,430	340,627	352,514	29%
Government	129,544	144,048	152,256	156,940	160,890	163,735	166,994	18%
Self Employed & domestics	30,089	31,313	33,369	34,803	35,567	36,210	37,190	20%

Table 6.3: SANDAG median household income

Year	2000	2005	2010	2015	2020	2025	2030	Growth rate
Median household income	$48,960	$48,877	$50,469	$53,788	$58,235	$61,749	$66,795	36%

Table 6.4: Actual water use years 2005 and 2010

	Actual 2005		Actual 2010	
	#Accounts	Volume (AFY)	#Accounts	Volume (AFY)
Single-family	217,983	77,864	220,862	62,367
Multi-family	28,443	39,220	28,361	36,324
Commercial	14,468	33,099	14,542	27,244
Industrial	253	4,276	186	2,325
Institutional/Governmental	2,341	16,842	2,321	13,774
Landscape	7,245	27,877	7,327	20,257
Total	270,733	199,178	273,599	162,291

Table 6.5: Projected water use years 2015, 2020, 2025 and 2030

	Projected 2015		Projected 2020		Projected 2025	
	#Accounts	Volume (AFY)	#Accounts	Volume (AFY)	#Accounts	Volume (AFY)
Single-family	231,346	75,922	236,639	79,992	241,491	83,370
Multi-family	32,082	47,266	37,330	56,700	42,662	66,070
Commercial	14,376	31,617	14,783	33,541	14,681	34,012
Industrial	186	2,071	186	2,157	176	2,077
Institutional	2,302	13,359	2,302	13,772	2,247	13,639
Landscape	7,583	25,452	7,869	27,247	8,192	28,893
Total	287,587	195,688	298,582	213,409	308,505	228,061
	Projected 2030		Projected 2035			
	#Accounts	Volume (AFY)	#Accounts	Volume (AFY)		
Single-family	244,138	85,633	245,682	86,471		
Multi-family	47,910	75,328	52,420	82,781		
Commercial	14,100	33,116	13,853	32,740		
Industrial	166	1,995	166	1,967		
Institutional	2,172	13,399	2,154	13,329		
Landscape	8,162	29,301	8,543	30,698		
Total	315,534	238,772	321,337	247,986		

Table 6.6: Projected low income water use

	Low Income Water Demands (AFY)				
	2015	2020	2025	2030	2035
Single family	28,774	30,319	31,514	32,284	32,600
Multi-family	17,914	21,491	24,974	28,399	31,208
Total	46,688	51,810	56,488	60,684	63,808

6.2.6 Water Revenue

Besides authorized water consumptions which are billed, there are water losses and unbilled water consumptions which make the difference between water produced into the system (input) and water delivered (output) to the users or metered consumption by users. Table 6.7 demonstrates "non-revenue water" which is a term proposed by the International Water Association (IWA) (City of San Diego Public Utilities, 2010).

As shown in Table 6.7, real water loss includes revenue loss due to leaks, breaks and storage overflows. Water use for firefighting, line flushing and other authorized, but unbilled, use is classified as unbilled consumption. In 2008, the difference between water deliveries and metered demand was calculated 9% and assumed to remain 9% for the future forecasts since many efforts are being made to reduce water losses such as improving billing accuracies or detecting leaks (City of San Diego Public Utilities, 2010).

Table 6.7: The International Water Association (IWA) water audit format

<table>
<tr><td rowspan="4">Authorized consumption</td><td rowspan="2">Billed Consumption</td><td rowspan="2">Revenue water</td><td>Billed metered consumption</td></tr>
<tr><td>Billed unmetered consumption</td></tr>
<tr><td rowspan="2">Unbilled Consumption</td><td rowspan="7">Non-revenue Water (NRW)</td><td>Unbilled metered consumption</td></tr>
<tr><td>Unbilled Unmetered consumption(firefighting, line flushing)</td></tr>
<tr><td rowspan="5">Water losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized consumption</td></tr>
<tr><td>Meter inaccuracies and data errors</td></tr>
<tr><td rowspan="3">Real losses</td><td>Leakage on mains</td></tr>
<tr><td>Leakage and overflow at storage</td></tr>
<tr><td>Leakage on service connections</td></tr>
</table>

6.2.6.1 Revenue Impacts of Reduced Sales

Any reduction in water consumption due to any emergency such as power shortages, seismic vulnerability, leak in a main break, or fire hydrant knock-over or reduction in imported or local water supply may result in reduction in water sales. In order to mitigate the financial impacts of a water shortage, three reserve funds are currently considered by the City of San Diego as a backup plan. The first is the Secondary Purchase Reserve equal to six percent of the annual water purchase budget in the event of drought or sudden water disruptions. The second is a 45-day Operating Reserve for unanticipated normal water disruptions. The third is the Rate Stabilization Fund to secure funds from current revenues for the time when the revenue decreases. Without the use of these reserves or emergency storage water, it would be necessary to increase water tariff by 20 to 50 percent in the year that there is a 50 percent reduction in water sales. In order to replace the reserves, the tariff increase is still necessary. In such emergency events, evaluation of operation and maintenance cost reduction, potential of additional debt acquisition or the possibility of debt buy-down is necessary (City of San Diego Public Utilities, 2010).

6.2.7 Wastewater Collection System

The City's collection system consists of 61,717 sewer manholes, over 3,000 miles of sewer mains, 83 sewer pump stations, and 54 storm water interceptor stations, with approximately 10 percent of the sewer lines located in canyons and open space. The sewer main diameters range from 4 inches to 114 inches.

6.3 Financial Analysis

In this section key parameters and assumptions will be discussed. Careful and realistic selection of the assumptions is made to obtain objective results from the financial analysis.

In order to conduct financial analysis, Real Prices (P^t_{iR}) for project life are estimated and assumptions about Future Inflation Rate(s) are made. Real Prices ($P^t_{iR} = P^t_i / P^t_I$) express prices of goods and services relative to the general price level. P^t_i stands for the nominal price of good or service at time (t); and P^t_I stands for the price level index at time period (t). The price level for an economy is calculated as a weighted average of a selected set of nominal prices. When the nominal price is divided by a price level index, the inflationary component, which is change in the general price level, is eliminated from the nominal price of the item. By using this method, the impact of the forces of demand and supply on the price of the good relative to other goods and services in the economy is identified (Jenkins, et al., 2011).

After determining Nominal values of Cash Requirements, Financing Requirements, Income Taxes and Taxable income, a Cash Flow Statement in Nominal Values is constructed. Nominal Net Cash Flows from different points of view will be deflated by general Price Index for each year to Obtain Real Cash Flow Statements. Afterwards, Debt Service Capacity Ratios (DSCR) is calculated to examine feasibility of undertaking the project for Total Investment (Banker's) Point of View. Two decision making criteria, NPV and IRR for Owner's Point of View are later calculated to determine whether the project is worth undertaking or not. Lastly, the Sensitivity Analysis is performed to examine sensitivity of NPV, IRR and DSCR to changes in value of one parameter at a time (Jenkins G. , 2010).

6.3.1 Parameters and Assumptions

The financial model of the project for the operator and the lender(s) is developed based on the following assumptions and parameters:

Water Tariff: On this research all the studied past projects were single-family or mutli-family domestic customers with 1-inch and 2-inch meters respectively. For this reason, commercial and industrial customers were not included in the research since the investment cost of the project didn't cover construction of such water services.

The bill of a typical single-family domestic customer with a 1-inch meter is a combination of the monthly meter base (which is based on the size of the meter) and the amount of water used. For billing purposes, the City of San Diego's Public Utilities Department measures water used by hundred cubic feet (HCF). Each HCF equals 748.05 gallons. The bi-monthly charges for a typical single-family domestic customer are;

- Base fee: 1 inch meter: $37.78 & 2 inch meter: $60.03
- 0-8 HCF used are billed at $3.64 per HCF
- 9-24 HCF used are billed at $4.08 per HCF
- 25-36 HCF used are billed at $5.82 per HCF
- Each HCF used after the initial 36 HCF is billed at $8.19.

It is assumed that the tariff will rise at the rate of inflation in USA (4.80%) and every three years 5% increase will be imposed on the base price of 2014.

Sewer Tariff: Base sewer fee is $15.33 and $ 5.0276 per HCF which is assumed to increase at USA's inflation rate (4.80%); and the base price of 2014 will increase by 5% every three years. According to acquired information from the Public Utilities Department, each single family's bi-monthly bill can be between $100-$400 based on the number of residents, landscaping, seasonal changes and dimensions of the property.

Interest on Loan: It is assumed that project financing is possible through obtaining a loan with amount of $20 million, with a repayment period of 12 years. The loan repayment will start in year one when the project's construction is complete and sewer and water lines are put into service. The loan's interest rate is 8.00% in nominal terms, and 1.62% in real terms.

Taxes and Inflation: 10% income tax on annual revenue is factored in also; and the project will be exempt from income tax charges in a certain year if it suffers losses in that year.

The inflation rates from 1999 to 2013 are displayed in table 6.8 and from 2013 ahead is assumed to be constant 3.8% the project. Table 6.9 is a summary of the parameters and assumptions used in financial analysis.

Table 6.8: Inflation rates (1999-2013)

Yr.	2000	01	02	03	04	05	06	07	08	09	10	11	12	13
Infl. (%)	3.4	2.8	1.6	2.3	2.7	3.4	3.2	2.8	3.8	-0.40	1.6	3.2	2.1	1.5

Table 6.9: Table of parameters and assumptions

Parameters	Per City of San Diego	Assumption
Water Tariff	▪ bi-monthly charges for a typical single-family domestic customer are; ▪ Base fee: 1 inch meter: $37.78 & 2 inch meter: $60.03 ▪ 0-8 HCF used are billed at $3.64 per HCF ▪ 9-24 HCF used are billed at $4.08 per HCF ▪ 25-36 HCF used are billed at $5.82 per HCF ✓ Each HCF used after the initial 36 HCF is billed at $8.19. HCF: Hundred Cubic Feet	▪ rise at the rate of inflation in USA (4.80%) ▪ 5% increase every three years on 2014 base price.
Sewer Tariff	▪ Base sewer fee is $15.33 and $ 5.0276 per HCF.	▪ rise at the rate of inflation in USA (4.80%) ▪ 5% increase every three years on the 2014 base price.
Interest on Loan	✓ The interest rate: 8.00% in nominal terms, 1.62% in real terms.	✓ repayment period : 12 years ✓ $20 million loan repayment starts in year one, upon construction completion and when the water and sewer will be put into service.
Taxes & Inflation	✓ 10% income tax on annual revenue	✓ the project is exempt of income tax in a certain which has suffered losses. ✓ Inflation rates from 2013 ahead to be constant 3.8%.

Working Capital:

Operator's Accounts Receivable: Accounts receivables represent the uncollected bills of the users of the facility. Since the users of the facility can delay a payment for just one period, it is assumed that the accounts receivable are 15% of the gross sales, and the accounts receivable for the operator's sales will be settled after one month. The account receivables are not cash items, therefore only the change in the accounts receivables is projected in the cash flow statements. The change in accounts receivable is calculated as the accounts receivable at the beginning of the period less accounts receivable at the end of the period (Harberger & Jenkins, 2002).

Operator's Accounts Payable: 15% of the gross operating costs is the assumption used for the accounts payable. Accounts payables are not a cash item and similar to accounts receivables, only the change in accounts payables will be recorded in the cash flow statements.

Depreciation: The expected useful life for the facilities is assumed to be 50 years. A linear depreciation for the facilities is assumed.

6.3.2 Project Costs and Financing

$43,981,319.00 is the total investment cost of the project for the whole project which includes prefeasibility, design, construction and inspection costs. It's assumed that the construction phase will be one year. Sewer and water replacement projects can be constructed in separate phases and each phase can be put into operation immediately. The financial analysis in this study is carried out on a project which takes one year to be built and is put into operation immediately.

70% of project financing is by aid of debt acquisition. 30% remainder of financing will be covered by equity. The amount of debt financing is 20.000 million dollars which will be paid back in twelve years. Equity financing amount is 23,981,319.000 million dollars.

6.3.3 Operating and Maintenance Cost

The operating and maintenance cost include salaries of the staff plus facility maintenance costs. In the industry it is common to assume annual maintenance costs as a percentage of construction cost. In this study maintenance cost was 2% of the total construction cost. This information was obtained from a Senior Accounting officer at the City of San Diego.

6.3.4 Financial Analysis Results

Cash flow analysis from the total investment point of view (the banker's perspective) and the equity holder's point of view (Concessionaire's point of view) is conducted. Analyzing a project, considering different perspectives is necessary to examine the viability of financing, implementing and executing a project for the parties involved. Undertaking a project must be attractive to the government (owner), concessionaire, lenders, operators and other stakeholders to acquire approval (Harberger & Jenkins, 2002). The sections below elaborate on the results of aforementioned cash flows.

6.3.4.1 Cash Flow Results (Total Investment Point of View)

To insure that the annual cash flow of a project would cover the equity holders' financial expectations as well as the creditors', the expected possible revenues and expenditures should be examined to assess viability of the project and likelihood of debt repayment with regard to the project investment being comprised of equity and debt capital which is called cash flow analysis from the banker's (or total investment) point of view (Jenkins, et al., 2011). The Annual Debt Service Coverage Ratios (ADSCR) and Loan Life Cover Ratio (LLCR) were calculated to gauge the ability of the project to pay its operating expenses and meet its debt servicing obligations (Jenkins, et al., 2011).

The annual debt service capacity ratio (ADSCR) is the ratio of the annual net cash flow of the project over the amount of debt repayment due on a year to year basis as follows (Jenkins, 2004):

$ADSCR_t = [ANCF_t / (\text{Annual Debt Repayment}_t)]$;

Where $ANCF_t$ is annual net cash flow of the project before financing for period t, and Annual Debt Repayment $_t$ is annual interest expenses and principal repayment due in the specific period t of the loan repayment period.

If ADSCR > 1, the project can repay its debt from its cash flow. If ADSCR < 1, the project cannot meet its debt obligation by relying only on its cash flow and needs to seek other financial instruments such as bridge financing to meet its debt service obligation. To examine whether the project has sufficient net cash flow for bridge financing in the years subsequent to the years with shortage, project's loan life cover ratio (LLCR) is computed as the present value of net cash flows over the present value of loan repayments from the current period t to the end period of loan repayment (Jenkins, et al., 2011):

$$LLCR_t = PV_{(\text{ANCF t to end year of debt})} / PV_{(\text{Annual Debt Repayment t to end year of debt})}$$

Where, $PV_{(\text{ANCF t to end year of debt})}$: sum of the present values of annual net cash flows; and

$PV_{(\text{Annual Debt Repayment t to end year of debt})}$: sum of the present values of annual debt repayments

And, the discount rates used are the interest rate being paid on the loan financing. Table 6.10 displays the ADSCR and LLCR for this project. ACF and ADR stand for annual cash flow and annual debt repayment respectively.

Table 6.10: ADSCR and LLCR results

Year	ACF (Real) $	ADR(Real) $	ADSCR	LLCR
1	11,329,511.50	3,218,390.80	3.5	4.1
2	11,095,129.81	3,041,406.81	3.6	4.2
3	10,864,774.64	2,868,950.98	3.8	4.4
4	10,442,893.35	2,651,297.92	3.9	4.5
5	10,036,594.19	2,444,856.61	4.1	4.6
6	9,362,731.83	2,249,125.06	4.2	4.8
7	9,034,261.52	2,063,622.16	4.4	4.9
8	8,716,870.96	1,887,886.86	4.6	5.1
9	8,410,192.04	1,721,477.38	4.9	5.3
10	8,113,868.82	1,563,970.43	5.2	5.5
11	7,827,557.11	1,414,960.45	5.5	5.7
12	7,550,924.08	1,274,058.97	5.9	8.5

6.3.4.2 Cash Flow Outcomes (Concessionaire's Point of View)

The cash flow statement from the concessionaire's point of view examines viability of undertaking the project by the investor. Contrary to the banker, the concessionaire includes the loan in the net cash flows from the total investment point of view as cash receipt, and considers payments of interest, loan repayment and any financing fees as cash outlays (Jenkins, et al., 2011). The evaluation criteria to assess the project's financial viability are Net Present Value (NPV) and Internal Rate of Return (IRR). The discount rate used is the required rate of return on equity, in real terms, which is 12%. NPV is sum of the present values of the expected incremental net cash flows for a project over the project's determined lifetime (Jenkins, 2004).Taking inflation and rate of returns into account, NPV compares the present value of money today to the present value of money in the future. NPV=0 demonstrates that the investors would recoup the project's outlay and obtain a rate of return equal to the assumed discount rate on their capital that would have been earned if it were invested somewhere else (opportunity cost of funds). A positive NPV project shows besides recovering their capital investment, the investors would receive a rate of return on their capital higher than the discount rate. Never the less, a project with NPV less than zero wouldn't seem attractive since neither the rate of return would be equal to the discount rate, nor can the investors recover their invested capital. Only for strategic reasons, a project with a negative NPV may be undertaken (Jenkins, et al., 2011).

The formula below calculates NPV where C_t is net cash inflow during the period t, r is the annual discount rate, and t represents the number of time period:

$$NPV^0 = (\Sigma\ Ct) / (1+r)^t$$

Another criterion which is not as reliable as NPV is the internal rate of return (IRR). For a certain project, IRR would be the very discount rate (ρ) that is obtained when NPV equals to zero. The following equation gives the solution (Jenkins, 2004).

$$\sum_{j=0}^{n} [(Bj - Cj) / (1+\rho)^j] = 0$$

Where B_j and C_j are cash inflow and outflow in year t to capital respectively.

From the financial analysis, it is derived that the obtained NPV in real terms with the discount rate of 15% is $29,633,077.00 and the IRR obtained from the cash flows is 11.11%. However IRR should be greater than the discount rate which is the opportunity cost of capital.

6.4 Sensitivity Analysis of the Financial Results

Sensitivity analysis provides a useful tool for analyzing the impact of changes on the outcome of the project's evaluation (Grimsey & Lewis, 2004). Sensitivity analysis carries out a clear and adjustable procedure by varying the parameters randomly one at a time to observe the impact of changes on the outcome (Jenkins, 2010).Variables which their variation could have a substantial impact on the project's outcome, namely NPV, IRR and LLCR, will be separated as alternative input variables for Monte Carlo Analysis. The analyzed parameters on this study are capital expenditure overrun, operation and maintenance overruns, wage growth rate, number of employees, change in user tariff, loan, interest rate and discount rate.

As it is displayed on Table 6.11, the range assumed for the interest rate is between 4% and 12%. Change on this variable does not impact NPV, IRR and debt service ratios.

Discount rate appears to be a really sensitive factor. Variation in discount rate has a great impact on NPV. As it was discussed before, discount rate is the opportunity cost of capital investment spent in the project. This project's capital investment would have been used in other investment projects; but now they have been invested on this project. The opportunity cost of these funds is the profit that would have been obtained in another investment project which is now abandoned (Jenkins, et al., 2011).

The discount rate is a key variable and its correct selection in project appraisal is critical especially by knowing that a slight change in its value may impact the results of the analysis greatly and alter the decision making criteria of undertaking a project.

Correct selection of the discount rate rests with the private party to consider a realistic opportunity cost for its investment.

Variations in wage growth rate, number of employees, and changes in the amount of loan do not impact the outcome considerably.

Change in user tariff is having a significant impact in the project outcome. The selected range for this variable is from -4% up to 8% with an increment of 2%. As table 6.11 shows, increasing the user tariff by 8% increases the NPV to $229,561,276. However even if the user tariff drops down by 4% the project‘s NPV is still viable ($21,463,989). Therefore we would not assume this factor as a risk variable. However, obtaining the users' willingness to pay, and conducting supply and demand analysis at the conceptual stage would be conducive for both parties, especially if the government wants to impose a ceiling price for the delivered service.

Per Tables 6.11, capital expenditure overrun can be subject to many changes throughout the construction period and has a critical effect on the financial outcome of the project. The assumed limit for this variable is between -20% and 20% with an increment of 10%. The trend observed with the increase in the capital expenditure shows a substantial decrease in the NPV.

Decreasing this variable by 20% increases the NPV from base case of $55,570,446 to $68,542,533. Increase of cost overrun factor by 20% plunges NPV to $42,596,395.

Operation and maintenance cost of the infrastructure is assumed to be a percentage of capital expenditure. Consequently this factor is directly dependent on the latter. The range assumed for changes on this factor is 1% to 9% with incremental of 2%. By following the NPV and IRR changes, it can be observed that operation and maintenance factor is a major risky variable as well because the NPV drops from base case of $55,570,446 to $38,859,298 once the maintenance and operation rate increase to 9%. This factor is assumed to be a percentage of investment cost. Investment cost is such a factor that if the assessment of which is conducted realistically, this will help perform an objective project appraisal also. For this reason, the authors were prompted to undertake a research to formulate a model which gives an improved cost estimation of a project capital investment in the conceptual stage of a project assessment. Following sections are allocated to this purpose.

Table 6.11: Sensitivity analysis results

Increments	NPV	IRR	ADSCR-1	ADSCR-2	ADSCR-3	DSCR-1
			Interest Rate			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
4%	58,016,466	33.9%	4.55	4.66	4.77	5.08
8%	55,570,446	32.2%	3.52	3.65	3.79	4.12
10%	54,342,760	31.3%	3.16	3.31	3.45	3.74
12%	53,035,193	30.3%	2.85	3.00	3.15	3.42
			Discount Rate			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
4%	94,760,208	32.2%	3.52	3.65	3.79	4.12
8%	55,570,446	32.2%	3.52	3.65	3.79	4.12
12%	34,414,755	32.2%	3.52	3.65	3.79	4.12
13%	30,661,351	32.2%	3.52	3.65	3.79	4.12
15%	24,368,879	32.2%	3.52	3.65	3.79	4.12
			Investment Cost Overruns			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
-20%	68,542,533	54.9%	3.66	3.81	3.95	4.29
-10%	62,057,471	41.0%	3.59	3.72	3.87	4.20
0%	55,570,446	32.2%	3.52	3.65	3.79	4.12
10%	49,083,421	26.1%	3.45	3.57	3.71	4.03
20%	42,596,395	21.7%	3.37	3.50	3.63	3.94
			Overall O&M			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
1.0%	71,725,344	38.9%	3.98	4.15	4.32	4.79
3.0%	63,840,681	35.8%	3.77	3.92	4.09	4.46
5.0%	55,570,446	32.2%	3.52	3.65	3.79	4.12
7.0%	47,214,872	28.4%	3.23	3.34	3.47	3.76
9.0%	38,859,298	24.6%	2.94	3.04	3.15	3.41
			Wage Growth Rate			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
0%	57,528,056	32.5%	3.53	3.66	3.81	4.16
1%	56,619,875	32.4%	3.52	3.66	3.80	4.14
2%	55,570,446	32.2%	3.52	3.65	3.79	4.12
3%	54,350,901	32.0%	3.52	3.64	3.78	4.09
4%	52,925,642	31.8%	3.51	3.63	3.76	4.06

Table 6.11: Sensitivity analysis results (continued)

Increments	NPV	IRR	ADSCR-1	ADSCR-2	ADSCR-3	DSCR-1
			Number Of Employees			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
5	63,252,722	35.3%	3.72	3.88	4.05	4.41
10	59,428,897	33.8%	3.63	3.77	3.92	4.27
15	55,570,446	32.2%	3.52	3.65	3.79	4.12
20	51,711,996	30.6%	3.41	3.53	3.66	3.97
25	47,853,545	29.0%	3.29	3.41	3.53	3.82
			Changes in User Tariff			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
-4%	21,463,989	22.9%	3.35	3.29	3.24	3.14
-2%	36,345,734	27.8%	3.43	3.47	3.51	3.60
0%	55,570,446	32.2%	3.52	3.65	3.79	4.12
4%	115,267,232	40.4%	3.69	4.02	4.38	5.37
6%	162,663,859	44.3%	3.78	4.21	4.69	6.13
8%	229,561,276	48.0%	3.87	4.40	5.01	7.00
			Loan			
	55,570,446	32.19%	3.52	3.65	3.79	4.12
5,000,000	51,745,123	23.4%	13.57	14.10	14.68	16.16
10,000,000	53,020,231	25.5%	6.87	7.13	7.42	8.13
20,000,000	55,570,446	32.2%	3.52	3.65	3.79	4.12
30,000,000	58,031,428	47.1%	2.37	2.46	2.57	2.77

6.5 Cost Estimation at the Conceptual Stage

Cost estimation is fundamental at feasibility study of infrastructure projects. Accurate estimation will help decision makers consider best alternatives without misconstruing technical and economic approaches. At the conceptual phase of a project the urgency of undertaking the project is explored, technical and funding options are evaluated and objectives of the project are set (Wideman, 1995).

In common form of an infrastructure project development, a public agency (owner) designs a project and invites the private sector firms (contractors) to bid the construction of the project. Contract to undertake the project is awarded to the lowest bidder (DeCorla-Souza & Mayer, 2010).

Cost estimate at the conceptual phase becomes cost and budget control baseline for both the owner and the contractor (Hendrickson & Au, 1998).

Reliable cost prediction, based on limited information at early stages of the planning phase of modernizing and upgrading infrastructure projects, becomes of grave importance to utilize limited available resources accordingly and allocate adequate budgets for their successful completion. Shehab (Shehab, et al., 2010) reported that according to the City officials' experience, in the past, unrealistically high cost estimates withheld the project for future fiscal years or low cost estimates resulted in inadequate budget allocation and constructing projects below ideal standards (Shehab & Farooq, 2013).

Recurrent incidents of sewer overflows into rivers and streams as well as water main breaks in the cities manifest that there is a dire need for upgrading aging and deteriorating drinking water and wastewater infrastructures. In fiscal year 2012, the U.S. Environmental Protection Agency (EPA) funded the Clean Water program $1.5 billion and the Drinking Water program $918 million from congressional appropriations. EPA grants capitalization funds to states of USA, which in turn provides low- or no-interest loans to local communities or utilities to pay for water distribution pipelines, treatment plants, sewer lines, and other similar infrastructure. EPA estimated funding requirements of almost $335 billion for drinking water infrastructure and $298 billion for wastewater infrastructure (Gómez, 2013).

Various methodologies of machine learning techniques such as regression models and artificial intelligence techniques can be employed for modelling a nonlinear system such as cost estimation. Two most renowned artificial intelligence methods used in nonlinear modelling are artificial neural networks (ANNs) (Haykin, 1999) and Genetic Programming (GP) (Koza, 1992) (Gandomi, et al., 2013).

Artificial intelligence methods have been widely used as prediction tools in recent decades. Review of comparative studies on artificial intelligence and traditional statistical techniques in various fields of applications shows that artificial neural networks outperform regression models as a tool for classification and prediction problems (Paliwal & Kumar, 2009) (Kim, et al., 2004).

ANNs are renowned pattern recognition systems that are capable of learning from experience. ANNs are vastly used in cost estimating of building and infrastructure projects (Tatari & Kucukvar, 2011). Several researchers attempted to develop cost estimation models in the earlier stages of developing infrastructure projects using regression models or ANNs.

Hegazy T. et al. (Hegazy & Amr, 1998) used a neural network approach to develop a parametric cost estimating model for highway projects. Adeli (Adeli & Wu, 1998) formulated a regulation neural network based on a solid mathematical foundation for estimation of highway construction costs. Sodikov (Sodikov, 2005) used ANN to analyse the impact of a different set of variables on the highway project cost and proposed a cost estimation technique for developing countries.

Successful usage of ANNs and regression models on cost estimation of aforementioned infrastructure projects encouraged the researchers to apply such models on cost estimation of sewer and water replacement or rehabilitation projects.

Using regression techniques, Clerk et al. (Clark, et al., 2002) proposed seven separate cost estimating equations for water supply distribution models, summation of which would yield to the direct cost of replacing a new water distribution system. Besides shortfalls of regression techniques in comparison with other techniques and the tedious procedure of using several models, indirect costs such as contractor's overhead, profit, bonds, insurance and social costs were not taken into account.

Shehab et al. (Shehab, et al., 2010) developed two models for utility rehabilitation projects using ANN and regression analysis and argued that ANN provided more accurate results.

Alex (Alex, et al., 2010) developed cost prediction model using ANN for installation of water and sewer systems incorporating factors such as geographical location of the project, seasonal variation, average monthly temperature and historical construction cost data divided into four categories of labour, equipment, material and other costs. However, estimating the cost of mentioned four categories requires undertaking a detailed resource and productivity analysis as well as punctilious construction technology assessments which at the early stages of the studying the project seems to be abstract and superfluous.

Shehab (Shehab, et al., 2010) utilized ANN to develop a cost prediction model for installation of water and sewer systems using 50 historical data sets to evaluate the impact of six categories of pipes, sidewalks, manholes, pavement, soil, services and assemblies on the cost of the projects. Developing a model based on fewer sample projects does not yield a plausible and reliable model. Furthermore, despite promising application of ANNs on engineering problems, the process of obtaining a solution from available information is unknown and extracting practical prediction equations are not usually possible. Moreover, a neural network structure requires the researcher to predefine it (Alavi & Gandomi, 2011).

Genetic algorithm (GA) is a robust optimization mechanism which takes biological evolution's idea of natural selection (Gandomi & Alavi, 2011). GA is considered to be efficiently applicable to vast spectrum of different engineering problems (Milani & Milani, 2008).

Genetic programming (GP) is a derivative of GA, which its usage on optimization of complex problems was pioneered by John Koza (Koza, 1992). GP solutions are computer programs in lieu of fixed length character strings (Banzhaf, et al., 1998). GP is a nonlinear structured alternative to fixed length solutions (Ferreira, 2006). GP is based on Darwin's theory of evolution, expressed as "survival of the fittest". A group (population) of computer programs (individuals) continues reproducing with each other till the best individuals will survive and finally evolve to perform well in the specified scenario (Walker, 2001).

GP's ability to develop simple prediction equations with no need to considering an existing relationship is its main superiority over the conventional statistical and ANN techniques (Gandomi, et al., 2012).

When the analyst creates an equation, applicability and validity of the cost estimation model is more discernible since an equation can check with common sense especially in the case of proposals requiring acquisition of management and owner approval (Smith & Mason, 2010).

Anew specialization of GP is Gene expression programming (GEP) which is able to evolve computer programs of different sizes and shapes. GEP is extremely adaptable and supersedes the existing evolutionary techniques (Ferreira, 2001). Several scientists applied GEP to construction and civil engineering realm (Alavi & Gandomi, 2011) (Gandomi, et al., 2011).

This study utilized the GEP technique to build a predictive model for cost estimation of water and sewer utility rehabilitation and replacement infrastructure projects to our best knowledge for the first time. The developed model considers readily available variables with substantial impact on the cost of the projects. Sensitivity analysis technique and professional experiences were employed to determine the contributions of the qualitative factors and quantifiable parameters affecting the cost estimate.

6.5.1 Genetic Programming

GP, an extension of GA, was invented by Cramer (Cramer, 1985) and further developed by Koza (Koza, 1992) (Ferreira, 2006). Although GP applies most of key ideas of GA and uses GA operators such as selection, crossover and mutation with slight modifications, its nonlinear structure creates a more versatile system of representation than that of GA (Ferreira, 2006) (Gandomi, et al., 2012). GP produces computer programs with dynamic variability and hierarchical character presented in form of parse trees (Koza, 1992). A population member in hierarchically structured tree-based GP composes of functions and terminals chosen from a set of functions and a set of terminals. Figure 6.1 is an illustration of a simple tree-based GP model (Gandomi, et al., 2012). In the next section, the GP model and how to read and express the model will be explained in detail. GP can be implemented using any programming language (like LISP) capable of working with computer programs as data and linking, compiling and executing new programs (Koza, 1992). The GP represents preliminary form of the approximation model accompanied by its parameter values; however GA solutions are fixed length strings of numbers. The GA, similar to other traditional optimization techniques, is employed in parameter optimizations to develop the best values for a proposed set of model parameters (Javadi & Rezania, 2009) (Alavi & Gandomi, 2011).

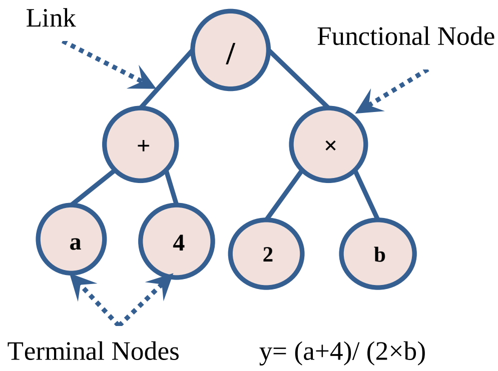


Figure 6.1: Illustration of a GP model in a tree expression

The GP optimizes a population of computer programs in terms of a fitness landscape which defines how good a candidate solution (program) to achieve the set aim is; in other words, GP intends to optimize the fitness function, a particular objective function, which is used to evaluate the fitness of each program (Alavi & Gandomi, 2011).

GEP is a linear extension of GP comprised of autonomous entities of genotype and phenotype (Ferreira, 2001). In genetics, an organism's complete hereditary information is called genotype; and an organism's actual observed properties, such as morphology, development, or behaviour is called phenotype. Ferreira (2001) translated the language of chromosomes into the language of expression tree (ET), a tree-like structure.

6.5.1.1 Gene Expression Programming (GEP)

The GEP is an expansion of GP introduced by Ferreira (2001). The GEP comprises of five main components: 1) function set, 2) terminal set, 3) fitness function, 4) control parameters, and 5) termination condition (Gandomi, et al., 2012).

In GEP, individuals are linear strings of fixed length (the genome or chromosomes) which later are represented in form of nonlinear structures of different sizes and shapes (phenome, i.e. expression trees (ETs)). Since genotype and phenotype of an individual are independent, only the genome is carried to the next generation. Respectively, replication and mutation of the structures are not required any more (Ferreira, 2006).

Therefore, the chromosomes and expression trees are key components in GEP. GEP technique creates very simple genetic diversity because of the advantage of GEP that genetic operators make changes at the chromosome level (Gandomi, et al., 2012).

Furthermore, multigenic nature of GEP forms complex multisubunit expression trees (ETs) (programs) which are both separate entities and part of a more complex, hierarchical structure at the same time (Ferreira, 2001). Each GEP gene includes a list of fixed-length symbols that can be any element from a function set like {þ, −, ×, ⁄, Log} and the terminal set like {a, b, c, 3} (Gandomi, et al., 2012).

Ferreira (Ferreira, 2001) developed a new language of GEP, called Karva language to read and express the information encoded in the chromosomes which, as an important feature of GEP, are capable of representing any pars-tree.

The mathematical expression below:

$$(4\times a)/\ (2+\cos\ (b+c)) \quad (1)$$

can be expressed in Karva language as follows:

$$/\times+4a2cos+bc \quad (2)$$

Where a, b, and c = variables; and 2 and 4 = constants. The variables or constants used in a problem are called terminals. This GEP gene can be illustrated as an ET shown in Figure 6.2 This kind of expression is the phenotype of GEP individuals (Ferreira, 2001).

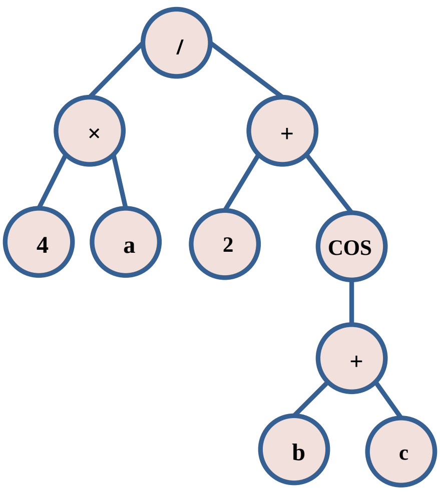


Figure 6.2: Typical illustration of an ET

The conversion starts from the first position in the K-expression, which corresponds to the root of ET, and reads through the string one by one. By recording the nodes from left to right in each layer of the ET, from root layer down to the deepest one, an ET can be expressed in K-expression. The assemblage of ET is complete when the deepest layer is composed only of terminals, meaning that there is no longer any function left to make a link to any terminal. The transfer of information from a gene into an ET is called translation (Ferreira, 2001).

Since GEP chromosomes comprise of predetermined fixed length genes, the only variable would be the size of the related ETs, meaning that some elements of the gene are not useful for the genome mapping. Therefore, the acceptable length of a K-expression may be equal or less than the length of the GEP gene. Each GEP gene comprises of a head and a tail. The head may have both function and terminals, while the tail may contain terminals only (Ferreira, 2001).

Consider a gene comprised of the following functions and terminals {×, /, -, +, a, b}, For instance length of head (h) = 8 and length of tail (t) = 11, therefore the length of the gene is 8+11=18. Let's build a gene below:

0123456701234567890
× /+b -+ ab**aababab bba** (3)

Figure 6.3 shows the ET for the gene (3).

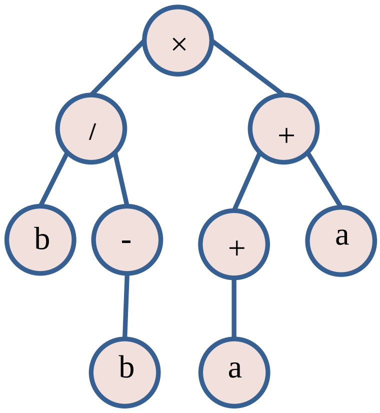


Figure 6.3: ET for gene (3)

In the case above, termination point for ET is at position 8 while termination point for the gene is at position 18.

From the example above it is shown that despite its fixed length, each gene has the potential to code for ETs of different sizes and shapes. But when modification (mutation) occurs and for instance one terminal gene replaces a function or vice versa, the termination point can shift and create an ET shorter or equal to the length of the gene (Ferreira, 2001).

GEP chromosomes are generally comprised of more than one gene of equal length. Each gene is translated into a sub-ET and the sub-ETs interact with each other. One of the simplest interactions between the sub-ETs is the function which links them together.

The type of linking function, the number of genes, the length of each gene and the type of linking function are assumed for each problem. It is good to start with a single gene chromosome, and increase the length of the head gradually. If the gene becomes very large, increasing the number of genes, and choosing a linking function between them would be next option (Ferreira, 2001) .

Figure 6.4 demonstrates the basic steps of GEP (Ferreira, 2001) as follows: first the chromosomes of the initial populations are randomly generated. Then the chromosomes are expressed, and the fitness of each individual is evaluated. The individuals which are fit to reproduce with modification are selected. Therefore, there remains offspring with new traits. The new generation's individuals will also undergo the same evolutionary process. The process is repeated for a certain number of generations until a solution is achieved.

A typical algorithm employs three operators namely: selection, crossover, mutation. Crossover can be: transposition, root transposition, gene transposition, gene recombination, and one- and two-point recombination.

During reproduction, along with replication, which the genome is copied to the next generation, genetic variation is also introduced into the population by operators that randomly select the chromosomes (Ferreira, 2001).

Selection applies pressure on the population (like natural selection in biological systems). Weaker individuals are eliminated and better performing, or fitter, individuals promote the information they contain into the next generation. Crossover is an operator through which solutions exchange information (similar to sexual reproduction in biological systems).

Mutation is used to randomly alter one or more gene values in a chromosome from its initial state (Coley, 1999). Mutations can happen anywhere in the chromosome but the structure of chromosomes, namely the length of the head and the number of genes, should stay unchanged. In the heads any symbol can change into another function or terminal; while in the tails terminals can only change into terminals. The mutation rate used is equivalent to two point mutations per chromosome.

The transposable elements of GEP are fragments of the chromosome that can be activated and jump to another place in the chromosome. In GEP there are three types of transposable elements. (1) Short fragments with a function or terminal in the first position that transpose to the head of genes, except to the root (insertion sequence elements or IS elements). (2) Short fragments with a function in the first position that transpose to the root of genes (root IS elements or RIS elements). (3) Entire genes that transpose to the beginning of chromosomes. Typically, an IS transposition rate and RIS transposition rate of 0.1 are used. However, n gene transposition can happen too. In gene transposition an entire gene transposes itself to the beginning of the chromosome. The chromosome to undergo gene transposition is randomly chosen.

In GEP there are three kinds of recombination: one-point, two-point, and gene recombination. In all cases, two parent chromosomes are randomly chosen and paired to exchange some material between them.

During one-point recombination, the paired chromosomes cross over a randomly chosen point to form chromosomes that exhibit different properties from those of the parents. The paired chromosomes are cut at randomly selected point, and exchange the information downstream from the crossover point, In two-point recombination the paired chromosomes cross over two points of recombination that are randomly selected, The material between the recombination points is exchanged between the two chromosomes, and forms two new chromosomes, The transforming power of two-point recombination is indeed greater than one-point recombination.

In gene recombination an entire gene is exchanged during crossover. The exchanged genes are randomly chosen and occupy the same position in the parent chromosomes. The individuals created by this operator are different arrangements of existing genes, meaning that this operator is unable to create new genes.

The crossover rates of one-point recombination, two-point recombination and gene recombination are dependent on each other, and typically 0.7 is used as the sum of the rates of the three (Ferreira, 2001).

In this study, the GEP approach was utilized to acquire a valid relationship between the cost of sewer and water replacement/rehabilitation projects and impacting variables.

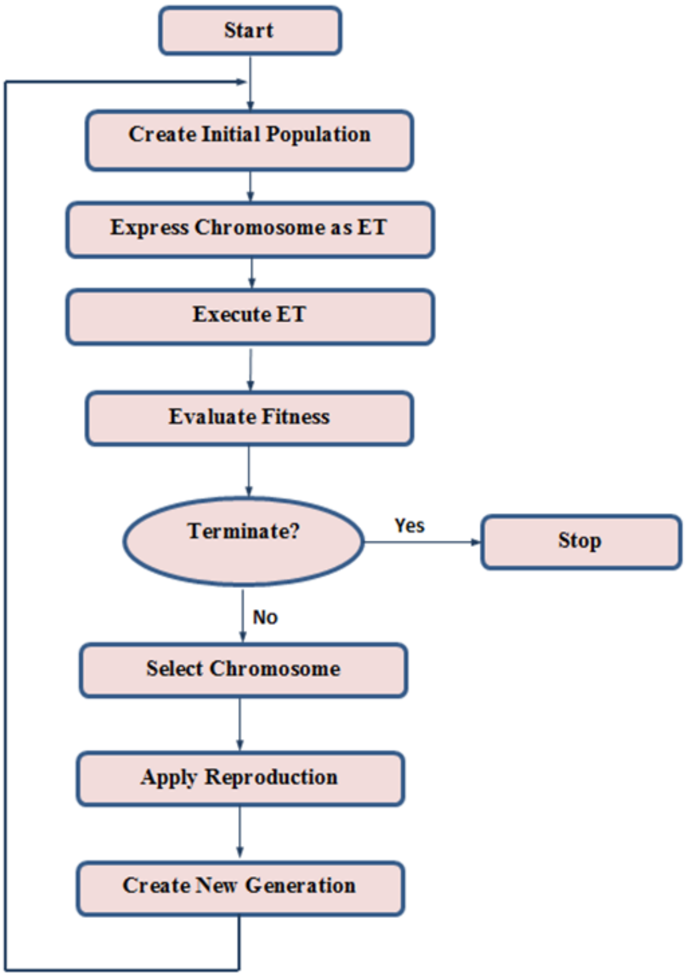


Figure 6.4: Basic demonstration of the GEP algorithm

6.5.2 Data Preparation

This study is proposing a predictive model for cost estimation of rehabilitation and/or replacement of sewer and water projects utilizing GP technique leading to improved results as well as simplified procedures. To develop the prediction model, 210 actual proposals related to water and sewer projects submitted to the City of San Diego, CA by the lowest bidders (1999-2013) were obtained. The City of San Diego designs the utility systems. The design may be performed in house; or may be outsourced by hiring a private engineering company, Afterwards the City invites prequalified construction Contractor s to bid the designed project. The bid which is submitted by the competing Contractors is based on bill of quantities; and comprises of itemized component values, The City awards each construction contract to the lowest, qualified bidder.

Since each project's cost estimation includes many components such as pipes, manholes, pavement, curb and gutter, water pollution control plan, etc., in this study, the most important items with higher impact on the outcome which could be easily assessed in the conceptual stage were chosen as inputs to the GP model. These items were selected by the aid of sensitivity analysis and expert judgment. Sensitivity analysis is a useful tool for studying the impact of changes in input variables in terms of bid evaluation (Grimsey & Lewis, 2004). As it was mention in the previous chapters, in sensitivity analysis the parameters are varied randomly one at a time to be able to observe the impact of a certain variable changes on the outcome. A number of incremental changes are made for any selected parameter and the final indicator value (outcome) is computed each time recording the degree of change from its baseline (Jenkins, et al., 2011). Variables, which their variation would have a substantial impact on the projects' outcome, will be separated as alternative input variables to GP model. Afterwards professional judgment/experience will be utilized to choose among the variables that can be readily and accurately assessed at the conceptual stage. There are a few qualitative factors that can impact productivity such as soil classification, pavement condition, traffic and finally seasonal effect. The latter's impact is not substantial in San Diego since no dramatic weather fluctuation is observed in San Diego's weather forecast. Qualitative factors mentioned above will be identified by evaluating corresponding project bid items to incorporate in developing GP cost estimation model.

6.5.2.1 Sensitivity Analysis for GP Data Preparation

As it has mentioned in the previous chapters before to perform sensitivity analysis or what if analysis on Excel spreadsheet following actions will be taken:

Bringing all data pertinent to each project in one spreadsheet since the City of San Diego announces information regarding each bid result such as bid items, quantities, unit costs and proposed cost by the lower bidder in separate spreadsheets.

- Identifying the variables (bid items) with significant impact on the outcome of the projects (and can be easily assessed in the conceptual stage).
- Identifying range of these variables with a mean of the most likely assumed values.
- Computing the effect of variable changes on the total cost of the projects (Rogers & Duffy, 2012).

6.5.2.2 Data Analysis

While most of the projects studied in this research involved the replacement/rehabilitation of both sewer and water mains in a neighbourhood, some jobs were exclusively water or sewer replacements or sewer rehabilitation. Prevalently utilized construction method was excavation (open trench) replacement; occasionally different rehabilitation technologies such as cured-in-place pipe (CIPP), close fit lining, and slip-lining or trenchless replacement methods such as boring and pipe bursting were applied.

Trenchless methods are more expensive in comparison to open trench methods; they are the best option for the installation of pipelines under a road, railroad, freeway, or in other situations where trenching is not possible; there is little business and human costs (social costs) associated with traffic congestion, restriction of access, dirt, noise, air pollution. Natural habitats and landscaping will remain undisturbed. Therefore, revegetation and erosion control provisions will not be required. These methods are less labour intensive with faster completion (EPA, 1999). But it is observed that in the City of San Diego, these methods have been utilized only where there was not a possibility of implementing an open trench technology therefore the common practice was assumed to be open trench and CIPP if it was possible, thus the construction technology selection was not an influential factor in model development.

Normally each proposed project is broken down into approximately 110-140 bid items. By aid of sensitivity analysis, 24 bid items were identified to be most influential on the cost estimation of a project. The 24 items were grouped into 5 categories below

1. Replacement or rehabilitation of sewer and water mains.

2. Installation of manholes, sewer laterals, private replumbs and water services with various diameters and thicknesses.

3. Pavement conditions including asphalt concrete, concrete pavement replacement, temporary resurfacing, slurry seal, asphalt concrete patching, pavement removal, crack sealing, pavement fabric, cold milling, pavement

restoration adjacent to trench, striping, extra thick pavement removal. According to professional experience, most of the field order allowance (which usually is listed as a bid item) ends up to be allocated for pavement repair purposes because most of the time, the pavement condition is not objectively evaluated on the conceptual stage; therefore field order item was studied under pavement category.

4. Soil conditions taking into account the soil type impact and proposed costs of shoring, dewatering and pipe installation since if the soil condition declines, the installation would be more difficult, slower, labour incentive and cost of activities such as shoring and dewatering would increase and consequently the price allocated for overall installation would rise.

5. Traffic control including traffic control plans and set up cost and studying the neighbourhood traffic conditions. But the cost of traffic control was determined approximately 1% to 2% of the total project's proposed cost therefore was not an influential input to GP model.

The abbreviations below were used for the items:

$S_{\text{diameter (inches), pipe type}}$ = Sewer Main Length (Linear Feet), $S_{\text{diameter (inches) rehab}}$ = CIPP Sewer Main Length (Linear Feet), $W_{\text{diameter (inches)}}$ = Water Main Length (Linear Feet), $SL_{\text{diameter (inches)}}$ =Number of Sewer Laterals, $WS_{\text{diameter (inches)}}$ =Number of Water Services, MH=Number of Manholes.

Input Variables to GP model are listed below:

X_1: Soil Condition (1=best through 10=least desirability according to the table of relative desirability of soils (Soil compaction handbook, 2011).)

X_2: Pavement Condition (1: Good (allocated cost per category (3) items lower than 10% of total cost) 2: Average (between 10%-25 %) 3: Bad (above 25%))

X_3: Traffic Control (1: moderate, 2: busy)

Each bid item's quantity related to a certain pipe (with different size and property) can be used as one input variable for GP model; but this way the number of input variables will unnecessarily be numerous. In order to simplify GP model, equation (4) is proposed to combine quantities of different pipes with different sizes and properties to bring certain bid items (that have linear relation with each other) together and generate one input for GP model in lieu of numerous input variables, where the parameter values in equation (4) are the average unit price of related item per unit price of 8'' sewer main item during 1999-2013.

$$X_4 = 2.65S_{27''} + 2.04(S_{24''} + S_{18''}) + 1.74S_{15''} + 1.63S_{12''} + 1.37S_{10''} + S_{8''} + 1.45S_{8''_{special}} + 1.34W_{16''} + 1.26W_{12''_{class235}} + 1.48W_{12''_{class150}} + W_{8''} + 0.74(S_{6''_{rehab}} + 1.25S_{8''_{rehab}} + 1.5S_{10''_{rehab}} + 1.75S_{12''_{rehab}} + 10S_{36''_{rehab}}) \quad (4)$$

Similar to equation (4), in order to reduce the number of input variables to one input, equation (5) was used to combine the number of sewer laterals, water services, and manholes with different sizes and properties to generate one input for GP model, where the parameter values in equation (5) are the average unit price of related item per unit price of 4'' sewer lateral during 1999-2013.

$$X_5 = 1.3SL_{6''} + SL_{4''} + 5.6SL_{private\ replumb} + 2.09WS_{2''} + 0.97WS_{1''} + 5MH_{new} + 2.74MH_{rehab} \quad (5)$$

Nominal values of the projects' proposed costs by the lowest bidders were converted to real values by the relevant price indexes released by U.S. Department of Labour, Bureau of Labour Statistics (Calculator, 2014). It is worth mentioning that the outcome of GP formula would yield a cost estimate in real prices; in order for the user to come up with the nominal cost estimate, the outcome should be brought back to nominal values.

6.5.2.3 Database

The GP model was generated by using 210 sets of data related to 210 sewer and water replacement/ rehabilitation projects in San Diego, California. The essential objective of a Machine Learning approach is to find solutions that perform well not only on the cases used for learning but also on cases of new unseen data. This is known as generalization ability, and failure to fulfil this is called overfitting (Gonçalves, et al., 2011). Overfitting is usually the result of excessively trained algorithm which in spite of decreasing the training error, it increases the testing error rapidly (Gandomi, et al., 2012). An effective method to prevent overfitting and improve generalization of the model is to examine the extracted models on a validation set to achieve a better generalization (Banzhaf, et al., 1998) which was employed in this research. Correspondingly, the available data sets were broken down randomly into learning, validation, and testing subsets. To perform genetic evolution, the learning data were used for training purposes. To determine the generalization capability of the models on the untrained data, the validation data were used for model selection purposes. Training data alluded to learning and validation data which both were involved in the modelling process. Finally, as the outcome of the runs, the model which performed best on the learning and validation data sets both is selected. To examine performance of the optimal model derived from GP on unseen data, the testing data were engaged which had no affiliation with building the models.

In order to achieve a uniform data division, several combinations of the training and testing sets were selected by maintaining consistency of statistical characteristics of the parameters involved (e.g., maximum, minimum, and mean) in the training and testing data sets (Gandomi, et al., 2012). Out of the 210 data sets, 185 data vectors were taken for the training process (160 sets for learning and 25 sets for validation). The remaining 25 sets were used for the testing of the derived model.

6.5.3 Model Development

6.5.3.1. Performance Measures

Selection of the best model was based on the strategies below (Gandomi, et al., 2012):

1. The simplest model, however this was not the main element, which was controlled by the user through the parameter settings (e.g., number of genes or head size);

2. The model with the best fitness value on the learning data; and

3. The model with the best fitness value on the validation data.

The best GP model was inferred by minimizing the following objective function (OBJ) which was used to verify acceptability of predicted output versus the actual bid proposals.

$$OBJ=\left(\frac{No._{Learning}-No._{Validating}}{No._{Training}}\right)\rho_{Learning}+\frac{2No._{Validation}}{No._{Training}}\rho_{Validation} \quad (6)$$

Where No.Training, No.Learning, and No.Validation are the number of training, learning, and validation data respectively, and ρ is the performance index as follows (Gandomi & Roke, 2013):

$$\rho=\frac{RRMSE}{1+R} \quad (7)$$

The RRMSE and R are parameters prevalently employed for the performance measurement which respectively are: the root mean squared error, mean absolute error, and correlation coefficient. The following equations were employed to determine the RRMSE and R values (Milani & Benasciutti, 2010) :

$$RRMSE=\frac{1}{|\overline{h_i}|}\sqrt{\frac{\sum_{i=1}^{n}({h_i}^2-{t_i}^2)}{n}} \quad (8)$$

$$R=\frac{\sum_{i=1}^{n}(h_i-\bar{h}_i)(t_i-\bar{t}_i)}{\sqrt{\sum_{i=1}^{n}(h_i-\bar{h}_i)^2\sum_{i=1}^{n}(t_i-\bar{t}_i)^2}} \quad (9)$$

where h_i and t_i are respectively, the actual and calculated outputs for the ith output, $\bar{h}_i$ and $\bar{t}_i$ are average of the actual and calculated outputs; and n = number of samples.

Because when the output values predicted by a model shift equally, no change appears in R value, it is acknowledged that R value is not a good indicator for evaluating the accuracy of a model on its own. On the other hand, besides assuming the impact of various data divisions for the learning and validation data, the performance index (ρ) concurrently accounts for the changes of both RRMSE and R. Lower RRMSE and higher R values yield in lower OBJ indicating a more accurate model (Gandomi & Alavi, 2011). The values obtained for R, RRMSE, and ρ are respectively, 0.8467, 0.4065, and 0.220.

6.5.3.2. Model Development Using GP

Several preliminary runs were made to observe the performance. Population size (number of chromosomes) determines the number of evolved programs in the population. Larger size populations take longer runs. Complexity of the problem and the number of possible solutions define the suitable number of population (Gandomi, et al., 2012). The population size of 50, 150, and 300 were set as optimal levels. Head size and number of genes determine the structure of the developed GP models. Complexity of the evolved model is determined by the head size. The number of genes per chromosome determines the number of terms in the model. Each gene codes for a different sub-ET. Five optimal levels were considered for the head size and number of genes. In order to link the mathematical terms encoded in each gene, the addition and multiplication linking functions were used when the number of genes greater was greater than one.

There are 2 (linking functions) × 4 (head size) × 5 (number of genes) = 40 various parameter combinations. These combinations were tested, and replications for each combination were carried out. Table 7.13 demonstrates parameter settings for GP algorithm. In order for evolution to happen without improvement in best fitness, the acceptable period of is adjusted through the generations with no parameter change.

Basic arithmetic operators and mathematical functions were employed in this study to obtain the optimum GP model. The mean absolute error function was used to calculate the overall fitness of the evolved programs. On this GP model variable pressure function (variable pressure = 0.01) has been also employed. The program continued to run until no significant performance improvement was seen any more. The GP algorithm employed GeneXproTools (2006).

Table 6.12: The GP algorithm's parameter settings

Parameter	Settings
General	
Chromosome	50,150, 300
Genes	2, 4, 6, 10, 12
Head size	2- 6
Tail size	9
DC size	9
Gene size	23
Linking function	$\sum, \prod$
Genetic operator	
Mutation rate	0.044
Inversion rate	0.1
IS transposition rate	0.1
RIS transposition rate	0.1
One-point recombination rate	0.3
Two-point recombination rate	0.3
Gene recombination rate	0.1
Gene transposition rate	0.1
Numerical Constants	9
Constants per gene	
Data type	Floating-point
Lower bound	-10
Upper bound	10

6.5.4 Results and Discussion

6.5.4.1 GP-Based Formulation

The GP-based formulation of project cost estimation (K$) in terms of x_1, x_2, x_3, x_4, x_5 is as follows:

$$\text{Cost}=x_4(57.5303x_2+151.7352)+(8.9097x_2-42.7632)^2-0.3472(x_4+1.4305)(x_4-x_5)+\frac{x_1.x_3{}^3}{(x_4-0.386)} \quad (10)$$

The formulation mentioned above displays a combination of variables, constants and operators in a complex arrangement to predict cost estimation. The expression tree of the extracted equation is shown in Figure 7.5. The proposed equation is composed of four independent subprograms (genes) interrelated by the addition operator. Embodying a particular character of the problem, each subprogram adds a distinct function to the developed solution (Ferreira, 2001). In other words, each evolved subprogram includes essential information about the structure of the final model (Gandomi, et al., 2012). Each gene, as a part of the final equation, is engaged to address a certain aspect of the problem.

6.5.4.2 Comparison of GP model with the City of San Diego's Engineering Estimate

The City of San Diego announces a suggested cost estimate for each project in the project's bid documents. A project cost estimate, called engineering cost estimate, is attained through an in-house lengthy and rather expensive system which operates on an educated guess based on the past bids and the project manager (who puts the project bid documents together)'s judgement. Most of the time the engineering estimate is so much higher than the lowest bidder's proposed price or is lower. As mentioned earlier, engineering estimate becomes a gauge for budget allocation. Unrealistically high cost estimate prevents the project from being implemented or low budget allocation results in many shortfalls in the future. Besides, the announced engineering estimate somehow gives direction to the bidders. When an unrealistically high engineering estimate is announced, the Contractors are inclined to inflate their bid price to earn a bigger profit margin. To confirm that the proposed GP model would be a capable tool, the results driven from GP formulation were compared to the City's engineering estimates. Comparison of the results of GP equation with the engineering estimate proves the outperformance of the GP equation. Besides an improved accuracy of GP equation, its usage is very easy. The formula is built on the basis of extensive sets of data with plenty of possible real life scenarios. Furthermore, GP model takes into account qualitative factors that could impact productivity such as soil classification, pavement condition, and traffic.

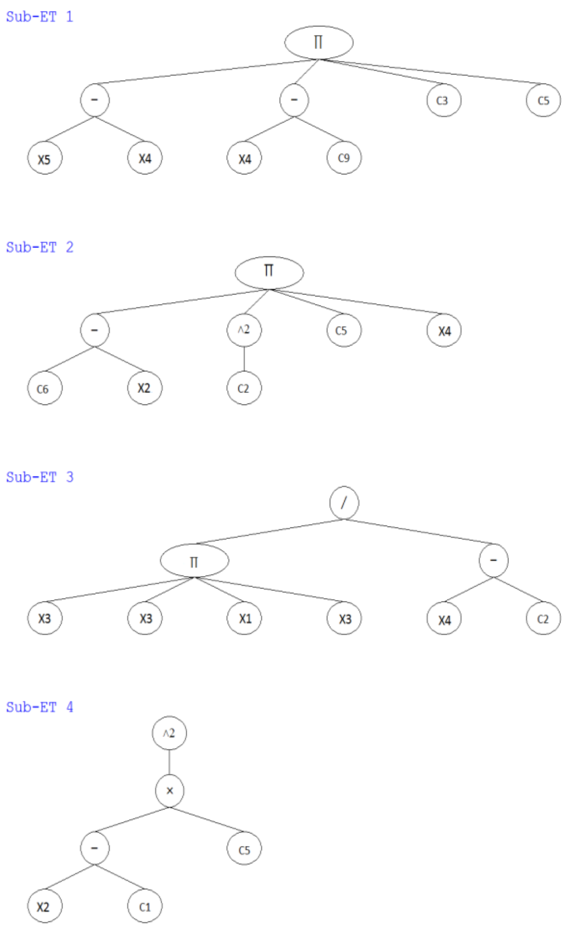


Figure 6.5: Expression tree (ET) for cost estimation of sewer and water projects

6.5.4.3. Model Validity

According to Smith (Smith, 1986), there is a solid correlation between the predicted actual values if a model maintains $R > 0.8$. Should the MAE values be at the minimum, the solution is considered reliable (Gandomi, et al., 2011).

Low RMSE and MAE and high R values demonstrate that the proposed GP model is able to predict the target values with satisfactory accuracy. Good performance of the model on the training (learning and validation) and testing data confirms reliable prediction and generalization ability of the model.

With great impact on the accuracy of the final model, the amount of data used for the modelling process, gains importance (Gandomi, et al., 2012). Frank and Todeschini (Frank & Todeschini, 1994) stated that a model can be considered acceptable if the minimum ratio of the number of objects per the number of selected variables is 3 preferably 5 yielding to more accurate solution. In this study, this ratio is as high as 160/5=32.

To examine external verification of the GP model on the testing data sets, Golbraikh and Tropsha's suggestion, that at least one slope of regression lines (k or k0) through the origin should be close to 1, was checked as well (Golbraikh & Tropsha, 2002).

Table 6.13 lists the used validation criteria and the pertinent outcomes of the proposed model. The final model meets the conditions. The validation phase justifies soundness and strength of the prediction model.

Table 6.13: Statistical parameters for external validation of GP model

Item	Formula	Condition	GP
1	R	$0.8 < R$	0.8467
2	k=$[\sum_{i=1}^{n}(h_i \times t_i)]/{h_i}^2$	$0.85 < k < 1.15$	1.0008
3	k'=$[\sum_{i=1}^{n}(h_i \times t_i)]/{t_i}^2$	$0.85 < k' < 1.15$	0.8950

The main feature of the proposed GP-based model is that it can readily be implemented by using the attainable accurate information with substantial impact on the project cost. Furthermore qualitative factors which affect productivity such as traffic, soil classification and pavement condition are incorporated into the model.

Many existing prediction models assume the structure of the model at the outset and suffer from its inadequacy. Therefore, the interactions and exchange between the dependent and independent variables are not considered effectively (Gandomi & Alavi, 2011).

Nevertheless, GP does not assume any initial existing relationships and generates clear relationships for project's cost estimation. It learns from provided data. Other soft computing approaches follow the same rule also (Gandomi, et al., 2012).

A remarkable advantage of GP compare to ANNs is that it generates a clear and structured system. Due to the complex nature of the network structure, ANNs do not display a clear function linking the inputs to the subsequent outputs.

6.5.4.4 Variable importance

In the GP analysis, the relative importance of each predictor variable can be assessed on GP model. GeneXproTools computes the variable importance of all the variables in the model by randomly choosing its input values and then computing the decrease in the R-square between the model output and the target. The results for all variables are then normalized in order that they add up to 1 (GepSoft, 2014). The variable importance of the predictor variables are displayed in Figure 6.6. As it is shown, the sewer and water main materials incur the highest cost which is known from professional point of view too. As per their experience, most of the Contractors are very careful about pricing the pipes in their bid proposal. Sewer laterals, water services, and manholes are the next costly items, soil and pavement conditions' impact on the outcome is much less. Traffic does not have any large impact on the total cost of the project.

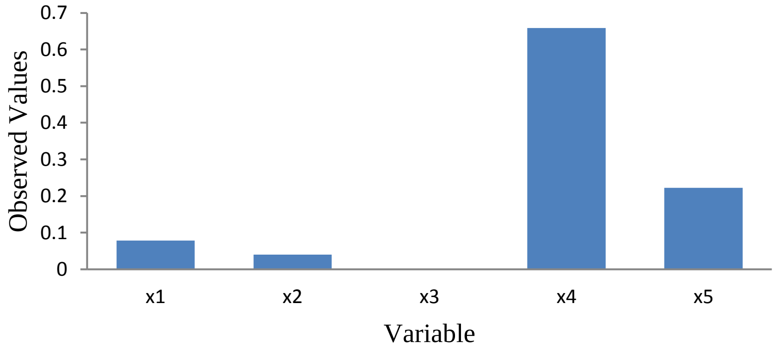
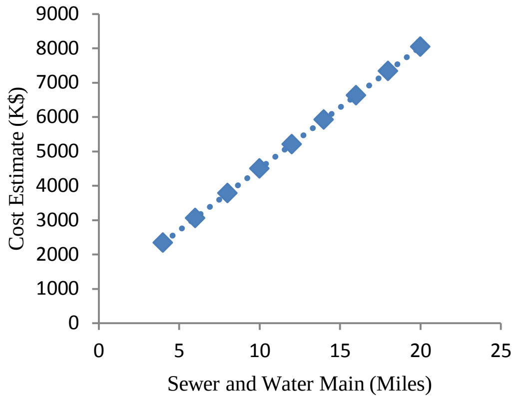


Figure 6.6: The predictor variables' contributions in the GP analysis

6.5.4.5. Parametric study

A parametric analysis was performed in this study to verify the robustness of GP-based prediction equation. The methodology is to change only one parameter at the time while other parameters are kept constant at the average values of their entire data sets. Figure 7.6 presents the parametric analysis of cost estimation in the GP model. An expected behaviour pattern is seen in the Figure 6.7. According to reported professional experience too sewer and water main installations incur most of the cost of a project.



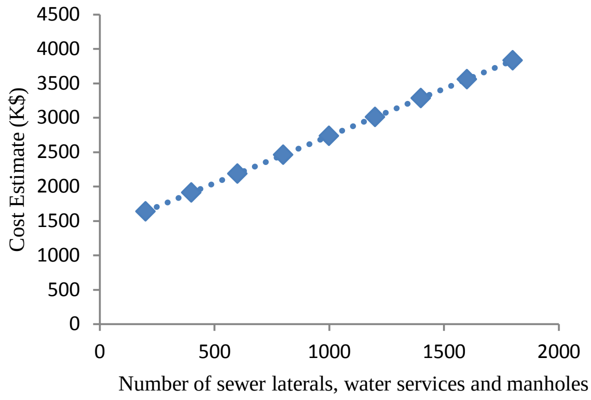


Figure 6.7: Parametric analysis of cost estimate in the GP model

6.5.5 Outcome

GEP, a variant of GP, was utilized to formulate the cost estimation of sewer and water rehabilitation/replacement projects. The proposed model, serving as a successful prediction tool, was developed based on data pertaining to 210 sewer and water replacement/rehabilitation projects from year 1999 to 2013 acquired from the City of San Diego, California, USA.

The conclusions below are drawn from this research:

- Validity of the model was examined on testing data sets which were not part of training data sets. The GEP prediction model efficiently satisfied the conditions of different criteria considered for its external validation as well.
- The developed system offers an improved cost estimation model with higher accuracy in comparison with the City of San Diego's published engineering estimates; however our model is an explicit formula also.
- Unlike engineering estimates, using such a simple formula opts out the need to go through expensive and protracted cost estimation process on the conceptual stage of a project assessment
- The GEP cost estimation formula gives a simple solution with fairly less inputs which are easily attainable at the conceptual stage of a project assessment.
- GEP model takes into account the qualitative productivity factors such as traffic, soil and existing pavement conditions.
- This model will lead to a more objective resource allocation for funding and decision making purposes and offers a more accurate cost baseline for both bidders and the City.

6.5.6 Conclusion

Imminent water shortages in the State of California, County of San Diego and frequent disruptions of service due to water main breaks alarmed the authorities to address the urgent need to reduce water loss and minimize water service interruptions. Most of the existing old cast iron (CI) mains have reached to the end of their predicted service life which necessitates their immediate replacement to halt water main breakage and water leakage.

The State of California Department of Public Health has mandated that cities replace at least 10 miles of CI pipe per year, with the goal of eliminating all CI pipe by 2017 (San Diego County Grand Jury, 2013).

This study proposes application of Build- Operate-Transfer (BOT) type of Public-Private-Partnership (PPP) to help overcome existing financial and operational shortfalls of water and sewer distribution services. As long as sufficient revenues can be generated to cover costs and fulfill financial commitments, private capital would help replace the old distribution services consequently decrease water interruptions due to break and curb the leakage, expand the coverage so that less wealthy households can have access to healthier and cheaper water versus expensive private vendors. Private sector management would help remedy the problems of operation by applying effective operational practices such as optimal levels of staffing, and 'user pays' pricing method to save water (Grimsey & Lewis, 2004).

Financial analysis and sensitivity analysis of concession-based BOT scheme sewer and water replacement project showed that the government and the private entity will be able to decide about entering a BOT contract objectively if the construction cost of the project would be anticipated more accurately at the outset.

Using GEP, a GP alternative, cost estimation of sewer and water rehabilitation/replacement projects was formulated resulting in a simple solution with fairly less inputs which are easily attainable at the conceptual stage of a BOT project assessment. The proposed prediction model was developed based on data pertaining to 210 sewer and water replacement/rehabilitation projects from year 1999 to 2013 acquired from the City of San Diego, California, USA. Validity of the model was examined on testing data sets which were not part of training data sets. Further comparison of the GEP model's results with the City of San Diego's engineering estimate displayed higher accuracy with correlation coefficient of 0.8467 as well.

Chapter 7

RISK ALLOCATION AND MITIGATION

7.1 Introduction

Public Private Partnership types of contracts are primarily concerned with long-term service provision of social and economic infrastructures. A PPP contract integrates design and construction costs, continuous facility deliverable, operational and maintenance costs. A PPP provides motivations for bidders to utilize novel approaches to fulfill highlighted requirements. PPP on the other hand enables the parties to share the risks involved, or transfer the risk to the party which can manage it better at less cost. This can substantially lower the overall cost to the project (Grimsey & Lewis, 2004). Therefore the project risk identification and devise a strategic mitigation plan are very important. This chapter will review various risk categorizations introduced by other researchers; risk allocation and risk response strategies will also be discussed.

7.2 Risk Identification and Risk Allocation

As mentioned before government enters into PPP arrangements to reduce public debt, alleviate tax burden and utilize private sector funds. Furthermore, government would like to enjoy the advantage of sharing the risks pertinent to the project (Sapte, 1997).

The high degree of risk in PPP projects can be attributed to the complex nature of construction activities, environment and organization (Kartam & Kartam, 2001). The reality is that the changes on a project are inevitable but the associated risks are manageable (Ng & Loosemore, 2007).

Risk allocation alludes to contribution of a capable party to the contract by assuming liability for dealing with a specific risk (Grimsey & Lewis, 2004). Smith R.J (1995) acknowledged failing to efficiently allocating risks in contracts as the main reason of construction disputes in the United States (Smith, 1995) . Risk allocation starts with categorizing risks, in other words risk identification.

Risk identification process starts with examination of: the project's stakeholders, scope of work, work breakdown structure, cost estimate, design, construction, procurement and operation phases, or developing general risk checklists (Ashley, et al., 2006). Risk identification helps to adopt a strategic approach to risk management for the project stakeholders. Different risk classifications have been found in the literature such as classifications associated with project phases (e.g. design and construction, operation) or related to the environment in which the project is undertaken (e.g. political, environmental, economic and financial). Other risk classification is based on levels of risk factors called meta-classification approach (e.g. macro level, meso level, micro level) (Issa, et al., 2012). On the latter approach, macro level deals with risks at industry and national levels upon conditions such as political, legal, economic, social and weather which are external factors to the project and beyond control of a project's stakeholders. The meso level risks are related to the problems within the project such as construction, design, technology or project demand. The micro level risks are internal risks like meso level risks but are associated with stakeholders' interests where interest of the private sector is to recoup the investment; and that of the government is to consider social perspective

(Bing, et al., 2005). Table 7.1 displays various risk categorizations found in the literature.

Table 7.1: Risk identification literature review

Source	Risks		
	General/ Country (Macro)	Project Specific (Meso)	Interrelated (Micro)
(Wideman, 1992)	▪ external/ unpredictable ✓ regulatory ✓ natural hazards ✓ postulated events ▪ external/ predictable ✓ market ✓ operational ✓ environmental impacts ✓ social ✓ inflation ✓ force majeure	▪ internal/nontechnical ✓ management ✓ schedule ✓ cost ✓ cash flow ▪ internal/technical ✓ changes in technology ✓ performance ✓ risk specific to technology ✓ design ✓ quality	▪ legal ✓ licenses ✓ contractual ✓ third-party suit
(UNIDO, 1996)	▪ commercial ▪ political ▪ legal	▪ construction/completion ▪ developmental ▪ operating	
(Grimsey & Lewis, 2002)		▪ developmental ✓ capital cost ▪ operational: ✓ revenue ✓ recurrent costs	
(Schaufelberger & Wipadapisut, 2003)	▪ political ✓ war ✓ revolution ✓ asset confiscation ✓ tax policy ✓ currency availability/convertibility ✓ export ▪ market (demand & price)	▪ financial ✓ currency exchange rate ✓ inflation ✓ cost of capital/ interest rate ▪ construction ✓ completion delays ✓ cost overrun ▪ operational (maintenance)	

Table 7.1: Risk identification literature review (continued)

Source	Risks		
	General/ Country (Macro)	Project Specific (Meso)	Interrelated (Micro)
(Grimsey & Lewis, 2004)	▪ financial risk ✓ interest rate ✓ inflation rate ▪ force majeure ▪ regulatory/political ▪ default	***site*** ▪ site condition ✓ ground condition ✓ supporting structures ▪ site preparation ✓ site redemption ✓ tenure ✓ pollution/discharge ✓ obtaining permits ✓ community liaison ✓ pre-existing liability ▪ land use ✓ native title ✓ cultural heritage ***technical*** ▪ fault in bid specifications ▪ contractor design fault ***construction*** ▪ cost overrun ✓ inefficient work practices ✓ wastage of materials ✓ Changes in law ✓ delays in approval ▪ completion delay ✓ lack of coordination ✓ failure to obtain standard planning approvals ✓ force majeure events ▪ quality failure ***operating*** ▪ cost overrun ✓ practice/spec changes ✓ repairs/maintenance ✓ occupational health and	

Table 7.1: Risk identification literature review (continued)

Source	Risks		
	General/ Country (Macro)	Project Specific (Meso)	Interrelated (Micro)
(Grimsey & Lewis, 2004) (continued)		✓ safety ▪ delays due to governmental approvals or operator fault ▪ low service quality ***revenue*** ▪ higher input prices due to contractual violations ▪ tariff/tax changes ▪ demand changes ***asset*** ▪ Technical obsolescence ▪ Termination ▪ Residual transfer value	
(Ng & Loosemore, 2007)	general ✓ natural ✓ political ✓ regulatory, ✓ Legal ✓ economic	project ✓ ground ✓ weather conditions ✓ technical/ designs, ✓ equipment/ materials ✓ suppliers/subcontractors, ✓ manpower/ unions ✓ contractual ✓ environmental/pollution	
(Wibowo & Mohamed, 2010)	***political risk*** ▪ change in legislation ✓ general changes in legislation ✓ discriminatory changes in legislation ✓ specific changes in legislation ▪ traditional political ✓ nationalization/ expropriation ✓ non-availability of foreign exchange (FX)	***land and construction risk*** ▪ construction cost escalation ▪ land cost escalation ▪ construction time overrun ▪ price protracted negotiation ***business risk*** ▪ tariff setting uncertainty ▪ breach of contract by operator ▪ premature termination by operator	

Table 7.1: Risk identification literature review (continued)

Source	Risks		
	General/ Country (Macro)	Project Specific (Meso)	Interrelated (Micro)
(Wibowo & Mohamed, 2010) (continued)	✓ transfer-ability restriction of FX ✓ exchange-ability restriction of FX ▪ Commercial ✓ breach of contract by government ✓ premature termination by government ***<u>force majeure risk</u>*** ▪ natural disaster ▪ man-made disaster ▪ declared war ▪ riot ▪ terrorism attack ▪ labor strike ***<u>macroeconomic risk</u>*** ▪ inflation fluctuation ▪ FX/ interest rate fluctuation	▪ abuse of power by government officials ▪ failure in financial closure ▪ failure in refinancing ▪ demand uncertainty ▪ entry of new competitors ▪ unpaid bills by consumers ***<u>Operational risk</u>*** ▪ operation and maintenance cost escalation ▪ equipment defect-caused interruption ▪ environment protest interruption ▪ unavailability of raw water ▪ water meter manipulation ▪ electricity blackout/leakage ▪ low quality of raw water	
(Pollard, et al., 2004)	✓ Compliance/legal	▪ financial ▪ commercial ▪ public health ▪ environmental	▪ relationship reputation
(Ke, et al., 2010)	▪ corruption ▪ change in law ▪ public opposition	▪ tariff change ▪ financial	
(Ameyaw & Chan, 2013)	▪ political and regulatory ✓ political interference ✓ contract termination ✓ commitment ✓ change in government ✓ regional instability ✓ corruption	▪ operational ✓ high cost ✓ equipment defect ✓ lack of maintenance ✓ obsolete technology ✓ service/water quality ✓ poor performance	▪ relationship ✓ strained relationship ✓ poor commitment ✓ no risk allocation mechanism ✓ weak capacity of partners

Table 7.1: Risk identification literature review (continued)

Risks		
General/ Country (Macro)	Project Specific (Meso)	Interrelated (Micro)
(Ameyaw & Chan, 2013) (continued)	✓ aesthetics ✓ operator default ✓ poor asset ✓ water theft ▪ market/revenue ✓ alternative sources ✓ fall in demand ✓ delayed/non payment ✓ uncertain tariff reviews ✓ profitability of schemes ▪ financial ✓ financial availability ✓ adverse global private investment environment ▪ project and private ✓ consortium selection ✓ suitability of operator ✓ unclear process ✓ performance record unsuitable PPP model	✓ inexperienced partners ✓ inexperienced partners ▪ third party ✓ unreliable supply ✓ employee theft

Risk identification, assessment and analysis practices establish the ground for reliable risk response options (Ashley, et al., 2006). There are six risk response strategies:

Avoid: It refers to bypassing an actual or potential risk due to a thread by changing the plans. Some risks, at the early stages of a project, can be avoided by: detailed investigation of requirements, seeking more information, improving communication and obtaining more knowledge. Risk avoidance might be achieved by loosening up triple constraint of scope, time, and resources.

Transfer: By transferring a risk, the thread is not eliminated; but liability for the risk and ownership of its response are delegated to a third party. Transference tools include but are not limited to using insurance, performance bonds, warranties, guarantees, etc.

Mitigate: Mitigation plan is to accept the impact of an adverse risk up to a manageable level and to limit exposure by taking some actions.

Exploit: When a risk has positive impact, the organization makes sure to fully realize the opportunity and engage required resources and plans to make the opportunity definitely happen.

Share: Sharing a positive risk means conceding control of an opportunity to a third party who is best able to seize it for the benefit of the project.

Enhance: Enhancing strategy is planning to facilitate and reinforce the conditions to grasp any probable opportunities (PMBOK, 2004).

In order to efficiently allocate the identified risk factors, four essential principles should always be followed:

1. Risks must be identified, understood and evaluated by all parties.

2. Risks must be undertaken by the party best able to manage them.

3. Risk allocation must be in accordance with project and customer-oriented performance goals.

4. When sharing the risks seems to be the optimum practice to achieve project goals, parties should be ready to accept to contribute (Ashley, et al., 2006).

7.3 Projects Risk Allocation and Mitigation Plans

Student housing projects are typically exposed to demand and price risks. Legislative decisions which central administration of the universities may make, impact this sector negatively (Attakora-Amaniampong, et al., 2014). On the other hand students' turnover rate is high which causes much more depreciations on their units. This incurs higher maintenance and refurbishment costs (RealtyMogul.com, 2015).

According to Clough et al. (2004) utility projects are acknowledged to bear accumulation of many infrastructure risks such as a large amount of investment cost, low rate of return, mandatory hurdle rates, political risks, numerous public policy schemes, various institutional setups, intractable asset condition, inconsistent consumers, unrealistic tariff assessment due to overlooking externalities, high sunk costs, lengthy rehabilitation process (Clough, et al., 2004). By reviewing literature, Ameway and Chen (2013) collected various water sector performance indicators which add up to the uncertainties associated with water and wastewater sector activities such as recoup outlay, non-revenue water (NRW) due to leakage, theft or metering inaccuracies, tariff collection methods, cross subsidization practices to charge a community more in order to subsidize lower tariffs for the impoverished community, labor productivity, continuity and coverage of water supply, tariffs and quality of services (Ameyaw & Chan, 2013).

7.3.1 Outset Risks

Bid Documents: Bid documents and project specifications should be thorough and precise to reflect the rules, regulations and expectations of the hosting government.

Specifications become the foundation of the contract with the concession company and evaluation criteria. Unclear or incomplete specifications create the thread of flaw, shortcoming, confusion, disagreement and conflict (RDTL Ministry of Finance, 2008).

Land acquisition process (negotiation, development, administration) and cost escalation: Infrastructure projects require sites for public facilities and rights-of-way for utilities, streets, parks, open spaces, etc. If private residences or businesses are impacted by these acquisitions, the acquisition program provides the occupants with resettlement assistance to minimize the impact.

Asset Management Division of the public sector negotiates, develops and administers lease agreements and permits for use of publically-owned properties by profit and non-profit organizations city-wide. This is a risk whose responsibility rests with the government to be managed more efficiently (City of San Diego, 2002-2014).

Authority Support: Besides the government entity that will finally own the infrastructure asset, other related government agencies should be supportive of the project to facilitate development and implementation of the infrastructure project during all the stages. The prospective concessionaire can enter into a support agreement with the host government to obtain incentives and assistance (World Bank, 2014).

Permits, Licenses and authorization: The government agency should secure procurement of required permits, licenses and authorization correspondences to prevent delays. Government support agreement would be a helpful means to reduce the risk of permit, license and authorization letters acquisition.

Project financing and funding: Concessionaire will be responsible for financing the project in some combination of equity and debt. Equity contributors who are generally project sponsors bear the highest risk because lenders have priority to project assets and revenues; however, equity contributors receive the highest returns due to bearing the highest risk. In a new infrastructure project, the lenders have to examine concessionaire's ability to fulfill debt servicing obligations by looking at operation revenues rather than physical asset. Since there will be no revenue at the construction phase, lenders will bear more risk until operation period starts therefore sponsor support is sometimes provided at construction stage. Sponsor support may include:

- Shortfall guarantees, where in spite of all other security rights, the concessionaire is in default.
- Buy-down agreements, to ensure lower interest rate for project debt repayments in particular situations.
- Offtake agreements, to secure a market with a certain price for the future output of the project
- Tax loss purchases, where a shareholder agrees to purchase certain tax losses from the project
- Technical support, through extended warranties and maintenance provisions.
- Contingent equity or junior debt (subordinated debt) in case of insolvency, to cover construction or other cost overruns (World Bank Group, 2014).

Contractors and suppliers: This risk arises when material suppliers or approved reliable sector contractors are not locally available. In such cases the concessionaire should bear the cost of acquiring materials and contractor arrangements overseas.

Inspection: The public agency and the concessionaire assign an independent entity to review, inspect and certify the activities of the project throughout the concession period. If two parties cannot come to an agreement about the independent engineer, the mitigation plan would be a bidding process in which each party nominate qualified persons to bid for such a position. The evaluation of the bid would be undertaken by a committee consisting of eligible members of both public agency and the concession company.

Design: The concessionaire should exclusively be responsive to any negligence in preliminary and detailed design specifications. The concessionaire can mitigate the risk of design and associated services by contracting with a trustworthy engineering and design company.

7.3.2 Site Risks

Site/easement Procurement: The public agency is held accountable for obtaining the project site for concessionaire through acquiring necessary permits and licenses on a timely manner.

Site clearance/ mobilization: Concessionaire has the responsibility of site clearance and project mobilization once the notice to proceed (NTP) is issued by the government agency. In case of a delay in NTP issuance, the government agency will bear all pertinent risks.

Archaeological, Paleontological and Native American resources: Concessionaire is to identify, preserve, prepare mitigation plans and make special provisions; and respond to public inquiries and government agencies pertaining to these resources. Concessionaire would be required to enter into a contractual agreement with an environmental consulting company at the construction phase of the project.

Interference of utilities or other facilities: On the design stage of the project, the concessionaire delegates dealing with risk to the design company. Designers are to hold a pre-design conference with other utility companies and water and sewer department principals to review all existing utilities' master plans to be aware of all existing utilities' locations to take into account in designing the project or request possible relocations to avoid utility interferences.

Site condition: The concessionaire delegates dealing with this risk to the design/construction company to assess the existing conditions and come up with mitigation plans to manage them.

7.3.3 Construction Risks

Maintenance and preservation of existing facilities and utilities: New construction activities should be compatible with existing utilities and facilities to preserve them from damage and corrosion. In case of any damage, if the utilities were shown on the existing plans, the construction company should bear the cost but if the exact locations of the utilities were not displayed on the plans, the utility companies would be held responsible.

Construction schedule: If all the necessary permits and licenses are obtained by the government agency, in case of any delay on construction schedule, the construction company would bear the cost and come up with mitigation plans.

Contractor default: Contractor default is a costly risk event on which the contractor fails to fulfill the contract obligations. Typically the construction company transfers this risk to the surety company through a performance bond which usually is 10% of contract price (Al-Sobiei, et al., 2005). If the contractor performs the contract obligations then the performance bond shall be void; otherwise it shall remain in full force. Retention (usually 5% of contract amount) is another means to ensure that the contractor properly completes the required activities. The amount retained is released on practical completion of construction contract.

Construction time and cost overrun: Cost and time overruns frequently give rise to disputes about who should be held accountable. Cost and time overruns may occur due to macro level changes, force majeure events or inept management such as utilizing inefficient technologies, careless material usage, ignorance of material lead time or review time for approval , etc. The concessionaire can transfer the risk by entering into a fixed-price or fixed-schedule contract with the construction company in which a firm price or schedule contract is established and the concessionaire pays a negotiated amount regardless of construction contractor's benefit or loss and expects the complete facility within a specific time frame.

Construction materials and equipment: To mitigate material/equipment delivery and defect risks, the concessionaire can enter into contractual agreements with the suppliers to specify exact description of the required materials/equipment, quality, time of delivery (taking material lead time and independent engineer's review span into account), price, liabilities and obligations of contracting parties.

Traffic control: Traffic control risk arises when no proper measures are taken to reroute the traffic during construction on site. The construction company can be held responsible to mitigate the risk.

Survey monument (property markers) preservation: Survey monuments are key survey points placed on the ground which establish the location of boundary lines and should be preserved. The risk of missing monuments should be allocated to the construction company to be cautious about tying off the monuments prior to demolition.

Storm water pollution control: Construction Company should come up with a comprehensive plan for effective storm water pollution prevention implementation which includes housekeeping, erosion control, tracking, and protection of the storm water conveyance system (City of San Diego, 2014).

Community Liaison: Keeping the communities satisfied with the construction activities are of grave importance. Communities, residents and pertinent council member office should be informed of ongoing construction activities on their neighborhood, construction schedule and working hours, traffic control, parking, pollution and noise impacts and measures, sewer and water service interruptions, etc. Construction Company can transfer the risk by hiring a Community Liaison sub-consultant.

Safety: Construction Company should bear the risk of safety. Typically construction companies transfers this risk to insurance companies by purchasing workers compensation insurance

Scope changes: In case of any scope change during the construction period of the facility, Concessionaire and the public agency are equally responsible. Any scope change may result in delay in operation phase of the project. Insurance provisions, government support agreements, financial support agreements are among remedial measures to mitigate the risk.

Performance standards: The construction company should deliver a facility according to the specifications. In case of any divergence from the specifications or failure in operation due to faulty construction, the construction company should compensate the risk. The concessionaire should apply quality assurance and quality control measures to inspect and examine the work of the contractor on each step to prevent delays and insure desirable delivery of the facility.

7.3.4 Operation Risks

Operation phase delay: Operation phase delays may occur due to delay in construction phase or operators' failure to timely commencement of operation. The concessionaire transfers the construction delay risks to the construction company through contractual agreements. The construction company would be obligated to compensate the concessionaire for uncollected revenue due to postponement of operation. Concessionaire may secure itself from operators' failures by entering into operation and maintenance contract or by buying insurance.

Maintenance delays: Late attention to maintenance of utilities may cause serious damages which drops service quality and increases the costs. Concessionaire can transfer this risk to maintenance companies by fixed price contracts. Concessionaire may furnish an account to ensure availability of funds for anticipated expenditures required to maintain utilities.

Operation and maintenance cost overruns: Operation and maintenance cost overruns can be due to inefficient management, unavailability of raw water, electricity blackouts, low quality of raw water, leakage during distribution, water meter manipulation, water theft, etc. These risks can be transferred to pertinent contractors through contracts. The project lender can establish an escrow account to provide liquidity in case of cost overruns.

Maintenance/ Operation Contractors default: Concessioner should contract with experienced and qualified maintenance and operation contractors. In case of a default, the contractor agrees to compensate the concessionaire for losses occurred due to their retreat.

Hidden defect: Hidden defects are construction deficiencies which are discovered once the facility is put into operation. Concessionaire may transfer this risk to Construction Company by setting up a specific warranty period. During the warranty period, any defects which shall affect integrity of the facility shall be repaired at the Contractor's expense in a manner mutually agreed upon.

Demand and Tariff: Forecast of water and waste water demand can sometimes be uncertain due to limited historical data on actual water use, probable losses in urban, irrigation and industrial water use, and subjective economic, social and demographic assumptions for demand forecasts (Herbertson & Tate, 2001). Entry of new competitors can drop the demand as well. Obviously concessionaire has slight influence in the water use demand. When the demand falls, the average cost of delivering water or treating wastewater rises. When the demand does not match the forecast level, it's improbable that the government consent to any tariff increase. In such case concessionaire should seek other remedies such as reducing capital investment, leakage reduction plans, obtaining cash deficiency guarantee from various resources, obtaining government guarantee and obtaining insurance (Mandri-Perrott & Stiggers, 2013) (Jenkins, 2010).

For the student housing sector, students mostly look for affordability of their accommodation choice because of their high expenses including their living cost and tuition fees, etc. Political decisions, changes in the policy of the country or universities may impact students' demand as well. In such case concessionaire should seek for a cap price and political security in order to maintain the expected profit margin.

Claims: Users, employees, authorities and other stakeholders may demand a right at any stage of the concession project. The concessionaire should see to the claims and settle them the most sensible way possible to prevent any delay or loss during any stage of the project.

Environmental: Urbanization impedes the natural hydrologic process of surface and underground water. By discharging pollutants and storm water to downstream surface waters, the traditional engineering practices has caused serious water quality degradation. It is of grave importance to maintain and improve the main hydrologic functions after any infrastructure development (City of San Diego, 2011). Concessionaire can obligate the construction contractor and operators and maintenance contractors to implement best management practices, establish environmental assessment and mitigation plans and abide by local environmental laws and regulations.

Force Majeure: Private parties normally agree to accept ownership of development, construction, commissioning and operation risks, but they become dubious when it comes to unquantifiable and external risks such as political, country risks, demand and force majeure risks (Wibowo & Mohamed, 2010). These risks can be mitigated by obtaining insurance from multilateral institutions which are created by a group of countries to provide financing and professional advising for development purposes.

7.3.5 Asset Transfer Risks

Concessionaire should take necessary actions at the operation stage of the concession period to be able to hand over the asset at the end of concession period in acceptable conditions spelled out in the concession contract with considerable working life at an acceptable maintenance cost otherwise the concessionaire will be assumed liable for any asset deficiencies (Grimsey & Lewis, 2004).

7.3.6 Financial Risks

Interest rate: Interest rate is generally difficult to be quantified with a real accuracy. Conducting sensitivity analysis on a financial model can be a useful tool to predict the likely impacts. If the interest rate would be a fixed rate, this will reduce cost fluctuations; if sponsors are unable to provide fixed rate debt then interest rate risks can be managed through hedging arrangements such as futures contracts, insurance and swaps to manage movements in exchange rates to convert variable rate debt to fixed rate debt (World Bank, 2014).

Inflation: Like interest rate, inflation rates are difficult to predict and sensitivity analysis can be conducted to reach a sense of its impact on the financial model. The construction cost inflation is undertaken by the construction contractor which usually is willing to provide a fixed price due to the short-term nature of the risk. Maintenance, operating and life cycle costs are generally indexed against inflation. If the inflation rate runs below the assumptions in the financial models, Concessionaire can enter into hedging arrangements to cover the risk (H.M. Treasury, 2006).

7.3.6 Contractual and relationship

On a PPP contract all dimensions of the PPP should be extensively addressed such as design, project scope, responsibilities, risk allocation, service performance standards and targets, payment mechanism, penalties, possible bonuses, security and performance bonds, insurance requirements, tendering method, conditions for termination , force majeure and changes in law, dispute resolution procedure, bid evaluation criteria and complete tender documents. The authorities should always be advised by experts before bid evaluation stage to implement award criteria in a most properly manner possible. The project managers of each party should prepare comprehensive organizational, responsibility and authority breakdown structure.

7.4 Conclusion

Understanding the involved risk in a project, objective risk identification and allocation at the conceptual stage would lead to a more stable contract agreement. Appropriate risk management plans would help both partners undertake the project with less surprising encounters. On this chapter we tried to identify some risks which are common in both dormitory and utility projects. We tried to offer some strategies for handling those risks also.

Chapter 8

CONCLUSION

8.1 BOT project assessment

A BOT approach can be very successful in infrastructure development by employing private sector's innovation and business insight while bestowing overall planning, coordination and regulatory supervision of the infrastructure networks upon public entities.

This research demonstrates how effective the appraisal and risk analysis of a project at the conceptual stage can be. From reviewing many BOT projects, it was even clearer that extensive risk evaluation and risk assessment at the outset helped the success of the projects. Beside a reliable project evaluation at the conceptual stage will stop viable projects from being rejected.

Because several stakeholders are party to BOT projects, stipulating objective risk allocation and risk sharing strategies in the contract is very important. Since a long period of time may be required to complete the contract, many uncertainties and risks threaten the performance of BOT agreements, therefore for a successful BOT implementation:

- clear and mutually acceptable objectives should be defined,
- stable legal and regulatory environment should be created,

- all the parties would assume responsibility and accountability, and
- all the BOT steps should be applied properly.

Under a BOT agreement public and private sector become one team. Both parties commit to improve government's operation system by:

- introducing market practices into the public services;
- encouraging and supporting involvement of private sector operators and their financial commitments,
- leting the private equity increase up-front financing, or make greater total debt capacity available through private sector credibility;
- expanding the number of participants in benefiting from the outcome;
- allowing for financial risks to be shifted from public to private investors;
- creating fundamental positive changes in public services and administrative procedures;
- allowing for authority sharing arrangements;
- cultivating cooperation and trust in lieu of competitive relations and command-and-control regulations;
- creating incentives for long-term investment returns and better asset management;
- creating a playground to share benefits of employing knowledge, or enduring responsibility and risk.

The reasons that a BOT project implementation might be unsuccessful are:

- not getting high-quality bids,
- no competition atmosphere to get quality bids,
- underestimation of the cost of the project,
- no understanding of project risks
- not stipulating risk sharing strategies and responsibilities which will give way to complications, litigations and delays.

In this research, two different case studies were scrutinized to demonstrate: how to undertake BOT appraisal and risk analysis in different projects with different circumstances; how to consider the complex nature of BOT arrangements; where and how soft computing methods can be utilized to facilitate and improve a BOT project's assessment.

It is obvious that decision makers' acumen and experience are important in selection of PPP procurement. However, in order to convince the parties to undertake BOT type of procurement, a vast and objective analysis of impacts of all probable risks, expenditures and earnings on each other must be probed also. To form a reliable decision making instrument, adequate number of similar past projects should be scrutinized.

Prior studies had developed an automated mechanism and were advocates of automating contract negotiating procedures. However, these studies either did not allocate risks, or did not incorporate influential factors on possible combinations of risk variables.

With utilizing ANN model's ability to incorporate many more data, this research attempted to include as many scenarios as could be generated. Both decision making criteria NPV and IRR which show financial viability of a project were considered to ensure that the selected project would have a positive outcome in the future. The ANN model, with its pattern recognition ability, is able to identify relationships between input variables by taking probable risks into account. Per literature review, ANN models have never been used in developing contract negotiation tools before. Our proposed ANN model formulates the relationship between project's important parameters or risk variables with more accuracy to help professionals identify a BOT project's concession terms and parameters.

Using actual data for dormitories in Cyprus helped demonstrate how to incorporate risk attributes and relevant parameters into the model formulation process to identify possible combinations of financial terms in a BOT project. On the basis of actual cash flow statements for six university dormitory construction projects and considering 15-, 20-, 25-, and 30-year concession periods for each, 24 conventional spreadsheets were prepared to NPV and IRR as project performance indicators for the various concession periods. With incorporating data sets drawn from Monte Carlo simulation and several important parameters on all the spreadsheets, 1871 random scenarios were produced, and each scenario with a selected set of eight input variables (capital expenditure cost overrun factor, occupancy rate, NPV, IRR, total dormitory area, number of rooms, number of beds, and concession period) was fed into the ANN. The ANN model with correlation coefficient of 0.94 succeeded in automating the negotiation process for a BOT-type contract by taking into account project risks and uncertainties along with several important parameters.

On another case study financial analysis and sensitivity analysis of concession-based BOT scheme sewer and water replacement project showed that the government and the private entity will be able to decide about entering a BOT contract objectively if the construction cost of the project would be anticipated more accurately at the outset. By having this reason on mind, we decided to utilize GEP soft computing method, a variant of GP, to formulate the cost estimation of sewer and water rehabilitation/replacement projects for the first time to the best of our knowledge. The proposed model, serving as a successful prediction tool, was developed based on data pertaining to 210 sewer and water replacement/rehabilitation projects from year 1999 to 2013 acquired from the City of San Diego, California, USA. The GP prediction model efficiently fulfills the conditions of different criteria considered for its external validation. The developed system offers an improved cost estimation model with higher accuracy with correlation coefficient of 0.8467 in comparison with the City of San Diego's published engineering estimates; however our model is an explicit formula also. Unlike engineering estimates, using such a simple formula opts out the need to go through expensive and lengthy cost estimation process on the conceptual stage of a project assessment. The GEP cost estimation formula gives a simple solution with fewer inputs. GEP model takes into account the qualitative productivity factors such as traffic, soil and existing pavement conditions. This model will lead to a more objective resource allocation for funding and decision making purposes and offers a more accurate cost baseline for both bidders and the City.

Nature of each project is unique and how to use several methods to simplify and accelerate the process of project evaluation depends on the team who are going to assess the project. It's worth mentioning that the purpose of this study was not comparing the soft computing methods and seeing which one outperforms the others. This research was simply performed to study various projects and circumstances; and attempted to propose applicable solutions depending on the conditions of each case study.

8.2 Recommendation

For those researchers who may be willing to know which soft computing method will outperform the others (in the same project with the same circumstances), it is recommended that they use ANN, GEP and regression models for each set of data to be able to compare the results and gauge accuracy of each model in comparison with the others.

For those researchers who are willing to further study applicability of undertaking BOT contracts, it is recommended to carry out economic analysis on each case study to determine the overall impact of the project on the entire society and see whether the BOT agreement is likely to increase the total net economic benefit of the society.

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