USING MONTE CARLO SIMULATION AND MULTI-AGENT SYSTEMS TO ESTIMATE FINANCIAL FEASIBILITY OF HEPP PROJECTS TENDERED ON A BOT BASIS: A CASE STUDY FROM TURKEY

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ABSTRACT

USING MONTE CARLO SIMULATION AND MULTI-AGENT SYSTEMS TO ESTIMATE FINANCIAL FEASIBILITY OF HEPP PROJECTS TENDERED ON A BOT BASIS: A CASE STUDY FROM TURKEY

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As a fast growing country, Turkey's energy demand has been increasing every year and new investments are needed in the renewable energy sector. Turkish government uses the Build-Operate-Transfer (BOT) model to realize urgent investments in the hydroelectric energy sector. Given the government's purchase guarantee of the generated electricity, hydroelectric power plant (HEPP) projects can be feasible options for investors. However, during the feasibility studies, risk factors stemming from the macro environment as well as project level risks should be considered. The objective of this thesis is to develop a methodology that can be used to predict the profitability of HEPP considering the risk factors. During the initial parts of this study, a checklist of risk factors has been prepared and Monte Carlo Simulation was proposed for risk analysis. However, another factor which is the "negotiation" between the broker and energy producer is important while estimating the energy price levels to be used during Monte Carlo Simulation. A Multi-Agent System (MAS) is proposed to be used in combination with the Monte Carlo Simulation for better estimation of energy prices and thus, profitability of an investment. Hence, in this thesis, a methodology to combine the risk assessment and negotiation process while determining the financial feasibility of HEPP projects is proposed. The methodology is tested on a real project. Expert judgement is used to compare the results of deterministic analysis, Monte Carlo Simulation and MAS integrated with Monte Carlo Simulation. Experts believe that MAS-enabled Monte Carlo Simulation gives more reliable results than the other two techniques. As a final remark, the results of the case study cannot be generalized, however the methodology offered in this thesis may be used for HEPP projects tendered on a BOT basis to predict financial feasibility considering risks and dynamics of the negotiation process.

Keywords: MAS, BOT, Monte Carlo Simulation, construction industry, energy

ÖZ

MONTE CARLO BENZETİMİ VE ÇOK ARACILI SİSTEM KULLANILARAK YAP-İŞLET-DEVRET MODELİ İLE İHALE EDİLEN HİDROELEKTRİK SANTRAL PROJELERİNİN FİNANSAL FİZİBİLİTE ANALİZİ: TÜRKİYE'DEN BİR VAKA ÇALIŞMASI

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Hızla gelişmekte olan bir ülke olarak Türkiye'nin enerji ihtiyacı her yıl artmakta ve dolayısıyla yeni yatırımlara gereksinim duyulmaktadır. Devletin, hidroelektrik santrallerinde üretilen elektriğe alım garantisi vermesiyle birlikte, hidroelektrik santraller yatırımcılar için uygun bir yatırım seçeneği haline gelmiştir. Fakat bu santraller için fizibilite çalışmaları yapılırken, çevresel koşullardan ve projeden kaynaklanan risk faktörlerinin de göz önünde bulundurulması gerekmektedir. Bu tezin amacı hidroelektrik santral projelerinin finansal fizibilitesini, risk faktörlerini de göz önünde bulundurarak hesaplayabilmek için bir yöntem geliştirmektir. Çalışmanın ilk kısmında hidroelektrik santralleri için risk faktörlerinin listesi hazırlanmış ve risk analizi Monte Carlo benzetimi kullanılarak yapılmıştır. Monte Carlo benzetiminde kullanılan enerji fiyatı, broker ile enerji üreticisi arasında geçen "pazarlık" sonucunda belirlenmektedir. Dolayısıyla enerji fiyatlarını daha gerçekçi olarak belirleyebilmek için broker ile enerji üreticisi arasında geçen pazarlık, Çok Aracılı Sistem (ÇAS) kullanılarak modellenmiş ve bu model Monte Carlo benzetimi ile birleştirilmiştir. Buradan hareketle, bu tez kapsamında HES projelerinin finansal fizibilitesini, risk faktörlerini de hesaba katarak belirleyen ve fizibilitenin içindeki enerji fiyatlarının pazarlık aşamasını birleştiren bir yöntem geliştirilmiş ve gerçek bir proje üzerinde denenmiştir. Deterministik, Monte Carlo benzetimi ve ÇAS entegre edilmiş Monte Carlo benzetimi sonuçlarını karşılaştırmak için uzman görüşlerine başvurulmuştur. Uzmanlar ÇAS entegre edilmiş Monte Carlo benzetiminin diğer iki yönteme göre daha gerçekçi sonuçlar verdiği görüşünü benimsemişlerdir. Sonuç olarak elde edilen gerçek proje sonuçları genellenemese de, bu tezde önerilen yöntemin Yap-İşlet-Devret sistemi ile ihale edilen HES projelerinin finansal fizibilitesinde, riskleri ve pazarlık aşamasını kapsayan bir yöntem olarak kullanımı önerilmektedir.

Anahtar Kelimeler: Çok Aracılı Sistem, Yap-İşlet-Devret, Monte Carlo benzetimi, inşaat sektörü, enerji

Dedicated to my family

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LIST OF ABBREVIATIONS

BOT	Build-Operate-Transfer
GDP	Gross Domestic Product
HEPP	Hydroelectric Power Plant
IEA	International Energy Agency
IT	Information Technology
JADE	Java Agent Development
MAS	Multi Agent System
MW	Megawatt
NPV	Net Present Value
PPP	Public Private Partnership

CHAPTER 1

INTRODUCTION

Energy is defined as the ability of an object or a system to perform work. It is one of the most important things for humanity and society. It is used in the home, at work, in hospitals and in every part of community life. Energy is also an important factor for the economic and social development of countries and is an indispensable factor for increasing the social welfare of a country.

With the rapidly increasing industrialization and population, the world's energy demands have also been increasing year by year. As a fast growing country, Turkey's energy demand has also been increasing each year. To produce energy, energy resources are required. There are two types of energy resources; non-renewable and renewable. Turkey is not a country rich in non-renewable energy sources. On the contrary, Turkey is a country rich in renewable energy sources such as sunlight, wind, and rain. In addition to this, compared to non-renewable energy, renewable energy is also cleaner and more environmentally conscious. The Turkish government leans towards renewable energy but does not have enough funds to invest in renewable energy power plants. Instead of constructing renewable power plants they have used a Built Operate Transfer (BOT) system for constructing renewable energy power plants. In a BOT system, the investments are made by the investors. The most important issue for the investors when deciding if to make an investment is the result of the cash flow analysis of the power plant. According to the targeted renewable power plant capacity that was announced by the Turkish government, until 2023 hydroelectric power plants will have the highest proportion of all of the renewable power plants. This thesis is about hydroelectric power plant projects carried out by the BOT model in Turkey.

Since 2005, there have been 575 hydroelectric power plant projects amounting to 6.5 billion USD tendered on a BOT basis in Turkey. The underlying idea of this thesis is that in developing countries like Turkey, hydroelectric power plant investments can be profitable investment alternatives for contractors, however risks should be analyzed and probabilistic assessments should be carried out considering the scenarios associated with the energy market. As a researcher, I observed the dynamics and trends in the Turkish energy market and found out that the general practices of feasibility studies are far from being realistic. The main motivation for this study has been that feasibility studies for hydroelectric power plant investments should take into account of the risk scenarios as well as the negotiations between the parties about the selling price of electricity. Although Turkish government gives a price guarantee in BOT projects, feasibility studies that consider the energy price as such would be misleading as the price of electricity in practice is determined by the prevailing market conditions. This thesis has been organized as follows:

Chapter 2 summarizes the energy system in Turkey concentrating on the major players in the energy system. In Chapter 3, the factors affecting the feasibility of a hydroelectric power plant are discussed and the cash flow parameters for a hydroelectric power plant investment are explained in detail. A case study is discussed and an example feasibility study has been conducted to demonstrate the parameters that are used in the cash flow analysis. In the cash flow analysis, the net present value of the project is calculated for a base case scenario. It is clear that to obtain more realistic results for the NPV, various scenarios, the energy price should be considered and risk factors determined. Monte Carlo Simulation is a stochastic risk analysis method that can be used to incorporate results of different scenarios during decision-making. After defining the risk factors associated with hydroelectric power plant project investments, Chapter 4 demonstrates how Monte Carlo Simulation can be carried out in practice. The results are discussed and the sensitivity of feasibility (NPV) to different factors is investigated. The selling price of the energy which is determined as a result of the negotiation process between the investor and the broker is the most critical parameter during the feasibility analysis. The Monte Carlo Simulation cannot, however, take into account the complex nature of energy price estimates as it cannot simulate the “negotiation process”. It is clear that as the probability distribution of the selling price of energy does not reflect the real conditions, a better approach is needed to take into account the variations in energy price during the cash flow analysis. In Chapter 5, it is suggested that a Multi Agent System can be used to model the negotiation process between the investor and the broker to make a realistic energy price prediction. The negotiation process is modeled in a Java Development (JADE) framework by using Java Development Language and the Zeuthen Strategy is used as the negotiation strategy. The selling price of energy for each scenario is obtained as a result of the MAS simulation. By using these values a more realistic probabilistic assessment can be made for the NPV of a hydroelectric power plant investment. Within the context of Chapter 6, the conclusions are reported as well as the recommendations for future research.

CHAPTER 2

ENERGY SECTOR

2.1 Energy Sector in Turkey

Energy is one of the indispensable things for people and society. As a result energy demand is a serious matter for governments. There are two main factors that determine the country's energy demand; Gross Domestic Product (GDP) and population. Gross Domestic Product is the total value of provided services and produced goods in a country in a year.

Turkey has $786 billion GDP, has the 6th largest economy in Europe, and also has the 17th largest economy in the world. Due to economic development in the last 10 years, Turkey has one of the fastest growing energy sectors in the world.

According to the International Energy Agency (IEA) (World Energy Outlook 2007 Publication), the energy demand in the world increased 48% between 1990 and 2010. And also it is expected that the global energy demand will increase dramatically until 2030. In Figure 2.1, the projected growth in global energy demand is shown.

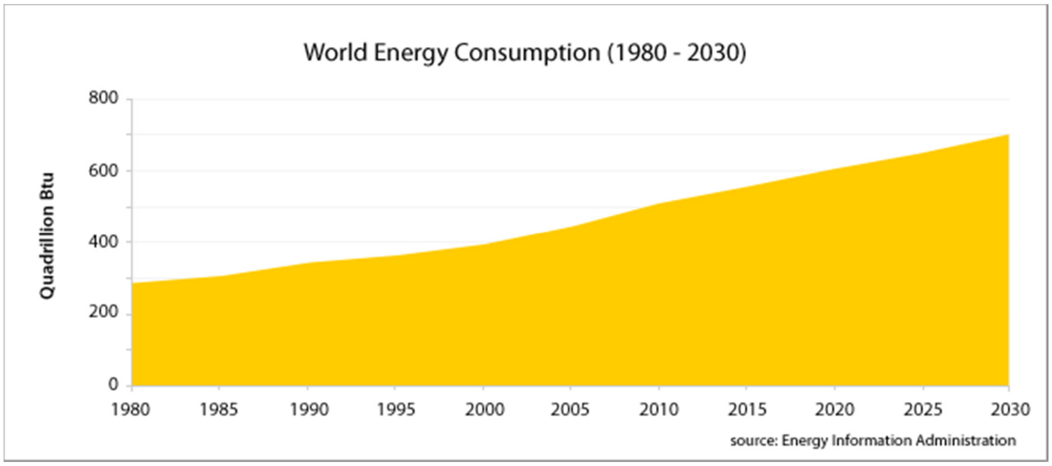

Figure 2.1: Projected Growth in Global Energy Demand

As a fast growing country, Turkey has also increased energy demand. It was announced by the Economist Intelligence Unit that Turkey's energy demand will have increased by an annual rate of 4.5% in 2015. In the light of this information, it is clear that Turkey needs to find resources in order to supply the increasing energy demand.

As shown in Figure 2.2, there are two alternative methods to produce energy. The first uses non-renewable energy resources. The main non-renewable energy resources are coal, natural gas, petroleum and nuclear energy. The second alternative is to use renewable energy resources. The main renewable energy resources are wind, sunlight, biological materials, geothermal heat and rain.

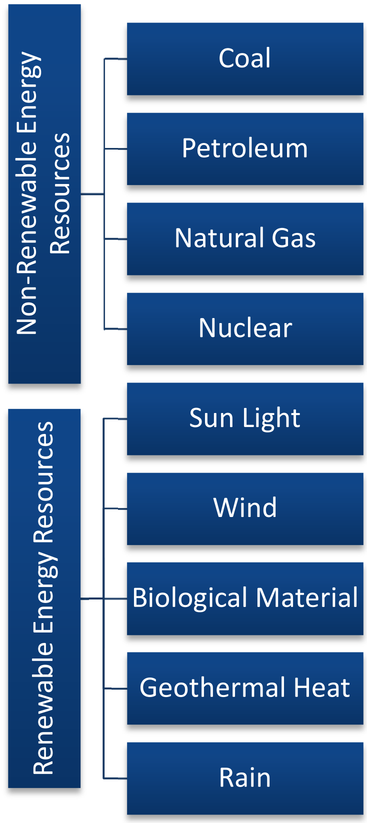

Figure 2.2: Non-Renewable and Renewable Energy Resources

Turkey is not a rich country in terms of non-renewable energy resources. As Topal and Arslan (2008) stated, Turkey has a 72.6% dependence on foreign countries for non-renewable energy resources. As an alternative to non-renewable energy resources, Turkey is a rich country in terms of renewable energy resources. It is reasonable therefore for Turkey to give more significance to renewable energy.

Turkey is a developing country and does not have sufficient funds to construct new renewable power plants. Like other developing countries, the Turkish government uses a Build-Operate-Transfer (BOT) system to increase the number of renewable power plants. In a BOT system, investors make the investment with their own resources or with bank credit and then make loan repayments by selling the energy.

By providing some conveniences in the construction stage and by giving a guaranteed price for the produced energy, the Turkish government has also encouraged investors to make investments in renewable energy power plants.

In Turkey, there are 5 alternatives for the investors who are considering investments into renewable energy power plants. These alternatives are explained in detail below.

2.1.1 Wind energy

Wind power plants are used to produce energy from the wind. The main portion of the wind power plants is the wind turbine (shown in Figure 2.3). The motion in the airflow rotates the wind turbine's blades and this rotation produces electricity with the help of the wind turbine's generator. Depending on the technology, the capacity of the turbine can change from 1 MW up to 6 MW.

Figure 2.3: Wind Turbines

Turkey has approximately 2013 MW installed wind power capacity. In recent years, as a consequence of the government's encouragement of investors towards renewable energy investments, the number of wind power plants has dramatically increased. In Figure 2.4, the total capacity of installed wind power plants in Turkey for each year is shown. The dramatic increase in the installed wind power capacity in the last 5 years can be easily seen.

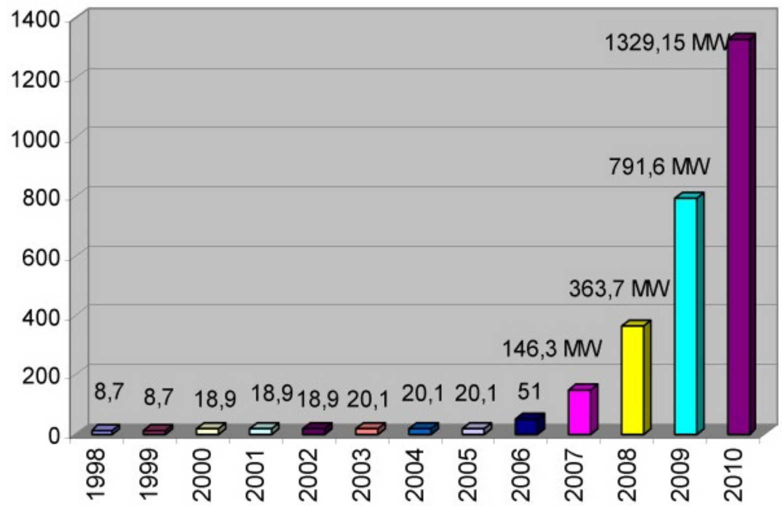

Figure 2.4: The Total Capacity for the Installed Wind Power Plants (MW)

The amount of produced energy in the wind power plants depends on the wind capacity and speed of wind at the location. In Figure 2.5, the distribution of installed wind power plant capacity for each city is shown. The coastal cities in the Aegean region form a substantial part of installed wind power capacity in Turkey. The Turkish government announced its target for installed wind power capacity as 20,000 MW by 2023.

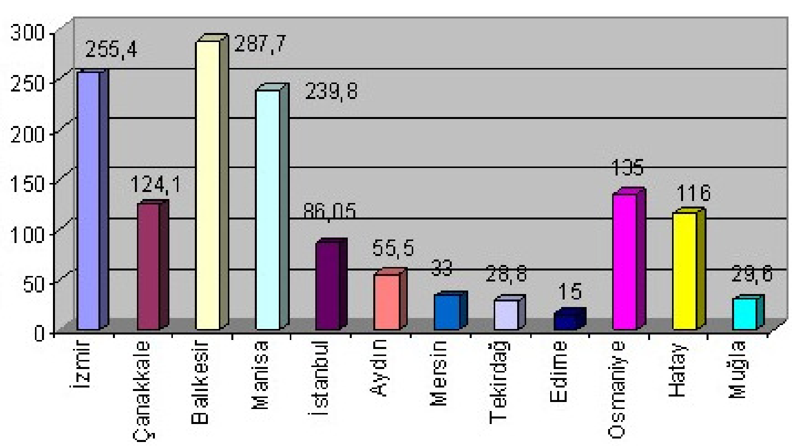

Figure 2.5: The Distribution of Installed Wind Power Plant Capacity (MW)

2.1.2 Solar energy

In a solar power plant, the energy is produced with the help of solar panels. An example of a solar panel installation is shown in Figure 2.6. In the solar power plant, the amount of produced energy depends on the amount of sun light. Turkey has a high potential for sunlight, so it is reasonable to set up solar power plants in Turkey. Despite having such a high potential for the solar energy, up to now, Turkey has only 34 MW of installed solar power capacity. This installed capacity is very small and needs to be increased. The Turkish government encourages investors to set up solar power plants by increasing the buying price of the energy. The Turkish government‘s target is to increase the installed solar power plant capacity to 600 MW by 2023.

Figure 2.6: Solar Panels

2.1.3 Biomass energy

In a biomass power plant, the mass energy of crops and residues are used to produce energy. The energy emerges with the combustion of crops and residues. These crops and residues can be agricultural crops and residues, sewage, forestry crops and residues, industrial residues, animal residues, municipal solid waste. Like the other renewable energy resources, the number of biomass power plants in Turkey has been increasing in recent years. The installed biomass power plant capacity in Turkey is 237

MW. The aim of The Turkish Government is to increase this number to 1500 MW by 2023.

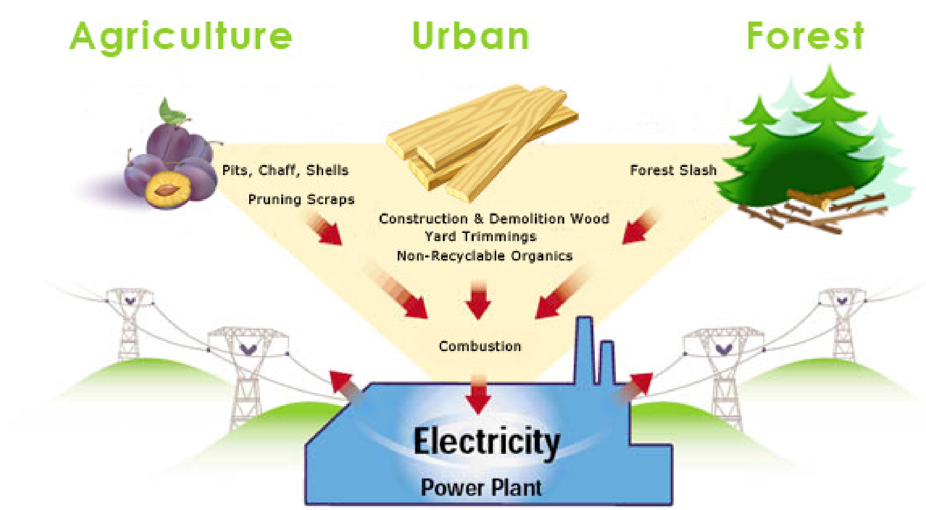

Figure 2.7: Illustration of Energy Production in Biomass Power Plant

2.1.4 Geothermal energy

In a geothermal power plant, energy is produced by using the internal heat of the earth. As shown in Figure 2.8, the steam and hot water come to the surface with the help of a production well. The steam rotates the turbine. With the rotation of the turbine, mechanical energy is produced and the generator converts this mechanical energy into electrical energy. Then steam and hot water enter the cooling tower. After the cooling process, then cold water is pumped deep underground by using an injection well. In Turkey, the installed geothermal electric capacity is currently 92 MW. The Turkish government's aim is to increase the installed geothermal power plant capacity to 600 MW by 2023.

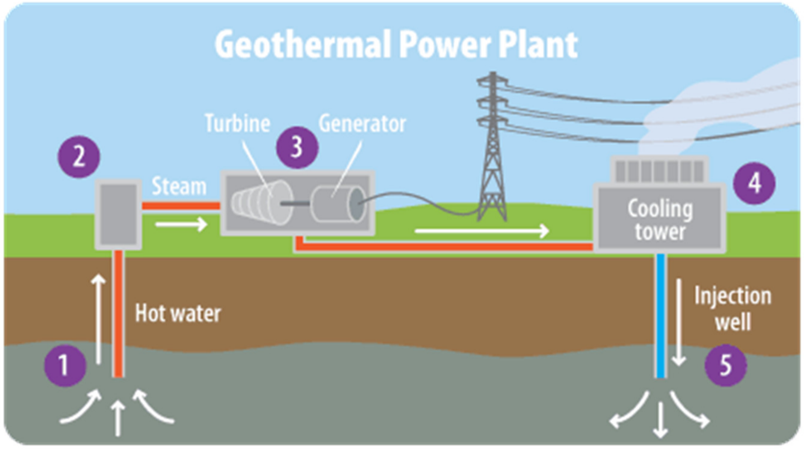

Figure 2.8: Illustration of Energy Production in Geothermal Power Plant

2.1.5 Hydroelectric energy

Hydroelectric power plants convert the energy of flowing water into electrical energy. The amount of energy in the water depends on flow rate and falling rate of the water. There are two types of hydroelectric power plants. The first one is a dam style hydroelectric power plant and the second is the run-of-the-river hydroelectric power plants. To produce energy in hydroelectric power plants, reservoirs are used to accumulate the water. The run-of-the-river hydroelectric power plants have no reservoir. Instead of reservoirs, regulators are used. The water is carried to the turbines with the help of penstock. The water which is coming from penstock rotates the turbines. This rotation produces mechanical energy. The turbines are connected to the generator. The generator converts mechanical energy to electrical energy as shown in Figure 2.9.

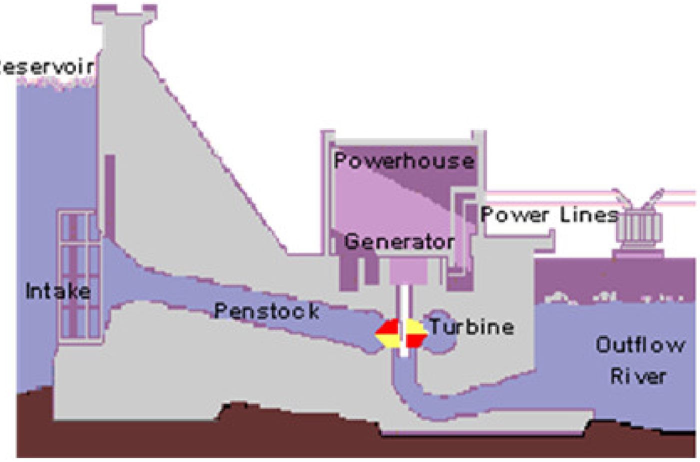

Figure 2.9: Illustration of Energy Production in Hydroelectric Power Plant

Turkey has a high potential for hydroelectric energy but this potential was not evaluated sufficiently until 2000. After 2000, with the growth of the economy, the installed hydroelectric power plant capacity in Turkey has been dramatically increased (shown in Figure 2.10). Now, there are lots of hydroelectric power plants in operation and the total capacity of these hydroelectric power plants is 17372 MW. The Turkish government's target is to increase the installed hydroelectric capacity to 36000 MW by 2023.

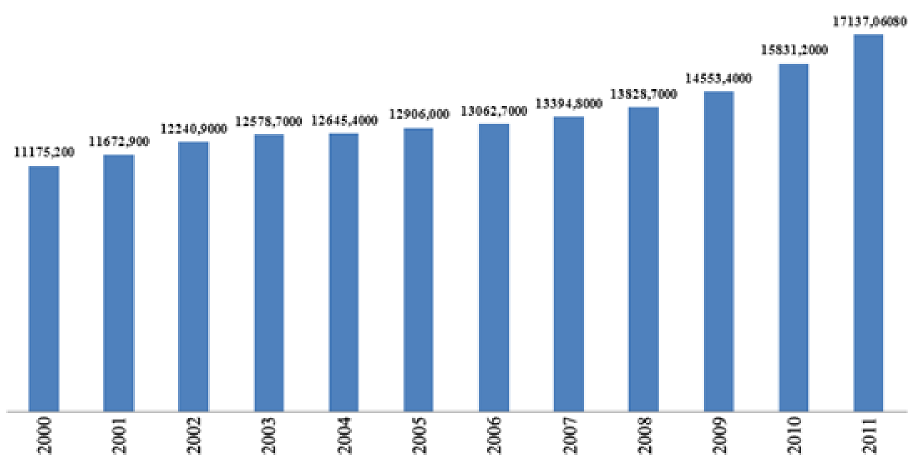

Figure 2.10: Total Installed Hydroelectric Power Plant Capacity Year By Year (MW)

As a summary, when the targeted power plant capacities up to 2023 (shown in Table 2.1) are compared, it can easily be seen that hydroelectric power plants have the highest percentage.

Table 2.1: Available and Targeted Capacity for Each Renewable Energy (Ministry of Energy and Natural Resources)

	Available Capacity (MW)	Targeted Capacity (MW) (Until 2023)
Wind Energy	2013	20000
Solar Energy	34	600
Biomass Energy	237	1500
Geothermal Energy	92	600
Hydroelectric Energy	17372	36000

Since hydroelectric power plants have the highest targeted capacity, in this research, the focus is directed to such investments.

2.2 Hydroelectric Power Plant Investments

When the investors begin to consider a hydroelectric power plant investment, they have two important questions in their mind;

1) What is the total cost of the hydroelectric power plant?
2) What is the total income expected from the hydroelectric power plant?

The main purpose of this thesis is to propose a methodology to estimate costs and expected incomes from a HEPP Project tendered on a BOT basis considering the demand and supply conditions prevailing in the energy market. Chapter 3 will demonstrate the steps of the feasibility study. Chapters 4 and 5 will propose different methods, namely the Monte Carlo Simulation and Multi Agent Systems, to tackle the impact of the “risks” and the “negotiation process between related parties” on the feasibility of the project, respectively.

CHAPTER 3

FEASIBILITY OF HYDROELECTRIC POWER PLANTS ON A BOT BASIS

In this part of the thesis, the feasibility study of hydroelectric power plant projects is explained and considered. In Turkey, the hydroelectric power plant projects are performed using a BOT system which is a form of Public Private Partnership (PPP). Public Private Partnerships are the contractual agreements between the public agency and private sector entity for financing, designing, implementing and operating infrastructure facilities provided by the government. There are several forms of PPP such as Design-Bid-Build, Private Contract Fee Services, Design Build, Build-Operate-Transfer, Long Term Lease Agreements, Design-Build-Finance-Operate and Build-Own-Operate. The BOT system is especially useful in developing countries where governments cannot finance infrastructure projects due to lack of funds. In the BOT system, the private sector provides an investment by providing design, construction, financing, operation and maintenance during the concession period in order to meet the public agency's requirement. At the end of the contract period, the investment transfers to the public agency.

3.1 BOT Model

In a BOT system, there are two main parties: the investor and the government. The investor finances, designs, builds, operates and maintains the facility, and then transfers it to the government at the end of the concession period (Zayed and Chang, 2002). The government is the owner of the facility. Before starting the project the government determines the specifications of the project according to its needs.

The BOT model was first introduced into Turkey in 1984 by the ex-prime minister of Turkey Turgut Özal, to solve the energy crisis of Turkey (Ozdoğan and Birgonul, 2000). However, this system was not initially successful. The investors hesitated in committing to this system because of the inadequacy of legal security. After 2000, with the growth of the economy, the government guaranteed the legal basis for a BOT system and as a result of this, investors started to invest in the system.

By making the electricity law 4628 in 2001, the government provided the legal basis for investors to produce and sell energy into the energy market. In 2005, the government made the renewable energy law 5346 which guarantees the purchase of energy from the investors. By making these laws, the government encouraged the investors to invest in renewable power plants using the BOT system. As Turkey has a high potential for hydroelectric energy, the hydroelectric power plants constitute a substantial proportion of these investments.

Wang et al. (2000) identified the risk factors for BOT projects in China. Mane and Pimplikar (2013) investigated the critical risk factors for BOT projects in India. Schaufelberger (2005) specified risk factors for Asian BOT projects and also developed risk management framework. Askar and Gab-Allah (2002) investigated the risk factors for BOT projects in Egypt. Al-Azemi et al. (2014) identified 28 risk factors for BOT projects in Kuwait. For BOT projects, it is very important to identify the risk factors and make good feasibility study from the very beginning of the project.

3.2 Feasibility Study for Hydroelectric Power Plants

In general, feasibility means the assessment of a situation before making an investment. It does not have to be an investment in a new facility. It can be the widening or the renovation of the existing facility. During a feasibility study, the time and amount of all the expenditures and all the revenues related to the investment are determined. By using cash flow analysis, the net profit or loss is determined. So with the help of cash flow analysis, the investor can decide whether to invest or not.

A feasibility study relating to hydroelectric power plants also uses a similar process. First of all, the parameters that affect the feasibility of a hydroelectric power plant are determined. Then the values of these parameters are determined by using necessary calculations. After this process, the cash flow elements are located in the cash flow. Finally by using the interest rate and the cash flow elements, the net profit or loss is identified. All of the parameters are explained below. For a clearer explanation, the parameters are grouped in two main titles as total income and total cost. An example of a cash flow diagram for a hydroelectric power plant project is shown in Figure 3.1.

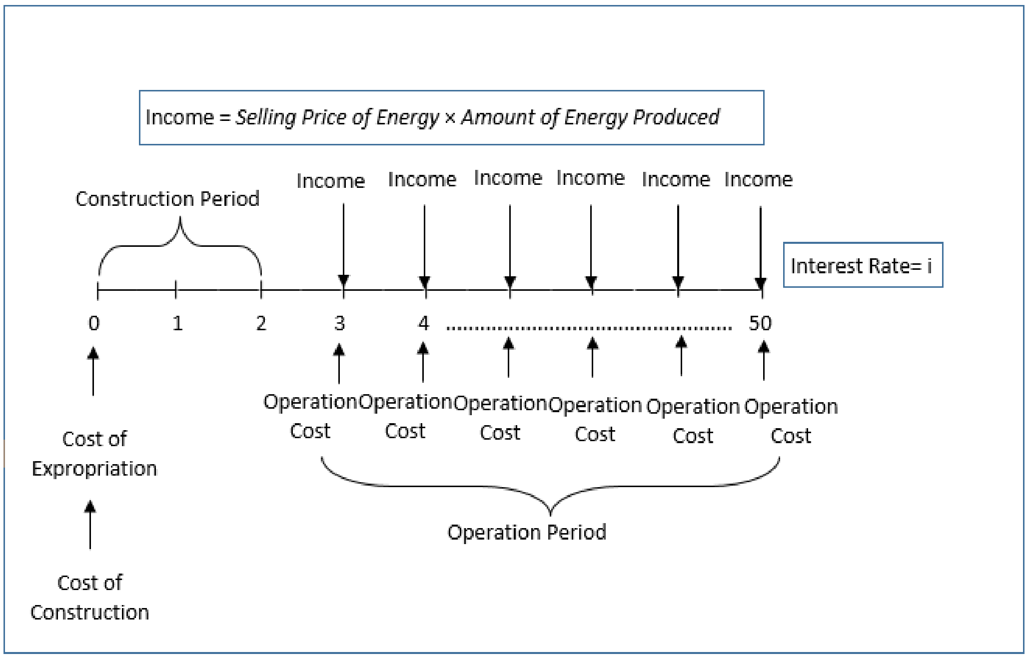

Figure 3.1: An Example of a Cash Flow Diagram for a Hydroelectric Power Plant

3.2.1 Total income

There are six main parameters used to determine the value of Total Income. These parameters also have some sub parameters. All the parameters and their sub parameters are shown in Figure 3.5, and are explained in detail below.

3.2.1.1 Selling price of energy

Shows the price that the investor sells the produced energy. Its unit is cent over kilowatt-hour (¢/kWh). The government gives the investor a price guarantee for the energy produced. So in the cash flow analysis of an investment, the investor uses this guaranteed price instead of the selling price of energy.

3.2.1.2 Amount of produced energy

Indicates the produced energy. This depends on the installed power capacity which is the function of the coefficient of system productivity, head difference and equivalence flow rate. The coefficient of system productivity is the ratio of produced energy over consumed energy. The head difference is the difference of water level. It is determined by total head and head loss. Total head is the fluids energy per unit weight. Head loss is the drop of the total head. The value of head loss depends on the friction coefficient of penstock (an example of penstock is shown in Figure 3.2), length of the penstock, flow rate, incline of channel (an example of a channel is shown in Figure 3.3), length of channel, friction coefficient of tunnel, radius of tunnel (an example of a tunnel is shown in Figure 3.4), velocity of water in the tunnel and the radius of the penstock.

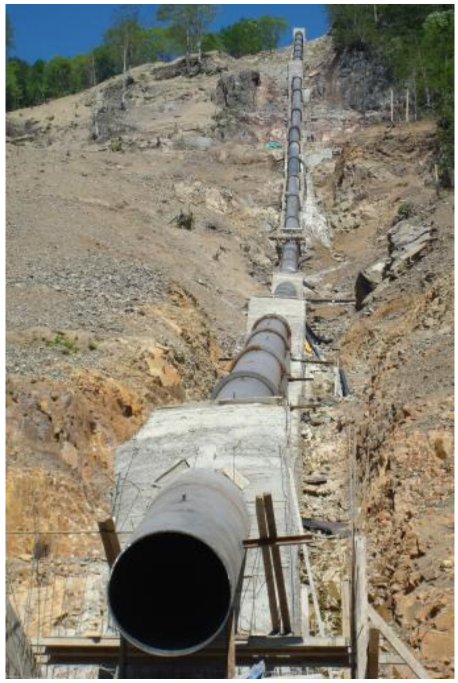

Figure 3.2: An Example of a Penstock

Furthermore, the radius of the penstock is designed according to the velocity of water in the penstock and flow rate. Another factor which determines the installed power is equivalence flow rate. Equivalence flow rate is determined by flow rate and percent of flow rate consistency. Flow rate is determined by using past data about it and the percentage of flow rate consistency is determined by using past data about it.

Figure 3.3: An Example of a Channel

3.2.1.3 System economic life

This is the period that the system works efficiently. In the feasibility process; the system economic life is extremely important because the period of cash flow is determined according to this economic life.

3.2.1.4 Interest rate

There are many costs and income components which exist in different years in the cash flow. To find the net profit/loss, it is necessary to get these components into the same time period. The interest rate is used in the calculation by carrying the components which have been in different time zones in the cash flow.

3.2.1.5 Construction period

This is the time period in which the hydroelectric power plant is constructed by the investor. In the cash flow analysis, all cost items related to construction of the hydroelectric power plant are shown in this period.

3.2.1.6 Operation period

This is the time period that starts when the construction of the hydroelectric power plant is finished. The duration is until the end of the system economic life. In this time period, the investor sells the produced energy which is generated.

Figure 3.4: An Example of a Tunnel

Figure 3.5 summarizes the income parameters to be used during cash flow analysis.

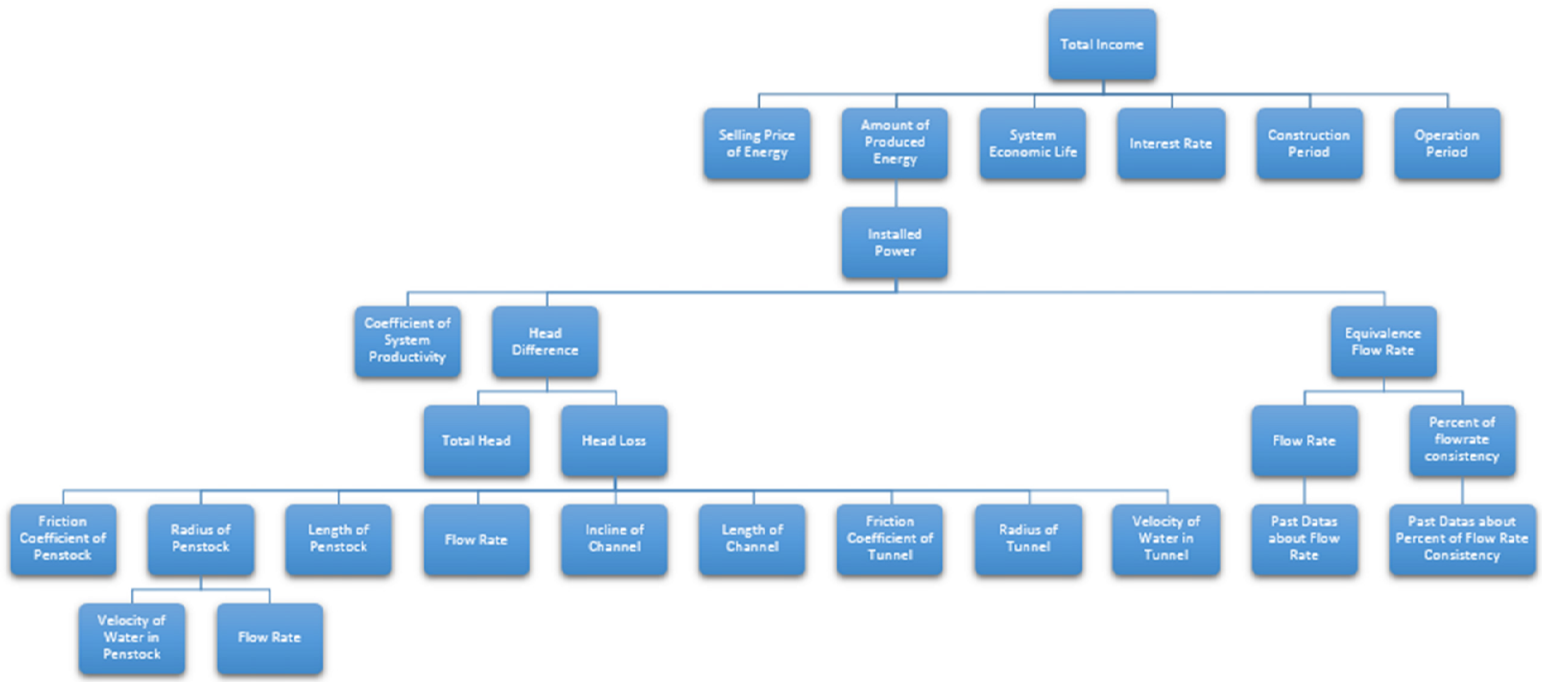

Figure 3.5: Total Income Parameters in the Cash Flow

3.2.2 Total cost

There are twelve main parameters used to determine the value of the total cost. In these twelve parameters, the interest rate, system economic life, construction period and operation period are the common parameters with total income. These four parameters are used under the heading of total income so they are not included in total cost. The other eight parameters and their sub parameters are explained in detail below.

3.2.2.1 Cost of weir

The weir is a barrier which slows down but does not stop the flow that comes from the channel in the Hydroelectric Power Plant. In general, there are four types of weir: rectangular, triangular, trapezoidal and broad-crested weir. An example of a weir is shown in Figure 3.6.

Figure 3.6: An Example of a Weir

3.2.2.2 Cost of turbine and generator

A turbine is a machine that converts the rotational energy of fluid into kinetic energy. The water flows into the turbine and rotates the turbine's blades. With the rotation of the turbine's blades, the turbine generator shaft rotates. A generator is a machine that produces electricity. By using the rotation of the turbine generator shaft, the generator turns and creates electricity. The electricity production process in a generator with the help of the turbine is shown in Figure 3.7. The cost of a turbine and generator depends on the capacity of installed power.

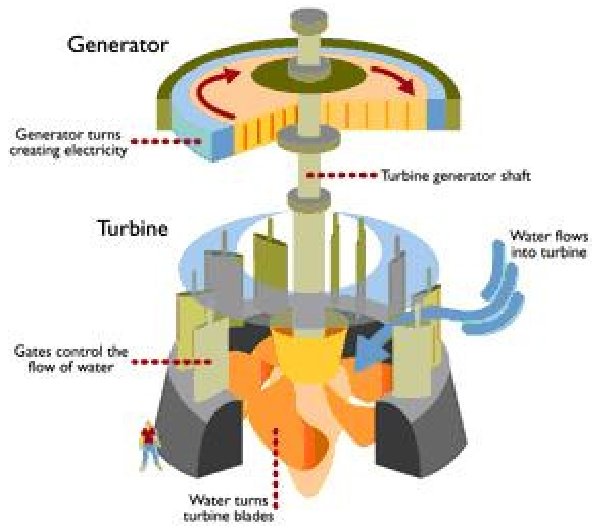

Figure 3.7: The Electricity Production Process

3.2.2.3 Cost of penstock

In a hydroelectric power plant, a penstock is laid to carry water from high elevations to low elevations. The cost of a penstock depends on the length, radius and thickness of the penstock and the radius and length of the tunnel.

3.2.2.4 Cost of power transmission line

Power transmission lines help transmit the produced energy in the hydroelectric power plant. The cost of power transmission lines depends on the length of the power transmission line. An example of a power transmission line is shown in Figure 3.8.

Figure 3.8: An Example of a Power Transmission Line

3.2.2.5 Cost of excavation

At the beginning of the hydroelectric power plant construction, there are some irregularities in the construction area. The surveyors determine the level of structures according to the project then the necessary areas are excavated. In brief, the cost of excavation is the cost for excavating the waste materials and it depends on the volume of the excavated area.

3.2.2.6 Cost of concrete and reinforcement

This parameter shows the cost for concrete works and reinforcement in the construction of the hydroelectric power plant.

3.2.2.7 Cost of expropriation

Expropriation is appropriating a private ownership of real estate, which is required for public benefit, by paying the actual value of the real estate. Before starting the construction of a hydroelectric power plant, the investor has to pay for the cost of the construction area and expropriate it.

3.2.2.8 Cost of operation

In the operation period of a typical hydroelectric power plant, qualified and non-qualified people are required to operate the plant. Also turbines, generators and other elements of hydroelectric power plants need annual maintenance. The cost of operation is the sum of costs of maintenance and employees for operating the power plant.

All the parameters and sub parameters of total cost are shown in Figure 3.9.

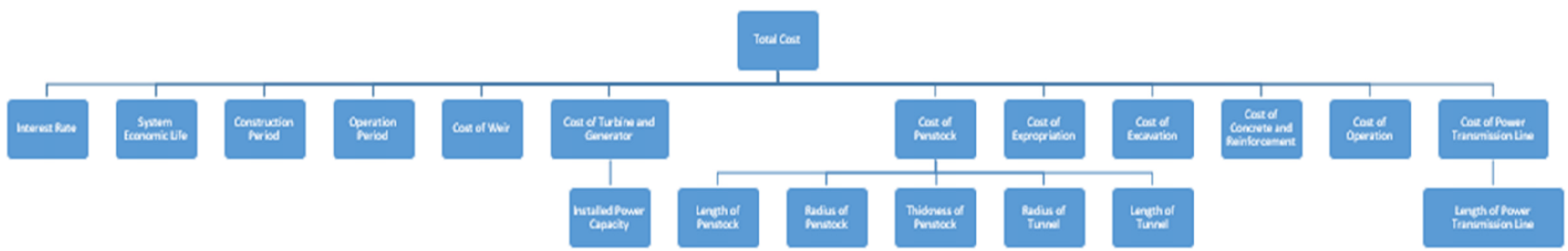

Figure 3.9: Total Cost Parameters in the Cash Flow

3.3 Cash flow Analysis of a Hydroelectric Power Plant: A Case Study

The case study was conducted using a hydroelectric power plant located in the black sea region of Turkey. As a result of the pre-feasibility studies, the capacity of the hydroelectric power plant was found to be 30 MW. The hydroelectric power plant has four successive parts and each part has 7.5 MW capacity. The yearly working hours of this hydroelectric power plant was found to be 3000 hours according to the feasibility studies.

The calculation of parameters as discussed in the previous areas of this thesis will be demonstrated using the data of this case study project. Firstly, the parameters used to determine the value of total income are considered, then the parameters are used to determine the value of total cost. Finally a cash flow analysis is performed and total income or loss is found.

3.3.1 Total income

3.3.1.1 Selling price of energy

In Turkey, as of May 10th 2005, the government gave a price guarantee of 6 dollar cent for one kilowatt-hour energy. In the cash flow analysis, this is the price used.

Energy Price ➔ ***6 ¢/kWh***

3.3.1.2 Amount of produced energy

The installed capacity of the hydroelectric power plant is 30 MW.

Amount of produced energy for one hour ➔ 30 MW.h

Yearly working time of power plant ➔ 3000 hours

Amount of produced energy for one year ➔ 30 MW × 3000 hours = 90.000 MW.h

Amount of produced energy for one year ➔ ***90.000.000* kW.h**

3.3.1.3 System economic life

For this hydroelectric power plant:

System economic life ➔ ***50 years***

3.3.1.4 Interest rate

According to Central Bank in Turkey:

The interest rate ➔ ***9.5 % / year***

3.3.1.5 Construction period

For this project the construction period is calculated as ***1 year***.

3.3.1.6 Operation period

System economic life is 50 years and construction period is 1 year,

So operation period is ***49 years***.

3.3.2 Total cost

3.3.2.1 Cost of weir

According to the project of this hydroelectric power plant:

The cost of weir ➔ ***<u>3.000.000 $</u>***

3.3.2.2 Cost of turbine and generator

<u>For 1 MW installed power plant:</u>

The total cost of turbine and generator ➔ 350.000 $

<u>For 30 MW installed power plant:</u>

The total cost of turbine and generator ➔ 350.000 $ × 30 = ***<u>10.500.000 $</u>***

3.3.2.3 Cost of penstock

<u>According to the design data of the penstock:</u>

The length of penstock ➔ 100 meters

Radius of penstock ➔ 4.88 meters

The wall thickness of penstock ➔ 0.0342 meters

<u>The volume of penstock for 100 meter length:</u>

$$= \pi \times \frac{(4{,}88 + (2 \times 0{,}0342))^2 - 4{,}88^2}{4} \times 100 = 53 \text{ m}^3$$

1 m^3 steel ➔ 7850 kg

53 m^3 steel ➔ 416.050 kg

Cost of 1 kg steel ➔ 2 $

Cost of 416.050 kg steel ➔ ***832.100 $***

3.3.2.4 Cost of power transmission line

The total length of power transmission line is 20 km.

For 1 km Power Transmission Line:

The cost of a Power Transmission Line ➔ 50.000 $

For 20 km Power Transmission Line:

The cost of a Power Transmission Line ➔ 50.000 $ × 20 = ***1.000.000 $***

3.3.2.5 Cost of excavation

The total excavation volume is 90.000 m^3.

For 1 m^3 excavation:

The cost of excavation ➔ 4 $ / m^3

For 90.000 m^3 excavation:

The cost of excavation ➔ 4 \$ × 90.000 = ***<u>360.000 $</u>***

3.3.2.6 Cost of concrete and reinforcement

The total concrete volume is 25.000 m^3.

<u>For 1 m^3 concrete:</u>

The cost of concrete and reinforcement ➔ 175 $

<u>For 25.000 m^3 concrete:</u>

The cost of concrete and reinforcement ➔ 175 \$ × 25.000 = ***<u>4.375.000 $</u>***

3.3.2.7 Cost of expropriation

The cost of expropriation for one m^2 area is 2 Dollars. The total area for expropriation is 150 000 m^2, the total cost for expropriation is:

<u>For 1 m^2 expropriation:</u>

The cost of expropriation ➔ 2 \$ / m^3

<u>For 150.000 m^2 expropriation:</u>

The cost of expropriation ➔ 2 \$ × 150.000 m^2 = ***<u>300.000 $</u>***

3.3.2.8 Cost of operation

<u>For 1 month</u>

Employees' salary ➔ 23.000 $ / month

Maintenance cost ➔5.000 $ / month

Total cost of operation ➔ 23.000 $ + 5.000 $ = 28.000 $ / month

For 1 year

Employees' salary ➔ 23000 $ × 12 = 276.000 $ / year

Maintenance cost ➔5000 $ × 12 = 60.000 $ / year

Total cost of operation ➔ 276.000 $ + 60.000 $ = ***336.000 $ / year***

3.3.3 Cash flow analysis

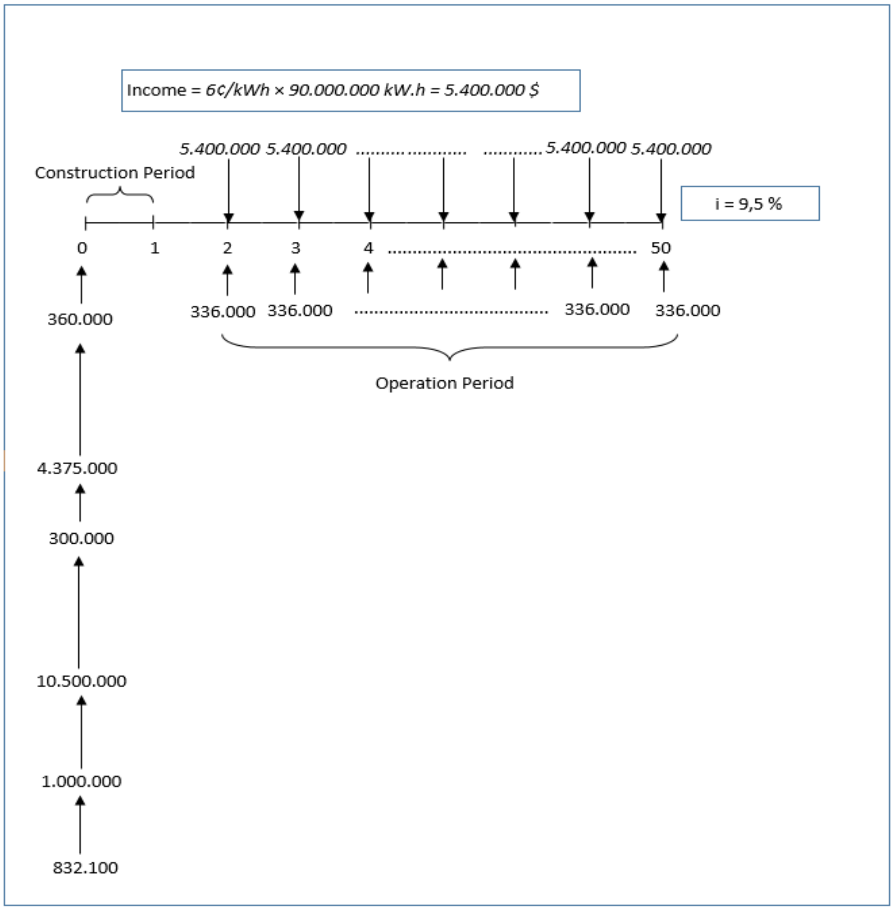

Figure 3.10: Cash Flow Diagram for the Case Study

The cash flow diagram for the case study is shown in Figure 3.10. According to the cash flow analysis, the net present value (NPV) is:

= **<u>27.845.376.65 $</u>**

3.4 Defining the Risk Factors for Hydroelectric Power Plants

In the cash flow analysis above, all of the parameters are calculated using "best estimates" considering the most likely scenario. But in real life there are risk factors and various possible scenarios that may affect the values of the parameters and results.

There are various definitions about the risk in the literature. PMBOK (2011) defines risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective such as time, cost, span or quality". Smith (1999) also describes risk as "a decision expressed by a range or possible outcome with attached probabilities." Al Bahar and Crandall (1990) explain risk as "the exposure to the chance of occurrences of events adversely or favorably affecting project objectives as a consequence of uncertainty".

In this part of the chapter, first the risk factors that affect these parameters are determined and then the impact of the risk factors for each parameter is determined. The methodology used during a risk assessment is shown in Figure 3.11.

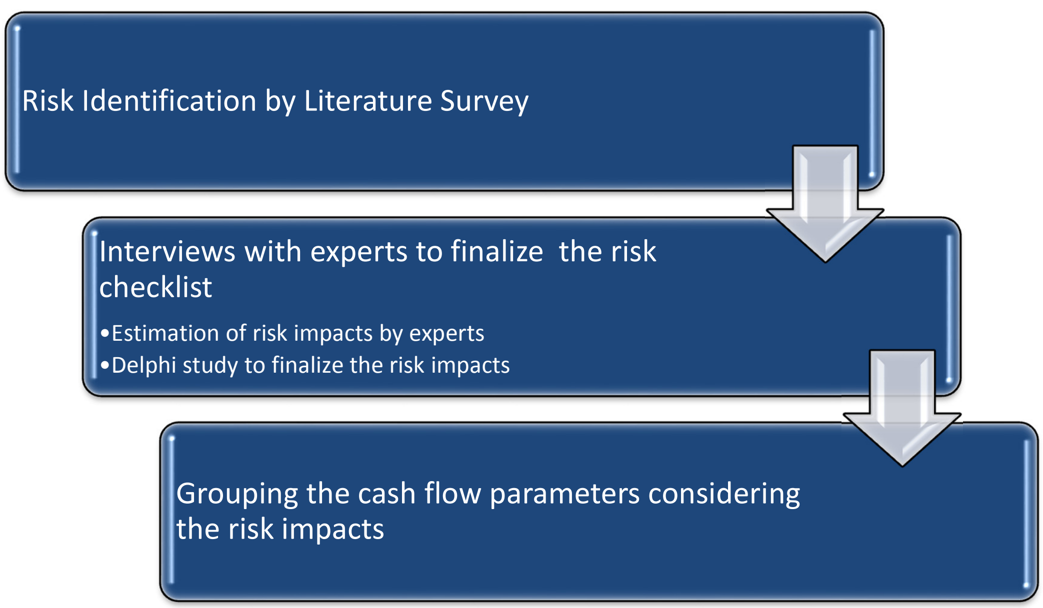

Figure 3.11: The Methodology Used During a Risk Assessment

Step 1: Literature survey

To determine the risk factors for the hydroelectric power plant projects, firstly an extensive literature review was carried out relating to the risk factors of Public Private Partnership (PPP) projects. This literature review, based on the works of; Abedgeno and Ogunlana (2006), Ibrahim et al. (2006), Li et al. (2005), Ng and Loosemore (2007), Shen et al. (2006), Singh and Kalidindi (2006), Wibowo and Mohamed (2010), Xiao and Zhang (2011), Yelin et al. (2009), Yongjian et al. (2009), Yuan et al. (2008), Zhang (2005), Xenidis and Angelides (2005), Karim (2011), all of the risk factors for Public Private Partnership (PPP) projects are listed. The risk factors found as a result of the literature review are listed in Tables 3.1 and 3.2. In total 30 risk factors were determined. These risk factors are clustered as external risk factors and technical risk factors. There are 20 external and 10 technical risk factors which are shown in Table 3.1 and 3.2.

Table 3.1: External Risk Factors

EXTERNAL RISK FACTORS
External Risk Factor-1. Change in law
External Risk Factor-2. Delay in project approvals and permits
External Risk Factor-3. Delay in expropriation /nationalization of assets
External Risk Factor-4. Change in government
External Risk Factor-5. Unavailability of material during construction
External Risk Factor-6. Unavailability of labor during construction
External Risk Factor-7. Unavailability of finance
External Risk Factor-8. Insolvency of subcontractors and suppliers
External Risk Factor-9. Change in tax regulations
External Risk Factor-10. Import restrictions
External Risk Factor-11. Inflation rate volatility
External Risk Factor-12. Changes in foreign exchange rates and inconvertibility
External Risk Factor-13. Adverse change in financial markets
External Risk Factor-14. Change in tariff rates by the government
External Risk Factor-15. Change in energy market demand
External Risk Factor-16. Public opposition to project
External Risk Factor-17. Change in interest rates
External Risk Factor-18. Force majeure risk
External Risk Factor-19. Unfavorable weather conditions during construction
External Risk Factor-20. Low flow rate during the operation period

Table 3.2: Technical Risk Factors

TECHNICAL RISK FACTORS
Technical Risk Factor-1. Problems with design
Technical Risk Factor-2. Delay of construction
Technical Risk Factor-3. Vagueness of geotechnical conditions
Technical Risk Factor-4. Poor quality of construction (rework)
Technical Risk Factor-5. Change of scope (increase/decrease in quantities)
Technical Risk Factor-6. Technical problems during operation
Technical Risk Factor-7. Technical problems (related with construction method etc.) during construction
Technical Risk Factor-8. Organization and coordination risk
Technical Risk Factor-9. Third party delays (suppliers, subcontractors etc.)
Technical Risk Factor-10. Accidents

Step 2: Interviews with experts

After determining the risk factors, their impacts on the HEPP Project should be quantified. Quantification should be based on the "impact" of the risk factors on the cash flow parameters.

To find the impact of the risk factors, a questionnaire is prepared. The five experts are named as Expert-1, Expert-2, Expert-3, Expert-4 and Expert-5. The detailed information about these experts are given below.

Expert-1 is an experienced civil engineer. He is an owner of a well-known construction company in Turkey. Four hydroelectric power plants were constructed by his company and now they are in operation. He knows all the steps relating to the construction and operation process of hydroelectric power plant projects in Turkey. His company also distributes natural gas to three cities in Turkey, so he knows the energy sector in Turkey very well. Due to the fact that he has a detailed knowledge of all steps related to the hydroelectric power plant and energy sector in Turkey, he is one of the most appropriate person to identify the risk factors related to hydroelectric power plant projects.

Expert-2 is a civil engineer with 10 years experience. He is a partner in a company which provides consultancy services to energy projects, especially hydroelectric power plant projects, in Turkey. He knows all the steps relating to hydroelectric power plant projects especially project development and licensing for developed projects. He has constructed a hydroelectric power plant as an investor and now he is operating this hydroelectric power plant. As he is experienced about the construction and operation of hydroelectric power plants, and also knows all the steps related to hydroelectric power plant projects, he is an appropriate person to complete the questionnaire.

Expert-3 is an engineer with 12 years experience. He is a partner in a company which also provides consultancy services to energy projects especially hydroelectric power plant projects in Turkey. Similar to Expert-2, he knows all the steps related to hydroelectric power plant projects but his speciality is in his knowledge of the construction process of hydroelectric power plant projects in his company. He has also constructed two hydroelectric power plants as an investor and now they are in the operation period. Due to his experience in hydroelectric power plant projects, he is an appropriate person to complete the questionnaire.

Expert-4 is a civil engineer with eight years experience. He is an owner of a construction and energy company. He has six hydroelectric power plant licenses. He constructed two of them and now he is operating them. He also has a natural gas distribution company. His company distributes natural gas to one city in Turkey so he is familiar to the energy sector in Turkey. He has much experience in the energy sector and he is an appropriate person to perform the questionnaire.

Expert-5 is a mechanical engineer with nine years experience. He is an owner of a company which provides consultancy services to energy projects. He has constructed three hydroelectric power plants and now they are in the operation period. He also has licenses for wind and solar energy. As he is a mechanical engineer, he knows the technical details about hydroelectric power plants, solar and wind energy very well. Due to his experiences in hydroelectric power plants and the energy sector, he is another appropriate person to complete the questionnaire.

Initially the risk checklist was examined by the experts and they are asked to add/eliminate any risk factors. The experts found the list satisfactory and no revisions were suggested.

In the questionnaire (see Appendix A) all of the risk factors and cash flow parameters are given to the experts in a tabular form. Each expert is asked to assess the impact of the risk factors for each parameter. The number “0” shows that the risk factor doesn’t affect the parameter, the number “1” shows that the risk factor affects the parameter categorized as low, the number “2” shows that the risk factor affects the parameter categorized as medium and the number “3” shows that the risk factor affects the parameter categorized as high.

As the questionnaire was applied to five experts, five different results were obtained. These five results need to be reduced to a single result. For the reduction process, the Delphi Method is used. In this technique the questionnaire is answered by the experts in two or more rounds. After each round, the questionnaire that includes all the expert’s answers are given to the experts and they are asked to revise their earlier answers in the light of the other experts’ answers. By performing this process, the range of the answers are minimized in each round and also the degree of consensus for the results is increased in each round. After all rounds are completed, the mean or mode of the answers are determined as a final result of the questionnaire.
In the questionnaire, five experts’ results (the number “0-3” which shows the impact of risk factors for each parameter) were written in the questionnaire. Then the mode is chosen for each cell. For example there are three “2”, one “1” and one “3”, “2” is chosen as an impact of risk factor. If one expert gives “0” and the other expert gives “3” to the same risk factor for a parameter, then it is considered to be a mistake in the understanding of the risk factor. This risk factor is explained to the experts again and then the impact of risk factor for a parameter is asked again. After making the reduction

process, a single result for the questionnaire is obtained and this is shown in Appendix B.

Step 3: Grouping the parameters with respect to risk factors

When the questionnaire results are examined, it can easily be seen that some cash flow parameters are affected by the same degree as the risk factors. These parameters are grouped and renamed. Instead of indicating system economic life, construction period and operation period separately, only the duration of construction is indicated as a parameter. The cost of weirs, cost of turbines and generators, cost of penstocks, cost of power transmission lines, excavation costs, costs of concrete and reinforcement are grouped and named as cost of construction. The new parameters are grouped considering the risk impacts as shown in Figure 3.12.

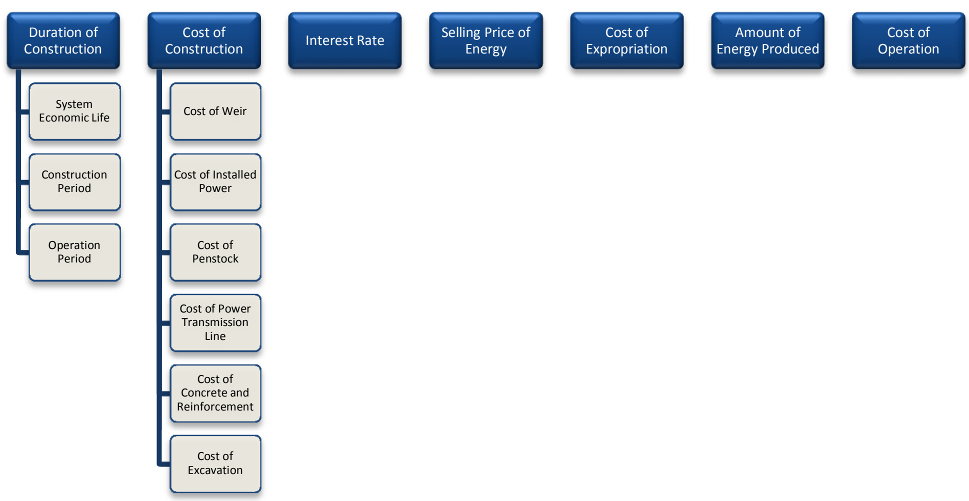

Figure 3.12: Cash Flow Parameters for Hydroelectric Power Plant

After all the risk factors and their impacts are determined, the next step is determining the possible scenarios for the parameters. By using these possible scenarios, determining the possible results for the NPV. For this purpose, a Monte Carlo simulation is chosen as the best method. This is explained in the next chapter.

CHAPTER 4

RISK ASSESSMENT USING MONTE CARLO SIMULATION

4.1 Fundamentals of Monte Carlo Simulation

Monte Carlo simulation is a technique that helps people solve mathematical and statistical problems which are too complicated to solve analytically. There are many fields in which Monte Carlo simulation is widely used by professionals. Energy, finance, project management, engineering, insurance, transportation and manufacturing are some of the widely used areas of the Monte Carlo simulation method.

To perform risk analysis by Monte Carlo simulation, first of all, the mathematical model must be identified. Then instead of entering numerical values into the mathematical model, the range of values (according to the probability distribution of variables) are entered into the model. The correlation between the variables are also determined. After this process, the program starts to calculate. For the calculation process, the program chooses different combinations of variables and by using these variables, possible outcome values for each combination are calculated. Monte Carlo simulation can run a thousand times or higher depending upon the number and distribution of variables. After the run process is finished, the cumulative probability distribution of possible outcome values and regression coefficients of the variables are obtained (Flanagan and Norman, 1993).

Microsoft Excel does not support Monte Carlo Simulation, but there are various forms of Monte Carlo simulation software that are add-ins to Microsoft Excel. Common Monte Carlo simulation software programs include RiskAMP, SimVoi, Oracle Crystal Ball, Monte Carlito, Palisade’s @Risk and Simulator. As it is extensively used and easy to use, in this research Palisade's @Risk software is used to perform the Monte Carlo simulation.

4.2 Monte Carlo Simulation for the Case Study

4.2.1 Determining the probability distributions for the cash flow parameters

To perform the risk analysis by Monte Carlo simulation, first of all the variables were identified. As indicated in the last part of Chapter 3, there are 7 parameters that are affected by risk factors. These are: duration of construction, cost of construction, interest rate, selling price of energy, cost of expropriation, amount of energy produced and cost of operation. The next step in the simulation is to determine the probability distributions for each variable. The risk factors and impact of risk factors for each parameter were also clarified in Chapter 3. With the help of these risk factors and their impact, the probability distributions for the parameters are determined. To determine the probability distributions, a meeting was arranged with the five experts (Expert-1, Expert-2, Expert-3, Expert-4 and Expert-5) who were described in Chapter 3. At this meeting, detailed information related to case study was given to the experts. The logic of Monte Carlo simulation was explained to them. By showing the risk factors and their impact, the experts were asked to identify the best and worst scenario and probability distribution for each parameter. With the help of their knowledge and experiences related to hydroelectric power plant projects, the experts agreed and determined the best and worst scenario and probability distribution for each parameter. The probability distribution for each parameter is explained below.

4.2.1.1 Duration of construction

The risk factors and their impact for the duration of construction are shown in Table 4.1. In the case study, the duration of construction was assumed as 1 year. When the risk factors and impact are taken into consideration, in the best scenario the project would be finished 10% earlier than the planned duration according to the experts. On the other hand in the worst scenario, the project would be finished 200% later than the planned duration. The probability distribution was determined by the experts as a triangle (by considering the best, most likely and the worst case) and shown in Figure 4.1.

Table 4.1: Risk Factors and Impact for Duration of Construction

Duration of Construction	
Risk factors	**Impact**
Change in law	3
Delay in project approvals and permits	3
Delay in expropriation /nationalization of assets	3
Change in government	1
Unavailability of material during construction	3
Unavailability of labor during construction	3
Unavailability of finance	3
Insolvency of subcontractors and suppliers	3
Import restrictions	3
Inflation rate volatility	2
Public opposition to project	3
Force majeure risk	3
Unfavorable weather conditions during construction	3
Problems with design	1
Delay of construction	3
Vagueness of geotechnical conditions	2
Poor quality of construction (rework)	2
Change of scope (increase/decrease in quantities)	2
Technical problems (related with construction method etc.) during	2
Organization and coordination risk	3
Third party delays (suppliers, subcontractors etc.)	3
Accidents	2

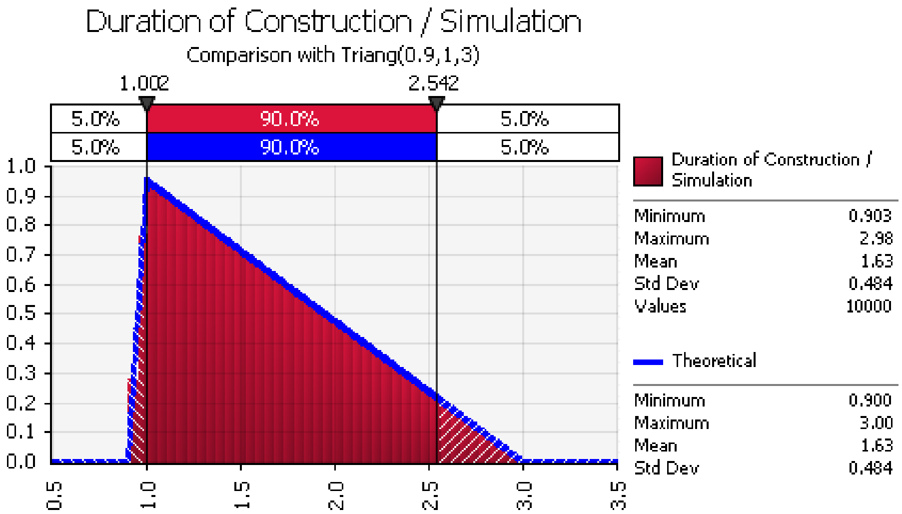

Figure 4.1: Probability Distribution for Duration of Construction

4.2.1.2 Cost of construction

The risk factors and their impact on the cost of construction are shown in Table 4.2. As mentioned in Chapter 3, the cost of construction is the sum of five parameters (cost of weirs, cost of turbines and generators, cost of penstocks, cost of power transmission lines, cost of excavation, cost of concrete and reinforcement). In the case study, the cost of construction was calculated as $20,067,100. If the risk factors and their impact on the cost of construction are taken into consideration, the experts defined the best scenario as 7% cheaper than the calculated cost. On the other hand, the worst scenario was defined by the experts as 50% more expensive than the calculated cost. The probability distribution for cost of construction was determined as a triangle (by considering the best, worst and normal scenario) and shown in Figure 4.2.

Table 4.2: Risk Factors and Impact for Cost of Construction

Cost of Construction	
Risk factors	**Impact**
Change in law	1
Delay in project approvals and permits	3
Delay in expropriation /nationalization of assets	3
Change in government	1
Unavailability of material during construction	2
Unavailability of labor during construction	2
Unavailability of finance	2
Insolvency of subcontractors and suppliers	3
Change in tax regulations	2
Import restrictions	2
Inflation rate volatility	2
Changes in foreign exchange rates and inconvertibility	2
Adverse change in financial markets	2
Public opposition to project	3
Change in interest rates	2
Force majeure risk	3
Unfavorable weather conditions during construction	2
Problems with design	2
Delay of construction	2
Vagueness of geotechnical conditions	2
Poor quality of construction (rework)	2
Change of scope (increase/decrease in quantities)	2
Technical problems (related with construction method etc.) during	2
Organization and coordination risk	2
Third party delays (suppliers, subcontractors etc.)	2
Accidents	2

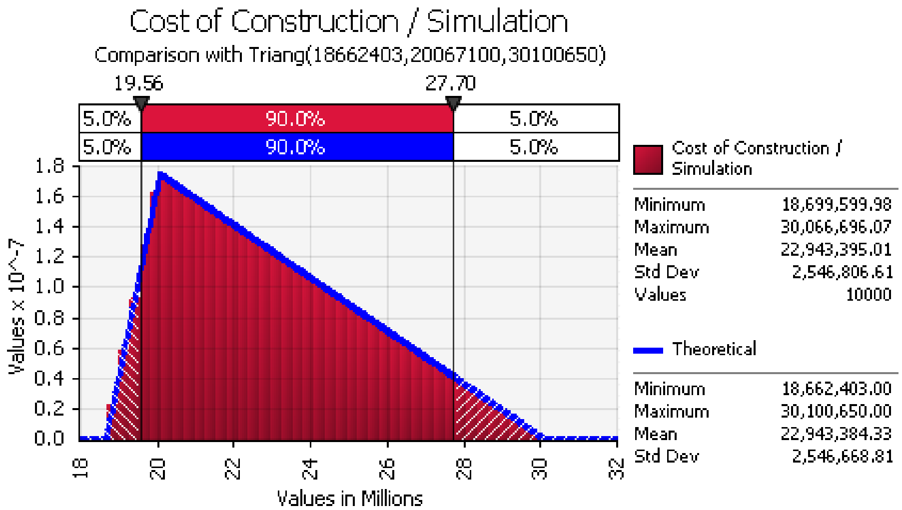

Figure 4.2: Probability Distribution for Cost of Construction

4.2.1.3 Interest rate

The risk factors and their impact on the interest rate are shown in Table 4.3. In the case study, the interest rate was accepted as 9.5% according to the central bank data. If the risk factors and their impact on the interest rate are taken into consideration, the interest rate was determined as 6% in the best scenario by the experts. In the worst case scenario, the interest rate was accepted as 14%. By taking into account the best, worst and most likely scenario, triangulated probability distribution for interest rates was determined and is shown in Figure 4.3.

Table 4.3: Risk Factors and Impact for Interest Rate

Interest Rate	
Risk factors	**Impact**
Change in law	2
Change in government	2
Unavailability of finance	3
Change in tax regulations	1
Import restrictions	1
Inflation rate volatility	3
Changes in foreign exchange rates and inconvertibility	3
Adverse change in financial markets	3
Change in tariff rates by the government	1
Change in interest rates	3
Force majeure risk	1

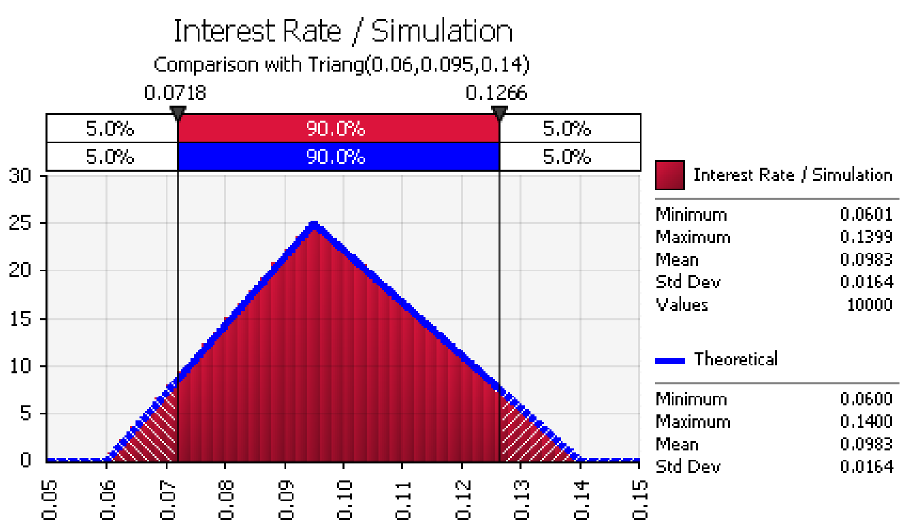

Figure 4.3: Probability Distribution for Interest Rate

4.2.1.4 Selling price of energy

The risk factors and their impact on the selling price of energy are shown in Table 4.4. In Turkey, the government gives a price guarantee for the selling price of energy and this price is 6 dollar cent for one kilowatt-hour energy. For the study calculation, the selling price of energy was taken as 6 dollar cent for one kilowatt-hour energy. However in practice, the investor sells energy to the broker at a higher price. So the selling price of energy can increase to 20 dollar cent for one kilowatt-hour energy. For the best case, the energy price is considered as 20 dollar cent for one kilowatt-hour and for the worst case the energy price is considered as 6 dollar cent for one kilowatt-hour. The probability distribution for the selling price of energy was determined as a triangle and shown in Figure 4.4.

Table 4.4: Risk Factors and Impacts for Selling Price of Energy

Selling price of energy	
Risk Factors	**Impact**
Change in law	3
Change in government	2
Change in tax regulations	2
Inflation rate volatility	2
Changes in foreign exchange rates and inconvertibility	2
Adverse change in financial markets	2
Change in tariff rates by the government	3
Change in energy market demand	3
Force majeure risk	1

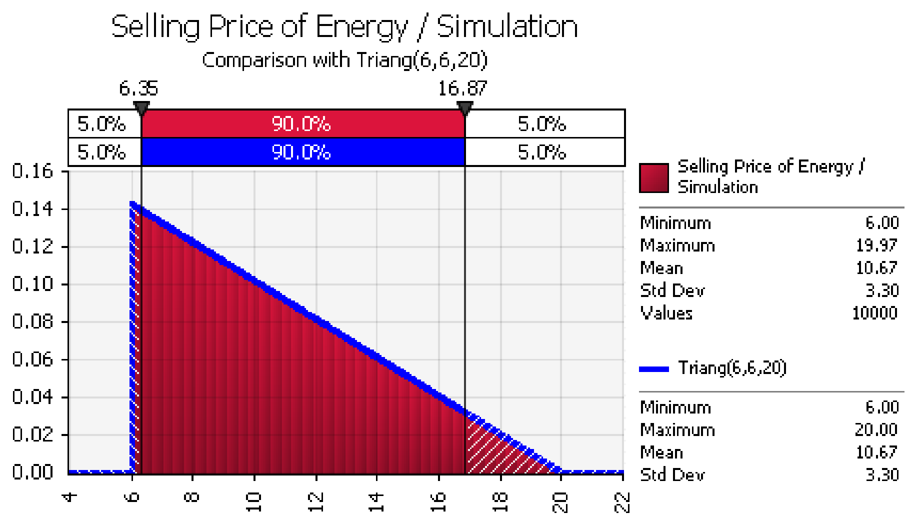

Figure 4.4: Probability Distribution for Selling Price of Energy

4.2.1.5 Cost of expropriation

The risk factors and their impact for the cost of expropriation are shown in Table 4.5. The cost of expropriation was calculated as $300,000 in the case study. If the risk factors and their impact on the cost of expropriation are taken into consideration, the experts defined the best scenario as 15% cheaper than the calculated cost of expropriation. On the other hand, the worst scenario was defined by the experts as 40% more expensive than the calculated cost of expropriation. The probability distribution for cost of expropriation was determined as a triangle (by considering the best, worst and most likely scenario) and shown in Figure 4.5.

Table 4.5: Risk Factors and Impacts for Cost of Expropriation

Cost of Expropriation	
Risk factors	**Impact**
Change in law	3
Delay in project approvals and permits	1
Delay in expropriation /nationalization of assets	2
Change in government	1
Change in tax regulations	1
Inflation rate volatility	1
Changes in foreign exchange rates and inconvertibility	1
Adverse change in financial markets	1
Public opposition to project	2
Change of scope (increase/decrease in quantities)	1
Organization and coordination risk	1
Accidents	1

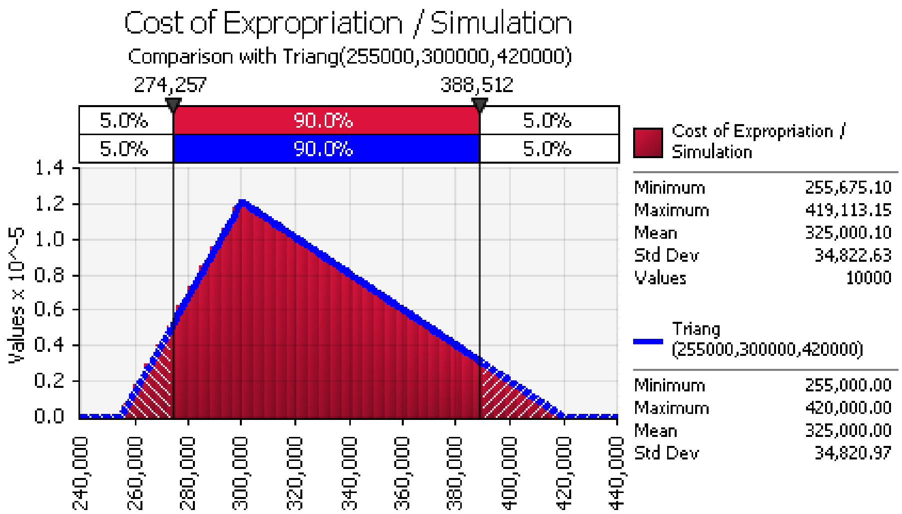

Figure 4.5: Probability Distribution for Cost of Expropriation

4.2.1.6 Amount of produced energy

The risk factors and their impact for the amount of produced energy are shown in Table 4.6. In the case study, the amount of produced energy for one year was calculated as 90,000,000 kW.h. If the risk factors and their impact on the amount of energy produced are taken into consideration, the experts defined the best scenario as 25% more than the calculated amount of produced energy. On the other hand, the experts defined the worst scenario as 25% less than the calculated amount of produced energy. The probability distribution for the amount of produced energy was determined as a triangle (by considering the best, worst and normal scenario) and shown in Figure 4.6.

Table 4.6: Risk Factors and Impacts for Amount of Produced Energy

Amount of Produced Energy	
Risk factors	**Impact**
Delay in expropriation /nationalization of assets	3
Public opposition to project	1
Force majeure risk	1
Low flow rate during the operation period	3
Problems with design	3
Delay of construction	1
Vagueness of geotechnical conditions	1
Poor quality of construction (rework)	1
Change of scope (increase/decrease in quantities)	2
Technical problems during operation	2
Technical problems (related with construction method etc.) during construction	1
Organization and coordination risk	1
Third party delays (suppliers, subcontractors etc.)	1
Accidents	2

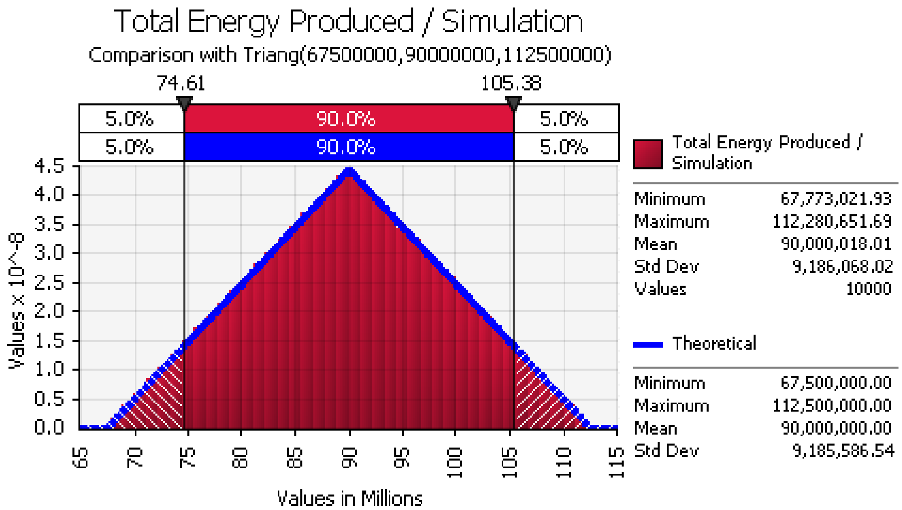

Figure 4.6: Probability Distribution for Amount of Produced Energy

4.2.1.7 Cost of operation

The risk factors and their impact on cost of operation are shown in Table 4.7. In the case study, the cost of operation for one year was calculated as $336,000. If the risk factors and their impact on the cost of operation are taken into consideration, the experts defined the best scenario as 20% less than the calculated cost of operation. However the worst scenario was defined by the experts as 50% more than the calculated cost of operation. The probability distribution for cost of operation was determined as a triangle (by considering the best, worst and normal scenario) and shown in Figure 4.7.

Table 4.7: Risk Factors and Impact for Cost of Operation

Cost of Operation	
Risk factors	**Impact**
Change in law	2
Change in government	1
Unavailability of material during construction	1
Unavailability of finance	1
Change in tax regulations	1
Import restrictions	2
Inflation rate volatility	2
Changes in foreign exchange rates and inconvertibility	2
Adverse change in financial markets	1
Public opposition to project	1
Change in interest rates	1
Force majeure risk	2
Problems with design	2
Poor quality of construction (rework)	2
Change of scope (increase/decrease in quantities)	1
Technical problems during operation	3
Technical problems (related with construction method etc.) during construction	1
Organization and coordination risk	2
Third party delays (suppliers, subcontractors etc.)	1
Accidents	2

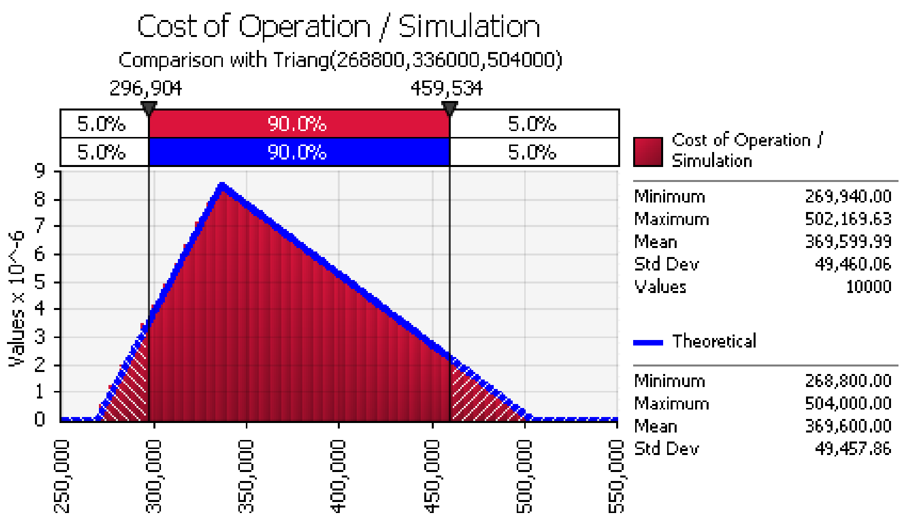

Figure 4.7: Probability Distribution for Cost of Operation

4.2.2 Determining the correlation coefficient between the cash flow parameters

After determining the probability distribution of the parameters, the next step is to determine the correlation coefficients between the parameters. A correlation coefficient shows the relationship between two variables. The value of a correlation coefficient can range from -1 to 0 and 0 to 1. When the correlation coefficient is positive, it shows that if one variable increases the other variable also increases. On the other hand when the correlation coefficient is negative, it shows that if one variable increases the other variable decreases. The correlation coefficient "1" shows positive perfect correlation and the correlation coefficient "-1" shows negative perfect correlation. Furthermore the correlation coefficient "0" means that there is no relationship between the variables. In performing the Monte Carlo simulation of the case study, the correlation coefficients between the variables were also determined by the experts in the consensus and shown in Table 4.8.

Table 4.8: Correlation Coefficients between the Parameters

Parameters	**Correlation Coefficient**
Cost of Construction - Duration of Construction	1
Cost of Construction - Cost of Operation	0,75
Interest Rate -Selling Price of Energy	0,75
Interest Rate - Cost of Operation	0,75
Cost of Expropriation - Cost of Construction	0,75
Cost of Expropriation - Interest Rate	0,75
Cost of Expropriation - Cost of Operation	0,75
Selling Price of Energy - Duration of Construction	0
Selling Price of Energy - Cost of Construction	0
Selling Price of Energy - Cost of Expropriation	0
Selling Price of Energy - Amount of Energy Produced	0
Selling Price of Energy - Cost of Operation	0
Amount of Energy Produced - Duration of Construction	0
Amount of Energy Produced - Cost of Construction	0
Amount of Energy Produced - Interest Rate	0
Amount of Energy Produced - Cost of Expropriation	0
Amount of Energy Produced - Cost of Operation	0
Interest Rate - Cost of Construction	0
Duration of Construction - Cost of Expropriation	0
Duration of Construction - Cost of Operation	0
Duration of Construction - Interest Rate	0

4.2.3 Results of Monte Carlo simulation

After determining the probability distributions and correlation coefficients, the mathematical model can be constructed. This model was also constructed in Chapter 3 while performing the cash flow analysis of a hydroelectric power plant project using deterministic values. This time, for stochastic analysis, the probability distribution of parameters are entered into the model and then a Monte Carlo simulation was performed. According to the results of the Monte Carlo simulation; the probability distribution for the net present value is as shown in Figure 4.8. As seen in Figure 4.8; the net present value for the best scenario is $188,813,602.43, on the other hand, the net present value for the worst scenario is – $2,641,703.74. In these results, the important value for the investor is the "mean" which also named as "expected value". According to the results, the expected value for the net present value is $56,433,577.87. When this value is compared with the calculated net present value (deterministic) for the case study, it is found that there is 13.5% probability that the NPV will be less than the deterministic value.

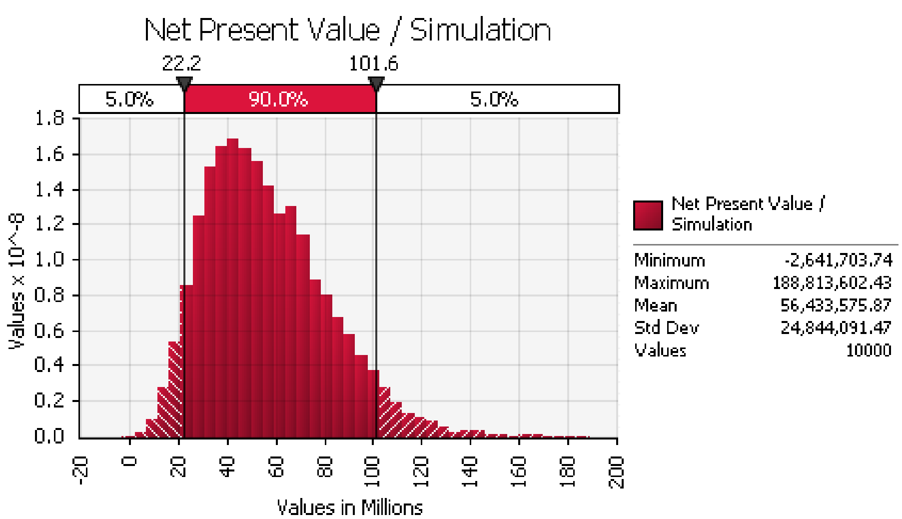

Figure 4.8: Probability Distribution for Net Present Value

The Monte Carlo Simulation method also gives a regression coefficient graph (Figure 4.9). This graph informs how the change in one parameter affects the net present value. According to this graph, the most critical parameters are the selling price of energy and interest rate. With the help of the interest rate, all the cost and income parameters are carried in the cash flow analysis. To see the effect of change in the interest rate more clearly, instead of giving probability distribution for the interest rate; the best, worst and most likely cases can be modelled and their simulations can be performed separately.

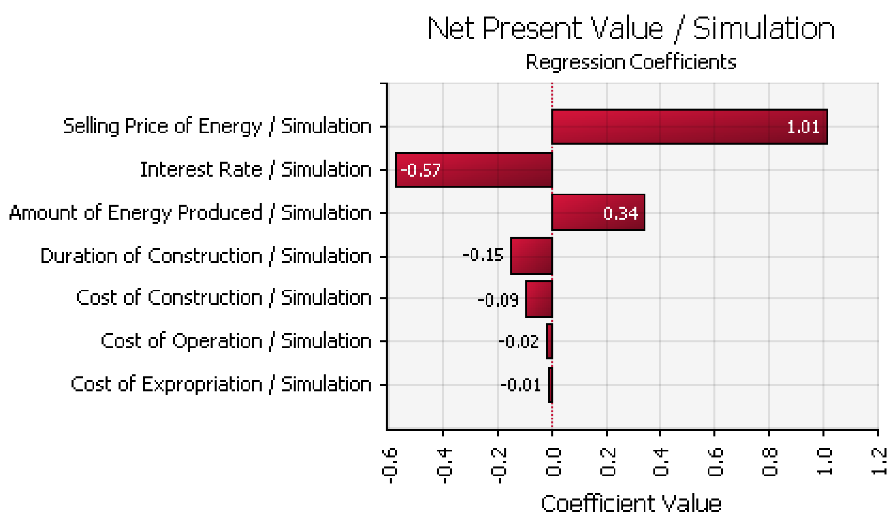

Figure 4.9: Regression Coefficients of Parameters

Monte Carlo simulation was repeated three times by changing the value of the interest rate. For the first case (most likely case) the interest rate used was 9.5%, for the second case (best case) the interest rate used was 6% and for the third case (worst case) the interest rate used was 14%. Whilst performing these three simulations, the probability distribution for other parameters were the same as the first simulation. The probability distributions and regression coefficients for all three cases are shown below in sequence.

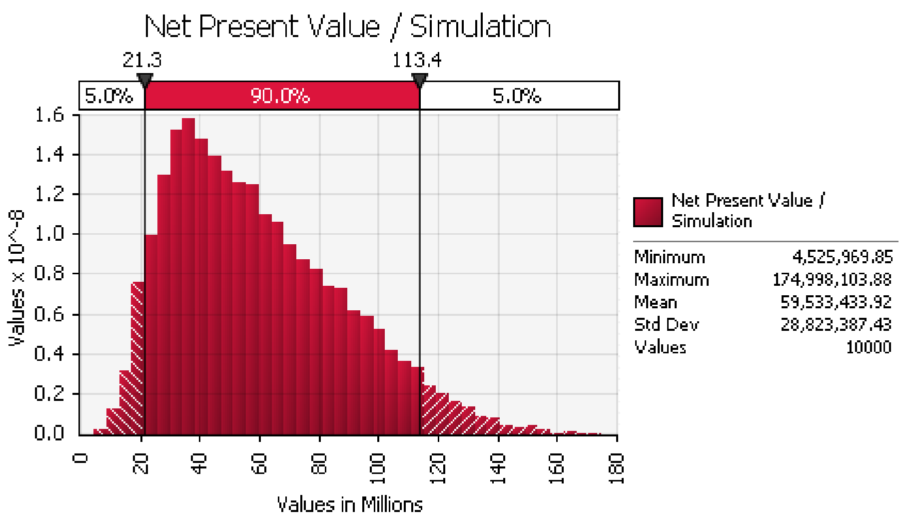

Figure 4.10: Probability Distribution for Net Present Value (Interest Rate = 9.5 %)

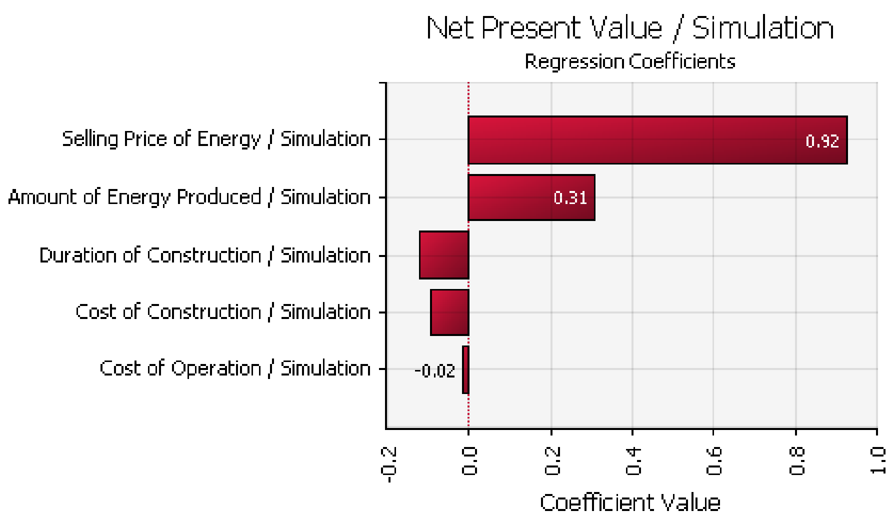

Figure 4.11: Regression Coefficients of Parameters (Interest Rate = 9.5 %)

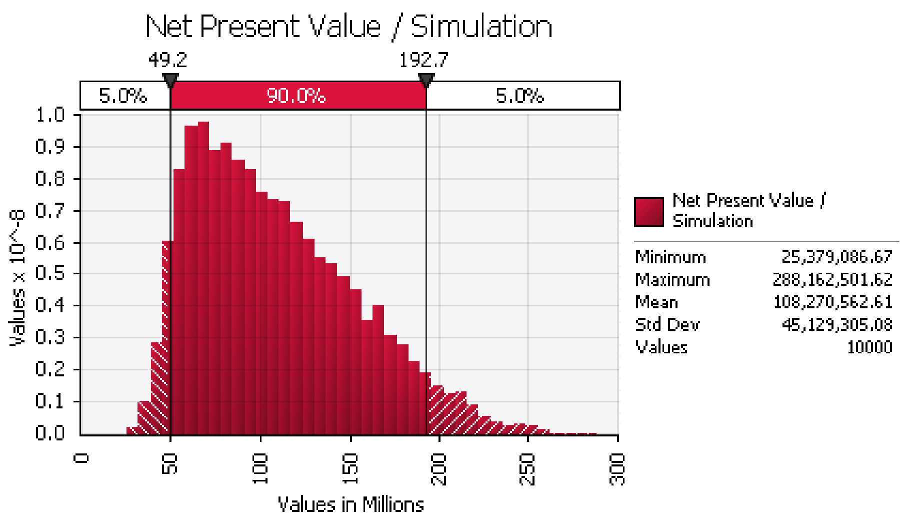

Figure 4.12: Probability Distribution for Net Present Value (Interest Rate = 6 %)

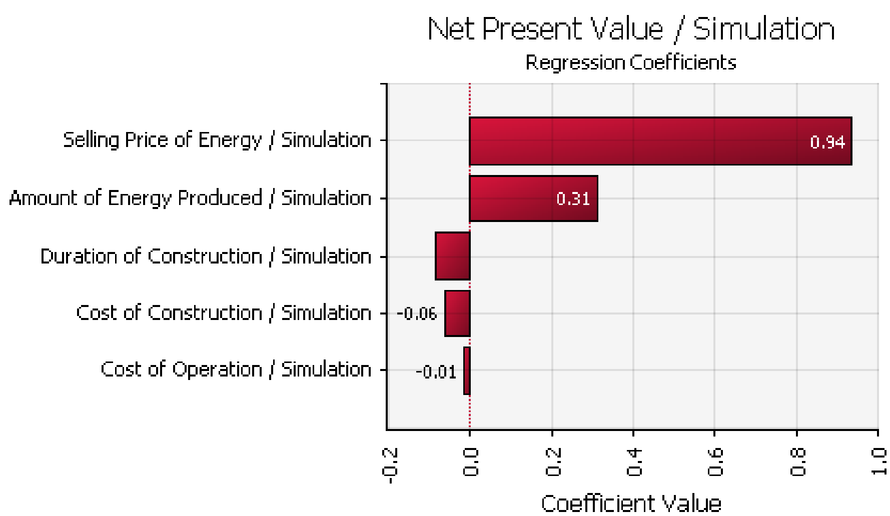

Figure 4.13: Regression Coefficients of Parameters (Interest Rate = 6 %)

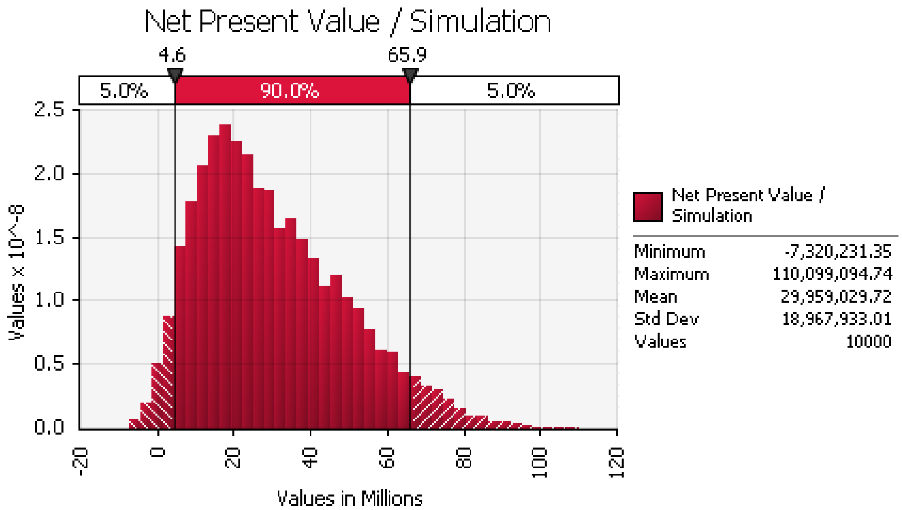

Figure 4.14: Probability Distribution for Net Present Value (Interest Rate = 14 %)

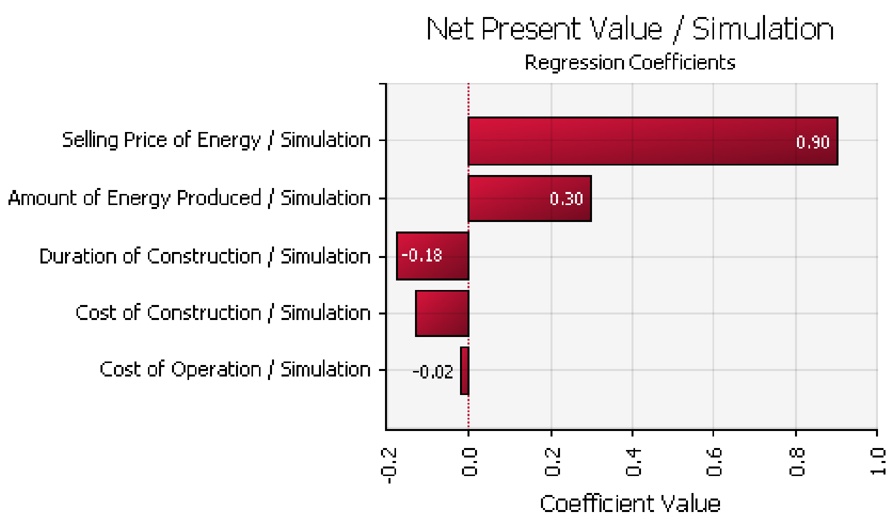

Figure 4.15: Regression Coefficients of Parameters (Interest Rate = 14 %)

4.3 Shortcomings of Monte Carlo Simulation

By performing Monte Carlo simulation, the possible outcomes for the net present value were obtained. If the expected values of different simulations are compared, the significant difference between the net present values can be observed. As expected, when the interest rate increases, the net present value decreases. According to the regression coefficient graph of the first simulation, the interest rate is the second effective parameter whilst calculating the net present value. If Monte Carlo simulation results of the three models (Figure 4.10, Figure 4.12 and Figure 4.14) are analyzed, it can clearly be seen that a change in interest rate can cause big changes in net present values. It means that a change in variable which has high regression coefficient, can cause big changes in output values. If all the regression graphs are analyzed, it can be seen that the selling price of energy is the most important variable in the Monte Carlo simulation whilst the net present value is being calculated. So the probability distribution of the selling price of energy is very important and should be as close to real distribution as possible. Experts determined the probability distribution of the selling price of energy in a triangular form. They also pointed out that the probability distribution of the selling price of energy is too complicated to be determined because the selling price of energy is determined as a result of a negotiation process between investors and brokers. So, to obtain more realistic results for the net present value, a more realistic approach is required while determining the probability distribution of the selling price of energy. In summary, Monte Carlo Simulation is based on the probability distributions determined considering the risk factors, however, the parameters are not only affected by risk factors but also by negotiations between parties. This issue cannot be systematically reflected in the probability distribution functions, thus, should be handled differently. In Chapter 5, Multi Agent Systems are proposed as a solution to model negotiations between parties.

CHAPTER 5

DETERMINATION OF ENERGY PRICE USING MULTI AGENT SYSTEMS

5.1 Negotiation Process for Determining the Selling Price of Energy

As mentioned in Chapter 4, the selling price of energy is the most important parameter when determining the net present value of a hydroelectric power plant project. As realistic an approach as possible is required whilst determining the value for the selling price of energy. In the feasibility study for hydroelectric power plants, the selling price of energy is accepted as 6 dollar cent/kWh which is the guaranteed price given by the government to the investor, however, in reality, the situation is different. There are companies who act as brokers who buy the energy from investors and sell this energy to factories, hotels and hospitals. In general, the investors don't sell their produced energy to the government. They sell their produced energy to the brokers because they give them a higher price than the government guarantee. The brokers contract annually with the investors. To determine the selling price of the energy the investor and broker enter into a negotiation process. The selling price of energy is determined at the end of this negotiation. There are some risk factors that affect this negotiation process, so in order to provide a more realistic net present value, the negotiation process between investor and broker needs to be modelled. The negotiation process is modelled by using Multi Agent System (MAS) with a Zeuthen strategy.

5.2 Definition of a Multi Agent System

A multi agent system consists of agents which are defined as multiple interacting intelligent elements within an environment. The agents have two important attributions. Firstly, they have autonomous actions. Shoham (1993) describes autonomous actions as the actions which are performed by the agents without required constant human guidance. In other words, it means that the agents behave according to the assigned design objectives. The second attribution of the agents is a capability to interact with other agents in the system. Kraus et al. (1995) specify that the agents can have different goals and targets and can have real competition with each other. By using agent interaction the real life negotiations can also be modelled. Kraus et al. (1995) clarify that agents can be designed according to their goals to ensure that negotiations and mutually acceptable solutions can be obtained. As Cleary (2001) states negotiations are a costly and time consuming process. It is important to find a solution to the negotiations. Some negotiation protocols simulate real life negotiations and are extensively used in MAS (Karakas, 2010). Kraus et al. (1995) describes negotiation protocol as the mechanism that is used for solving the conflicts in negotiation between the agents. The agents' behaviors and interactions are arranged according to the negotiation protocol. There are 2 main negotiation protocols that are commonly used. These are The Zeuthen Strategy and The Zeuthen Strategy with Bayesian Learning. In The Zeuthen Strategy, the agents are fully informed of each other's position which means they know each other's reservation value, on the other hand, in the Zeuthen strategy with Bayesian learning, the agents don't have full visibility of each other's position which means they don't know each other's reservation value. In this strategy, they assume their reservation values by using Bayesian theorem.

5.3 Literature Review of Multi Agent Systems and Their Use in Construction Projects

Multi Agent System (MAS) first appeared in the 1980's but using MAS in the construction sector is gaining the attention of more and more researchers. De Oliveira et al. (1997) prepared a model which manages resources in a construction company with the help of MAS. By using MAS, Tah (2005) generated a modelling and simulation platform for use in supply chain management. Kim and Paulson (2003) generated an agent based negotiation model to facilitate distributed coordination of project schedule changes. Taylor et al. (2009) proposed a multi agent simulation model to discover the effects of learning dynamics on project networks. By using MAS, Ng and Li (2006) developed automated negotiation for the sourcing of construction suppliers. Molinero and Núñez (2011) prepared a model using MAS, which plans work schedules during the construction of building. Xue et al. (2005) developed a framework based on MAS, which assists the coordination of the supply chain in construction. Ren and Anumba (2004) briefly explained MAS in the construction sector and stated the advantages of MAS. Xue et al. (2009) proposed an agent based negotiation model for the construction supply chain. By using MAS, Karakas et al. (2013) prepared a model that simulates the negotiation process between client and contractor relating to the sharing of cost overruns in construction projects. El-adaway and Kandil (2010) developed MAS to solve construction disputes.

5.4 Multi Agent System for Negotiation of Selling Price of Energy

In order to model the negotiation process for the selling price of energy, it is important to understand the negotiation process between the investor and broker. To understand this process, several negotiations between different investors and brokers were observed. When proposing a multi agent system for the negotiation of selling price of energy, the risk factors and their impacts on the negotiation process must first be determined.

5.4.1 Determining the risk factors for selling price of energy

The risk factors and their impact on the selling price of energy was determined in Chapter 3. The impact of these risk factors and any impact is not initially part of the negotiation process. So it is necessary to determine the risk factors and their impacts during the negotiation process. In order to do this several interviews were carried out with brokers and investors. According to the result of interviews, five risk factors were determined. These are listed in Table 5.1.

Table 5.1: Risk Factors for Selling Price of Energy Negotiation

Demand
Level of Competition
Production Capacity
Economic Condition
Legal Changes

After determining the risk factors related to the selling price of energy negotiation, the next step is to determine the impact of these risk factors in the negotiation. The impacts of these risk factors were also determined with the help of investors and brokers. The impact of risk factors were listed and then rated out of 10. The average results are shown in Table 5.2.

Table 5.2: Impact of Risk Factors

Demand	10
Level of Competition	6
Production Capacity	7
Economic Condition	3
Legal Changes	2

5.4.2 Determining the agents for the negotiation of the selling price of energy

The negotiation process to determine the selling price of energy is carried out between the investor and broker. So while modelling this process in MAS, two agents are defined. These agents are called the "investor agent" and the "broker agent".

5.4.2.1 Investor agent

The investor agent makes the first offer to the broker agent. The purpose is to sell the energy at as high a price as possible. To start the negotiation process, the investor agent needs two important input values. These are the first offer and reservation value. These values are determined according to who has the power over the risk factors in the negotiation and the calculation of these values are explained below.

5.4.2.2 Broker agent

The broker agent makes the first counteroffer to the investor agent. In contrast to the investor agent, the ultimate purpose is to buy the energy at the lowest possible price. The broker agent also needs the first offer and reservation value to start the negotiation. The calculation of these values is explained below.

5.4.3 Determining the input values

As noted above, to the start the negotiation process by using MAS, the first offer and reservation values need to be determined.

5.4.3.1 First offer

The first offer is the initial price given by agents. It is the price in which the investor agent and broker agent have the highest utility. While calculating the first offer for each agent, a procedure similar to Karakas et al. (2013) is used. The investor's first offer is determined by adding the percentage of risk factors in which investor has the power and the percentage of the risk factors that are shared. On the other hand, broker's first offer is determined by finding 70% of the broker's reservation value.

5.4.3.2 Reservation value

The reservation value shows the limit values for both agents. For the investor agent; it is the lowest price that can be accepted for the energy. The investor agent doesn't accept this price as it is lower than its reservation value. For the broker agent, this is the highest price for energy that can be given to the investor. The broker agent doesn't give a higher price than its reservation value. The investor's reservation value is determined by adding the percentage of the risk factors which are in the investor's control. The broker's reservation value is determined by adding the percentage of the risk factors in which the broker has control and those where the power is shared.

5.4.4 Determining the fuzziness levels for the risk factors

In the model, the input values are determined by using fuzzy logic. The fuzziness level of each risk factor needs to be determined in order to estimate the input values. Before determining the fuzziness levels of the risk factors, the fuzziness level grade should be defined. In the model, three fuzziness levels are defined. For the low fuzziness level, the fuzziness percentage is accepted as "15%", for the medium level, the percentage is accepted as "25%" and for the highest fuzziness level, the percentage is accepted as "35%". After the fuzziness percentage for each grade is decided, the fuzziness level for each risk factor is determined. This is shown in Table 5.3.

Table 5.3: Fuzziness Level for Each Risk Factor

Demand	Low
Level of Competition	Medium
Production Capacity	Low
Economic Condition	High
Legal Changes	Low

5.4.5 Determining the negotiation protocol

After calculating the input values for the broker and investor agents, the next step is to determine the negotiation protocol. The Zeuthen strategy is chosen as a negotiation strategy for using in the MAS. In a Zeuthen strategy, fully informed agents are used in the negotiation process. It means that both sides know each other's reservation values. In the negotiation process for the selling price of the energy, as the investor and broker know the condition of risk factors and also know each other's reservation value the Zeuthen strategy is the most appropriate negotiation strategy.

As Karakas et al. (2013) stated, in the Zeuthen Strategy, the negotiation process is simulated by comparing losses and gains. It means that for each proposal, the broker and investor agent calculate their loss of utility by accepting the offer and also calculate their loss of utility by rejecting the offer. In this negotiation process; the utility value for the broker's and investor's first offer is accepted as "1" and the utility value for their reservation values is accepted as "0,2". The utility value for each offer is calculated by linear interpolation between the first offer and the reservation value.

In the negotiation process there is also a time pressure on both parties. They are required to agree as quickly as possible, and to show this time dependent behavior of the negotiation process, "10%" loss of utility due time is added to the model. This ratio decreases from the calculated utility for each round.

5.4.6 Determining the scenarios for the selling price of negotiation

After the model is developed using the Zeuthen Strategy, the scenarios for the negotiation process should be determined. Five risk factors were determined for the negotiation process. Which agent has the power is decided by considering these risk factors.

The first risk factor is energy demand. If the energy demand is low, it shows that there are few alternatives for the investor to sell the produced energy. So the broker has the power. On the other hand, if the energy demand is high, there are many alternatives for the investor to sell the energy. In this situation, the investor has the power.

The second risk factor is level of competition. It shows the number of investors who produced energy. If the level of competition is low, the number of investors is few. So the investor has the power. If the level of competition is high, the broker has the power.

The third risk factor in the negotiation process is the production capacity of the hydroelectric power plant. If the investor has a hydroelectric power plant with high energy production capacity, more energy can be produced by the investor. As a result of this condition, the investor has the power in negotiation. On the other hand, if the investor has a hydroelectric power plant with a low energy production capacity, the broker has the power in the negotiation.

The fourth risk factor in the negotiation process is the current economic conditions. There are two possibilities; stable or unstable. In these two possible scenarios, neither party has total power. Both investor and broker have shared power. In these scenarios, the situation is called "shared" power. But when economic conditions are stable, the first offers of both parties are increased compared to the previous unstable economic conditions.

The fifth risk factor in the negotiation process is legal changes. When the legal changes are stable or unstable, both parties (investor and broker) have the same power, shared power. But when legal changes are stable, the first offers of both parties are increased compared when the situation is unstable.

The five risk factors, their possible scenarios and the party that possesses power in each scenario, are shown in Figure 5.1.

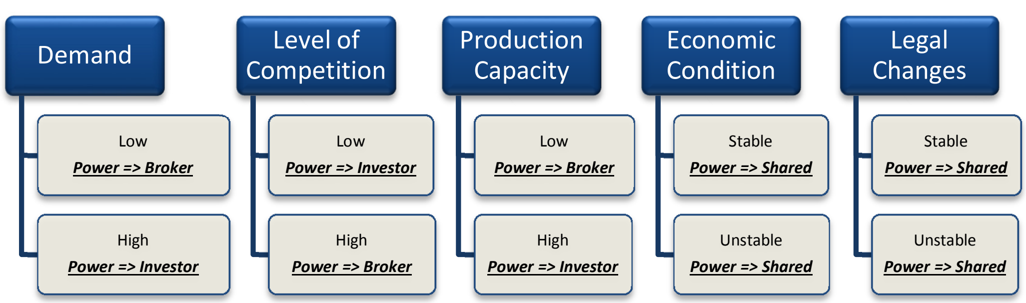

Figure 5.1: Risk Factors and Possible Scenarios

As shown above, there are five risk factors and each risk factor has two possible scenarios.

Number of total scenarios = $2 \times 2 \times 2 \times 2 \times 2$ = **32 Scenarios**

This means that there can be 32 different scenarios in the negotiation process between investor and broker. So by using MAS with Zeuthen Strategy, the selling price of energy is calculated for 32 different scenarios. For these scenarios; 32 different results are obtained for the selling price of energy. An example scenario template is shown in Table 5.4.

Table 5.4: An Example Scenario

Example Scenario						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35.7	L	15	35.7	0.0	0.0	41.1	0.0	0.0	30.3	0.0	0.0
Level of Competition	High	B	21.4	M	25	0.0	21.4	0.0	0.0	26.8	0.0	0.0	16.1	0.0
Production Capacity	Low	B	25.0	L	15	0.0	25.0	0.0	0.0	28.8	0.0	0.0	21.3	0.0
Economic Condition	Stable	S	10.7	H	35	0.0	0.0	10.7	0.0	0.0	14.4	0.0	0.0	7.0
Legal Changes	Stable	S	7.1	L	15	0.0	0.0	7.1	0.0	0.0	8.2	0.0	0.0	6.0
						35.7	46.4	17.8	41.1	55.5	22.6	30.3	37.3	13.0

Cmin	30.3
Coptimum	53.5

Investor	
First Offer	63.7
Reservation	30.3

Broker	
First Offer	37.5
Reservation	53.5

Start Negotiation

Maximum Price	20
Minimum Price	6

In the example scenario template, the first column shows the risk factors for the negotiation process. The second column shows the status of the risk factors. The third column shows the party with the power for each risk factor. The fourth column shows the percentage of impact of the risk factor. The percentages are found by using the impact of risk factors (Table 5.2).

<u>Calculation for the percentage of impact of risk factors</u>

The impact of demand = 10

The impact of level of competition = 6

The impact of production capacity = 7

The impact of economic condition = 3

The impact of legal changes = 2

Total impact of risk factors = 10 + 6 + 7 + 3 + 2 = 28

The percentage of impact of demand = (10/28) × 100 = **<u>35.7 %</u>**

The percentage of impact of level of competition = (6/28) × 100 = **<u>21.4 %</u>**

The percentage of impact of production capacity = (7/28) × 100 = **<u>25 %</u>**

The percentage of impact of economic condition = (3/28) × 100 = **<u>10.7 %</u>**

The percentage of impact of legal changes = (2/28) × 100 = **<u>7.1 %</u>**

The fifth column shows the fuzziness level for each risk factor and the sixth column shows the corresponding fuzziness values for each risk factor. The other nine columns show the percentage impact of each of the risk factors for "not fuzzy", "maximum fuzzy" and "minimum fuzzy" situations.

In the example scenario, it is clear that the reservation and first offer values of the parties are in percentages. These percentages show a value between the minimum and maximum energy price. These values are needed to convert the energy price and to start the negotiation. For this process, the minimum and maximum energy prices are required so that an interpolation can be performed.

For all scenarios, the minimum price is taken as 6 dollar cent/kwh which is the guaranteed price given by the government. This minimum price is always constant and corresponds to "0%" in the interpolation. The maximum price corresponds to "100%" in the interpolation. To determine the maximum prices for different scenarios, the brokers and investors were interviewed. There are two risk factors that affect the maximum price. These are the stability of economic conditions and the stability of legal changes. The maximum prices for different scenarios have been determined and shown in Table 5.5.

Table 5.5: The Maximum Prices for Different Scenarios

Economic Condition	Legal Change	Maximum Price (Dollar cent /kWh)
Stable	Stable	20
Stable	Unstable	19
Unstable	Stable	18
Unstable	Unstable	17

So after determining the maximum and minimum prices, it is easy to convert to percentage values the first offers and reservation values to the energy prices which are used in the MAS.

<u>For the investor's first offer in example scenario:</u>

First offer of investor in percentage = 63.7%

By performing interpolation between the minimum price (6 Dollar cent/kWh) and maximum price (20 Dollar cent/kWh);

The corresponding price for the investor's first offer "63.7%"

➔ $6 + ((20 - 6) \times 63.7/100)$ = **<u>14.9 Dollar cent/kWh</u>**

For all scenarios, the percentage values for the first offer and reservation values are converted to prices by interpolating in this way. The first offer and reservation values are obtained for both investor and broker agent, so the MAS with Zeuthen Strategy is ready to perform the negotiation process between investor and broker. All scenarios are defined in the system. So the results for each negotiation scenario is obtained easily. To computerize the model a Java Agent Development (JADE) Framework is used. After the modelling process is finished, 32 scenarios are entered into the computer and the simulation of negotiation is performed. The negotiation results are shown in Table 5.6. The broker and investor agents in the negotiation process for the example scenario are also shown in Figure 5.2 and Figure 5.3.

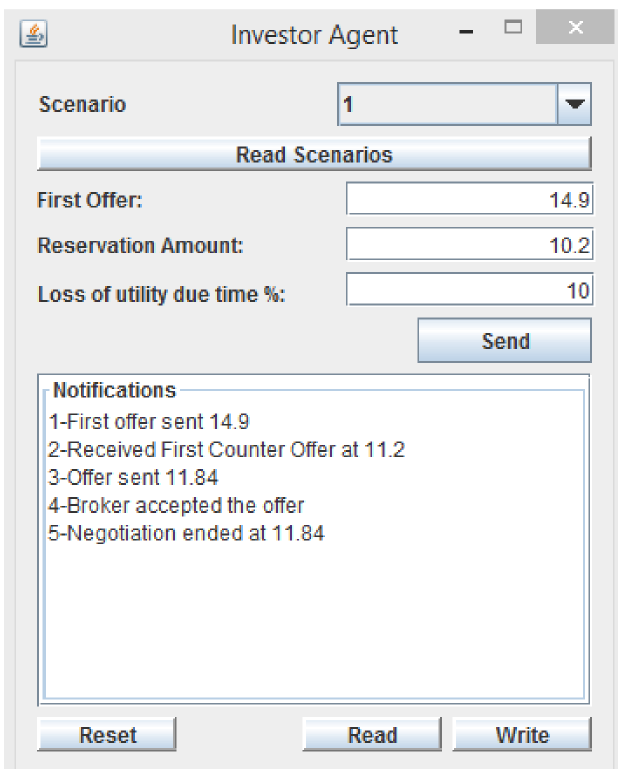

Figure 5.2: Investor Agent in Negotiation Process for the Example Scenario

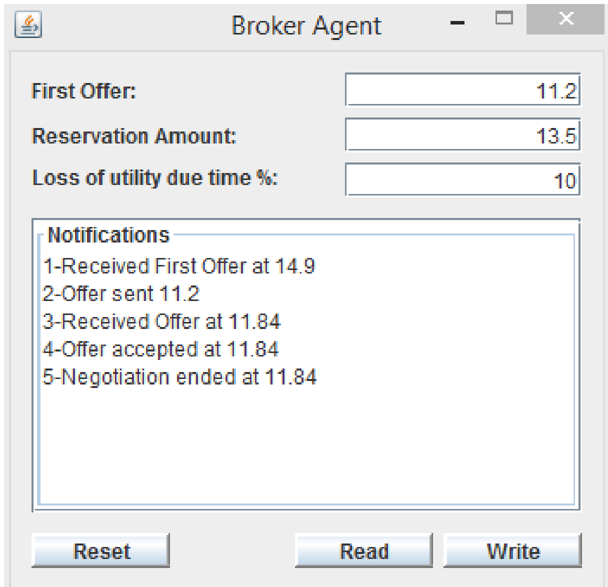

Figure 5.3: Broker Agent in Negotiation Process for the Example Scenario

Table 5.6: Negotiation Results for Each Scenario

	Selling Price of Energy (Dollar cent/kwh)
Scenario-1	**11.84**
Scenario-2	**11.42**
Scenario-3	**10.97**
Scenario-4	**10.59**
Scenario-5	**14.54**
Scenario-6	**13.85**
Scenario-7	**13.32**
Scenario-8	**12.65**
Scenario-9	**15.29**
Scenario-10	**14.64**
Scenario-11	**13.95**
Scenario-12	**13.3**
Scenario-13	**18.02**
Scenario-14	**17.15**
Scenario-15	**16.28**
Scenario-16	**15.4**
Scenario-17	**13.05**
Scenario-18	**12.5**
Scenario-19	**12.05**
Scenario-20	**11.58**
Scenario-21	**9.8**
Scenario-22	**9.6**
Scenario-23	**9.3**
Scenario-24	**9**
Scenario-25	**10.44**
Scenario-26	**10.15**
Scenario-27	**9.78**
Scenario-28	**9.44**
Scenario-29	**7.7**
Scenario-30	**7.6**
Scenario-31	**7.5**
Scenario-32	**7.4**

5.5 Calculation of NPV Using Monte Carlo Simulation and MAS Results

By modelling the negotiation process with MAS, more realistic results are obtained for the selling price of energy. So the next step is finding the net present value for the case study by using the 32 different scenarios.

5.5.1 Probability distribution for the selling price of energy

For the MAS, the 32 different scenarios were determined and so 32 different results for the selling price of energy were obtained. By entering the result of any scenario into the Monte Carlo model, the net present value for the requested scenario is obtained. To obtain a more general result for NPV, all the scenarios are considered as having same probability. So the probability distribution for the selling price of energy is appointed as discrete distribution with 32 different values having same probability. The probability distribution for the selling price of energy for 32 different scenarios are shown in Figure 5.4.

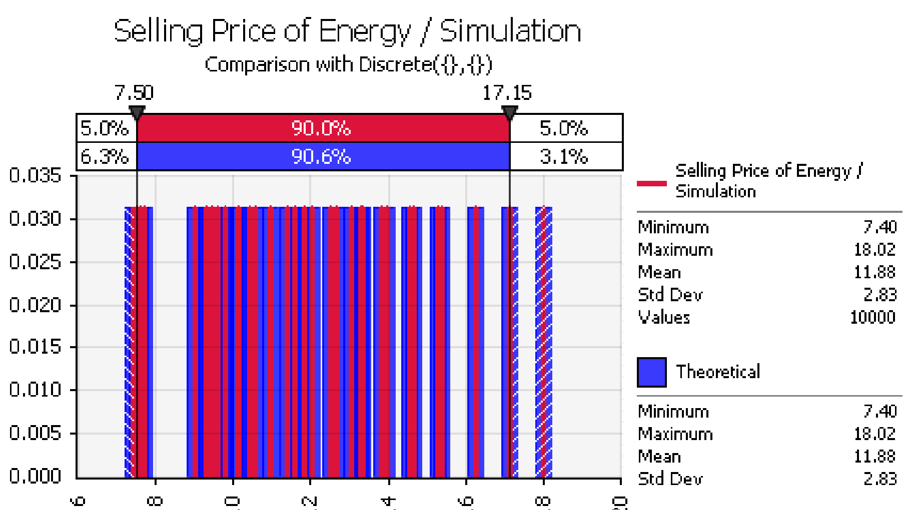

Figure 5.4: Probability Distribution for the Selling Price of Energy

5.5.2 Results of Monte Carlo Simulation

After entering the probability distribution for the selling price of energy for 32 different scenarios, the probability distribution of the NPV is found (Figure 5.5). In the Monte Carlo Simulation, distributions and correlation coefficients of all the parameters are the same as the simulation which was performed in Chapter 4. In the simulation, when the probability distribution for the selling price of energy was a triangle, the mean value of the NPV was found to be $56,433,575.87. On the other hand when the probability distribution for the selling price of energy is discrete, the mean value for NPV is found to be $66,475,096.17. It is clear then, that by using a more realistic approach, there is a 20% increase in the NPV.

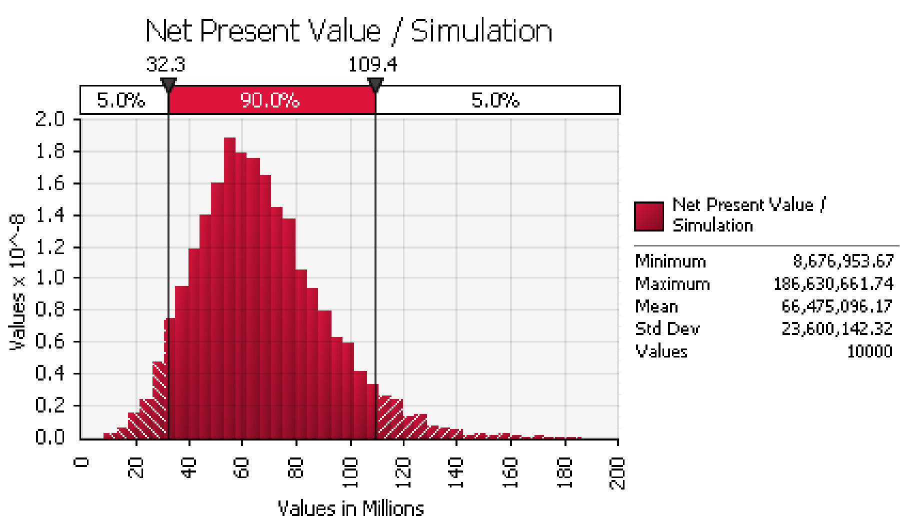

Figure 5.5: Probability Distribution for the Net Present Value

5.6 Evaluation of Results

The Net Present Values of the case study, for the deterministic case, for the Monte Carlo Simulation and for the Monte Carlo Simulation by using MAS are compared in Table 5.7.

Table 5.7: Net Present Values for the Case Study

	NPV
Deterministic value	**27.845.376,65 $**
Monte Carlo Simulation (most likely)	**56,433,575.87 $**
Monte Carlo Simulation (By using MAS) (most likely)	**66,475,096.17 $**

The significant differences between the Net Present Values can be seen in Table 5.7. These results were shown to the experts they were asked for their opinions. They all reached a consensus that the proposed model for determining the net present value is more realistic than the deterministic method. When the deterministic model is compared with the Monte Carlo Simulation, the significant increase in NPV can be easily seen. The experts explain the reason for this increase as "assumptions related with the selling price of energy" which is the most influential parameter when determining the NPV of this investment. In the deterministic model, the selling price of energy is thought to be the guaranteed price given by the government. However in reality, this guaranteed price is the worst scenario for the investors. According to the Monte Carlo results, the selling price of energy was found to be the most effective parameter while looking at the financial feasibility of the HEPP projects. So by using a more reasonable distribution instead of using worst case scenario for the most important parameter, the NPV increases dramatically. The results of the Monte Carlo Simulation are a more realistic alternative. Scenarios with all uncertain parameters including selling price of energy, duration of construction etc. are taken into account while determining the NPV of investment rather than only the "worst case scenario".

Experts state that using a "single" selling price of energy during feasibility studies is unrealistic as it changes under various conditions. They also state that the selection of the selling price of the energy for different scenarios is more realistic than the deterministic value of the selling price. For the proposed model the net present value is more realistic than the deterministic model. Experts state that the deterministic construction period and construction cost estimates generally do not come true so a risk assessment and probabilistic estimating for the construction period and construction cost would give more realistic results.

Moreover, when the model with MAS is compared with the model without MAS, the increase in the NPV is clear. This difference can also be attributed to the selling price of energy. In the model without MAS, the experts use their subjective judgement for the probability distribution of the selling price of energy, however, in the model with MAS, the distribution of selling price of energy is calculated as an average of 32 different real scenarios considering the negotiations between parties and demand-supply conditions. In the Monte Carlo Simulation with MAS, the expected value for the distribution of the selling price of energy is found to be higher (11.88 cent / kWh) than the model without using MAS (10.67 cent / kWh). As a result of the increase in the selling price of energy, the NPV is increased.

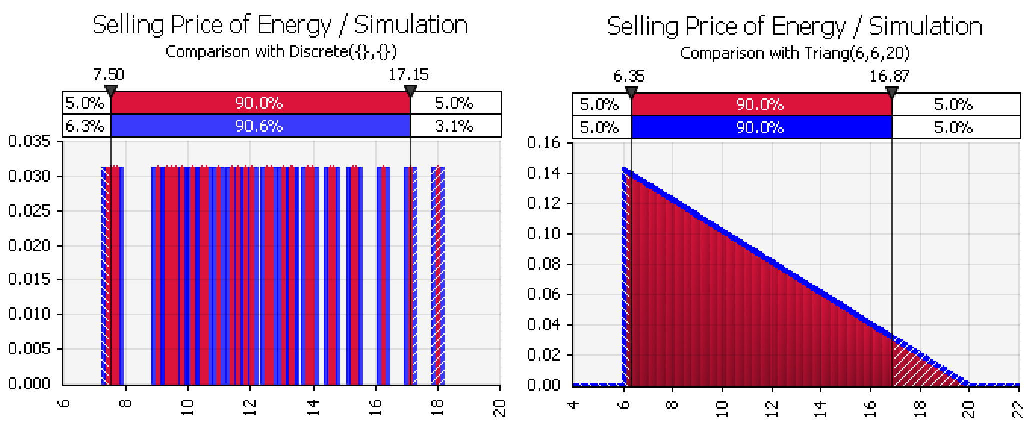

Figure 5.6: Probability Distribution for Selling Price of Energy with using MAS and without using MAS

One should also note that there are some assumptions while conducting the Monte Carlo Simulation and integrated methodology. One of the major assumptions is that the probability of each of the 32 scenarios as utilized in the integrated methodology (Monte Carlo Simulation and MAS) is the same. This is actually recommended by the experts as it is not easy to predict which scenarios are more likely to happen. Another assumption is that MAS results about the energy price are not correlated with the other parameters used during Monte Carlo Simulation and thus, the probability distributions of the rest of the parameters have not been updated.

CHAPTER 6

RESULTS AND CONCLUSIONS

In conclusion, this research, provides general information about the energy sector in Turkey. Different types of renewable energy are explained. The Turkish government's available and targeted installed power capacity for each renewable energy is clarified. The cash flow analysis for hydroelectric power plants is explained. All the cash flow parameters related to hydroelectric power plants are determined. These parameters can help the investors who might consider investing in hydroelectric power plants. Although the value of the parameters can be changed depending on the project, the cash flow analysis of the case study can give a general idea to the investors about the value of parameters.

All of the technical and external risk factors for the hydroelectric power plant projects are determined. The impact of the risk factors in HEPP projects for each parameter is clarified. In light of these risk factors and impacts, the risk analysis of HEPP projects in Turkey can be easily performed. These risk factors can also be the basis of the further risk analysis studies of the other renewable (wind, solar, biomass, geothermal) power plant projects in Turkey.

The cash flow parameters' probability distributions are determined. The percentage changes of parameters for the best and worst scenarios are found. These probability distributions and percentage changes can give the investors information about the best and worst scenarios of any HEPP projects in Turkey. By performing sensitivity analysis in the Monte Carlo Simulation, the importance of the cash flow parameters while determining the NPV of the case study is found.

The risk factors for the negotiation process for the selling price of energy between investors and brokers are determined. With the help of these risk factors, all the possible scenarios for the negotiation process between investors and brokers are determined. The negotiation process between investors and brokers is modelled by using a Multi Agent System. The Zeuthen Strategy is selected for the negotiation strategy.

The results demonstrate that deterministic NPV calculation is very pessimistic which may result in the rejection of a project which is actually a profitable one. Experts also mention that deterministic NPV is not very realistic as it is based on worst case scenarios regarding the selling price of energy. The NPV value which is calculated as a result of risk assessments using Monte Carlo Simulation is more realistic as it considers all possible scenarios. The probability distribution of the selling price of energy depends on subjective judgements and ignores the negotiation between the parties under different demand-supply conditions. In the case study, the MAS model results in a more optimistic NPV. Experts trust this figure because all possible scenarios (32 scenarios) are considered rather than "random" scenarios created during the Monte Carlo Simulation which hardly reflects real world conditions (negotiation between the parties, energy market etc. are neglected). It is important to note that, when the NPVs are compared, the most pessimistic value is associated with deterministic analysis, whereas the most optimistic value is calculated by MAS based Monte Carlo Simulation (integrated methodology). The results cannot be generalized, although, it is widely accepted that in deterministic calculations, decision-makers refer to worst case scenarios to be on the safe side. This judgemental view cannot be generalized as it depends on the risk-attitude of investors. Under some circumstances (mainly about the energy market) the results of MAS may give a more pessimistic NPV value as compared with the NPV as a result of Monte Carlo Simulation. Consequently, the pessimistic/optimistic values of different techniques (deterministic, Monte Carlo Simulation and integrated methodology) can not be generalized but it can easily be said that the integrated methodology gives more realistic results as it depends on both risk scenarios and negotiations about selling price of electricity. The risk attitude of decision-makers directly affect the way that they define the probability distribution of selling price of energy. Thus, the results regarding the comparison of different of NPVs found with different methods should not be generalized. The research findings do reveal however, that experts "trust" the results of a combination of Monte Carlo Simulation with MAS, because the risk factors as well as negotiation process are taken into account. Thus, they think that NPV found as a result of MAS is more "realistic" in the way it is calculated which reflects investment conditions in a better way.

The significance of this study originate from the contributions and potential benefits for the industry such as:

- It is the first study in the literature that gives a methodology that combines the risk assessment and negotiation process while determining the feasibility of an investment, by giving the results of a case study of a real renewable power plant project tendered on a BOT basis.
- By using this methodology, investors and brokers can carry out more realistic feasibility studies. The investors can use this methodology to calculate NPV and prepare more realistic offers during the bidding stage. Also after the bidding stage, if bank credits are used for the investment, which is usually the case, they can make more realistic income predictions and the repayment of bank credit can be scheduled more realistically. An IT tool can be developed to facilitate the utilization of this methodology (integration of Monte Carlo Simulation with MAS).
- Another IT tool that uses the integrated methodology can be developed for the brokers to estimate the buying price of energy under different scenarios. The brokers buy energy from the investors and sell this energy to other users such as factories, hospitals, hotels. Their profit depends on the difference between the selling price of the energy to the users and the buying price of the energy from the investors. If they can make a more realistic estimation of the price of energy, they can maximize their profit.

Finally, it is worth noting that the proposed integrated methodology can be used for risk assessment and financial feasibility of other types of investments. The methodology proposed in this thesis can be applied to various cases where the uncertainty is high and incomes (as well as costs) are realized as a result of negotiations between different parties. Projects tendered on a BOT basis are potential candidates for the application of this methodology as uncertainties are high and the incomes are prone to different factors such as demand, negotiations with government etc. It is believed that the methodology proposed in this thesis may also give realistic results in transportation projects (such as toll roads etc.) as well as energy investments.

REFERENCES

Abedgeno, M. P., and Ogunlana, S. O. (2006). "Good project governance for proper risk allocation in public-private partnership in Indonesia.", *International Journal of Project Management*, 24, pp. 622-634.

Al-Azemi, K. F., Bhamra R., and Salman A. F. M. (2014). "Risk Management Framework for Build, Operate and Transfer (BOT) Projects in Kuwait.", *Journal of Civil Engineering and Management*, 20(3), pp. 415-433.

Al-Bahar, J., and Crandall, K. (1990). "Systematic risk management approach for construction projects.", *Journal of Construction Engineering and Management*, 116, pp. 533-546.

Askar, M. M., and Gab-Allah, A. A. (2002). "Problems facing parties involved in build, operate and transport projects in Egypt.", *Journal of Management in Engineering*, 18(4), pp. 173-178.

Cleary, P. J. (2001). "The Negotiation Handbook.", *M. E. Sharpe Inc*.

De Oliveira, E., Fonseca, J., and Steiger-Garcao, A. (1997). "MACIV:A DAI based resource management system.", *Appl. Artif. Intell.*, 11(6), 525–550.

El-Adaway, I., and Kandil, A. (2010). "Multi-agent system for construction dispute resolution (MAS-COR).", *J. Constr. Eng. Manage.*, 136(3), 303–315.

Flanagan, R., and Norman, G. (1993). "Risk Management and Construction", *Victoria: Blackwell Science Pty Ltd, Australia.*

Ibrahim, A. D., Price, A.D.F., and Dainty, A.R.J. (2006). “The analysis and allocation of risks in public private partnerships in infrastructure projects in Nigeria”, *Journal of Financial Management of Property and Construction*, 11 (3), pp. 149-163.

International Energy Agency (2007). “Renewables in global energy supply, fact sheet”, *OECD/IEA*, Paris.

Karakas, K. (2010). “Development of a multi agent system for negotiation of cost overrun in international construction projects.”, *M.Sc. Thesis*, Middle East Technical Univ., Ankara, Turkey.

Karakas, K., Dikmen I., and Birgonul, M. T. (2013). “Multiagent System to Simulate Risk-Allocation and Cost-Sharing Processes in Construction Projects”, *Journal of Computing in Civil Engineering*, 27(3), pp. 307-319.

Karim, N. A. A. (2011). “Risk Allocation in Public-Private Partnership (PPP) Project: A Review on Risk Factors”, *International Journal of Sustainable Construction Engineering & Technology*, 2(2), pp. 8-16.

Kim, K., and Paulson, B. (2003). “Agent-based compensatory negotiation methodology to facilitate distributed coordination of project schedule changes.”, *J. Comput. Civil Eng.*, 17(1), pp. 10–18.

Kraus, S., Wilkenfeld, J., and Zlotkin, G. (1995). “Multiagent negotiation under time constraints.”, *Artificial Intelligance*, pp. 297-345.

Li, B., Akintoye, A., Edwards, P.J., and Hardcastle C. (2005). “The Allocation of Risk in PPP/PFI Construction Projects in the UK”, *International Journal of Project Management,* 23 (1), pp. 25-35.

Mane, S., and Pimplikar, S. S. (2013). “Risk Assessment of BOT Projects.”, *International Journal of Computational Engineering Research*, 3(8), pp. 63-69.

Molinero, C., and Núñez, M. (2011). “Planning of work schedules through the use of a hierarchical multi-agent system.”, *Automation in Construction,* 20(8), pp. 1227–1241.

Ng, S. T., and Li, W. (2006). “Parallel bargaining protocol for automated sourcing of construction suppliers.”, *Automation in Construction*, 15(3), pp. 365–373.

Ng, A., and Loosemore M. (2007). “Risk Allocation in the private provision of public infrastructure.”, *International Journal of Project Management,* 25(1), pp. 66-76.

Ozdoğan Dikmen, I., and Birgonul, M.T. (2000). “A Decision Support Framework for Project Sponsors in the Planning Stage of Build-Operate-Transfer (BOT) Projects”, *Journal of Construction Management and Economics*, 18(3), pp. 343-353.

PMBOK. (2011). “Project Management Body of Knowledge”, *Project Management Institute.*

Ren, Z., and Anumba, C. (2004). “Multi-agent systems in construction — state of the art and prospects.”, *Automation Construction*, 13(3), pp. 421–434.

Schaufelberger, J. E. (2005). “Risk management on Build-Operate-Transfer Projects.”, *Construction Research Congress*, paper 7547.

Shen, L.Y., Platten, A., and Dang, X. (2006). "Role of public private partnership to manage risk in public sector project in Hong Kong.", *International Journal of Project Management*, 24, pp. 587-594.

Shoham, Y. (1993). “Agent-Oriented Programming.”, *Artificial Intelligence*, pp. 51-92.

Singh, L.B., and Kalidindi, S.N., (2006). “Traffic revenue risk management through Annuity Model of PPP road projects in India.”, *International Journal of Project Management,* 24, pp. 605–613.

Smith, N.J. (1999). “Managing Risk in Construction Projects”, *Blackwell Science.*

Tah, J. H. (2005). “Towards an agent-based construction supply network.”, *Automation in Construction*, 14(3), pp. 353–359.

Taylor, J. E., Levitt, R., and Villarroel, J. A. (2009). “Simulating learning dynamics in project networks.”, *Journal of Construction Engineering and Management*, 135(10), pp. 1009–1015.

Topal, M., and Arslan, E.I. (2008). “Biyokütle Enerjisi ve Türkiye”, *VII. Ulusal Temiz Enerji Sempozyumu*, İstanbul, pp-241-248.

Wang, S. Q., Tiong, R. L. K., Ting, S. K., and Ashley, D. (2000). “Evaluation and management of foreign exchange and revenue risks in China’s BOT projects.”, *Construction Management and Economics*, 18, pp. 197-207.

Wibowo, A., and Mohamed, S., (2010). “Risk criticality and allocation in privatised water supply projects in Indonesia.”, *International Journal of Project Management*, 28, pp. 504-513.

Xenidis, Y., and Angelides, D. (2005). “The financial risks in build-operate-transfer projects.”, *Construction Management and Economics*, 23(4), pp. 431-441.

Xiao, H.J., and Zhang, G. (2011). “Modelling optimal risk allocation in PPP projects using artificial neural networks.”, *International Journal of Project Management*, 29, pp. 591–603.

Xue, X., Li, X., Shen, Q., and Wang, Y. (2005). “An agent-based framework for supply chain coordination in construction.”, *Automation in Construction*, 14(3), pp. 413–430.

Xue, X. L., Shen, Q. P., O’Brien, W., and Ren, Z. M. (2009). “Improving agent-based negotiation efficiency in construction supply chains: A relative entropy method.”, *Automation in Construction*, 18(7), pp. 975–982.

Yelin, X., Cheng, H., and Chan, P.C. (2009). "Risk factors for running Public Private Partnerships (PPP) – An Empirical.", *IEEE*.

Yongjian, K., ShouQing, W., and Albert P. C. C. (2009). “Preffered Risk Allocation in China’s Public Private Partnership (PPP) Projects.”, *Journal of Project Management*, 28, pp. 482-492.

Yuan, J.F., Peng, X., and Li, D.M. (2008). "Critical risks identification of Public Private Partnerships in China and the analysis on questionnaire survey", *IEEE*.

Zayed, T., and Chang, L. (2002). “Prototype Model for Build-Operate-Transfer Risk Assessment.”, *J. Manage. Eng.*, 18(1), pp. 7–16.

Zhang, X. (2005). “Paving the Way for Public–Private Partnerships in infrastructure development.”, *Journal of Construction Engineering and Management*, 131(1), pp. 71-80.

APPENDIX A

A. QUESTIONNAIRE

Table A.1: Questionnaire for Determining the Impact of Risk Factors

Risk factors	Selling price of energy	Amount of Energy Produced	Interest Rate	Duration of Construction	Cost of Expropriation	Cost of Operation	Cost of Construction
E1. Change in law							
E2. Delay in project approvals and permits							
E3. Delay in expropriation /nationalization of assets							
E4. Change in government							
E5. Unavailability of material during construction							
E6. Unavailability of labor during construction							
E7. Unavailability of finance							
E8. Insolvency of subcontractors and suppliers							
E9. Change in tax regulations							
E10. Import restrictions							
E11. Inflation rate volatility							
E12. Changes in foreign exchange rates and inconvertibility							
E13. Adverse change in financial markets							
E14. Change in tariff rates by the government							
E15. Change in energy market demand							

Table A.1: Questionnaire for Determining the Impact of Risk Factors (Continued)

Risk factors	Selling price of energy	Amount of Energy Produced	Interest Rate	Duration of Construction	Cost of Expropriation	Cost of Operation	Cost of Construction
E16. Public opposition to project							
E17. Change in interest rates							
E18. Force majeure risk							
E19. Unfavorable weather conditions during construction							
E20. Low flow rate during the operation period							
T1. Problems with design							
T2. Delay of construction							
T3. Vagueness of geotechnical conditions							
T4. Poor quality of construction (rework)							
T5. Change of scope (increase/decrease in quantities)							
T6. Technical problems during operation							
T7. Technical problems (related with construction method etc.) during construction							
T8. Organization and coordination risk							
T9. Third party delays (suppliers, subcontractors etc.)							
T10. Accidents							

APPENDIX B

B. RESULT OF QUESTIONNAIRE

Table B.1: Result of Questionnaire

Risk factors	Selling price of energy	Amount of Energy Produced	Interest Rate	Duration of Construction	Cost of Expropriation	Cost of Operation	Cost of Construction
E1. Change in law	3	0	2	3	3	2	1
E2. Delay in project approvals and permits	0	0	0	3	1	0	3
E3. Delay in expropriation /nationalization of assets	0	3	0	3	2	0	3
E4. Change in government	2	0	2	1	1	1	1
E5. Unavailability of material during construction	0	0	0	3	0	1	2
E6. Unavailability of labor during construction	0	0	0	3	0	0	2
E7. Unavailability of finance	0	0	3	3	0	1	2
E8. Insolvency of subcontractors and suppliers	0	0	0	3	0	0	3
E9. Change in tax regulations	2	0	1	0	1	1	2
E10. Import restrictions	0	0	1	3	0	2	2
E11. Inflation rate volatility	2	0	3	2	1	2	2
E12. Changes in foreign exchange rates and inconvertibility	2	0	3	0	1	2	2
E13. Adverse change in financial markets	2	0	3	0	1	1	2
E14. Change in tariff rates by the government	3	0	1	0	0	0	0
E15. Change in energy market demand	3	0	0	0	0	0	0

Table B.1: Result of Questionnaire (Continued)

Risk factors	Selling price of energy	Amount of Energy Produced	Interest Rate	Duration of Construction	Cost of Expropriation	Cost of Operation	Cost of Construction
E16. Public opposition to project	0	1	0	3	2	1	3
E17. Change in interest rates	0	0	3	0	0	1	2
E18. Force majeure risk	1	1	1	3	0	2	3
E19. Unfavorable weather conditions during construction	0	0	0	3	0	0	2
E20. Low flow rate during the operation period	0	3	0	0	0	0	0
T1. Problems with design	0	3	0	1	0	2	2
T2. Delay of construction	0	1	0	3	0	0	2
T3. Vagueness of geotechnical conditions	0	1	0	2	0	0	2
T4. Poor quality of construction (rework)	0	1	0	2	0	2	2
T5. Change of scope (increase/decrease in quantities)	0	2	0	2	1	1	2
T6. Technical problems during operation	0	2	0	0	0	3	0
T7. Technical problems (related with construction method etc.) during construction	0	1	0	2	0	1	2
T8. Organization and coordination risk	0	1	0	3	1	2	2
T9. Third party delays (suppliers, subcontractors etc.)	0	1	0	3	0	1	2
T10. Accidents	0	2	0	2	1	2	2

APPENDIX C

C. POSSIBLE NEGOTIATION SCENARIOS AND RESULTS

Table C.1: Scenario 1

Scenario-1														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						35,7	46,4	17,8	41,1	55,5	22,6	30,3	37,3	13,0

Cmin	30,3
Coptimum	53,5

Investor	
First Offer	63,7
Reservation	30,3

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	37,5
Reservation	53,5

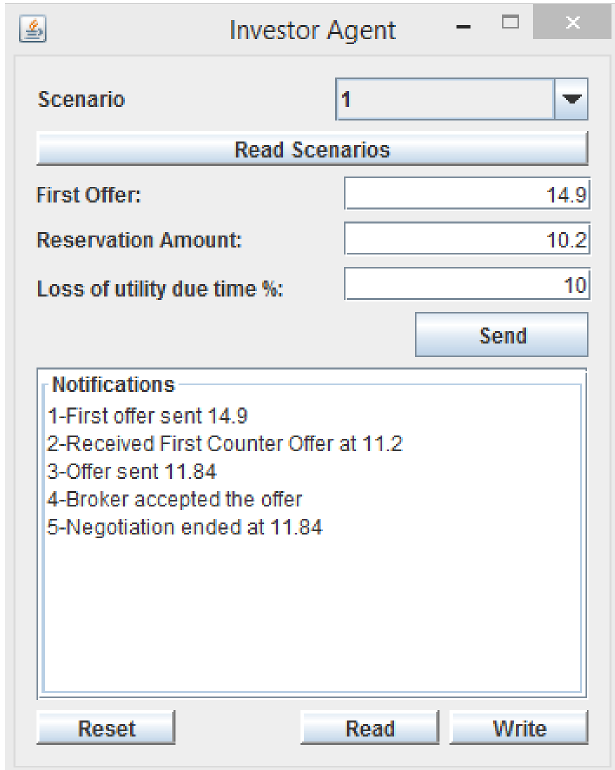

Figure C.1: Investor Agent in Negotiation Process for Scenario 1

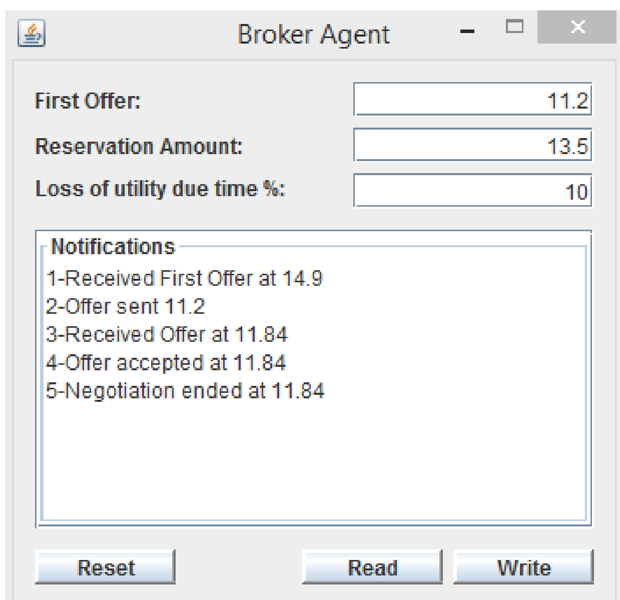

Figure C.2: Broker Agent in Negotiation Process for Scenario 1

Table C.2: Scenario 2

Scenario-2														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						35,7	46,4	17,8	41,1	55,5	22,6	30,3	37,3	13,0

Cmin	30,3
Coptimum	53,5

Investor	
First Offer	63,7
Reservation	30,3

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	37,5
Reservation	53,5

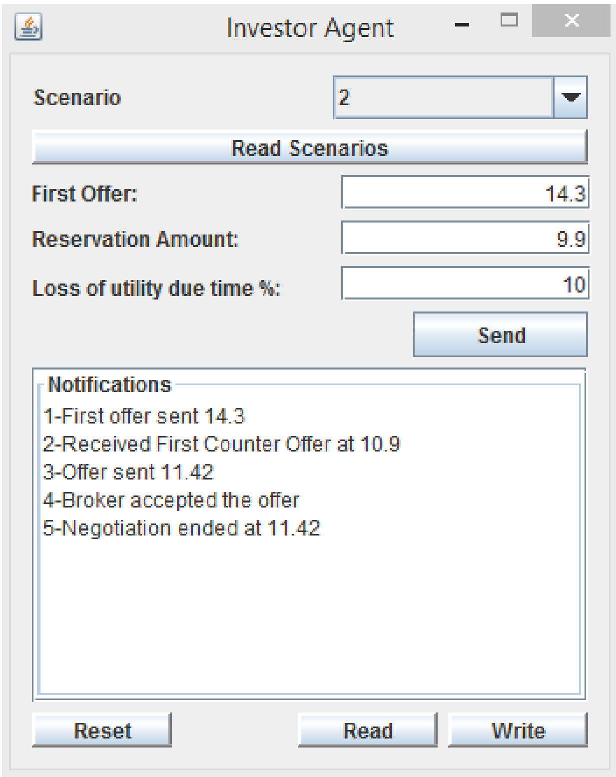

Figure C.3: Investor Agent in Negotiation Process for Scenario 2

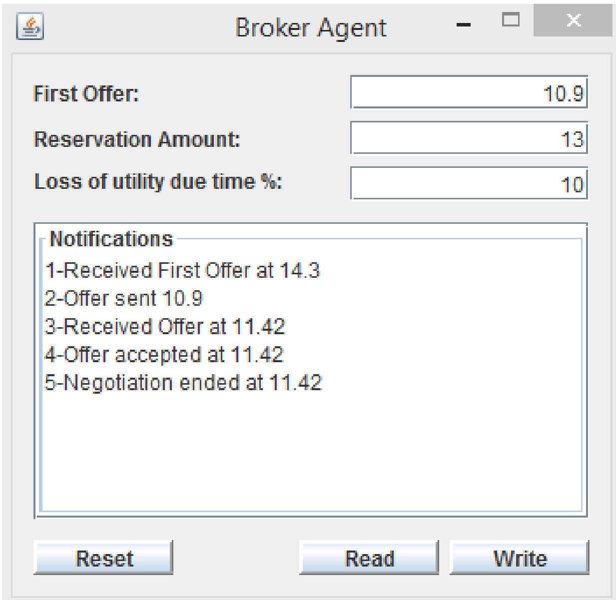

Figure C.4: Broker Agent in Negotiation Process for Scenario 2

Table C.3: Scenario 3

Scenario-3														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						35,7	46,4	17,8	41,1	55,5	22,6	30,3	37,3	13,0

Cmin	30,3
Coptimum	53,5

Investor	
First Offer	63,7
Reservation	30,3

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	37,5
Reservation	53,5

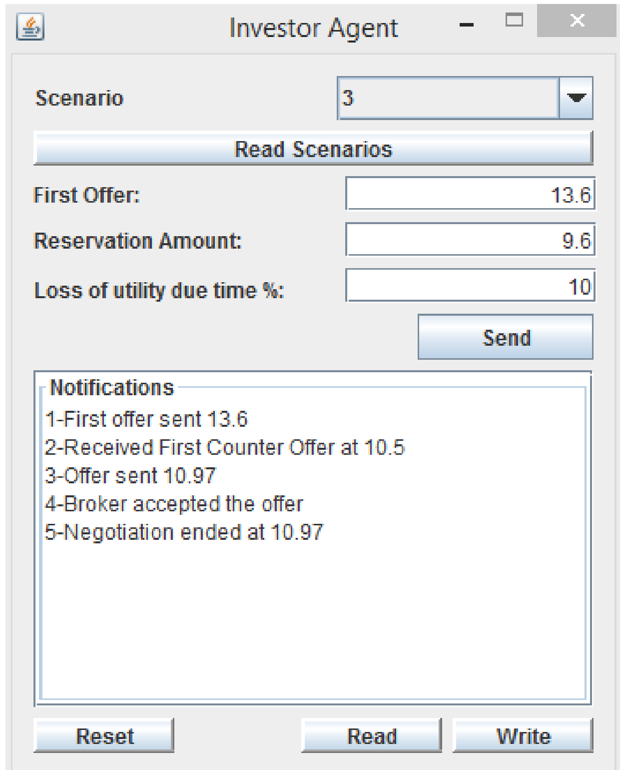

Figure C.5: Investor Agent in Negotiation Process for Scenario 3

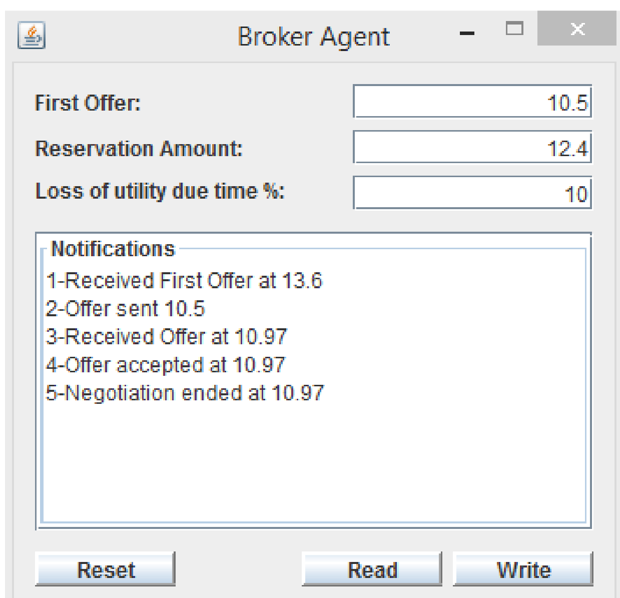

Figure C.6: Broker Agent in Negotiation Process for Scenario 3

Table C.4: Scenario 4

Scenario-4														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						35,7	46,4	17,8	41,1	55,5	22,6	30,3	37,3	13,0

Cmin	30,3
Coptimum	53,5

Investor	
First Offer	63,7
Reservation	30,3

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	37,5
Reservation	53,5

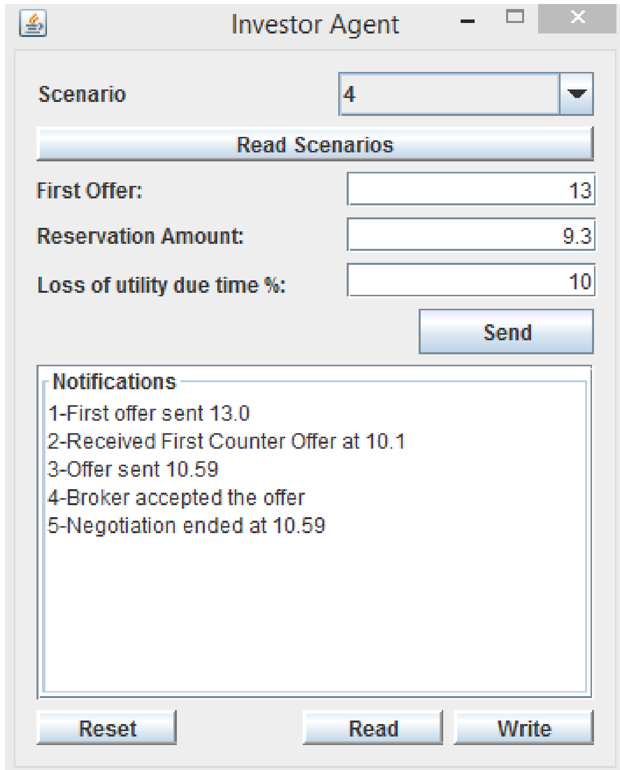

Figure C.7: Investor Agent in Negotiation Process for Scenario 4

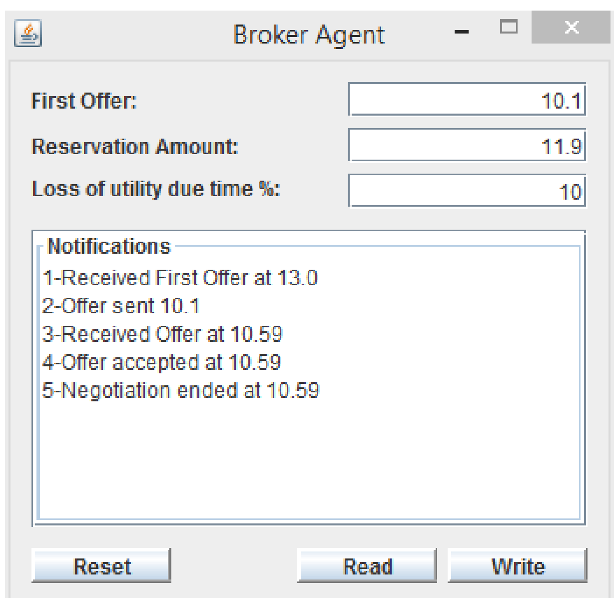

Figure C.8: Broker Agent in Negotiation Process for Scenario 4

Table C.5: Scenario 5

Scenario-5															
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						57,1	25	17,8	67,8	28,8	22,6	46,4	21,3	13,0

Cmin	46,4
Coptimum	74,9

Investor	
First Offer	90,4
Reservation	46,4

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	52,4
Reservation	74,9

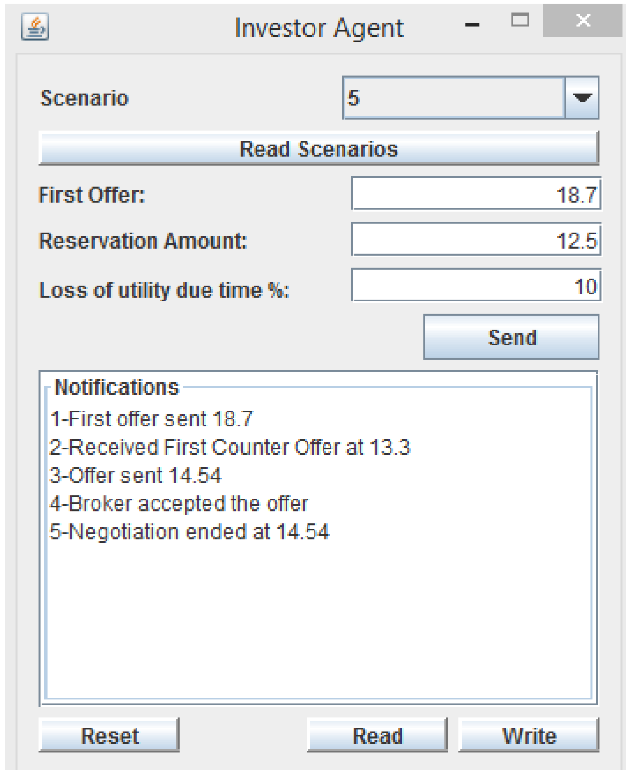

Figure C.9: Investor Agent in Negotiation Process for Scenario 5

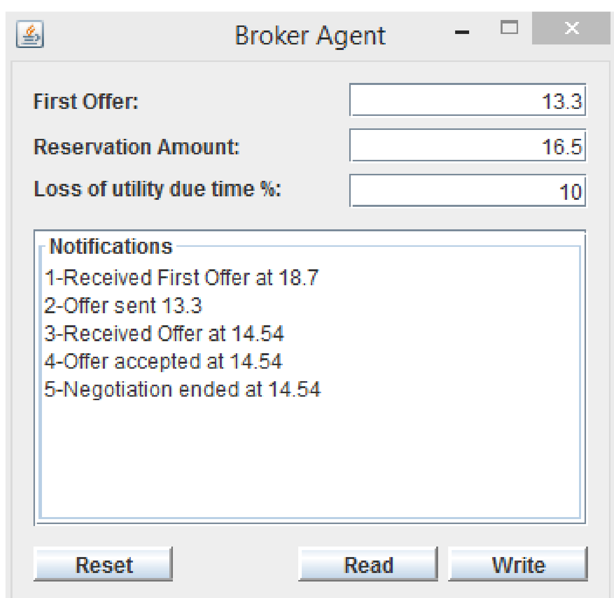

Figure C.10: Broker Agent in Negotiation Process for Scenario 5

Table C.6: Scenario 6

Scenario-6						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						57,1	25	17,8	67,8	28,8	22,6	46,4	21,3	13,0

Cmin	46,4
Coptimum	74,9

Investor	
First Offer	90,4
Reservation	46,4

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	52,4
Reservation	74,9

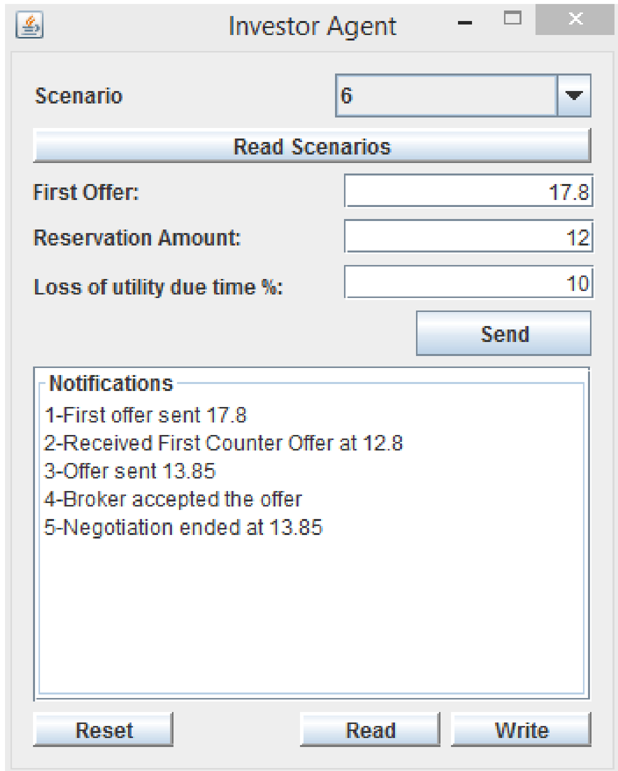

Figure C.11: Investor Agent in Negotiation Process for Scenario 6

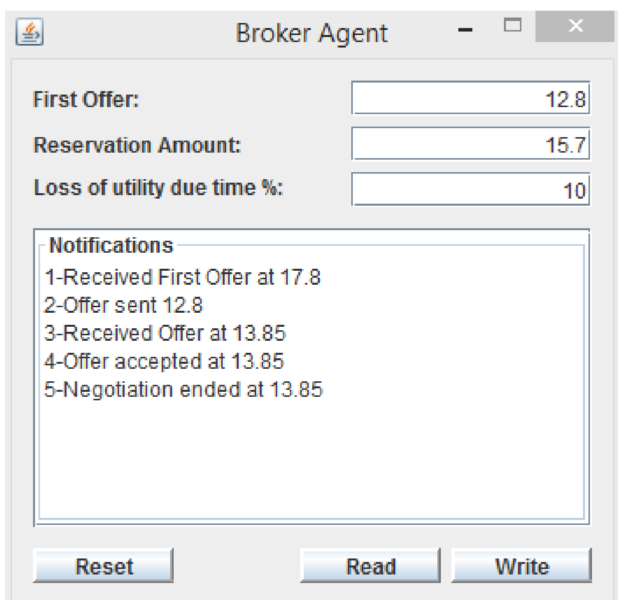

Figure C.12: Broker Agent in Negotiation Process for Scenario 6

Table C.7: Scenario 7

Scenario-7

	Case	Power	Weight	Fuzziness	Fuzziness Value	No Fuzzy			Fuzzy Max			Fuzzy Min		
						Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						57,1	25	17,8	67,8	28,8	22,6	46,4	21,3	13,0

Cmin	46,4
Coptimum	74,9

Investor	
First Offer	90,4
Reservation	46,4

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	52,4
Reservation	74,9

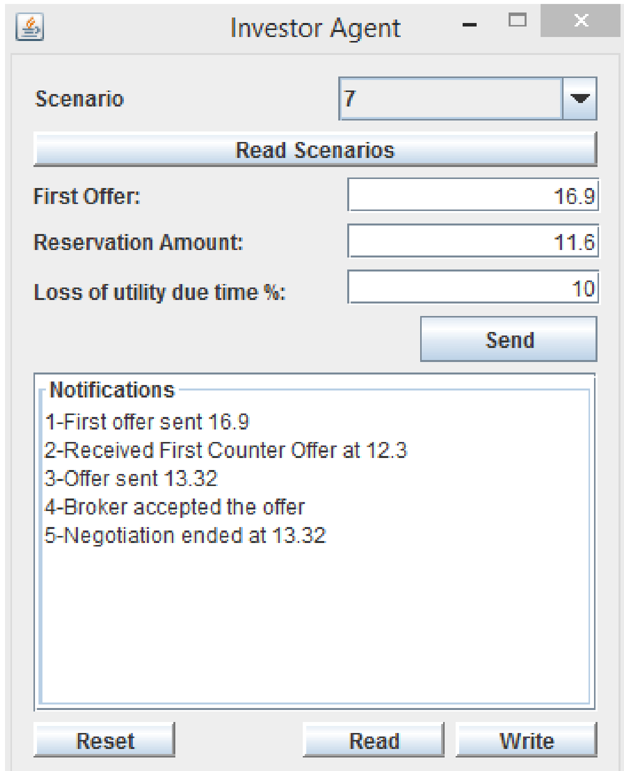

Figure C.13: Investor Agent in Negotiation Process for Scenario 7

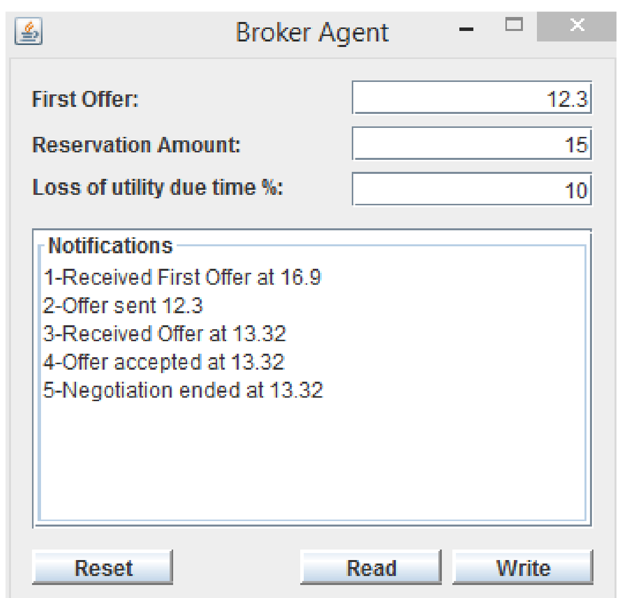

Figure C.14: Broker Agent in Negotiation Process for Scenario 7

Table C.8: Scenario 8

Scenario-8														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						57,1	25	17,8	67,8	28,8	22,6	46,4	21,3	13,0

Cmin	46,4
Coptimum	74,9

Investor	
First Offer	90,4
Reservation	46,4

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	52,4
Reservation	74,9

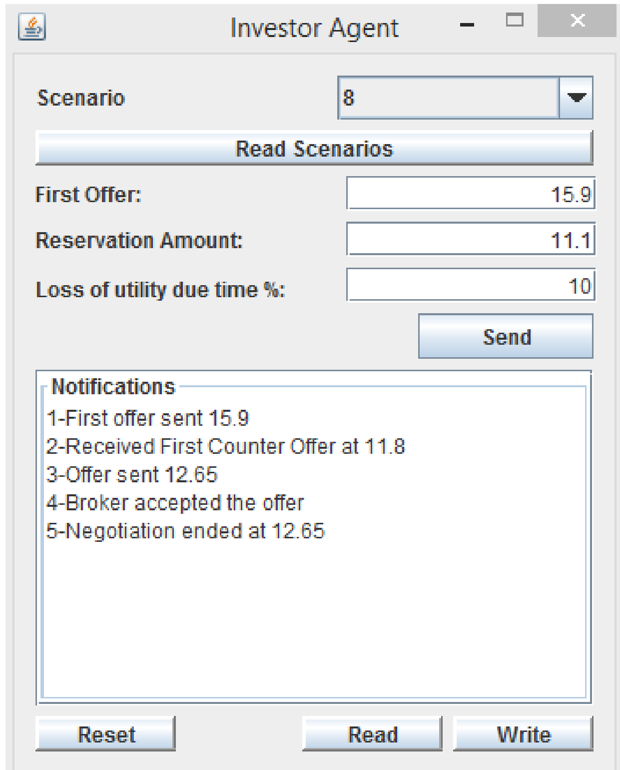

Figure C.15: Investor Agent in Negotiation Process for Scenario 8

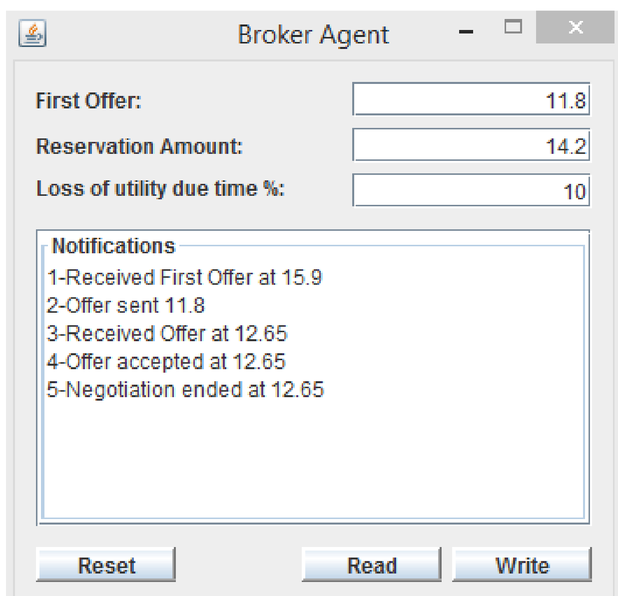

Figure C.16: Broker Agent in Negotiation Process for Scenario 8

Table C.9: Scenario 9

Scenario-9						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						60,7	21,4	17,8	69,8	26,8	22,6	51,6	16,1	13,0

Cmin	51,6
Coptimum	78,5

Investor	
First Offer	92,4
Reservation	51,6

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	55,0
Reservation	78,5

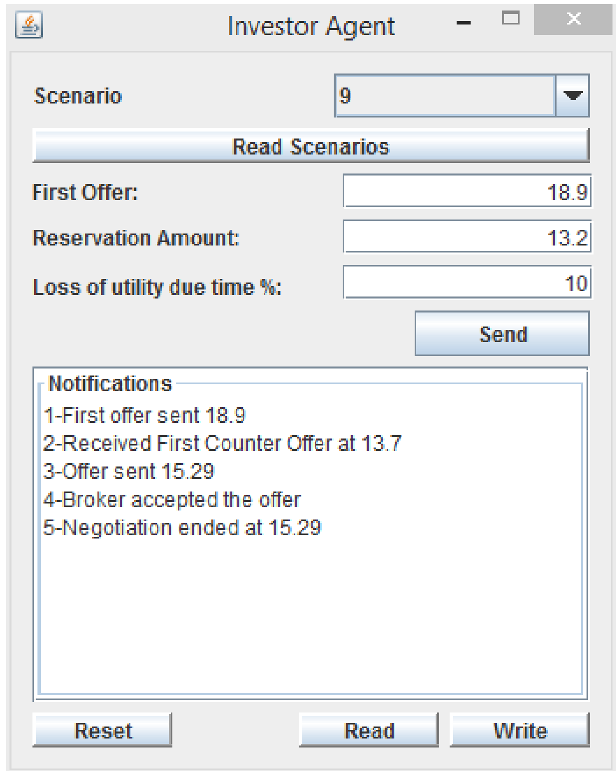

Figure C.17: Investor Agent in Negotiation Process for Scenario 9

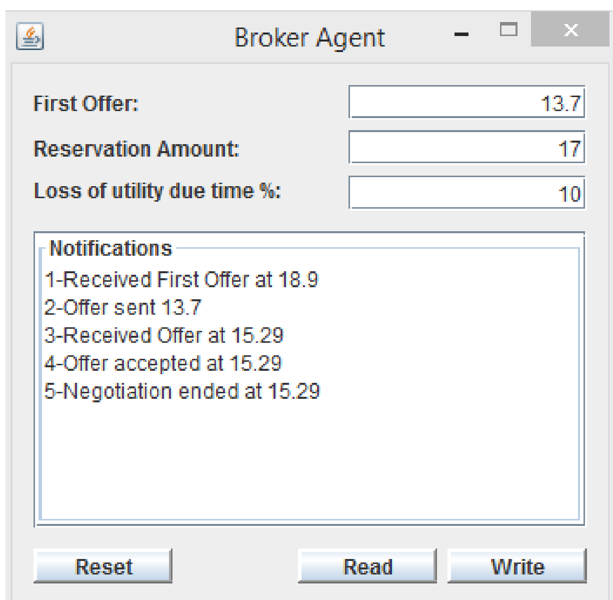

Figure C.18: Broker Agent in Negotiation Process for Scenario 9

Table C.10: Scenario 10

Scenario-10						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						60,7	21,4	17,8	69,8	26,8	22,6	51,6	16,1	13,0

Cmin	51,6
Coptimum	78,5

Investor	
First Offer	92,4
Reservation	51,6

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	55,0
Reservation	78,5

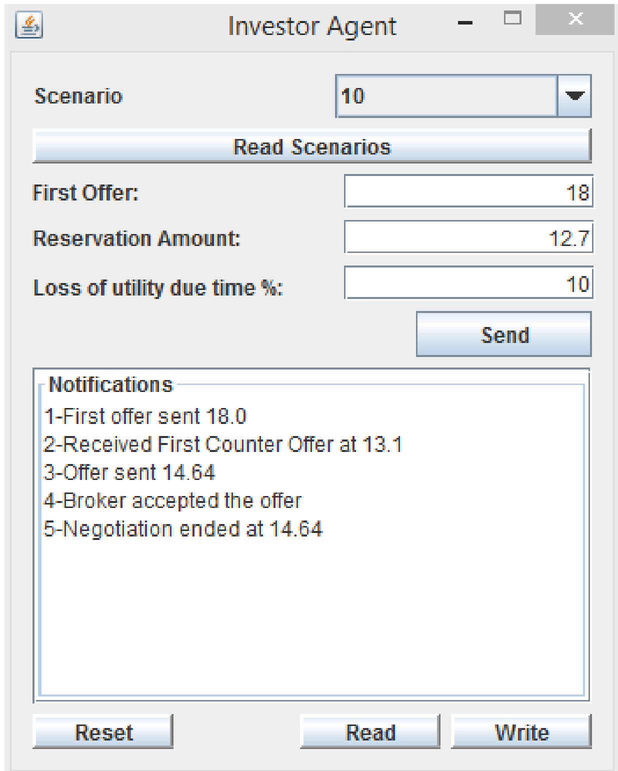

Figure C.19: Investor Agent in Negotiation Process for Scenario 10

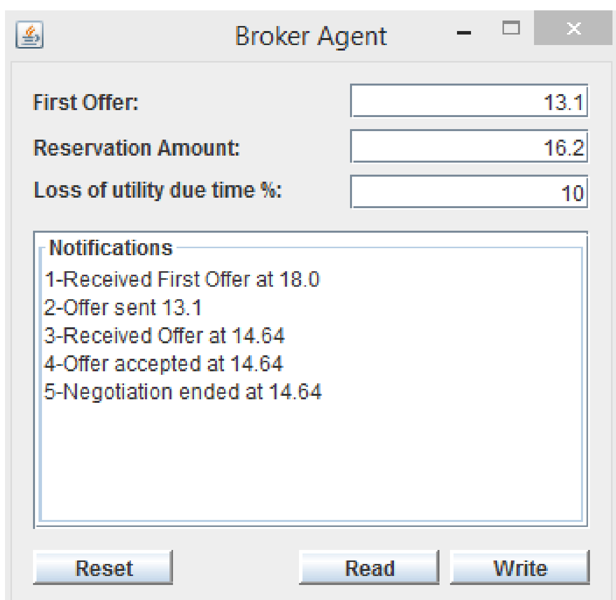

Figure C.20: Broker Agent in Negotiation Process for Scenario 10

Table C.11: Scenario 11

Scenario-11														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						60,7	21,4	17,8	69,8	26,8	22,6	51,6	16,1	13,0

Cmin	51,6
Coptimum	78,5

Investor	
First Offer	92,4
Reservation	51,6

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	55,0
Reservation	78,5

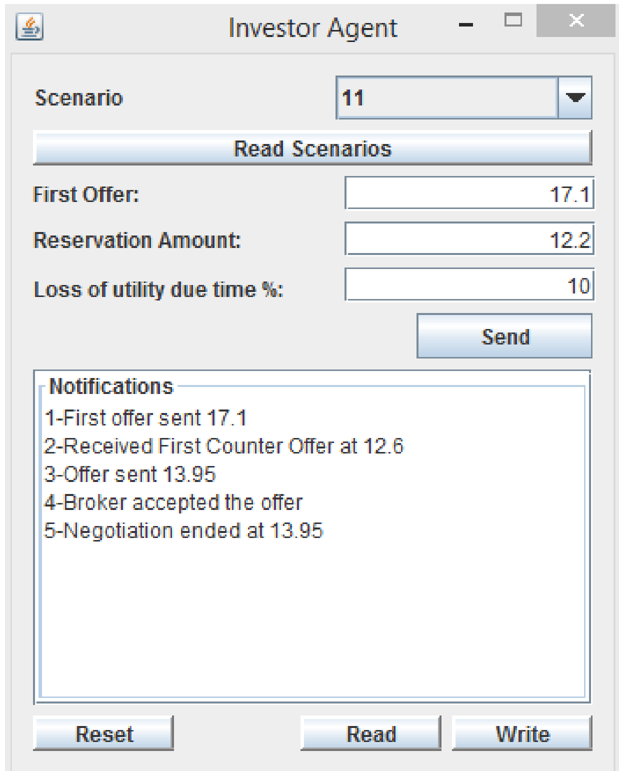

Figure C.21: Investor Agent in Negotiation Process for Scenario 11

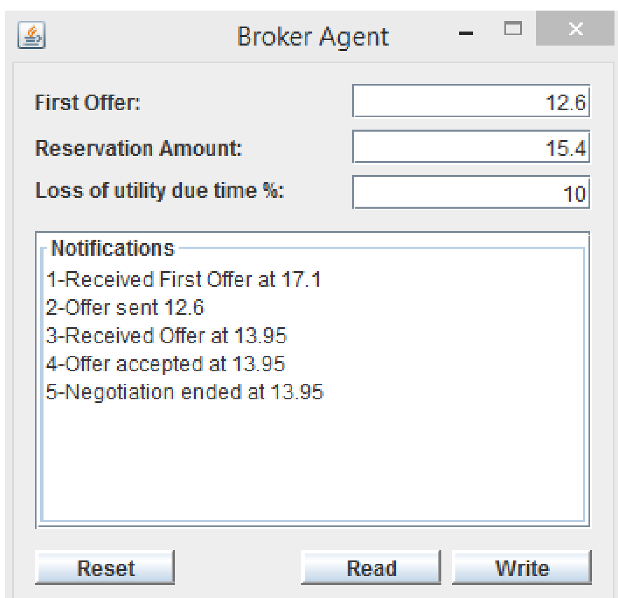

Figure C.22: Broker Agent in Negotiation Process for Scenario 11

Table C.12: Scenario 12

Scenario-12						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						60,7	21,4	17,8	69,8	26,8	22,6	51,6	16,1	13,0

Cmin	51,6
Coptimum	78,5

Investor	
First Offer	92,4
Reservation	51,6

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	55,0
Reservation	78,5

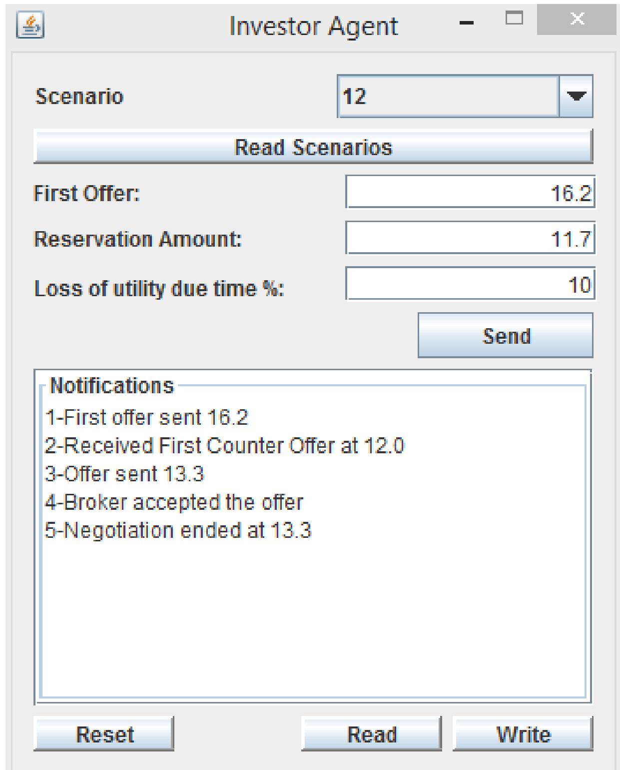

Figure C.23: Investor Agent in Negotiation Process for Scenario 12

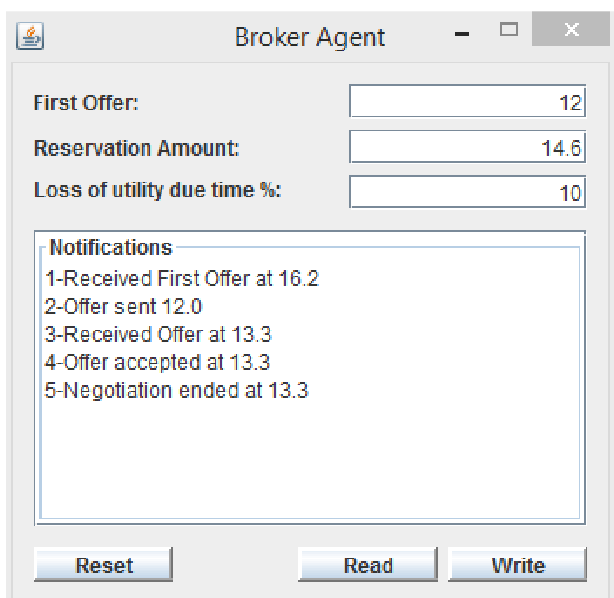

Figure C.24: Broker Agent in Negotiation Process for Scenario 12

Table C.13: Scenario 13

Scenario-13						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						82,1	0	17,8	96,6	0,0	22,6	67,6	0,0	13,0

Cmin	67,6
Coptimum	99,9

Investor	
First Offer	119,2
Reservation	67,6

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	69,9
Reservation	99,9

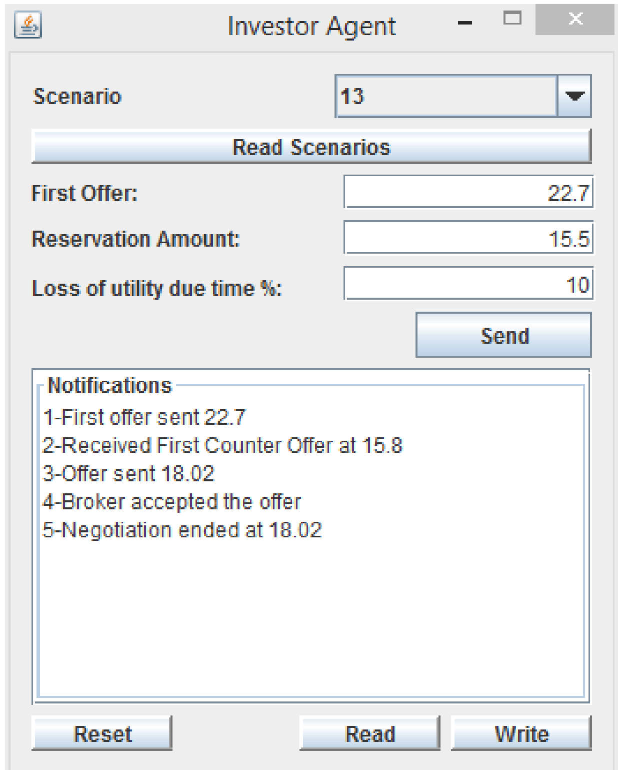

Figure C.25: Investor Agent in Negotiation Process for Scenario 13

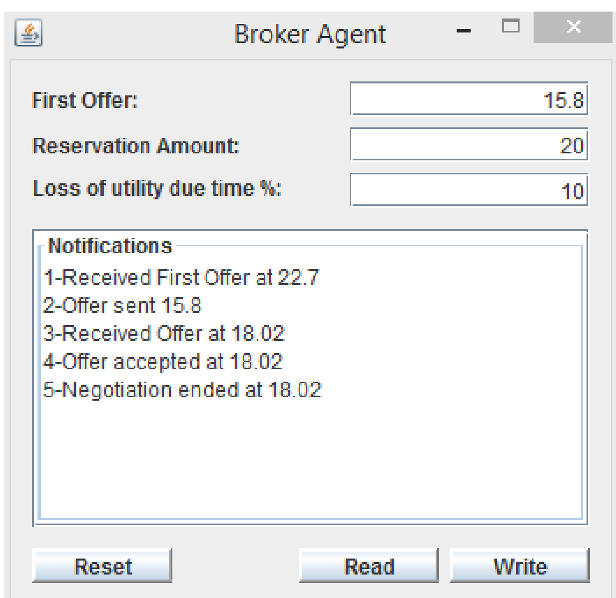

Figure C.26: Broker Agent in Negotiation Process for Scenario 13

Table C.14: Scenario 14

Scenario-14

	Case	Power	Weight	Fuzziness	Fuzziness Value	No Fuzzy			Fuzzy Max			Fuzzy Min		
						Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						82,1	0	17,8	96,6	0,0	22,6	67,6	0,0	13,0

Cmin	67,6
Coptimum	99,9

Investor	
First Offer	119,2
Reservation	67,6

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	69,9
Reservation	99,9

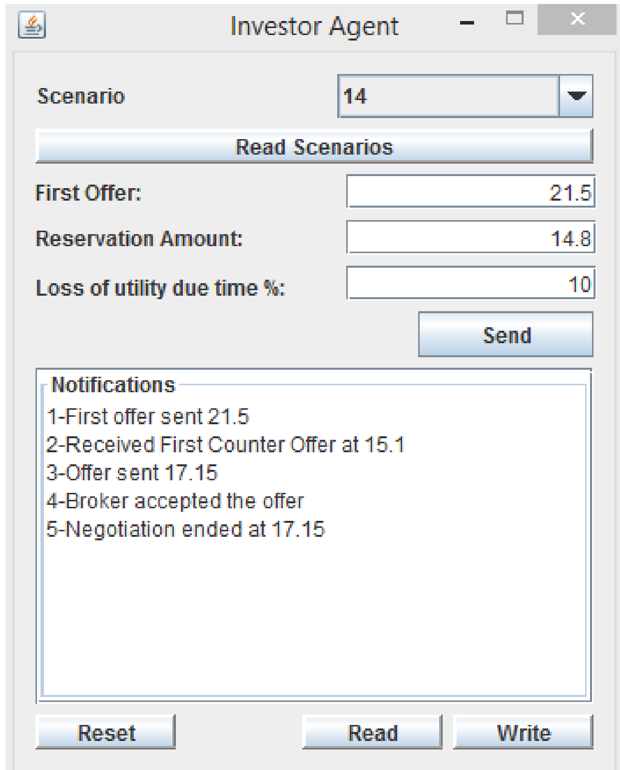

Figure C.27: Investor Agent in Negotiation Process for Scenario 14

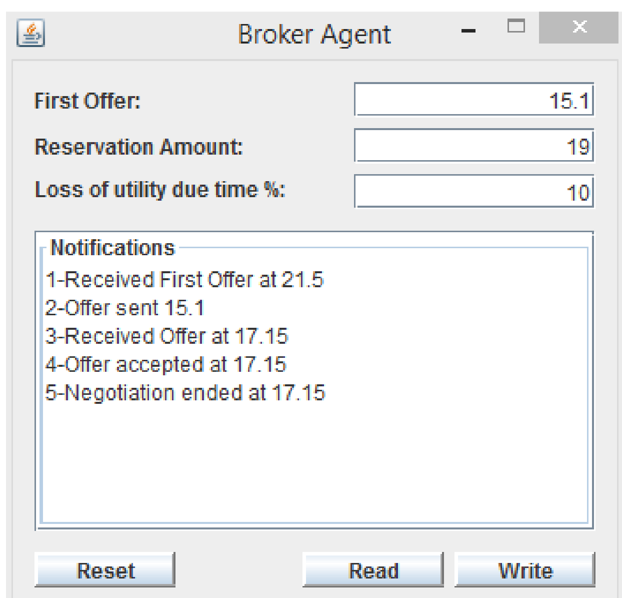

Figure C.28: Broker Agent in Negotiation Process for Scenario 14

Table C.15: Scenario 15

Scenario-15														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						82,1	0	17,8	96,6	0,0	22,6	67,6	0,0	13,0

Cmin	67,6
Coptimum	99,9

Investor	
First Offer	119,2
Reservation	67,6

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	69,9
Reservation	99,9

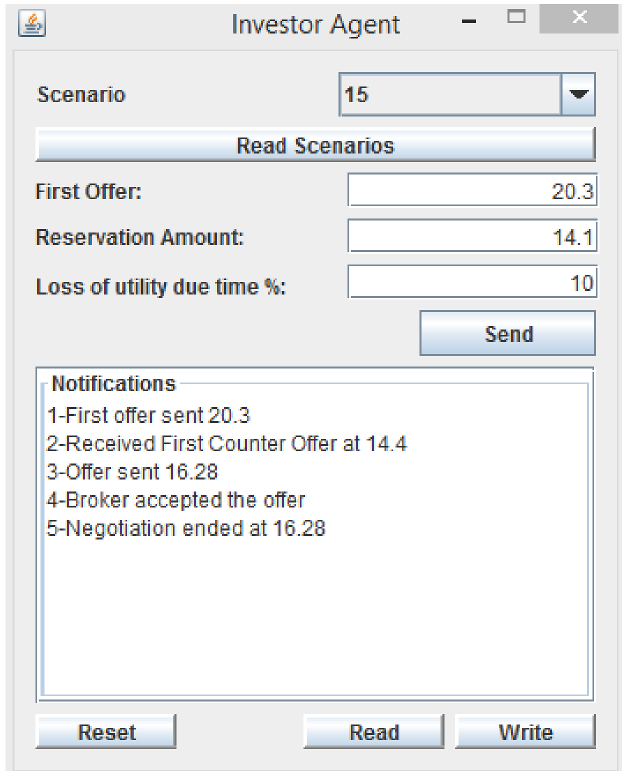

Figure C.29: Investor Agent in Negotiation Process for Scenario 15

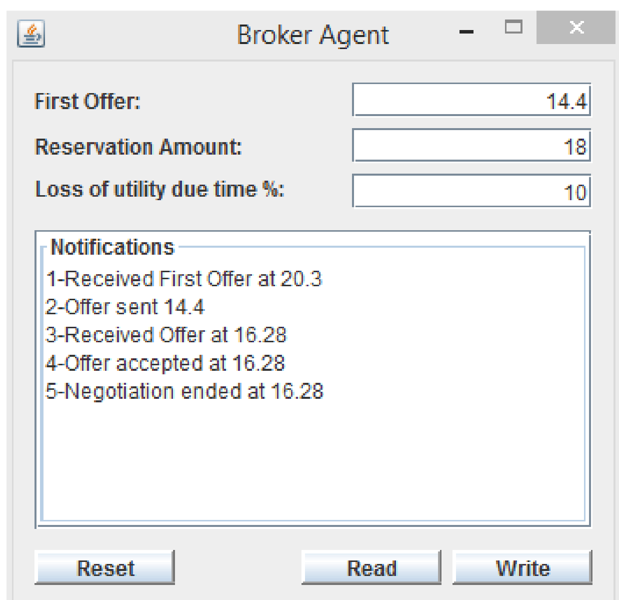

Figure C.30: Broker Agent in Negotiation Process for Scenario 15

Table C.16: Scenario 16

Scenario-16						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	High	I	35,7	L	15	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						82,1	0	17,8	96,6	0,0	22,6	67,6	0,0	13,0

Cmin	67,6
Coptimum	99,9

Investor	
First Offer	119,2
Reservation	67,6

Broker	
First Offer	69,9
Reservation	99,9

Start Negotiation

Maximum Price	17
Minimum Price	6

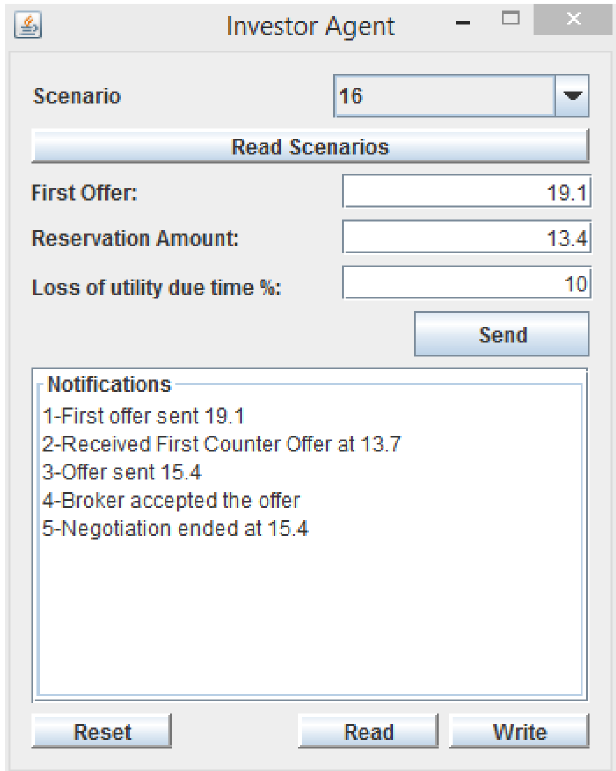

Figure C.31: Investor Agent in Negotiation Process for Scenario 16

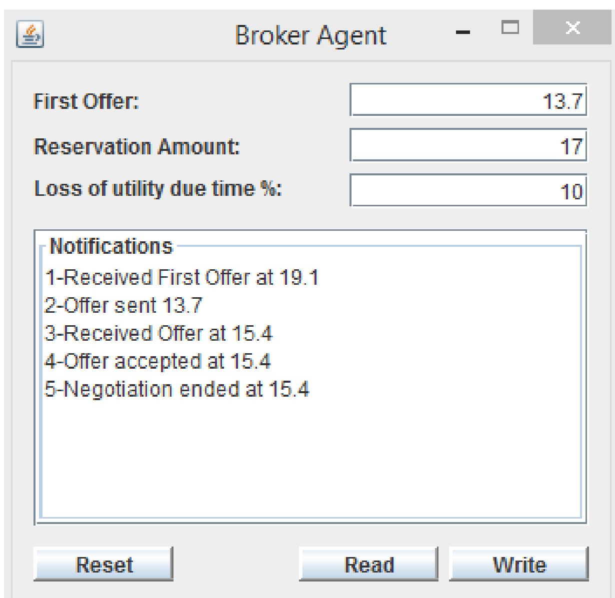

Figure C.32: Broker Agent in Negotiation Process for Scenario 16

Table C.17: Scenario 17

Scenario-17														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						46,4	35,7	17,8	55,5	41,1	22,6	37,3	30,3	13,0

Cmin	37,3
Coptimum	64,2

Investor	
First Offer	78,1
Reservation	37,3

Broker	
First Offer	44,9
Reservation	64,2

Start Negotiation

Maximum Price	20
Minimum Price	6

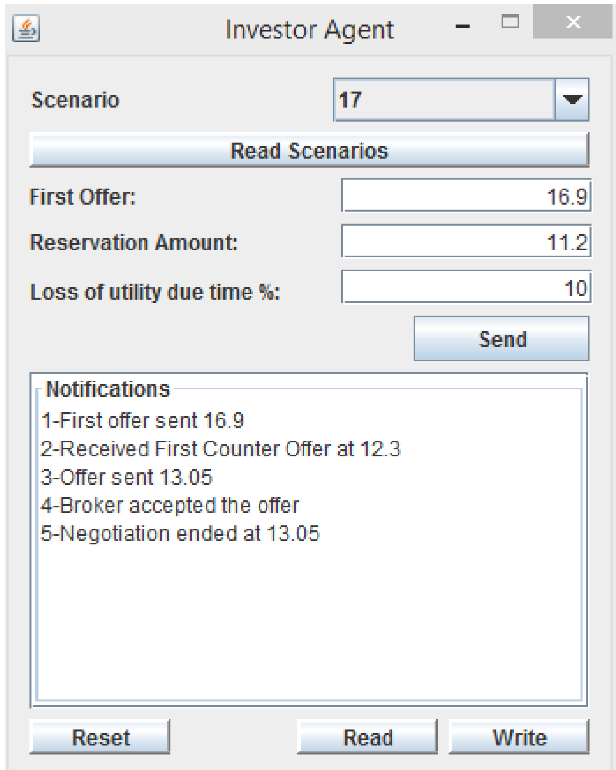

Figure C.33: Investor Agent in Negotiation Process for Scenario 17

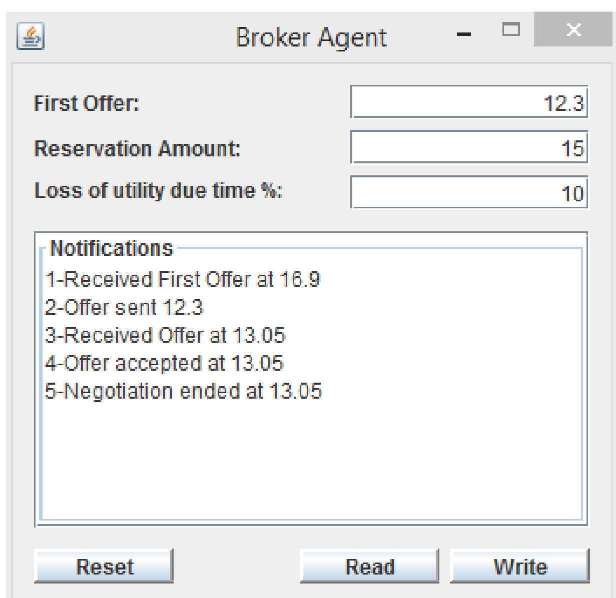

Figure C.34: Broker Agent in Negotiation Process for Scenario 17

Table C.18: Scenario 18

Scenario-18						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						46,4	35,7	17,8	55,5	41,1	22,6	37,3	30,3	13,0

Cmin	37,3
Coptimum	64,2

Investor	
First Offer	78,1
Reservation	37,3

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	44,9
Reservation	64,2

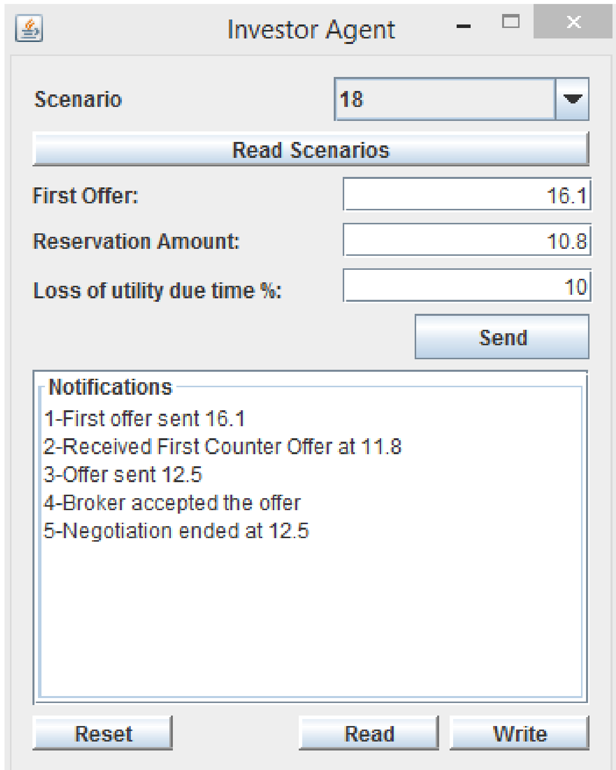

Figure C.35: Investor Agent in Negotiation Process for Scenario 18

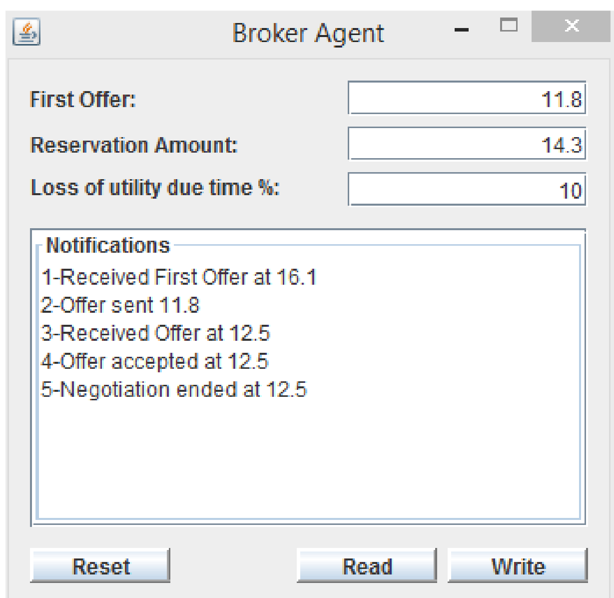

Figure C.36: Broker Agent in Negotiation Process for Scenario 18

Table C.19: Scenario 19

Scenario-19														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						46,4	35,7	17,8	55,5	41,1	22,6	37,3	30,3	13,0

Cmin	37,3
Coptimum	64,2

Investor	
First Offer	78,1
Reservation	37,3

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	44,9
Reservation	64,2

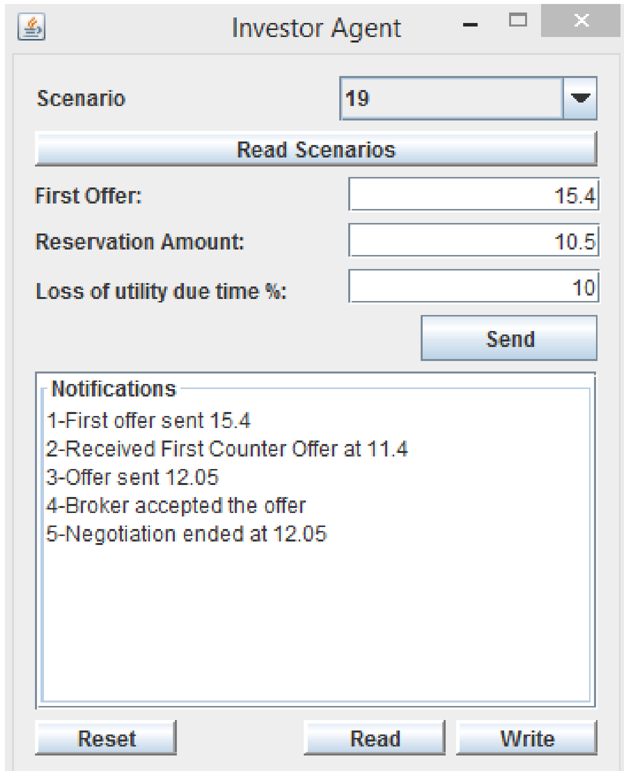

Figure C.37: Investor Agent in Negotiation Process for Scenario 19

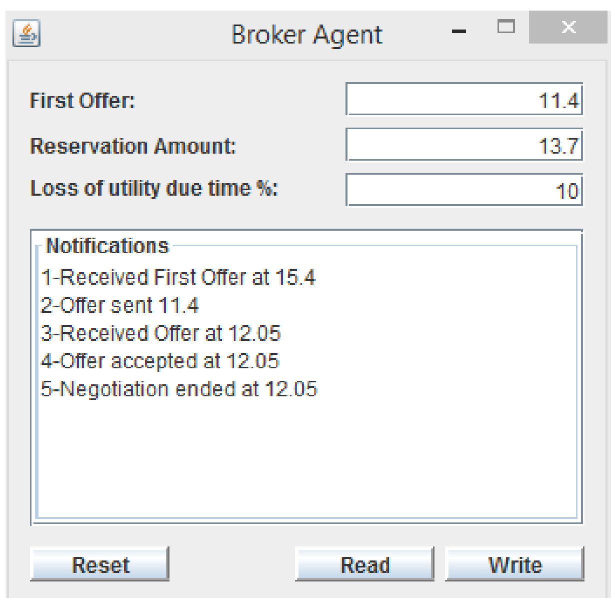

Figure C.38: Broker Agent in Negotiation Process for Scenario 19

Table C.20: Scenario 20

Scenario-20														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						46,4	35,7	17,8	55,5	41,1	22,6	37,3	30,3	13,0

Cmin	37,3
Coptimum	64,2

Investor	
First Offer	78,1
Reservation	37,3

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	44,9
Reservation	64,2

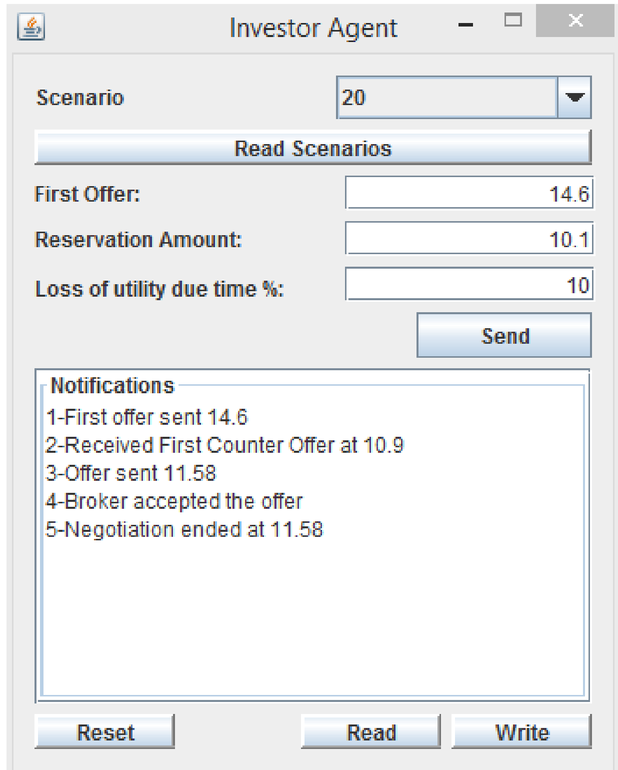

Figure C.39: Investor Agent in Negotiation Process for Scenario 20

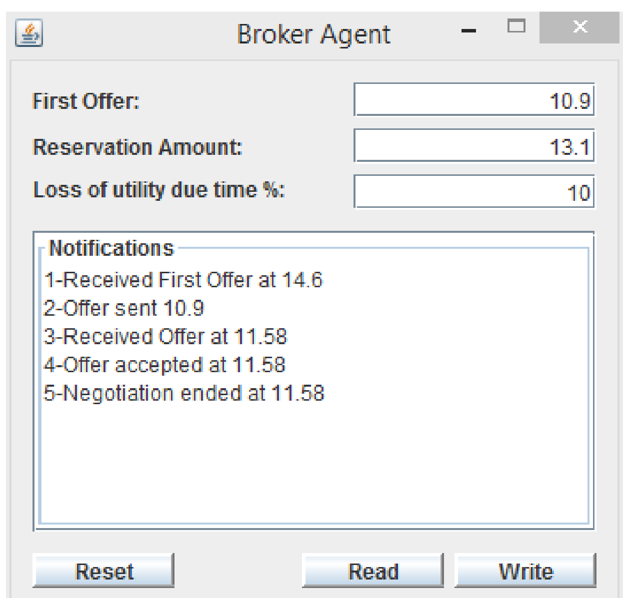

Figure C.40: Broker Agent in Negotiation Process for Scenario 20

Table C.21: Scenario 21

Scenario-21						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						21,4	60,7	17,8	26,8	69,8	22,6	16,1	51,6	13,0

Cmin	16,1
Coptimum	39,2

Investor	
First Offer	49,4
Reservation	16,1

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	27,4
Reservation	39,2

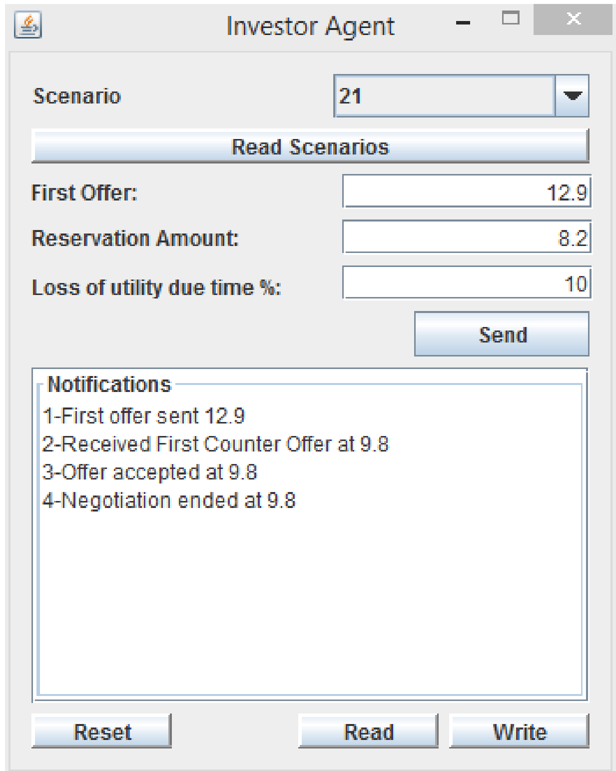

Figure C.41: Investor Agent in Negotiation Process for Scenario 21

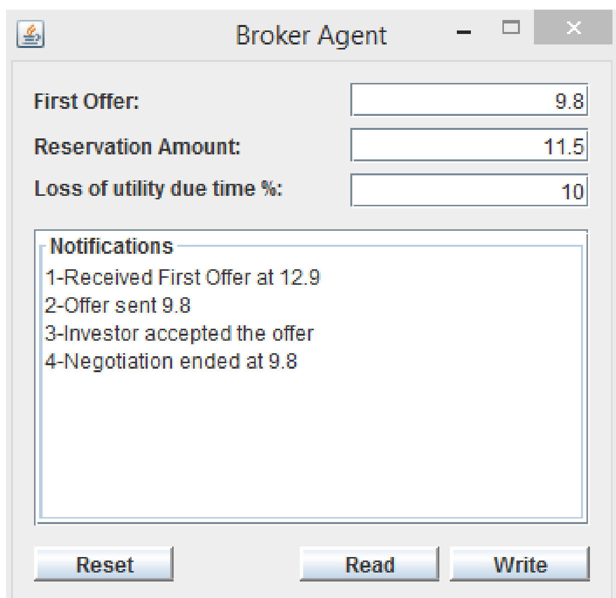

Figure C.42: Broker Agent in Negotiation Process for Scenario 21

Table C.22: Scenario 22

Scenario-22														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						21,4	60,7	17,8	26,8	69,8	22,6	16,1	51,6	13,0

Cmin	16,1
Coptimum	39,2

Investor	
First Offer	49,4
Reservation	16,1

Broker	
First Offer	27,4
Reservation	39,2

Start Negotiation

Maximum Price	19
Minimum Price	6

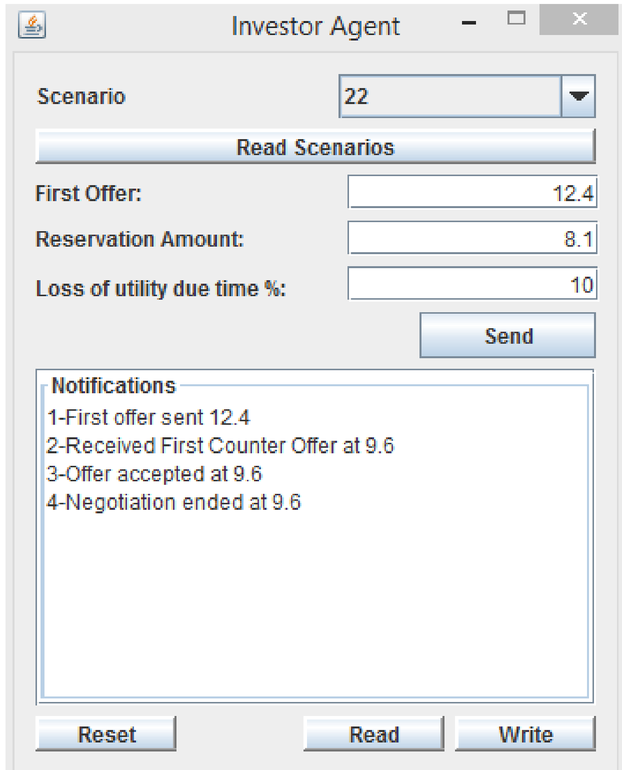

Figure C.43: Investor Agent in Negotiation Process for Scenario 22

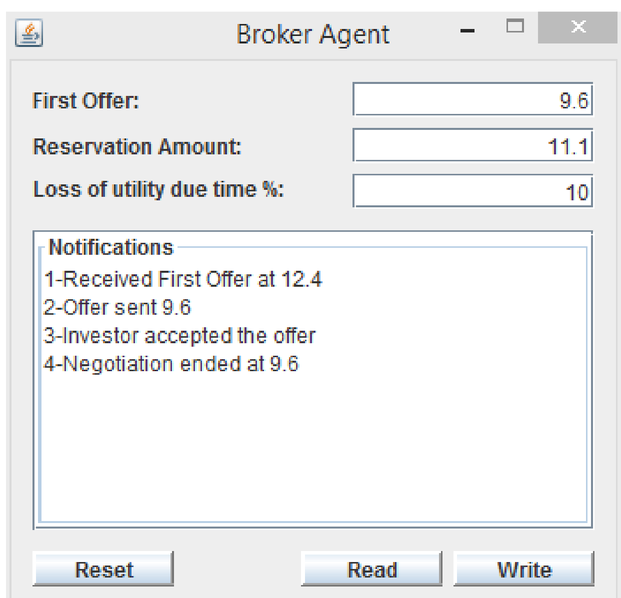

Figure C.44: Broker Agent in Negotiation Process for Scenario 22

Table C.23: Scenario 23

Scenario-23						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						21,4	60,7	17,8	26,8	69,8	22,6	16,1	51,6	13,0

Cmin	16,1
Coptimum	39,2

Investor	
First Offer	49,4
Reservation	16,1

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	27,4
Reservation	39,2

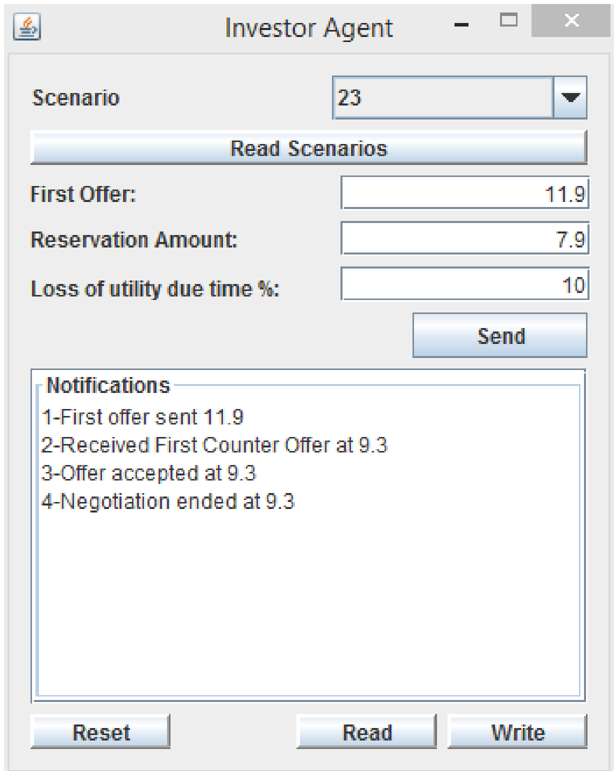

Figure C.45: Investor Agent in Negotiation Process for Scenario 23

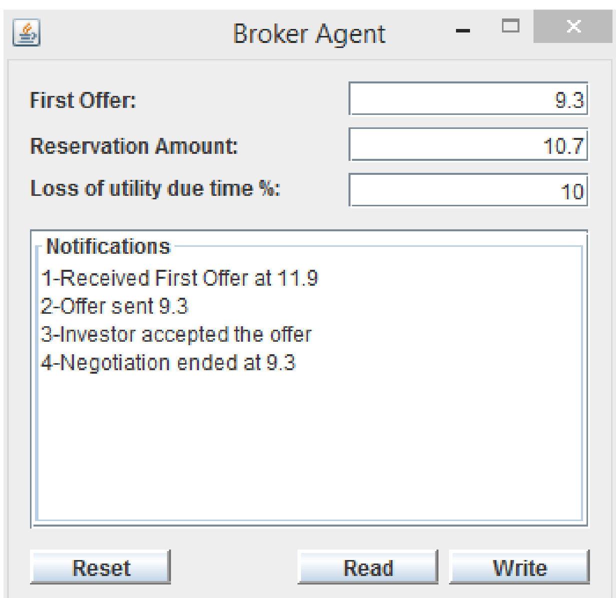

Figure C.46: Broker Agent in Negotiation Process for Scenario 23

Table C.24: Scenario 24

Scenario-24						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	Low	I	21,4	M	25	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						21,4	60,7	17,8	26,8	69,8	22,6	16,1	51,6	13,0

Cmin	16,1
Coptimum	39,2

Investor	
First Offer	49,4
Reservation	16,1

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	27,4
Reservation	39,2

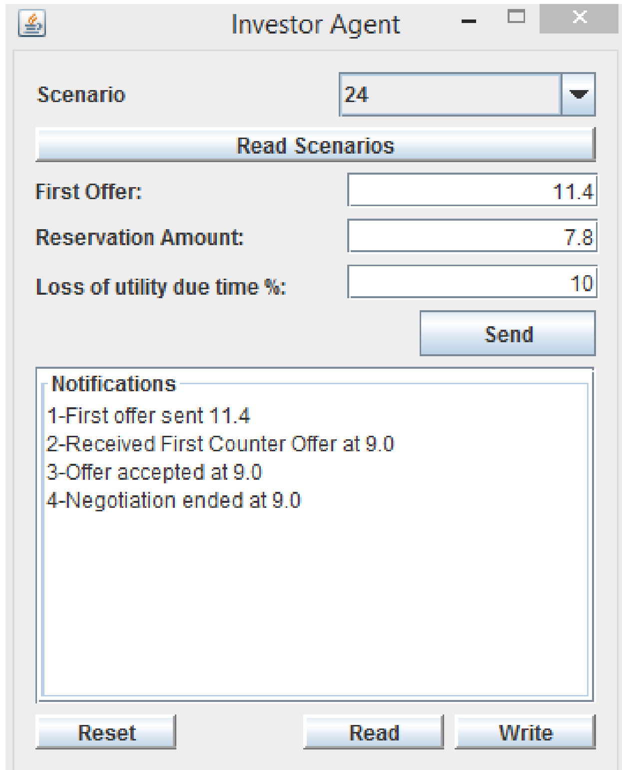

Figure C.47: Investor Agent in Negotiation Process for Scenario 24

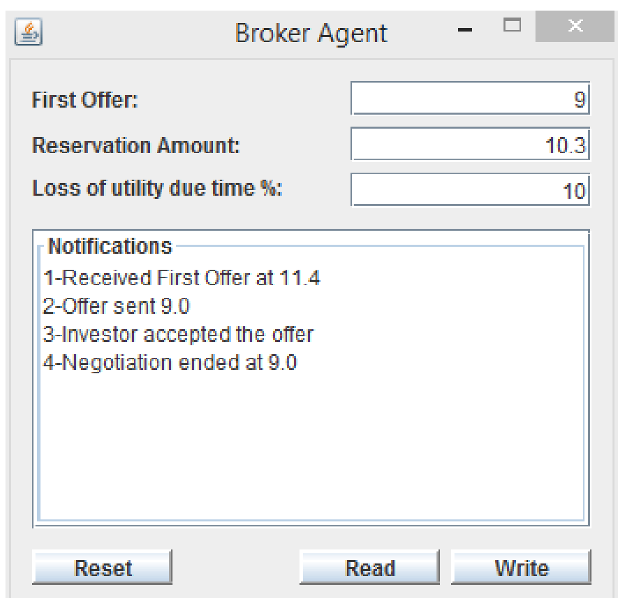

Figure C.48: Broker Agent in Negotiation Process for Scenario 24

Table C.25: Scenario 25

Scenario-25						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						25	57,1	17,8	28,8	67,8	22,6	21,3	46,4	13,0

Cmin	21,3
Coptimum	42,8

Investor	
First Offer	51,4
Reservation	21,3

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	30,0
Reservation	42,8

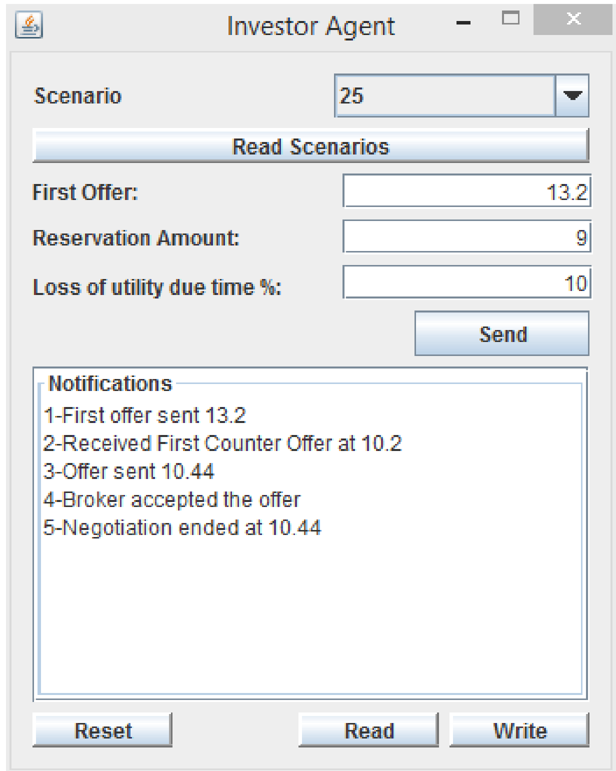

Figure C.49: Investor Agent in Negotiation Process for Scenario 25

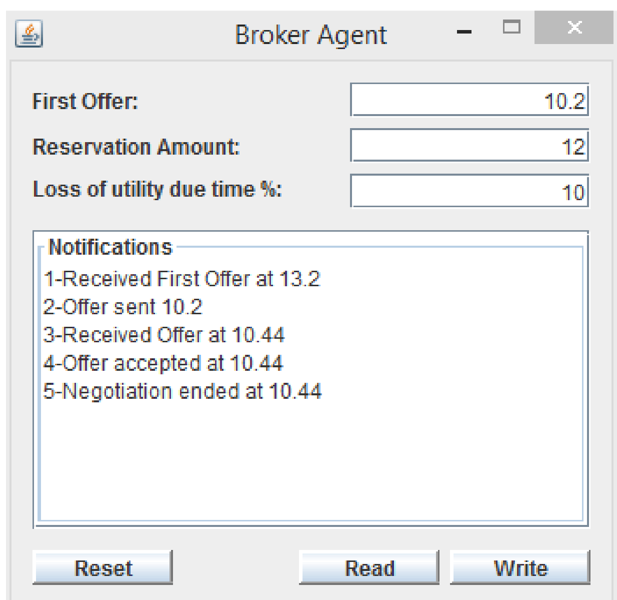

Figure C.50: Broker Agent in Negotiation Process for Scenario 25

Table C.26: Scenario 26

Scenario-26														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						25	57,1	17,8	28,8	67,8	22,6	21,3	46,4	13,0

Cmin	21,3
Coptimum	42,8

Investor	
First Offer	51,4
Reservation	21,3

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	30,0
Reservation	42,8

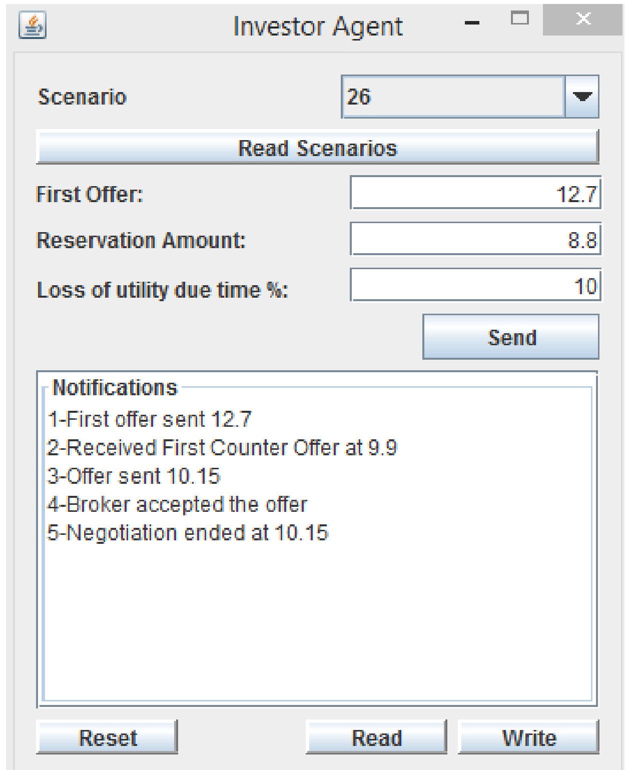

Figure C.51: Investor Agent in Negotiation Process for Scenario 26

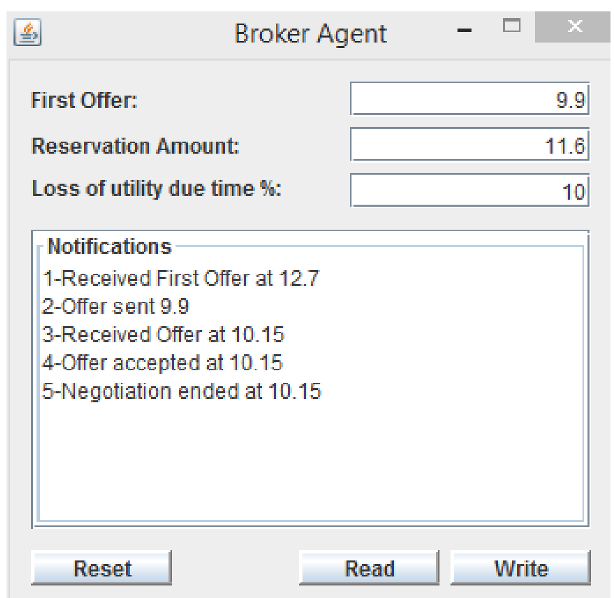

Figure C.52: Broker Agent in Negotiation Process for Scenario 26

Table C.27: Scenario 27

Scenario-27						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						25	57,1	17,8	28,8	67,8	22,6	21,3	46,4	13,0

Cmin	21,3
Coptimum	42,8

Investor	
First Offer	51,4
Reservation	21,3

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	30,0
Reservation	42,8

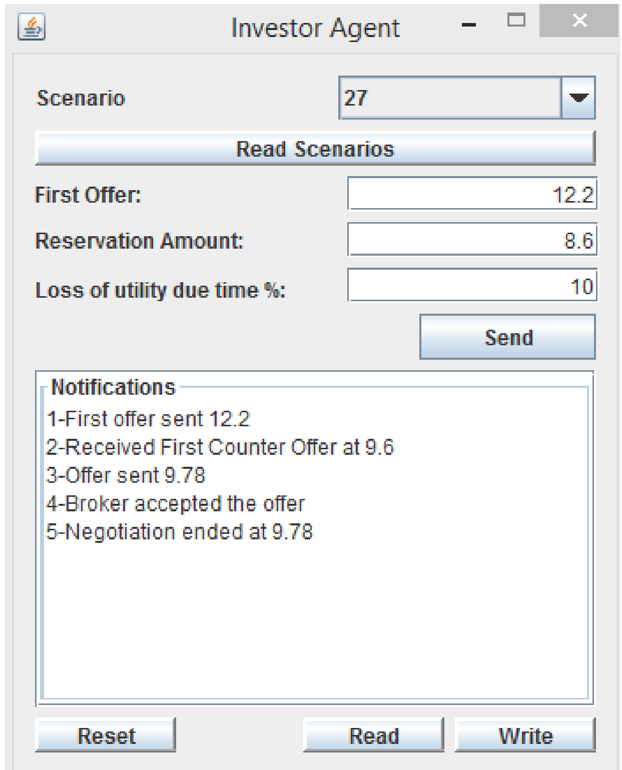

Figure C.53: Investor Agent in Negotiation Process for Scenario 27

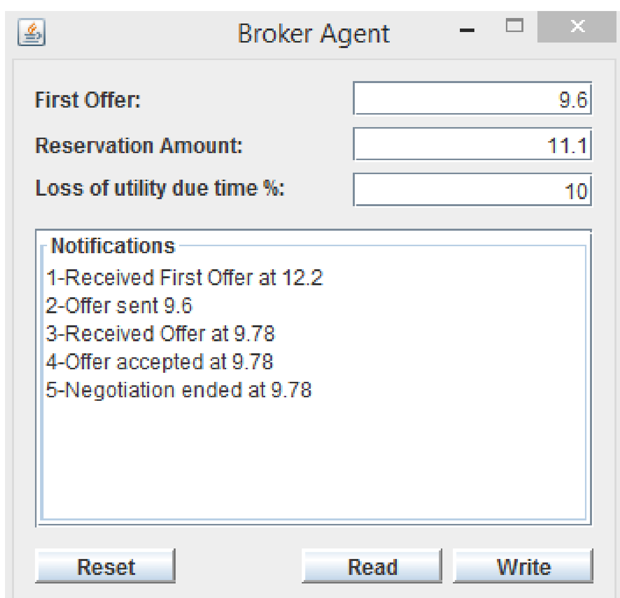

Figure C.54: Broker Agent in Negotiation Process for Scenario 27

Table C.28: Scenario 28

Scenario-28						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	High	I	25,0	L	15	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						25	57,1	17,8	28,8	67,8	22,6	21,3	46,4	13,0

Cmin	21,3
Coptimum	42,8

Investor	
First Offer	51,4
Reservation	21,3

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	30,0
Reservation	42,8

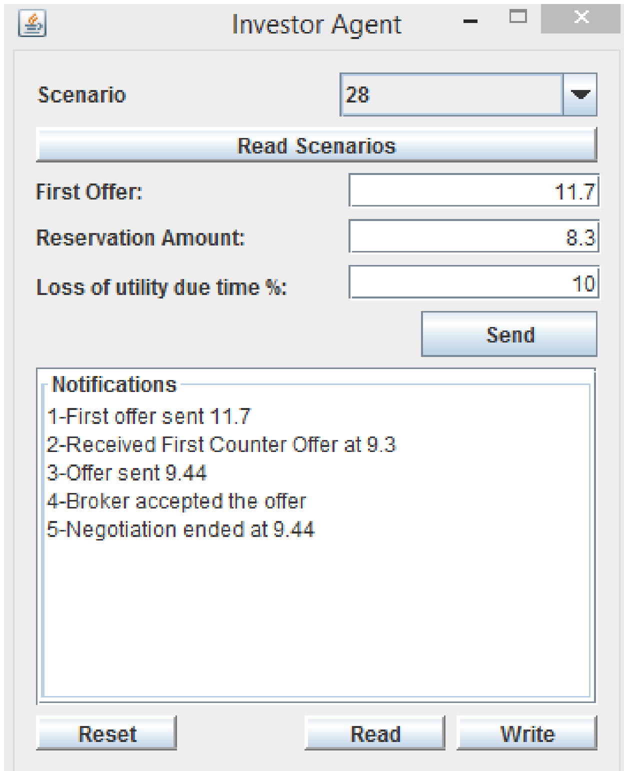

Figure C.55: Investor Agent in Negotiation Process for Scenario 28

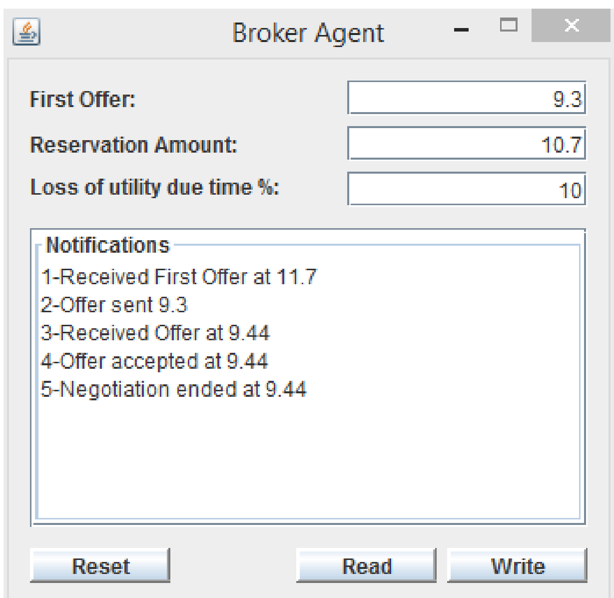

Figure C.56: Broker Agent in Negotiation Process for Scenario 28

Table C.29: Scenario 29

Scenario-29						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						0	82,1	17,8	0,0	96,6	22,6	0,0	67,6	13,0

Cmin	0,0
Coptimum	17,8

Investor	
First Offer	22,6
Reservation	0,0

Start Negotiation

Maximum Price	20
Minimum Price	6

Broker	
First Offer	12,5
Reservation	17,8

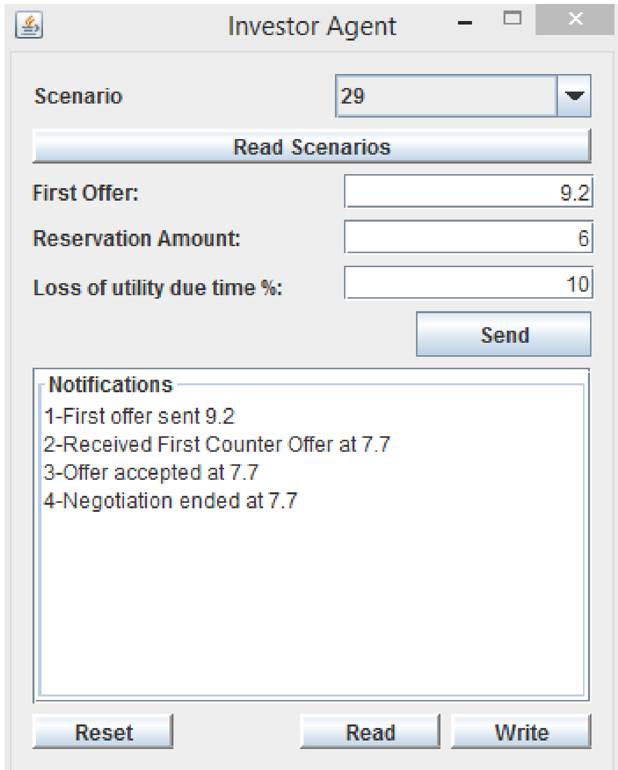

Figure C.57: Investor Agent in Negotiation Process for Scenario 29

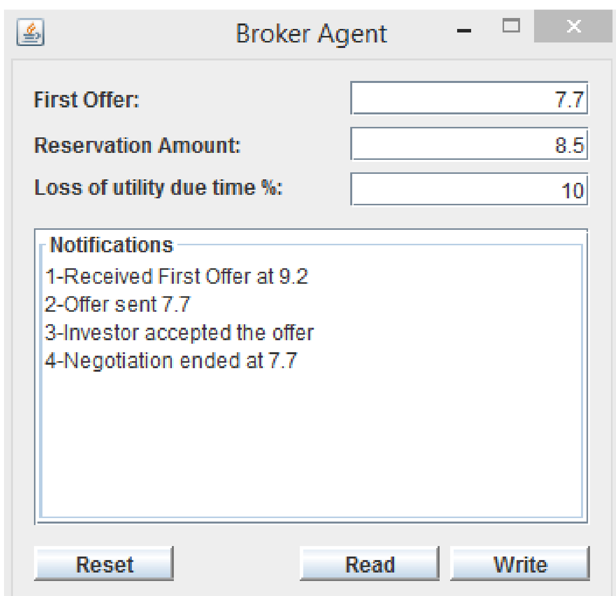

Figure C.58: Broker Agent in Negotiation Process for Scenario 29

Table C.30: Scenario 30

Scenario-30						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Stable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						0	82,1	17,8	0,0	96,6	22,6	0,0	67,6	13,0

Cmin	0,0
Coptimum	17,8

Investor	
First Offer	22,6
Reservation	0,0

Start Negotiation

Maximum Price	19
Minimum Price	6

Broker	
First Offer	12,5
Reservation	17,8

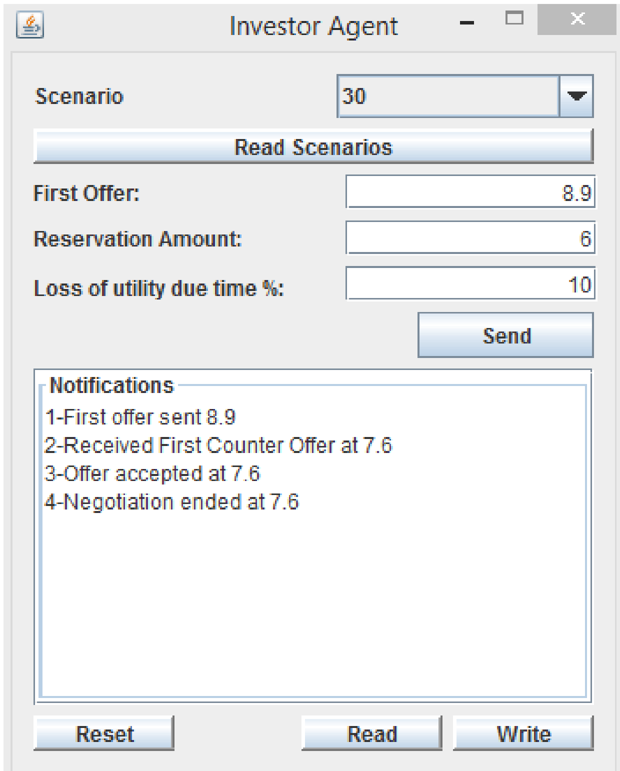

Figure C.59: Investor Agent in Negotiation Process for Scenario 30

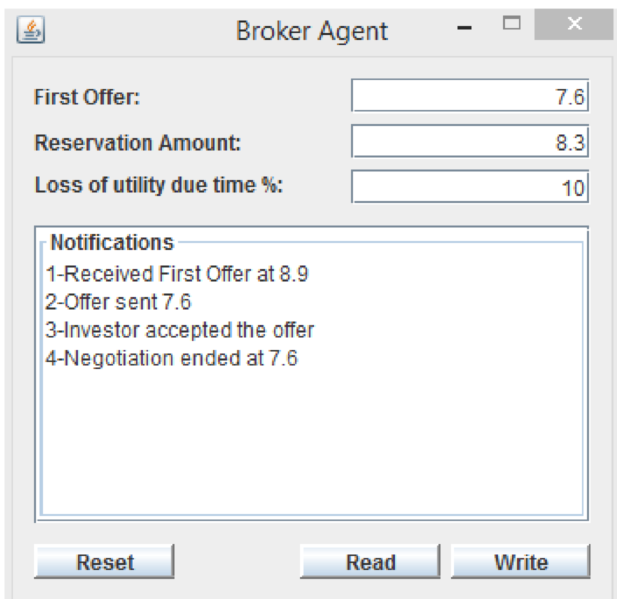

Figure C.60: Broker Agent in Negotiation Process for Scenario 30

Table C.31: Scenario 31

Scenario-31						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Stable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						0	82,1	17,8	0,0	96,6	22,6	0,0	67,6	13,0

Cmin	0,0
Coptimum	17,8

Investor	
First Offer	22,6
Reservation	0,0

Start Negotiation

Maximum Price	18
Minimum Price	6

Broker	
First Offer	12,5
Reservation	17,8

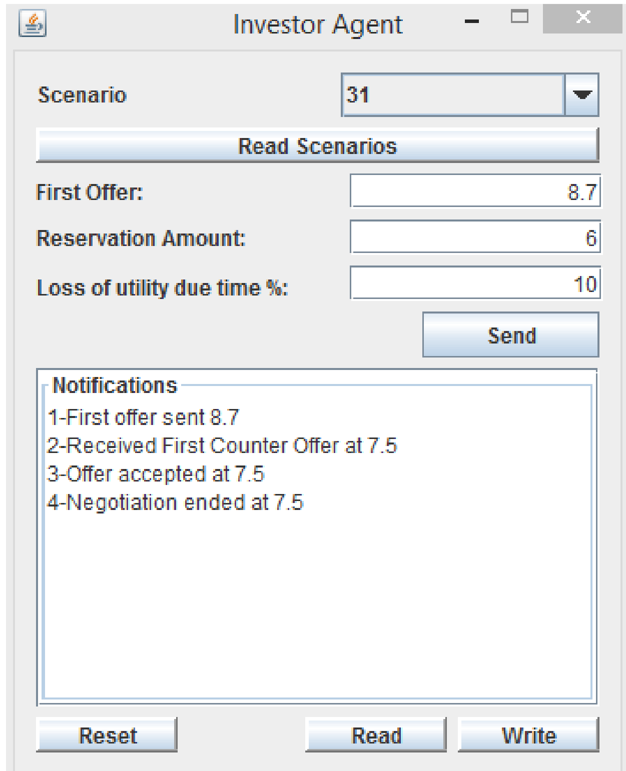

Figure C.61: Investor Agent in Negotiation Process for Scenario 31

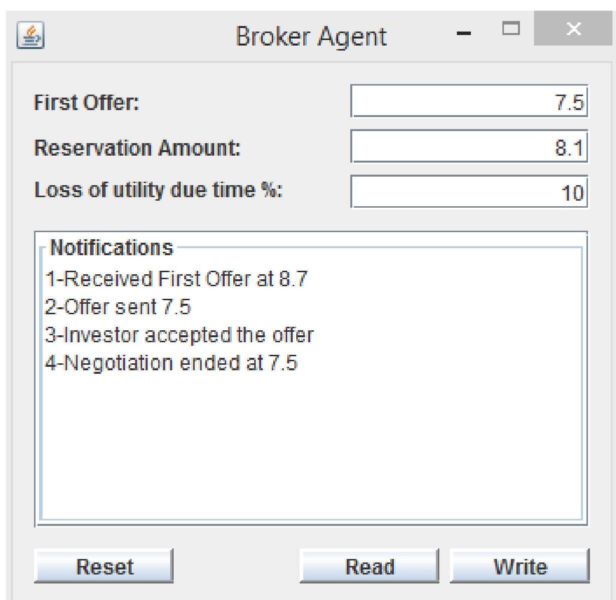

Figure C.62: Broker Agent in Negotiation Process for Scenario 31

Table C.32: Scenario 32

Scenario-32														
						No Fuzzy			Fuzzy Max			Fuzzy Min		
	Case	Power	Weight	Fuzziness	Fuzziness Value	Investor	Broker	Shared	Investor	Broker	Shared	Investor	Broker	Shared
Demand	Low	B	35,7	L	15	0,0	35,7	0,0	0,0	41,1	0,0	0,0	30,3	0,0
Level of Competition	High	B	21,4	M	25	0,0	21,4	0,0	0,0	26,8	0,0	0,0	16,1	0,0
Production Capacity	Low	B	25,0	L	15	0,0	25,0	0,0	0,0	28,8	0,0	0,0	21,3	0,0
Economic Condition	Unstable	S	10,7	H	35	0,0	0,0	10,7	0,0	0,0	14,4	0,0	0,0	7,0
Legal Changes	Unstable	S	7,1	L	15	0,0	0,0	7,1	0,0	0,0	8,2	0,0	0,0	6,0
						0	82,1	17,8	0,0	96,6	22,6	0,0	67,6	13,0

Cmin	0,0
Coptimum	17,8

Investor	
First Offer	22,6
Reservation	0,0

Start Negotiation

Maximum Price	17
Minimum Price	6

Broker	
First Offer	12,5
Reservation	17,8

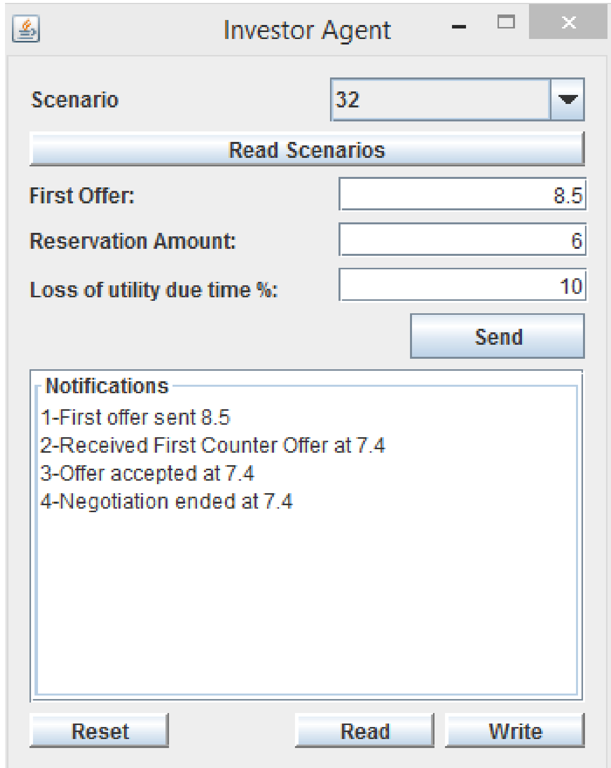

Figure C.63: Investor Agent in Negotiation Process for Scenario 32

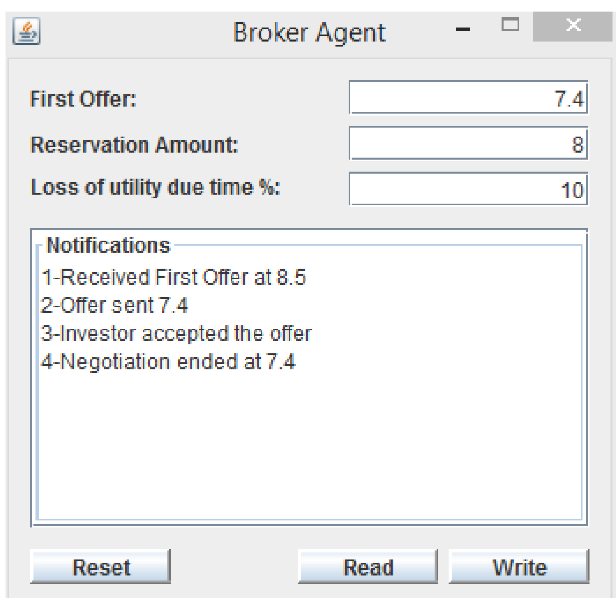

Figure C.64: Broker Agent in Negotiation Process for Scenario 32

APPENDIX D

D. CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Akçay, Emre Caner

Nationality: Turkish (TC)

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Marital Status: Single

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EDUCATION

Degree	**Institution**	**Year of Graduation**
Ph. D.	METU Civil Engineering	2014
M. Sc.	METU Civil Engineering	2010
B. S.	METU Civil Engineering	2008
High School	Atatürk Anatolian High School, Ankara	2004

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2008-2014	METU Department of Civil Engineering	Research Assistant

FOREIGN LANGUAGES

Advanced English

PUBLICATIONS

1. Akcay E. C. and Ergan S. "Test Results for Locating Structural Steel Assemblies and Packages using RFID" , CIB W78, 30th International Conference on Applications of IT in the AEC Industry, Beijing, China, October 9-12, 2013

2. Akcay E. "Yapısal Çelik Elemanların Ön Montaj Aşamasında Radyo Frekanslı Kimlik Belirleme Sistemi ile Takibi ", 2nd Project and Construction Management Congress, Izmir, Turkey, September 13-16, 2012

3.Ergan (Kiziltas) S., Akcay E. C. and Ergen E. "A Model-Based and RFID Integrated Approach to Streamline Component Information Flow in Construction Projects", International Conference on Computing in Civil and Building Engineering (ICCCBE 2010), June 30-July 2, 2010, Nottingham, UK, pp. 109-115.

HOBBIES

Football, Cinema, Technologies, Movies, Tennis