LUT School of Business Management

REAL OPTIONS STRATEGY ANALYSIS – CASE: VANTAA ENERGY'S SEASONAL HEAT STORAGE PROJECT

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1 Introduction

1.1 Introduction about the project

The climate change and need of energy transition have led to a rapidly growing demand for the renewable energy production. In recent years, consumers are more interested in the environmentally friendly energy. However, is a fact that the renewable energy production level does not meet the demand in the consumption level. As a result, innovative energy storage solutions are considered as the key to a carbon free energy system.

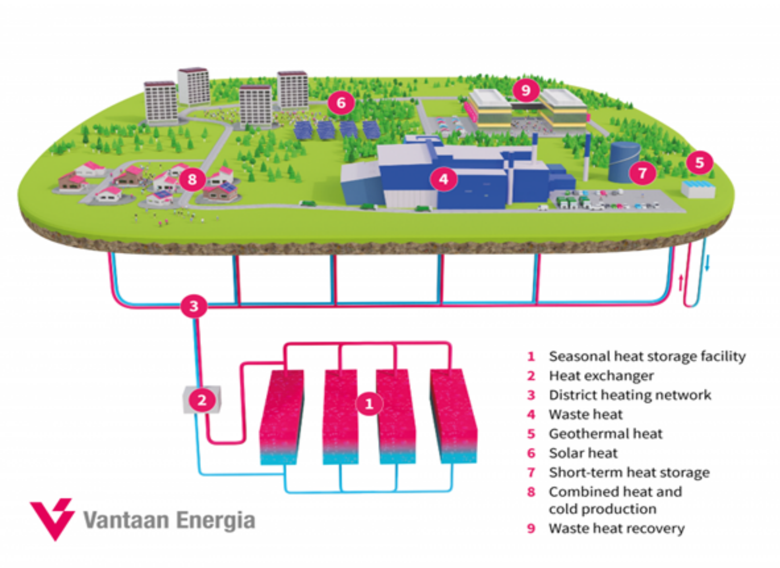
Vantaa Energy Oy has targeted its mission to phasing out the fossil fuels by 2026. One of the key projects of this mission is the seasonal thermal energy storage facility. The project is the largest cavern thermal energy storage (CTES) in the world with the capacity of 90 GWH, which is equalled to average amount of heating consumption in an area with 40000 residents. The location of the facility will be in Vantaa, which is a growing city in the capital region. The city itself has already developed heat production in the summertime as the consumption level is expected to increase. The Vantaa Energy Cavern Thermal Energy Storage (VECTES) has missions to store the excess emission-free and low-emission energy produced in the summertime and discharge the energy in the winter when the heating consumption is higher. VECTES does not only provide the stable environmentally friendly energy but also plays a key role in reducing the emission and helping EU reach its climate target.

VECTES is considered as the world's biggest thermal heat storage project, with the huge amount of investment cost. As a result, it is important to evaluate the risks and costs during the preparation stage. The Vantaa Energy separated the project into different stages due to the time and financial limitations. The beginning stage is development stage, next is the investment and lastly the construction stage with different choices of timeline and budget. The operation period of this facility is 20 years after completion. The facility location is separated into two parts: the urban and rural areas. As a result, the company has 2 options whether building the whole area at once or building the urban first then rural area later. The urban area is near the residential area which translates into lesser costs and higher demand. While the rural area consists of fewer buildings and likewise lesser demand for heating consumption. It is important for the company to evaluate which amongst these are the best options to implement.

The goal of this report is to apply different real-option methods to evaluate all available options in order to find the best time and budget for each stage of the VECTES project. We applied the Fuzzy Pay Off method, Datar-Mathews model and binomial model tree into the project. After that, there is a comparison and overview of how each option performs. The VECTES project is a reality project of Vantaa Energy Oy that going to produce by the 2026. However, our study has a limitation that we cannot collect completely correct numbers of cost and revenue of this real-life project because of privacy issue. As a result, we calculated and estimated approximately the final numbers based on the same project of heating energy storage implementation in Canadian energy market. Though the energy market sizes between Canada and Finland are different, our team has modified the numbers so that it is more realistic in Finnish energy market and Vantaa area's energy demand.

1.2 The Vantaa Energy Cavern Thermal Energy Storage (VECTES)

The VECTES receives much attention in the EU countries due to its capability of reducing the annual emissions in heating by approximately 65 000 tons each year. The facility implemented the seasonal heat storage technology in the depth of 60 meters. The main storage will consist of four main caverns with approximately 220 000 cubic metres each, which makes the storage capacity reach up to 90 GWh. This is corresponded as the annual heating consumption of an average-sized Finnish city. The storage is the first of its kind, which stored the water in the depth, high pressure and heated up to 140 Celsius degrees. Besides that, the heating storage is connected with the district heating system by the heat exchangers which transfer the thermal energy between the water in the district system and the water inside VECTES. As a result, the efficiency is further improved.



The business model of the VECTES is based on sales of low-emission and emission-free energy. The seasonal storage is charged with the waste energy in the summer and discharge the same energy in the winter to customers, hence replacing highly costly traditional fuel energy. The waste energy is collected during summer, while being emitted from air conditioners, data centres, solar, geothermal waste etc. Then this energy is used in the winter when the heat consumption is at its peak due to which the traditional heating system cannot meet the demand. The storage is linked with the district heating system which helps it with easier collection and consumption of energy.

The company cooperates with ARFY Finland and YIT Oy to build the VECTES project. The project includes the development phase, investment phase, implementation phase. Right after the implementation please, the heat storage can be put in operation to generate revenues, and the operation phase lasts 20 years. The location is in Vantaa and divided into 2 parts called urban and rural area. The urban area is near the residential location and close to the district heating system, while the rural part does not have many available residents and costs more in order to build and connect to the district heating system. However, there will be many new buildings in rural area according to the development of Vantaa city. The company has considered 2 options for this project with:

- **Option 1**: The company chooses to build the system in the entire location at once.
- **Option 2**: The company choose to build the system in the urban area first and in the rural area in 5 years.

The table below describe the information of the project with different stage costs, duration, and revenue. The cost and revenue of 2 options in the implementation stages are presented into 3 scenarios: minimum, maximum, and best guess. The methods used to choose the optimal option are Fuzzy pay-off and Datar-Mathews.

Table 1. Details about the project

	Stages	Phase	Duration	Costs	Revenue	Discount rate
	First stage	Development phase	1 year	5 MEUR		1.35 %
	Second stage	Investment phase	1 year	10 MEUR		1.35 %
Option 1	Third stage	Implementation phase (whole area)	4 years	23/30/38 MEUR/year		1.35 %
	Operation	Whole area	20 years		10/18/24 MEUR/year	7.00 %
		Increase rate				1.50 %
Option 2	Third stage	Implementation phase (urban area)	2 years	20/25/28 MEUR/year		1.35 %
	Fourth stage	Implementation phase (rural area)	2 years	21/27/34 MEUR/year		1.35 %
	Operation	Urban area	20 years		8/13/17 MEUR/year	7.00 %
		Rural area	21 years		2/5/7 MEUR/year	7.00 %
		Increase rate				1.50 %

In the next step, we assume that the company chooses option 2: build the system in urban area first and then in the rural area after 5 years. When the construction of the urban area are done, at year 4, the Vantaa Energy re-evaluates the plan building the heating storage system in the rural area. They have 1 year to decide whether to build the system or not in year 5. In the near future, Vantaa city has the plan to build various blocks of apartments in the rural area. This is an opportunity for the company to review the option, we also put this option into evaluation with the binomial model for the company to have the information and choice in the future. Since the urban area construction is finished, the company involves making investment cost of 54 million euro for building the rural area. Moreover, we estimate the (gross) present value of the expected future cash inflows from production is 49.8 million euro (the Excel file enclosed). We use the binomial model method to calculate the real option of this opportunity.

2 Different Valuation Methods

2.1 Fuzzy Pay Off Method

The idea behind fuzzy logic is to simplify the complex world and its phenomena by defining the true value of a matter in a closed range between zero and one. The true value can be any real number between zero and one depending on how significantly it is true. Option valuation of fuzzy logic is particularly useful because it requires the ability to handle the approximation and inaccuracy of the data in use (Collan et al. 2009, 165-167).

In option valuation, the fuzzy logic is based on an examination of the estimated cash flow scenarios generated by the project. Cash flow scenarios are usually defined as maximum, best guess, and minimum scenarios for which net present values are calculated and assisted by fuzzy arithmetic to outline a triangular or trapezoidal return distribution depending on the number of different cash flow scenarios. The net present values generated by the different scenarios determine the extremes of the triangle. The value of the real option can then be determined by calculating the fuzzy mean of the positive values - i.e. the possibilistic mean - which is multiplied by the success rate of the project. Success rate refers to the number of positive scenarios out of the total cash flow distribution (Collan et al. 2009, 168).

2.2 Datar-Mathews Model

The Datar-Mathews model has been developed precisely to value real options. The model is based on simulation and aims to utilize cash flow scenarios according to fuzzy logic. However, unlike the traditional net present value method, the Datar-Mathews model takes into account market dynamism and uncertainty through simulation. Unlike the valuation model based on fuzzy logic, the Datar-Mathews model simulates cash flow scenarios through the Monte Carlo model. This is the most significant difference between the fuzzy logic model and the Datar-Mathews model. The simulation results in a probability distribution for the projected present values of the project (Datar et al. 2007, 96-100).

Similarly, different discount rates may be used in the model for project returns and costs because they may have different risk profiles, so the amount of risk may be different. The value of a real option is determined using a return distribution by determining the values of positive and negative outcomes. Because the values for the negative outcomes are shown to be zero, the final value of the option is the weighted average of the positive outcomes from the return distribution of the option (Datar et al. 2007, 100-101).

2.3 Black-Scholes Model

The Black-Scholes (1973) method is based on the valuation of options through a differential equation. The model has been used first in financing options and then also in real options. In the model, the price variation of the underlying is modeled using the geometric Brownian motion as a stochastic process, because the option determination is based on the idea that the price variation of the underlying occurs randomly. The background of the model is the law of one price, ie if two investments have the same cash flows and involve the same amount of risk, their price must be the same in a complete market (Datar & Mathews 2004, 45-47).

2.4 Binomial Model

The Binomial model, which differs significantly from the Fuzzy payoff method and the Datar-Mathews model, looks at the valuation of real options as a tree model for the entire life cycle of the option. Cox & Ross (1979) developed a binomial model that is modeled as a bifurcated decision tree in which the number of branches increases over time. In other words, the model is based on modeling the time values of the price of the underlying asset. The model assumes that the value of the underlying asset follows a binomial distribution, i.e., in one unit of time the value of an option can increase by U with probability q or decrease by D with probability 1-q (Hull 2012, 200-203).

The valuation of the real option takes place in the binomial model through three different steps. First, outline all the outcomes of the binomial option. Second, the value of the option is calculated for all interfaces, and finally, the value of the entire option at all previous interfaces is calculated by iterating backwards from the last interfaces.

3 Implementation of the different methods

3.1 Fuzzy Pay-off method

For the fuzzy pay-off method, the analysis is carried out on Excel software. The table 1 sums up the information about this project. As presented in section 1, there are 3 main phases: development phase, investment phase and implementation phase. Each phase has a fixed time period to be carried out. The amount of money in the third stage (implementation phase) has 3 scenarios. The best scenario represents the minimum value, the best guess is the most likely scenario, and the worst scenario implies the maximum value of cost. In contrast, the best scenario of revenue is when it reaches the highest value and vice versa.

The analysis of the option 1 is first carried out, which includes the implementation phase of the whole Vantaa area. After the first 2 years of the development phase and investment phase, the project has 4 years for the implementation phase with 3 scenarios. With discount rate of 1.35%, the cost is calculated back to year 0.

Right after the implementation phase, the heating storage system could be put in use. The project now goes to the next stage: Operation stage. Revenue generated from this phase is analyzed in 3 scenarios (max, min and best guess). They are also computed back to year 0 to calculate the NPV and its cumulative value. Table 3 in Appendix A shows the calculation process of the first option of this project.

Similarly, appendix A (at the end of this report) shows the calculation process of the second option. The final 3 scenarios of NPV in both options is summed up in the following table.

	Option 1	Option 2
Maximum NPV	100 176 076.32 €	128 736 340.53 €
Best guess NPV	22 748 215.06 €	52 983 942.94 €
Minimum NPV	-75 399 558.90 €	-38 549 432.76 €
ROV	26 711 315.26 €	51 493 357.16 €

The real option value (ROV) of option 2 is twice as much as of option 1.

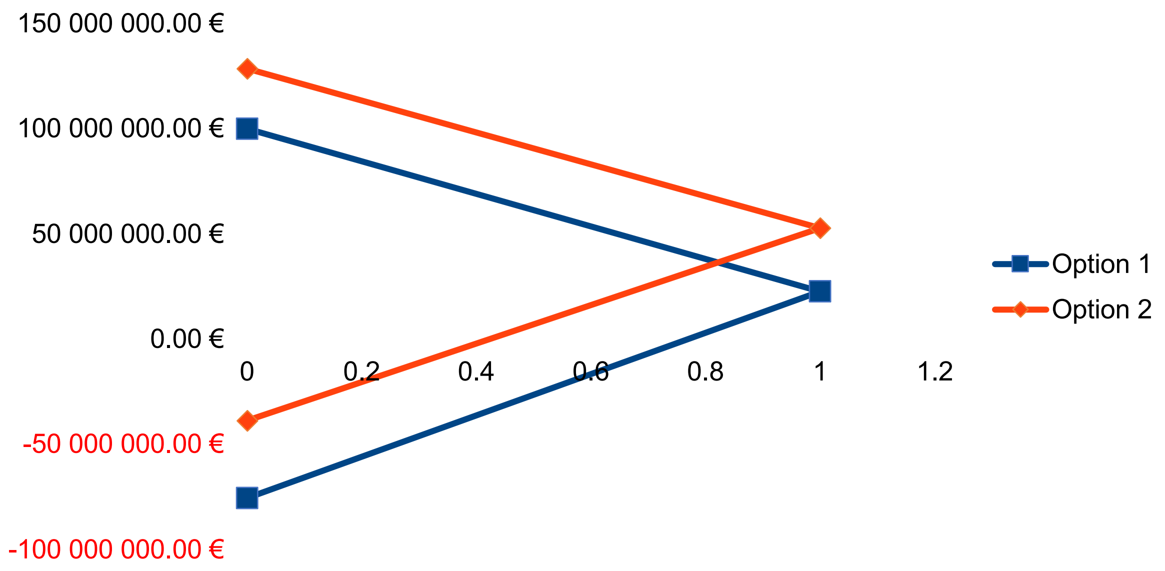


Figure 1. Comparison NPV of 2 options

Based on figure 1, the triangle of option 2 is higher than option 1's, which implies that this option seems to be more beneficial than the other one. The gap between the min and max of option 2's NPV is also smaller than of option 1. The value of costs comparison between 2 options is analyzed in the table below.

Nominal value of costs			
	Option 1	Option 2	Cost of real option
Maximum	107 000 000 €	55 000 000 €	-52 000 000 €
Best guess	135 000 000 €	65 000 000 €	-70 000 000 €
Minimum	167 000 000 €	71 000 000 €	-96 000 000 €

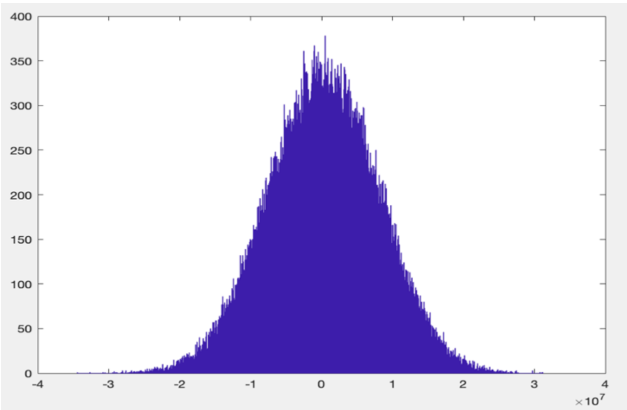
Real value of costs			
	Option 1	Option 2	Cost of real option
Maximum	102 658 506 €	92 563 640 €	-10 094 867 €
Best guess	129 377 722 €	113 381 233 €	-15 996 489 €
Minimum	159 913 968 €	132 188 456 €	-27 725 512 €

Cost of option 2 is smaller than option 1. Obviously, option 2 is an optimal choice.

The project is also analyzed in other methods. The following part is the implementation of this project with Datar-Mathew method in MATLAB.

3.2 Datar-Mathews method

The code part of this method is provided in Appendix C and D. The analysis is implemented by running Monte Carlo simulation of different variables. In the first option, the probability distribution is applied to the implementation cost of the whole area (cost of stage 3 in option 1), and the operation revenue of the whole area. Triangle probability distribution is used with 3 values A, B, C representing the min, best guess and max values. Simulation is done with 100 000 iterations. The outputs of the program are the histogram, probability and real option value.




```
probability =

    0.5144


rov =

   3.2541e+06
```

Figure 2. The distribution of NPV simulation of option 1.

The probability that we have positive outcome is 51.44%. The ROV is computed as the mean of all positive NPVs. The ROV of option 1 calculated on MATLAB is 3.254 million euros.

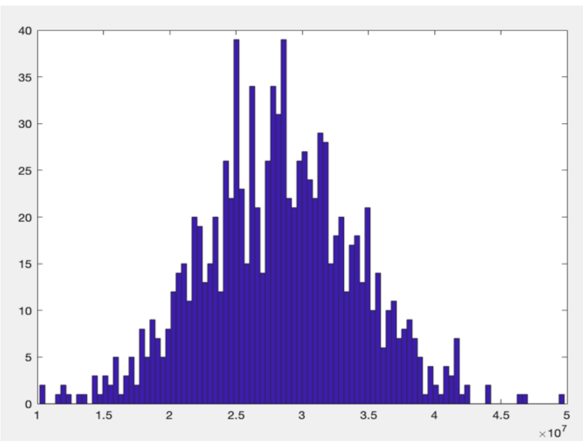


Figure 3. The distribution of NPV simulation of option 2.

The second option seems to be more optimal than the other one with the ROV of 28.184 million euros, much larger than of the other option. The positive outcomes also have higher percentage in the simulation (figure 3).

Overall, option 2 is proved to be the better option in both methods fuzzy pay-off and Datar-Mathews. The company should build the heating storage in the urban area first and put it in use for few years before starting another construction in rural areas instead of building the system in whole Vantaa area all at once.

3.3 One-step binomial model

Assumed that the company chooses option 2, after the urban areas are built, at year 4, the company would have the chance to evaluate the investment in the rural area in 1 year. They have 1 year to decide whether to build the system or not in year 5. The rural area is going to add more capacity for the storage and productivity of the company. We applied one-step binomial model to evaluate the value of the option to build the rural capacity.

The value of the option is calculated below:

Type of Option: European Call Option

Present value of project expected cash flows of the rural area (S): 49.8 (million euros)

Value of project investment cost in building the system in rural area (K): 54 (million euros)

Length of time in which the investment opportunity exists (T): 1 (year)

Volatility of investment returns (Sigma): 33.65%

Risk free interest rate (r): 1.35%

No. of steps = 1

Delta T = T/N = 1/1 = ***1***

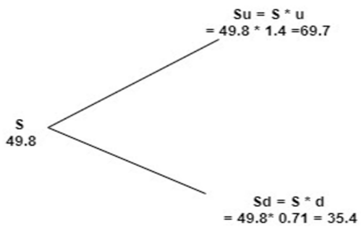
1) ***Compute, u,d and q values***

   $u = e^{\sigma\sqrt{\Delta T}}$ = *1.4*

   $d = e^{-\sigma\sqrt{\Delta T}} = 0.71$

   $q = (e^{r\Delta T} - d)/\,(u - d)$ = *0.44*

2) ***Calculating the development of the asset***



3) ***Calculating the value of the option at maturity and present value of the option:***

- Value of : Cu = max (Su-K;0) = max(69.7 - 54; 0) = 15.7
- Value of : Cd = max (Sd-K;0) = max(35.4 - 54; 0) = 0
- Value of : C = $e^{-r\Delta T}(qC_u + (1-q)C_d) = 6.82$

As we can see, the present value of the option to build the heating energy storage system in rural area at year 5 using binomial model is 6.82 million euros.

4 Comparison and conclusion

The purpose of the study was to examine the Vantaa Energy Seasonal Heat Storage Project from the perspective of real options, using Fuzzy Pay-Off method, Datar-Mathew for the 2 options in the beginning of the implementation stage whether building all the area at once or start with the urban first and rural area later in 5 years. Both methods show that option 2 is a better option for Vantaa Energy in building VETCES project. With the Fuzzy Pay off method, the scenario where the investment in the whole area is implemented at once, the value of the real option is around 26.7 million Euro. In the scenario where the company first input system in the urban area and then in the rural area, the ROV is around 51.5 million Euro, which is a more attractive option for the company. On the other hand, with the Datar-Mathews, the ROV of the option 1 is 3.254 million Euro, while the ROV of the option 2 is 28.184 million Euro. After considering both methods, we realized that the option 2 building the urban area first then rural area is a better option with higher value.

At year 4, supposed that the company made their choice on option 2, the company has the opportunity in 1 year to decide whether to input the system in the rural area in year 5. We applied the binominal model method and evaluated this opportunity with the present value of the option is 6.82 million Euro.

The findings of our study on the impact of real options and risks on investment are largely in line with real option theory: As uncertainty increases, the value of a real option increases and, on the other hand, the firm has an incentive to seek to defer irreversible investments. There is a limitation of the publicity statistic information which are used in the study. Therefore, it is important for further research if the information is completely provided.

Besides, Vantaa Energy should consider that the positive value of a real option is not in itself an automation for the implementation of a project. In the light of real option theory, investments that include real value-added value, compared to traditional investment projects and the valuation of real options provide a good addition to traditional investment profitability calculation.

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Appendices

Appendix A: Option 1 - Calculation Process

Table 2. Nominal cost and revenue cash flow

Cost cashflows:													
Discount rate	1.35 %												
	0	1	2	3	4	5							
Minimum	5 000 000.00 €	10 000 000.00 €	23 000 000.00 €	23 000 000.00 €	23 000 000.00 €	23 000 000.00 €							
Best guess	5 000 000.00 €	10 000 000.00 €	30 000 000.00 €	30 000 000.00 €	30 000 000.00 €	30 000 000.00 €							
Maximum	5 000 000.00 €	10 000 000.00 €	38 000 000.00 €	38 000 000.00 €	38 000 000.00 €	38 000 000.00 €							
Revenue source: whole area													
Discount rate	7.00 %												
Increase rate	1.50 %												
	0	1	2	3	4	5	6	7	8	9	10	11	12
Maximum							24 000 000.00 €	24 360 000.00 €	24 725 400.00 €	25 096 281.00 €	25 472 725.22 €	25 854 816.09 €	26 242 638.33 €
Best guess							18 000 000.00 €	18 270 000.00 €	18 544 050.00 €	18 822 210.75 €	19 104 543.91 €	19 391 112.07 €	19 681 978.75 €
Minimum							10 000 000.00 €	10 150 000.00 €	10 302 250.00 €	10 456 783.75 €	10 613 635.51 €	10 772 840.04 €	10 934 432.64 €
	13	14	15	16	17	18	19	20	21	22	23	24	25
Maximum	26 636 277.91 €	27 035 822.08 €	27 441 359.41 €	27 852 979.80 €	28 270 774.50 €	28 694 836.12 €	29 125 258.66 €	29 562 137.54 €	30 005 569.60 €	30 455 653.14 €	30912487.94	31376175.26	31846817.89
Best guess	19 977 208.43 €	20 276 866.56 €	20 581 019.56 €	20 889 734.85 €	21 203 080.87 €	21 521 127.09 €	21 843 943.99 €	22 171 603.15 €	22 504 177.20 €	22 841 739.86 €	23184365.96	23532131.44	23885113.42
Minimum	11 098 449.13 €	11 264 925.87 €	11 433 899.75 €	11 605 408.25 €	11 779 489.37 €	11 956 181.71 €	12 135 524.44 €	12 317 557.31 €	12 502 320.67 €	12 689 855.48 €	12880203.31	13073406.36	13269507.45

Table 3. NPV Calculation

Present value scenarios of the cost													
	0	1	2	3	4	5							
Minimum	5 000 000 €	9 866 798 €	22 391 353 €	22 093 096 €	21 798 812 €	21 508 448 €							
Best guess	5 000 000 €	9 866 798 €	29 206 112 €	28 817 082 €	28 433 233 €	28 054 497 €							
Maximum	5 000 000 €	9 866 798 €	36 994 409 €	36 501 637 €	36 015 428 €	35 535 696 €							
Present value scenarios of revenue													
	0	1	2	3	4	5	6	7	8	9	10	11	12
Maximum							15 992 213 €	15 170 184 €	14 390 408 €	13 650 714 €	12 949 042 €	12 283 437 €	11 652 045 €
Best guess							11 994 160 €	11 377 638 €	10 792 806 €	10 238 036 €	9 711 781 €	9 212 578 €	8 739 034 €
Minimium							6 663 422 €	6 320 910 €	5 996 003 €	5 687 798 €	5 395 434 €	5 118 099 €	4 855 019 €
	13	14	15	16	17	18	19	20	21	22	23	24	25
Maximum	11 053 108.36 €	10 484 957.93 €	9 946 011.49 €	9 434 767.91 €	8 949 803.20 €	8 489 766.59 €	8 053 376.72 €	7 639 418.10 €	7 246 737.73 €	6 874 241.87 €	6 520 892.99 €	6 185 706.90 €	5 867 750.00 €
Best guess	8 289 831.27 €	7 863 718.45 €	7 459 508.62 €	7 076 075.93 €	6 712 352.40 €	6 367 324.94 €	6 040 032.54 €	5 729 563.58 €	5 435 053.30 €	5 155 681.40 €	4 890 669.74 €	4 639 280.17 €	4 400 812.50 €
Minimium	4 605 461.82 €	4 368 732.47 €	4 144 171.45 €	3 931 153.30 €	3 729 084.67 €	3 537 402.75 €	3 355 573.63 €	3 183 090.88 €	3 019 474.06 €	2 864 267.45 €	2 717 038.74 €	2 577 377.87 €	2 444 895.83 €
Net present cash-flow scenarios for the investment													
	0	1	2	3	4	5	6	7	8	9	10	11	12
Maximum	-5 000 000.00 €	-9 866 798.22 €	-22 391 352.65 €	-22 093 095.86 €	-21 798 811.90 €	-21 508 447.85 €	15 992 213.37 €	15 170 183.71 €	14 390 407.91 €	13 650 714.05 €	12 949 041.83 €	12 283 436.88 €	11 652 045.26 €
Best guess	-5 000 000.00 €	-9 866 798.22 €	-29 206 112.16 €	-28 817 081.56 €	-28 433 232.91 €	-28 054 497.20 €	11 994 160.03 €	11 377 637.78 €	10 792 805.94 €	10 238 035.54 €	9 711 781.37 €	9 212 577.66 €	8 739 033.95 €
Minimium	-5 000 000.00 €	-9 866 798.22 €	-36 994 408.73 €	-36 501 636.64 €	-36 015 428.36 €	-35 535 696.45 €	6 663 422.24 €	6 320 909.88 €	5 996 003.30 €	5 687 797.52 €	5 395 434.10 €	5 118 098.70 €	4 855 018.86 €
	13	14	15	16	17	18	19	20	21	22	23	24	25
Maximum	11 053 108.36 €	10 484 956.93 €	9 946 009.49 €	9 434 764.91 €	8 949 799.20 €	8 489 761.59 €	8 053 370.72 €	7 639 411.10 €	7 246 729.73 €	6 874 232.87 €	6 520 882.99 €	6 185 695.90 €	5 867 738.00 €
Best guess	8 289 831.27 €	7 863 718.45 €	7 459 508.62 €	7 076 075.93 €	6 712 352.40 €	6 367 324.94 €	-9 952 180.83 €	-9 440 620.13 €	-8 955 354.61 €	-8 495 032.65 €	-8 058 372.09 €	-7 644 156.70 €	-7 251 232.76 €
Minimium	4 605 461.82 €	4 368 732.47 €	4 144 171.45 €	3 931 153.30 €	3 729 084.67 €	3 537 402.75 €	-8 638 586.40 €	-8 194 546.91 €	-7 773 331.88 €	-7 373 768.09 €	-6 994 742.63 €	-6 635 199.78 €	-6 294 138.11 €
Cumulative net present cash-flow scenarios for the investment													
	0	1	2	3	4	5	6	7	8	9	10	11	12
Maximum	-5 000 000.00 €	-14 866 798.22 €	-37 258 150.88 €	-59 351 246.74 €	-81 150 058.64 €	-102 658 506.49 €	-86 666 293.12 €	-71 496 109.41 €	-57 105 701.49 €	-43 454 987.44 €	-30 505 945.61 €	-18 222 508.73 €	-6 570 463.47 €
Best guess	-5 000 000.00 €	-14 866 798.22 €	-44 072 910.38 €	-72 889 991.94 €	-101 323 224.85 €	-129 377 722.05 €	-117 383 562.02 €	-106 005 924.24 €	-95 213 118.30 €	-84 975 082.77 €	-75 263 301.39 €	-66 050 723.73 €	-57 311 689.79 €
Minimium	-5 000 000.00 €	-14 866 798.22 €	-51 861 206.96 €	-88 362 843.60 €	-124 378 271.95 €	-159 913 968.41 €	-153 250 546.17 €	-146 929 636.29 €	-140 933 632.99 €	-135 245 835.47 €	-129 850 401.37 €	-124 732 302.67 €	-119 877 283.81 €
	13	14	15	16	17	18	19	20	21	22	23	24	25
Maximum	4 482 644.88 €	14 967 602.81 €	24 913 614.30 €	34 348 382.21 €	43 298 185.42 €	51 787 952.01 €	59 841 328.73 €	67 480 746.83 €	74 727 484.57 €	81 601 726.43 €	88 122 619.42 €	94 308 326.32 €	100 176 076.32 €
Best guess	-49 021 858.52 €	-41 158 140.07 €	-33 698 631.46 €	-26 622 555.52 €	-19 910 203.12 €	-13 542 878.18 €	-7 502 845.64 €	-1 773 282.06 €	3 661 771.24 €	8 817 452.64 €	13 708 122.38 €	18 347 402.56 €	22 748 215.06 €
Minimium	-115 271 822.00 €	-110 903 089.53 €	-106 758 918.07 €	-102 827 764.78 €	-99 098 680.11 €	-95 561 277.36 €	-92 205 703.73 €	-89 022 612.85 €	-86 003 138.80 €	-83 138 871.35 €	-80 421 832.61 €	-77 844 454.73 €	-75 399 558.90 €

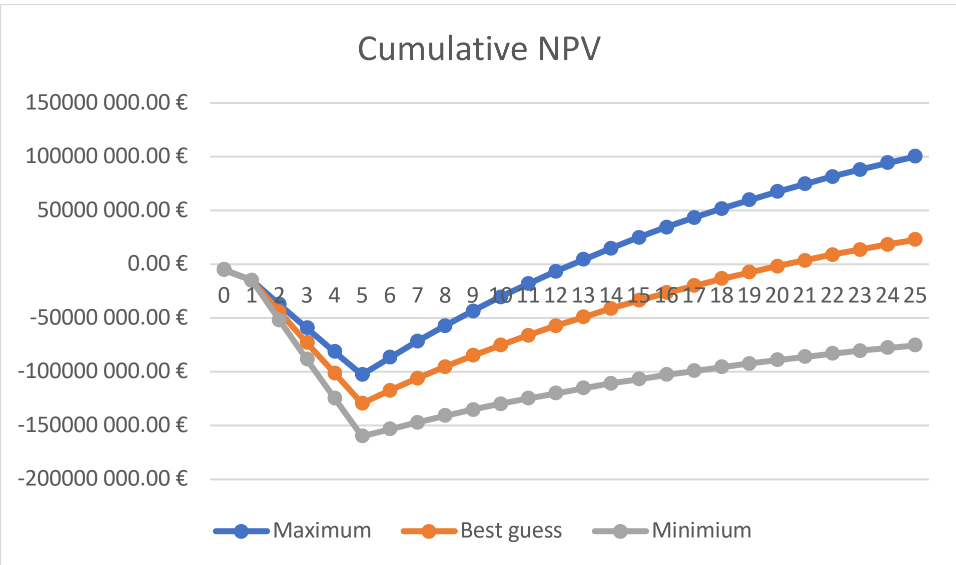

Figure 4. Cumulative NPV

Table 4. ROV Calculation

Maximum NPV	100 176 076.32 €	**alpha**	98147774
Best guess NPV	22 748 215.06 €	**a**	22748215
Minimum NPV	-75 399 558.90 €	**beta**	77427861
ROV	26 711 315.26 €		

Appendix B: Option 2 - Calculation Process

Table 5. Cost of phases

Cost cashflows: Development phase + Investment phase + Urban area implementation phase							
Discount rate	1.35 %						
	0	**1**	**2**	**3**	**4**	**5**	**6**
Minimum	5 000 000.00 €	10 000 000.00 €	20 000 000.00 €	20 000 000.00 €			
Best guess	5 000 000.00 €	10 000 000.00 €	25 000 000.00 €	25 000 000.00 €			
Maximum	5 000 000.00 €	10 000 000.00 €	28 000 000.00 €	28 000 000.00 €			
Cost cashflows: Rural area implementation phase							
Discount rate	1.35 %						
	0	**1**	**2**	**3**	**4**	**5**	**6**
Minimum						21 000 000.00 €	21 000 000.00 €
Best guess						27 000 000.00 €	27 000 000.00 €
Maximum						34 000 000.00 €	34 000 000.00 €

Table 6. Revenue of urban area

Revenue source: urban area												
Discount rate	7.00 %											
Increase rate	1.50 %											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Maximum					17 000 000.00 €	17 255 000.00 €	17 513 825.00 €	17 776 532.38 €	18 043 180.36 €	18 313 828.07 €	18 588 535.49 €	18 867 363.52 €
Best guess					13 000 000.00 €	13 195 000.00 €	13 392 925.00 €	13 593 818.88 €	13 797 726.16 €	14 004 692.05 €	14 214 762.43 €	14 427 983.87 €
Minimum					8 000 000.00 €	8 120 000.00 €	8 241 800.00 €	8 365 427.00 €	8 490 908.41 €	8 618 272.03 €	8 747 546.11 €	8 878 759.30 €
	12	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Maximum	19 150 373.97 €	19 437 629.58 €	19 729 194.03 €	20 025 131.94 €	20 325 508.91 €	20 630 391.55 €	20 939 847.42 €	21 253 945.13 €	21 572 754.31 €	21 896 345.62 €	22 224 790.81 €	22 558 162.67 €
Best guess	14 644 403.63 €	14 864 069.68 €	15 087 030.73 €	15 313 336.19 €	15 543 036.23 €	15 776 181.77 €	16 012 824.50 €	16 253 016.87 €	16 496 812.12 €	16 744 264.30 €	16 995 428.27 €	17 250 359.69 €
Minimum	9 011 940.69 €	9 147 119.80 €	9 284 326.60 €	9 423 591.50 €	9 564 945.37 €	9 708 419.55 €	9 854 045.85 €	10 001 856.53 €	10 151 884.38 €	10 304 162.65 €	10 458 725.09 €	10 615 605.96 €

Table 7. Revenue of rural area

Revenue source: rural area													
Discount rate	7.00 %												
Increase rate	1.50 %												
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Maximum								7 000 000.00 €	7 105 000.00 €	7 211 575.00 €	7 319 748.63 €	7 429 544.85 €	7 540 988.03 €	7 654 102.85 €
Best guess								5 000 000.00 €	5 075 000.00 €	5 151 125.00 €	5 228 391.88 €	5 306 817.75 €	5 386 420.02 €	5 467 216.32 €
Minimum								2 000 000.00 €	2 030 000.00 €	2 060 450.00 €	2 091 356.75 €	2 122 727.10 €	2 154 568.01 €	2 186 886.53 €
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Maximum	7 768 914.39 €	7 885 448.11 €	8 003 729.83 €	8 123 785.78 €	8 245 642.56 €	8 369 327.20 €	8 494 867.11 €	8 622 290.11 €	8 751 624.47 €	8 882 898.83 €	9 016 142.32 €	9 151 384.45 €	9 288 655.22 €	9 427 985.05 €
Best guess	5 549 224.56 €	5 632 462.93 €	5 716 949.88 €	5 802 704.13 €	5 889 744.69 €	5 978 090.86 €	6 067 762.22 €	6 158 778.65 €	6 251 160.33 €	6 344 927.74 €	6 440 101.65 €	6 536 703.18 €	6 634 753.73 €	6 734 275.03 €
Minimum	2 219 689.83 €	2 252 985.17 €	2 286 779.95 €	2 321 081.65 €	2 355 897.87 €	2 391 236.34 €	2 427 104.89 €	2 463 511.46 €	2 500 464.13 €	2 537 971.10 €	2 576 040.66 €	2 614 681.27 €	2 653 901.49 €	2 693 710.01 €

Table 8. Present value scenarios of cost

Present value scenarios of the cost							
	0	**1**	**2**	**3**	**4**	**5**	**6**
Minimum	5 000 000 €	9 866 798 €	19 470 741 €	19 211 388 €	0 €	19 638 148 €	19 376 564 €
Best guess	5 000 000 €	9 866 798 €	24 338 427 €	24 014 235 €	0 €	25 249 047 €	24 912 726 €
Maximum	5 000 000 €	9 866 798 €	27 259 038 €	26 895 943 €	0 €	31 795 097 €	31 371 580 €

Table 9. NPV calculation

Present value scenarios of revenue														
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Maximum	0 €	0 €	0 €	0 €	12 969 219 €	12 302 577 €	11 670 201 €	15 429 579 €	14 636 470 €	13 884 128 €	13 170 458 €	12 493 472 €	11 851 284 €	11 242 106 €
Best guess	0 €	0 €	0 €	0 €	9 917 638 €	9 407 853 €	8 924 271 €	11 579 296 €	10 984 098 €	10 419 495 €	9 883 914 €	9 375 862 €	8 893 925 €	8 436 761 €
Minimium	0 €	0 €	0 €	0 €	6 103 162 €	5 789 448 €	5 491 859 €	6 455 067 €	6 123 264 €	5 808 517 €	5 509 949 €	5 226 727 €	4 958 063 €	4 703 210 €
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Maximum	10 664 241 €	10 116 079 €	9 596 093 €	9 102 836 €	8 634 933 €	8 191 082 €	7 770 045 €	7 370 650 €	6 991 785 €	6 632 394 €	1 777 502 €	1 686 135 €	1 599 465 €	1 517 249 €
Best guess	8 003 096 €	7 591 722 €	7 201 493 €	6 831 323 €	6 480 180 €	6 147 087 €	5 831 115 €	5 531 385 €	5 247 061 €	4 977 352 €	1 269 644 €	1 204 382 €	1 142 475 €	1 083 749 €
Minimium	4 461 456 €	4 232 129 €	4 014 589 €	3 808 232 €	3 612 482 €	3 426 793 €	3 250 650 €	3 083 560 €	2 925 060 €	2 774 706 €	507 858 €	481 753 €	456 990 €	433 500 €
Net present cash-flow scenarios for the investment														
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Maximum	-5 000 000.00 €	-9 866 798.22 €	-19 470 741.44 €	-19 211 387.70 €	12 969 218.60 €	-7 335 571.51 €	-7 706 363.32 €	15 429 579.14 €	14 636 469.93 €	13 884 128.02 €	13 170 457.89 €	12 493 471.74 €	11 851 283.94 €	11 242 105.79 €
Best guess	-5 000 000.00 €	-9 866 798.22 €	-24 338 426.80 €	-24 014 234.63 €	9 917 637.76 €	-15 841 194.84 €	-15 988 454.26 €	11 579 295.91 €	10 984 098.45 €	10 419 495.26 €	9 883 913.73 €	9 375 862.09 €	8 893 925.25 €	8 436 760.87 €
Minimium	-5 000 000.00 €	-9 866 798.22 €	-27 259 038.01 €	-26 895 942.79 €	6 103 161.70 €	-26 005 649.05 €	-25 879 721.15 €	6 455 066.99 €	6 123 264.48 €	5 808 517.24 €	5 509 948.60 €	5 226 726.94 €	4 958 063.41 €	4 703 209.68 €
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Maximum	10 664 240.54 €	10 116 078.64 €	9 596 093.29 €	9 102 836.16 €	8 634 933.37 €	8 191 081.65 €	7 770 044.74 €	7 370 649.92 €	6 991 784.74 €	6 632 393.93 €	1 777 501.98 €	1 686 135.06 €	1 599 464.56 €	1 517 249.10 €
Best guess	8 003 095.59 €	7 591 721.52 €	7 201 492.84 €	6 831 322.65 €	6 480 179.90 €	6 147 086.54 €	5 831 114.80 €	5 531 384.60 €	5 247 061.09 €	4 977 352.34 €	1 269 644.27 €	1 204 382.18 €	1 142 474.69 €	1 083 749.35 €
Minimium	4 461 455.91 €	4 232 128.74 €	4 014 589.41 €	3 808 232.01 €	3 612 481.77 €	3 426 793.45 €	3 250 649.86 €	3 083 560.38 €	2 925 059.62 €	2 774 706.09 €	507 857.71 €	481 752.87 €	456 989.88 €	433 499.74 €
Cumulative net present cash-flow scenarios for the investment														
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Maximum	-5 000 000.00 €	-14 866 798.22 €	-34 337 539.66 €	-53 548 927.37 €	-40 579 708.76 €	-47 915 280.28 €	-55 621 643.60 €	-40 192 064.46 €	-25 555 594.52 €	-11 671 466.50 €	1 498 991.39 €	13 992 463.12 €	25 843 747.06 €	37 085 852.85 €
Best guess	-5 000 000.00 €	-14 866 798.22 €	-39 205 225.02 €	-63 219 459.65 €	-53 301 821.90 €	-69 143 016.74 €	-85 131 470.99 €	-73 552 175.09 €	-62 568 076.64 €	-52 148 581.38 €	-42 264 667.65 €	-32 888 805.56 €	-23 994 880.31 €	-15 558 119.44 €
Minimium	-5 000 000.00 €	-14 866 798.22 €	-42 125 836.24 €	-69 021 779.02 €	-62 918 617.33 €	-88 924 266.38 €	-114 803 987.53 €	-108 348 920.54 €	-102 225 656.06 €	-96 417 138.82 €	-90 907 190.22 €	-85 680 463.28 €	-80 722 399.87 €	-76 019 190.20 €
	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Maximum	47 750 093.39 €	57 866 172.03 €	67 462 265.32 €	76 565 101.48 €	85 200 034.85 €	93 391 116.50 €	101 161 161.24 €	108 531 811.16 €	115 523 595.90 €	122 155 989.83 €	123 933 491.82 €	125 619 626.87 €	127 219 091.44 €	128 736 340.53 €
Best guess	-7 555 023.85 €	36 697.67 €	7 238 190.52 €	14 069 513.17 €	20 549 693.06 €	26 696 779.60 €	32 527 894.40 €	38 059 279.00 €	43 306 340.09 €	48 283 692.44 €	49 553 336.71 €	50 757 718.89 €	51 900 193.58 €	52 983 942.94 €
Minimium	-71 557 734.28 €	-67 325 605.55 €	-63 311 016.14 €	-59 502 784.13 €	-55 890 302.36 €	-52 463 508.91 €	-49 212 859.04 €	-46 129 298.66 €	-43 204 239.04 €	-40 429 532.96 €	-39 921 675.25 €	-39 439 922.37 €	-38 982 932.50 €	-38 549 432.76 €

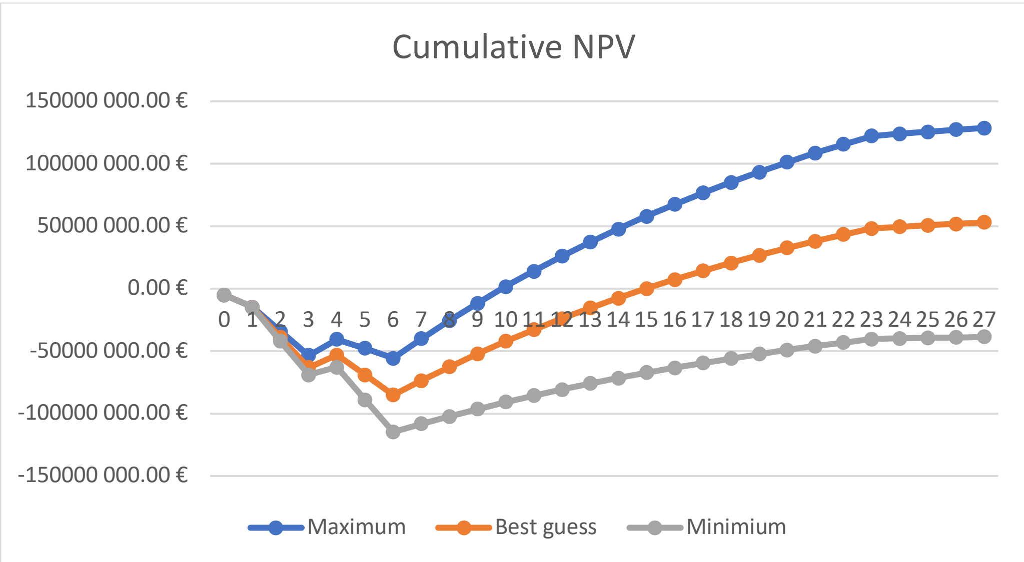

Figure 5. Cumulative NPV

Table 10. ROV calculation

Maximum NPV	128 736 340.53 €	**alpha**	91533376
Best guess NPV	52 983 942.94 €	**a**	52983943
Minimum NPV	-38 549 432.76 €	**beta**	75752398
ROV	51 493 357.16 €		

Appendix C: Matlab code (Datar-Mathews method): Option 1

```
%number of simulation
n=100000;
dis_cost = 0.0135; % discount rate of cost
dis_revenue = 0.07; % discount rate of revenue
beginning_cost = 5000000 + 10000000/(1+dis_cost);
npv = zeros(1,n);

%probability distribution (pd) of implementation cost for the whole area (first option):
im0_pd = makedist('Triangular','A',23000000,'B',30000000,'C',38000000);

%probability distribution (pd) of operation revenue of a whole area:
opWh_pd = makedist('Triangular','A',10000000,'B',18000000,'C',24000000);

for i = 1:n
  im0 = random(im0_pd,1,4); %generate random cost
  revenue = random(opWh_pd,1,20); % generate random value
  total_cost = beginning_cost;
  total_revenue = 0;
  for j = 1:4
    total_cost = total_cost + im0(j)/(1+dis_cost)^(j+1);
  end
  for j = 1:20
    total_revenue = total_revenue + revenue(j)/(1+dis_revenue)^(j+5);
  end
  npv(i) = total_revenue - total_cost;
end

hist(npv,1000)
s=0;
for i = 1:n
  if npv(i)>=0
    s = s + npv(i);
  end
end
probability = sum(npv>=0)/n
rov = probability*s/sum(npv>=0)
```

Appendix D: Matlab code (Datar-Mathews method): Option 2

```
%number of simulation
n=1000;
dis_cost = 0.0135; % discount rate of cost
dis_revenue = 0.07; % discount rate of revenue
beginning_cost = 5000000 + 10000000/(1+dis_cost);
npv = zeros(1,n);

%probability distribution (pd) of implementation cost for the urban area (second option):
im1_pd = makedist('Triangular','A',20000000,'B',25000000,'C',28000000);

%probability distribution (pd) of implementation cost for the rural area (second option):
im2_pd = makedist('Triangular','A',21000000,'B',27000000,'C',34000000);

%probability distribution (pd) of operation revenue of urban area:
opUr_pd = makedist('Triangular','A',8000000,'B',13000000,'C',17000000);

%probability distribution (pd) of operation revenue of rural area:
opRu_pd = makedist('Triangular','A',2000000,'B',5000000,'C',7000000);

for i = 1:n
  im1 = random(im1_pd,1,2); %generate random cost (urban area)
  im2 = random(im2_pd,1,2); %generate random cost (rural area)
  revenue1 = random(opUr_pd,1,20); % generate random revenue (urban area)
  revenue2 = random(opRu_pd,1,20); % generate random revenue (rural area)
  total_cost = beginning_cost;
  total_revenue = 0;
  for j = 1:2
    total_cost = total_cost + im1(j)/(1+dis_cost)^(j+1);
  end
  for j = 1:2
    total_cost = total_cost + im2(j)/(1+dis_cost)^(j+5);
  end
  for j = 1:20
    total_revenue = total_revenue + revenue1(j)/(1+dis_revenue)^(j+3);
  end
  for j = 1:20
    total_revenue = total_revenue + revenue2(j)/(1+dis_revenue)^(j+7);
  end
  npv(i) = total_revenue - total_cost;
end
hist(npv,100)
s=0;
for i = 1:n
  if npv(i)>=0
    s = s + npv(i);
  end
```

```
end
p = sum(npv>=0)/n
rov = p*s/sum(npv>=0)
```