Shuichi Masunaga
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Demand Projection in Engineering-based Real Options Model

Abstract:

Despite the validity of its theory, the real options analysis has not been widely used in real estate industry. The probable reason is that it requires a full understanding of academic theory as well as advanced techniques. In order to resolve this discrepancy, many studies have been done to make the academic theory applicable and understandable for developers in the real world. During the MSRED courses at MIT, I have learned two types of Excel spreadsheet based real options models: economics based model and engineering based model. In the MSRED thesis, I am going to examine the procedure of these models and clarify the difference by comparing their results. As a goal, I hope to create a new, more practical real options model by integrating these two models. In this paper, I will examine the engineering based approach, mainly focusing on the demand projection method in the model.

Introduction:

In recent years, the real options analysis gains more attention as an innovative decision-making method in real estate industry. However, compared with other financial analyses such as the NPV method, the real options analysis requires more advanced understanding of theory and mathematical techniques. Potentially because of that, the real options analysis has not been fully utilized in the real world.

As far as I learned here at MIT, there are two types of acknowledged models for evaluating real options. One of them is a traditional, economics based model using the binominal tree approach which we learned in Prof. David Geltner's Real Estate Finance and Investments course in Fall 2006. The other is a relatively simple, engineering based model which has been developed by Prof. Richard de Neufville at MIT Engineering Systems Division. Both models are based on the Excel spreadsheet, but the concept and the calculation procedure are slightly different between these two models.

In the economics based real options model, we estimate the value of "wait" options based on binominal tree approach. We first calculate the expected value of the developed property based on traditional NPV method. Then, we estimate a certain amount of volatility to the expected value (upside and downside). Also, we take the construction costs growth into account. Based on other assumptions such as interest rates and the return of underlying asset, the spreadsheet model can show us the value of "wait" option, which equals to the optimal value of the developable land.

On the other hand, the engineering based model was created for the purpose of introducing the "academic" real options theory into the real world. The model is also based on Excel spreadsheet, and aims at making itself easily understandable for most engineers and managers without using difficult statistical data such as the volatility of the underlying asset. Instead, the model requires simple inputs such as demand increase, and runs the Monte-Carlo simulation by using the built-in function of Excel software. From the engineering point of view, this model allows the flexibility to be in the building structure in order to absorb the future demand by adding more buildings. By managing the uncertainty through the flexibility, this model enables designers and engineers to cut the downside risks as well as maintain the upside potential. In general, this model is more intended to calculate "expanding" option value of the development project, and more suitable for the design of infrastructure systems such as highways and parking garage development.

For the first step of my MSRED thesis, I will examine the engineering based real options model in this paper, by using the parking garage case which has been introduced by Prof. Richard de Neufville in the class. I will mainly focus on the assumption of demand projection, because that assumption is one of the most important components in this model.

Methodology:

In this paper, I will extend the discussion based on the Excel spreadsheet model named "de Neufville Garage Example Spreadsheet", which was posted in the Stellar course website. I will keep the all assumptions same except for the demand projection. As for the demand projection, I will try to propose the way of setting the demand projection which is more intuitively understandable and more consistent with the reality. Then, I will compare the results between the original demand projection and the proposed demand projection.

Introduction to Parking Garage Case:[1]

The case deals with a multi-level car park for a commercial center in a region that is growing as population expands. The basic data are that:

- The deterministic point forecast is that demand on opening day is for 750 spaces, rises exponentially at the rate of 750 spaces per the first decade, and rises exponentially at the rate of 500 spaces per the next decade;
- Average annual revenue for each space used is $10,000, and the average annual operating cost for each space available (often more than the spaces used) is $2,000;
- The lease of the land costs $3.6 Million annually;
- The construction will cost $16,000 per space for pre-cast construction, with a 10% increase for every level above the ground level;
- The site is large enough to accommodate 200 cars per level; and
- The discount rate is taken to be 12%, and the time horizon for the NPV calculation is taken to be 15 years.
- Land leasing cost ($3,600,000/year) is paid upfront at the beginning of each year. No payment is made at the end of the last year.

[1] The explanation of most assumptions has been quoted from the "ReadMe" tab of the spreadsheet.

- In this paper, the initial levels of the parking are assumed to be six.

Additionally, economic analysis needs to recognize that actual demand is uncertain, given the long time horizon. The case assumes that future demand could be 50% off the projection, either way, and that the annual volatility for growth is 15% of the long-term average.

The owners can design stronger footings and columns to the original building so that they can add additional levels of parking easily. In this case, it has been assumed that the owners will expand one level of the garage if the demand excesses the capacity in the past continuous two years.

Value of Flexibility:

First, if we do not assume any volatility in the future demand, the demand shows an exponential upward curve as illustrated in Exhibit 1. Based on this static demand, the project NPV is calculated to be ￡2,685.886.

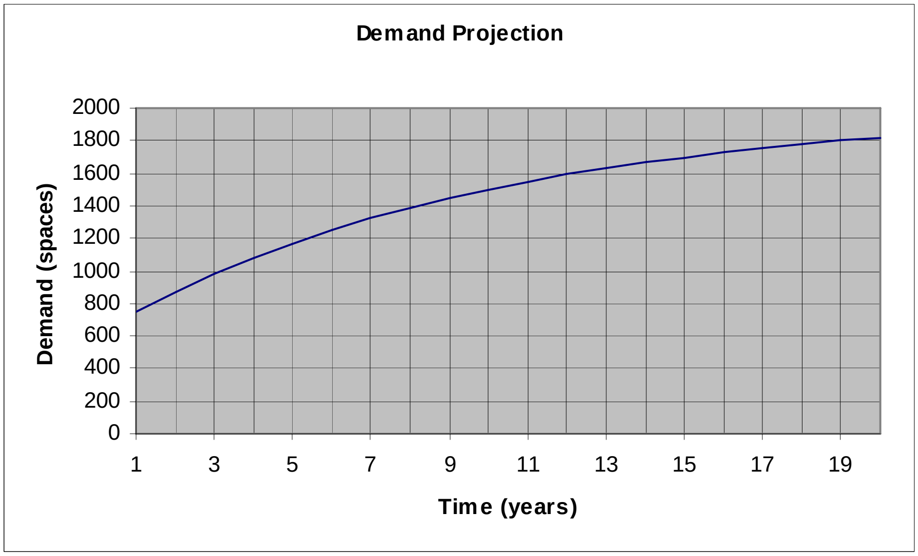

Exhibit 1. Static Demand Projection

Then, if we assume the volatility of the future demand, the graph moves above or below the static demand projection curve, and the example of this relationship is shown in Exhibit 2. Under this particular example, the project NPV is negative £2,022,784. Also, from the Exhibit 3 which shows 2,000 times of Monte-Carlo simulation of the project NPV, the mean of NPV is £1,530,251, lower than the NPV under the static demand projection. This result is due to the limitation of upside potential, since the garage size has been assumed not to be able to expand according to the demand increase.

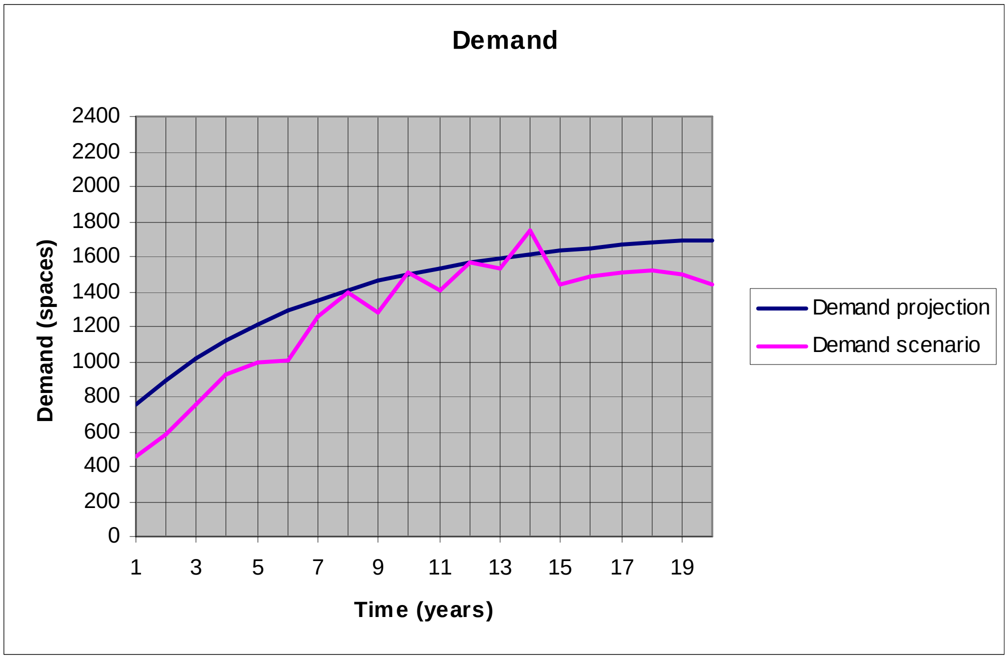

Exhibit 2. Example of Demand Projection with Uncertainty

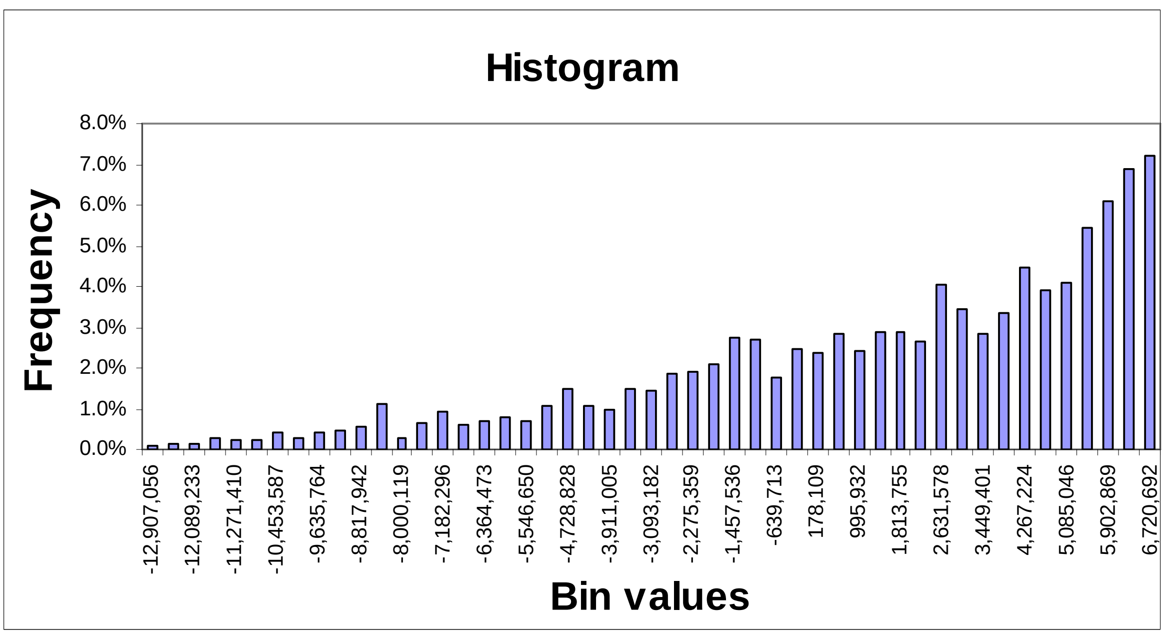

Exhibit 3. Example of NPV Histogram with Uncertainty

Finally, we assume the flexibility in the original structure. Under the same example as above, the histogram of the project NPV is shown in Exhibit 4. Now, developers can benefit more from upside cases. The mean NPV has been increased to be ￡1,896,693.

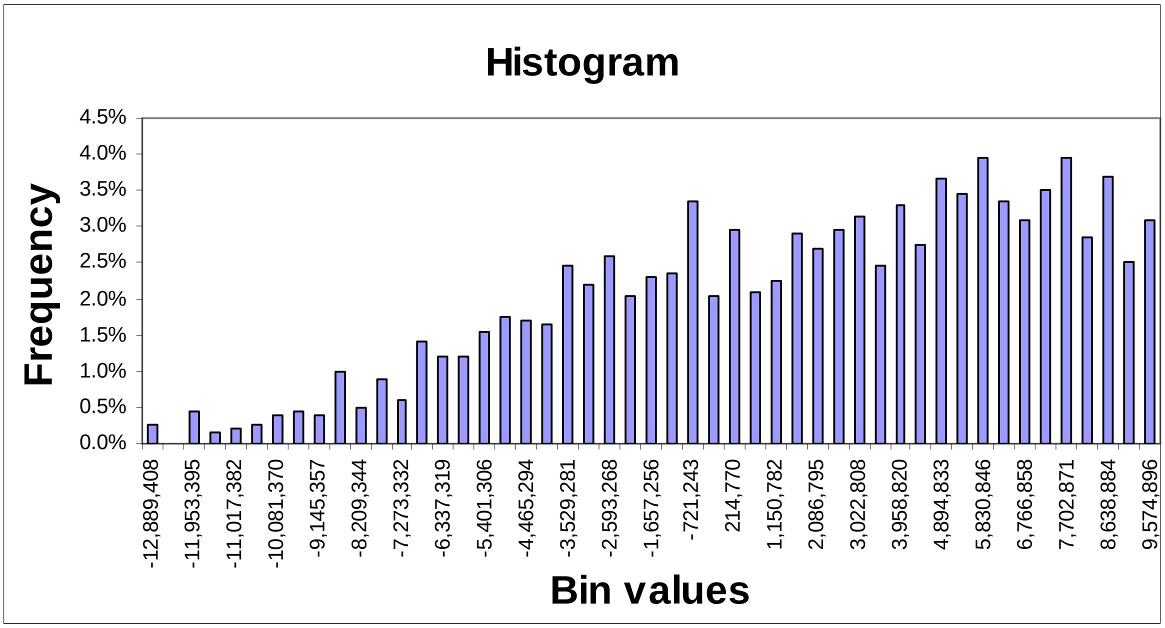

Exhibit 4. Example of NPV Histogram with Uncertainty and Flexibility

The value of the option is calculated to be the difference between the mean NPV of the flexible garage that can be expanded and the mean NPV of the inflexible garage that cannot be expanded. In this particular example, the difference is ￡366,442. In order to decide whether or not the project should be undertaken, developers can compare this difference to the cost of adopting the flexibility. [5% of the original construction cost in this case.]

Proposal for Demand Projection Method:

As is mentioned before, this case assumes two types of volatility in the future demand; the future demand could be 50% off the projection, either way, and the annual volatility for growth is 15% of the long-term average. Although this model is easily understandable and highly informative, it might be a little difficult to set the appropriate assumptions of volatility. At the same time, this assumption of volatility is one of the most influential components in this model. Therefore, here I would like to propose a simpler and potentially better way of assuming the volatility for future demand. The three steps to form the proposed method follow below.

1. Use the same assumptions for the deterministic demand on the first year (750 spaces), and the exponential increase during the first decade (750 spaces) and during the next decade (500 spaces).
2. Calculate the "base" demand growth projection based on the demand projection calculated above.
3. Assume the annual volatility for each year's demand which is projected based on the base demand growth.
4. When calculating next year's demand, start the calculation from the previous year's realized demand calculated by this method.

Realized demand in year T

$D_T = D_{T-1} * (1+G_T) * (1 – V + 2 * V * RAND())$

where

D_t = realized demand at year t (£)

G_t = "base" demand growth projection at year t (%)

V = annual volatility for demand (%)

RAND() = random number between 0 and 1 (uniform distribution)

From now on, I will call the original method of demand projection as "Scenario 1", and the proposed method as "Scenario 2". Exhibit 5 shows the result of the demand projections by two scenarios.[2] Due to the difference of the method, the demand curve of scenario 2 is more "smoothed", while the demand curve of scenario 1 is rather "random walk". Considering the cyclical movement of the real estate market, I believe that scenario 2 can reflect the demand movement in a more realistic way. Moreover, since scenario 2 uses only one assumption for the volatility, I believe that it will make the demand projection easier and more foreseeable.

[2] In Exhibit 5, annual volatility has been assumed to be 15% in scenario 2.

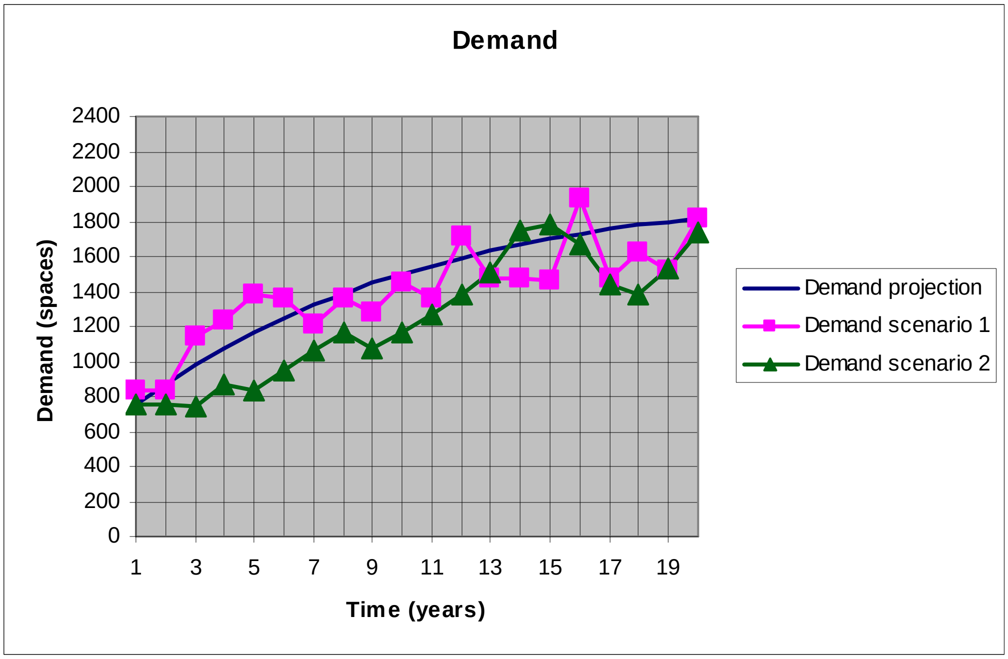

Exhibit 5. Example of Demand Projection of two scenarios

Comparison of two scenarios:

In order to find out the equivalent volatility level that makes the result f scenario 2 nearly equal to that of scenario 1, I compared the calculated NPVs by both scenarios under the inflexible garage case. Exhibit 6 shows the result of 2,000 times of Monte-Carlo simulation, graphing an example of the histogram of [the mean NPV of scenario 1 – the mean NPV of scenario 2].[3] If we increase the annual volatility in scenario 2, the NPV in scenario 2 will decrease and the difference from the NPV in scenario 1 will become larger. Exhibit 7 shows the result of the sensitivity analysis of this NPV difference, based on

[3] In Exhibit 6, annual volatility has been assumed to be 15% in scenario 2.

various percentages in annual volatility. Each trial denotes the mean of the difference calculated by 2,000 times of Monte-Carlo simulation. According to this result, the equivalent volatility level seems to be around 17% in the inflexible garage case.

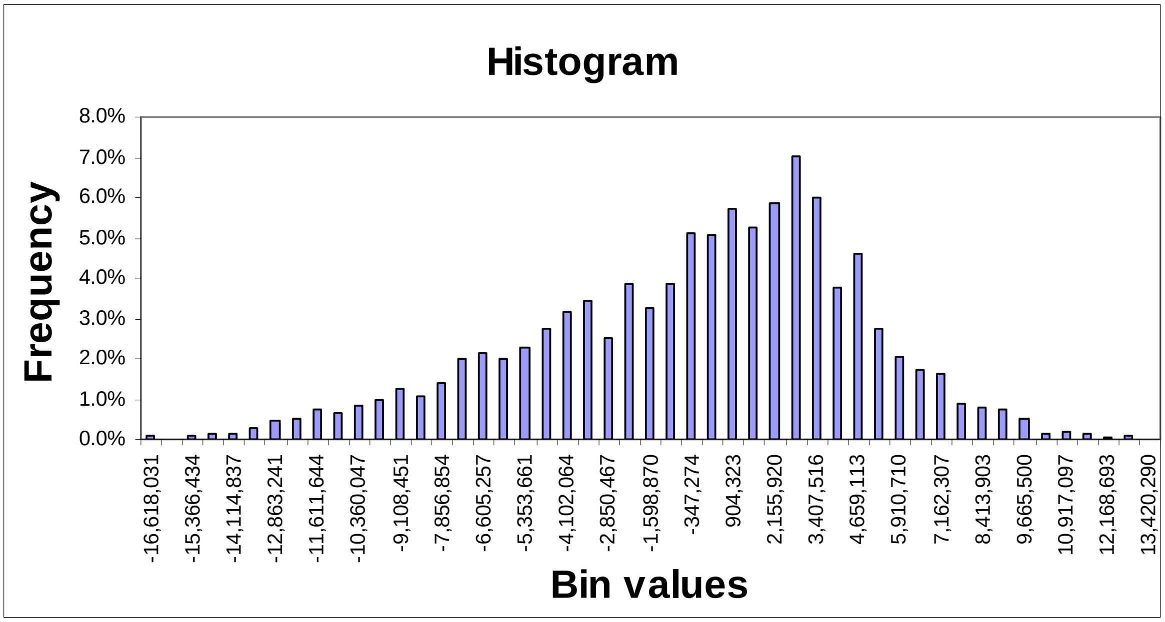

Exhibit 6. Example of Histogram of [scenario 1 NPV – scenario 2 NPV]

	Annual Volatility in scenario 2			
	15.0%	16.0%	17.0%	18.0%
Trial 1	-£ 281,607	-£ 49,938	-£ 69,319	£ 56,728
Trial 2	-£ 160,649	-£ 70,071	-£ 31,937	£ 1,640
Trial 3	-£ 361,396	£ 3,263	£ 18,489	£ 339,267
Trial 4	-£ 363,347	-£ 44,964	-£ 134,465	£ 178,104
Trial 5	-£ 324,208	£ 73,228	£ 19,571	£ 279,186
Trial 6	-£ 114,611	-£ 30,352	£ 57,317	£ 109,875
Trial 7	-£ 129,970	£ 99,459	£ 192,509	£ 280,030
Trial 8	-£ 167,453	-£ 319,979	£ 21,554	£ 262,951
Trial 9	-£ 186,331	-£ 284,782	£ 7,259	£ 277,595
Trial 10	-£ 57,427	£ 179,759	-£ 15,085	£ 185,598
Average	-£ 214,700	-£ 44,438	£ 6,589	£ 197,098

Exhibit 7. Sensitivity Analysis of [scenario 1 NPV – scenario 2 NPV]

Then, I will conduct the same analysis in the flexible garage case as well. Exhibit 8 shows the result of the same sensitivity analysis as done in the inflexible garage case. Here, the equivalent volatility level is around 15%, about 2% lower than the level in the inflexible garage case. If we assume the same level of annual volatility both in the inflexibility garage case and in the flexibility garage case, the NPV difference will be larger in the flexibility garage case. In other words, the value of expanding option tends to be higher in scenario 1 than in scenario 2.

	Annual Volatility in scenario 2			
	14.0%	15.0%	16.0%	17.0%
Trial 1	£ 162,425	£ 46,925	£ 95,758	£ 417,930
Trial 2	-£ 7,027	-£ 16,825	£ 199,284	£ 270,406
Trial 3	-£ 248,808	-£ 176,874	£ 13,197	£ 211,737
Trial 4	-£ 185,509	£ 152,611	£ 405,340	£ 255,282
Trial 5	-£ 1,429	£ 44,487	-£ 42,735	£ 206,032
Trial 6	-£ 22,209	£ 47,791	£ 329,057	£ 89,084
Trial 7	-£ 184,042	£ 49,476	£ 324,324	£ 397,685
Trial 8	-£ 89,138	£ 192,904	£ 351,063	£ 486,506
Trial 9	£ 30,966	£ 138,214	-£ 107,927	£ 463,465
Trial 10	-£ 232,774	-£ 191,684	£ 298,690	£ 387,405
Average	-£ 77,755	£ 28,703	£ 186,605	£ 318,553

Exhibit 8. Sensitivity Analysis of [scenario 1 NPV – scenario 2 NPV]

Where does this difference come from? In order to solve this interesting question, I examined the probability and the timing of the expanding option exercise. Exhibit 9 shows the result of the Monte-Carlo simulation on the number of expansion and the year of first / second expansion under both scenarios.[4] Again, each trial denotes the mean of

[4] In exhibit 9, annual volatility has been assumed to be 17% in scenario 2. In both scenarios, even if the two expanding options are not exercised within 20 years horizon, the

2,000 times of Monte-Carlo simulation. According to these results, scenario 2 has less chance to exercise expanding options than scenario 1, and the time to expand is longer in scenario 2 than in scenario 1. Based on these facts, I supposed that the “smoothed” and “cyclical” demand projection in scenario 2 makes the expanding options less likely to happen.

	Number of Expansion		Year of 1st Expansion		Tear of 2nd Expansion	
	scenario 1	scenario 2	scenario 1	scenario 2	scenario 1	scenario 2
Trial 1	1.831	1.68	8.3575	9.358	11.043	11.9375
Trial 2	1.8505	1.654	8.274	9.146	10.8685	12.034
Trial 3	1.828	1.647	8.254	9.099	10.829	11.7775
Trial 4	1.8435	1.6915	8.3815	9.259	11.165	12.0295
Trial 5	1.8375	1.65	8.4735	9.318	10.7685	11.9875
Trial 6	1.8375	1.65	8.4735	9.318	10.7685	11.9875
Trial 7	1.829	1.6535	8.166	9.104	10.952	12.0445
Trial 8	1.834	1.6675	8.492	9.1965	10.9135	11.9285
Trial 9	1.833	1.6525	8.408	9.0695	11.067	11.972
Trial 10	1.836	1.663	8.408	9.0695	11.067	12.0505
Average	1.836	1.6609	8.3688	9.19375	10.9442	11.9749

Exhibit 9. Monte-Carlo Simulation of Expanding Option Exercise

Conclusion:

After reviewing the basics of the parking garage case, I proposed a new method of demand projection in the model, and compared its results to those of the original method. I revealed that two different methods of future demand projection could lead to significant difference in the value of “expanding” real options. Although I am not completely sure about the reasons behind this fact, I believe it worthwhile to keep this difference in mind when we evaluate the value of real options based on the demand volatility. In my MSRED

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model assumes the remaining expansion(s) takes place in year 20.

thesis, I will mainly focus on the economics based real options model, but I would like to extend this analysis further at the same time. Also, I may be able to try to compare the engineering based model to the economics based model in a similar way that I adopted in this paper.

Reference:

Ariizumi, T. (2006). *Evaluation of Large Scale Industrial Development Using Real Options Analysis – A Case Study –*. Research Paper, Massachusetts Institute of Technology

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