

Optimizing Business Operation Strategies Under Uncertainties---A Simulation Approach

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Abstract—Optimizing business strategy for maximal profit is challenging due to the variabilities and uncertainties of parametric inputs required for estimating future profits. Incorporating economic uncertainties into profit estimating process through stochastic simulation could be an option for reliable business decision analysis. In this paper, a convenient simulation-based decision procedure is presented to identify the optimal business strategy of a laptop store by exploring, quantifying and calculating inherent information uncertainties. Optimal profitability is calculated, and the associated sensitive factors are revealed.

Keywords—simulation; uncertainty; sensitivity; strategy

I. INTRODUCTION

Maximizing profits is generally the primary objective for business operations. Nevertheless, many factors can affect the practical business profits, such as market demand, selling price, ordering cost, holding cost, etc. Moreover, these factors are often unstable due to market fluctuations, and the variations associated with these factors may render the consequential profits to be random and uncertain. Therefore, deterministically calculating profits may result in decision errors and then bring risks in business investments. Probabilistic information could be useful for the estimates and analysis in business profits.

Invented by Von Neumann, IT based simulation has been widely used in business and engineering fields for various purposes as a convenient sampling method [1] to complex systems or processes. It essentially builds a mathematical or logical model of a system and performs virtual experiments to observe the system behavior. According to Evans and Olson [2], simulation is particularly useful in handling problems with uncertainty through modeling any appropriate assumptions to deal with probabilistic information and execute probabilistic calculations with sampling method. In [1], simulation technology was adopted to predict the number of meals needed by air flights under uncertainties. Rodriguez and Padua [3] determined the probabilistic risks of hydrocarbon projects by simulation. Benson [4] found that simulation could come up with better estimates on business cycle times. By using simulation, French and Gabrielli [5] were able to perform calculations on uncertain information.

In this paper, a simulation-based process is presented to identify the optimal investment strategy among alternatives to maximize the operational profitability of a store with uncertain information. The store plans to rent a space to sell laptops of Acer and HP (screen size ranges from 13.3 to 15.6 inches) in

Lincoln, NE. The brand constituent of laptops is to be determined along with annual ordering quantity to optimize profits. Through uncertainty simulation, the uncertainties associated with the parameter inputs of operation profits are quantified. Probabilistic profits for alternative plans within a specific period are estimated to determine optimal strategy by using predefined criteria. Sensitive factors of optimal strategy are revealed through stochastic sensitivity analysis.

II. METHODOLOGY

In order to use simulation method to obtain probabilistic information for optimized investment decision, a specific procedure is developed as follows: 1) Conceptual model. Based on investment principle, a conceptual model is constructed (FIGURE I). Major input variables include fixed cost associated with room rent, workers' salary and required business equipment, such as receipt printer, credit card scanner and so forth, variable cost associated with products ordering, holding, packaging, ordering amount, income associated with regular sales and salvages.

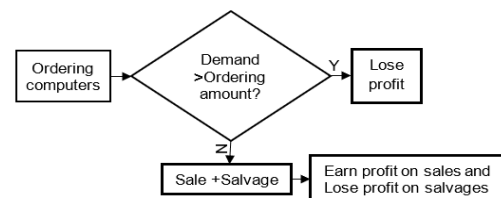


FIGURE I. YEARLY BUSINESS PROCESS

2) Simulation model. Probabilistic distributions of input variables are either fitted to collected data or cited from related documents. Profits are determined by (1).

$$\text{Profit} = \sum[(\text{Unit selling price} - \text{Unit ordering cost} - \text{Unit packaging cost}) * \text{Amount of sold products} + (\text{Unit salvage value} - \text{Unit holding cost}) * \text{Salvaged units}] - \sum(\text{Room rent} + \text{Equipment cost} + \text{Worker salary}) \quad (1)$$

3) Numerical experiments. Decision variables including brands of laptops and annual ordering amounts are changed to examined variations. Simulation is run with a designated period of 5 years. In total, 10,000 times of simulation are run.

4) Verification and validation. Physical logicity of the developed models is verified. Both *face validity* and *data validity* are tested [2]. The former refers to asking experts on whether the model structure is reasonable while the latter compares the outputs with historical data to determine model validity.

5) Determine optimal strategy. Mean value and coefficient of variation (CV) are used as decision criteria for the determination. The investment plan with a larger mean value but smaller CV is chosen as optimal.

$$CV = \sigma/\mu \quad (2)$$

III. RESULTS

A. Data Distributions

Data collection process is made as local as possible. For some specific variables, like unit selling price, unit ordering cost and inflation for which data sources are rich, as many as data samples are collected (FIGURE II) and fitted by goodness of fit test. Where local data are unavailable, data distributions are cited from related documents, e.g. [6-10].

Data points for ordering cost(Acer)	Data points for selling price(Acer)	Data points for ordering cost(HP)	Data points for selling price(HP)	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ave
\$389.99	\$449.99	\$448.98	\$528.00	2011	1.6	2.1	2.7	3.2	3.6	3.6	3.6	3.8	3.9	3.5			
\$467.99	\$499.00	\$356.02	\$399.97	2010	2.6	2.1	2.3	2.2	2	1.1	1.2	1.1	1.1	1.2	1.1	1.5	1.6
\$399.99	\$529.00	\$384.99	\$429.99	2009	0	0.2	-0.4	-1	-1.3	-1.4	-2	-1.5	-1	-0	1.8	2.7	-0.4
\$414.99	\$499.00	\$378.98	\$398.98	2008	4.3	4	4	3.9	4.2	5	5.6	5.4	4.9	3.7	1.1	0.1	3.8
\$589.99	\$629.99	\$379.99	\$499.99	2007	2.1	2.4	2.8	2.6	2.7	2.7	2.4	2	2.8	3.5	4.3	4.1	2.8
\$414.99	\$499.00	\$399.99	\$599.99	2006	4	3.6	3.4	3.5	4.2	4.3	4.1	3.8	2.1	1.3	2	2.5	3.2
\$499.99	\$629.99	\$349.99	\$499.00	2005	3	3	3.1	3.5	2.8	2.5	3.2	3.6	4.7	4.3	3.5	3.4	3.4
\$579.99	\$649.99	\$499.99	\$749.99	2004	1.9	1.7	1.7	2.3	3.1	3.3	3	2.7	2.5	3.2	3.5	3.3	2.7
\$359.00	\$379.00	\$359.00	\$679.99	2003	2.6	3	3	2.2	2.1	2.1	2.1	2.2	2.3	2	1.8	1.9	2.3
\$399.99	\$499.00	\$339.99	\$449.99	2002	1.1	1.1	1.5	1.6	1.2	1.1	1.5	1.8	1.5	2	2.2	2.4	1.6
\$299.00	\$499.00	\$299.97	\$349.97	2001	3.7	3.5	2.9	3.3	3.6	3.2	2.7	2.7	2.6	2.1	1.9	1.6	2.8
\$225.00	\$475.00	\$349.99	\$579.99	2000	2.7	3.2	3.8	3.1	3.2	3.7	3.7	3.4	3.5	3.4	3.4	3.4	3.4
\$422.00	\$475.00	\$574.99	\$699.99	1999	1.7	1.6	1.7	2.3	2.1	2	2.1	2.3	2.6	2.6	2.6	2.7	2.2
\$475.00	\$502.00	\$489.99	\$639.99														
\$396.00	\$475.00	\$449.99	\$599.99														
\$419.99	\$429.00	\$487.49	\$649.99														
\$399.99	\$449.99	\$424.99	\$599.99														
\$409.00	\$450.00	\$549.99	\$749.99														
\$349.95	\$424.95	\$479.99	\$579.99														
\$239.99	\$499.99	\$669.99	\$849.99														
\$329.99	\$399.99	\$419.99	\$549.99														
\$349.99	\$499.99	\$469.99	\$599.99														
\$589.99	\$629.99	\$399.99	\$549.99														
\$314.10	\$449.97	\$499.99	\$649.99														
\$399.99	\$529.99	\$499.99	\$544.99														
\$449.99	\$699.99	\$428.00	\$448.00														
\$338.95	\$399.99	\$549.00	\$799.00														
\$349.99	\$429.99	\$579.99	\$749.99														
\$359.97	\$479.97																
\$599.99	\$699.99																
\$349.99	\$449.99																

FIGURE II. DATA COLLECTION

The data distribution results are summarized in TABLE I.

TABLE I. DATA DISTRIBUTIONS (UNIT: \$)

Input variables	Distribution parameters
Unit ordering cost (Acer)	L (406.50,95.8)
Annual increase	\$5
Unit selling price (Acer)	L (504.42,88)
Unit ordering cost (HP)	L (451.57,96)
Annual increase	\$5
Unit selling price (HP)	BetaPERT(280.61,571.24,954.65)
Monthly inflation	Weibull (15.58,13.97)
Demand increase	Triangular (5.75%, 6.0%,12.1%)
Rent rate(\$/SF/year)	Logistic (13.63,2.71)
Annual increase	10% (chance 50%) or no change
Total equipment cost	\$3,000
Unit packaging cost	Uniform (0.10,1.00)
Demand of last year	1500 pieces
Unit salvage value(Acer)	Uniform (169.00,369.00)
Unit salvage value(HP)	Uniform (209.00,679.00)
Workers' annual salary	Triangular (27,000,35,000,46,000)
Unit holding cost rate	Triangular (24%, 30%, 36%)
Shares of demand	Acer 40%; HP 60%
Decision variables	
Amount(HP)	1000-2000 pieces (Step=100)
Share(HP)	50%-60% (Step=5%)

B. Simulation Model Results

Simulation model is constructed as follows. Input Variables and Decision Variables are created (FIGURE III) based on TABLE I. Output measurements are obtained based on concept model (FIGURE I) and the general formula (1).

Input									
Unit ordering cost(Acer)(1st year)(\$)	406.50	Demand ratio: Acer:40%						Total area	1076.00
Annual increase(Acer)	5.00	HP:60%							
Unit selling price(Acer)(1st year)(\$)	504.42								
Unit ordering cost(HP)(1st year)(\$)	451.57								
Annual increase(HP)	5.00								
Unit selling price(HP)(1st year)(\$)	589.99								
Inflation(1st year)	1.50	2nd year	1.50	3rd year	1.50	4th year	1.50	5th year	1.50
Demand increase rate(annually)	0.00	2nd year	0.00	3rd year	0.00	4th year	0.00	5th year	0.00
Room rent rate(last year)(\$/SF/year)	13.63								
Annual increase rate(1st year)	0.00	2nd year	0.00	3rd year	0.00	4th year	0.00	5th year	0.00
Total business equipment cost(\$)	3000.00								
Unit packaging cost(\$)	0.20								
Demand for last year	1500.00								
Unit salvage value(Acer)(\$)	269.00								
Unit salvage value(HP)(\$)	444.00								
Workers' annual salary(\$)(1st year)	38000.00								
Unit holding cost rate(Acer)	0.30	Unit holding cost rate(HP)	0.30						
Decision variable									
HP share	0.60								
Acer share	0.40								
Total ordering amount	2000.00								
Output									
	1st Year	2nd Year	3rd Year	4th Year	5th Year				
Profit from sale	192820.99	200489.85	206994.07	209396.00	199396.00				
Profit from salvage	-72191.95	-49044.18	-22566.34	0.00	0.00				
Fixed cost(Rent+Salary+Equipment)	54399.17	52169.13	52977.59	53826.47	54717.79				
Total profit	67229.86	99276.54	131450.15	155569.53	144678.21				
Total profit(net present value)	65589.85	94492.09	92187.04	89938.21	87744.25				
Cumulative profit(net present value)	65537.74	160029.83	252216.87	342155.08	429899.34				

FIGURE III. SIMULATION MODEL

During the simulation (10,000 times), *Decision Table* function of Crystal Ball software is used to generate output using *total ordering amount* (Lower bound=1,000 upper bound=2,000, step=100) and *share of HP* (Lower bound=0.5, upper bound=0.6, step=0.05) as decision tables. The results are shown in FIGURE IV.

Trend Chart	HP share (1/2)	HP share (5/9)	HP share (3/5)	
Overlay Chart				
Forecast Chart				
Total ordering amount (1,000.00)	269670.80	277968.31	286265.82	1
Total ordering amount (1,100.00)	321182.28	330309.54	339436.80	2
Total ordering amount (1,200.00)	372693.75	382650.77	392607.78	3
Total ordering amount (1,300.00)	422470.03	434991.99	445778.76	4
Total ordering amount (1,400.00)	450103.14	487333.22	498949.74	5
Total ordering amount (1,500.00)	426084.08	530271.91	552120.72	6
Total ordering amount (1,600.00)	395302.76	539583.77	604870.10	7
Total ordering amount (1,700.00)	364521.45	518524.97	634022.78	8
Total ordering amount (1,800.00)	333740.13	491716.73	598593.23	9
Total ordering amount (1,900.00)	302958.81	449356.34	511260.54	10
Total ordering amount (2,000.00)	264610.87	368098.39	422488.77	11
	1	2	3	

FIGURE IV. DECISION TABLE FUNCTION OUTPUT

C. Optimal Strategy Determination

Mean value of profit (NPV) shows the average of possible profits. A greater Mean value indicates a greater average profit. From FIGURE IV, three Mean values are around \$600,000, shown in the cells of (3,7), (3,8) and (3,9). However, the values are relatively close. These three corresponding strategies are preliminarily targeted as better ones. They are 1) Total ordering amount=1,600 pieces, share of HP=3/5; 2) Total ordering amount=1,700 pieces, share of HP=3/5; 3) Total ordering amount=1,800 pieces, share of HP=3/5. The sequence order in terms of Mean value is (3,8)>(3,7)>(3,9). Although Mean value can show the average value, it cannot show the associated risk of each alternative. To find the optimal strategy, the resulting distributions of three strategies are compared (FIGURE V). From FIGURE V, it is still hard to clearly see the difference in their Standard Deviation (SD) values, which means the absolute difference in SD values are small. However, the statistics table clearly shows the difference. From the table, the sequence of absolute variations in three strategies is (3,9)>(3,8)>(3,7). The optimal strategy should have the smallest SD and the greatest Mean values. From the above two orders, it is hard to find the optimal strategy. CV values for three strategies are calculated as follows: $CV(3,7) = 1.33$, $CV(3,8) = 1.34$, $CV(3,9) = 1.48$. The strategy (3,7) that, 1600 pieces laptops are ordered and 3/5 of them are HPs, is the optimal one with the smallest CV. An employee from the laptop store at the University of Nebraska confirmed the model assumptions, structure and results.

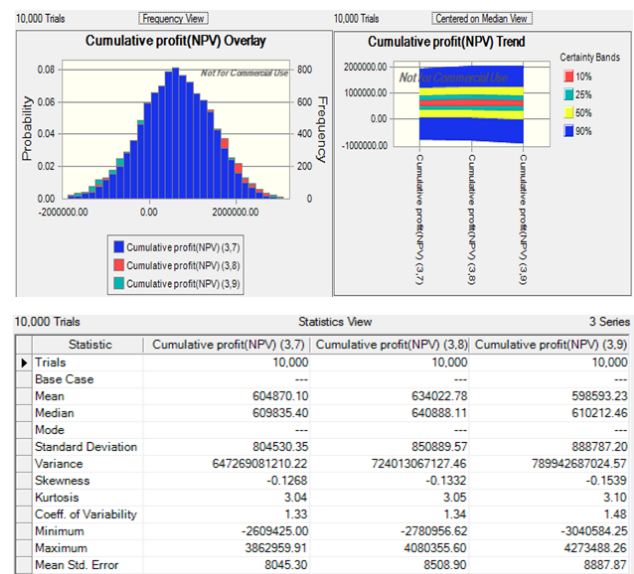


FIGURE V. COMPARISON BETWEEN THREE PRELIMINARY STRATEGIES

D. Optimal Strategy Analysis

From FIGURE VI, the optimal strategy (3,7) outputs are fitted to Beta (100,100). The probability of earning money for this business is 77.53%. It means that we still have more than 22% chance of losing money. But the risk is not that high. The 90% confidence interval for the mean profit is [\$591635.58, \$618104.62].

From sensitivity analysis, ordering costs for HP and Acer are the most crucial factors that can positively contribute 17.7% and 9.3% to the variations of the cumulative profits (NPV), respectively. The increase in the fifth-year room rent rate and the demand increase rate for the third year are also important but negatively impact the variation of cumulative profit (NPV) with 8.9% and 6.7% contributions, respectively. Other factors, such like unit packaging cost, salvage value, the first-year annual increase in room rent rate, demand increase rates for the first and fourth years, have a total contribution of 31.1% to the final resulting variation. All the above variables explain 73.7% of the resulting variations.

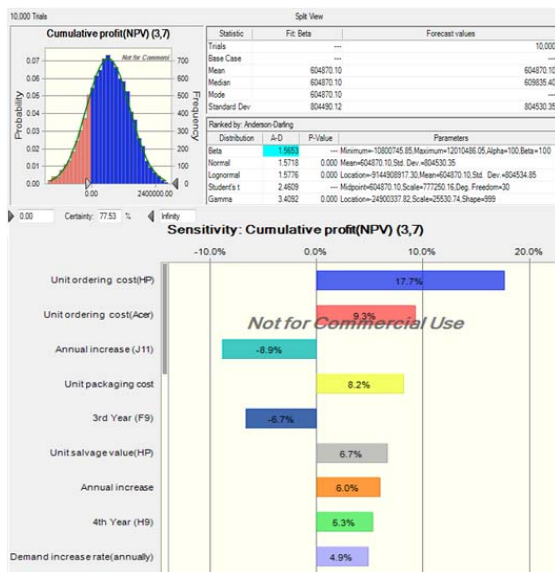


FIGURE VI. ANALYSIS OF OPTIMAL STRATEGY

IV. CONCLUSION

Estimating future business profit is an uneasy task due to the variability of information inputs. A convenient stochastic decision-making procedure is presented to determine the optimal business strategy under uncertain information. The case study analysis showed big variations for the NPV values of profit between the products. The best strategy can be found by considering both the mean and the variation values of profits. The procedure can also identify the most sensitive factors relative to profits. The presented procedure may benefit business decision makers in reliably determining an optimal portfolio before investment by understanding inherent uncertainties.

REFERENCES

- [1] W. Zhao, "Application of Crystal Ball Software in Management Simulation," Computer Science and Service System (CSSS), 2011 International Conference, Nanjing, China, 27-29 June, 2011.
- [2] J. Evans and D. Olson, "Simulation and Risk Analysis," Pearson Custom Publishing, ISBN:0-536-91528-8, 2005.
- [3] J. Rodriguez, K. Padua, "An Application of Portfolio Optimization with Risk Assessment to E&P Projects," Proceedings of the 2005 Crystal Ball Users Conference, Denver, CO, 13-15 June, 2005.
- [4] P. Benson, "Applying Crystal Ball® to Transaction Process Analysis," Proceedings of the 2006 Crystal Ball User Conference. Denver, Colorado, 1-3 May, 2006.
- [5] N. French and L. Gabrielli, "Discounted Cash Flow: Accounting for Uncertainty," J. Property Investment Fin., vol. 23, pp. 75-89, 2005.
- [6] S. Chopra, "Choose the Channel That Matches Your Product," Supply Chain Strategy, vol. 2, pp. 8-9, 2006.
- [7] J.A. Muckstadt, A. Saprà, "Principles of Inventory Management," Springer Series in Operations Research and Financial Engineering, ISBN 978-0-387-24492-1, 2010.
- [8] J.E. Vardaman, "Low Cost Options for Next Generation Packaging," Proceedings of 3rd Electronics Packaging Technology Conference, 05-07 Dec, 2000.
- [9] Wikipedia, "Market Share of Leading PC Vendors," 2017.
- [10] K. Lorette, "Commercial Landlord & Tenant Act," eHow, 2011.