Real options evaluation of financial investment in flexible manufacturing systems in the automotive industry

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Abstract: With increasing technology advancement and global economic cooperation and competition, leading companies in the automotive industry are now refocusing on better operational performance through advanced technology, as well as being competitive, flexible and responsive to changing market conditions. Flexible Manufacturing Systems (FMSs) have once again become highly desirable in the configuration of high performance manufacturing systems for strategic manufacturing capability planning to achieve sustainable growth and market responsive production. Due to large investment requirements and long-term implications, the economic evaluation of financial investment in FMSs remains an important and challenging issue for strategic business planning and capital allocation.

The research within illustrates an economic evaluation process for financial investments in an automobile engine plant for flexible production capability. Because of the application of advanced manufacturing technology and equipment with FMSs, the initial investment is relatively large and additional investment is needed to expand production capability to capture future growth opportunities. Since traditional Net Present Value (NPV) analysis alone may not fully justify the investment decision, real options analysis was, therefore, applied to evaluate the investment project in two phases, with the expansion investment viewed as a real option. Its exercise will depend on the initial investment and future market developments.

Keywords: flexible manufacturing system; automotive investment; investment for flexibility; real options analysis.

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1 Introduction

The very competitive global automotive industry requires original vehicle manufacturers and suppliers to operate more and more efficiently and be highly responsive to changing consumer demand and new technology developments. Rising fuel cost and the demand for fuel efficient and environment friendly cars have promoted the development of new technologies such as Gas-Electric Hybrid and Plug-in Hybrid Electric technologies. The successful application of these technologies for new vehicle production will require automobile manufacturers and their suppliers to modify or redesign their current manufacturing processes so that new parts (such as engines for hybrid drive systems) and new vehicles can be built quickly in response to changing market demand. Flexible Manufacturing Systems (FMSs) have once again become highly desirable in the configuration of high performance manufacturing systems for strategic manufacturing capability planning in order to achieve sustainable growth and market responsive production. Economic evaluation of financial investment in FMSs in the automotive industry remains an important issue for strategic business planning. The need for quick product development, and the need for effective manufacturing process planning, have been the most important driving forces behind the continued transformation in manufacturing practice in the automotive industry from mass production systems to FMSs (Piller, 2004; Kaighobadi and Venkatesh, 1994).

A traditional FMS is an arrangement of machines interconnected by a part transport system. In the early days of application in the manufacturing industry, FMSs were often applied in the design and configuration of job shops where different types of parts and components can be processed in small batches. The key benefit from an early FMS is the capability to process multiple types of parts with the same set of machines and equipment. Those systems were ideal for part suppliers serving many customers with low to medium quantity but large part variety.

With the development of computer technology and its application in the industry, advanced processing control technologies, such as Programmable Logical Control (PLC) and Computer Numerical Control (CNC) were developed and applied in the manufacturing industry since the 1970s up to the present time. The need for high volume production with higher productivity and efficiency, as well as the need for flexibility to produce different parts without major retooling costs, have promoted the design of much more efficient FMSs with automatic control and material handling capability (Chen and Small, 1996; Gerwin, 1993). These modern FMSs are high performance systems in terms of production efficiency, machining accuracy, manufacturing automation, and reduced production cycle times. They become highly desirable for market responsive production and they were applied in major manufacturing plants in the automotive industry and other industries around the world (Burcher and Lee, 2000; Chen and Small, 1996).

With FMSs, manufacturers could easily change the type of product to be produced by the selection of a different part processing control programme integrated with the CNC machines and the automatic material handling system, and modify tool settings accordingly in a relatively short period of time. The capability of relatively fast change-over to produce different types of products at high production rates offered by FMSs, created strategic, long term manufacturing advantages. Such advantages may include: reduced production cost, extended effective service life time of the production system, better investment effectiveness for long term production, and quick response to changing market demand, such as the demand for smaller, more fuel efficient hybrid engines and cars. These advantages offered by FMSs are of strategic value to manufacturing companies in the automotive industry, which faces constantly changing consumer demand, market and economic environment, changing regulatory environment, and global competition.

2 Real options analysis complements traditional investment evaluation

Complementary to traditional discounted cash flow evaluation, real options analysis provides a new view and new approach to capital budgeting and financial evaluation, which combined financial options pricing theory and discounted cash flow method to assess the benefit and risks associated with real world industrial investments (Amram and Kulatilaka, 1999; Copeland and Keenan, 1998). Of particular importance is the capability of real options analysis to capture the value of management and operational flexibility in many investment projects, such as investment in FMSs. With the advancement in real options analysis in recent years, it is possible to analyse the strategic benefits of a FMS in financial terms. The added strategic value created by a FMS will help corporate executives and financial managers to get a better understanding of the true value offered by such systems, so that they could be confident in financial investment in FMSs, knowing that such systems will add economic value and strategic competitiveness to the company. The objective of this paper is to present a case of real world application of real options analysis of financial investment in FMSs in the automotive industry.

3 The investment project background

FDM Company is a global leading automobile manufacturer in the USA. The company has significant business operations in all major regions and countries around the world in order to pursue a globally integrated and competitive business development and growth strategy. With continued economic development in China over the last 20 years, business perspective for foreign direct investment remains promising. Since the early 1990s FDM Company has successfully increased its business operation in China.

JLC Corporation is a major manufacturer of automobile engines, light trucks, and mini vans in China. With continuous improvement in quality, product design, and cost effectiveness, the company has successfully evolved from an automobile part supplier to a major engine and vehicle manufacturer in China. The new development strategy, since its joint-venture with FDM Company, has focused on new product design, high product quality, competitive pricing, and superior customer service. Market demand for its products has been very strong since later 1980s, and this trend is expected to continue well into the future since its joint venture with FDM. With growing market demand for its light trucks, mini vans, and engines, top management at JLC Corporation has been considering the expansion of its engine production capacity with advanced technology such as FMSs (Gerwin, 1993; Kaighobadi and Venkatesh, 1994; Burcher and Lee, 2000).

For the expansion of the engine plant, the company plans to invest in new production capacity in the first phase to improve productivity, operational efficiency, and quality of the current engine plant to meet current and future market demand. In the next two years, the company intended to expand its current engine plant into a modern production facility with a new building, FMSs with Computer Numerically Controlled (CNC) machines and automatic material handling systems for added capacity and production flexibility with a wider scope of product supply, which will make the company more responsive to changing customer demand and remain competitive in the emerging market. This expansion project will ensure that the expanded engine plant has enough production capacity and flexibility to meet growing market demand in the future, and to remain competitive and responsive for new product development.

The current engine plant includes several component production lines and one engine assembly line. A technical assessment team has estimated that an initial investment of 40 million US dollars would be required to purchase necessary equipment to maintain the current manufacturing capability and meet market demand for the next two years. Before the end of Year 2, an additional investment of US$166 million will be committed to expand the engine plant in both production capacity and flexibility to meet future market demand.

Recognising the new investment project in engine plant will have a strategic impact on the long term development of the company, the technical and financial teams agreed to perform an economic evaluation of the investment project with both traditional Net Present Value (NPV) evaluation as well as a real options analysis (Kester, 1984; Amram and Kulatilaka, 1999; Botteron, 2001; Kogut and Kulatilaka, 1994; 2001). Since a major part of the investment will be contributed by FDM Company, economic evaluation of the investment project will be performed in US dollars. Foreign exchange risk considerations will be discussed in a separate paper.

4 Project evaluation with traditional net present value analysis

4.1 Project required rate of return for investment in international markets

From the most recent financial information on cost of debt and equity, it was determined that the Weighted Average Cost of Capital (WACC) of FDM Company, which will invest in the engine plant in its joint venture in China, is approximately 15% for investment projects in its home market. Considering the added risk involved in financial investment in emerging markets, such as China, the management has determined that it would be appropriate to add a 4% risk premium to the investing company's weighted average cost of capital, therefore, the Required Rate of Return for this project will be:

$$\mathbf{k} = \text{WACC} + \text{Project Specific Risk Premium}$$

$$= 15\% + 4\% = 19\%. \tag{1}$$

This required rate of return should be used to evaluate FDM invested projects in China market.

4.2 Project net present value analysis with Monte Carlo simulation

4.2.1 Selection of risk factors as simulation input

In order to consider the uncertainty in market demand, revenue and cost, Monte Carlo simulation will be applied to estimate a mean value and distribution of investment project NPV with key input factors as random variables. The investment in the engine plant expansion project will be implemented in two phases:

Phase I, a relatively small initial investment of US$40 million will ensure the smooth operation of the current plant to meet ongoing market demand for the next two to three years, while technical evaluation and vendor selection for the new technology and equipment for Phase II investment with flexible manufacturing capabilities will be carried out.

Phase II, a larger investment of US$166 million in Year 2 for new facility and equipment to expand the plant with higher production capacity and better flexibility to meet future market demands for increased volume of different types of products.

Based on the most recent experience of the top management and the sales forecast on market demand, the most likely value of sales revenue for the engine plant for Year 1 has been estimated at US$152 million, and it will increase by 5% from Year 1 to Year 2. Revenue in Year 3, one year after the engine plant expansion is completed, is projected at US$272 million, and it is expected to grow by 5% for the following five years, given the strong market demand and growth potential.

With appropriate tax rate of 33% (China tax rate for companies with foreign investment), total cost of goods sold, including all variable and fixed costs, has been estimated at US$132 million in Year 1, and US$230 million in Year 3. Similarly cost is assumed to increase by 5% annually. To reflect the market risk in demand and cost factors, annual sales revenue and total cost are assumed to be random variables following Pert distributions. (A Pert distribution is an alternative to the Triangular distribution. Pert distribution requires the same three parameters, but interprets them with a smooth curve that places less emphasis on the furthest extreme.) with appropriate minimum, most likely, and maximum values assigned in Table 1.

Table 1 Simulation of project annual cash inflows and net present value (2005 cash flow estimates in millions of US dollars)

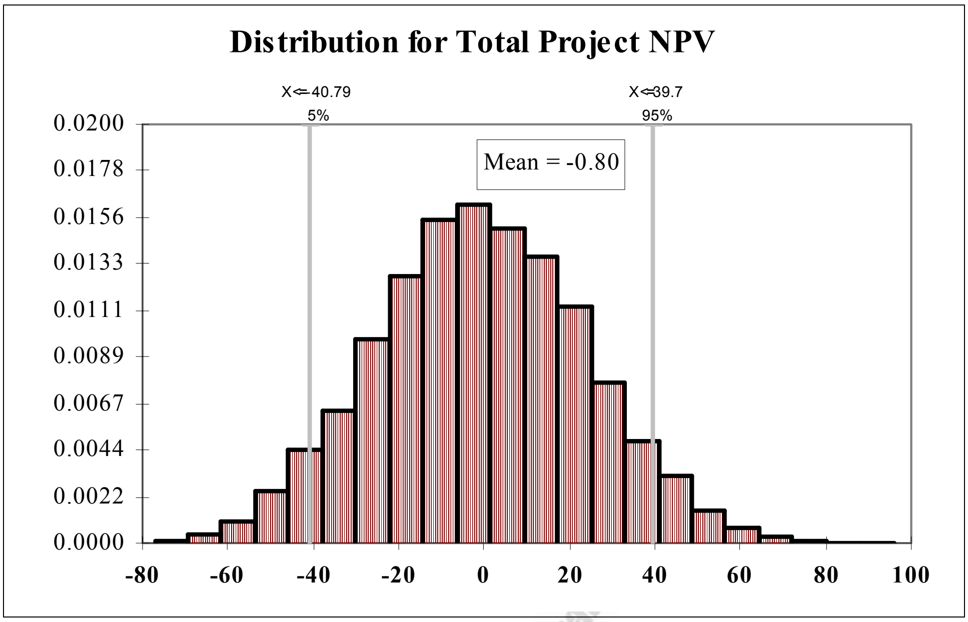
Input data (base value)						*Distributions of input variables*			
Revenue at Year 1	\$152					Pert (132, 152, 174)			
Revenue at Year 3	272					Pert (236, 272, 312)			
Total cost at Year 1	132					Pert (118, 132, 145)			
Total cost at Year 3	230					Pert (200, 230, 250)			
Tax rate	0.33					Fixed			
PRR	0.1900					Fixed			
				Income statement					
Year	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8 …*
Sales revenue	\$	152.33	160.50	274.33	288.33	302.33	317.33	333.33	350.33
Total cost		131.83	137.83	228.33	239.33	251.33	264.33	277.33	291.33
Taxable income		20.50	22.67	46.00	49.00	51.00	53.00	56.00	59.00
Income tax at 33%		6.77	7.48	15.18	16.17	16.83	17.49	18.48	19.47
Net income		13.74	15.19	30.82	32.83	34.17	35.51	37.52	39.53
				Cash flow statement					
Cash flow from operations		13.74	15.19	30.82	32.83	34.17	35.51	37.52	247.58
Net investments	*40.00*		*166.00*						
Net cash flow	(40.00)	13.74	(150.81)	30.82	32.83	34.17	35.51	37.52	247.58
Total project NPV				*–0.80*					

Net present value for any investment project is most closely related with sales revenue and total cost of the business operation. In the analysis of the FDM-JLC Engine Plant Expansion Project, total sale revenue and total cost are considered as the major risk factors, and are used as simulation input. Annual operation cash flows after Year 8 were assumed the same as that of Year 8 without any further increase, and were discounted back to Year 8 at the same required rate of return. Column 9 in Table 1 shows all operation cash flows generated in Year 8 and beyond.

4.2.2 *Simulation distribution of overall project NPV and Expansion phase project value V_0*

With sales revenue and total cost set up as simulation input variables with given distributions in Table 1, stochastic distributions for overall project NPV, and the NPV of all cash inflows in Project Phase II, which is noted as V_0, can be estimated with Monte Carlo simulation. With 10 000 iterations a distribution for total project NPV was simulated with output shown in Figure 1. And the simulation output for the current value of project Phase II cash inflows, V_0, was given in Figure 2.

Figure 1 Distribution of total project NPV (millions of USD) (see online version for colours)



As we can see from the simulation output in Figure 1, the overall project NPV, considering initial investment and expansion investment, as well as all cash inflows from operations in both Phase I and Phase II, is:

$$\text{NPV} = -\text{US\$}0.80 \text{ million.} \tag{2}$$

According to traditional NPV evaluation, even a relatively small negative total project NPV will cause the management to be concerned about approving the investment project, although it is well understood that the expansion project is needed for the company to be better prepared for future production flexibility and future growth opportunities.

Current value of the expansion phase cash inflows, V_0, is also roughly normally distributed with a mean value of:

$$V_0 = \text{US\$}134.15 \text{ million,} \tag{3}$$

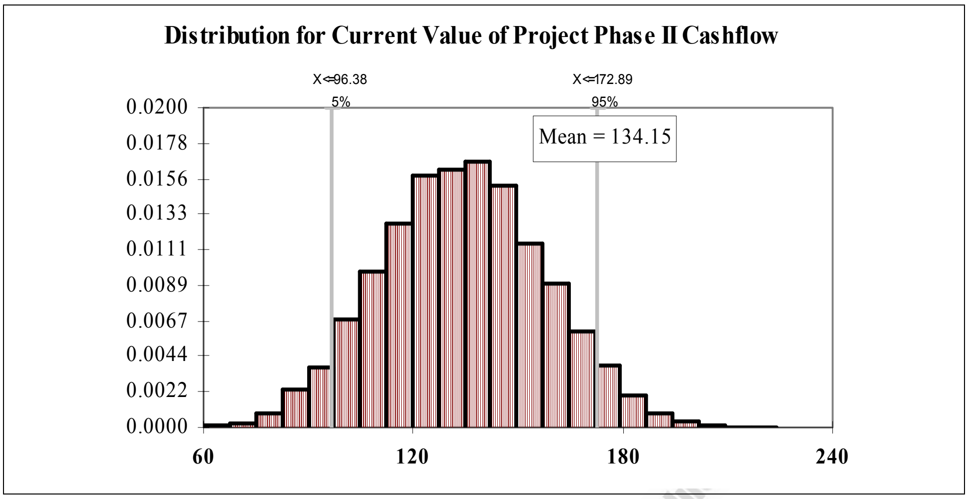
and a standard deviation of US$23.14 million. These values will be used in the next section as one approach to estimate the volatility of the project value.

Simulation output for the NPV for Project Phase I is:

$$\text{NPV}_1 = -\text{US\$}7.73 \text{ million.} \tag{4}$$

This negative NPV for Phase I investment is due to the relatively large initial investment to run current production, and to invest in the basic capability for future expansion for better flexibility, also due to the small net cash inflows in the first two years. For the two-phased investment project for engine plant expansion, it is hoped that future production for a wider scope of products with higher demand will bring better returns and give the investing company a better competitive advantage in the market.

Figure 2 Distribution of Phase II project value (millions of USD) (see online version for colours)

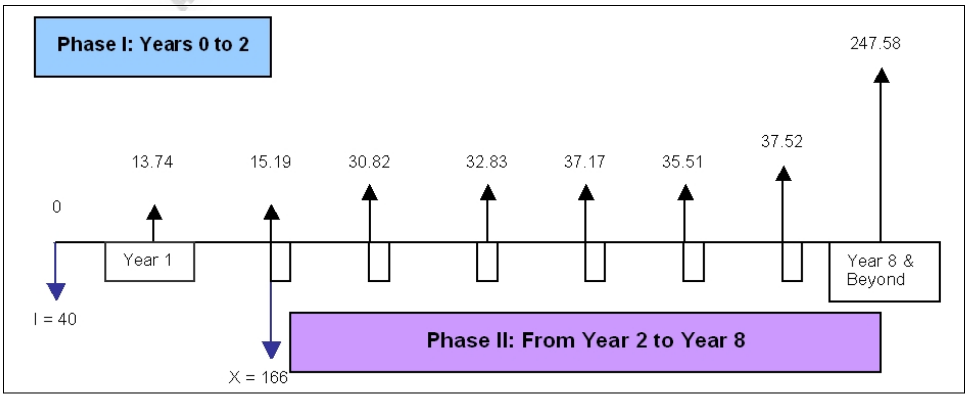


5 Project evaluation with real options analysis

The financial investment in the FDM-JLC joint venture engine plant could also be evaluated in a real options perspective, where the phased investment project is put in a real options framework, and the key parameters required to conduct a real options analysis have to be determined first.

As it has been discussed in early sections, in order to keep the initial production running while preparing for the expansion project in Year 2, it is necessary to carry out the whole project in two phases. This phased approach will allow management the flexibility to modify the scale of investment according to market development. The value of flexibility in making investment decisions can be valued in a real options perspective (Merton, 1973; 1998; Lefley, 1996; Mehrabi *et al.*, 2002; Zhang, 2008). For the FDM-JLC joint venture engine plant expansion project, the whole investment will be implemented in two phases as shown in Figure 3.

Figure 3 Investment requirements and cash flow schedule in millions of USD (see online version for colours)



Phase I — Invest US$40 million in the current engine plant now, so as to make necessary improvement in the engine plant manufacturing process and equipment, to meet the current production needs for at least two to three years. This phase of investment is necessary not only to keep the current operation, but to keep the options open for future investment opportunity to expand the engine plant if market development is favourable.

Phase II — Invest another US$166 million in Year 2 to expand the current engine plant into a larger engine manufacturing facility with the flexibility to produce more types of products for strategic growth in the future, in the perspective of positive economic development and strong market demand. Phase II investment is only an option to the joint venture company, although it is highly likely that the company may choose to exercise its 'real option' in order to keep its competitive market position and grow its business. Cash flow for each year has been estimated with Monte Carlo simulation, and the investments and cash flow schedule is shown in Figure 3 above.

5.1 Real options evaluation of investments in non-financial industries

Applying financial option pricing theory and the mathematical model (Black and Scholes, 1973) to real world investment evaluation, real option analysis has quickly emerged as a new approach to financial evaluation and selection of strategic investment alternatives (Merton, 1973; 1998; Busby and Pitts, 1997; Copeland and Keenan, 1998). The basic real options evaluation model is the same as the financial option pricing model, or the Black-Scholes model developed by Fischer Black, Myron Scholes, and Robert Merton in 1973. The model indicates that the value of a European call option on a share of common stock with a current price of S_0, strike price of X, time to expiration of T years from now, given that the volatility of the return on the stock is σ, and the risk free rate of return is r, can be determined by the following equation:

$$c = S_0\, N(d_1) - X\, e^{-rT}\, N(d_2), \tag{5}$$

where:

$$d_1 = \frac{Ln\left(\frac{S_0}{X}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{6}$$

$$d_2 = d_1 - \sigma\sqrt{T}. \tag{7}$$

Here, N(x) is the value of the cumulative standard normal distribution function. It can be determined as:

$$N(x) = \text{Probability of } [X \le x], \tag{8}$$

where X is a random variable following standard normal distribution.

Equations (5) to (8) are the basic Black-Scholes models for valuation of European call options written on a share of common stock having a current market value of S_0.

Analogous to financial option pricing, real options evaluation intends to evaluate the value of financial investment opportunities in different industries in the real world. In applying financial option pricing theory to real option analysis of different investment opportunities, the first step is to analyse the investment project, and estimate its key economic values that will be used as real option evaluation input parameters, so that the investment project can be fit correctly into the real options analysis framework. Table 2 below shows the structural analogy between the basic properties of financial options and that of real options.

Table 2 Properties of financial options and real options

Financial options		*Real options*
Call option on stock	=	Opportunity to undertake a future investment project
Call option price, c	=	Current value of the future investment opportunity, c
Current stock price, S_0	=	Present value of future project cash flows, V_0
Strike price, X	=	Future investment required at time T for the project, X
Time to expiration, T	=	Time to make future investment decision, T
Risk free interest rate, r	=	Risk free interest rate, r
Stock return volatility, σ	=	Future cash flow or project value volatility, σ

5.2 *Parameter estimate for real options analysis of the engine plant expansion project*

In order to conduct a real options evaluation for the FDM-JLC engine plant expansion project, it is necessary to estimate all basic parameters required for real options valuation. For this specific project evaluation, key parameters are: current value (NPV) of the expansion project cash inflows in Phase II, investment requirement for the expansion, time from now to make the expansion decision, risk free rate of return, and the volatility of project value.

5.2.1 *Current value of all cash inflows after the expansion*

As we already estimated with Monte Carlo simulation in Section 4, the mean of current value of all future cash inflows generated in the expansion phase of the project, discounted at the project required rate of return of 19%, is:

$$V_0 = \text{US\$134.15 million.} \tag{9}$$

5.2.2 *Investment required for the expansion phase implementation*

Based on a detailed review of investment requirements for the engine plant expansion project, the management has estimated that the investment required for the expansion in project Phase II will be:

$$X = \text{US\$166.00 million.} \tag{10}$$

Which represents the exercise price of the real option to expand the production capacity for a wider scope of supply far into future years.

5.2.3 Time to make the expansion decision

Although the time to expansion could be any time from now into the next few years, the management has come to an understanding that starting the expansion in two years from now would be most appropriate, given the time required to finalise the technical design for the expanded engine plant, and the need to have a larger engine production capacity as soon as possible to capture the best growth opportunity, therefore, time to exercise the expansion option is set to be two years from now.

$$T = 2 \text{ years.} \tag{11}$$

5.2.4 Risk free rate of return

Although the 10-year US Treasury bill rate of return can be used as the risk free rate of return for investment evaluation, the fact that the investment will be made in a foreign country usually raises expected rate of return, it is therefore appropriate to adjust the US risk free rate of return slightly upward to reflect a higher expected risk free rate of return for investment made in a foreign country, such as China.

The average rate of return on 10-year US Treasury Bill in 2005 (when the investment project was initially evaluated) was 4.29%, with an upward adjustment of 1.75% to reflect higher expected return for investment in a foreign country, the risk free rate of return for the purpose of this investment project evaluation is:

$$\mathbf{r} = 4.29\% + 1.75\% = 6.04\%. \tag{12}$$

5.2.5 Volatility of the Phase II project value

Volatility of the project value generated by the cash inflows during the expansion phase is a key parameter in real options evaluation. Similar to the valuation of financial options, the higher the variability of the underlying asset, the more valuable the option written on the underlying asset will tend to be. Therefore it is very important to estimate the volatility of the project value appropriately. In real options analysis there are several approaches to estimate project volatility, here we will present two project cash flow based estimates with Monte Carlo simulation, and one additional estimate based on the historical return on the investing company's common stock.

Estimate volatility with project value coefficient of variance

As discussed in earlier sections, the current value of the expansion project, V_0 can be obtained from Monte Carlo simulation with appropriate input values of revenue and cost as random variables. For the FDM-JLC engine plant expansion project here, the output of project value estimate comes with a mean value of US$134.15 million, and a standard deviation of US$23.14 million, the expansion phase (optioned phase) project value volatility can be estimated with its own coefficient of variance:

$$\sigma = \frac{SD(V_0)}{E(V_0)}, \tag{13}$$

or,

$$\sigma = \frac{23.14}{134.15} = 0.1725. \tag{14}$$

Estimate project value volatility with return on project value

As it has been discussed in the literature (Godinho, 2006), project value volatility could also be estimated with the standard deviation of the return on project value. Two project values can be calculated from estimated future project cash flows at the beginning of the investment project as V_0 and at the end of Year 1 as V_1, continuously compounded annual return on the optioned project value, *k*, is defined as:

$$k = Ln\left(\frac{V_1}{V_0}\right), \tag{15}$$

where:

$$V_0 = \sum_{i=0}^{N} \frac{CF_i}{(1+k)^i} \tag{16}$$

$$V_1 = \sum_{i=1}^{N} \frac{CF_i}{(1+k)^i}. \tag{17}$$

Here CF_i should only include the cash inflows generated in the optioned phase of the investment project from year (T + 1) to year N. In the FDM-JLC engine plant expansion project evaluation, those cash flows are the ones generated in the expansion phase after Year 2.

With Monte Carlo simulation, return on the optioned (Phase II) project value, k, as defined in Equation (15), can be estimated as a simulation output. The estimated project value volatility is the standard deviation of the project return k, or:

$$\sigma = \text{Standard Deviation of (k)}. \tag{18}$$

From our simulation, the output for this value is:

$$\sigma = 0.1778. \tag{19}$$

Please note that the last two estimates of Phase II project value volatility are similar to each other, and relatively small in value, due to the relatively smooth increase in revenue and cost over time.

Estimate of project value volatility with investing company historical stock return volatility

From the most recent weekly historical stock price of FDM Company at the time of initial project planning and evaluation, continuously compounded weekly rate of return can be calculated as,

$$r_i = Ln\left(\frac{P_i}{P_{i-1}}\right) \qquad \text{i} = 1, 2, \ldots, \text{N}, \tag{20}$$

where P_i and P_{i-1} are two consecutive weekly stock prices.

The sample standard devastation of these weekly returns, is calculated as:

$$s = 0.0448. \tag{21}$$

The annualised volatility of FDM stock return will be:

$$\sigma = \frac{s}{\sqrt{\frac{7}{365}}} = 0.3235\,. \tag{22}$$

This is the most recent estimate of the stock price volatility for FDM Company, and since FDM is the major investor in the engine plant expansion project, this stock volatility will be used in real options evaluation of the investment project.

5.3 *Real options evaluation of the investment project*

With all the necessary parameters estimated in the last section, the economic value of the FDM-JLC joint venture engine plant expansion project Phase II could now be evaluated as a real option. Since the time to make the expansion decision is 2 years, which was determined by the management together with technical, financial, and marketing staff of the company, it is appropriate to evaluate the expansion phase of the investment project as a two-year European real call option, where:

$$V_0 = \text{US\$}134.15 \text{ million} \qquad X = \text{US\$}166.00 \text{ million}$$
$$T = 2 \text{ years} \qquad \sigma = 0.3235$$
$$r = 6.04\%.$$

Applying Black-Scholes Model for a European call option evaluation, we have:

$$c = V_0 N(d_1) - Xe^{-rt} N(d_2), \tag{30}$$

where:

$$d_1 = \frac{Ln\left(\frac{V_0}{X}\right) + \left(\frac{r+\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$
$$= \frac{Ln\left(\frac{134.15}{166}\right) + \left(\frac{0.0604+0.3235^2}{2}\right)\times 2}{0.3235\sqrt{2}} = 0.02715$$
$$d_2 = d_1 - \sigma\sqrt{T} = 0.02715 - 0.3235\sqrt{2} = -0.4303$$
$$N(d_1) = 0.5108 \qquad N(d_2) = 0.3335.$$

From Equation (30):

$$\begin{aligned} c &= 134.15 \times 0.5108 - 166e^{-0.0604*2} \times 0.3335 \\ &= \text{US\$}19.47 \text{ million.} \end{aligned} \tag{31}$$

This real option value is the value of Phase II investment project to the investor, with the option to expand the engine plant in two years from now, in order to capture future growth opportunities.

After investing an initial 40 million USD to improve and keep operation of the engine plant, the FDM-JLC joint venture company has the option to expand the engine plant into a wider scope engine manufacturing facility to meet growing market demand for different types of automobile engines. The Strategic Net Present Value (SNPV) for the combined investment project, which is the NPV of the initial Phase I investment, plus the real option value to expand the production capacity with additional investment in Phase II, is therefore:

$$\begin{aligned} \text{SNPV} &= \text{Net Present Value of Initial Phase I Investment} \\ &\quad + \text{ Real Option Value to Expand in Year 2} \\ &= -17.73 + 19.47 \\ &= \text{US\$1.74 million.} \end{aligned} \tag{32}$$

The combined value of project Phase I and the value of investment in expansion in Phase II, is about US$1.74 million, due to the fact that the value of management and operational flexibility were taking into consideration with the option to invest in capacity expansion, given positive market development. Compare this SNPV to the overall project NPV of negative US$0.80 million in Equation (2) in Section 4.2, the company should approve this investment project based on real option analysis. The company should invest in Phase I now, and be prepared to implement the engine plant expansion two years from now if market development is positive.

6 Concluding remarks and recommendations

Both real options analysis and NPV evaluations of the FDM-JLC engine plant expansion project illustrate the common issues and typical economic evaluation process for strategic capital budgeting decisions in the automotive industry. FMSs, if well planned and implemented, could contribute to the long term strategic growth. Similar principles and financial evaluation models can be applied to capital budgeting processes in the general manufacturing industry as well as in other industries.

The economic analysis of an industrial investment project presented here includes traditional NPV evaluation, Monte Carlo simulation, parameter estimates for real options analysis, and brief comments on evaluation result from real options analysis and that from NPV evaluation.

Unlike traditional NPV analysis, Real Option evaluation helps investing companies to understand the true value of management and operational flexibility in the timing and decision making for financial investment in the industry, where real world investment decisions have to be made, with regard to project value, market condition, as well as competitive landscape, which can be reflected indirectly in the project value volatility, average return in the market, and the timing to pursue certain projects.

Based on our evaluation, it is recommended that the real option to expand the joint venture engine plant be taken and carried out as planned. The investment project will not only return a positive value to the investing company in terms of SNPV, but also help to put the company in a more competitive position in the fast growing China market, which is now an important part of the world market.

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