Evaluation of Wireless Mobility Investment by Using a Compound Options Approach

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Abstract

Wireless mobility (WM) technology has created significant competitive and productivity advantages for companies by extending computing and the Internet into the wireless medium and increasing flexibility in communication, collaboration, and information sharing, thus improving working process, increasing internal communication and knowledge sharing, and enhancing sales and marketing effectiveness. While WM technology has attracted much attention among researchers, limited management research has been performed examining how firm executives optimize WM investment decision to reduce expenditure irreversibility and market uncertainty. In addition to investigating the evaluation of a WM project using the traditional net present value (NPV), this study demonstrates how adding real options can enhance WM investment decision-making. Analysis results indicate that the real options approach is superior to NPV, owing to its ability to explicitly explain project irreversible expenditures, managerial flexibility, and uncertainty, and identify values ignored by the NPV approach. The theoretical and managerial implications of the results are also discussed. This study contributes to efforts to develop and validate WM technology related theories, as well as helping firm executives to implement successful WM investment.

EFM Classification Codes: 220, 430, 760, 210

Keywords: Project evaluation, real options, wireless mobility, compound options, investment under uncertainty.

1. Introduction

With the advent of the Internet and new e-business models, information technology (IT) is continuing to rapidly develop and evolve. While computer science and telecommunications have recently advanced significantly, wireless mobility (henceforth WM) technology is an especially rapidly area within the IT field. Emerging wireless technologies naturally offer increasing potential as a solution to numerous current industrial problems, but the challenges confronted by forward-looking industries are multimedia information gathering and system integration through wireless technology adoption (Egea-Lopez et al., 2005; Gerpott and Jakopin, 2005).

The definition of wireless technology remains controversial. According to the definition of MSN, wireless technology refers to the transmission of a signal over radio waves rather than via a physical wire. The term wireless thus typically indicates that information is being delivered from one place to another by electromagnetic waves traveling through the air. These waves, high or low frequency waves, exhibit different traits depending on frequency. Wireless systems developers thus can select a frequency favorable for a specific application to exploit some of these traits.

Decision processes such as those regarding investment in WM are difficult to estimate and manage owing to uncertainty regarding expected benefits and irreversibility of implementation costs. When uncertainty and irreversibility are high and when executives have flexibility in relation to the timing and structure of technology adoption investments, there is empirical evidence that managers with good awareness of certain options better manage risky IT investment (Trigeorgis, 1993; Dixit and Pindyck, 1994; Fichman, 2004).

With regard to telecommunications economics, Alleman (2002) pointed that managers cannot afford to ignore applications developed by real options analysis, including strategic evaluation, estimation and telephony cost modeling. On the basis of this perspective, initial investment during the first phase of a multi-phase implementation produce options (Taudes, 1998). While IT investment and real options recently have attracted increasing research interest (McGrath, 1997; Benaroch and Kauffman, 1999; Campbell, 2002; Coldrick et al., 2005; Isik, 2005; Wu and Tseng, 2006), the use of a real options approach for evaluating WM investment remains limited.

Gauging WM investment using real options offers value to both researchers and practitioners. Such gauging of investment can enable researchers to justify real options as an effective method in the context of WM investment and examine causality between the successful evaluations of a WM project. Practitioners can adopt the real option approach in the implementation phase as an evaluation mechanism. Such a study will enable executives to better justify their activities with regard to WM, especially if they devote a significant portion of their organizational budgets to these activities.

This study evaluates WM investment from a real options perspective. The remainder of this paper is organized as follows. Section 2 introduces the real options perspective. Section 3 then describes a case study used to estimate WM investment. Next, numerical analyses are presented via traditional net present value (NPV) and compound options. Finally, the managerial implications and directions for future research are also presented.

2. Real options perspective

Many academics and practicing managers now recognize that the traditional financial analysis tools to capital budgeting are inadequate, such as the net present value (NPV) rule and the discounted cash flow (DCF) approaches. However, the application of the option pricing theory (OPT) has been well received to capital budgeting. That's also called real option approach.

IT investment policy in most firms is focused on producing value by determining whether or not expected returns on a given investment exceed the costs for that type of investment. In such situations, cash flow is discounted by an appropriate charge to enable managers to compare investments and returns. If NPV is positive, risk-adjusted return exceeds the cost of investment, such IT investments are favorable and supported.

However, there are several limitations of using DCF and NPV alone to estimate the benefits of IT investments. First, DCF does not promote the assessment of the non-cash value regarding decision flexibility, since IT project investment could teach firm managers how to continually enhance their operations. Second, portfolios submitted by firm decision makers may also be suspect, because NPV fails to value the consequences of sequential decisions. Third, given uncertain outcomes, the NPV lens does not always provide a useful perspective on business cases. Specifically, NPV may fail to appropriately address the variability and risk of the IT investment, and typically omits the likelihood of managerial intervention to add value.

Most previous research regarding the valuation of staged IT project investment as real options has focused on the application Black-Scholes (B-S) option formula (1973) (Benaroch and Kauffman, 1999; Taudes et al., 2000) and has assumed that investment costs are known and certain. Some researchers have investigated IT projects investment using the financial option of Margrabe (Kumar, 2002), and the Cox-Ross-Rubinstein Binomial Model (Copeland and Antikarov, 2001; Copeland

and Tufano, 2004).

This study used a compound options approach to evaluate opportunities associated with WM investment. Since much of the value of such investment derives from the potential of follow-on projects, and since such benefits can only be measured by characterizing projects as stages in an overall development strategy and explicitly recognizing the potential value of follow-on projects, the compound options approach provides a better method of assessing the value of WM investment. Consequently, this study selects the compound options as the evaluation method. This article briefly reviews the characteristics of compound options as follows.

A compound option is an option on an option. A compound option has two expiry dates and two exercise prices. Taking a European call on a call as an example: on the first expiry date T_1, the owner has the right to buy a second call at exercise price X_1. Meanwhile, the second call has expiry date T_2 and exercise price X_2. Let the present time be 0, while S denotes the implied asset price and $C(S,\tau;X)$ represents the value of a call with expiration time τ and exercise price X. Furthermore, let C_c represent the current value of the call on a call. On the first expiry date T_1, the value of the call on a call is given by:

$$C_c = max[X_1, C(S, T_2 - T_1; X_2)] \qquad (1)$$

Let S^* denote the decisive asset price such that $C(S, T_2 - T_1; X_2) = X_1$. When $S > S^*$, then $C(S, T_2 - T_1; X_2) > X_1$, and thus the owner should exercise the first call at T_1. The present value of the call on a call is determined by the joint likelihood that the asset price exceeds S^* at T_1 and X_2 at T_2. The equation of the compound options model thus can be presented as follows (Geske, 1979).

$$C_c = Se^{-\delta T_2} M(k, h; \rho) - X_2 e^{-rT_2} M(k_-, h_-; \rho) - X_1 e^{-rT_1} N(k_-)\,, \qquad (2)$$

where

$$k = \frac{\ln(S/S^*) + (r - \delta + \frac{1}{2}\sigma^2)T_1}{\sigma\sqrt{T_1}}, \quad h = \frac{\ln(S/X_2) + (r - \delta + \frac{1}{2}\sigma^2)T_2}{\sigma\sqrt{T_2}},$$

$$k_- = k - \sigma\sqrt{T_1}\ , \quad h_- = h - \sigma\sqrt{T_2}\ ,$$

and

S denotes the present value of the implying asset, S^* represents the critical value over which the first call option will be exercised, X_1 is the exercise price of the first call option, X_2 denotes the exercise price of the second call option, r represents the risk-free rate, δ is the dividend yield, σ denotes the volatility, ρ represents $\sqrt{T_1/T_2}$, T_1 is the expiration date of the first call option, T_2 denotes the expiration date of the second call option, $N(.)$ represents the univariate cumulative normal distribution, and $M(a,b;\rho)$ is the two-dimensional cumulative normal distribution.

Here, the first term in Eqn. (2) denotes the expected asset value given $S > S^*$ at T_1 and $S > X_2$ at T_2, the second term denotes the expected expenditures upon exercise at T_2 and the final term represents the expected expenditures upon exercise at T_1.

3. Illustrative example: Wireless technology adoption in an organization

This section presents an example describing the manner in which a firm deals with the problem of WM project implementation. Company ABC is a large organization, comprising 14,000 employees in 250 different offices. This company comprises medical R&D, importing, manufacturing and sales. The one thousand sales personnel employed by ABC do not sell directly. Instead, these sales personnel have the job title medical representatives, and their function is to promote drugs by notifying doctors of newly released products or research findings.

If, after a one-year analysis the experts would advise from experience that ABC should implement a WM project to increase cost savings, sales force productivity, sales effectiveness, and overall firm competitive advantage by enabling medical representatives to access wireless data via PDAs (personal digital assistant). Consequently, top managers of ABC prefer to deploy modular solutions with features that fit the needs of their organizations rather than full-scale WM solutions, thus preventing firm ABC from making a large and immediate investment in implementing the WM project. Company ABC has a complete stepwise plan utilizing four development phases and this development plan is summarized in Table 1 and Fig. 1.

Insert Table 1 about here.

Insert Figure 1 about here.

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4. Traditional NPV analysis

Company ABC must invest immediately in phase 1 to launch the WM project. After one year the company will have the option to invest in phase 2. If the company invests in phase 2, it will get the option after a further year to invest in phase 3, and if it invests in phase 3, it will get the option in year 4 to invest in phase 4. Tables 2, 3, 4, and 5 summarize the expected net cash flows from phases 1, 2, 3, and 4, respectively.

The main benefits of the proposed project include: (1) improving monitoring effectiveness by reducing time required to create sales activity reports, visit plans, and performance reports, (2) boosting sales effectiveness by helping medical representatives share information with doctors and gather accurate data for information analysis, and (3) improving regulatory compliance through call schedule arrangement. The primary expenditures comprise the implementation of planning software and hardware, including wireless connection via pocket wireless card, ISP/Cellular service, mobile computers/PDAs, software applications for mobile environments, system installation, integration and training, data encryption and centralized management of security settings, and so on.

Insert Table 2,3,4,5 about here.

From Table 6, based on NPV, the expected present value of the WM project from the perspective of Company ABC is negative $3.55 million and NPV would advise against investing, owing to the impossibility of justifying the enormous investment in WM that the experts recommend as necessary to ensure the future prosperity of the company. The problem is that nobody can credibly demonstrate the effectiveness of the WM or the risks that firm ABC will take. Senior managers of ABC lack experience of estimating the benefits of WM. For example, the suggestion of wireless technology experts that future customer satisfaction will increase as a result of better customer, order, and service management is difficult to assess using the NPV approach.

Insert Table 6 about here.

Furthermore, NPV did not perform well in evaluating long term and potentially risk. Therefore, if a serious competition emerges, NPV will lead to the underestimation of benefits in relation to the WM investment, possibly resulting in good timing for WM project implementation being missed and consequent irreversible losses.

5. Real options analysis

To further examine the value of this investment, Company ABC considers the WM project from an options perspective. The firm believes that the real options framework can identify value neglected by NPV. Additionally, the firm applies a compound options approach to value the multi-phased WM project investment, because the potential value of follow-on projects or the capabilities that the firm establishes as part of the initial project should be considered when evaluating the initial investment. While the NPV neglects the benefits learned from firm customers, the compound options model can more accurately capture and identify value related to the four-phase WM project.

The NPV during phase 1 may be considered the option payment paid by ABC today to obtain the right, but not the responsibility, to invest in phases 2, 3 and 4 in years 1, 2 and 4, respectively. From a present decision-making perspective, the ABC will invest in the upfront outlays provided the flexible net present value (FNPV) is positive. FNPV thus can be expressed as:

FNPV = $C_I + C_A + C_B$ = NPV of phase 1 + compound option to invest in phase 2 and 3 + compound option to invest in phases 3 and 4 (3)

C_I denotes the actual amount the ABC plans on expending today in upfront costs, while C_A and C_B are calculated using the compound options model. Figures 2 and 3 show the cash flow for these two compound options frameworks.

Insert Figure 2, 3 about here.

The NPV of phase 1 is negative \$0.05M. Upon investing \$0.05M, Company

ABC has the option to invest in phase 2 in year T_1 =1. The expenditure associated with the option to invest in phase 2 is the NPV of phase 2 during year 1 or X_2 = 2.0e$^{(0.1*1)}$ = \$2.21M. If the firm invests in phase 2, it gets the option in year T_2 = 2 to invest \$7M in phase 3, X_1 = \$7M. By solving Eqn. (4), developed by Black (1976), for S^*, it is possible to obtain the critical value of phase 3 cash inflows, S^* = \$9.44M, over which the option on phase 3 should be obtained at T_1. That is, if the current value of phase 3 cash inflows exceeds \$9.44M (namely, S > \$9.44M), then the investment will be undertaken during phase 2.

$$X_2 = e^{-r\tau}[S^* N(d_1) - X_1 N(d_2)], \qquad (4)$$

where

$$d_1 = \frac{\ln(S^*/X_1) + \frac{1}{2}\sigma^2\tau}{\sigma\sqrt{\tau}}, \quad d_2 = d_1 - \sigma\sqrt{\tau}, \quad \tau = T_2 - T_1,$$

and

S^* denotes the critical value over which the second call option should be obtained at T_1; X_1 represents the exercise price of the first call option; X_2 is the exercise price of the second call option; r denotes the risk-free rate; σ represents the volatility; T_1 is the expiration date of the first call option; T_2 denotes the expiration date of the second call option; and $N(.)$ represents the univariate cumulative normal distribution.

Using the inputs S = \$9.5M (given $S > S^*$), S^* = \$9.44M, X_2 = \$2.21M, X_1 = \$7M, T_1 = 1 years, T_2 = 2 years, σ = 5%, δ =0.02, and r = 10%, in Eqn. (2), the value of the compound option to invest during phases 2 and 3 is C_A = \$0.98M. Similarly, the expenditures of the option to invest in phase 3 comprise the NPV of phase 3 in year 2 or X_2 = 1.3e$^{(0.1*2)}$ = \$1.59M. If the firm invests in phase 3, it obtains the option in year T_2 = 4 to invest \$6M in phase 4, X_1 = \$6M. Equation (4) can obtain the critical value of phase 4 cash inflows, S^* = \$7.94M. Once again using the data inputs S = \$8M (given $S > S^*$), S^* = \$7.94M, X_2 = \$1.59M, X_1 = \$6M, T_1 = 2 years, T_2 = 4 years, σ = 5%, δ =0.02, and r = 10%, in Eqn. (2), the value of the compound option to invest in phases 3 and 4 is C_B = \$1.41M, and the FNPV = -\$0.05M + \$0.98M + \$1.41M = \$2.34M.

Comparing the FNPV with the traditional NPV valued in the previous section, the option of ABC to invest in phases 2, 3 and 4 is identified as being worth an extra \$5.89M. Namely, to the value of managing the WM project investment is identified as being \$5.89M more than the value using the conventional NPV approach. The compound options framework thus identifies and assesses managerial flexibility when benefits exceed costs at each multi-phased decision point. Eventually, the ABC should determine it is starting to implement the multi-phased WM project, since the FNPV is positive and has significant value if Company ABC is to implement the WM project.

6. Implications for practice

Through the above analysis, a study using a real options approach for valuing a WM investment project was developed, and the compound options model was also revalidated in the context of WM investment projects. This research provided several implications for WM practitioners.

First, this illustrative result emphasized the importance of considering the potential value of follow-on projects when the initial investment was evaluated. Many IT projects fail because of the projects' irreversible capital expenditures, time lag between investment and benefits, and uncertainty. In these situations, evaluating a case using NPV will distort the real value of projects that involve options. In other words, the greater the uncertainty, the greater likelihood the option's value may be underestimated by the NPV. Based on NPV, assessing a WM investment may discourage top managers from investing in it because the investment project value is underestimated. The virtual example of Company ABC illustrates the limitations of NPV, which top managers usually use when estimating the value of WM investment. This represents that CEO-level-business-leaders may decide not to invest in such a huge project, gradually leaving their firms losing competitive advantages.

Second, this study put focus on the benefits of options thinking and of constructing multi-staged WM investment to produce options to expand or contract follow-on projects. Without such kind of thinking, firms could not get sufficient managerial flexibility to learn from their users. In addition, before the options' being exercised, top managers have to lay stress on validating the critical assumptions built into the WM case or evaluating whether the pre-determined expectation is realized or not.

Third, the compound options method, used in this study, is designed to be applicable across a broad spectrum of WM related projects, and will provide a fast and early feedback to the firm. The data scope, when necessary, can be adapted or modified based on a particular firm's request. As the compound options approach with good validity is used to assess a multi-staged WM project, top managers can use this real options approach to enhance their understanding of the investment of WM projects success and take corrective actions if necessary.

7. Implications for research

Wireless technology has been thought of as an important research agenda regarding information and communication technology. A growing body of literature has been developed to explore wireless with mobility management (Beaubrun et al., 2005; Gozalvez and Dunlop, 2005), mobile applications (Ghini et al., 2005; Grantham and Tsekouras, 2005), mobile technology acceptance (Lu et al., 2005; Bruner II and Kumar, 2005), and strategic impact (Sheng et al., 2005). According to previous wireless mobility technology related literature, wireless mobility technology extends computing and the Internet into the wireless medium, and provides greater flexibility in communication, collaboration, and information sharing for the purpose of improving working process, increasing internal communication and knowledge sharing, and enhancing sales and marketing effectiveness. However, prior researchers have indicated the shortage of financial analysis applied to IT investment and the importance about senior financial executives' becoming aware of the need to precisely view risky IT investment (Dixit and Pindyck, 1995; Nichols, 1994). Therefore, in this study, we examined a case of WM investment, provided analysis using both the NPV and compound options, and analyzed their advantages/disadvantages with various parameters.

Based on the conception of real options valuation, future research efforts may explore and test other options pricing models so as to conduct an advanced understanding of WM investment. The findings can provide firms' executives more insights into how to implement a successful WM project within the organizations. This study can also provide wireless technology researchers with a means for measuring the different WM investment, and a way for explaining and comparing differences among the results.

8. Conclusions

A primary contribution of this study was to pursue a stream of research on evaluating WM investment via a real options approach, and improve executive understanding of how to comprehensively consider the value of building managerial flexibility into WM investment. While wireless mobility technology has received extensive attention among researchers, there has been little research on how firm executives optimize WM investment decisions to reduce expenditure irreversibility and market uncertainty. This investigation thus has presented a WM investment case incorporating multiple variables, and has focused on predicting the long-term benefits of WM investment. Finally, it is hoped that our study can help wireless technology practitioners and researchers improve understanding of the influence of adopting the real options evaluation method.

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Table 1. Wireless Mobility Project of Company ABC

Phase	Development plan
Phase 1 T=0 Initial investment	➢ Hiring experts to conduct a pilot program and perform analysis to make a decision regarding wireless mobility implementation
Phase 2 One year in the future 1st expansion investment	➢ Wireless connection via pocket wireless card ➢ ISP/Cellular service ➢ Mobile computers/PDAs
Phase 3 Two years in the future 2nd expansion investment	➢ Software application development for mobile environment (such as, creating sales reports, providing information on doctors/hospitals, and creating new sales information *etc*.) ➢ System installation, integration and training ➢ Additional mobile devices and other new hardware
Phase 4 Four years in the future 3rd expansion investment	➢ Continuing system training and support ➢ Additional mobile computers and devices ➢ Sales trend analysis and forecasting ➢ Data encryption and centralized management of security settings

Table 2. Phase 1 expected net cash flows (in $millions)

WM Investment	Year 0	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Total
Expenditures	0.05	0	0	0	0	0	0	0	0	0	0	0.05
Benefits	0	0	0	0	0	0	0	0	0	0	0	0
Net Benefit	-0.05	0	0	0	0	0	0	0	0	0	0	-0.05
Discounted at 10%	-0.05	0	0	0	0	0	0	0	0	0	0	-0.05

Table 3. Phase 2 expected net cash flows (in $millions)

WM Investment	Year 0	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Total
Expenditures	0	3	0	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	5.4
Benefits	0	0	0	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.1	4.2
Net Benefit	0	-3	0	-0.2	-0.1	0	0.1	0.2	0.4	0.6	0.8	-1.2
Discounted at 10%	0	-2.7	0	-0.2	-0.1	0	0.06	0.1	0.19	0.25	0.31	-2

Table 4. Phase 3 expected net cash flows (in $millions)

WM Investment	Year 0	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Total
Expenditures	0	0	7	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	10.5
Benefits	0	0	0	0	1	1.2	1.4	1.8	2.1	2.5	3	13
Net Benefit	0	0	-7	0	0.5	0.7	0.9	1.3	1.6	2	2.5	2.5
Discounted at 10%	0	0	-5.8	0	0.34	0.43	0.51	0.67	0.75	0.85	0.96	-1.3

Table 5. Phase 4 expected net cash flows (in $millions)

WM Investment	Year 0	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10	Total
Expenditures	0	0	0	0	6	0.2	0.2	0.2	0.2	0.2	0.2	7.2
Benefits	0	0	0	0	0	0.8	1.2	1.5	1.7	2	2.4	9.6
Net Benefit	0	0	0	0	-6	0.6	1	1.3	1.5	1.8	2.2	2.4
Discounted at 10%	0	0	0	0	-4.1	0.37	0.56	0.67	0.7	0.76	0.85	-0.2

Table 6. NPV of WM investment project (in $millions)

WM Investment phase	NPV
Phase 1	-$0.05
Phase 2	-$2.0
Phase 3	-$1.3
Phase 4	-$0.2
Total	-$3.55

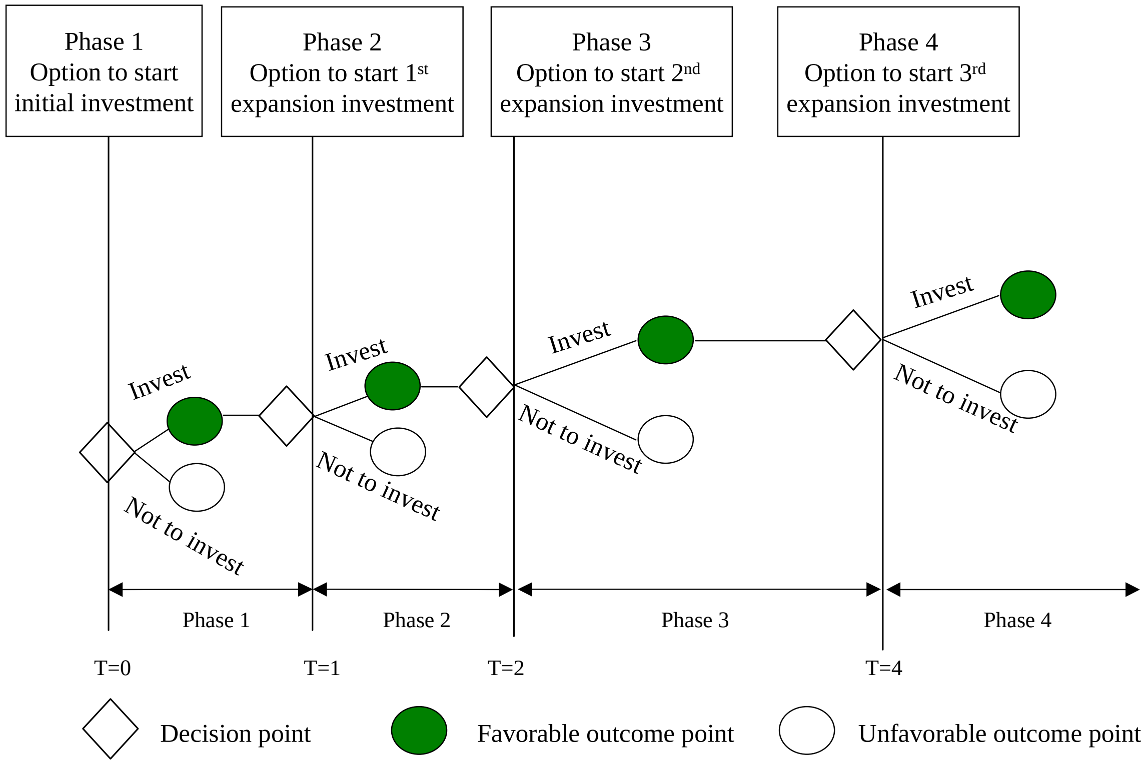

Figure 1. The evaluation model of the wireless mobility project of Company ABC

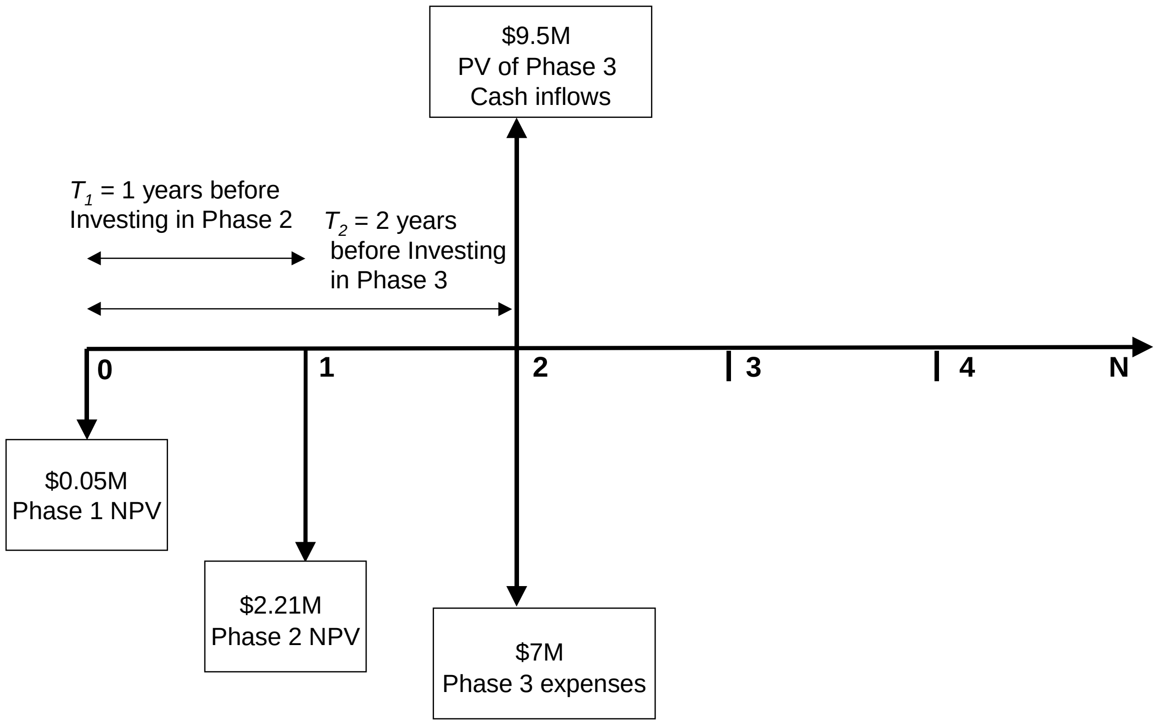

Figure 2. Compound options framework to invest in phase 2 and 3

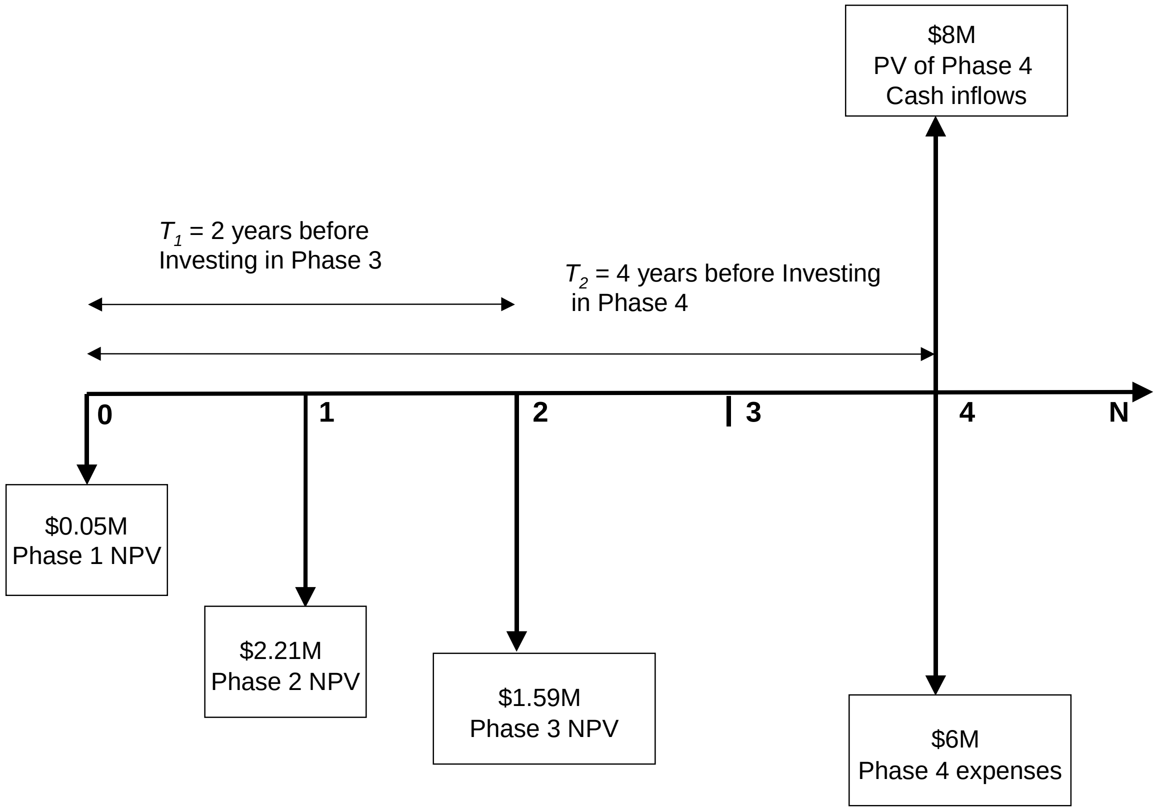

Figure 3. Compound options framework to invest in phase 3 and 4