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THE OPTION VALUATION FOR RDA PROJECT WITH PATENT DECISIONS

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Abstract

This paper proposes an application of an option valuation approach to evaluate a project investment in three stages: research (R), development (D) and acquisition (A) by incorporating the patent sale as alternative to the decision to invest in the follow-on stages. The model also takes the market uncertainty into the valuation of the first two technical stages (R&D) of the project. The decision tree model is solved to determine the option values and optimal decisions in each of the RDA stages subject to decision rules, critical values, and certain boundary conditions through the dynamic programming. We subsequently evaluate the model effectiveness by comparing its decisions with those of an existing valuation model and the net present value method (NPV). The Monte Carlo simulation results show that under the option valuation approach, a positive profit in a wide range can be obtained with more than 50% chance, in spite of the small average profit.

Keywords: option approach, RDA project valuation, patent option, dynamic programming, simulation

1. INTRODUCTION

As an alternative valuation tool to the traditional discounted cash flow (DCF) techniques, an option approach has been widely accepted for a capital investment such as manufacturing system investment (Karsak and Ozogul, 2005) contract investment (Brennan and Schwartz, 1985) and capital investment (Dixit and Pindyck, 1994; Luehrman, 1998). It has also been employed in the valuation of R&D project as presented by Mechlin and Berg (1980), Kester (1984), Mitchell and Hamilton (1988), Morris, *et al.*, (1991) and Boer (2000). A comprehensive review on option pricing was given by Achdou and Pironneau (2005).

However, most of the option valuation models of the R&D project have been concerned with the value of follow-on investment at the commercialization stage only (Newton and Pearson, 1994; Faulkner, 1996; Pennings and Lint, 1997; Perlitz, *et al.*, 1999; Perdue, *et al.*, 1999; Angelis, 2001; Huchzermeier and Loch, 2001; Schwartz, 2004). The investment in the R&D project can lead to patents of new technologies or products. Consequently, the chance to sell the patent should be one of the options embedded in the R&D investment and considered as alternative decision by the *government funding agencies, such as national research institutes and universities*. The patent of the R&D project has been considered as real options by Schwartz (2004), who showed that the life of the patent can affect the option value of R&D project.

Nevertheless, the firm can indeed choose the option to wait for the new information concerning the future uncertainty before making the investments therefore, it makes more sense to incorporate in our decision model an alternative to postpone the start of R&D project, as it has been done in the analysis of other types of capital investments (Dixit and Pindyck, 1994; 1995).

The RDA (Research-Development-Acquisition) project investment is a learning investment (Amram and Kulatilaka, 1999). The value of next investment, then, depends largely on the updated uncertainty, which can be different by type and value. One major type of uncertainty that is private and called *technical uncertainty* is quite crucial to the research and development decisions. Another type called *market uncertainty* is also very important to the decision to launch the product. Since the value of developed product is also driven by the market uncertainty, the decision to invest in the research and development stages analyzed based on the technical uncertainty alone is not sufficient (Amram and Kulatilaka, 1999). It is, thus, important to consider both uncertainties in our RDA project valuation.

The purpose of this paper is to incorporate, in the RDA option valuation model especially for the funding agency, both technical and market uncertainties and more practical decision alternatives, namely the chance to sell the patent and the ability to postpone the start of a project. Our proposed model is derived based on the valuation model developed by Dixit and Pindyck (1995), as follows. Firstly, the model is extended from the valuation model for capital investment to the model for the technical R&D stages. Secondly, the decision to invest in the R&D stages is for a follow-on investment in the next stage, and also for the chance to sell the patent. Thirdly, the option values and optimal decisions of the R&D stages are involved both technical and market uncertainties. Finally, at every decision points, the postponement of investment is added as the third alternative due to market uncertainty.

The paper is organized as follows: the second section detail out the assumptions underlying the RDA project investment, while the RDA valuation model is proposed in the next section. To evaluate the model, a real case obtained from a government funding agency is solved by the proposed and existing models. Their results are comparatively discussed and additionally analyzed based on simulated results. Conclusions are finally provided in the last section.

2. ASSUMPTIONS

The R&D project defined in most literature often consists of two decision stages in which the first stage combines research and development together, while the second stage involves commercialization. We address rather, in this work, the RDA project made in three complete stages: research (R), development (D) and acquisition (A) (also known as commercial stage), as defined by Carter and Edwards (2001), to demonstrate the possibility of the patent sale which is embedded in any stage of the R&D project except the beginning of the research stage. To implement the project, a series of fixed investment outlays at the beginning of each stage (R, D and A) is required and defined as I_R, I_D and I_A. All investment expenditures are assumed to be partly irreversible. Although, the investments in the future stage, I_D and I_A, varies in some cases (Huchzermeier and Loch, 2001; Schwartz, 2004), in this case the required investments for the entire project should be fixed or not be varied much due to the government procedure of the advance budget planning. Under this government condition, all required investments are assumed to be fixed and must be defined in advance since the beginning of the project.

Since the R&D project takes years to complete, the amount of time required to complete its research and development work must be defined in the R&D project proposal. Let's denote them by T_R and T_D, respectively. As mentioned before T_R and T_D for the government funding proposal must be fixed and known in advance, although the amount of time during the acquisition stage cannot be firstly defined, but normally estimated by the product life cycle. In this work, the amount of time during stage A is assumed to be perpetuity.

In general, the project does not yield any cash inflow during the R&D stages, but will generate a stream of cash inflow in the acquisition stage. Occasionally, the firm may decide to license or to sell the patent to other firms at the end of either R or D stage to generate a return in the form of patent value rather than to pursue the next stage by itself. Since the R&D project is considered as an intellectual property, it is often difficult to determine its patent value. The method called the relief-from-royalty method is one of the practical methods for approximating patent value by license payments. The value of a license traditionally consists of two parts (Bertha, 1996). The first part is called a disclosure fee (D_f) and due upon the signing agreement. The second part is a royalty fee, which is paid to the firm every year for a specified contract period. The royalty structure of a typical license is quoted as a percentage of total sales. To simplify the understanding of the model, the royalty fee (R_f) is assumed to be a percentage of the project value in the acquisition stage (V_A), and to be less than the same percentage of total sales. The patent value at the completion of each stage can also be different. Practically, the patent value at the end of the research stage would be less than the value at the end of the development stage. Let ρ denote the discount rate per period. The values of license at the end of the R&D stages are respectively calculated as:

$$D_f(R)+R_f(R)(V_A/(1+\rho)^{T_D}) \text{ and } D_f(D)+R_f(D)V_A \,. \quad (1)$$

Due to the uncertainty in the future, the RDA project value during stage i, V_i, is assumed to evolve according to the following combined stochastic process of the geometric Brownian motion and the Poisson jump process to zero.

$$dV_i = \alpha_i V_i dt = \sigma_i V_i dz + V_i dq_i \,, \quad (2)$$

where:

i = Stage: research (R), development (D), and acquisition (A)

V_i = Present value of the expected return from immediately undertaking stage i or project value at the beginning of stage i

dV_i = Increment of the project value in stage i in small time interval dt

α_i = Constant instantaneous mean of dV_i/V_i, conditional on the Poisson not occurring in stage i

σ_i = Constant instantaneous standard deviation of dV_i/V_i conditional on the Poisson not occurring in stage i

dz = $\varepsilon\sqrt{dt}$ = Increment to a standard Wiener process

ε = Normal error term with mean zero and unit standard deviation

dq_i = Increment to a Poisson process in stage i with mean arrival rate λ_i

$$dq_i = \begin{cases} -1 & \text{with probability } \lambda_i dt \\ 0 & \text{with probability } 1-\lambda_i dt \end{cases}$$

This process is the typical combined stochastic process to describe the change in the R&D project value as presented by Perlitz, *et al.*, (1999), and Perdue, *et al.*, (1999). Note that this process does not allow only the continuous change in the project value but also the discrete change described by the Poisson jump downward process.

3. THE VALUATION MODEL

Given the assumption that the RDA project value evolves according to the combined stochastic processes (Eq. 2), the problem is to determine the option values and optimal investment decisions at the beginnings of RDA stages. The option value and optimal decision in each stage can be determined by employing the dynamic programming (DP) as firstly applied to the option valuation approach by Dixit and Pindyck (1995). The basic idea of DP is to make a series of decisions, each of which yields, in each stage, the highest present value calculated by applying a backward recursive function. The recursive function includes two components of values of decisions, i.e., the payoffs from the immediate decision in the current stage and the consequent, future values. All decisions or options available in each stage must be initially identified. As explained in the previous section, the ability to postpone the investment is embedded at the beginning of each stage, and the chance to license the patent is possible only at the beginnings of the development and acquisition stages.

3.1 General Decision Rules

Fig.1 illustrates the corresponding decision tree and summarizes the optimal investment policy and decision to be made at the beginning of each stage. Dynamic programming starts in the acquisition stage, calculating the option value, $F_A(V_A)$, and works backwardly through the decision tree, calculating the value of option to invest in the D and R stages accordingly. Three common decision choices, investment, postponement, and abandonment are considered in each stage, while the chance to sell the patent or patent option is considered only at the beginning of the last two stages. One simple decision rule to abandon the RDA project in stage i is when the project value $V_i \le 0$, i =R,D,A which implies that this project has not been successful through stage i and is based on the critical value V_i^*. When $0 < V_i < V_i^*$, the optimal decision is to postpone the investment. Otherwise, the further analysis is made by comparing the discounted net payoff of the further investment with that of patent sale.

3.2 Determination of the Option Value in the Acquisition Stage

Assume that the RDA project has passed all technical uncertainties and is entering into the acquisition stage. Then, there is only market uncertainty left in this stage and the firm has the opportunity to delay or postpone investment or, in other words, to wait for new information about the future cash flow before committing an irreversible investment. This opportunity has value called the value of option to invest and is driven by the market uncertainty. We begin our derivation by firstly comparing the values of two common decisions between investing and postponing. Starting from the acquisition stage, given the discount rate per period, ρ, we let $F_A(V_A)$ denote the value of option to invest in the acquisition stage with project value V_A. To determine $F_A(V_A)$, the model developed by Dixit and Pindyck (1995), is modified to accommodate the Poisson jump downward to zero.

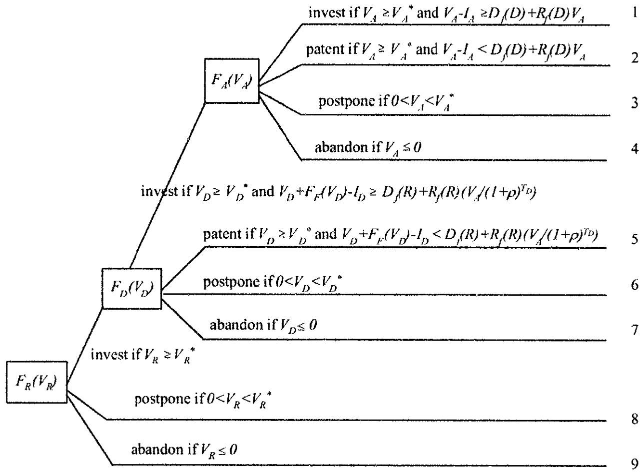


Fig. 1 Optimal investment decisions of an individual project

The decision rules are normally based on the critical value V_A^*. It is optimal to postpone the project's investment, if $V_A < V_A^*$, or to invest if $V_A \ge V_A^*$ (See Dixit and Pindyck, 1995, for more details). In this paper, we enhance the decision rules by taking the patent option into account. As shown in Fig. 1, since V_A is the present value of the acquisition stage, the NPV rule can be applied at the acquisition stage when $V_A \ge V_A^*$. The investment should be made, if the discounted net payoff of investment, $V_A - I_A$, is greater than the discounted value of patent sale, $D_f(D) + R_f(D)V_A$, as specified in Eq. 1. Otherwise, the patent sale here should be preferred. In addition, the option value $F_A(V_A)$ can be obtained from the equations given in Fig. 2.

3.3 Determination of the Option Value in the Development Stage

Since there are two kinds of uncertainty involved in the development stage, the technical and market uncertainties, which cause different affects on the investment decision, each uncertainty must be treated differently on the value of option. The market uncertainty acts in the same role here as in the acquisition stage in making the value of option to wait more meaningful. On the other hand, the technical uncertainty increases the option value of follow-on investment in the next stage through this stage's investment. Together, both uncertainties would increase the value of the investment opportunity. This statement may be different from the conclusion of Huchzermeier and Loch (2001), which implies that more variability or uncertainty does not always increase the value of managerial flexibility or the option value. As the product performance variability (technical uncertainty) increases, the value of the managerial flexibility in term of downside protection is reduced. Nevertheless, the options embedded in the R&D project investment are not only the chance to abandon the investment but also the options to postpone and to follow the investment which in this case increases when the uncertainty increases.

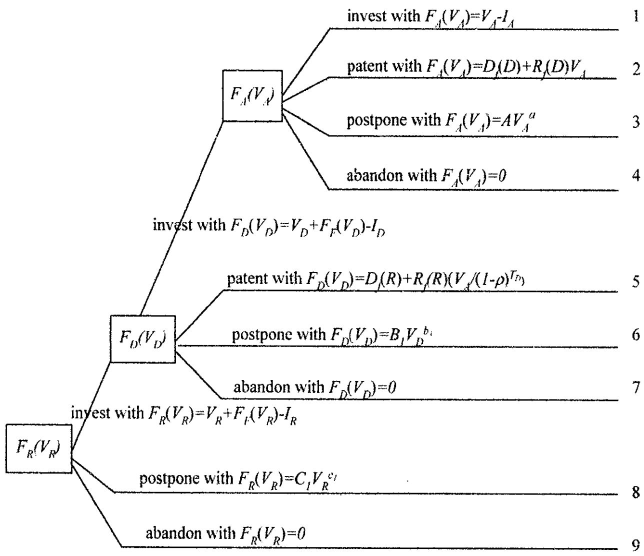


Fig. 2 Option values at each stage of a project

To clarify this, we let $F_P(V_D)$ denote the value of option to postpone investment at this stage due to the market uncertainty and $F_F(V_D)$ denote the option value of the follow-on investment in the next stage caused by the technical uncertainty during the development stage. To obtain the option value of the development stage, $F_D(V_D)$, we follow the same procedure of determining $F_A(V_A)$ by comparing the value of investing and postponing. Since the derivations used in the acquisition stage are derived for the infinite time stage, the additional boundary condition is set for the fixed time development stage by using the expected option value of the acquisition stage as the boundary value. The investment rules still take the form of critical value V^*.

In the postponement region, the firm holds the postponement option, $F_P(V_D)$, caused by the market uncertainty and must be satisfied by the following differential equation,

$$\frac{1}{2}\sigma_A^2 V_D^2 F_P''(V_D)+\alpha_A V_D F_P'(V_D)-(\rho+\lambda_A)F_P(V_D)=0 \qquad (3)$$

To satisfy the condition that $F_P(0)=0$, the value of postponement option must take the form of

$$F_P(V_D)=B_1V_D^{b_1}, \qquad (4)$$

$$\text{where } b_1=\frac{1}{2}-\frac{\alpha_A}{\sigma_A^2}+\sqrt{\left(\frac{\alpha_A}{\sigma_A^2}-\frac{1}{2}\right)^2+\frac{2(\rho+\lambda_A)}{\sigma_A^2}}. \qquad (5)$$

As mentioned earlier, since $F_F(V_D)$ is caused by the technical uncertainty, the differential equation that must be satisfied by $F_F(V_D)$ can be written as:

$$\frac{1}{2}\sigma_D^2 V_D^2 F_F''(V_D)+\alpha_D V_D F_F'(V_D)-(\rho+\lambda_D)F_F(V_D)=0. \qquad (6)$$

Similarly, to satisfy the condition that $F_F(0)=0$,

$$F_F(V_D) = B_2V_D^{b_2}, \qquad (7)$$

$$\text{where } b_2=\frac{1}{2}-\frac{\alpha_D}{\sigma_D^2}+\sqrt{\left(\frac{\alpha_D}{\sigma_D^2}-\frac{1}{2}\right)^2+\frac{2(\rho+\lambda_D)}{\sigma_D^2}}. \qquad (8)$$

In the investment region, when the firm invests, it must not only disburse the investment cost I_D, but also give up the value of postponement option $F_P(V_D)$. Instead, it receives the value of the development stage V_D as the consequent project value and the option value of follow-on investment in the acquisition stage $F_F(V_D)$. The corresponding value-matching and smooth-pasting conditions are therefore:

$$F_P(V_D^*)=V_D^*+F_F(V_D^*)-I_D, \text{ and} \qquad (9)$$

$$F_P'(V_D^*)=1+F_F'(V_D^*). \qquad (10)$$

By Eqs. 4 and 7, Eqs. 9 and 10 can be simplified to:

$$B_1V_D^{*b_1}=V_D^*+B_2V_D^{*b_2}-I_D, \text{ and} \qquad (11)$$

$$b_1B_1V_D^{*b_1-1}=1+b_2B_2V_D^{*b_2-1}. \qquad (12)$$

Besides the conditions shown in Eqs. 9~12, with a fixed time T_D, an additional boundary condition is defined as the expected option value of follow-on investment in the acquisition stage which will be occurred after T_D periods,

$$\mathrm{E}[F_F(V_D)]_{T_D}=F_A(V_A).$$

By Eq. 7,

$$\mathrm{E}[B_2V_D^{b_2}]_{T_D}=F_A(V_A) \text{ or } B_2(\mathrm{E}[V_D]_{T_D})^{b_2}=F_A(V_A). \qquad (13)$$

Given that the project value of the development stage evolves according to the combined stochastic process (Eq. 2) and V_D is the project value at the beginning of the development stage, the expected value of V_D at T_D can be formulated (Dixit and Pindyck, 1994) as:

$$\mathrm{E}[V_D]_{T_D}= V_De^{(\alpha_D-\lambda_D)T_D}. \qquad (14)$$

The constant B_2 can be found by substituting $\mathrm{E}[V_D]_{T_D}$ from Eq. 14 into Eq. 13 and manipulating it. Thus,

$$B_2=\frac{F_A(V_A)}{(V_De^{(\alpha_D-\lambda_D)T_D})^{b_2}}. \qquad (15)$$

With the constant values b_1, b_2 and B_2 calculated by Eqs. 5, 8 and 15 and two boundary conditions (Eqs. 11~12), V_D^* is the solution of the following equation:

$$(b_1-b_2)B_2V_D^{*b_2}+(b_1-1)V_D^*-b_1I_D=0.$$

Subsequently, B_1 can be calculated as:

$$B_1=\frac{V_D^*+b_2B_2V_D^{*b_2}}{b_1V_D^{*b_1}}.$$

The critical value, V_D^*, is then employed to develop the decision rules in the development stage as shown in Fig. 1, and the option value of the development stage, $F_D(V_D)$, is calculated according to the equations given in Fig. 2.

3.4 Determination of the Option Value in the Research Stage

We finally work backward to find the option value $F_R(V_R)$ of the research stage in the same way that we obtain $F_D(V_D)$. The same boundary conditions must be satisfied. Although the firm can still postpone the investment, it does not have the chance to sell the patent at the beginning of the project. Since the research stage also involves both technical and market uncertainties, we let $F_P(V_R)$ denote the value of option to postpone investment in the research stage due to the market uncertainty and $F_F(V_R)$ denote the option value of the follow-on investment in the next stage caused by the technical uncertainty during the research stage. The differential equations for $F_P(V_R)$ and $F_F(V_R)$ are the same as those for $F_P(V_D)$ and $F_F(V_D)$ as shown in Eqs. 3 and 6, except that subscript i is denoted here by R rather than D.

To satisfy the condition $F_P(0)=F_F(0)=0$, $F_P(V_R)$ and $F_F(V_R)$ must take the form of $C_1V_R^{c1}$ and $C_2V_R^{c2}$, respectively, where,

$$c_1=\frac{1}{2}-\frac{\alpha_A}{\sigma_A^2}+\sqrt{\left(\frac{\alpha_A}{\sigma_A^2}-\frac{1}{2}\right)^2+\frac{2(\rho+\lambda_A)}{\sigma_A^2}}\text{, and}$$

$$c_2=\frac{1}{2}-\frac{\alpha_R}{\sigma_R^2}+\sqrt{\left(\frac{\alpha_R}{\sigma_R^2}-\frac{1}{2}\right)^2+\frac{2(\rho+\lambda_R)}{\sigma_R^2}}.$$

Similar to the determination of B_2 given by Eqs. 9~15, the constant C_2 can be obtained as follows:

$$C_2=\frac{F_D(V_D)}{(V_R e^{(\alpha_R-\lambda_R)T_R})^{c2}},$$

and V_R^* is the solution of the following equation:

$$(c_1-c_2)C_2V_R^{*c2}+(c_1-1)V_R^*-c_1I_R=0$$

In addition,

$$C_1=\frac{V_R^*+c_2C_2V_R^{*c2}}{c_1V_R^{*c1}}.$$

The decision rules and option values in the research stage can be summarized as shown in Figs. 1~2 respectively.

4. ANALYSES AND DISCUSSION ON A CASE STUDY

To test the model, one RDA project proposal from a government-funding agency of Thailand was selected. The project involved research and development of a medical product, which has a long product life cycle. General information of the project investment usually shown in the project proposal, such as 1) type of product, 2) the investment costs for each stage, 3) the amount of time required to complete the research and development stages, 4) the expected return from cash flow, 5) the weighted average cost of capital (WACC) and 6) the disclosure fee and the royalty rate are collected. The probabilities of achieving research and development stages, denoted by $\Pr_R$ and $\Pr_D$ respectively, are needed to determine the values of the key variables. In the present study, the values $\Pr_R$ and $\Pr_D$ are arbitrarily set to 0.5 by assuming the unbiased situation. We also consider the present value of expected return from cash flow of undertaking the acquisition stage as the project value V_A at the beginning of the acquisition stage. At this point, the firm has another option to sell the patent to other firms, receiving in return an amount of disclosure fee plus a royalty fee every year for a specified period.

In our comparative experiment, we compare the optimal decisions determined by three approaches: (1) the proposed model (the option approach with patent decision); (2) the option approach proposed by Perdue, *et al.*, (1999), here referred to as the base model; and (3) the net present value (NPV). The option valuation approach and dynamic programming developed by Dixit and Pindyck (1995), was also applied by Perdue, *et al.*, (1999), to determine the option value and optimal decision rules but only at the commercial stage of a R&D project. Their project value during the commercial stage is assumed to evolve according to the combined stochastic process (Eq. 2). Once the option value at the commercial stage is determined, the expected discounted values of the R&D stages are obtained through a decision tree model using the probability of success associated with each stage. However, their work is limited to two decision choices between to invest and to not invest in the first stage and an additional decision choice to delay the investment in the commercial stage. The traditional NPV method, on the other hand, determines the project investment valuation by its net present value of the expected return from cash flow (V_A) and the expected total investment (I_R, I_D, I_A). The NPV decision rule is to invest in the project, if the NPV is positive. Otherwise, it is better not investing.

While the base model applies the combined stochastic process (Eq. 2) and option approach only in the acquisition stage, our proposed model applies Eq. 2 to describe the changes in project values in all three stages. In addition, it differs significantly from the base model by the incorporation of market uncertainty in the valuation of the technical R&D stages. If it is optimal not to invest, the postponement option yields an extra option value which is always greater than or equal to the zero value of the abandonment decided by the base model. When the optimal decision is to postpone, the same analysis is repeated in the next time period with the updated market uncertainty.

4.1 Comparative and Sensitivity Analyses

Table 1 compares in each stage the values and optimal decisions determined by three approaches. As summarized in Table 1, at the beginning of the acquisition stage, all approaches yield the same value of 519,920 Baht which is the net present value of payoff V_A-I_A from the investment in the acquisition stage, since all approaches use the same weighted average cost of capital as the discount rate. Because NPV is based on the now-or-never decision, the decision decided by NPV is made only at the beginning of the RDA project which is to abandon all stages of the RDA project, while the decisions decided by the proposed model and the base model for the development and acquisition stages are contingent and shown in parentheses. Moving backwardly to the beginning of project investment, the decision suggested by the proposed model to invest in the research stage is significantly different from the abandonment decided by the base model and the NPV, despite the same payoff in the acquisition stage. In the base model, losses are limited to zero value of abandonment, while NPV yields the negative value. One advantage of the option approach over the NPV is that the former takes the results of the research and development stages into account, while the NPV does not. This situation is often referred to in the real option literatures (Dixit and Pindyck, 1995; 1994; Luehrman, 1998; Perdue, *et al.*, 1999) as the managerial flexibility. As a result, the NPV can underestimate the RDA project by the value of option to abandon the development and acquisition stages, if the research result is not as expected. The zero value determined by the base model reflects a direct consequence of the probability of success in the R&D stages.

Table 1 Optimal decisions and values

Optimal decision and value at the beginning	Proposed Method	Base model	Net Present Value (NPV)
the acquisition stage	(Invest) 519,920	(Invest) 519,920	Abandon 519,920
the development stage	(Invest) 652,099	(Invest) 32,823	Abandon 235,590
the research stage	Invest 471,197	Abandon 0	Abandon -29,332

The probability of success, $\Pr_i$, plays an important function in valuing the R&D stages by the base model. Once the option value $F_A(V_A)$ is determined, the expected values of preceding stages are obtained through a decision tree by using $\Pr_i$ and the investment cost I_i in stage *i*. The option values of the R&D stages determined by the base model are as follows:

$$F_D(V_D) = \text{Max}[\Pr_D * F_A(V_A) - I_D, 0], \text{ and}$$

$$F_R(V_R) = \text{Max}[\Pr_R * F_D(V_D) - I_R, 0], \text{ respectively.}$$

For example, given $F_A(V_A)$ and I_D, Fig. 3 shows the solid-lined threshold of investment as a function of the probability of success for both R&D stages. The optimal decision rule decided by the base model is to invest in the development, if $F_A(V_A)$ (marked by the dotted-line) is greater than the threshold of investing ($\Pr_D \geq 0.436$), or otherwise to abandon it. The optimal decision to abandon the investment in the development stage decided by the base model over the range [0, 0.436] of $\Pr_D$ also reflects the zero values of $F_D(V_D)$, while the decision to invest makes $F_D(V_D)$ linearly increasing as $\Pr_D$ increases from 0.436 to 1.0. The value 32,823 of $F_D(V_D)$ shown in Table 1 and the dashed-line in Fig. 3 is determined by the base model with pre-specified $\Pr_D = 0.5$. Since it is smaller than the threshold of investment for all values of $\Pr_R$, the optimal decision is, then, not to invest in the research stage, even though the research stage has 100% success rate. Based on the abandon decision, $F_R(V_R)$ is consequently zero for all values of $\Pr_R$. We can regard that the option values of the research and development stages in the base model are very sensitive to the probability of success associated with each stage.

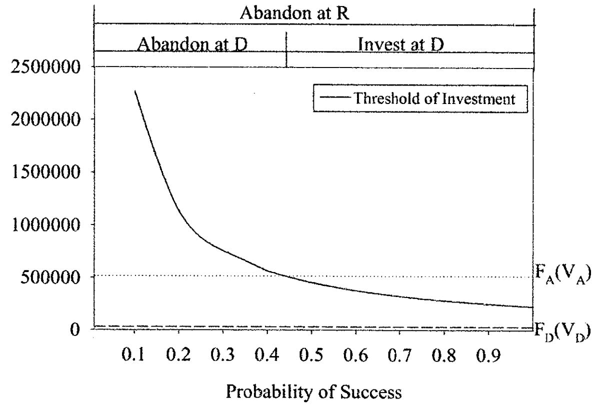


Fig. 3 Thresholds of investment by the base model

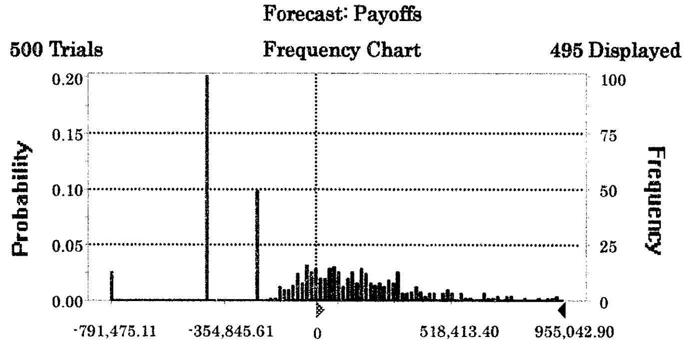
4.2 Simulation Experiment and Analysis

Since the optimal decisions decided by the proposed model differ from the other two decisions, we further evaluate the effectiveness of the proposed model and its decision, applying the Monte Carlo simulation. The simulated experiment is designed by firstly investing in the research stage as determined by the proposed model and set for the stochastic change of the project value (V_R and V_A) during the first 3 years, the time required to complete the research stage. At the beginning of the development stage, the optimal decision is determined following the proposed model with the updated market uncertainty and project value at the end of the research stage. If it is optimal to invest in the development stage, the project value (V_D and V_A) is allowed to stochastically change for another 2 years to complete the development stage. But if the optimal decision at the development stage is to postpone the investment, the decision is made again next year with the updated market uncertainty. To avoid the postponement indefinitely, the decision is set to abandon the project if the postponement decisions occur twice consecutively. At the beginning of the acquisition stage, if the optimal decision is to invest, the updated project value (the updated V_A) is allowed to stochastically change for another 10 years.

The profit obtained is the present value of the net profit generated from firstly deciding to invest in the research stage. The statistics of profit response obtained from 500 replications of the Monte Carlo simulation and its histogram are summarized in Fig. 4. The mean profit of 200.6 or the return of 0.025% is quite low when compared with total investment costs of this RDA project. However, as indicated by the certainty level in Fig. 4, there is 52.2% chance that the firm can still make profitability. In addition, the net profit can be obtained up to the maximum of approximately 200% of the total investment.

At this point, it should be noted that the expected rate of return or the value of drift term (α) of the geometric Brownian motion in the combined stochastic process (Eq. 2) is set in the simulation experiment to be the risk-free rate. As a result, $\alpha \leq \rho$, the discount rate (See more detail in Dixit and Pindyck, 1995). When the drifted project values are discounted back to its present value by a higher discount rate, the average present value of the simulated project value would inevitably be small. It is, however, expected that the actual growth rate of the RDA project value in each stage would be higher than the risk-free rate used and that with a higher probability of making profit, the project investment would consequently generate the actual profit much higher than 200.6 Baht. In addition, the negative range of profit and other statistics are expected to be improved. In general, the simulated results do confirm that the decision to invest in this project is perhaps more worthwhile than the decision to abandon as suggested by the base model and NPV.

Based on the combined stochastic process (Eq. 2) of the geometric Brownian motion and Poisson process, three situations in which the project value can evolve, namely upside, downside and jump situations, occur in 500 replications. The first two situations occur according to the standard deviation ($\pm\sigma$) of geometric Brownian motion, whereas the last case happens according to the mean arrival rate (λ) of Poisson jump downward process. The standard deviation $\pm\sigma$ makes the project value fluctuating around the expected rate and consequently the profit fluctuating as evidently shown by its standard deviation of 350,832 in Fig. 4. The upside situations happen if the project value changes following the upside uncertainty ($+\sigma$). The effect of high uncertainty to the profit is indicated by the maximum value of 1.6 million. The downward situations, however, happen if the project value is evolved according to the downside uncertainty ($-\sigma$) indicating some failure. The additional Poisson jump process to zero in any stage does amplify the project failure, evidently found in the loss figures. However, the loss under these circumstances would normally be limited to the investment cost. The first 30% percentile of 500 profits: -791,475; -417,846; and -227,137, are respectively equal to the investments spent in all three stages, in the first two stages, and in the first stage only, as shown by these three discrete events of the three bars on the left-hand side of Fig. 4. Especially, the second bar on the left marks the value of -417,846, the mode that occurs when the project fails during the development stage. Our detailed analysis indicates that this unfavorable situation is a direct consequence of the Poisson jump process to zero that frequently occurs in the development stage. This situation, however, is not considered in the base model and NPV.



Summary:
Certainty Level is 52.20% from 0.00 to +Infinity
Display Range is from -791,475.11 to 955,042.90
Entire Range is from -791.475.11 to 1,624,484.49

Statistics:

	Values
Trials	500
Mean	200.60
Median	11,799.76
Mode	-417,846.02
Standard Deviation	350,831.93
Variance	1.23E+11
Range Minimum	-791,475.11
Range Maximum	1,624,484.49
Range Width	2,415,959.60
Mean Std. Error	15,689.68

Fig. 4 Results of simulated profits

It may be worthwhile to note that this case study is one of a government-funding agency, a non-profit organization. The project involved the research, development and acquisition of a medical product, and its main objective was to substitute the imported by locally made products. This indirect benefit is not included in our analysis of the expected cash flow, and therefore, the projection of return and value of patent sales is lower than usual. In practice, this RDA project was implemented and succeeded in all three stages.

5. CONCLUSIONS

This paper presented an alternative valuation method based on the option approach for the RDA project investment especially for funding agencies. By incorporating the chance to sell the patent and the ability to postpone the investment into the valuation of the technical stages of the RDA project investment, the method is to evaluate all values embedded in this RDA project, namely the value of postponement option created by the market uncertainty, the option value of follow-on investment created by the technical uncertainty. It was shown that the option values determined by the proposed model have the positive correlation with the technical and market uncertainties. Nevertheless, they effect the investment decision in conflicting ways. With the model developed here, the RDA project in the R&D stages seems more attractive and accelerated by the high technical uncertainty.

The proposed model was tested on a real case study and its results were compared with those obtained by the traditional NPV and Perdue, *et al.*, (1999). The option model suggested for the investment in the project, while the other two recommended abandoning the project. Based on these different results, further analysis and simulated experiment were conducted to validate the model and to study its behavior. Our analyzes found that although the project value and decision in each stage depended on the level of uncertainty, they were less sensitive in the proposed option model than in the base model of Perdue, *et al.*, (1999). Although the simulated results also showed the small average payoff of project investment, there existed more than 50% chance that the investment could lead to a positive payoff and even in a large amount, while the loss was limited only to different investment costs. The small mean payoff was indeed mainly contributed by (1) the lower value of stochastic upward trend or growth rate of project value than the discount rate, and (2) the downward trend and jump of the combined stochastic process used in the model.

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