Decision to rescue failed product innovation projects based on the leading innovation strategy

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Abstract

The leading innovation strategy is one of the important methods used to rescue failed product innovation projects. Rescuing failed projects based on the leading innovation strategy, rescuing time and points of competitors participating in the market can affect the probability of success. The established mathematical economic model can be used to analyse the cost of rescuing failed product innovation projects and income when competitors participate in the market in the introduction period, growth period, or mature period. The model can also be used to determine the feasibility of the leading innovation strategy and measures that enterprises should take to obtain greater profits under different competitive environments.

Keywords: leading innovation, product innovation, failed projects, rescue

1 The connotation of failed product innovation projects

According to the definition of project from the American Project Management Institute, the product innovation project is defined as a set of all types of technological activities with start and end dates to provide better products and services to customers in the prescribed time, cost, and performance parameters. It has a specific target to be completed, clear start and end dates, and limited project budget. It is an investment activity that has high risk and low success rate. Nearly 16,000 types of new products entered the market in 1991, but 90% did not achieve their business goals [1], thereby demonstrating the characteristics of product innovation projects.

Research showed that two-thirds of new products fail when they enter the market, and only less than 15% of innovative products achieve real success [2]. Numerous failed projects have brought heavy burden to enterprises. Failed projects are projects that fail to obtain the expected economic benefits and are unable to have a normal operation because of some uncertain factors. Failed product innovation projects are projects that do not reach anticipated goals. However, such projects are not worthless because they help the succeeding projects avoid risk. Knowledge gained from failed projects, as well as technical ability, will lay a solid foundation for subsequent projects [3].

2 Cost analysis of rescuing failed product innovation projects using the leading innovation strategy

Any new products with new technology have difficulty in achieving long-term endurance in the market. Enterprises must constantly research new technologies and new products to occupy or expand market shares [4]. The leading innovation strategy seeks the leading technology and products, and establishes and maintains the competitive advantages. According to Siemens, the profit of a new product will increase by 0.3% if set into production one day in advance, 1.6% if five days in advance, and 2.5% if ten days in advance. Based on failed product innovation projects, enterprises should draw from their experiences, maximize the use of the resources of failed projects, and continue product innovation using the innovation strategy to meet consumers' needs. Thus, enterprises can achieve optimal allocation of resources, differentiate the new product from other products, and determine the low cost advantage of the new product, which are important to rescue failed product innovation projects.

According to the study of Graves S. B. and Griffin A., the R&D cycle of the product D, R&D cost of the product C, and product performance Q have the following relationship: $C = C\ (Q,\ D) = Q\ (\alpha - \beta D + D^2)$, $(\alpha > 0$, $\beta > 0$, and $4\alpha > \beta^2)$.

The R&D cycle D is the time from R&D to market entry for new products. The R&D cost of the product C is the sum of labour, materials, equipment, and other expenses in the process of R&D. The product performance Q is the level of the quality, function, and appearance of new products.

Whether products meet the demand of users is the key to success for projects [5]. Lei K. and Schmidt E. J. [6] believe that the uniqueness of products and degree of meeting users' demand are very important to the success or failure of product innovation projects. Enterprises must continue to research and develop new products so that the

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performance of products can be improved after failure. The performance of a new product will reach $(Q + M)$ $(M > 0)$, and the R&D cycle will reach $(D + N)$ $(N > 0)$. In addition, some costs, including the human resource cost, machine and equipment depreciation cost, and capital cost (such as interest from the original product entering the market), should be considered in the research and development of a new product. At the same time, the product in this period can obtain a certain income. The difference between the two parts is shown in C_0. The R&D cost C is expressed as follows: $C = C_0 + (Q + M)\ (\alpha - \beta\ (D + N) + (D + N)^2)$, $(\alpha > 0, \beta > 0$, and $4\alpha > \beta^2)$.

3 Benefit analysis of rescuing failed product innovation projects using the leading innovation strategy

Enterprises need to analyse the target market and select the target customers, economy, technology, and other factors prior to researching a new product [7]. Thus, the failed project enterprises gain more experience. This experience can help enterprises promote the rate of rescuing failed product innovation projects using the leading innovation strategy. For better analysis, we assume the following:

1) Only two enterprises exist, namely, the enterprise and competitor.

2) The barriers of entry to the market are low. Enterprises can choose any strategy to rescue the failed product innovation projects.

3) No other factors influence the enterprises to use the leading innovation strategy.

3.1 ANALYSIS OF TOTAL MARKET DEMAND AND CONTRIBUTION MARGIN

3.1.1 Market demand of the new product changes with time

As shown in Figure 1, N is the R&D cycle of the new product. ρ_1 is the average growth of sales in the introduction period and $tg\,\varpi = \rho_1$. ρ_2 is the average growth of sales in the growth period and $tg\theta = \rho_2 - \rho_1$. ρ_3 is the average reduction in sales in the recession period and $tg\,\vartheta = \rho_3$. $N + r_1$ is the time the new product enters the growth period. $N + r_1 + r_2$ is the time the new product enters the mature period and $N + r_1 + r_2 + r_3$ is the time the new product enters the recession period.

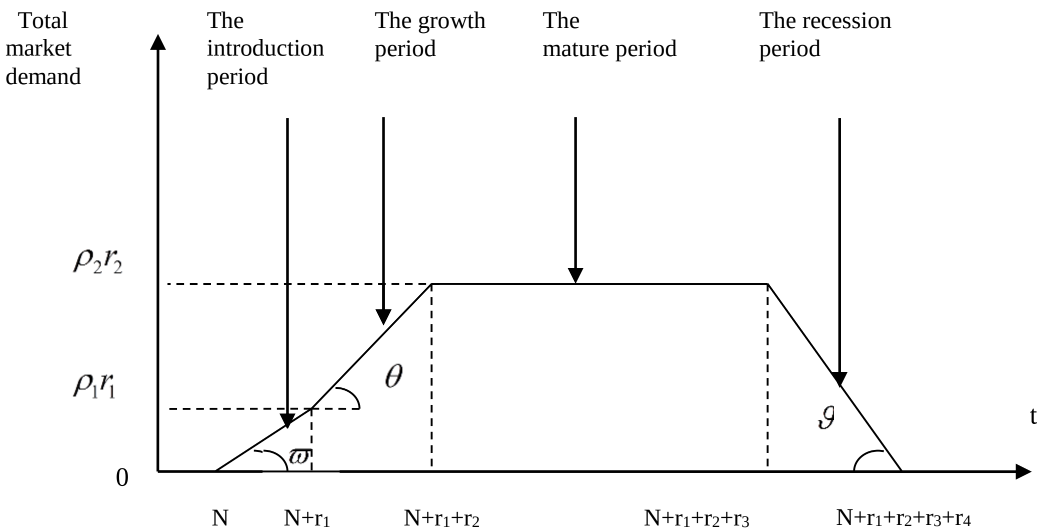

FIGURE 1 Total market demand of the new product in different periods

The total sales M of different periods are as follows:

If $N \le t \le N + r_1$, $M = \rho_1 (t - N)$;

If $N + r_1 \le t \le N + r_1 + r_2$, $M = \rho_2 (t - N - r_1)$;

If $N + r_1 + r_2 \le t \le N + r_1 + r_2 + r_3$, $M = \rho_2 r_2$;

If $N + r_1 + r_2 + r_3 \le t \le N + r_1 + r_2 + r_3 + r_4$, $M = \rho_3 (N + r_1 + r_2 + r_3 + r_4 - t)$.

3.1.2 Contribution margin of unit product in different times

Suppose that P_1 is the average price of the new product in time t, and C_1 is the average manufacturing cost of the new product in the time t. With the continuous application of the new technology, the average sales price P_1 of the new product will decline with the time t, C_1 will reduce with increasing of the production scale. According to the nature of $y = e^{-x}$, $y = e^{-x}$ will decrease with increasing production scale. According to the nature of $y = e^{-x}$, it will decrease with increasing x if $x > 0$. Thus, we suppose that P_1 and C_1 are the exponential functions of base e^{-1}.

Suppose that $P_1 = pe^{-\varepsilon t}$ (ε>0) and $C_1 = ce^{-\varepsilon t}$ (ε>0), where p is the unit price of the new product entering the market, c is the average manufacturing cost of the new product entering the market, and ε is the time trend coefficient.

Therefore, $R = P_1 - C_1 = (p - c)\, e^{-\varepsilon} = ve^{-\varepsilon t}$, where v is the contribution margin of the unit product entering the market.

3.2 PROFIT ANALUSIS OF RESCUING FAILED PRODUCT INNOVATION PROJECTS

3.2.1 Profit analysis when the competitor enters the market during the introduction period

Suppose that the competitor enters the market while $(N + r_5)$ $(0 \le r_5 \le r_1)$ in the introduction period because of low barriers of entry to the market. The profit of the new product can be divided into two sections in the leading innovation strategy. One is the profit T_1 before the competitor enters the market. The other is the profit T_2 after the competitor enters the market.

T_1: suppose that the enterprise has obtained the market capacity G before the competitor enters the market, and $G = \rho_1\,(t - N)$, $(N \le t \le N + r_5)$. $R = ve^{-\varepsilon t}$. $G \times R = \rho_1\,(t - N) \times ve^{-\varepsilon t}dt$. Given that G and R change with time, the profit of the enterprise before the competitor enters the market is expressed as follows:

$$T_1 = \int_N^{N+r_5} \rho_1(t-N)\times ve^{-\varepsilon t}dt\,. \tag{1}$$

T_2: -after the competitor enters the market, the profit of the enterprise is: $T_2 = T_3 + T_4 + T_5 + T_6$.

According to the study of Cooper and Nakanishi, the market share of the new product is the performance function of new products of the enterprise and competitor: $S(Q,Q_c) = \gamma Q / (\gamma Q + Q_c)$. In this formula, Q is the performance of the new product of the enterprise, Q_c is the performance of the new product of the competitor, and γ is the market advantage of the enterprise to the competitor. If the performance level is the same, $Q = Q_c$.

$\gamma > 1$ indicates that the market share of the enterprise is over 50%.

If $N + r_5 \le t \le N + r_1$, $G = \rho_1(t-N)$,

$$T_3 = \int_{N+r_5}^{N+r_1} \rho_1(t-N)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt\,.$$

If $N + r_1 \le t \le N + r_1 + r_2$, $G = \rho_2(t-N-r_1)$,

$$T_4 = \int_{N+r_1}^{N+r_1+r_2} \rho_2(t-N-r_1)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt\,.$$

If $N + r_1 + r_2 \le t \le N + r_1 + r_2 + r_3$, $G = \rho_2 r_2$,

$$T_5 = \int_{N+r_1+r_2}^{N+r_1+r_2+r_3} \rho_2 r_2\times S(Q,Q_c)\times ve^{-\varepsilon t}dt\,.$$

If $N + r_1 + r_2 + r_3 \le t \le N + r_1 + r_2 + r_3 + r_4$,

$G = \rho_3(N + r_1 + r_2 + r_3 + r_4 - t)$,

$$T_6 = \int_{N+r_1+r_2+r_3}^{N+r_1+r_2+r_3+r_4} \rho_3(N+r_1+r_2+r_3+r_4-t)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt.$$

Thus, the profit of the enterprise in all the periods can be expressed as follows:

$$\begin{aligned} T_1+T_2 &= T_1+T_3+T_4+T_5+T_6 = \int_N^{N+r_5}\rho_1(t-N)\times ve^{-\varepsilon t}dt+\int_{N+r_5}^{N+r_1}\rho_1(t-N)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\\ &\int_{N+r_1}^{N+r_1+r_2}\rho_2(t-N-r_1)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\int_{N+r_1+r_2}^{N+r_1+r_2+r_3}\rho_2 r_2\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\\ &\int_{N+r_1+r_2+r_3}^{N+r_1+r_2+r_3+r_4}\rho_3(N+r_1+r_2+r_3+r_4-t)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt. \end{aligned} \tag{2}$$

After R&D

$$C = C_0 + (Q+M)\left(\alpha - \beta(D+N) + (D+N)^2\right),$$

$$S(Q,Q_c) = \frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\,.$$

$$\begin{aligned} \phi_1 &= \int_N^{N+r_5}\rho_1(t-N)\times ve^{-\varepsilon t}dt+\int_{N+r_5}^{N+r_1}\rho_1(t-N)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\\ &\int_{N+r_1}^{N+r_1+r_2}\rho_2(t-N-r_1)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\int_{N+r_1+r_2}^{N+r_1+r_2+r_3}\rho_2 r_2\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\\ &\int_{N+r_1+r_2+r_3}^{N+r_1+r_2+r_3+r_4}\rho_3(N+r_1+r_2+r_3+r_4-t)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt - C_0 - (Q+M)\left(\alpha-\beta(N+D)+(N+D)^2\right). \end{aligned} \tag{3}$$

If $\partial\phi_1 / \partial N = 0$ and $\partial\phi_1 / \partial M = 0$, the extreme value of ϕ_1 is obtained.

$$\rho_1 v\left[\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_5)}-e^{-\varepsilon N}\right)-r_5 e^{-\varepsilon(N+r_5)}\right]+\rho_1 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[r_1 e^{-\varepsilon(N+r_1)}-r_5 e^{-\varepsilon(N+r_5)}+\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1)}-e^{-\varepsilon(N+r_5)}\right)\right]+$$
$$\rho_2 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[r_2 e^{-\varepsilon(N+r_1+r_2)}+\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_2)}-e^{-\varepsilon(N+r_1)}\right)\right]+$$
$$\rho_2 r_2 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[e^{-\varepsilon(N+r_1+r_2+r_3)}-e^{-\varepsilon(N+r_1+r_2)}\right]-(Q+M)(2N+2D-\beta)+ \tag{4}$$
$$\rho_3 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_2+r_3)}-e^{-\varepsilon(N+r_1+r_2+r_3+r_4)}\right)-r_4 e^{-\varepsilon(N+r_1+r_2+r_3)}\right]=0.$$

and

$$\rho_1 v\left[\frac{r_5}{\varepsilon}e^{-\varepsilon(N+r_5)}-\frac{r_1}{\varepsilon}e^{-\varepsilon(N+r_1)}+\frac{1}{\varepsilon^2}\left(e^{-\varepsilon(N+r_5)}-e^{-\varepsilon(N+r_1)}\right)\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)+$$
$$+\rho_2 v\left[-\frac{r_2}{\varepsilon}e^{-\varepsilon(N+r_1+r_2)}+\frac{1}{\varepsilon^2}\left(e^{-\varepsilon(N+r_1)}-e^{-\varepsilon(N+r_1+r_2)}\right)\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)+$$
$$+\frac{\rho_2 r_2 v}{-\varepsilon}\left[e^{-\varepsilon(N+r_1+r_2+r_3)}-e^{-\varepsilon(N+r_1+r_2)}\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)-\left(\alpha-\beta(N+D)+(N+D)^2\right)+ \tag{5}$$
$$+\rho_3 v\left[\frac{r_4}{\varepsilon}e^{-\varepsilon(N+r_1+r_2+r_3)}+\frac{1}{\varepsilon^2}\left(e^{-\varepsilon(N+r_1+r_2+r_3+r_4)}-e^{-\varepsilon(N+r_1+r_2+r_3)}\right)\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)=0.$$

When the R&D cycle and performance meet the above two formulas, the enterprise can obtain maximum profits.

3.2.2 Profit analysis when the competitor enters the market during the growth period

When the competitor enters the market in the growth period, the profit is as follows:

$$\phi_2=\int_N^{N+r_1}\rho_1 r_1\times ve^{-\varepsilon t}dt+\int_{N+r_1}^{N+r_1+r_5}\rho_2(t-N-r_1)\times ve^{-\varepsilon t}dt+$$
$$\int_{N+r_1+r_5}^{N+r_1+r_2}\rho_2(r_2-r_5)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\int_{N+r_1+r_2}^{N+r_1+r_2+r_3}\rho_2 r_2\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+ \tag{6}$$
$$\int_{N+r_1+r_2+r_3}^{N+r_1+r_2+r_3+r_4}\rho_3(N+r_1+r_2+r_3+r_4-t)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt-C_0-(Q+M)\left(\alpha-\beta(D+N)+(D+N)^2\right).$$

If $\partial\phi_2/\partial N=0$ and $\partial\phi_2/\partial M=0$, the extreme value of ϕ_2 is obtained.

$$\rho_1 v\left[r_1 e^{-\varepsilon(N+r_1)}+\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1)}-e^{-\varepsilon N}\right)\right]+\rho_2 v\left[r_2 e^{-\varepsilon(N+r_1+r_5)}+\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_5)}-e^{-\varepsilon(N+r_1)}\right)\right]+$$
$$\rho_2 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[r_2\left(e^{-\varepsilon(N+r_1+r_2+r_3)}-e^{-\varepsilon(N+r_1+r_5)}\right)-r_5\left(e^{-\varepsilon(N+r_1+r_2)}-e^{-\varepsilon(N+r_1+r_5)}\right)\right]- \tag{7}$$
$$-\rho_3 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_2+r_3+r_4)}-e^{-\varepsilon(N+r_1+r_2+r_3)}\right)-r_4 e^{-\varepsilon(N+r_1+r_2+r_3)}\right]-(Q+M)(2N+2D-\beta)=0.$$

and

$$\rho_2 v\left[\frac{r_2-r_5}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_5)}-e^{-\varepsilon(N+r_1+r_2)}\right)+\frac{r_2}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_5)}-e^{-\varepsilon(N+r_1+r_2+r_3)}\right)\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)+$$
$$+\rho_3 v\left[\frac{r_4}{\varepsilon}e^{-\varepsilon(N+r_1+r_2+r_3)}+\frac{1}{\varepsilon^2}\left(e^{-\varepsilon(N+r_1+r_2+r_3+r_4)}-e^{-\varepsilon(N+r_1+r_2+r_3)}\right)\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)-\left(\alpha-\beta(N+D)+(N+D)^2\right)=0. \quad (8)$$

When the R&D cycle and performance meet the above two formulas, the enterprise can obtain maximum profits.

3.2.3 Profit analysis when the competitor enters the market during the mature period

When the competitor enters the market in the mature period, the profit is as follows:

$$\phi_3=\int_N^{N+r_1}\rho_1(t-N)\times ve^{-\varepsilon t}dt+\int_{N+r_1}^{N+r_1+r_2}\rho_2(t-N-r_1)\times ve^{-\varepsilon t}dt+\int_{N+r_1+r_2}^{N+r_1+r_{2+}r_5}\rho_2 r_2\times ve^{-\varepsilon t}dt+$$
$$\int_{N+r_1+r_2+r_5}^{N+r_1+r_2+r_3}\rho_2 r_2\times S(Q,Q_c)\times ve^{-\varepsilon t}dt+\int_{N+r_1+r_2+r_3}^{N+r_1+r_2+r_3+r_4}\rho_3(N+r_1+r_2+r_3+r_4-t)\times S(Q,Q_c)\times ve^{-\varepsilon t}dt-$$
$$C_0-(Q+M)\left(\alpha-\beta(N+D)+(N+D)^2\right). \quad (9)$$

If $\partial\phi_3/\partial N=0$ and $\partial\phi_3/\partial M=0$, the extreme value of ϕ_3 is obtained.

$$\rho_1 v\left[r_1e^{-\varepsilon(N+r_1)}+\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1)}-e^{-\varepsilon N}\right)\right]+\rho_2 v\left[r_2e^{-\varepsilon(N+r_1+r_2)}+\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_2)}-e^{-\varepsilon(N+r_1)}\right)\right]+$$
$$\rho_2 r_2 v\left[e^{-\varepsilon(N+r_1+r_2+r_5)}-e^{-\varepsilon(N+r_1+r_2)}\right]+\rho_2 r_2 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[e^{-\varepsilon(N+r_1+r_2+r_3)}-e^{-\varepsilon(N+r_1+r_2+r_5)}\right]-$$
$$\rho_3 v\frac{\gamma(Q+M)}{\gamma(Q+M)+Q_c}\left[\frac{1}{\varepsilon}\left(e^{-\varepsilon(N+r_1+r_2+r_3+r_4)}-e^{-\varepsilon(N+r_1+r_2+r_3)}\right)-r_4e^{-\varepsilon(N+r_1+r_2+r_3)}\right]+$$
$$(Q+M)(2N+2D-\beta)=0. \quad (10)$$

and

$$-\frac{\rho_2 r_2 v}{\varepsilon}\left[e^{-\varepsilon(N+r_1+r_2+r_3)}-e^{-\varepsilon(N+r_1+r_2+r_5)}\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)-\left(\alpha-\beta(N+D)+(N+D)^2\right)$$
$$+\rho_3 v\left[\frac{r_4}{\varepsilon}e^{-\varepsilon(N+r_1+r_2+r_3)}+\frac{1}{\varepsilon^2}\left(e^{-\varepsilon(N+r_1+r_2+r_3+r_4)}-e^{-\varepsilon(N+r_1+r_2+r_3)}\right)\right]\left(\frac{Q_c r}{\left[r(Q+M)+Q_C\right]^2}\right)=0. \quad (11)$$

When the R&D cycle and performance meet the above two formulas, the enterprise can obtain maximum profits.

4 Conclusions

By analysing the profit in these three cases, enterprises can examine different situations while rescuing. Enterprises can analyse the feasibility of the leading innovation strategy, as well as different measures to confront competitors using the leading innovation strategy.

1) $\phi_1>0$, $\phi_2>0$, or $\phi_3>0$ shows that rescuing the failed product innovation project in the leading innovation strategy is profitable. For the maximized value, the enterprise will analyse the profits of different investment activities to determine the optimal investment scheme, and decide whether to rescue the failed project. Moreover, introducing the concept of rescuing costs in the model, which is related to s rescuing time, may help enterprises determine the best rescuing chance according to the final conclusion of the model.

2) $\phi_1<\phi_2<\phi_3$ or $\phi_1<\phi_3<\phi_2$ shows that the greatest effect to the profit is observed when the competitor enters the market during the introduction period. In this case, enterprises can increase the intensity of research and development of innovative products, promote the degree of differentiation of the product, reduce costs, maintain a high market threshold to entry, and decrease the speed of

other enterprises entering the market to obtain more profits.

3) $\phi_2 < \phi_1 < \phi_3$ or $\phi_2 < \phi_3 < \phi_1$ shows that the greatest effect to the profit is observed when the competitor enters the market during the growth period. In the growth period, enterprises can quickly grab the market share by innovation products. If a competitor enters the market in this period, it will change the pattern of the market and influence the goal of expanded market share within a short time period. Only by accumulating adequate resources and shortening the growth period of innovative products can the enterprise reduce the negative effects from a competitor.

4) $\phi_3 < \phi_1 < \phi_2$ or $\phi_3 < \phi_2 < \phi_1$ shows that the greatest effect to the profit is observed when the competitor enters the market during the mature period. An enterprise in the mature period has formed a relatively stable customer base. If the competitor chooses to join the market at this time, the risk and probability of failure are high. Therefore, the probability of $\phi_3 < \phi_1 < \phi_2$ or $\phi_3 < \phi_2 < \phi_1$ is low.

In the different life cycles, the internal and external environments of enterprises differ, so an optimal innovation model does not exist. Enterprises need to create new products constantly to meet the needs of customers because of unstable customer demand. Even though a competitor enters the market, enterprises should continue to innovate, seek for the best balance point in the R&D cycle, and develop product performance, and research development costs and benefits to obtain the largest profit. In view of failed product innovation projects, rescuing time and rescuing strategy are the keys to success.

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