Determining the Best launch Time for New Products in a Competitive Market Situation

The Analysis of Launch Time with Risk Considerations

Zahra Sharifonnasabi [*a] and Mehdi Sheikhzadeh [b]

School of Management and Economics, Sharif University of Technology, Iran
[a] Zahra.sharifonasabi@gmail.com [b] sheikhzadeh@sharif.edu

Abstract

Managing New Product Development (NPD) has become a critical success factor for most companies, given aspects of competition in business environment. In any NPD project, a critical decision is about best time to launch new product(s). Given many influential factors, such as research and development cost, quality improvements rate, production rate, market share, and level of competition and demand in the market, systematically determining the optimal launch time is often too complicated. Incorporating risk considerations can augment the complexity even more and consequently it has not been addressed well in literature despite risky nature of NPD projects. In this research, we develop a model incorporating risk considerations while systematically determining the optimal launch time for companies facing diminishing returns on product quality and growing market competition over time. Specifically, we analyze role of both Quality of NPD Process (QNPDP) and completion level, respectively from internal and external perspectives. We demonstrate that risk considerations can lead to totally different results. In particular, at the lower levels of QNPDP, the risk is monotonically increasing over time while at the higher levels of QNPDP the risk will not be increasing over time, any more. This implies that risk-averse decision makers prefer launching the new product earlier or later times depending on level of QNPDP.

Introduction

New Product Development (NPD) has become one of the instrumental managerial decisions in recent years, given increasing rate of capabilities offered by technology advancements and expansion of markets, variety of products, and customer’s demands. Despite high failure rate of NPD projects, NPD is one of the critical success factors in most leading companies. One primary reason is that proactive product development can influence the competitive success and renewal of organizations [1]. A key issue in this emerging field has been the reduction in the development cycle time or time-to-market [2]. Decision on time of introducing a new product is quite challenging as it requires a careful trade-off analysis. For instance, there are conflicting objectives from marketing and operational perspectives with respect to launching time of a new product [3]. Specifically, “from a marketing perspective, the team prefers to launch the product sooner, as this would lead to higher life cycle sales. From the operations perspective, the team prefers to spend additional time on the detailed engineering of the product and process, leading to lower product unit cost." Therefore, a too late entry could likely lead to significant loss of opportunity while a too early entry could possibly not be receptive enough from customers, channel members, and other required partners [4]. In summary, some researchers such as Bayus [5] and Cohen et al. [6] believed that firms must delay new product launches in many instants to utilize their ability to improve product quality. While some other researchers such as Armstrong and Levesque [7], Morgan et al. [8], Mahajan and Muller [9], Nault and Vandenbosch [10], Wilson and Norton [11], and Norton and Bass [12] stressed that such a prescription do not readily extend to cases in which firms have the ability to launch multiple versions of a product over the time horizon, or they are in a high competitive market condition.

Our work focuses on a single firm analyzing best launch time of a single product. The current literature in this category, considers a variety of internal and external parameters such as development cost, quality improvements rate, production rate and capacity, market share, and level of competition and demand in the market. All such models are based on one specific trade-off between those parameters. Among these trade-offs, the trade-off between time and quality is the most dominant one. For example, Armstrong and Levesque [7] applied time-quality trade-off and formulated a model of time-to-market decision for entrepreneurs. But, in the existing literature on developed models of launch time of a new product decision makers are assumed to be risk neutral as the firm's objective is assumed to be maximizing either the expected profit in probabilistic models or merely profit in deterministic models. However, launching a new product is associated with so much risk and there is lack of such consideration with respect to launch time decision. This necessitates developing a model addressing risk considerations, which is indeed contribution of our work. With respect to the subject of risk, pioneered by Markowitz in the 1950s, the Mean-Variance (MV) formulation has become a fundamental theory for risk management in finance [13]. The MV approach provides practical, since it needs only mean and the variance, and approximate solution. In our study, we follow MV approach for risk considerations. Specifically, we maximize the expected profit subject to the variance constraint, which should not be more than some predetermined level.

Model Formulation

We consider an enterprise developing a new product based on a predetermined fixed budget B ($B>0$) to cover all development costs in each time bucket. We use i ($i=1,2, \ldots$) as index of time bucket where $i=T$ represents the time bucket at which the product is launched ($T \geq 1$). The rate of quality improvement in each time bucket is assumed to be a continuous random variable q_i, where q_i's are *iid* random variables with average of μ_q and standard deviation of σ_q. Without loss of generality, we assume q_i's are Normally distributed; $q_i \sim N(\mu_q, \sigma_q^{\ 2})$. The competition level in the market before beginning of product development is C_0 ($C_0 \geq 0$) and competition level is likely increasing as other competitors are similarly developing new competitive products. With respect to competition, the level of competition increment in each time bucket is also assumed to be a continuous random variable c_i, where c_i's are *iid* random variables with average of μ_c and standard deviation of σ_c. Similar to q_i's we assume c_i's are normally distributed, $c_i \sim N(\mu_q, \sigma_q^{\ 2})$.

The launch time of the new product under development, T, depends on both cumulative quality level up to the time of product launch $Q(T)=\sum_{i=1}^{T} q_i$, and cumulative competition level during product development $C(T)=\sum_{i=1}^{T} c_i$. Given the fact that random variables are *iid*, $Q(T)$ follows a Normal distribution; $Q(T) \sim N(T\mu_q, T\sigma_q{}^2)$ and expected value and standard deviation of $C(T)$ are respectively $T\mu_c$ and $T\sigma_c^2$.

Similar to Armstrong and Levesque [7], we assume the revenue realized at launch time $R(T)$ follows a concave function of quality as the following:

$$R(T) \sim R_{\max}(1-e^{-\alpha Q(T)}), \tag{1}$$

where $R_{max}>0$ is maximum revenue generated by a product with perfect quality and α is penalty cost of quality issues ($\alpha>0$). The form of concave function can be intuitively justified as improving the same amount of quality is harder over time. In other words, with the same amount of budget or effort in each time bucket, the firm can improve quality of the product more at earlier times and it would much harder to achieve the same quality improvement later on. Of course, such an assumption is also a common assumption in the literature; see for example [14] or [15]. Based on the same reference, [7], a higher competition is assumed to impose some loss following an increasing linear function of competition level. That is, the loss function due to completion level at the time of product launch $L(T)$ is as follows:

$$L(T)=\beta(C_0+C(T)), \tag{2}$$

where β is penalty loss of competition level ($\beta>0$). The linear competition level over time, which is a common assumption in time-to-market and time-based competition models, incurs the mentioned loss function as one of the components of total cost at the time of launching the new product. Another component is cumulative total development cost up to launch time, i.e. BT. Thus, the profit level at the time of product launch $P(T)$ is simply:

$$P(T)=R(T)-L(T)-B(T)=R_{\max}(1-e^{-\alpha Q(T)})-\beta(C_0+C(T))-BT \tag{3}$$

Proposition 1. The expected value of $P(T)$ follows the following equation:

$$E[P(T)]=R_{\max}(1-e^{A_1.T})-(\beta\mu_c+B)T-\beta C_0, \tag{4}$$

where $A_1=-\mu_q\alpha+\sigma_q{}^2\alpha^2/2<0$ (or equivalently $\sigma_q{}^2\alpha/2<\mu_q$). It is noticeable that variance of quality improvement rate in each time bucket ($\sigma_q{}^2$) appears in expected value of profit. This is somehow counter intuitive, as expected profit depends on variance of quality random variable!

Proposition 2. The variance of *P(T)* follows the following equation:

$$V[P(T)] = R^2{}_{\max}(e^{2A_2.T} - e^{2A_1.T}) + \beta^2\sigma_c{}^2 T\,, \tag{5}$$

where $A_2 = A_1 + \sigma_q{}^2\alpha^2/2$ (so, $A_1 < A_2$).

Risk neutral case

The objective function in this case is simply to maximize $E[P(T)]$ and decision maker has no risk considerations. The general shape of $E[P(T)]$ can be understood from equation (4). The first term has an exponential part that increases over time but its increase is diminish type. This is due to the concave function that we assumed for revenue versus quality. In other words, most benefits of quality improvements are achieved at early stages of product development and in long-run quality improvement has marginal positive impact on revenue. However, the second term represents the total cost that is a linear function of T and it is continuously reducing the expected profit. Therefore, as time goes toward infinity the expected profit will become negative as total cost dominants marginal revenue increment due to quality improvement. Thus, it is intuitively expected to have an optimal time T_E^* at which $E[P(T)]$ is maximized. This is expressed by the following proposition.

Proposition 3: The optimal launch time maximizing $E[P(T)]$ follows the following equation:

$$T_E{}^* = \left\lceil \frac{\ln A_3 - \ln(1 - e^{A_1})}{A_1} \right\rceil, \tag{6}$$

where $\lceil x \rceil$ is nearest integer to x and $A_3 = \dfrac{\beta\mu_c + B}{R_{\max}}$, where $0 \le A_3 \le 1$ (or, equivalently $\beta\mu_c + B < R_{\max}$). Here, $\mathrm{T_E}^* \ge 0$ leads to $A_3 < 1 - e^{A_1}$. Note that in many instances, especially when time is independent variable of a function (such as future contracts in finance), we can safely treat a discrete variable as a continuous variable since function has good behavior and no radical changes are expected between each pair of points in time. Here, we similarly treat time as a continuous variable so that we can take differentiation and derive optimal points. However, results are valid even if we view time as discrete variable.

Corollary 1: T_E^* is always an increasing function of R_{max} while it is a decreasing function of μ_c, β, and B. This above behavior makes sense as by increasing R_{max} the contribution of revenue in $E[P(T)]$ is more and it is attractive to spend more time on development. On the other hand, higher average competition level in each time bucket (μ_c), higher penalty for competition (β), and higher total development cost (B) all augment contribution of total cost and as a result the launch time should happen in earlier time. However, behavior of T_E^* is kind of counter intuitive with respect to other parameters as the following corollary indicates.

Corollary 2: T_E^* does not have monotonic behavior with respect to μ_q, σ_q^2, and α. Specifically, T_E^* will be an increasing function of the mentioned parameters if the following conditions in Table 1 hold, else it will be decreasing function (In the table, $A_4 = \frac{A_1 e^{A_1 T}}{1-e^{A_1 T}} + \ln(1-e^{A_1 T})$).

Parameter	Conditions
μ_q	$A_4 < \ln(A_3)$
σ_q^2	$A_4 > \ln(A_3)$
A	$(\alpha > \mu_q / \sigma_q^2$ and $A_4 < \ln(A_3))$ or $(\alpha < \mu_q / \sigma_q^2$ and $A_4 > \ln(A_3))$

Table 1 – Conditions for having a later launch time by increasing μ_q, σ^2_q, and α.

Intuitively, it is expected that T_E^* to be decreasing function of average rate of quality improvement (μ_q) as same level of quality level can be reached at some earlier time. However, the above corollary indicates that this is not the necessarily the case. Specifically, more competitive market (or equivalently lower potential revenue, R_{max}) will increase likelihood of meeting the condition of $A_4 < \ln(A_3)$. In this situation, firms must increase the quality improvement rate to meet the minimum required level of feasibility condition. Note that behavior of T_E^* is reverse with respect to μ_q and σ_q^2. That is, increasing quality improvement rate is equal to decreasing variance of quality improvement. In other words, impacts of μ_q and σ_q^2 on T_E^* are completely opposite of each other, as also shown by numerical examples in the next section.

Risk averse case

As described in the literature review section, the employed model for the risk averse case is:

$$Max. E[P(T)] \tag{7}$$

$$\text{Subject to } V[P(T)] \le \gamma,$$

where γ is risk averseness parameter ($\gamma>0$). We use T_R^* as optimal launch time for the risk averse case.

Proposition 4: if $A_2>0$, then $V[P(T)]$ is an increasing function of T. Based on proposition1, the NPD project is feasible if $\alpha\sigma_q^2 < \mu_q$ (or, equivalently $\sigma_q < \left(\frac{2\mu_q}{\alpha}\right)^{1/2}$ so having

$A_2>0$ means $\alpha\sigma_q^{\ 2}/2<\mu_q<\alpha\sigma_q^{\ 2}$ (or, equivalently $\left(\frac{\mu_q}{\alpha}\right)^{1/2}<\sigma_q<\left(\frac{2\mu_q}{\alpha}\right)^{1/2}$). In this situation $V[P(T)]$ is always an increasing function of T. So, $V[P(T)]$ has only one intersection with $V[P(T)]=\gamma$. Let $T_v^{\ 0}$ be the intersection and also $\gamma_2=V[P(T_E^{\ *})]$, so, we have:

$$T_v^{\ 0}=Arg\{T:V[P(T)]\}=\gamma \tag{8}$$

Corollary 3: If $\alpha\sigma_q^{\ 2}/2<\mu_q<\alpha\sigma_q^{\ 2}$, then $T_R^*=\begin{cases}T_V^0 & \text{if} \quad V[P(T_E^*)]>\gamma \\ T_E^* & \text{else}\end{cases}$. (9)

Given the fact that always $T_v^{\ 0}<T_E^{\ *}$, the above corollary indicates that if $A_2>0$ condition holds then optimal time of launching the new product under risk averse situation is less than or equal the optimal time of launching the new product under risk neutral. In fact, increasing variance of expected profit over time (when $A_2>0$) seems an expected behavior.

Proposition 5: If $A_2<0$, then by increasing T, $V[P(T)]$ will increase up to a maximum, and then it will reduce to a minimum, and eventually line of $\beta^2\sigma_c^{\ 2}T$ is asymptotic of $V[P(T)]$ when T goes toward infinity. Furthermore, the turning point of $V[P(T)]$ happens at $T_v^{\ Turn}$, where $T_v^{\ Turn}=2\frac{\ln(A_1/A_2)}{(\alpha\sigma_q)^2}$.

The condition of $A_2<0$ means variance of quality improvement in each time bucket is more restricted and the firm has higher capability in product development process. That is, $\mu_q>\alpha\sigma_q^{\ 2}$ or equivalently $\sigma_q<\left(\frac{\mu_q}{\alpha}\right)^{1/2}$. In such a case, behavior of variance of profit seems unexpected to some extent. Due to a better quality of product development, the variance of profit will not be monotonically increasing function anymore and behaves based on the above proposition. In fact, such a behavior is one of the key results of our study. Figure 1 shows feasible zone of product development and relations between its parameters with behavior of variance of profit.

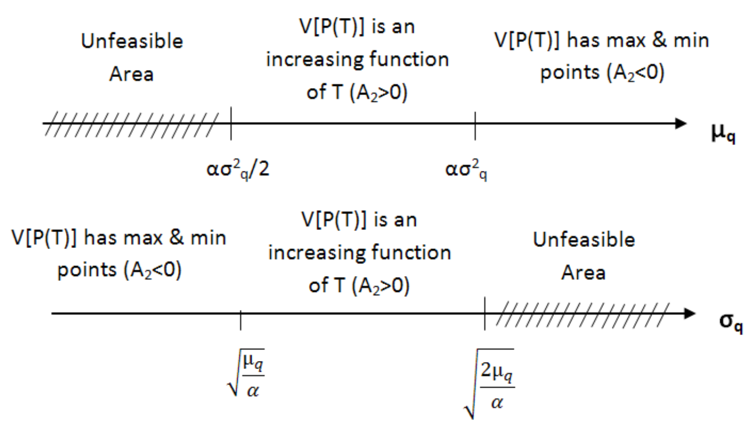

Figure 1 – Domains of unfeasible, monotonically and not monotonically increasing *V[P]*

Corollary4: As opposed to the proposition 4, where $T_R^* < T_E^*$, when $A_2<0$ there are situations in which risk averseness causes later launch time in comparison with launch time for a risk neutral decision maker. Thus, due to higher product development quality, there is a good chance for firms to introduce more improved products later in time. Summary of all of the previous results are shown in Table 2, where $T_E^* = \left\lceil \frac{\ln A_3 - \ln(1-e^{A_1})}{A_1} \right\rceil$, $\gamma_1 = \min\{V[P(T)] > 0\}$ and $\gamma_2 = V[P(T_E^*)]$.

Primary condition	**Behavior of *V[P(T)]***	**Secondary Condition**	T_R^*	T_R^* **vs.** T_E^*
$\alpha\sigma_q^2/2 < \mu_q < \alpha\sigma_q^2$	An increasing function of *T*	$\gamma_2>\gamma$	T_v^0	<
		$\gamma_2<\gamma$	T_E^*	=
$\mu_q > \alpha\sigma_q^2$	Has a max & min	$\gamma>min(\gamma_1,\gamma_2)$	T_v^0	<
		$\gamma>max(\gamma_1,\gamma_2)$	T_E^*	=
		$\gamma_1<\gamma<\gamma_2$	$Arg\{T : Max(E[Arg\{T : V[P(T)] = \gamma\}$	< or >
		$\gamma_2<\gamma<\gamma_1$	T_E^*	=

Table 2 – Comparison of optimal launch time in risk neutral and risk averse situations.

Proposition 6: If $A_2<0$, then the variance of profit is smaller, the optimal launch time (T_R^*) is greater and the optimal expected profit is greater than situations when $A_2>0$. This proposition states that reward of a firm having higher capability in product development (when $A_2<0$) is having higher expected profit and smaller variance of profit than when the firm has lower capability in product development (when $A_2>0$).

Corollary 5: Based on Table 2, the optimal launch time in risk averse scenario, T_R^*, always happens at the intersection point of variance and risk averseness parameter; $V[P(T)] = \gamma$. So, the constraint in (7) actually becomes an equality constraint in risk averse scenario. That is, according to Lagrange Multipliers Method, the optimization model in (7) can be written as:

$$Max\, Z(T) = E[P(T)] + \lambda(V[P(T)] - \gamma), \tag{10}$$

where λ is Lagrange Multiplier. In order to find the optimal launch time, T_R^*, the following equations must be satisfied simultaneously:

$$\frac{\partial Z(T)}{\partial T} = -R_{\max} A_1 e^{A_1 T} - (\beta\mu_c + B) + \lambda\left\{2R_{\max}{}^2[A_2 e^{2A_2 T} - A_1 e^{2A_1 T}] + \beta^2\sigma_c{}^2\right\} = 0 \tag{11}$$

$$\frac{\partial Z(T)}{\partial \lambda} = -R^2{}_{\max}[e^{2A_2 T} - e^{2A_1 T}] + \beta^2\sigma_c{}^2 T - \gamma = 0\,. \tag{12}$$

So, as long as $\gamma<max(\gamma_1,\gamma_2)$ the variance constraint is active and $V[P(T)] = \gamma$ is used to find the best launch time T_R^*.

Conclusions

In this research, for a firm developing a new product or service, we developed a model for optimal launch time by maximizing the expected profit with risk considerations, while firm's revenue is a concave function of product quality and market competition is growing over time. With this general model, we first derived the optimal launch time for risk neutral decision makers. We illustrated that NPD projects are feasible if firms have a minimum level of QNPDP. We showed that the optimal launch time does not have a monotonic behavior with regards to the average quality improvement and variance of quality improvement in each time bucket. By increasing competition in the market, NPD project's feasibility requirements become stricter and firms must improve their production quality to have the same profitability. We also demonstrated that the optimal launch time decreases while market competition or development expenses increasing over time. On the contrary, by increasing the potential NPD project's revenue, firms hope to make greater profit by spending more time on product development and introduce the new products relatively later.

We then imposed a constraint to the model to analyze impact of risk considerations on the optimal launch time. We specifically applied Markowitz's Mean-Variance model and conducted NPD project's risk analysis based on profit variance that must be less than firm's risk averseness tolerance. It was observed that incorporating risk considerations the model can lead to totally different results in comparison with risk neutral case. We demonstrated that, high quality production leads to smaller profit variance, later optimal launch time, and greater optimal expected profit. In fact, having high production quality leads to decreasing behavior of profit variance for some development intervals. So, firms can take advantage of such an opportunity and spend more time on developing new products while profit variance staying in tolerable range. It was shown that a high QNPDP can lead to a later optimal launch time in risk averse case than the best launch time in risk neutral cases.

We further observed that even though increasing NPD project's potential revenue increases the optimal launch time for risk neutral decision makers, with risk considerations the behavior changes. Specifically, by increasing potential revenue project's failure expenses increases as well and risk averse decision makers tend to launch new products earlier due to a greater profit variance. Also, any improvement in QNPDP (increasing average quality improvement or decreasing variance of quality improvement) leads to a later optimal launch time due to smaller profit variance. In such situations, risk neutral decision makers launch new products sooner due to faster quality improvement rate.

In summary, it was demonstrated that risk consideration should be one of the critical factors for making decision on launch time of any NPD project. In fact, risk considerations in decision making process lead to a better understanding of the trade-off between the advantage of spending more time to develop new product (having a better product quality) and the advantage of early market entry (having a better market opportunity). In our model, the optimal launch time was dependent upon the firm's tolerable risk, the firm's QNPDP, and level of competition in the target market.

Reference

[1] Cooper, R., Aouad, G., Lee, A., Wu, S., Fleming, A., Kagioglou, M. (2005). *Process management in design and construction*. Wiley-Blackwell.

[2] Bhaskaran, S. R., & Ramachandran, K. (2006). Technological Evolution and Launch Timing: An Analysis of the Time-Quality Trade-off under Competition. *Mccombs Research Paper Series No. IROM-04-06*.

[3] Savin, S., & Terwiesch, C. (2005). Optimal Product Launch Times in a Duopoly: Balancing Life-Cycle Revenues with Product Cost. *Operations Research*, 53(1), 26–47.

[4] Dacko, S. G., Liu, B. S., Sudharshan, D. (2008). Dynamic capabilities to match multiple product generations and market rhythm. *European Journal of Innovation Management*, 11(4), 441-471.

[5] Bayus, B. L. (1997). Speed-to-market and New Product Performance Trade-offs. *Journal of Innovation Management*, 14(6), 485-497

[6] Cohen, M. A., Eliashberg, J, Ho, T.H. (1996). New product development: The performance and time-to-market trade off. *Management Science* , 42(2), 173–186.

[7] Armstrong, M. J., & Levesque, M. (2002). Timing and quality decisions for entrepreneurial product development. *European Journal of Operational Research*, 141(1), 88–106.

[8] Morgan, L. O., Morgan, R. M., Moore, W. L. (2001). Quality and Time-to-Market Trade-offs when There Are Multiple Product Generations. *Manufacturing & Service Operations Management*, 3(2), 89–104.

[9] Mahajan, V., & Muller, E. (1996). Timing, Diffusion, and Substitution of Successive Generations of Technological Innovations: The IBM Mainframe Case. Technological *Forecasting and Social Change*, 51, 109-132.

[10] Nault, B. R., & Vandenbosch, M. B. (1996). Eating Your Own Lunch: Production Through Preemption. *Organization Science*, 7 (3), 342-358.

[11] Wilson, L. O., & Norton, J. A. (1989). Optimal Entry Timing for A Product Line Extension. *Marketing Science*, 8(1), 1-17.

[12] Norton, J. A., & Bass, F. M. (1987). A diffusion theory model of adoption and substitution for successive generations of high-technology products. *Management Science*, 33(9), 1069-1086.

[13] Markowitz, H. M. (1959). *Portfolio Selection: Efficient Diversification of Investment*. John Wiley & Sons, New York.

[14] Reich, Y., & Levy, E. (2004). Managing Product Design Under Resource Constraints. *International Journal of Production Research*, 42(13), 2555-2572.

[15] Browning, T. R. (2003). On Customer Value and Improvement in Product Development Processes. *System Engineering*, 6(1), 49-60.