IPRPD
International Journal of Business & Management Studies
ISSN 2694-1430 (Print), 2694-1449 (Online)
Volume 02; Issue no 08: August, 2021

How many ideas do we need? Model of optimized creativity to maximize innovation

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Abstract

Despite the positive correlation between innovation and organization performance, many organizations have de-emphasized innovation as a strategic goal in light of the crisis brought on by the Covid pandemic. Despite strategic goal shifting away from innovation, companies can weather the storm and emerge with increased performance post-crisis by expanding the focus on innovation. Innovation, however, remains challenging for many organizations. Building upon a model of inventory management, this paper presents a model of optimized creativity to maximize innovation. First, the necessary amount of creativity, demonstrated through the number of ideas to be developed given an expected profit, can be calculated using the known development and implementation cost of ideation. Optimized innovation leads to cost efficiency and maximized profit. Second, our model demonstrates how the reliability of idea generation impacts the optimal number of ideas to be developed. The optimal number of ideas to be developed increases first as the idea generation process gets more reliable, and then decreases. We discuss how reliability can be increased through the enhanced effectiveness and efficiency of the ideation process.

Keywords: Optimization of creativity, innovation maximization, calculation of the optimized number of ideas developed

"The value of an idea lies in the using of it."
– Thomas Edison

1. Introduction

Growth organizations have long prized innovation as a key strategic goal to maintain sustained competitive advantage (Hughes et al., 2018). Innovation, however, has taken a backseat in light of the crisis brought on by the Covid pandemic. Strategic goals have shifted and innovation may be deprioritized. In a recent McKinsey survey of over 200 organizations across different industries (McKinsey, 2020), 55% of respondents pre-Covid and 23% of respondents in April 2020 stated innovation as their top 2 priorities. Similarly, executives from seven out of eight industries, with pharmacy and medical supplies as the lone exception, refocused from innovation to short-term issues such as minimizing risk.

Data from the 2008 economic crisis suggests that organizations that invested in innovation during the crisis outperformed their peers during the recovery, with some outperforming by as much as 30% during the post-crisis years (McKinsey, 2020). Despite organizations broadly de-emphasizing innovation and managers tending to narrow their strategic focus during crisis situations (Staw, 1976), companies can weather the storm and emerge with higher performance post-crisis by expanding the focus on innovation. Innovation, however, remains challenging for many organizations (Bundy et al., 2017; Migdadi, 2021).

Organizations have long attempted to figure out how to best manage and unleash creativity in order to achieve innovation. Specifically, there is a pervasive problem of determining the appropriate investment in and managing ideation in the organization in order to efficiently develop and deploy employee creativity (Chanaron and Carayannis, 2007). One of the major inputs of creativity is through employee voice, or constructive input coming from employees, particularly ideation. Employee voice is fraught with risks and fear (Milliken and Lam, 2009; Bashshur and Oc, 2015). Employees often find it difficult to speak up to their managers or up the hierarchy because the decision to speak up can be risky (Ashford et al., 1998; Morrison and Milliken, 2000, 2003). Organizations must work to enable employee voice in order to stimulate ideation. While ideation can lead to innovation, resources need to be deployed to enable and facilitate employee voice. Thus, there is cost to ideation. It is optimal for managers to take profits, encourage and also discourage ideation (Lam and Sheth, 2020). Firms, then, should consider both the cost of generating ideas and the resulting profit from ideation implementation in order to determine the optimized innovation point. This paper presents a model to calculate this optimized innovation point, and arms organizations with a way to determine how much ideation to solicit to achieve a specific amount of profit.

2. Calculating optimization if innovation

Ideation has associated costs, whether it is time, resources, or attention (Lam and Sheth, 2020). Thus, to maximize profit from implementation of ideas, the cost of ideation can be used to calculate the optimized innovation and maximized profit. The cost of creativity and benefits of innovation can be utilized to determine an organization's optimization of innovation. Because employee voice can be challenging to solicit, and that creativity is generally perceived by managers to be positive, organizations often spur ideation without knowing an optimized number of ideas. Some organizations solicit too few ideas from employees. In addition, the "more the merrier" philosophy of ideation also prevents organizations from maximizing profit from implementing creativity.

Creativity and innovation can be quantified to determine the optimal number of ideas to implement in order to achieve the desired amount of profit. We propose a model to calculate the optimal number of ideas to develop to achieve a coveted amount of profit. We build upon an inventory management model (Pan and Huynh, 2015) for the calculation of optimized innovation. Ideas are stored, intangible products within an organization and thus can be treated as inventory of a firm. Solicitation and management of ideation are a type of inventory management. The inventory management model predicts an optimal level of inventory in order to maximize the expected profit. Similarly, the model we built determines the number of ideas an organization should develop in order to maximize the expected profit. With this model, an organization can target a specific number of ideas to develop. If too few ideas are developed, managers can continue to solicit ideation. Once the ideal number of ideas for implementation is reached, further ideation can be discouraged. Optimized innovation leads to cost efficiency and maximized profit.

There are two types of costs associated with every idea: 1) development cost and 2) implementation cost. Development cost denotes the cost to solicit and formulate the idea. Implementation cost denotes the cost to turn creativity into innovation; that is, to implement the idea into an outcome. Not all the ideas will be qualified to be implemented after the full development. Specifically, only a random fraction of the ideas developed will be qualified to be implemented. The revenue for each idea that is successfully developed and implemented is fixed. Below we discuss in detail the model and parameters for the model.

3. Propositions and Model Formulation

The model determines the optimal number of ideas to implement in order to maximize the expected profit. Managers set the revenue amount to generate for each fully developed and implemented idea. Our first proposition posits that the optimal number of ideas to develop can be determined using the cost of ideation and expected profit.

Let c_d be the allocated development cost for each idea.
Let c_i be the implementation cost for each idea.
Let Q denote the number of ideas to develop.
Let ϵ be the reliability factor of the ideas, where ϵ is between $[0,1]$ and follows a density and cumulative distributions of $g(.)$ and $G(.)$. Then the actual number of ideas that are qualified to be implemented is ϵQ.
Let μ be the expected value of ϵ.
Let p be the revenue resulted from implementing one idea that is successfully developed.
Let d denote the number of ideas that can be implemented. It depends on the implementation cost, i.e., $d = a - bc_i$, where $b > 0$.
Let $\pi(Q)$ be the expected profit and it can be rewritten as

$$\pi(Q) = E[(p - c_i)min(tQ, a - bc_i)] - c_d Q$$
$$= (p - c_i)\int_0^{\frac{a-bc_i}{Q}} tQg(t)dt + (p - c_i)\int_{\frac{a-bc_i}{Q}}^{1}(a - bc_i)g(t)dt - c_d Q. \qquad (1)$$

Define $\bar{p} = \frac{c_d}{\mu} + c_i$ as the minimum revenue income resulted from implementing one idea that is successfully developed, below which it is not profitable for the organization to develop the ideas. Also, define Q^*as the optimal number of ideas to be developed.

Define Q^o as the solution of Q that satisfies the following equation:

$$\int_0^{\frac{a-bc_i}{Q}} tg(t)dt = \frac{c_d}{p - c_i}.$$

Proposition 1.

$Q^* = Q^o$ when $p \geq \bar{p}$. Otherwise, $Q^* = 0$.

Proof. The first order condition of the expected profit given in equation (1) in terms of Q is given by

$$\frac{\partial \pi(Q)}{\partial Q} = (p - c_i) \int_0^{\frac{a-bc_i}{Q}} tg(t)dt - c_d. \qquad (2)$$

The second order condition of the expected profit given in equation (1) in terms of Q is given by

$$\frac{\partial^2 \pi(Q)}{\partial Q^2} = -\frac{(p-c_i)(a-bc_i)^2}{Q^3} g\left(\frac{a-bc_i}{Q}\right) < 0. \quad (3)$$

It is straightforward that the expected profit function given in equation (1) is strictly concave in Q, and Q^o satisfies the first order condition given in (2). Q^o maximizes the expected profit given in (1). This follows that the optimal expected profit can be written as

$$\pi^*(Q^o) = (p - c_i) \int_{\frac{a-bc_i}{Q^o}}^1 (a - bc_i) g(t)dt. \qquad (4)$$

Clearly, when it is profitable for the organization to develop the ideas, the minimum number of ideas is $d = a - bc_i$. From the first order condition given in (2), we have

$$\frac{\partial \pi(a-bc_i)}{\partial Q} = (p - c_i)\mu - c_d. \qquad (5)$$

It is straightforward that $\frac{\partial \pi(a-bc_i)}{\partial Q} \geq 0$ when $p \geq \bar{p}$. Also, when $Q \to \infty$, $\frac{\partial \pi(Q)}{\partial Q} = -c_d < 0$ in (2). Since $\frac{\partial \pi(Q)}{\partial Q}$ in (2) is strictly decreasing in Q, $Q^o \geq a - bc_i$ and $\pi^*(Q^o) \geq 0$ when $p \geq \bar{p}$.

Since $\frac{\partial \pi(a-bc_i)}{\partial Q} < 0$ when $p < \bar{p}$ and $\frac{\partial \pi(Q)}{\partial Q}$ is strictly decreasing in Q, $Q^o < 0$ when $p < \bar{p}$. Therefore, $Q^* = 0$ when $p < \bar{p}$.

Proposition 1 also demonstrates that Q^o is the unique optimal number of ideas that will maximize the expected profit of the organization from developing and implementing the ideas when it is profitable for the organization to develop the ideas. It is straightforward that Q^o increases when p increases, c_d decreases, or c_i decreases. This is intuitive. As the revenue income from implementing a fully developed idea is higher, the development cost for each idea is lower, or the implementation cost for each idea is lower, the organization should develop more ideas. Our next proposition will discuss how the underlying supply reliability factor ϵ would affect the optimal number of ideas to be developed, Q^o.

Suppose that the yield factor ϵ follows a power distribution with cumulative distribution function $G(t) = t^n$. It is well known that as n increases, ϵ becomes larger in first order stochastic dominance sense. We investigate the impact of n on the value of Q^o in Proposition 2.

Our second proposition posits that the relationship between the number of ideas developed and expected profit is not linear. Specifically, we postulate that there is an initial increase in the optimal number of ideas to be developed with an objective of maximizing the expected profit. Further, as reliability increases, as denoted by enhanced efficiency and effectiveness of organizational processes, the number of ideas needed for development decreases. Organizations will require a smaller number of ideas to be developed to maximize the expected profit..

Proposition 2:

When $p \geq \bar{p}$, Q^o first increases and then decreases as n increases.

Proof. It follows from Proposition (1) and $G(t) = t^n$ that

$$Q^o(n) = \frac{a-bc_i}{\left(\frac{c_d}{p-c_i}\frac{n+1}{n}\right)^{\frac{1}{n+1}}}. \qquad (6)$$

We also have

$$\frac{\partial \pi(Q^o)}{\partial Q} = (p - c_i) \int_0^{\frac{a-bc_i}{Q^o}} tg(t)dt - c_d = (p - c_i)\frac{n}{n+1}\left(\frac{a-bc_i}{Q^o}\right)^{n+1} - c_d = 0. \qquad (7)$$

Consider equation (7) as a function of Q^o and n, and apply the Implicit Function Theorem to obtain

$$\frac{dQ^o}{dn} = \frac{\frac{\partial}{\partial n}\left(\frac{\partial \pi(Q^o)}{\partial Q}\right)}{\frac{\partial^2 \pi(Q^o)}{\partial Q^2}} = \frac{ln\left(\frac{a - bc_i}{Q^o}\right) + \frac{1}{n(n+1)}}{\frac{n+1}{Q^o}}$$

Note that when $G(t) = t^n$, $\mu = \frac{n}{n+1}$. When $n = \frac{1}{\frac{p-c_i}{c_d}-1}$, $Q^o(n) = a - bc_i$. It directly follows that $\frac{dQ^o}{dn} = \frac{\frac{1}{n(n+1)}}{\frac{n+1}{Q^o}} > 0$. When $n \to \infty$, we have $\frac{1}{n(n+1)} \to 0$ and $ln\left(\frac{a-bc_i}{Q^o}\right) < 0$. Therefore, $\frac{dQ^o}{dn} < 0$ when $n \to \infty$. This directly follows that there exists some value n, denoted by n^*, such that $\frac{dQ^o}{dn}|_{n=n^*} = 0$. We next show that such a n^* is unique. Suppose that n^* is not unique. There must exist n_1 and n_2 with $n_1 < n_2$ such that $\frac{dQ^o}{dn}|_{n=n_1} = 0$ and $\frac{dQ^o}{dn}|_{n_1<n\le n_2} > 0$. Since $n_1 < n_2, \frac{1}{n_1(n_1+1)} > \frac{1}{n_2(n_2+1)}$. Since $\frac{dQ^o}{dn} > 0$ when $n_1 < n \le n_2$, $Q^o(n_1) < Q^o(n_2)$ and thus $ln\left(\frac{a-bc_i}{Q^o}\right)|_{n=n_1} > ln\left(\frac{a-bc_i}{Q^o}\right)|_{n=n_2}$. Therefore, $ln\left(\frac{a-bc_i}{Q^o}\right)|_{n=n_2} + \frac{1}{n_2(n_2+1)} < ln\left(\frac{a-bc_i}{Q^o}\right)|_{n=n_1} + \frac{1}{n_1(n_1+1)} = 0$. The last equality comes from the fact that $\frac{dQ^o}{dn}|_{n=n_1} = 0$. This directly follows that $\frac{dQ^o}{dn}|_{n=n_2} < 0$, which is a contradiction. Thus, n^* is unique.

Proposition 2 demonstrates how the reliability of idea generation impacts the optimal number of ideas to be developed. Surprisingly, the optimal number of ideas to be developed increases first as the idea generation process gets more reliable, and then decreases. There are two factors that impact the optimal number of ideas to be developed. As the idea generation process gets more reliable, the effective cost of developing one idea decreases. Therefore, the organization gets to develop more ideas. On the other hand, the number of fully developed ideas increases as the idea generation process gets more reliable. Thus, the organization does not need to develop as many ideas initially. When the reliability of the idea generation is low, the first factor dominates. Thus, the optimal number of ideas that should be developed increases as the idea generation process gets more reliable. When the reliability of the idea generation is high, the second factor dominates. Thus, the optimal number of ideas that should be developed decreases as the idea generation process gets more reliable.

4. Model illustration

In this section, we will illustrate some numerical examples. Suppose the development cost for each idea c_d is \$500. The implementation cost for each idea c_i is \$500. The revenue earning from implementing a fully developed idea is \$2,500. Assume that the supply reliability factor ϵ follows a power distribution with cumulative distribution function $G(t) = t^n$ where $n = \frac{1}{2}$. Thus, the mean of the reliability factor for the idea generation process is $\frac{n}{n+1} = \frac{1}{3}$. It means that on average, one out of three ideas that are developed are qualified to be implemented. Further assume that $a = 5{,}500$ and $b = 10$. Thus, the number of ideas that can be implemented is $a - bc_i = 5{,}500 - 10 * 5{,}00 = 500$. From equation (6) and equation (4), we have the optimal number of ideas to be developed $Q^o = 606$ and the optimal expected profit $\pi^*(Q^o) = \$91{,}440$.

Suppose that through the employee training, the organization can improve the reliability of the idea generation process. More specifically, the cumulative distribution for the power distribution is $G(t) = t^n$ with $n = 1$. Thus, the mean of the reliability factor for the idea generation process is $\frac{n}{n+1} = \frac{1}{2}$. . It means that on average, one out of two ideas that are developed are qualified to be implemented. From equation (6) and equation (4), we have the optimal number of ideas to be developed $Q^o = 707$ and the optimal expected profit $\pi^*(Q^o) = \$292{,}893$. In this case, as the reliability of the idea generation process improves, i.e., n increases from $\frac{1}{2}$ to 1, the optimal number of ideas to be developed increase to 707 from 606 with an additional expected profit of $\$292{,}893 - \$91{,}440 = \$201{,}453$. It is clear that if the cost of the employee training is less than the expected profit increase of $\$201{,}453$, then the organization should invest in the employee training.

Suppose that through another employee training program, the organization can further improve the reliability of the idea generation process. More specifically, the cumulative distribution for the power distribution is $G(t) = t^n$ with $n = 3$. Thus, the mean of the reliability factor for the idea generation process is $\frac{n}{n+1} = \frac{3}{4}$. It means that on average, three out of four ideas that are developed are qualified to be implemented. From equation (6) and equation (4), we have the optimal number of ideas to be developed $Q^o = 658$ and the optimal expected profit $\pi^*(Q^o) = \$561{,}309$. In this case, as the reliability of the idea generation process improves, i.e., n increases from 1 to 3, the optimal number of ideas to be developed decrease to 658 from 707 with an additional expected profit of $\$292{,}893 - \$91{,}440 = \$268{,}416$. It is clear that if the cost of the additional employee training is less than the expected profit increase of $\$268{,}416$, then the organization should further invest in the employee training.

5. Conclusion

Our model of optimized creativity is built upon an inventory management model. Ideation is akin to inventory for an organization, as ideas are intangible products that are pitched to be implemented. Our model supports our two propositions. First, the necessary amount of creativity, demonstrated through the number of ideas to be developed, can be calculated using the known cost of ideation. There are two costs of ideation - development and implementation. It is only profitable for the organization to develop the ideas when the revenue resulting from implementing one fully developed idea is higher than the sum of the effective development cost and the implementation cost for one idea. Further, implementation of ideas come from developed ideas, but not all developed ideas are implemented. We factored it in reliability to account for the delta between the two. Proposition demonstrates that the required number of ideas to be developed can be determined. Using the model of optimized creativity, organizations have the capability to know how much creativity they need from their employees.

Our second proposition shows the phenomenon of ideation front loading. That is, the required number of ideas developed is impacted by the reliability of idea generation so that more ideas are required in the beginning of the idea generation process. When reliability is high, fewer ideas are necessary to be developed in order to maximize the expected profit. Reliability can be increased through enhanced effectiveness and efficiency of processes. For example, organizations can engender more employee voice by decreasing the perception of risk in speaking up the hierarchy (Islam and Zyphur, 2005), or by increasing psychological safety among team members (Nembhard and Edmondson, 2006). Developing a culture of innovation can also increase reliability (Kwan et al., 2018). At the managerial level, exhibition of certain leader behaviors toward employees such as leader inclusiveness or leader openness (Detert and Burris, 2007) can enhance the process of idea generation and overcome a potential bias against creativity despite a desire for it (Mueller et al., 2012).

One limitation of this study is the theoretical nature of the modeling. For future work, data from field studies can validate the modeling. Further, the examination of process enhancement to increase reliability give organizations a blueprint to boost capacity to innovate.

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