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AUTHORS

Yushan Zhao

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Yushan Zhao (USA)

A stochastic model for market opportunity assessment

Abstract

Market opportunity assessment is crucial for organizational survival. Past research is mostly static and not able to deal with dynamic real world problems. A serious shortcoming of past research is that market opportunity assessment is treated as a static decision rather than a dynamic, ongoing process. Researchers do not include considerations such as the timing of the decision and changing conditions.

Based on the research of the knapsack problem (secretary problem), this study develops a model of dynamic market opportunity assessment that takes into account opportunities that will emerge in the future. The firm, thus, can decide on real time whether it accepts or rejects the existing opportunity or wait for the upcoming opportunity.

The proposed model is of great potential for practical application. At each time period, a critical value is calculated for the opportunity assessment. If the value of the coming opportunity is greater than the critical value, the firm is recommended to accept and implement the opportunity. If the value of the coming opportunity is less than the critical value, the firm is recommended to reject the opportunity and wait for the upcoming one.

Keywords: market opportunity, model, knapsack.

Introduction

One of the major challenges in strategic marketing planning is the difficulty in measuring dynamic market opportunities (Aboulnasr et al., 2008; Bond and Houston, 2003; Gruber, MacMillan, and Thompson, 2008; Houston et al., 2001; Woodruff, 1976). Woodruff and Gardial (1996) find that most new firms are unsuccessful. The major reason for the failure is that firms do not select the right market opportunity for investment. In practice, market opportunities appear and disappear quickly and are short-lived (Golicic et al., 2003). Therefore, the calculations and execution must be performed very efficiently (Yang, Tan, and Sun, 2009). Further, market opportunity should fit the given firm's marketing strategy and the firm's organizational goals and capabilities (Bond and Houston, 2003; Fildes et al., 2007). For example, the market opportunity may be significant, but the organization may not have the organizational capacity to execute the opportunity.

Many market opportunities may be identified by the marketing department. Some opportunities may be of great value for investment, but most of the remaining opportunities will not have sufficient potential for further investigation (Cavusgil, Kiyak, and Yeniyurt, 2004; Woodruff and Gardial, 1996). If each opportunity advanced to the execution phase, costs would be prohibitive. Furthermore, competition in the market-place would grow fiercer as market opportunities remain fleeting (Fildes et al., 2007). The external environment does not give firms sufficient time to make decisions. Firms with poor evaluation systems are likely to lose valuable opportunities and to wind up being at a disadvantage in the competitive market (Golicic et al., 2003).

Previous research has developed many mathematical models to formulate the selection of market opportunities (Gruber, MacMillan, and Thompson, 2008; Woodruff and Gardial, 1996). These models include simple checklists, cost-benefit analysis, multiple criteria analysis, and analytical hierarchy process. Traditionally, the decision-analytic approach toward market opportunity selection first evaluates opportunities by two steps: (1) quantifying the probability that an opportunity would yield success (using subjective estimates from marketing); and (2) quantifying the benefits attributable to an opportunity if it were to yield success. Then, several market opportunities are compared with one another to identify the best one capable of maximizing firm profits (Bond and Houston, 2003; Gruber, MacMillan, and Thompson, 2008; Yang and Shi, 2002).

According to critics, these approaches rest on fixed-criteria assumptions that lack mechanisms for adapting various changing conditions within the planning cycle (Cavusgil, Kiyak, and Yeniyurt, 2004; Houston et al., 2001). These models cannot deal with complex, real-world problems (Bordley, 1998; Gruber, MacMillan, and Thompson, 2008; Reddy, 1990). A serious shortcoming that has beset past research is that it treats project selection as a static, once a year decision event rather than a dynamic, ongoing process. Researchers who subscribe to these models seldom consider such matters as the timing of the decision and changing conditions. Most of the studies in this field have assumed the existence of different types of market opportunities and, therefore, have examined the apparently most appropriate policy for selecting from the existing list of opportunities.

This study considers a different setup: the dynamic process of the market opportunity evaluation. This research does not assume the existence of a fixed number of market opportunities. Instead, it assumes

that opportunities appear randomly and are random in quality. The study proceeds to determine and analyze optimal opportunity assessment strategies in dynamic contexts, where accepting one opportunity may cause the marketing department to forfeit a better opportunity in the future.

The model proposed in the study will deal with the dynamic process of market opportunity assessment. This paper will develop a mechanism that allows a decision-maker to select market opportunities in real time. In particular, this study addresses the potential market opportunities that will appear in the future when firms make the decision as to whether they should wait for the upcoming opportunities or accept the existing one.

1. The classical models

Classical approaches to market opportunity evaluations presume the existence of a set of candidates as the basis for the selection. The basic selection method is to rank the opportunities according to certain criteria. The opportunity selection sometimes treats the constraints on firm capability. Thus, researchers formulate the opportunity evaluation as a constrained optimization problem (Bond and Houston, 2003; Gruber, MacMillan, and Thompson, 2008; Oh et al., 2009; Schmidt and Freeland, 1992). The main models are checklist, cost-benefit analysis, multiple-criteria analysis, and the analytical hierarchy process.

In the classical methods, the researchers assume that there exists a set of market opportunities: $\{C^1, C^2, C^3, \dots, C^n\}$, the researchers use these models to select one opportunity C^i , $\{i = 1, 2, 3, \dots, n\}$, that is the best among these opportunities. The main differences among these models concern the criteria for selecting the opportunities and the opportunity-ranking methods.

1.1. Checklist. The checklist is based on a set of criteria for market opportunity evaluation. The total rating number T_i is developed for each opportunity (see Jackson, 1983). Here:

$$T_i = \sum_j s_{ij},$$

$s_{ij} = 1$ when the i^{th} project is judged to meet the j^{th} criterion, and $s_{ij} = 0$ otherwise. Total scores (T_i) for all opportunities are compared. The market opportunity with the highest score is the champion.

1.2. Cost-benefit analysis (CBA) and multiple criteria analysis (MCA). In a CBA, the potential gains and losses of all market opportunities are calculated and compared on the basis of decision rules for determining which opportunity is most desirable in relation to firm capability (Nas, 1996; Van der Zee, Achterkamp, and de Visser, 2004). The method is very popular as a way to design a quick scan for the

selection of market opportunities. According to the method of CBA, the relevant costs and benefits of a market opportunity have to be identified and measured. After this, the opportunities are compared and the most promising one is selected. MCA is a systematic approach with which decision-makers specify and evaluate criteria for selecting the best opportunity (Beim and Levesque, 2004). CBA relates opportunity to a single financial dimension, and MCA helps rate opportunities according to multiple dimensions.

1.3. Analytical hierarchy process. The analytical hierarchy process (AHP) is a decision-aiding method (Saaty, 1994; Yang and Shi, 2002). It has been proposed in recent literature as an emerging solution approach to large and complex real world decision-making problems. It integrates expert opinion and evaluation and divides the complex decision-making system into a hierarchy system. AHP defines the problem and determines the organizational goals, structures a top-down hierarchy consisting of decision-makers' objectives, and uses mathematical calculations to effectively evaluate market opportunities and, in turn, to assist managers in their long-term strategic planning.

These methods have proven useful in screening decisions, in conducting comprehensive analysis, and in facilitating communication for structuring decision processes. However, all of these methods assume there to be available market opportunities and ignore the dynamics of the selection process (Cavusgil, Kiyak, and Yenyurt, 2004). In real situations, market opportunities present themselves to marketing departments in a dynamic process.

1. Market opportunities present themselves to marketing departments continuously, so it is impossible to predetermine a set of opportunities from which to select.
2. There are market opportunities that are of potential value but that do not appear at the time of selection (the classical models assume the non-existence of such potential opportunities).
3. The values of the potential opportunities are not known until they appear.

2. The model

The motivation of this study stems in large measure from the study of dynamic knapsack problems, or secretary problems (Babaioff et al., 2008; Carraway, Schmidt, and Weatherford, 1993; Freeman 1983; Papastavrou, Rajagopalan, Kleywegt, 1996; Sakaguchi, 1984; Smith, 1975). In a secretary problem, a position is available. An unknown number of applicants present themselves in random order to an employer who observes each applicant. At each stage, the employer must decide whether to accept the present applicant or to reject the applicant and continue

to interview further applicants. The optimal stopping rule is to maximize the probability of employing the best applicant.

There is an analogy between market opportunity assessment and secretary problem or knapsack problem. It can be described as follows: there exists a time deadline T for the selection. A given amount c_t of investment is available for the new market opportunity in the firm in each time period t ($t = 1, 2, \dots, T$). Market opportunities arrive in time according to a stochastic process. It is assumed that the demand of each opportunity in terms of the amount of investment is the same ($e_1 = e_2 = \dots = e_T = e$). Benefits b associated with each opportunity are random. Each opportunity's success rate is r . If the opportunity is rejected, it cannot be recalled.

Using EV_t^c to denote the accumulated expected benefits from time t to the deadline. This study is interested in determining decision rules on how to select the opportunity so as to maximize the accumulated expected benefits.

At time t , if an opportunity with benefits b arrives, the firm has to decide whether to accept it or reject it.

If the firm accepts it, the firm will invest the amount of e to the opportunity, and expected accumulated benefits are:

$$b + EV_{t+1}^{c-e} \tag{1}$$

If the firm rejects the opportunity, the expected accumulative benefits are:

$$EV_{t+1}^c \tag{2}$$

This study is interested in deciding the optimal benefits from equations (1) and (2). So the decision rule is:

$$\text{Max} \{ b + EV_{t+1}^{c-e}, EV_{t+1}^c \} \tag{3}$$

Lemma 1. EV_t^c is a non-decreasing function of c ; EV_t^c is a non-increasing function of t .

This can be proved intuitively. The more the firm can invest, the higher the expected benefits, supporting (1) of Lemma 1. The less time left, the lower the expected benefits, supporting (2) of Lemma 1.

Theorem 1. If at time t , the remaining amount of investment is c , an opportunity with benefits b arrives, then the optimal decision rule is characterized by a sequence of "critical benefits":

$\{ B_t^c \}$ ($t = 1, 2, 3, \dots, T$) such that,

if at the beginning of period t , an opportunity of benefits $b < B_t^c$ is rejected. If $b \geq B_t^c$, the opportunity is accepted.

Proof. The decision rule is to select $\text{Max} \{ EV_{t+1}^c, EV_{t+1}^{c-e} + b \}$. Because EV_t^c is a monotone increase in c , there exists, at most, one critical benefits B_t^c , defined by:

$$EV_{t+1}^c = EV_{t+1}^{c-e} + B_t^c, \text{ i.e.,}$$

$$B_t^c = EV_{t+1}^c - EV_{t+1}^{c-e}, \text{ such that:}$$

1. if $b < B_t^c$, then $EV_{t+1}^c > EV_{t+1}^{c-e} + b$, therefore, the opportunity is rejected.
2. if $b \geq B_t^c$ then $EV_{t+1}^c \leq EV_{t+1}^{c-e} + b$, therefore, the opportunity is accepted.

Corollary 1. The expected value of rejecting the opportunity is:

$$\int_0^{B_t^c} EV_{t+1}^c f(b) db.$$

Proof. According to Theorem 1, the opportunity is rejected if $b < B_t^c$. The probability of $b < B_t^c$ is $P\{b < B_t^c\} = \int_0^{B_t^c} f(b) db$. Expected value of rejecting the opportunity is:

$$EV_{t+1}^c P\{b < B_t^c\} = \int_0^{B_t^c} EV_{t+1}^c f(b) db.$$

Corollary 2. When the success rate of the opportunity is r , the expected benefits of accepting the opportunity if it is successful is:

$$r \int_{B_t^c}^{\infty} (b + EV_{t+1}^{c-e}) f(b) db.$$

Proof. According to Theorem 1, an opportunity is accepted if $b \geq B_t^c$. The probability of accepting the opportunity is $p\{b \geq B_t^c\} = \int_{B_t^c}^{\infty} f(b) db$. So, the expected value of accepting opportunities is:

$$(EV_{t+1}^{c-e} + b) p(b \geq B_t^c) = \int_{B_t^c}^{\infty} (EV_{t+1}^{c-e} + b) f(b) db.$$

Therefore, when the success rate is r , the expected value of accepting the opportunity is:

$$r(EV_{t+1}^{c-e} + b) p(b \geq B_t^c) = r \int_{B_t^c}^{\infty} (EV_{t+1}^{c-e} + b) f(b) db.$$

Corollary 3. The expected value of accepting the opportunity if it is not successful is:

$$(1-r) \int_{B_t^c}^{\infty} EV_{t+1}^{c-e} f(b) db.$$

Proof. The expected value of the opportunity if it is not successful is:

$$EV_{t+1}^{c-e} p\{b \geq B_t^c\} = \int_{B_t^c}^{\infty} EV_{t+1}^{c-e} f(b) db.$$

If the probability of failure is $(1-r)$, then the expected value of accepting the opportunity when it is not successful is:

$$(1-r)(EV_{t+1}^{c-e} p\{b \geq B_t^c\}) = (1-r) \int_{B_t^c}^{\infty} EV_{t+1}^{c-e} f(b) db.$$

Corollary 4. The total expected benefits when an opportunity arrives is:

$$EV_{t+1}^{c-e} + B_t^c F(B_t^c) + r \int_{B_t^c}^{\infty} bf(b) db.$$

Proof. The total expected benefits is the sum of rejecting and accepting the opportunity.

Summarizing results in Corollaries 1, 2, and 3, the total expected benefits will be:

$$\int_0^{B_t^c} EV_{t+1}^c f(b) db + r \int_{B_t^c}^{\infty} (b + EV_{t+1}^{c-e}) f(b) db + (1-r) \int_{B_t^c}^{\infty} EV_{t+1}^{c-e} f(b) db = EV_{t+1}^c F(B_t^c) + rEV_{t+1}^{c-e} (1 - F(B_t^c)) + r \int_{B_t^c}^{\infty} bf(b) db + (1-r) EV_{t+1}^{c-e} (1 - F(B_t^c));$$

$$\int_0^{B_t^c} EV_{t+1}^c f(b) db + r \int_{B_t^c}^{\infty} (b + EV_{t+1}^{c-e}) f(b) db + (1-r) \int_{B_t^c}^{\infty} EV_{t+1}^{c-e} f(b) db = EV_{t+1}^{c-e} + (EV_{t+1}^c - EV_{t+1}^{c-e}) \times F(B_t^c) + r \int_{B_t^c}^{\infty} bf(b) db;$$

$$\int_0^{B_t^c} EV_{t+1}^c f(b) db + r \int_{B_t^c}^{\infty} (b + EV_{t+1}^{c-e}) f(b) db + (1-r) \int_{B_t^c}^{\infty} EV_{t+1}^{c-e} f(b) db = EV_{t+1}^{c-e} + B_t^c F(B_t^c) + r \int_{B_t^c}^{\infty} bf(b) db.$$

Corollary 5. The critical value B_t^c can be calculated recursively:

- ◆ $B_t^c = \infty$, if $e > c$.
- ◆ $B_t^c = 0$, if $t \geq T$ and $e \leq c$.
- ◆ $B_t^c = EV_{t+1}^c - EV_{t+1}^{c-e}$, if $t < T$ and $e \leq c$.

Corollary 5 implies that when the required capacity of opportunity is greater than a firm's existing capacity, the firm has to reject the opportunity because the

firm lacks the capability. Once the deadline for opportunity assessment passes, the firm runs into the risk of accepting any upcoming opportunity. Because the expected benefits and critical value of last period are known, expected benefits and critical values of other time periods can be calculated recursively (see Papastavrou, Rajagopalan, and Kleywegt, 1996).

3. A numerical simulation

The purpose of the simulation is to explore the relationship between time period (t) at which the opportunity is selected, firm available amount of investment (c) when the opportunity appears, and critical values B_t^c for opportunity selection. The basic question is: how does opportunity assessment criteria change at different time periods? The simulation will investigate how the critical value B_t^c changes when the time of opportunity assessment approaches the deadline.

The simulation uses the most commonly used distribution: exponential distribution (see Figure 1). That is, opportunities with great benefits are very rare, and most of the opportunities do not have sufficient potential values. Therefore,

$$f(b) = \lambda e^{-\lambda b}$$

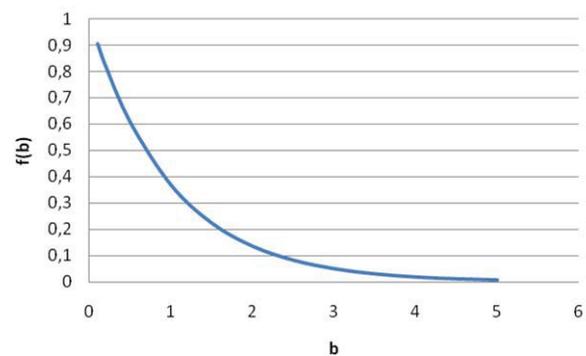


Fig. 1. Exponential distribution

In the experiment, it is also assumed that:

$$\lambda = \frac{1}{5}, T = 10, c = 12, r = 0.6.$$

The permitted time periods are ten: ten periods are available to assess and select the opportunity. There are 12 units (amount) of investment that are available for the firm. For simplicity, each opportunity is assumed to need one unit (amount) of investment. The success rate of opportunity is 0.6.

According to the property of exponential distribution, $\mu = \frac{1}{\lambda} = 5$. The mean of the potential benefits is five. Therefore,

$$f(b) = \frac{1}{5} e^{-\frac{1}{5}b},$$

$$F(B_i^c) = \int_0^{B_i^c} f(b)db = 1 - e^{-\frac{1}{5}B_i^c},$$

$$\int_{B_i^c}^{\infty} bf(b)db = B_i^c e^{-\frac{1}{5}B_i^c} + 5e^{-\frac{1}{5}B_i^c}.$$

When time $t = 1$, it is defined as the first period. Therefore, there are nine periods left. When time $t = 10$, it is in the last period of opportunity assessment.

The experiment adopts the backward calculation method, which is the most common method for the knapsack problem. The experiment begins with the last period ($t = 10$) and the remaining amount of investment is one ($c = 1$). Therefore, $T = 10$, $c = 1$, $r = 0.6$, and $e = 1$.

In the last period $B_{10}^1 = 0$.

$$EV_{10}^1 = EV_{11}^{1-1} + B_{10}^1 F(B_{10}^1) + r \int_{B_{10}^1}^{\infty} bf(b)db = 0 + 0 + 5 \times 0.6 = 3.$$

From this B_9^1 is calculated:

$$B_9^1 = EV_{10}^1 - EV_{10}^0 = 3 - 0 = 3.$$

and then we can get EV_9^1 and B_8^1 and so on.

Based on the above results, the critical values are calculated when the remaining units of the amount of investment are two, three, four, and so on. The critical values are shown in Figure 2 and Table 1.

Figure 2 and Table 1 show that critical values decrease as the last decision deadline approaches ($T = 10$). When $t = 1$, the critical value is 6.29. However, when $t = 9$, the critical value decreases to 3. Critical value is zero when $t = 10$, which implies that the firm is at the risk of accepting any incoming opportunity. Critical values increases as the remaining amount of investment decreases.

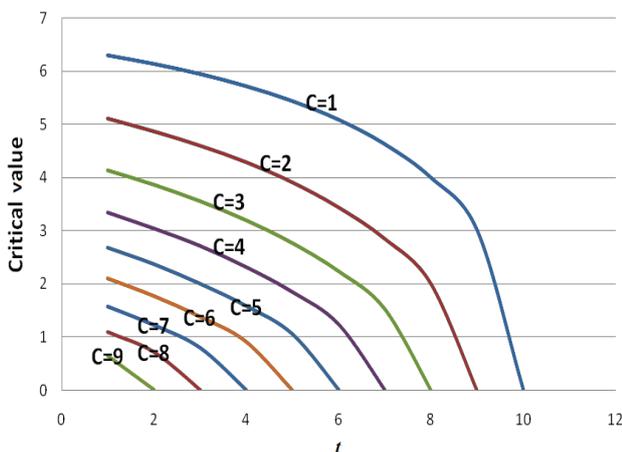


Fig. 2. Critical value (b is exponential distribution)

Table 1. Summary of critical value (exponential distribution)

c/t	Deadline									
	1	2	3	4	5	6	7	8	9	10
1	6.29	6.13	5.94	5.71	5.43	5.08	4.62	3.99	3.00	0
2	5.11	4.87	4.60	4.29	3.91	3.44	2.85	2.01	0	0
3	4.14	3.87	3.56	3.20	2.77	2.24	1.53	0	0	0
4	3.35	3.05	2.72	2.32	1.85	1.24	0	0	0	0
5	2.68	2.37	2.00	1.58	1.05	0	0	0	0	0
6	2.10	1.77	1.38	0.91	0	0	0	0	0	0
7	1.58	1.23	0.80	0	0	0	0	0	0	0
8	1.10	0.72	0	0	0	0	0	0	0	0
9	0.65	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0

Note: *first period: $t = 1$; last period: $t = 10$.

Conclusion

It has been a main issue for the decision-makers whether strategic marketing planning will be successful or not (Bond and Houston, 2003). Previous studies are not sufficient to evaluate the dynamic process of market opportunity (Gruber, MacMillan, and Thompson, 2008). They are not fit for the volatile market even though they try to consider multi-criteria of the marketing decision. Also, customers' needs and market situations have changed dramatically, fueled by the advance of technology. Firms need a comprehensive evaluation tool for evaluation of market opportunity more than ever.

This paper examines the problem of determining sequential selection rules for randomly arriving market opportunities of random benefits. It develops a dynamic model of market opportunity assessment based on the knapsack problem. The new method calculates the critical values in each time period for the opportunity assessment. If the potential benefits of coming opportunity exceeds the critical value, the firm accepts the opportunity and if the coming opportunity has a benefits lower than the critical values, the firm rejects the opportunity.

Because of the dynamic nature of the market opportunity assessment, the critical values change at different time periods. Specifically, when remaining time gets less, the critical values get smaller, which implies that the firm has to accept the opportunity with lower benefits. The critical values are different as the firm's remaining amount of investment changes. As the remaining amount of investment decreases, the critical values increase, which implies that a high quality of opportunity should be selected to increase the efficiency of a firm's operation. Future research should be directed at integrating this model with the classical models to develop a comprehensive framework for the real-time market opportunity assessment.

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