

MODELING THE PRODUCT DEVELOPMENT FUNCTION FOR AN ENTREPRENEURIAL FIRM

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ABSTRACT

The purpose of this paper is to explore a variation of the sine function that represents the product development process in a small, one-product, entrepreneurial firm. The function utilizes two primary decision variables, cumulative time and cumulative capital expended on product development. Before the product may be marketed, it must successfully complete both an Alpha and Beta test, both of which are modeled as stochastic functions. The game that the functions have been developed for is DUALITY; a review of Duality was presented at the 2002 ISAGA conference.

INTRODUCTION

New products are very important to businesses. At Gillette, 50% of sales are from products less than 5 years old (Kahn 2001, page 17). A benchmarking project by the Product Development and Management Association (Griffin et al, 1997) found that one-third of company sales come from products introduced within 5 years of the measurement date. More than 90% of new product developments, however, did not successfully make it out of the product development stage (Kahn, 2001). Further, a Booz, Allen and Hamilton (1982) study found that only one in three new products were successful after market introduction. Thus, much goes wrong during the entire new product development process. Perhaps if simulations could effectively model this process it could help to reduce failure rates.

BACKGROUND

In spite of the fact that fifty percent of business profits are reported to be from products that are less than five years old (Lin and Dwyer, 1995), few business simulation authors have developed this important process within the decision framework of their games. Gold and Pray (1998, page 156) lament: "Although these dynamic changes are of growing

importance and influences in the market, little attention has been given in the simulation and gaming literature to these considerations." While not the major decision orientation of major business games, product development has been utilized in previous business games and simulations. The first game primarily devoted to product development was described in a paper by Wynne, Klosky and Snyder (1979). This game modeled the management of a product development project, where a cost plus incentive fee contract was the objective of the participant teams. The leadership simulation, LOOKING GLASS, McCall, and Lombrado (1982), developed an *in-basket* exercise and simulated product development along with capital investment, firm vision, mission and other items of importance to senior corporate officers to develop leadership skills. Recently, Nicholson and Oliphant (2002) developed a semester long experiential exercise in new product development. Business games that have used product improvement or development include: MICROMATIC (Scott and Strickland, 1985), which uses lump sum commitments for product improvements to allow for product differentiation; THE BUSINESS STRATEGY GAME (Thompson and Strappenbeck, 1995), which uses Quality control to minimize reject rates; THE BUSINESS POLICY GAME (Cotter and Fritzsche, 1991) which has players divide R&D expenditures into two parts, one part is for Process R&D to reduce costs and the other part is for new product development, which results in developing advanced designs of the current product; MARSTRAT (Larreche and Gatignon, 1997) which allows the marketing department the development of a new product. In MARSTRAT, there is a definite Product Development – Marketing interface. But in none of these games is the Product Development function one of the primary concerns of the game.

DUALITY

The product development algorithm described in this paper was designed for a business game DUALITY (Teach and Schwartz, 2002), which simulates both technology-based start-ups and a set of venture capital firms (VCs).

The VCs provide capital in exchange for shares of the start-up firms' common stock. Whenever a start-up firm has need for additional capital resources, it negotiates the best deal it can obtain from one of the VC firms in the game. The start-ups and the VCs co-exist in the same game with participants managing both sets of firms.

In DUALITY, players assign hours of their simulated time among the various tasks needed to operate their specific firm, i.e., either a VC or start-up. They must devote time to product development as well as, searching for capital, fighting fires, (a euphemism for solving the immediate and serious problems that arise suddenly in organizations), planning and strategy development, marketing, managing people, networking and selling.

Both time and the more traditional monetary expenditures play a role in the game. Capital must be allocated to product development, salaries for the officers, new hires, etc. There are general overhead costs and costs for marketing and sales, materials and supplies. Budgets need to be developed and cash flows must be constantly monitored in the start-ups. DUALITY is a game that deals with technology based firm developments and the paradigms that involve the interchange between venture capitalists and the firms' developers, i.e., a duality. Thus, a product development algorithm is central to this game.

SIMULATION OF THE PRODUCT DEVELOPMENT PROCESS

The product development process for an entrepreneurial firm is far simpler than that of a large firm. An entrepreneurial firm usually starts with a single product concept, whereas a large, existing firm has a portfolio of new and developing products. This paper describes the algorithm developed for the simulation, DUALITY, for simulating the product development process for a single product. It is a stochastic function and uses two variables for decision-making: the investment of capital and the amount of time devoted to the overall product development process. In the previously mentioned games, only money invested in R&D or product development determined the simulation outcomes. (MARKSRAT included product attributes). Perotti and Pray (2002) used only a monetary budget for their product development function.

There are substitution effects in this function at all points except when the value of the function is at its maximum value. Thus, if more time is spent on product development, then less capital needs to be invested in product development and vice-versa.

THE FUNCTION

The product development algorithm has three parameters that can be used to control its behavior. The basic function is a modified sine curve and is in the form of:

$$Y(p) = A * \left\{ \text{sine} \left(\frac{\pi * (d')}{2B} \right) \right\}^C \quad (1)^1$$

In this equation, d' is the value (money or time) used in the simulation for the actual decision for a particular period and A, B and C are controllable parameters. B is the amount of the budget (time and money) the product development process will actually take. The parameter p is the period being simulated. Estimates of B_p are provided to the game players, initially a randomly selected number centered on 70 percent of the actual values. This estimate is continually updated and approaches the actual values as game play progresses. The input variable d (the actual decision) is conditionally exponentially smoothed as shown in equation 2.

$$\text{Value of } d' \text{ at period } p = \text{Value of } d' \text{ at period } p-1 + ES(d)_p \quad (2)$$

where $ES(d)_p = [ES(d')_{p-1} * \alpha] + (d)_p * (1-\alpha)$ and values of $(d)_p$ that are greater than or equal to $[(d)_{p-1} * (1-\alpha)]$.

When $(d)_p$ is less than $[(d)_{p-1} * (1-\alpha)]$ then:

$$ES(d)_p = [ES(d')_{p-1} * \alpha] + (d)_p \quad (3)$$

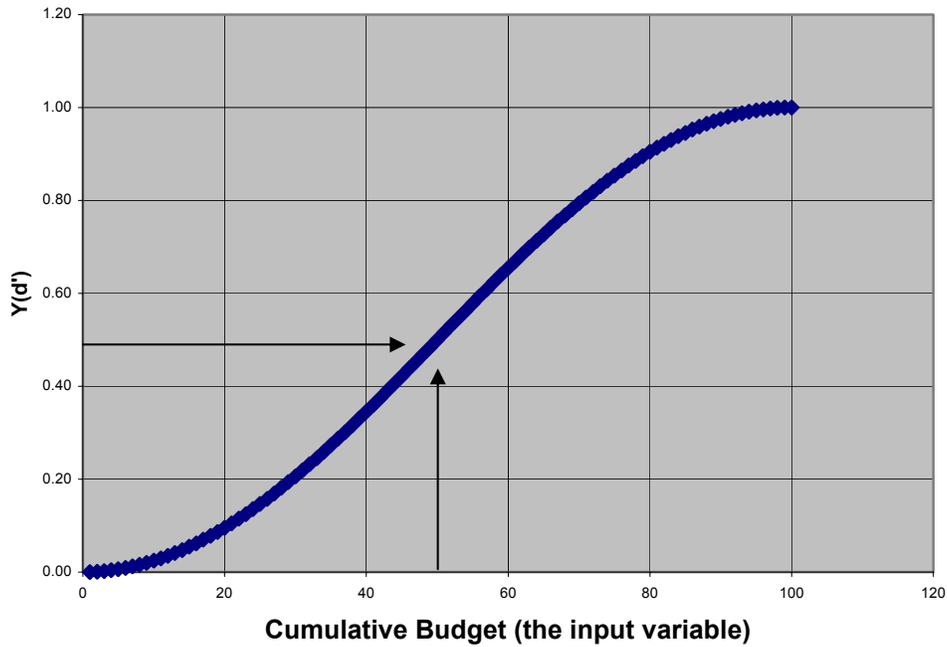
The value of $(d)_p$ is the actual decision for period p. and $(d')_p$ is the value of the accumulated and exponentially smoothed decision used in the simulation for period p. At the starting point when $p = 1$, $ES(d)_{p-1}$ is set to a specific value selected by either the game designer or the game facilitator.

The process of exponentially smoothing prevents sudden and dramatic changes resulting from radical decisions that can result in an unwanted impact on the outcome. Simulations results are a function of the mathematics included in a game. If sudden and radically different levels of inputs occur, most algorithms fail to provide realistic results. (See Perotti and Pray, 2000, while this article does not directly address this specific issue, it does show that algorithms may not behave as expected under unforeseen decisions. Exponential smoothing simply dampens the affect of radical decision changes.

The function for accumulated capital spent on product development is the same one used for the accumulated time devoted to product development. The parameters A, B and C and the exponential smoothing constant *Alpha* may all be different. Figure 1 graphically depicts the shape of the function Y(p) across multiple values of the input variable d' .

¹ The authors recommend that interested readers program this function into a spreadsheet and plot the results for about 100 points. Then they should vary the parameters and watch how the function performs.

Figure 1
A graph of the function values for a range of the input variable



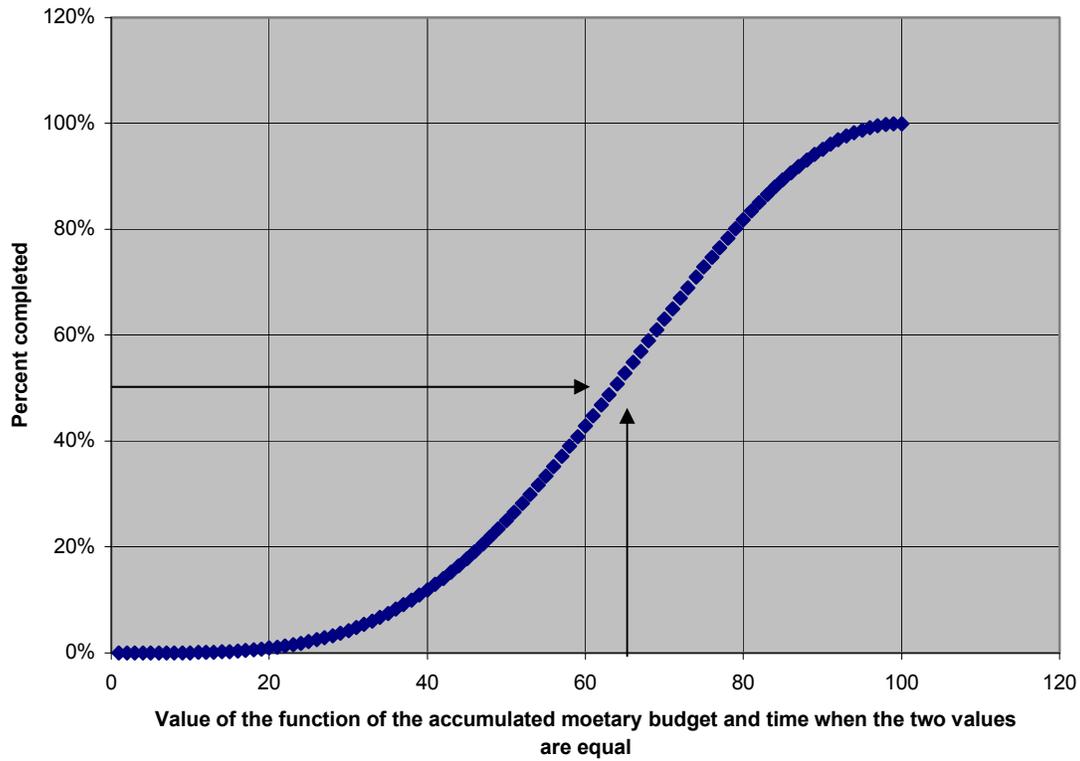
The arrows point to the inflection point

The value of the parameter “A” has been set to the value 1. The parameter A is a scalar and alters the maximum value of each sub-function. At a value above 1, the product of the two sub-functions changes shape. The parameter “B” is the point at which the first derivative of the function is equal to zero. The value of B is the maximum amount of either time or the maximum amount of capital to be invested in the project. The inflection point is influenced by the selection of the parameter C, and for the purposes of this paper, C is defined as equal to 2. The selection of this

value results in the inflection point always being at the mid-point of the function.

As noted, there are two variables used in the simulation of product development, the accumulated capital invested and the accumulated time expended. The function can represent both time and money variables and the values of the two functions are multiplied together to produce the joint function for both variables. Since the values of both functions are less than one, the combined function has its inflection point shifted to the right. The shape of the total product development function is shown in Figure 2.

Figure 2
The Product Development Function



The arrows point to the inflection point

Certain marketing processes accompany the overall product development process. Alpha and Beta testing are two of those. Alpha tests are done earlier in product development when the product is only partially ready for market. Beta tests are generally conducted when the final product form is in place and ready for limited test market. The simulation can model these tests.

ALPHA AND BETA TESTING

A priori, the new product will be defined to be ready for Alpha testing whenever the product development function is equal to 0.80 or greater. In reality, product development has no upper limit. When successful in-house (alpha) testing occurs and when the market is willing to accept the product (a successful beta test), it can be marketed. However, one needs to realize that further development may increase the product's utility to its buyers. For the purpose of the game, the probability of a successful alpha test $P_{(\text{Alpha Success})}$ should be about 0.50 when Y is equal to 0.80 and $P_{(\text{Alpha Success})}$ should be about 0.60 when Y is equal to 0.85 and $P_{(\text{Alpha Success})}$ should be about 0.90 when Y is equal to 1.00 (See Tables 1 and 2). Beta testing can only take place after a

successful Alpha test. Beta test probabilities would be expected to be lower than the probabilities of a successful Alpha test when the value of the function Y are comparable. These numbers are arbitrary and can be varied, thus influencing the outcome of the simulation. The functions used to produce these probabilities are discussed in appendix A

Costs for an Alpha Test can be defined by the game administrator and would vary depending on what product developments are being simulated. Beta testing is done with a limited number of select customers and either "free" or at reduced prices in order to be attractive to potential users and thus costs are much more to run a Beta Test. The game has been set so that three Beta test failures lead to market failure (although this number can easily be changed).

Probability functions

To determine the function for the probability statements, Microsoft EXCEL™ was utilized. The coefficients and the resulting alpha test functional values are shown in Table 1.

Table 1:
The coefficients and the resulting functional values for the Alpha Test

Term	Final Coefficients	Functional Values	Estimated Probabilities	Resulting Probabilities
Intercept	23.75	Y(0.80)	0.50	0.48
Linear term	-92.00	Y(0.85)	0.60	0.61
Squared term	117.00	Y(0.90)		0.73
Cubic term	-47.00	Y(0.95)		0.82
		Y(1.00)	0.90	0.88

Table 2 shows the final coefficients that were found with their expected and approximated probabilities for the beta testing function.

Table 2
The coefficients and the resulting functional values for the Beta Test

Term	Final Coefficients	Functional Values	Estimated Probabilities	Resulting Probabilities
Intercept	-75.4	Y(0.80)		0.44
Linear term	232.0	Y(0.85)	0.60	0.63
Squared term	-234.0	Y(0.90)	0.70	0.73
Cubic term	79.0	Y(0.95)		0.77
		Y(1.00)	0.85	0.80

STAGE GATE PROCESS

If one wanted to include a more sophisticated *stage-gate process* (O'Connor, 1994), a series of probability estimates could be developed for each gate. The gates would be placed to occur at different points along the function Y. Care needs to be taken, because a realistic simulation may have too few successes to be played in a normal classroom environment. It must be remembered that a business simulation is a learning device and not necessarily descriptive of an actual situation.

SUMMARY

This paper has discussed a product development algorithm that may be used in a game where new product development is the primary focus of a game or simulation. Its original purpose was to be used in a game that emphasized entrepreneur endeavors. That is, when the firm must succeed in product development or fail. In large, well-financed firms, product development is a continuing process and frequently involves the development of multiple products. Games developed for large firms with multiple products “play the probabilities.” But, entrepreneurial firms, while facing the same probabilities, have only one time to “roll the dice.” If the product fails, the firm fails. This is what the game DUALITY simulates.

APPENDIX A

DETERMINING THE FUNCTIONS FOR THE PROBABILITY STATEMENTS

The probability functions are easy to develop using Microsoft EXCEL™. First put in the three function values in one column, the squares of these function values in the second column, the cubes of the function in the third column, then in the fourth column, key in the desired probabilities. Then add 2 or 3 additional lines with values close to the three values originally selected (This prevents a degrees of freedom error.). After the derived solution, check to make sure the function is monotonic (that is one that is always increasing, never decreasing). Write the equation on the spreadsheet and provide 20 to 30 values and plot the result. This plot will indicate if you have a non-monotonic function. If you do have a non-monotonic function, adjust the coefficients until you get a monotonic function. When using the suggested probabilities for the alpha test given in the previous section, a non-monotonic function resulted. After a few adjustments, coefficients were found that approximated the desired values.

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