Modeling and Evaluating of Business Revenue Models under Different Product Life Cycles Using System Dynamics Simulation

K.-J. Wang

J.L. Tzeng

S. P. Jiang

MODELING AND EVALUATING OF BUSINESS REVENUE MODELS UNDER DIFFERENT PRODUCT LIFE CYCLES USING SYSTEM DYNAMICS SIMULATION

Wang, K.-J. [1] (Corresponding author), Tzeng J.L. and Jiang S. P.
Department of IndustrialManagement
National Taiwan University of Sciecne and Technology (Taiwan Tech)
[1]kjwang@mail.ntust.edu.tw

Abstract

Business revenue modelling is one of the important aspects of enterprise planning to create values for enterprises. In this study, we construct a system dynamics simulation model to evaluate various business revenue models applied to e-platforms. Machining tools industry is investigated as a case study. Products with different life cycles are examined as applying different business models. Computational experiments are conducted and results are discussed. Specific research issues/contributions of the study include: 1. To propose four effective business revenue models in such an industry. 2. To evaluate the proposed business revenue models as well as their advantages/disadvantages by a system dynamics simulation. 3. To address managerial implications of these business revenue models to the industry. As a conclusion to our research, we show that: (i) Firms with products under growth or mature stage of life cycle adopt/switch appropriate business revenue models conforming to their requirements in different stages and result in high performance outcomes than those remaining in a single business revenue model. (ii) Business revenue models represented by causal loops of system dynamics and examined by system simulation can capture not only steady states but transient states of business activities. By taking advantages of the proposed approach, managers can thus efficiently make right decisions for reducing time and cost.

Keywords: Business Revenue Model, System Dynamic, Operate Performance Evaluate, Technology Life Cycle

Introduction

Business model is important to enterprise for earning profit [1,2,3,4]. Even an enterprise has excellent quality of products and services, the lack of a good business model still cannot obtain high profit. Enterprises cannot find their suitable business model by try-and-error which would leads to fatal failure. System Dynamics (SD) and simulation is a powerful tool to examine suitable business models for enterprises [5,6,7].

In this study, a case company in the measurement instrument industry is investigated. It currently follows a traditional business model, in which the firm's products are sold through direct sales force, distribution, OEM and sales agents to customers. However, the quality and technical ability of the products provided by the other firms in this industry is almost the same. There is few gaps between the firm and its competitors and thus weaken the ability of its revenue growth [3,5]. This study aims at examining potential profitable business models, and opened the gap with its competitors.

According to above description for the background and motivation has established the following three objectives: 1. To propose potential business models. 2. To develop a system dynamics simulation model to assess the advantages of the proposed models. 3. To assist enterprise applications in the business model.

The rest of this paper is organized as follows. Literature review in section two is conducted to define business model, performance evaluation and system dynamics modeling methodology. In section 3, we establish several novel business models and use system dynamics to represent their system architecture. Section 4 uses scenario-based simulation to investigate the outcomes of different models. Finally, conclusion and recommendation is in given in section 5.

Literature Review

Business model is defined by Magretta [8]. Business model is actually a story of how to operate a company and is a plan to make money. System dynamics (SD) is a powerful tool in the creation of feedback theories. Many guidelines and case studies have been developed by founders and practitioners of this field for the model building process and a series of tests to build confidence in the models created. An SD approach can be used to demonstrate how managing processes of accumulation and depletion of strategic assets, detecting inertial effects of decisions to help entrepreneurs in understanding opportunities and pitfalls related to e-commerce strategies. SD is a method of solving problems by computer simulation. Like many simulation methods, it offers

the promise of less expensive learning to experiment with the effect of new policies on a computer model than on a real system with real people, equipment, and processes. SD can be applied in various fields, such as analyzing mine disasters, dealing failure and robustness in single development projects, and working on e-commerce strategies. SD can also be combined with other management tools: for instance, to combine system dynamics with conjoint analysis for strategic decision making.

This study not only constructs a common business model, but also constructs the other two new potential business models. This study uses Powersim® simulation software to build the system dynamics models and evaluates via scenario-based simulation for the case company of this study.

Model Construction

For the construction of business models, this study sets the followings assumptions: (1) Only a single product exists. (2) The demand of a product subjects to a normal distribution (Normal (μ = 2.5, σ = 0.8) (Number / Day). The forecast uses a naive method that the forecast of the upcoming period is equal to the actual sales of the last period. (3) No backorder. (4) The payment collection risk subjects to a Uniform distribution (Uniform (0,1)) (5) The account receivables will not recover if such failure occurs. (6) The product price is inversely proportional to its remaining life cycle. (7) Product unit cost is inversely proportional to its remaining life cycle. (8) Installment interests uses a simple interest calculation. (9) After the product reaches its maturity stage in life cycle, it continues to be sold.

In this study, the product life cycle and technology development is classified as Sustained Matured Products (Type A), Rapid Matured Products (Type B), Slow Matured Products (Type C) and Entire Life-Cycle Products (Type D). The following section describes the technology life-cycle cost and price assumptions.

Product types

There are four types of products addressed in the study, sustained mature products, rapid matured products, slow matured products and entire life cycle products.

The technology life-cycle curve of **Sustained Mature Products (Type A)** is constant, such as daily necessities, The demand is stable, The product technology is difficult to get a breakthrough. The unit price and cost is constant as shown in Figure 1.
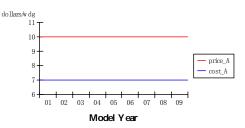

Figure 1. The relationship between price and cost (Type A)

Rapid matured products (Type B) is the second type of products investigated in the study. Kuznets (1930) proposed S-curve model for describing future technological change in the technology evolution. Foster (1986) advocated that S curve can be used to establish a technology life cycle and present the results of technology development.

The S curve equation is given below: $Y_t = \dfrac{K_1}{1+e^{\alpha+\beta t}}$ where Yt is the technical performance at time t; K1 is the upper limit of technology performance; α is the parameter of lower limit of technology performance; and β : shape parameter.

The lower limit of technology performance, u_1, is defined as follows for simulation use. The parameter α is converted to be the function of the lower limit of technology performance.

$$\alpha = \ln\left(\frac{K_1}{u_1}-1\right)$$

The derivation is as follows:

$$Y_t = \frac{K_1}{1+e^{\alpha+\beta t}} \qquad \Rightarrow 1+e^{\alpha+\beta t} = \frac{K_1}{Y_t}$$

$$\Rightarrow e^{\alpha+\beta t} = \frac{K_1}{Y_t}-1 \quad \Rightarrow e^{\alpha+\beta t} = \frac{K_1}{Y_t}-1$$

when t=0, let Yt=u1. Therefore,

$$\alpha = \ln\left(\frac{K_1}{u_1}-1\right)$$

The technology life cycle curve of Rapid matured products (Type B) is shown in Figure 2.
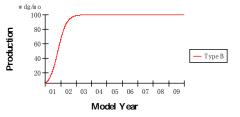

Figure 2. Technology life cycle curve (Type B)

The rapid matured products in the life cycle technology saturate within a short time, such as consumer electronics products. We assumed that the time of technology life cycle is inversely proportional to the product price. The price is high

during products introducing to the market, and the scale of demand and production is small. When the product technology is matured, the price and cost is lowed. The S-curve formula is defined as follows:
$P_t = \dfrac{(Y_t - u_1)(K_2 - u_2)}{(K_1 - u_1)}$ where P_t is the price at time t;

K_1 is the upper limit of Technology performance; K_2 is the upper limit of price; u_1 is the lower limit of technology performance; and u_2 is the lower limit of price.

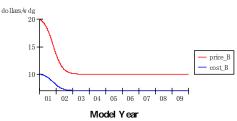The cost and price curve of rapid matured product is shown in Figure 3.

Figure 3. Price and cost curve (Type B)

The third type of products is defined as slow matured products (**Type C**). The products require long time for the phase of its maturity stage owing to such as technological development bottleneck, difficulty in promotion, low customer acceptance or other factors. The technology life cycle curve and the price and cost curve are shown in Figures 4 and 5.
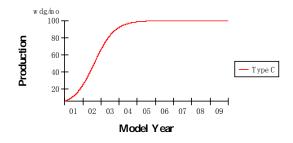

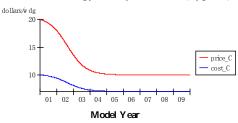Figure 4. Technology life cycle curve (Type C)

Figure 5. Price and cost curve (Type C)

The **Entire Life Cycle Products (Type D)** are the type of luxury was launched with very significant features becoming a pioneer (Figure 6). The customer is attracted to buy it under initial stage of market hot, but the competition increases

dramatically. Then, the amount of the consumers and profits will reduce quickly. The curve of the entire life cycle technology presented by Gamma distribution as follow: $Y_t = u_1 + t^{a-1}e^{-t/b}$ where Y_t is the technical performance at time t; K_1 is the upper limit of technology performance; α is the parameter of lower limit of technology performance; β is the shape parameter.
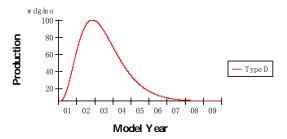

Figure 6 Technology Life Cycle Curve (Type D)

The price and cost relation is as follows: $P_t = -\left(t^{a-1}e^{-t/b}\right)\left(\dfrac{K_2 - u_2}{K_1 - u_1}\right) + K_2$, where P_t is the price at time t; K_1 is the upper limit of technology performance; K_2 is the upper limit of price; u_1 is the lower limit of technology performance; u_2 is the lower limit of price. The price and cost curve of Entire-Life-Cycle Products is shown in Figure 7.
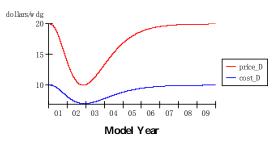

Figure 7. Price and cost curve (Type D)

Business models

There are three business models addressed in the study, basic business model, sale-combined-with-installment-service business model, and with-installment-and-agent business model.

The **basic business model (denoted as m1)** is shown in Figure 8. A company employs sales records as the basis for demand forecasting and develops its production plans. When the demand is less than planned production, inventory is kept in a warehouse. After shipping, customers pay by checks of three-months.
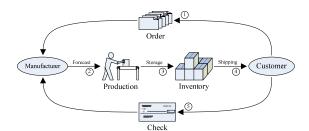
Figure 8. The basic business model of instruments sales

According to the basic business model this study develops a causal feedback loop as shown in Figure 9. The performance indicator of business model of instrument manufacturer is represented by sales profit. The sales profit considers revenue and sales cost. There are two types of costs, inventory cost and the risk of disbursement payment for goods by checks. Base on the causal feedback loop as aforementioned, we construct system dynamics of the basic business model by using Powersim as shown in Figure 10. The system dynamics model also includes two subsystems of the technology performance and sales loss.
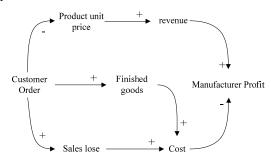

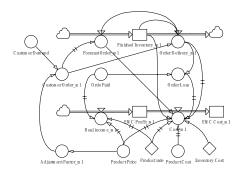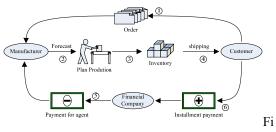Figure 9. The causal and feedback loop of basic business model

Figure 10. The basic business model represented in system dynamics

A sale-combined-with-installment-service business model **(denoted as m2)** is proposed by the study as follows. In the basic business model as aforementioned, customers pay the payment by checks for three months. Since the credit investigation ability of the instrument manufacturer is not good enough, the checks have high risk that

cannot be cashed and thus cause loss of sales. Financial service industry of leasing, installment and factoring is well-developed up-to-date. The installment service industry can provide installment service for customers. From the instrument manufacturers' perspective, by integrating installment service companies in the existing business model, they can receive the payment for goods quickly to increase turnover rate and transfer the risk to installment service companies. From the customers' aspects, they can reduce the pressure of gathering mass capital and reserve cash on hand to decrease the managerial risk. From the installment service providers' viewpoint, they can earn the installment interest from the instrument manufacturer. The business model structure of sale-combined-with-installment-service is shown in Figure 11. According to the sale-combined-with-installment-service model, we develop a causal feedback loop as shown Figure 12.

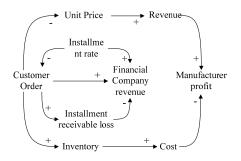gure 11. sale-combined-with-installment-service business model

Figure 12. A causal feedback loop diagram of sale-combined-with-installment-service business model

The with-installment-and-agent business model **(denoted as m3)** is proposed as follows. Instrument manufacturers expect to reduce the pressure of inventory and expend the market share, so they can cooperate with financial service companies and agents to develop this business model with installment and agents, as shown in Figure 13.
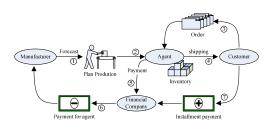
Figure 13. The with-installment-and-agent business model

The agents ask discounted price to instrument manufacturer for purchasing products. The manufacturer sells the products to agents who respond for sales and channel management. The agents bear finish goods cost and take the margin between of market price and discounted price. Furthermore, the financial service companies provide the installment service to earn interest. In this model, the manufacturer transfers the receivable payment risk and inventory cost to its partners. According to the with-installment-and-agent business model we develop the causal feedback loop as shown in Figure 14. Table 1 is a comparison of three proposed models.
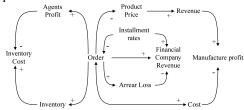

Figure 14. a causal feedback loop model of with-installment-and-agent business model

Table 1. Comparison of the business models

Model / Parameters	Basic Business Model (m1)	Sale-combined-with-installment-service (m2)	With-installment-and-agent (m3)
Inventory Costs	Managed By Manufacturer	Managed By Manufacturers	Managed By Agents
Receivables Risk	Managed By Manufacturer	Managed By Financial Service Companies	Managed By Financial Service Companies
Installment Interest Rates	-	Impact To Customer Willing	Impact To Customer Willing
Discount Percentage	-	-	Impact To Agents Profit and Willing

Simulation results

The case company under investigation is a measurement instrument company in Taiwan. The company want to determine which business model should be adopted. We set three business scenarios as shown in Table 2. Individual viewpoints in terms of profit will be evaluated in this section.

Table 2. Parameters settings of profits impact of the measurement instrument company

Parameters / Business Scenario	Inventory Cost	Arrear Risk	Installment Risk	Discount Percentage
Default	0.1 (103 NT/Unit)	0.02	5%	85%
Worst	0.2 (103 NT /Unit)	0.03	6% (to decrease # customers by 10%)	80%
Desired	0.05 (103 NT /Unit)	0.01	4% (Customer +10%)	90%

Resulted from the simulation, the measurement instrument company is suggested to adopt the following strategies as shown in Table 3. For instance, in order to deal with the sustained mature products (Type A) the company can employ Sale-combined-with-installment-service business Model (m2). For the rapid matured products (Type B), slow matured products (Type C) and entire life-cycle products (Type D), in the initial stage of product introduction, the With-installment-and-agent business model (m3) are adopted, when the products become mature, the models are suggested to shift to the Sale-combined-with-installment-service business model (m2).

Table 3. Business model suggestions for the measurement instrument company

Product Type / Business Scenario	A	B	C	D
Default	m2	m3→m2	m3→m2	m3→m2
Worst	m2→m1	m1	m1	✕
Desired	m2	m2	m2	m3→m2

✕: do not suggest;   m*b*→m*a*: Transfer business model from b

to a

Resulted from the simulation, the financial service company is suggested to adopt the following strategies as shown in Table 4.

Table 4. Business model suggestions for the financial service company

Product Type / Business Scenario	A	B	C	D
Default	m2	m3	m3	m3
Worst	m2→✕	✕	✕	✕
Desire	m2	m2	m2	m3

Resulted from the simulation, the agents always loss under the worst situation. The profit performances of the other two scenarios (Default and desired) are depicted in Figures 15 and 16.
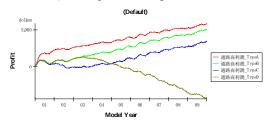

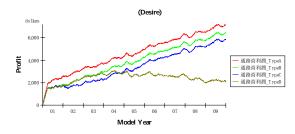Figure 15. Channel agent profit under the default scenario.

Figure 16. Channel agent profit under the desired scenario

Conclusions

This study has developed three business models which have been justified by system dynamics simulation in different settings of situations to advise the case company for choosing its appropriate business model against various product life-cycles. Profitable suggestion for applying as well as shifting to the most appropriate business model are given for different viewpoints of instrument manufacturers, channel agents, and financial service companies. The proposed system dynamics evaluation method can reduce survey time for business and lower operational cost.

As a conclusion to our research, we have shown that: (i) Firms with products under growth or mature stage of life cycle adopt/switch appropriate business revenue models conforming to their requirements in different stages and result in high performance outcomes than those remaining in a single business revenue model. (ii) Business revenue models represented by causal loops of system dynamics and examined by system simulation capture not only steady states but transient states of business activities. By taking advantages of the proposed approach, managers can thus efficiently make right decisions for reducing time and cost.

References

[1] Porter, M. E. (1985) "Competitive Advantage", New York: The Free Press.

[2] Knight, G. (2000) "Entrepreneurship and marketing strategy: The SME under globalization", Journal of International Marketing, 8 (2), 12-32.

[3] Mitchell, D. and Coles, C. (2003) "The Ultimate Competitive Advantage: Secrets of Continually Developing a More Profitable Business Model", San Francisco: Berrett-Koehler Publishers, INC.

[4] Venkatraman, N. and Ramanujam, V. (1986) "Measurement of business performance in strategy research: a comparison of approaches", Academy of Management Review, 11(4), 801-815.

[5] Chesbrough, W. H. (2003) "Open innovation: The New Imperative for Creating and Profiting from Technology", Boston: Havard Business School Press.

[6] Chakravarthy, B. (1986) "Measuring strategic performance", Strategic Management Journal, 7(5), 437-458.

[7] Afuah, A. (1998) "Innovation Management: Strategies, Implementation, and Profits", New York: Oxford University Press.

[8] Magretta, J. (2002) "What Management Is: How It Works and Why It's Everyone's Business", Commonwealth Publishing.