Developing the Product Strategy via Product Life Cycle Simulation according to the System Dynamics Approach

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Abstract
Nowadays, it seems that prediction is one of the most important issues in all economic-managerial fields—gradually, new methods have been offered with the goal of minimizing the prediction error. Policy makers prefer to have mechanism which can help them to decide correctly because of multiplicity of variables which influence managerial issues. So, in order to achieve better and more accurate results with less error, policy makers are trying to refer to the prediction and simulation method. Historical methods are used in many complicated and nonlinear systems which predicting, controlling and modeling of them through classic method are very difficult and partially impossible. Product life cycle is an important concept that informs managers about dynamics competitive concepts. This paper is to propose a dynamics model to simulate product life cycle to help manager to formulate product policies. In this method, system behavior predicts during the time through feedback chains in systems parts.

Keywords: Product life cycle, System dynamics, Simulation, Loyalty

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1. Introduction

Products usually go through different stages of development and completion. The product life cycle can be used as a tool to determine the stage that the product is staying in. So, this will help the managers to make a favorable decision for continuing use of the method and introduce the time of the new product. Therefore, product life cycle is one of the fundamental concepts in management, because the managers are under pressure before and after the changing points and sale rate is different during different stages of product life cycle. Furthermore, the managers need to be aware of such changes for developing a proper strategy for different factors such as product rate, stock, employer affairs, sale, marketing, advertisement and etc. In order to formulate strategy for producing graph of life cycle, methods have been studies regarding to the system needs. But method errors rate, determine the distance point with verity axis. Historical methods mostly predict due to linear methods.

Two studies about the history of the marketing done by Bartels 1976 and Converse 1959 have been reviewed, but nothing was found about the origin of the product life cycle. However, Rink and Swan, mentioned Joal Din as person who introduced the product life cycle in 1950. He offered a paper entitled "New Product Pricing Policies" which used product life cycle for the first time in managerial text. On the other hand, he made a biological analogy and coined the expression "product life cycle in managerial context". (William F.Muhs, 1986). Frank Bass offered a model to predict the product life cycle in 1969. (Peres et al, 2009) His model is so famous in marketing fields. Bass proposed that people usually buy products because of the company’s advertisements or because of other customer’s suggestion. In other words, customers falls into two categories (effective and potential customers). This model is one of the most applicable and famous new product sale scale prediction model which is used in marketing, developing strategy, and technology management. Alvares and Lourenco proposed a model for tourism in 2002. They used plan – processing methods. This model has been developed in 70th Mario Tabucano, made a sample system dynamics model for product life cycle. He investigated the factors affecting the product life cycle curve. They fell into different categories including market factors, advertisement factors, customer’s factors. This factors divided into two groups. The first group included direct factors related to producer and customers behavioral factors and the second one included the factors related to markets which were market direct factors, factors related to product outpouring from market and factors affected the innovation variance. Jeferry Morison predicted the product life cycle while there is not enough historical data (Morison, 1995). Tsure predicted the sales of the next stage of the product life cycle in 2002. He used AHP methods and knowledge of the experts. At last, he used the fuzzy logic to determine the product life cycle curve (Tsure, 2002). Solomon could forecast forecast the electronic part life cycle and their obsolescence as well (Solomon et al, 2000). Emil Petrescu proposed the statistical distribution to predict the four stages of the product life cycle. This distribution is the so-called ALPHA distribution (Emil petresku, 2009). Alexandru ISAIC-MANIU analyzed a modified model for product life cycle from the reliability theory viewpoint. (ISAIC-MANIU etal, 2008)

Determining the behavior of the most important factors affecting the product life cycle, the behavior of the product during its life would be simulated via system dynamics concept. Finally, the most suitable strategy for increasing the sales would be proposed. This paper aims at
simulating the prediction product life cycle through system dynamics method and nonlinear relation in variables
Following, we will describe system dynamics concepts, then reference modes, casual loops and components of the model would be described, sensibility and developing strategy would be stated and conclusion would be the last part of this paper is.

System Dynamics

This method was introduced by Forrester in MIT during the end of 50th decade. System dynamics is a method for comprehending the behavior of a complex system during the time. This method studied the system behavior by focusing on loops feedback, nonlinear effects, delays of the variables and type of the variables (Stock and flow) and the situation of a system. Based on the numeral nature of system dynamics, it is possible to simulate models based on this method by using computer and predict systems situation in future by using different variables.

2. Steps of system dynamics methodology

Generally, models play an important role in helping managers to lead the organization well. System dynamics is useful in this way .System dynamics methodology with its casual philosophy and with the goal of obtaining deep conception about system operation, emphasizes on indrawn approach to system. In this methodology, subjects are considered matters which are made with system internal structure. The steps of this method are as below:

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- Defining the problem

System dynamics is an approach that simulates the variables in virtual world. In addition to decreasing the costs, by use of system dynamics simulation, mathematical models are proposed as well. One of the most important stages of the modeling is defining the problem. This step includes studying the current situation, finding the cause of the problem, defining the key words and drawing the reference modes in a suitable time(Sterman, 2000).
o **Reference modes**

Table 1 presents the reference modes showing the factors affected the product life cycle according to the literature review.

**Table 1: Table of reference modes**

<table>
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<tr>
<th>Reference modes</th>
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<tbody>
<tr>
<td>Reference mode“ adoption from word of mouth”</td>
<td>Bass believes that product adoption during its life cycle behaves as it is shown. The horizon line shows the time and the vertical one indicates the number of people who bought the product because of word of mouth. As it can be seen, at the beginning the rate of accepting the product because of the word of mouth is too small but gradually it increases and finally it decreases again. (Sterman, 2000).</td>
</tr>
<tr>
<td>Reference mode“ adoption from advertisement”</td>
<td>Bass and Kotler believe that because of the company advertisement, the adoption of the products is high at the time that the product enters the market. But people gradually purchase the goods because of word of mouth instead of company’s advertisement. So decreases. (Sterman, 2000) The horizon line shows the time and the vertical one is the number of people who has bought the product because of the company's advertisement.</td>
</tr>
<tr>
<td>Reference mode“ customers”</td>
<td>The horizon is time and the vertical one show the number of people who accepts the product. Bass believes that by launching new product to the market the number of customers increases at first after that it reaches to a constant rate. (Sterman 2000)</td>
</tr>
<tr>
<td>Reference mode“ potential customers”</td>
<td>Bass believes that the number of potential customers decreases during the time. The horizon line shows time and the vertical one shows the number of customers. (Sterman, 2000).</td>
</tr>
<tr>
<td>Reference mode“ Loyalty”</td>
<td>Edson Crescitelli believes that usually the percent of the customer's loyalty increases. After a while it reaches a constant rate. The horizon line shows the time and the vertical one shows the percent of loyalty. (Edson Crescitelli, Julio Bastos Figueiredo 2009)</td>
</tr>
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</table>

- **Conceptualizing system and formulating dynamic hypothesis**

A dynamic hypothesis is an efficient and effective hypothesis which shows the state of problem existence. An endogenous hypothesis produces system dynamics through variables and factors which have been shown in the model. Focusing on the endogenous relation does not mean that all the exogenous parts are omitted. It means that, the number of exogenous inputs are less and they are considered exactly if important feedback of endogenous elements to variables
exist or not. For reaching this goal, several tools are introduced. The most important ones include subsystem graph and casual loops. (Sterman, 2000).

**Figure 1: Subsystems**

- **Casual Loops graph**
  
  In order to show the casual loop relations among the variables and feedback structure of system, the best way is using the casual loop graphs (Figure 2).
• **Figuring the model**

This step includes drawing the stock and flow graph and entering the equations. You can find the proposed stock and flow graphs of product life cycle simulation model systems in the next part.
Population stock and flow graph
In the proposed model of Bass, the population was a constant variable. While in this paper, the total population is stock, which is affected by the birth and death rates. In this model, population means the percent of total population which the product produced for (Figure 3).

Customers stock and flow graph
As it is shown in Figure 4, portion of the total population changed into the potential customers with a rate. Then potential customers change into the customers with the rate called “adoption rate (product life cycle)”. Percent of customers with a rate called “rate of exiting the market “halt the product consumption. On the other hand, some of them return to the potential customers with a rate called “successive purchase”. (Sterman, 2000).The other entering rate to stock potential customers is called “goal population changing rate to the potential customers which is a dependent variable to the loyalty, product attractiveness and goal population.

Product attractiveness stock and flow graph
Figure 5 indicates the effective factors of product attractiveness. As it is shown, the effect of price, sustainability to the customer's need, effect of delivery delay, and quality are most important factors. These factors are according to Jim Hines conceptual model (Otto, 2008)
Telis stated that quality influences the product life cycle. (Tellis, 1988), two perceived price and quality variables considered as a goal-related loops in this research. As it is shown in Figure 6, price satisfaction is regarded as the gap between perceived price and expected price. The definition of quality satisfaction is the same. When the expected price is more than perceived price, customers are dissatisfied with the price and when the perceived price is more, customers are satisfied with the price. That is the same for quality satisfaction and dissatisfaction. Kotler stated that satisfaction is the feeling of enjoy or hatred towards a special product. This belief is concluded from comparing the perceived quality, price with expected quality ones. (Kotler 2008) the sum of quality satisfaction and price satisfaction is called satisfaction. And the sum of quality dissatisfaction and price dissatisfaction is called dissatisfaction. Perceived price is in fact the idea of the customers on the price of the product. That is the same for the perceived quality. Meanwhile, there is gap between perceived price and expected price. On the other hand, there is a gap between perceived and expected quality Zeithaml,V.A(1988). According to what Edson said, perceived price and quality influenced the satisfaction. (Edson Crescitielli, 2009).This fact is taken into consideration in the proposed model.

**Figure 5: Stock – flow of product attractiveness**
Customer's loyalty influenced the product life cycle (Kuusik believed that Customer's loyalty to the brand can be taken place because of different reasons. Forcing to be loyal, loyalty because of inertia, and functional loyalty are as of the most important factors. Also, Anderson proved the relationship between loyalty and satisfaction (Kuusik, 2007). Therefore, investing on direct communication can affect his loyalty. Edson Crescitelli (2009) Figure 7 states that the loyalty of customers, satisfaction and dissatisfaction are taken into the consideration among other factors.

The Model assumptions consist of:
1. All of the customers who are satisfied with the product will buy the product again. This will cause increasing the brand loyalty.
2. Investment in direct communication causes increasing the brand loyalty (Edson Crescitelli, 2009).
3. Satisfaction “exists or not” and the other possible states like it “increase or decrease” is not taken into the consideration.
4. The investment of the company on advertisement depends on the company’s income and market share. But they considered as the exogenous variables.

3. Model simulation

Inputs which are used in this model related to the producing mouse by an Iranian company and the time consider 100 months. For simulating this model we used Vensim PLE. In the following section, the results of this simulation are defined.
The behavior of population and adoption from word of mouth

According to the WHO (World Health Organization) statistics, the present Iran population is about 70 million people. The death rate is 5 in 1000 persons and the birth rate is 17 in 1000 persons. In Figure 7 and 8, the behavior of the population and adoption from word of mouth after simulation has been shown.

Figure 8: Simulation of Population behavior  Figure9: Simulation of Adoption from word of mouth behavior

The behavior of potential customers and customers

Based on the Figures 10 and 11, number of potential customers and also customers increases at first. But after passing the maturity stage, the potential customers keep increasing for a while simultaneously, the customers decrease. We can come to this conclusion that small percent of the potential customers buy the product. Then after the time 100, the potential customers decrease.

Figure 10: Simulation of potential customer behavior  Figure11: Simulation of customer behavior

The behavior of the adoption rate (product life cycle)

The adoption rate has been shown in Figure 12. It indicates the rate of changing the potential customers to the customers. In other words, it includes the total number of people who has bought the goods because of word of mouth or because of company’s advertisement.
Validation

There are different ways to test the validity of a model. Some of them are defined below.

- **Boundary test**
  
  It tests the extremes and boundaries of a model. The first step of this test is to determine the boundary of the model. In the product life cycle model, at first the variables including quality, price mentioned as the exogenous variables. But by consulting the policy makers, they mentioned as auxiliary variables. Then after running the model and studying the result, we knew that they are more than just simple auxiliary variables. So, we mentioned them as floating goals. It could not take us to the place wanted. At last they mentioned as accidental numbers. By assuming them as accidental numbers, they can easily show the fluctuations in these variables.

- **Extreme conditions test**

  In this test, the extremes are determined for some of the variables. Then the behavior of the model compares with the behavior of the real system. In fact, the model should not act unusual in the extreme points. Product life cycle model was examined under the circumstances that all the goal market changes into the potential market. The model worked properly and sales increased to a great degree.

- **Parameter verification test**

  In the product life cycle model, the evaluating of the parameters was done from statistical point of view. For instance, the growth and the death rate are according to the WHO’s statistics. In the meanwhile, data relating to the variables like advertisement, Effect of competitor’s advertisement, compatibility to the accepted quality, compatibility to the accepted price and effect of services were collected by the questionnaire.

- **Sensibility analysis**

  This test is to determine the rate of the model sensibility to the changes in parameters and variables.

- **Sensibility analysis population adoption rate auxiliary variables**

  Adoption rate devoted 0.2% of whole percent in the product life cycle prediction model. It was determined according to the skilled and producer’s ideas. The range of this variable is between 0 and 1. In order to test the model, at first we assumed that it is 1. It means that all of
the population of the country buys this product. Then we assumed that it is 0.02. In both states
the model run and the results are as Figur12-19:

Figure 12: Simulation of product life cycle when the total population adoption rate is 0.02
Figure 13: Simulation of product life cycle when the total population adoption rate is 0.5
Figure 14: Simulation of adoption from WOM when the total population adoption rate is 0.02
Figure 15: Simulation of product life cycle when the total population adoption rate is 0.5
Figure 16: Simulation of potential customers when the total population adoption rate is 0.02
Figure 17: Simulation of potential customers when the total population adoption rate is 0.5
Product strategy via product life cycle simulation

Figure 18: Simulation of customers when the total population adoption rate is 0.02

Figure 19: Simulation of customers when the total population adoption rate is 0.5

Sensibility analysis of investment in direct communication

In the proposed model, the percent of investment in communication is mentioned as a lookup variable. It includes percentages which change during the time. Such percents are according to amount of investment of the producer in this field and it is in the range of 0 to 100 percent. The behavior of this variable while it increases over the time and its effect on the other variables is shown as Figure (20-23):
Finishing the sensibility analysis, a system dynamics model for product life cycle was proposed which can be used to predict the sales of the product in future.

- **Changing the initial value**

Another way to test the model is changing the stock variables. It usually perceived that model behavior of changing in initial value of stock variables in comparison with other parameters has been influenced Changing the stock variable initial value of the potential customers, has an effect on product life cycle-at first ,for simulation initial value decreased from 1500000 to 500000 and then it increased up to 3500000.Figures 24 and 25 show the result of changing in initial values.

![Figure 22: Simulation of adoption from advertisement direct communication increased](image1)
![Figure 23: Simulation of adoption from when the advertisement when the direct communication increase](image2)

![Figure 24: Simulation of potential customers when the initial value is 500000 and 3500000](image3)
4. Proposing the strategy of the product

Two scenarios in the favorable and unfavorable circumstances were proposed in this paper. The results of them are shown below. Then according the scenarios and the sensibility analysis a new strategy was proposed in order to increase the sales. Comparing the results, we concluded that with modifying the investment in communication, total population adoption rate (the factors affecting this variable do not mentioned) and increasing the product quality (to become closer to the accepted quality of the customers) this product enter the maturity stage at the time 70. But if the mentioned variables decrease the product life cycle curve will be changed and become as it is shown in Figure 26. As it is seen in the Figure 27, under the unfavorable circumstances, the sales at the maturity stage become about 75,000. That is by far less than the real model.

Figure 25: Simulation of product life cycle when the initial value of potential customers is 500,000 and 3500

Figure 26: Simulation of adoption rate
Figure 27: Simulation of product life cycle in the in the favorable and unfavorable circumstances
Drafting the product strategy

In the previous section, the results of the favorable and unfavorable circumstances were discussed. While, in the real world, the decisions which are taken by the managers regarding the competitors strategies could not be predicted by portraying the merely favorable or unfavorable situation. But the fact is that managers try to expand the life of the product and increase the sales. According to the results of the sensibility analysis of the key variables, below strategies are proposed:

1. From the time 50 the investment in communication should be increased up to 80 percent.
2. Expanding the average time that the product exists in the market up to 150 month will lead to increase the sales at the maturity stage up to 140,000. But increasing the average time more than 150 month will decrease the sales.
3. As it was mentioned in this paper, the total population rate is 20 percent. This rate depends on many different factors like competitors, advertisement and other issues which are not stated in this model. According to the producer’s estimation, market study, the result of the factors is 20 percent. If we can improve this rate through investing on the mentioned factors, the total population rate will be increased to a great extend.
4. Based on the data in sensibility analysis, changing the compatibility to the customer’s accepted quality and customer’s accepted price, the sales of the product at the maturity stage will be increased. But after analyzing the results we observed that changing the price of this product, to become acceptable by customers, is more effective in increasing the sales than changing the quality. So it is proposed to be more alert to the accepted price of the customers from the 50th time.

5. Conclusion

Different variables that may affect the rate of product sales during its life are shown in this paper. Reviewing the literature, the authors attempted to produce a working system dynamics model concerning the product life cycle that could be used to enrich current mental model among the strategy makers. This paper attempted to show the most important factors affecting the product life cycle and below recommendations will help to produce workable results. As it is stated above, many variables can affect the product life cycle during the time. For simplifying the model making and its analysis and also because of the existing limitations, some of the factors which play important role are taken into the consideration and studying the rest factors are upon other researchers. Resorting such factors will enable them to make more accurate and comprehensive simulation models. In this paper, it assumed that satisfaction exists or does not exist regardless of the effect of its increasing or decreasing. Studying this matter in future will be a key to make more appropriate models in this field. Several factors can affect the customer’s satisfaction and loyalty. Simulating such factors can be a goal of the future studies. Regarding the fact that many of the factors which affect the potential customers to choose the products are qualitative, running the model with the Fuzzy data can be done in future studies.
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