THE STUDY OF DYNAMIC SIMULATION ON PRODUCT DIFFUSION AND COMPETITION

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ABSTRACT

The objective of this study is to investigate product diffusion and competition based on the theory of innovation diffusion and ant colony theory using the discrete event simulation technique of artificial world. This study fit the traits with consumer and products to get the satisfaction and convert diffusion of word-of-mouth and the mass media, and metaphor the pheromone of ant colony theory. In addition, to produce the behavior of purchase that consumers based on accumulated pheromone to correspond amount of cumulative possibility. The model is modified by diffusion model and become the pattern of multiple generation products diffusion, competition, and experiment. In the competition of dual goods diffusion experiment, the same product appeared with different results. If the no competitive products included in the competition experiment of dual goods, two products that gap merchandise in the original competition in the market to produce dogfight phenomenon. In addition to explain the slight differences in individual behavior to affect the overall trend, also illustrates

some useless factors can play the key role of the system. This research is mainly established a model that can study overall complex phenomenon through a micro-interaction between the individual consumer.

KEYWORDS: Diffusion Model, Competition, Ant Colony Theory, Artificial World.

INTRODUCTION

The study of product diffusion is one of important issues in marketing. Bass (1969) was representative study of diffusion. Afterwards, most of study was found of the model, and import some variable of market or apply in the transnational study or diffusion of multiple generation products (Nigel and Towhidul, 2006). However, the behavior of product diffusion actually was a process that individual customer do the most advantageous decision for his own goal. Customers are an individual that act on their own (Kotler, 1994). They make strategic decision and actions on their own. In fact, the process of product diffusion is the aggregation of interaction that individual customer interacts with others and customers interact with merchandise. For previous study, the whole appearance only can be explained, yet micro phenomenon.

Hence, the study adopts simulation technique of article world that simulate for individual level in dynamic way for complex system of product. In other words, all customers interact with merchandise individually, and customers interact with each other to observe phenomenon of whole diffusion simulate in decrease by time. The objective of the study is to adopt the simulation transform the public price that traits of product fit with traits of consumers. Also, it analogies pheromone of ant colony theory (ACT) by integrate mass media (Dorigo et al., 1996). Besides, customer produce behavior of purchase by accumulated pheromone correspond chances of purchase. The model of this study becomes the pattern that many kinds of merchandise diffuse and complete simultaneously by modifying model of

diffusion.

The method of this study that adopt article world is not that emphasize how to react every module subtly in the real world, but that extract the important performance. It builds the interaction of every module to observe dynamic behavior and possible consequence in utilizable way on its own. There are three parts as follows. First of all, background review. Second, it could be explained by the structure of model and the way of utilization. Also, it could be experimented three types of experiments by the structure. Finally, the conclusion is induced by experiment, and the structure of suggestion in the future is proposed.

LITERATURE REVIEW

Bass (1969) is the main pioneer of Diffusion Module in diffusion of marketing. It supposed to potential receivers of new product is affected in two propagation mode, one is mass media (Fourt and Woodlock, 1960), and others are only affected by word-of-mouth (WOM) (Mansfield, 1961). However, it focuses on three parts in the following 25years. First, it bring market variable. Second, it considers different countries and period. The last one is many generation diffusion of technique (Nigel and Towhidul, 2006). However, it is a complex structure in environment that much product and consumers compose marketing (Goldenberg et al., 2001); the method ignore the process of feedback and cannot be known how to affect and response in time deferral by the way of cause and effect. Sterman (1989a; 1989b) thinks that feedback is most important in dynamic and complex circumstances. Goldenberg et al. (2001) further points that diffusion module and relative survey is an aggregate estimate and observation rather than individual correlation. We can loosen homogeneity to heterogeneity for consumers in diffusion module in simulative way. We also see individual supposition or behavior how to affect the whole consequences.

Sendil and Daniel (2004) emphasize on the survey of complex and interactive system

is one of core study in management and social society. The simulative method of article world is a method that survey social phenomenon (Terano, 2000).   As the above mentioned, Terano (2000) confer interactive survey of electronic social group. Chen et al. (2002) build an interactive system that employee and leaders to confer how to get with each other, yet Dolnicar et al. (2005) thinks that the effect of organization use different market segmentation to competition.

RESEARCH FRAMEWORK

The model is to study product diffusion of competition with the theory of diffusion of innovation with theory of social vulnerable groups, and the framework as Figure 1. According to the theory of diffusion of innovation, enterprises affect consumers' aspiration of purchase for the first time by mass media and WOM. The study is that analogies pheromone of ant colony theory (ACT) by integrating mass media and word-of-mouth, and transforms pheromone into customers' aspiration of purchase. Besides, pheromone accumulates gradually, and customers receive transmission of mass media and recommendation of friends gradually. Information dissemination is like the place that conveys the food location in ACT. Therefore, accumulated pheromone transforms into purchase probability. Simon and Sebastin (1987) also think that mass media dissemination accumulated by time.

Furthermore, it further explains the formwork of Figure 1. If consumers decide to buy it, consumers evaluate satisfaction for product. The way of evaluation is that traits of consummation compare with difference of product for consumers. The smaller differences are the higher satisfaction. The meaning is that enterprise's launch of the product meets the needs of consumers. Higher consumer satisfaction, the more willing to engage in positive word-of-mouth spread, full of low will spread negative word-of-mouth. Weerahandi and Dalal (1992) thinks assumption that consumers are homogeneity in diffusion can exclude. In

other words, it can take the way of different character to survey for consumers. Glen and Cheryl (2005) also claims that the assumption is diffusion of operations-oriented with product attribute rather than exterior market attribute.
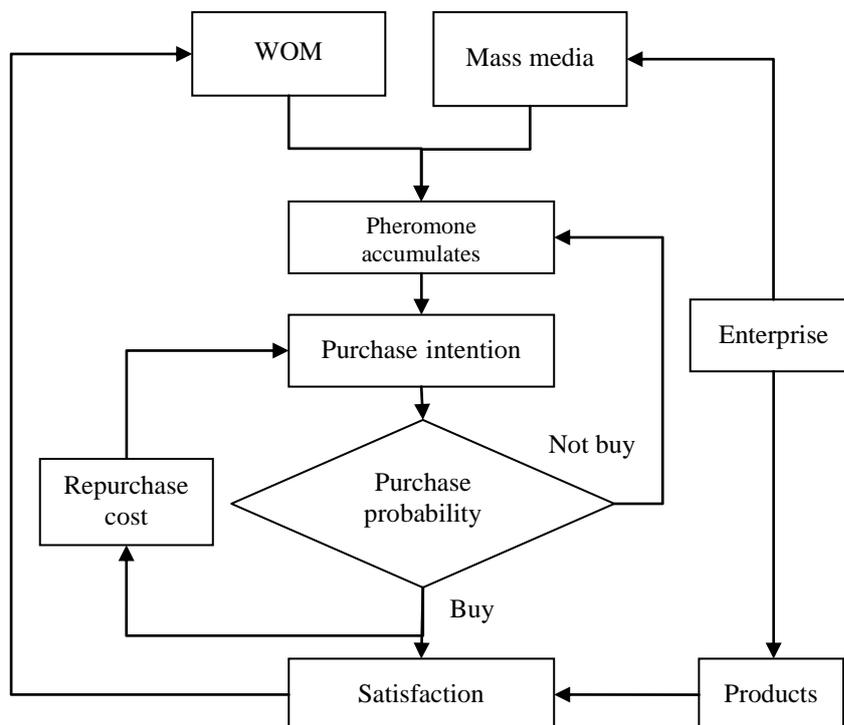

Figure 1. The research framework of present study

On the other hand, the module is a type of continuous purchase integrates with mechanism of purchase at the first time and purchase again. However, after consumers finished behavior of purchase, the probability of re-purchase is quite low. It means that the cost of repurchase is the highest, but the cost of repurchase decreases gradually. Therefore, the cost of repurchase become reduced item of purchase aspiration, and it decreases aspiration of purchase after purchase finished.

According to the above mentioned the difference of the module and Bass diffusion module as Figure1. And, the meaning of every framework as follows.

Table 1. The difference of the Bass model and the model of present study

Bass model	The model of present study
Customers differentiae the effect of mass media dissemination or WOM	Customers affected by mass media dissemination or WOM
Only estimate potential customers	Notes the interaction of single customer
It suppose that all customers' dissemination are the same	Customers' word-of-mouth and satisfaction are in positive relationship, and decrease by time
All positive dissemination	Exist positive and negative dissemination
Single product diffusion	Dual or triple products compete each other
Only analyze purchase at the first time	Analyze purchase at the first time and re-purchase at the same time
not consider the suitability of product characters and customer character	consider the suitability of product characters and customer character
Customers are homogenous	Customers are heterogeneous

The Evaluation of Satisfaction

The evaluation of satisfaction is that every customer evaluates all products according to customers' characters. The way of evaluation is that customers receive trait from products fit preference from previous, customers' satisfaction is the highest; similarly, the wide the satisfaction gap and the less the customers' satisfaction decrease.

We suppose that enterprise release standardized products to summarize the value of fixed characters that between zeros to one. Every customer all has a fixed consumption characters that between zeros to one, but customers' consumption characters are not the same (customer heterogeneity). It is supposed to a normal distribution. They show a reverse U curve between consumption satisfactions and marketing stimulation. It means that appropriate marketing stimulation can increase customers' satisfaction. On the contrary, excessive stimulation decreases satisfaction.

We take 0.5 as average, and 0.2 as standard deviation to produce 50,000 potential

customers. Therefore, every customer has different satisfaction for the same product. We suppose to the difference between customer traits and product traits. Take examples as (Fig. 2) those two customers with different average of consumption (c_1 and c_2). If the trait is P that enterprises provide, two customers give different satisfaction (S_1 and S_2).

Figure 2. The satisfaction of different consumers for the organization traits

The Pheromone of Dissemination

According to the above the evaluation of satisfaction, every customer that consumed already give the satisfaction for the product that the value between zeros and one. It is supposed to customers consume the product; it takes positive dissemination when satisfaction get high, yet it takes negative dissemination when satisfaction get low. When the satisfaction doesn't have obvious change, it doesn't take dissemination. We set satisfaction 0.5 as standard, it doesn't disseminate for 0.4 to 0.6, 0.6 over and above are positive recommendation, and 0.6 below and under are negative recommendation. Anti-linear relationship is supposed to the highest number of dissemination and satisfaction as Figure 1. The number of dissemination is to choose the highest dissemination randomly. For example, the highest number of dissemination is ten which adopt the number that 0-10 produce randomly.

Table 2. The relationship between satisfaction and the number of dissemination

Dissemination way	Backward dissemination				No dissemination	Forward dissemination			
Satisfaction	0.0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	04-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1.0
Number of dissemination	10 person	6 person	3 person	1 person		1 person	3 person	6 person	10 person

Furthermore, the survey is supposed to the radical the satisfaction, the more satisfaction, the more extreme the higher the intensity of the recommended is propagated to the other side of pheromone. The computing mode of pheromone likes (Fig.1), 0.5 is standard with satisfaction between 0-1, so the value of disseminated pheromone between -1 to 1. If the volume is positive number, it's positive recommendation. On the contrary, it's negative number. In other words, it disseminates when satisfaction is high and low. The study is to adopt the same strength for positive and negative dissemination. Therefore, the strength in the study may offset each other, but retain the chances of the negative dissemination greater than positive dissemination in the future.

$$Ph = 2 \text{ (Satisfaction - } 0.5)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Pheromone of Mass Media Dissemination

The stronger the strength of mass media dissemination, the more the number of customers affected. It is to study mass media affect the strength of customers that take the fixed proportion of potential customers as indication like innovation coefficient in Bass model. For example, if the strength of customers is 5% which means that there are 5% customers can accept the information, and customer increase pheromone for the products. The study differ from Bass model is that the strength of mass media with continuous accumulation is affected number. On the contrary, the innovation coefficient in Bass model is that the strength is

affected by mass media dissemination to decide the customer number of purchase. The strength is discreet or not. The other viewpoint is that the innovation coefficient in Bass model is fixed proportion of customers that is not consumed, but the study is proportion of all customers. Therefore, the strength of mass media dissemination is to disseminate all customers that already consumed and consumed not yet. The main concept is pheromone for intensity of mass media dissemination with word-of-mouth. Basically, the degree of mass media dissemination is tiny than word-of-mouth. Therefore, if take word-of-mouth as one unit of pheromone, it can set certain percentage for mass media dissemination. For example, if it set the relationship is 4%, it means that certain customer accept 25 times for mass media dissemination equal to one times of word-of-mouth dissemination.

Aspiration of Purchase and Probability of Purchase

One customer's aspiration of purchase means that the amount of word-of-mouth pheromone and mass media dissemination pheromone. We take the number of accumulative pheromone axis as aspiration of purchase (Fig. 4), and take probability as vertical axis. And, we select sigmoid function to transform it as the formula 2. It is set about the number of 10 pheromone unit achieve the highest aspiration 1.0 for customers. Customers have accumulative aspiration of purchase for all products, they estimate whether buy or not in this period, and only choose the highest aspiration of purchase to decide whether buy or not. The

$$f(x) = \frac{1}{1 + e^{5-x}}$$

reason of sigmoid function adoption is to explain customers diffuse one unit of praise in different period in addition to dual-approaching line, and the effect of purchase probability is different.

…..…………………………………………………….……… (2)

x is accumulated pheromone , $f(x)$ is purchase probability.
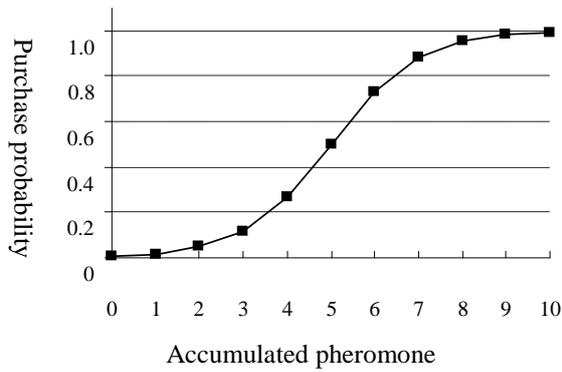
Figure 3. The relationship of accumulative pheromone and probability of purchase

The strength of mass media dissemination or word-of-mouth fades away by time, and accumulates continuously every period. Therefore, the concept likes volatilization and accumulation of pheromone in ACT. Mass media dissemination and word-of-mouth volatilized and accumulated continuously in the study, and the operational method as formula (3). Now the study set coefficient of volatilization f to 0.2., and accumulate the fifth period.

$$Ph_t^i = (1 - f) \times (Ph_{t-1}^i) + Ph^i$$

………………………………………………………..………. (3)

Ph^i : Consumer receives pheromone for commodity i during this cycle;

Ph_t^i : Consumers accumulate pheromones for commodity i at time t;

Ph_{t-1}^i : Consumers accumulate pheromones for commodity i at time $t\text{-}1$.

In the circulation of the module, pheromone is accumulated continuously. However, customers finished the behavior of purchase; the probability of purchase again is very low.

$$f(y) = 1 - \frac{1}{1 + e^{5-y}}$$

The customer has new aspiration purchase again by time. It is repurchase cost that after customers purchase certain product, it doesn't have obstruction of consumption for repurchase. Repurchase cost decrease by time. The study also adopts sigmoid function that

modified to simulate formula 4. As formula 4, when certain customer checks to purchase certain product, the repurchase cost is the highest 1, and then it decrease every period.

…………………………..…………………………….…………(4)

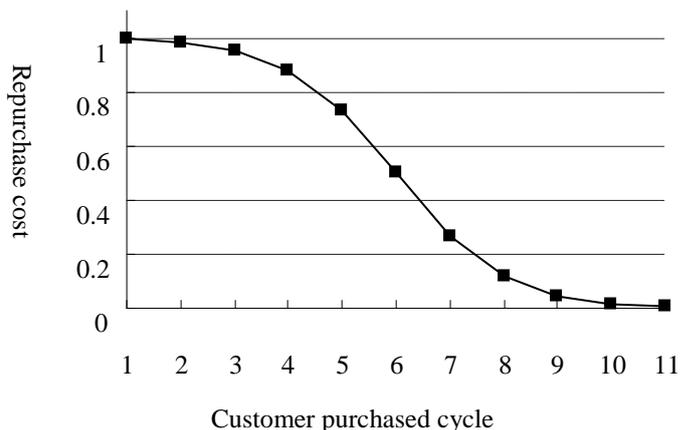Where y is the number of cycles after the purchase; $f(y)$ is the repurchase cost.

Figure 4. Relationship between repurchase cost and customer purchased cycle

CERTIFICATION OF MODEL PARAMETER AND ANALYSIS OF EXPERIMENT RESULT

According to the above framework of diffusion simulation, first of all, initial parameter experiment, then to study diffusion for many products in order. In the first step, there is traits 0.5 of products that that one product in the parameter experiment, and customers' traits take 0.5 as average; and take 0.2 as standard deviation of normal distribution randomly (the reason mentioned in the previous sections), it total 50,000. First of all, it is continuous mass media dissemination for five periods and stops it instantly to observe the diffusion of word-of-mouth. The second step, the study is to find the parameter of experiment that suit competitive experiment to do the experiment of diffusion for dual-product and tri-product. The experiment illustration of two periods as follows:

Experiment of Parameter

The study is to comprehend the effect of every important parameter in system simulation to system expression to acquire accordance of parameter selection in further experiment, and examine export of the module whether reasonable. The most important parameter is chosen in three systems as follows: (1) the degree of mass media dissemination strength. (2) The degree of word-of-mouth. (3) The proportion of mass media dissemination and WOM. It illustrate as follows.

Figure 5 is the experiment of diffusion for mass media dissemination to represent the strong and weak of effect for affected proportion of mass media dissemination every period, 5%、3%、1% adopted to study dividedly. Figure(a) is the number of consumption every period，Figure(b) is the number of consumption accumulatively. It is shown that the greater the strength of mass media dissemination diffuse, the greater diffusion is, and finished all diffusion in short time with short period of product life. (Figure 5a)The curve of diffusion likes the curve of bell, yet (Figure 5b) shows the curve of S. The above result is similar with Bass diffusion model. The peak are formed that after put in public for periods that mass media dissemination initially. It means that there are more customers try to purchase when mass media dissemination bring out certain products. However, the following behavior that people purchase depends on the appearance of the product. On the other hand, it means the characteristic of commodity whether fit customers' demand to increase diffusion of pheromone by increasing customers' satisfaction.

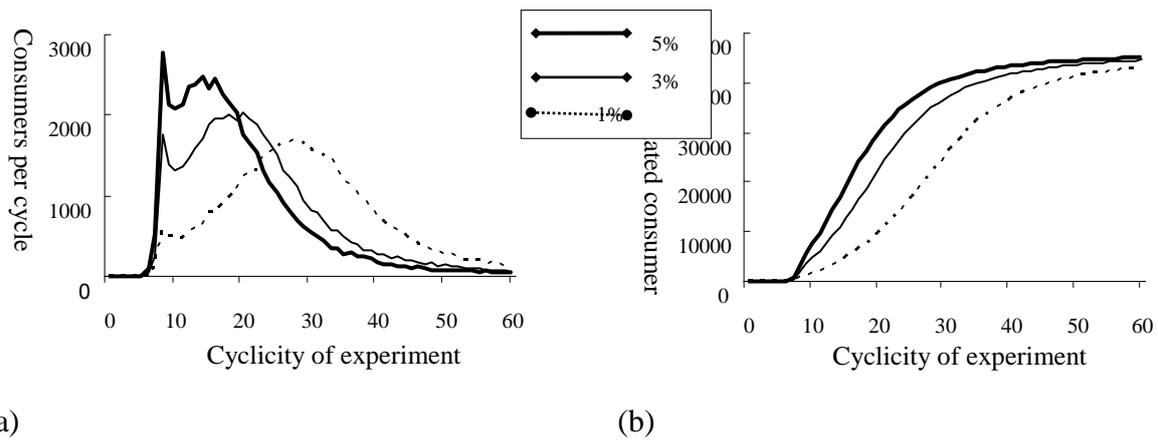(a)   (b)

Figure 5. The study of strong and weak mass media dissemination

The second experiment of parameter is set WOM in 4 units, 2 unit, and 1 unit to represent the strong, middle, and small strength of WOM. The result of study as Figure 6, the strong the WOM disseminates, the strong the diffusion is, and finished all diffusion in short time. And, it is similar to mass media dissemination.
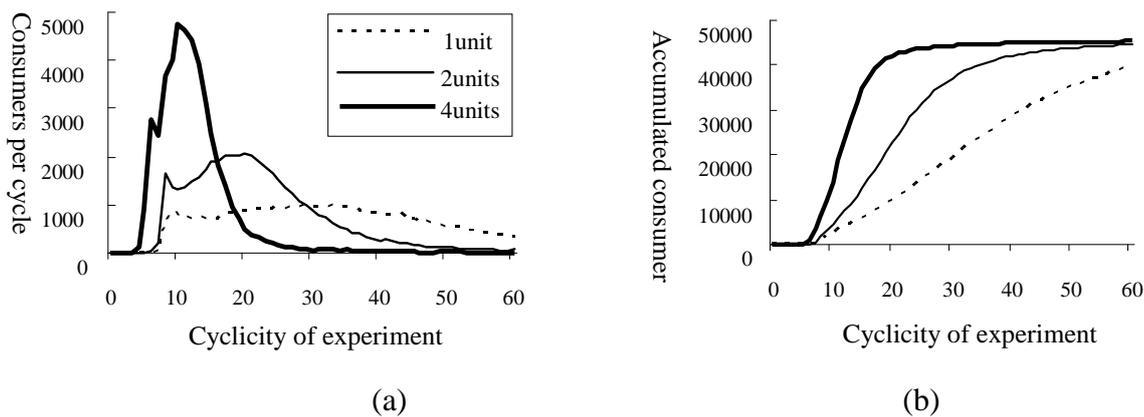

(a)   (b)

Figure 6. The study of strong and weak public praise

The third experiment of parameter is taking the proportion of mass media dissemination and WOM as objects. The difference between the first experiments of parameter is that the first experiment is breadth of marketing, and the third experiment is depth. In other words, the third experiment is the number of customers affected (the number of receiving pheromone). Take example in practice, the third one is an advertisement in a publication or broadcasting frequently that many people got known the products, yet the first one is to

increase the aspiration of purchase in low price, discounts, and sales promotion.

The result of study is figure 7 as follows. There are only has little influence on mass media dissemination and proportion of WOM for the number of consumption every period. However, the low the proportion accumulate the long the period of accumulative consumption saturation. Especially mentioned, we found that the proportion is 1%, the peak of consumption is not clear. (About the eighth period of Figure 7a). The result illustrate that it could not be appeared increase of shorten sales volume when the strength of mess media dissemination comparatively weak to judge the erroneously estimate of selling in the future. On the other hand, sales have to understand the phenomenon of selling enthusiastically when the strength of mess media dissemination is comparatively strong, and don't too optimistic for the future.
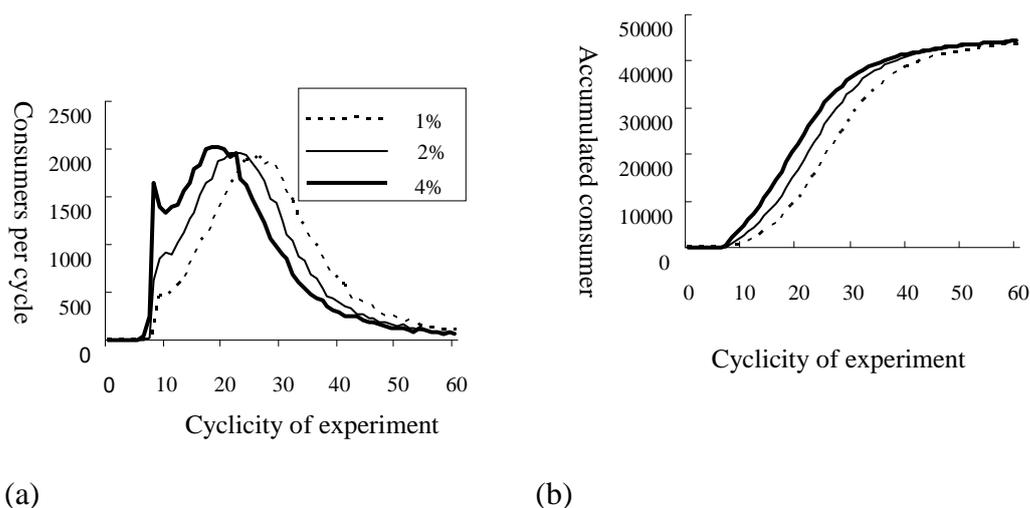

(a)   (b)

Figure 7. The proportion experiment of mess media dissemination and public praise

The Experiment of Dual Product Competition Diffusion

The above experiment of parameter is the foundation of following experiment by selecting the parameter of measurement and comparative value. The effect of mess media dissemination is 3% every period, WOM is 2 units, and the strength of mess media dissemination is 4% of WOM. Consumers' trait is to distribute 50,000 with 0.5 as average,

and adopt the technique of public sales dissemination in the first five weeks.

First of all, we do the competition diffusion of dual product. There are three parts to observe the effect of product traits to diffusion: different product, similar product, same product. It is supposed that the trait of different product is 0.5 and 0.2. The former product fit most customers' trait (customers' traits is normal distribution of 0.5 averages), yet 0.2 products not fit the product of customers' demand. On the contrary, similar product adopt the traits is 0.5 and 0.6. Same product set 0.5 for two competitive product traits. The result of above three competitive diffusion experiment is Figure 8, Figure 9, and Figure 10.

Figure 8 shows the enterprise that bring out 0.5 products to strive for more customers. However, after mess media dissemination the 0.2 product, the sale number of the sixth period and enterprise of 0.5 products instantly, but the number of consumption decreases because WOM cannot be brig out. If we change product 0.2 into product 0.6 as the result of figure 9 that shows competitiveness of enterprise for the company of 0.6 and 0.5. There are obvious difference appeared until the fifteenth period with more accumulative number of consumption than 0.2 products. In the following figures, it explains the reasonable phenomenon of the product in the module close to the diffusion of consumption traits.
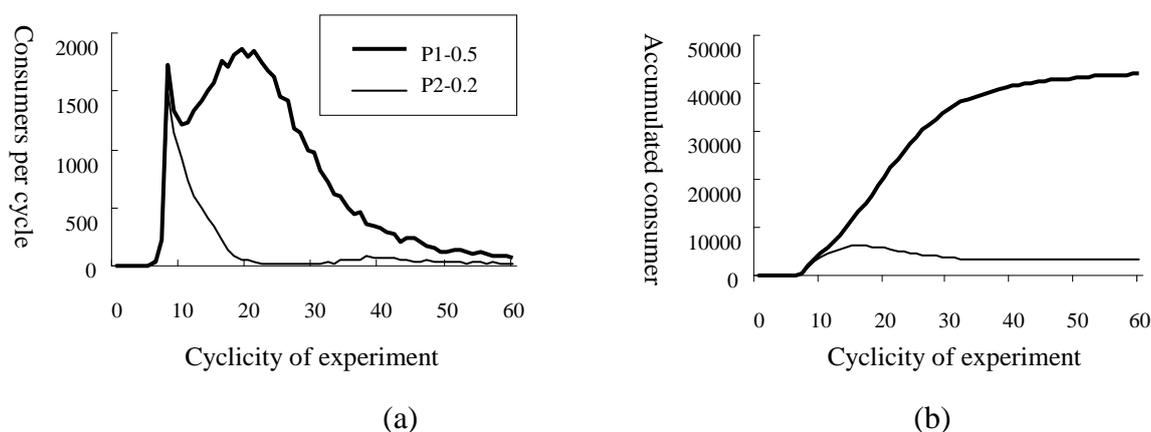

(a)　　　　　　　　　　　　　(b)

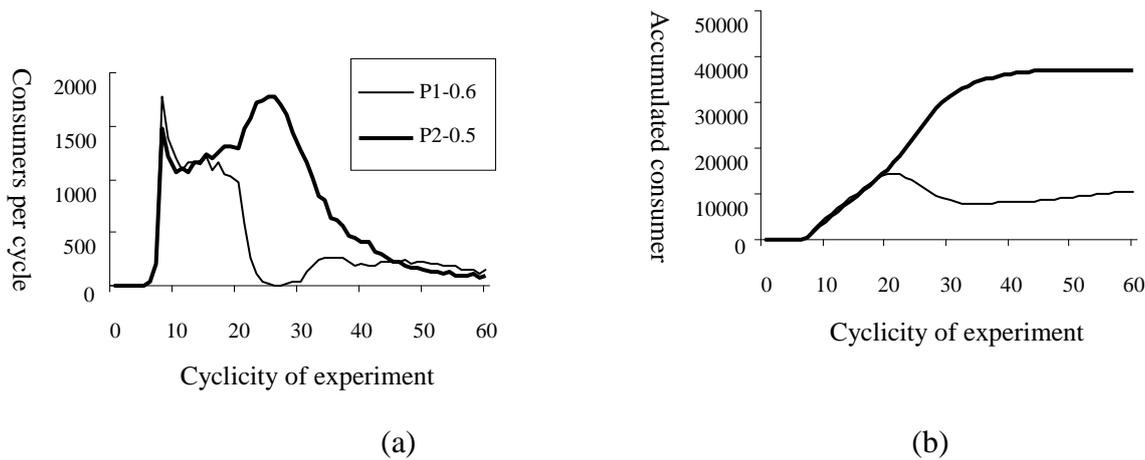Figure 8. The diffusion experiment of different product competition

Figure 9. The diffusion experiment of similar products traits compete with each other

Figure 10 is the result for diffusion competition experiment of two similar product traits. It is different from general module is that all consumers are not divided equally with victory or defeat. Due to the module is the whole phenomenon that integrates with interactive behavior of individual consumer. Therefore, it might be affected by little difference in individual difference to affect the trend of whole consumption.
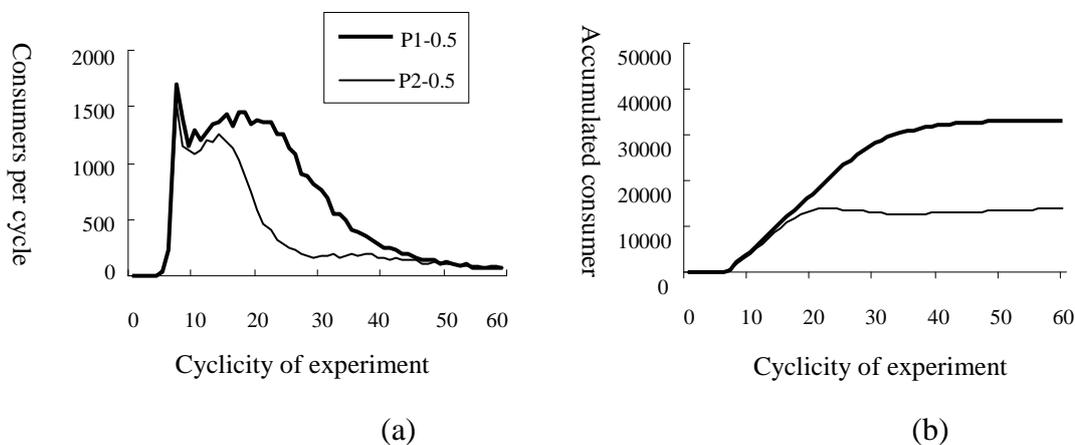

Figure 10. The diffusion experiment of similar products traits compete with each other
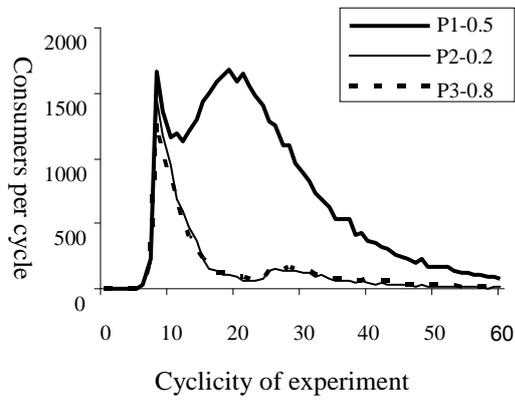
The Experiment of Three Product Competition Diffusion

If we increase three competitive businesses, above phenomenon appeared. We choose the product that more difference to do the competition which one strong and two weak as figure
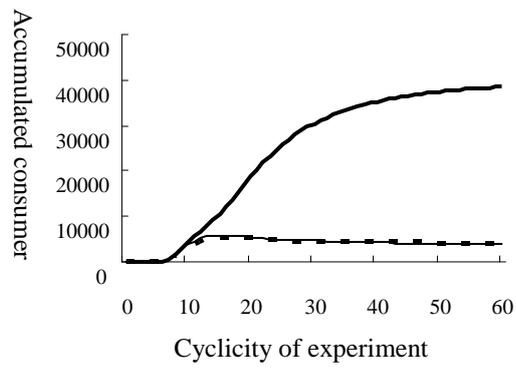
11. The traits of product are set by 0.5, 0.2, and 0.8. One of business that totally fit consumers' product is 0.5, yet 0.3 product that consumption normality distribution differences are 0.2 and 0.8. The result of diffusion competition shows that the result of Figure 8(a). In other words, the diffusion process of more difference product 0.2 and 0.8 are almost overlapped, and cannot be compete with 0.5 products.

If we change 0.8 products into 0.6 products that close to consumers' demand, the special phenomenon are appeared like figure 12. Although the diffusion style of 0.6 products is similar to 0.2, the strength of WOM is appeared slowly after 10 weeks to produce more competition than 0.2 product with the number of consumers between 0.5 and 0.2.

However, the peak of diffusion 0.5 falls suddenly after the twenty weeks, but the diffusion of 0.6 product rises again, falling behind to staying even 0.5 product in the 26 period, and get ahead quickly to become the pattern of competition that similar to substation. Then, the number of accumulated consumption almost gets ahead 0.5 products in the 40 period (Figure 11b). Moreover, we do the second study in the same conditions and get the same result as Figure 13. We further found that 0.6 products and 0.5 products almost get entangled in the beginning, and keep pace with 0.5 products continually. At last, 0.6 products follow and behind the number one product closely in little distance. In the same words, the competition of 0.5 and 0.6 products is dual-product competition that compare to above experiment of Figure 9. Nevertheless, it plays an important role after 0.2 products that uncompetitive get involved in the study. As the saying goes, be more a spoiler than a helper, it may be a pattern of thought of competitive strategy.
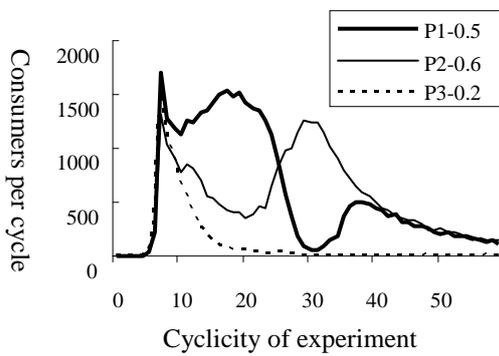
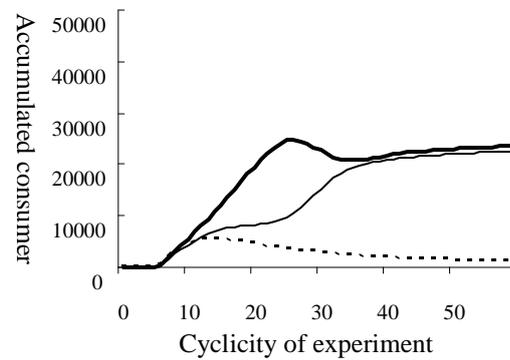(a)   (b)

Figure 11. The diffusion experiment of similar product traits compete among three product

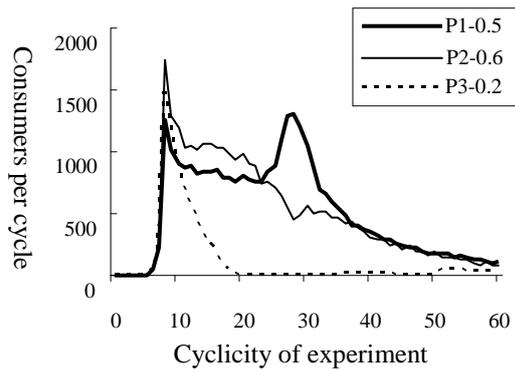(a)   (b)
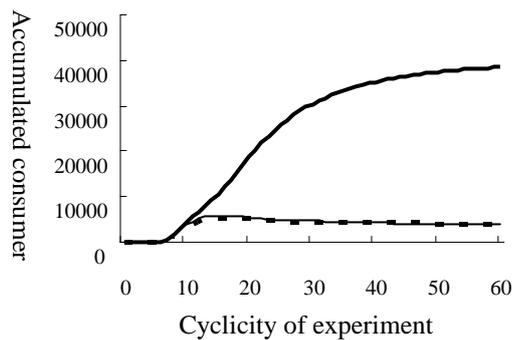
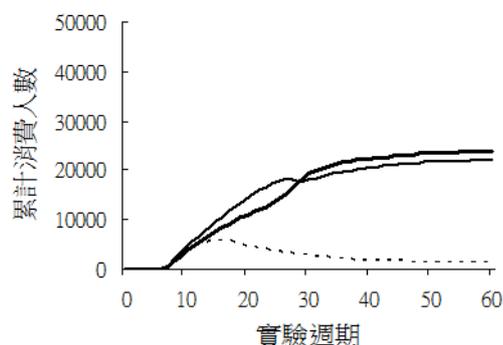Figure 12. The study of dissemination of strong, middle, weak products of experiment 1

(a)   (b)

Figure 13. The study of dissemination of strong, middle, weak products experiment 2

CONCLUSION

The study quote system simulated method of artificial world to do diffusion study of two stages. In addition to the fit of examine pattern and suitable experimental parameter with strong public dissemination in the three parameter study in the first step, marketing sales have to know that the phenomenon of hot sales and it can't be over optimistic for the future. Besides, there is study of dual product competition in the second step. The two same product traits of diffusion competition are still loses and gains rather than getting the result that divide all consumers equally like general pattern. The little difference in individual behavior may affect trend of whole diffusion, because the model integrate with whole phenomenon by individual consumers' individual behavior. Although the study cannot be analyze the reason of phenomenon appeared, for the model, it get the result that differ from general research method and provide and confer the probability of reasons that appears.

In the experimental type of tri-product, we found that it plays a key role after adding the third products that uncompetitive in competitive market dual product originally, so two products with large sale drop become the pattern that compete with each other. It is similar to the process of complex and dynamic competition in real world. For enterprise, it is a thinking pattern of innovative strategy that adopt be more a spoiler than a helper. Schelling (2006) also responds to the result, slight motivation and behavior may initiate great view. Ordeshook

(1986) also thinks that the only correct way of understanding community actions is to understand individual how to do each decisions for own goals. Although the model of study only is a framework that initial consumer integrate with products, yet there are some phenomenon that uneasy to experiment and analysis appeared. The model only interpreted in analog way, but the diffusion study is an understanding of diffusion (Nigel and Towhidul, 2006).

We can supposed to products that bring out couldn't fit the consumers' demand in the future research, and change the property of communities gradually to simulate diffusion of polybasic communities in the experimental period. Besides, Apart from that, this model can also be added into external research of the product network, to add the purchase quantity into the willingness of consumer purchase, where, when the willingness increases with respect to the accumulated sale out quality. This perhaps can help to simulate the explosive effect of a killer product.

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