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Full Length Research Paper

An optimization model of product line rollover: A case study of the notebook computer industry in Taiwan

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As product life cycles become shortened, companies frequently launch new products and discontinue existing ones. Companies with large and complete product lines do not have the extra resources to extend them, so they must plan successful product rollover schemes that launch new products and discard existing ones simultaneously. In previous studies, new product launch schemes and existing product discontinuation strategies have been considered separately (two-phase model). This study modifies the product line design model formulated within a conjoint analysis framework to obtain an optimized model of product line rollover and proposes a genetic algorithm to solve them. The product line rollover procedure in the proposed model is achieved in one phase. The results show that the proposed model takes into account the complementarity between product additions and deletions, which helps companies with complete product lines to formulate better product line rollover schemes.

Key words: Product line rollover, conjoint analysis, genetic algorithm, complementarity.

INTRODUCTION

Due to the increasing demand for notebook computers (NB), most companies launch and eliminate NB products frequently to meet consumers' requirements. Most NB products are designed and manufactured by NB companies in Taiwan to meet the demands across the world. For the NB companies in Taiwan that are trending away from original equipment manufacturer (OEM) towards ordnance bench mark (OBM) business models, responding fast to market trends and needs will improve their brand-name recognition. This study considers the actual requirements of the NB industry to develop a one step model for product line rollover optimization.

In previous studies, new product launch schemes and existing product discontinuation strategies have been considered separately. Those procedures are called two-phase models in this paper, while design product line rollover schemes (PLRS) are referred to as step-by-step models. The two-phase procedure limits the rollover scheme design because it does not take various kinds of rollover schemes into account. Fonseca et al. (2007) suggested that the product line rollover procedure should consider the complementarity between product additions and deletions. To meet the actual requirements of companies with complete product lines, this study proposes an optimization model of product line rollovers. The model considers the effects of the addition of new products and the discontinuation of existing ones on the overall market share. However, the proposed model also considers the complementarity between the product additions and deletions.

Previous studies on product line rollover have focused on strategy analysis and not the design of optimal rollover schemes. Many studies (Greenley and Bayus, 1994; Billington et al., 1998; Krishnan and Ulrich, 2001; Lim and Tang, 2006; Pasandideh and Niaki, 2008) assume various situations to analyze various product line rollover strategies. They divide the product development region into a variety of research domains. Within these research domains, the product line rollover is a domain of great importance. An empirical study (Greenley and Bayus, 1994) was conducted to provide qualitative data on American and British firms to help formulate a conceptual model of product line rollover strategies. Lim and Tang

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(2006) developed optimal models to determine the best times to launch new products and to discontinue existing ones.

Many studies have focused on strategy analysis of product discontinuation (Hart, 1989; Anlonitis et al., 2003), product line extension (Kadiyali et al., 1999), product line rollover (Greenley and Bayus, 1994; Billington et al., 1998; Lim and Tang, 2006) and scheme selection of product line extension based on consumer preferences (Kohli and Krishnamurti, 1989; Nair et al., 1995; Azarm and Li, 2002). These product line design models obtain the optimal scheme for a new product launch through measurements that reflect individual consumer values and preferences. However, these models do not meet the requirements of an optimal scheme selection for product line rollover. As a result, companies must wait until new products are launched to decide on a suitable existing product discontinuation scheme based on actual or simulated sales.

The method proposed in the present study is an extension of product line design model to the product line rollover problem. However, it is well known that the product line design problem is NP-hard (Kohli and Krishnamurti, 1989; Alexouda and Paparrizos, 2001). For this reason, many researchers have proposed heuristic procedures to solve the problem. Balakrishnan and Jacob (1996) developed a genetic algorithm (GA) for the single product design problem, while Steiner and Hruschka (2003) proposed a GA for the product line design problem.

The rest of this paper is organized as follows. The product line design optimization model (Kohli and Sukumar, 1990), which is based on consumer preferences, is modified to obtain the optimization model of product line rollover in this study. This study contains a formal description of the GA for the optimization model of product line rollover. Also, it compares the results of both the proposed and two-phase models and discusses the reasons for the differences. Finally, it contains the conclusions.

Problem formulation

This study develops an optimal integer programming model to solve the product line rollover problem. The model is based on the share of problem choices in product line design (Kohli and Sukumar, 1990; Alexouda, 2004). However, the number of buyers who would choose one of the candidate items of the PLRS is maximized.

The production capability and shelf space of companies with complete product lines are nearly saturated. Since existing product lines cannot be extended, they must be reviewed from the perspective of a product line rollover. Unlimited product variety is not a good strategy (Alam et al., 2010). During the course of a product line rollover, new products will use the company's production resources and shelf space. Companies with complete product lines do not have the extra resources required to launch new products without discontinuing existing ones. As a result, they must thus plan a successful PLRS that launches new products and eliminates existing ones simultaneously.

This study proposes a product line rollover model that considers product launch and discontinuation simultaneously. The product line rollover problem is formulated as a 0 - 1 integer programming problem using a conjoint analysis framework. The optimal PLRS of the proposed model includes a new product launch scheme and an existing product discontinuation scheme. Products are described using attributes and attribute levels. The part-worth utility of each attribute level for buyers is estimated using conjoint analysis. However, a method that links each attribute level directly to buyers' preferences is introduced. The model evaluates what kinds of product each buyer likes and dislikes using part-worth utility.

The proposed model designs an optimal PLRS in one phase that takes complementarity into consideration, in which the results are better than those of the two-phase model. The appendix contains a formal description of the proposed model for product line rollover optimization.

A GENETIC ALGORITHM FOR THE OPTIMIZATION MODEL OF PRODUCT LINE ROLLOVER

Due to the fact that the proposed model is an NP-hard problem, it is impossible to solve real-sized problems in a reasonable time using methods that guarantee a global optimal solution. This paper proposes a GA to solve the proposed model. The proposed method is an extension of the product line design model used to address the product line rollover problem.

In the formal description of the GA, the expected market share that is maintained in matrix $TOTAL\_SOC_R$ is used for the fitness evaluation of the population elements (PLRS $r \in R$). Figure 1 shows the flowchart of the PLRS $r \in R$ fitness evaluation.

For each individual, $i \in \Theta$, the maximal utilities of the competitors' products are stored in matrix $COMPU_I$, while matrix $EXIPU_{IN}$ maintains the part worth utilities of each product, $n \in \Lambda$, in the existing product line. R denotes the set of the candidate, PLRSs, which includes new product launch schemes and existing product reserve schemes, while $Num = |R|$ denotes the population size. The population is maintained in matrix POP_{R*M*K} and POP_{R*N}. The elements of POP_{rmk}, which are $r \in R$, $m \in \Psi$ and $k \in \Omega$, denote the selected level of each attribute, that is, if level $j \in \Phi_k$ of attribute $k \in \Omega$ is assigned to product $m \in \Psi$ of PLRS $r \in R$, then $POP_{rmk} = j$. The elements of POP_{rn}, which are $r \in R$ and $n \in \Lambda$, denote the reserved product of the existing product line, that is, if existing product $n \in \Lambda$ is reserved

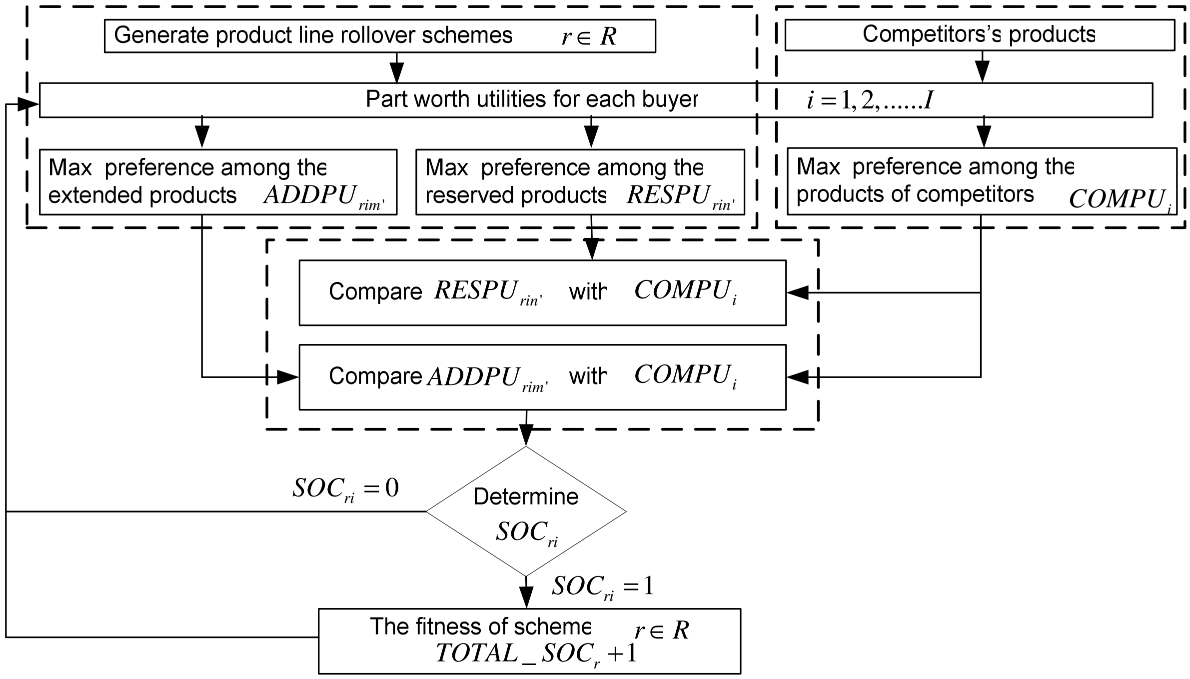

Figure 1. Flowchart for fitness evaluation of PLRS $r \in R$.

in PLRS $r \in R$, then $POP_{rn} = 1$, otherwise $POP_{rn} = 0$. The initial population of candidate PLRSs is randomly generated and stored in matrix POP_{R*M*K} and POP_{R*N}.

The fitness of the population is evaluated according to the market share maximization criterion. Matrices $ADDPU_{R*I*M}$, $RESPU_{R*I*N}$, SOC_{RI} and $TOTAL\_SOC_R$ are computed in order to evaluate the expected market share of the PLRSs. For each buyer $i \in \Theta$, matrix $ADDPU_{R*I*M}$ maintains the utilities of the different M launch products of each candidate PLRS $r \in R$, and matrix $RESPU_{R*I*N}$ maintains the utilities of the different $N - D$ reserved products of each candidate PLRS $r \in R$. As was mentioned previously, the element w_{ijk} denotes the part worth utilities associated with level $j \in \Phi_k$ of attribute $k \in \Omega$ for buyer $i \in \Theta$. The different M launch products of each candidate PLRS $r \in R$ can be computed as follows:

$$ADDPU_{rim} = \sum_{k \in \Omega} w_{i(POP_{rmk})k}$$

where $r \in R$, $i \in \Theta$, $m \in \Psi$.

The different reserved products of each candidate PLRS $r \in R$ can be computed as follows:

$$RESPU_{rin} = EXIPU_{in} \times POP_{rn}$$

where $r \in R$, $i \in \Theta$, $n \in \Lambda$.

If the existing product $n \in \Lambda$ is eliminated in PLRS $r \in R$, then $RESPU_{rin} = 0$.

Let m' denote index m such that

$$ADDPU_{rim'} = \max_{m \in \Psi} ADDPU_{rim}$$

where $r \in R$, $i \in \Theta$;

Let n' denote the index n such that $RESPU_{rin'} = \max_{m \in \Psi} RESPU_{rin}$,

where $r \in R$, $i \in \Theta$.

If $ADDPU_{rim'} > COMPU_i$ or $RESPU_{rin'} > COMPU_i$, that is, if buyer $i \in \Theta$ would buy one of the items of the PLRS $r \in R$, then $SOC_{ri} = 1$, otherwise $SOC_{ri} = 0$.

The number of buyers of each candidate PLRS $r \in R$ is stored in matrix $TOTAL\_SOC_R$, and can be computed as follows:

$$TOTAL\_SOC_r = \sum_{i \in \Theta} SOC_{ri}, \quad where\ r \in R$$

The GA in this study can be formally described as follows:

Step 0: Input module

Input data: $COMPU_I$ and $EXIPU_{IN}$

Step 1: Initialization module

Generate an initial population of candidate PLRSs and store the population in matrix POP_{R*M*K}.

Step 2: Evaluation module

Evaluate fitness for the initial population and compute matrices $ADDPU_{R*I*M}$, $RESPU_{R*I*N}$, SOC_{RI} and $TOTAL\_SOC_R$ as described in this study. The last element in sorted matrix $TOTAL\_SOC_R$ corresponds to the best candidate scheme. The flowchart for the fitness evaluation of PLRS is shown in Figure 1.

Step 3: Sorting module

Sort the elements in matrix $TOTAL\_SOC_R$ and choose the best candidate scheme for the initial population.

Step 4: New population generation module

Selection: Choose the (40%) N best candidate schemes and then choose the elements that correspond to the (40%) N last elements of the sorted matrix $TOTAL\_SOC_R$.

Crossover: Randomly create (20%) N pairs of candidate schemes from the ones created in the (40%) N best candidate schemes from 'selection'. Perform the uniform crossover operator on these pairs to generate (40%) N new candidate schemes.

Mutation: Randomly pick (20%) N candidate schemes from the (80%) N candidate scheme set, which was created in selection and crossover. Randomly alter values at random string positions of each candidate scheme.

Step 5: Stopping module

Repeat steps 2 - 4 until the best candidate scheme does not improve in 50 consecutive iterations.

CASE STUDY

The proposed model takes into account the complementarities of consumer groups that are attracted to possibly discontinued and launch products. The PLRS is the best combination of both the discontinued and launch products. With regard to the PLRS obtained from the proposed model, the launch product has a very strong appeal to consumers who originally preferred the eliminated product and competitor's product effectively. The proposed model considers all combinations of both launch and discontinued products; hence, the resulting PLRS has the best market share expansion capability.

The optimization models, proposed by previous scholars, carry out product line rollovers in two phases. It is either they introduce new products first and then discontinue old ones, or vice versa. The PLRS obtained from a two-phase model is meant to ensure that launch and discontinued products create the largest possible new market expansion and the lowest possible old market share loss, respectively (Alam and Khalifa, 2009). However, the PLRS in the two-phase model does not consider whether consumer groups attracted to the launch products and the possible discontinued products are complementary to each other. This PLRS is not necessarily the optimal solution.

Here, it uses real cases to simulate the results of product line rollover models and uses real numeric values to illustrate the aforementioned situations. This study uses the leading brand in Taiwan's NB industry as the example company and attempts to find its optimal PLRS. In this process, the study collects consumer preferences and information about existing products in the market. The optimal PLRS uses two two-phase models as well as the model proposed in this study. This study compares the differences between these three models and analyzes the reasons for their differences. It also uses one product rollover in an existing product line to explain the differences between the proposed model and the two-phase model.

Data collection

An online questionnaire (http://140.116.74.4/ox/NB.htm) was used to collect data about consumer preferences in Taiwan from January - May 2007. The consumer preference data was used to analyze the results of the three models. The example company has a large and complete product line and has held the largest NB market share for a long time. The product profile and market share of each existing product sold by the example company are shown in Table 1.

A total of 342 responses were collected using the online questionnaire and 256 responses were validated. The proposed product line rollover model and Alexouda's product line extension model were programmed, in visual C++ 6.0, on a computer with a 2.8GHz Pentium (R) 4 CPU and 1 GB of RAM running Windows XP to obtain the optimal schemes. Five product attributes (K = 5) were matched and they were: case material, battery, backlight, hard disk and size. The sixth attribute (price) was derived by adding each attribute's price after the attribute level was selected, but not matching them randomly. The price attribute was specified as a linear variable, and a linear marginal utility for purchase prices between NTD 20,000 and NTD 120,000 was suggested. The five attributes had 4, 2, 2, 2 and 10 levels, respectively ($J_1 = 4$, $J_2 = 2$, $J_3 = 2$, $J_4 = 2$, $J_5 = 10$). The number of buyers was 256 (I = 256).

RESULTS

In product line rollover, companies must launch new products and discontinue existing ones. Previous studies have discussed new product launch schemes and existing product discontinuation strategies separately. A product line rollover procedure that uses these studies as a basis must be carried out in two phases (two-phase model). Two-phase models can be divided into two types:

Table 1. The existing product line of the example company.

Index of existing products	Product attributes and levels						OMS (%)
	Size (inch)	Case	Battery	Backlight	Hard disk	Price	
1	7	Plastic	LI	CCFL	HDD	48,000	2.73
2	11	Metal	LI	LED	HDD	66,000	7.03
3	12	Plastic	LI	CCFL	HDD	55,000	5.86
4	13	Plastic	LI	CCFL	HDD	45,000	3.90
5	14	Plastic	LI	CCFL	HDD	50,000	5.86
6	15	Plastic	LI	CCFL	HDD	51,000	4.69
7	17	Metal	LI	CCFL	HDD	64,000	1.56

OMS: Original market share of each product in the existing product line.

Table 2. The deletion product of the two-phase model (I).

	Index of existing products (%)						
	1	2	3	4	5	6	7
OMS	2.73	7.03	5.86	3.90	5.86	4.69	1.56
OMSTEPL	0.78	1.95	1.56	1.56	1.95	0.78	0.00
LMS	1.95	5.08	4.30	2.34	3.90	3.90	1.56

OMS: Original market share of each product in existing product line. OMSTEPL: Original market share transfer to the other products of existing product line. LMS: Loss of market share if the product was deleted.

two-phase model (I) and two-phase model (II). For two-phase model (I), the original market share (OMS) of each product in the existing product line of the example company must first be simulated. However, it eliminates the product with the least loss of market share (LMS). The model then finds the launch product with the greatest expansion of market share that belongs to competitors (EMSC) using the product line design model. In contrast, the two-phase model (II) finds the launch product with the greatest EMSC first. It then simulates the market share of each product after the launch of the new product. Consequently, it discontinues the products that result in the least real loss of market share (RLMS).

This study proposes a product line rollover model that finds both the launch and discontinuation schemes, simultaneously. The proposed model takes complementarity into consideration, so its results are better than those of the two-phase model. A product replacement in an existing product line is used to explain the difference between the proposed model and the two-phase models.

Two-phase model (I): Delete first and then, launch later

Phase one

In this phase, the OMS of each product in an existing product line was simulated using consumer preferences. The LMS for each product that was about to be discontinued was simulated and the results are shown in Table 2. The OMS of product number 7 was 1.56%, that is, the lowest among all products. If this product were to be discontinued, the market share that would be transferred to other products in the existing product line is 0.00% (OMSTEPL). Therefore, the LMS for product number 7 was 1.56%, that is, the least loss of all the products. So, product number 7 was discontinued.

Phase two

After product number 7 was discontinued, the other six products were kept in the existing product line. Using Alexouda’s model, the optimal new product launch scheme with the greatest EMSC could be found. The results are shown in Table 3. This new product (14, metal, LP, LED, HDD, 53000) could take a 4.30% market share from competitors, but it would not attract any consumers who originally chose the discontinued product in phase one (ALMS = 0.00%).

The PLRS obtained using the two-phase model (I) is shown in Table 4. This PLRS discontinued product number 7 and launched a new product. After the product line was rolled out, the EMSC of the new product was 4.30% and consumers who had originally chosen the discontinued product (OMS = 1.56%) chose other products in the existing product line (OMSTEPL = 0.00%) and in the newly launched products (OMSTNLP = 0.00 %) or in the competitors’ products (RLMS = 1.56 %). The real lost market share (RLMS = OMS – OMSTEPL - OMSTNLP) of the discontinued product was 1.56%.

Table 3. The launch product of the two-phase model (I).

Launch product attributes and levels						EMSC of launch product (%)	ALMS of launch product (%)
Size	Case	Battery	Backlight	Hard disk	Price		
14 inch	Metal	LP	LED	HDD	53,000	4.30	0.00

EMSC: Market share expansion from competitors. ALMS: Attracts the loss of market share of the deletion product.

Table 4. The rollover scheme of two-phase model (I).

	Products		PLRS
	Deletion product (No. 7)	Launch product (14 inch, Metal, LP, LED, HDD, 53,000)	
OMS (%)	1.56		
EMSC (%)		4.30	
OMSTEPL (%)	0.00		
OMSTNLP (%)	0.00		
RLMS (%)	1.56		
OMSI (%)			2.74

OMS: Original market share of each product in existing product line. EMSC: Market share expansion from competitors. OMSTEPL: Original market share transfer to other products in existing product line. OMSTNLP: Original market share transfer to new launch product. RLMS: Real loss of market share if the product was deleted. OMSI: Overall market share increase of the PLRS.

Table 5. The launch product of two-phase model (II).

Launch product attributes and levels						EMSC of launch product (%)
Size	Case	Battery	Backlight	Hard disk	Price	
14 inch	Metal	LP	LED	HDD	53,000	4.30

EMSC: Market share expansion from competitors.

However, choices made by these consumers affected the overall market share increase (OMSI = EMSC - RLMS) of the PLRS.

Two-phase model (II): Launch first and delete later

Phase one

The optimal new product launch scheme of the product line, composed of the original seven products, was found using product line design model and the results are shown in Table 5.

Phase two

After the new product was launched, the RLMS of each existing product was simulated and the results are shown in Table 6. After the new product with the greatest EMSC was launched, the RLMS of each possibly discontinued product was simulated. Product number 7 was discontinued since it had the lowest RLMS. The consumers who had originally chosen product number 7 (OMS = 1.56 %) chose other products in the existing product line (OMSTEPL = 0.00%), newly launch products (OMSTNLP = 0.00%) or competitors' products (RLMS = 1.56 %).

In this case study, the PLRS obtained using the two-phase model (II) were the same as that obtained using two-phase model (I). It can be seen in Table 7 that there are two potential reasons why the two aforementioned models achieved the same result. The first reason is that the OMS of product number 7 was significantly lower than those of the other products. As a result, product number 7 was discontinued by both models. The second reason is that the consumers who had originally chosen product number 7 did not easily switch to other products. This shows that this segment of consumers had a strong preference for this type of product. Since this segment of consumers, who prefer products of the same type as product number 7, was smaller than others and also had stronger preferences for this type of product, the reselection of these consumers did not easily affect the

Table 6. The deletion product of two-phase model (II).

	Index of existing products (%)							Launch product (%)
	1	2	3	4	5	6	7	
OMS	2.73	7.03	5.86	3.90	5.86	4.69	1.56	
EMSC								4.30
OMSTEPL	0.39	1.56	1.56	1.56	1.56	0.78	0.00	
OMSTNLP	0.00	0.39	0.00	0.39	1.56	0.78	0.00	
RLMS	2.34	5.08	4.30	1.95	2.73	3.13	1.56	

OMS: Original market share of each product in existing product line. EMSC: Market share expansion from competitors. OMSTEPL: Original market share transfer to other products in existing product line. OMSTNLP: Original market share transfer to new launch product. RLMS: Real loss of market share if the product was deleted.

Table 7. The rollover scheme of the proposed model.

	Products		PLRS
	Deletion product (No. 2)	Launch product (11 inch, Carbon fiber, LI, LED, HDD, 81,000)	
OMS (%)	7.03		
EMSC (%)		3.91	
OMSTEPL (%)	1.95		
OMSTNLP (%)	4.30		
RLMS (%)	0.78		
OMSI (%)			3.13

OMS: Original market share of each product in existing product line. EMSC: Market share expansion from competitors. OMSTEPL: Original market share transfer to other products in existing product line. OMSTNLP: Original market share transfer to new launch product. RLMS: Real loss of market share if the product was deleted. OMSI: Overall market share increase of the PLRS.

selection of the launch product.

Proposed model

The proposed model takes into consideration both the market share expansion caused by the launch of a new product and the loss of market share caused by the discontinuation of an existing product. The complementarity between product addition and elimination is a key factor that helps the proposed model to find a better PLRS than that chosen by a two-phase model. In this model, the launch and discontinuation schemes are determined in one phase. The launch product does not necessarily have the greatest, EMSC while the discontinued product is not necessarily that with the lowest LMS. Nevertheless, the combination of these two products has better complementarity.

The optimal PLRS obtained using the proposed model is shown in Table 8. This model looks for the optimal roll-over scheme for both the addition of a new product (11, CF, LP, LED, SSD, 81000) and the elimination of an existing product (11, CF, LI, LED, HDD, 66000). The proposed model considers new selections made by consumers whose original choice was the discontinued product; however, consumers selected the launch product (OMSTNLP = 4.30%) or other products within the existing product line (OMSTEPL = 1.95 %). The rollover scheme did not lose these consumers; only that the real loss was consumers who selected competitors' products (RLMS = 0.78%). Therefore, the OMSI of the proposed model's optimal rollover scheme (3.13%) was better than that of the two-phase model (2.74%).

Comparison between two-phase and proposed model

The PLRS obtained using two-phase model (I) was the same as that obtained by the two-phase model (II). The discontinued product was product number 7, which had the lowest OMS, while the launch product was new product number 1, which had the greatest EMSC. Since the consumers who had originally chosen product number 7 did not prefer new product number 1 or other products in the existing product line, both the OMSTNLP and OMSTEPL were 0.00%. The OMSI (2.74%) of the PLRS was calculated as: 4.3% (EMSC) - 1.56% (OMS) + 0.00% (OMSTNLP) + 0.00% (OMSTEPL).

Table 8. The comparison between two-phase model and proposed model.

		OMS (%)	EMSC (%)	Two-phase model (I)	Two-phase model (II)	Proposed model
Existing products	1	2.73				
	2	7.03				Deletion
	3	5.86				
	4	3.90				
	5	5.86				
	6	4.69				
	7	1.56				
Launch products	New 1		4.30	Launch	Launch	
	New 2		3.91			Launch
OMSTEPL				0.00	0.00	1.95
OMSTNLP				0.00	0.00	4.30
OMSI				2.74	2.74	3.13

OMS: Original market share of each product in existing product line. EMSC: Market share expansion from competitors. OMSTEPL: Original market share transfer to other products in existing product line. OMSTNLP: Original market share transfer to new launch product. OMSI: Overall market share increase of the PLRS.

The PLRS obtained from the proposed model and the two-phase models were different. For the PLRS obtained from the proposed model, the discontinued product was product number 2, which was not the product with the lowest OMS. Conversely, the launch product was new product number 2, which was not the product with the greatest EMSC. Nevertheless, many consumers who had originally chosen the discontinued product preferred the launch product and the products in the existing product line. The OMSI (3.13%) was calculated as 3.91% (EMSC) - 7.03% (OMC) + 4.30% (OMSTNLP) + 1.95% (OMSTEPL). Consequently, the PLRS obtained from the proposed model had the highest OMSI.

Conclusion

Complementarity between product addition and deletion is the key to finding the optimal PLRS. Two-phase models take the market expansion capability of a new product as the principle of optimization. However, they do not consider the selection made by consumers whose original choice was an existing product. Moreover, they do not take the above key factors into consideration. Even though the two-phase models can find a good rollover scheme, it is not necessarily going to be the optimal scheme. The proposed model considers selections made during the entire product line rollover process and designs the optimal PLRS in one phase. The OMSI of the proposed model's optimal PLRS is thus equal to or better than that of the two-phase models.

When a company has enough resources and its product line is not yet complete, the most aggressive product line extension scheme can be found by using a product line design model proposed in previous studies. However, if a company does not have extra resources and their product line is already complete, it must employ product line rollover strategy. Therefore, this study proposes an optimization model to help companies with complete product lines formulate a rollover strategy. The rollover strategy formulated by the proposed model is better than that formulated by the two-phase model. Besides, the decision-making process of the proposed model is simplified.

NB companies in Taiwan, which are known for their flexible product design and manufacturing and their proficient utilization of new technologies for designing PLRS can not only help to expand market share, but also enhance brand image. NB companies in Taiwan may gain immediate competitive advantages if they can efficiently design and manufacture products that reflect consumers' preferences. Regarding operating practice, attention should be paid to the number and characteristics of survey participants, so that different segments of the market can be considered in the product line rollover problem.

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Appendix

The proposed product line rollover model is an extension of product line design problem. Variables D, d_{in} and z_n are added to denote the deletion and reservation of existing products, so that the proposed model can take into consideration the complementarity between product addition and deletion. This problem can be formulated as follows:

$$\min \sum_{i \in \Theta} f_i \quad (1)$$

subject to

$$\sum_{j \in \Phi_k} x_{jkm} = 1, \quad k \in \Omega, \quad m \in \Psi \quad (2)$$

$$\sum_{n \in \Lambda} z_n = N - D, \quad (3)$$

$$\sum_{k \in \Omega} \sum_{j \in \Phi_k} c_{ijk} \, x_{jkm} + h_{im} > 0, \quad i \in \Theta, \quad m \in \Psi \quad (4)$$

$$z_n \times d_{in} + g_{in} > 0, \quad i \in \Theta, \quad n \in \Lambda \quad (5)$$

$$f_i - (\sum_{m \in \Psi} h_{im} + \sum_{n \in \Lambda} g_{in}) \geq 1 - [M + (N - D)], \quad i \in \Theta \quad (6)$$

$$x_{jkm}, z_{im}, h_{im}, g_{in}, f_i, = 0,1 \text{ integer}, \quad i \in \Theta, \quad j \in \Phi_k \quad k \in \Omega \quad m \in \Psi \quad n \in \Lambda \quad (7)$$

where

$\Omega = \{1, 2, ..., K\}$ denotes the set of K attributes, $k \in \Omega$

$\Phi_k = \{1, 2, ..., J_k\}$ denotes the set of J_k levels of attribute k, $j \in \Phi_k$

$\Theta = \{1, 2, ..., I\}$ denotes the set of I buyers, $i \in \Theta$

$\Psi = \{1, 2, ..., M\}$ denotes the set of M items in the new product addition scheme, $m \in \Psi$

$\Lambda = \{1, 2, ..., N\}$ denotes the set of N items in the existing product line, $n \in \Lambda$

D denotes the number of deletion items in the existing product line

j^*_{ik} denote the level of attribute that appears in the competitors' product, which has maximal part-worth utilities for buyer $i \in \Theta$

j^n_{ik} denotes the level of attribute $k \in \Omega$ that appears in the existing product $n \in \Lambda$ for buyer $i \in \Theta$

w_{ijk} denotes the part-worth utilities associated with the level $j \in \Phi_k$ of attribute $k \in \Omega$ for buyer $i \in \Theta$

$w'_{ijk} = w_{ijk} / \sum_{k \in \Omega} \sum_{j \in \Phi_k} w_{ijk}$ normalized part worth utilities associated with the level $j \in \Phi_k$ of attribute $k \in \Omega$ for buyer $i \in \Theta$ (each buyer's part worth utilities are normalized to sum up to 1)

$W_{in} = \sum_{k \in \Omega} \sum_{j \in \Phi_k} w'_{i(j^n_{ik})k}$ denotes the total part worth utilities associated with the existing product $n \in \Lambda$ for buyer $i \in \Theta$

$c_{ijk} = w'_{ijk} - w'_{i(j^*_{ik})k}$ buyers' relative part worth utilities (it is compared with the fondest competitors' product for buyer $i \in \Theta$)

$d_{in} = \sum_{k \in \Omega} \sum_{j \in \Phi_k} w'_{i(j^n_{ik})k} - \sum_{k \in \Omega} \sum_{j \in \Phi_k} w'_{i(j^*_{ik})k}$ buyers' relative total part worth utilities (existing product $n \in \Lambda$ is compared with the fondest competitors' product for buyer $i \in \Theta$)

Decision variables

$x_{jkm} = \begin{cases} 1 \\ 0 \end{cases}$ if level $j \in \Phi_k$ of attribute $k \in \Omega$ is assigned to product $m \in \Psi$ or otherwise.

$z_n = \begin{cases} 1 \\ 0 \end{cases}$ if existing product $n \in \Lambda$ is reserved in product line or otherwise.

$h_{im} = \begin{cases} 1 \\ 0 \end{cases}$ for buyer $i \in \Theta$, if the utility of the fondest competitors' products is higher than the utility of product $m \in \Psi$ or otherwise.

$g_{in} = \begin{cases} 1 \\ 0 \end{cases}$ for buyer $i \in \Theta$, if the existing product $n \in \Lambda$ is deleted or the utility of existing product $n \in \Lambda$ is lower than the maximal utility of competitors' products or otherwise.

$f_i = \begin{cases} 1 \\ 0 \end{cases}$ $f_i = \begin{cases} 1 \\ 0 \end{cases}$ for buyer $i \in \Theta$, if the utility of the fondest competitors' products is higher than the utility obtained in any one of the selected items of the launch and reserved products or otherwise.

The objective function (1) minimizes the number of instances in which f_i = 1; in other words, this function maximizes the number of instances in which f_i = 0, that is, it maximizes the number of buyers who obtain a higher utility from at least one item of PLRS than form any one of the competitors' products. The meaning of the constraints is as follows: Constraint (2) requires each item of the product line extension scheme to be described by one level of each attribute. Constraint (3) limits the reserved products of the existing product line to N-D items. An individual's relative utility derived from a product cannot be less than -1, and as a result, $h_{im} = 1$ and $g_{in} = 1$ are sufficient to always satisfy constraints (4) and (5). Constraint (4) forces h_{im} to be 1 only if buyer $i \in \Theta$ prefers the competitors' product which has maximal part worth utility to product $m \in \Psi$; whereas, constraint (5) forces g_{in} to be 1 when the existing product $n \in \Lambda$ is deleted or the utility of the existing product $n \in \Lambda$ is lower than the maximal utility of the competitors' products. For each buyer $i \in \Theta$, constraint (6) imposes f_i to be 1 only if both h_{im} and g_{in}=1 are for $m \in \Psi$ and $n \in \Lambda$, that is, if buyer $i \in \Theta$ prefers none of the items in both launch and reserved products.