A Service based Platform Design Method for Customized Products

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Abstract

In this paper, we propose a method for developing service based product platforms to generate economical and feasible design strategies for a product family and evaluate design feasibility within dynamic market environments. We will model design strategies for a product family as a market economy where product family platform configurations are generated through market segments based on services. A coalitional game is employed to evaluate which services provide more benefit when included in the platform based on the marginal profit contribution of each service. To demonstrate implementation of the proposed method, we use a case study involving a family of mobile products.

Keywords

Product Family Design, Service based Platform Design, Service Quality, Coalitional Game

1 INTRODUCTION

Companies that generate a variety of products increasingly utilize services to satisfy customers' needs, offer differentiated products, and survive in today's competitive market environment. Additional services provide value-added functions or activities in the life cycle of products and flexibilities in product development. Customized products or services are an important source of revenue for many companies, particularly those working with in a mass customization environment where customer satisfaction is of paramount importance. Mass customization depends on a company's ability to provide customized products or services based on economical and flexible development and production systems [1]. By sharing and reusing assets such as components, processes, information, and knowledge across a family of products and services, companies can efficiently develop a set of differentiated economic goods by improving flexibility and responsiveness of product and service development [2]. Product family design is a way to achieve cost-effective mass customization by allowing highly differentiated products to be developed from a common platform while targeting products to distinct market segments [3].

Historically, design has been adapted to changing environments, such as customers' preferences, technologies, economic situations, company's strategies, and competitive moves. Strategic adaptability is essential in capitalizing on future investment opportunities and responding properly to market trends in a dynamic environment [4]. The value of services depends on market segmentation strategies that are identified by information derived from the relationship between customer needs and service providers [5]. In dynamic market environments, the valuation of a product increases the flexibility in decision-making for developing new products or redesigning existing products and affects product life cycles [6]. To identify the valuation of services in a product family, we investigate strategic service sharing among products for designing a platform using market based decision making. Market-based product design is one way to reflect various and dynamic market environments by capturing dynamic factors, such as customer needs and trends, companies' strategies, regulations, resources, and technologies, in product design. Game theoretic approaches provide a rigorous framework for managing and evaluating strategies to achieve players' goals using their complete or incomplete information and knowledge [7].

The research presented here is motivated by the need to provide a basis of service based design methods in product family development. In this paper, we extend concepts from product family design and mass customization to service design. We use a module-based service model to facilitate product design and represent the relationships between functions and services in a product. The objective of this research is to propose a method for developing a service based product platform to generate economical feasible design strategies for a product family and evaluate design feasibility within dynamic market environments. We model design strategies for a product family as a market economy where product family platform configurations are generated through market segments based on services. A coalitional game is employed to evaluate which services provide more benefit when included in the platform based on the marginal profit contribution of each service.

The remainder of this paper is organized as follows:. Section 2 reviews related literature and background for customized family design as well as market based design decision making. Section 3 describes the proposed method to determine a service based platform for designing customized families of products using a module-based service model and a coalitional game. Section 4 gives a case study using a family of mobile products. Closing remarks and future work are presented in Section 5.

2 LITERATURE REVIEW AND BACKGROUND

2.1 Customized Product and Service Design

Modular design concepts have been applied to increase a variety of products and develop a product family that is created by adding, substituting, and/or removing one or more modules from the platform [2]. In a highly competitive market, modular design concepts can be considered as appropriate marketing strategies by providing the broadest market segment.

A typical approach to create a variety of services is to provide customers with various options and choices related to individual customer needs, which often warrant additional charges as they add value to the initial offering [8]. Based on theories and methodologies for mass customized product design, families of services and service platforms have been developed and applied to provide solutions in various customized service industries [9,10]. Meyer and DeTore [9] proposed a platform-based approach to develop new services using methods and processes for applying product family and product platform design and used this approach to define a new service platform in an international insurance company. Jiao et al. [10] discussed how design theories and methodologies for products and manufacturing systems can be applied to the design of service delivery systems for mass customization. They considered a service delivery system as a product system instead of an operational system. Perters and Saidin [11] investigated key factors for the implementation of mass customization in a services context and used service modules to represent the levels of modularization of the scope of work and process in designing mass customization processes. Li [12] introduced some concepts and assumptions for service package and service product module level in service innovation and service product development. Moon et al. [13] proposed a method to identify a service platform along with variant and unique models for service family design using a service process model and a fuzzy c-mean clustering method based on functional similarities.

2.2 Market based Design Decision Making

Market based decision making methods can provide the ability of investigating additional flexibility and strategic value in engineering design and product development. A game theoretic approach can be used as a market based method to evaluate design strategies that are affected by company's decision, competitors' action, and new technologies. A game is a description of a strategic interaction that includes constrains based on players' actions. Game theory provides reasonable solutions for various games and evaluates their properties [7, 14]. In engineering design, game theoretic approaches have been applied to model strategic relationships between designers for sharing design knowledge and solving design problems. The economic models and mathematical models of engineering design are developed and utilized to determine product design strategies for maximizing company's profits by integrating game theoretic approaches.

Xiao et al. [15] applied game theoretic approaches and design capability indices to model the relationships between engineering teams that were described as cooperative, non-cooperative, and leader/follower protocols, and facilitate collaborative decision-making during a product realization process. Fernandez et al. [16] proposed a framework for establishing and managing collaborative design spaces by combining elements of cooperative and non-cooperative behaviour, and formulating strategic and extensive games with utility theory. Lewis and Mistree [17] presented mathematical constructs for modeling a multidisciplinary design optimization problems using game theoretic principles and the compromised Decision Support Problem (DSP) in a collaborative, sequential, and isolated design environment. Huang et al. [18] described a multi-stage non-cooperative configuration game between platform products and supply chains to determine the optimal configuration decisions of a manufacturer and suppliers for mass customization, and demonstrated the applications of the proposed game and solution procedure using a series of simulation experiments and a numerical example. Moon et al. [19] introduced a market-based negotiation mechanism to support product family design by determining an appropriate number of common modules using a dynamic multi-agent system in an electronic market environment. Ford and Sobek [20] applied real options concepts to product development processes for managing uncertainty through flexibility impacts project behaviour, performance, and value. Gamba and Fusari [21] proposed a stochastic dynamic framework for valuing the contribution of modularization process and modular operations in the design of systems using real options. In the next section, we discus service-based platform design and the proposed coalitional game for product family design.

3 SERVICE BASED PLATFORM DESIGN FOR A PRODUCT FAMILY

Figure 1 shows the proposed method to determine a service based platform for a product family using a top-down and module-based approach. The proposed method consists of four phases: (1) identify market segments, (2) develop platform design strategies, (3) identify service quality, and (4) determine a platform strategy. The market study begins by establishing target markets and customers. In the initial phase, customer needs are analyzed to develop market segments for a product family. Customer needs are also used to identify required functional requirements for individual, as well as a range of products. Then, platform design strategies are developed using a modular approach. In this paper, we introduce a metric for quality that reflects how well services satisfy customers' needs through the product. After evaluating different platform design strategies using service quality and the coalitional game theoretic approach, a final platform is determined to generate a product family.

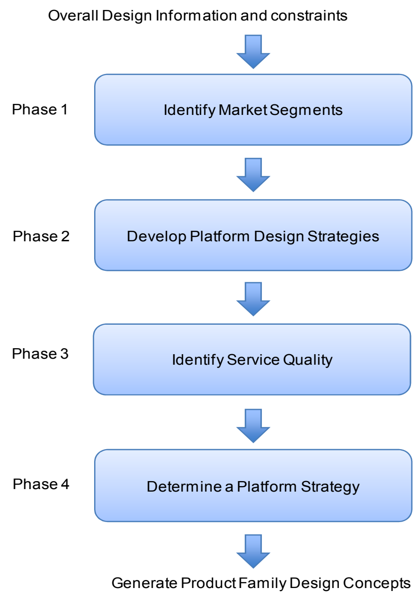

Figure 1: Service based product platform design

3.1 Phase 1: Identify Market Segments

Dividing a market into homogenous groups of consumers' preference is known as market segmentation [22]. Because a market segment provides guidelines for determining and directing customer requirements, it can be used to identify the criteria for designing a product family more accurately [23]. The basic development strategy within any product family is to leverage the product platform across products that target multiple market segments. In the initial phase, customers are classified into groups based on their characteristics and preferences. Products are also clustered as groups based on potential suitability for customers. For example, Meyer and Lehnerd [22] introduced three platform leveraging strategies based on market segments within a grid during the conceptual design phase.

In product design, customers' preference may vary based on specific functional requirements. Service preference information can help develop market segmentation for a product family by identifying an initial platform based on core common services. For example, Figure 2 shows three platform leveraging strategies for service based product family design based on approaches applied by Mayer and Lehnerd [22].

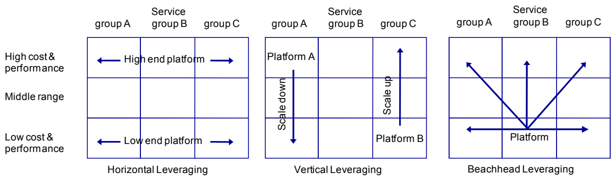

Figure 2: Three platform leveraging strategies for service based design

3.2 Phase 2: Develop Platform Design Strategies

3.2.1 Module based Service Presentation

Based on the concepts of the product module-based design [24], we assume that a service can be decomposed into service modules, which provide specific services, and the modules are achieved by the combination of product modules. As shown in Figure 3, a product is categorized into two different levels in a conceptual design phase: (1) a strategic level and (2) an operational level. The strategic level consists of service modules for developing service design strategies. The operational level is represented by product functions and provides a designer with cost information related to specific product functional modules and design strategies. To effectively define the relationships between functional hierarchies in the strategic and operational levels, an appropriate representation scheme must be adopted for the product.

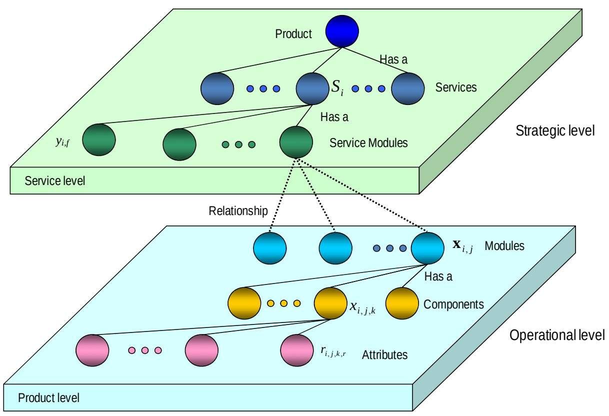

Figure 3: Product strategic and operational levels and hierarchy

Suppose that a product has I services, $P = (S_1, S_2, \ldots, S_I)$, and a service consists of f_i service modules, $S_i = (y_{i,1}, y_{i,2}, \ldots y_{i,f}, \ldots, y_{i,f_i})$, where $y_{i,f}$ denotes service module f in service i. For product modules, suppose that a service consists of m_i product functional modules, $S_i = (\mathbf{x}_{i,1}, \mathbf{x}_{i,2}, \ldots, \mathbf{x}_{i,j}, \ldots, \mathbf{x}_{i,m_i})$, where $\mathbf{x}_{i,j}$ is functional module j in service i, and consists of a vector of length nm, $x_{i,j} = (x_{i,j,1}, x_{i,j,2}, \ldots, x_{i,j,k}, \ldots, x_{i,j,n_m})$, and the individual scalar components $x_{i,j,k}$ (k=1, 2,…, n_m) of a functional module $x_{i,j}$ are called functional features. Each functional feature consists of several attributes, $a_{i,j,k,t}$ (t=1, 2, …, t_n) $\in A_i$, representing the component, $x_{i,j,k} = (a_{i,j,k,1}, a_{i,j,k,2}, \ldots, a_{i,j,k,t}, \ldots, a_{i,j,k,t_n})$, where t_n is the number of attributes defined by product analysis and A_i denotes the set of attributes in product service i.

Based on a module based design approach, we introduce service module cost based on product module cost to develop service cost in the proposed service hierarchy.

Different from the product cost, the service cost includes operational cost related to service delivery processes and operations. In this research, the operational cost can be identified by attributes that are related to product components. The product module cost is used to determine the expected design cost for product family and platform strategies in the next section.

3.2.2 Platform Design Strategy and Cost Model

A designer generates a feasible set of products and platform strategies to satisfy product requirements using traditional methods. The different platform strategies are constructed by combining the different functional modules into common and variant modules. A well-defined platform reduces production costs by improving economies of scale and reducing the number of different components that are used [19, 23].

An appropriate platform level for a product family can be determined by minimizing the production costs associated with commonality levels. The appropriate platform level for the product family can be represented as a mathematical programming model in which production costs are minimized, customer satisfaction is maintained, and profit is maximized [19]. Based on a proposed product design concept, product cost can be determined by total expected product volume, material cost, direct labor, production resource usage, tooling and capitalization costs, system cost (overhead or indirect costs), and development costs [25].

To develop platform strategies based on common modules, we introduce an expected strategy cost that represents additional costs for developing a new platform for a product family. Such costs could come from redesigning components, creating convenient interfaces, or having some components essentially overdesigned for most of the product family such that it works sufficiently for one specific product.

Suppose that a product family consists of I products, $PF = (P_1, P_2, \ldots, P_i, \ldots, P_I)$. Let A be a set of strategies for increasing the platform level and let $c(s_y)$ be the expected strategy cost for strategy $s_y\ (y = 1,2,\ldots,S)$. Then, the expected strategy cost can be calculated as follows [19]:

$$c(s_y) = \eta \times \frac{\sum_{i \in I} C_i^a}{f \times r} \quad (1)$$

where C_i^a is the additional design cost of product i associated with the new platform, η is a factor for overhead cost, and f is a strategy weight function as follows:

$$f = \begin{cases} 1, \text{if a module is unique} \\ l, \text{otherwise} \end{cases} \quad (2)$$

and *r* is a volume penalty factor related to product sales quantity. Hence, the expected total product cost, *TC*, for the product family using platform strategy, s_y, can be calculated by:

$$TC(s_y) = \sum_{i \in I} C_i + c(s_y) \quad (3)$$

Where C_i is the product cost of product *i*. For a given set of products, the value of $c(s_y)$ varies depending on the strategy for platform design. The expected strategy cost function will be used to determine a platform for a product family and can be developed by various cost functions based on products' characteristics and/or company's strategy in product family development. The next section introduces a service quality model for evaluating functions in a product.

3.3 Identify Service Quality

To evaluate and measure performance of a product based on services, we propose a quality metric that is positively related to product quality, customer preference, and price. In this paper, we introduce two quality levels to determine the performance of a product: (1) marginal quality and (2) full quality. The marginal quality is defined as the level of quality that customers want to buy a product with their preference. Customers have zero preference if the quality of the product is below the marginal quality. Full quality is represented as the level of quality that customers are willing to pay the price for purchasing a product. The full quality is determined by services depending on customers' preferences in market segments. Figure 4 shows two service quality functions of a product for different customers' groups. In between marginal and full qualities, customers have various preferences related to service's quality.

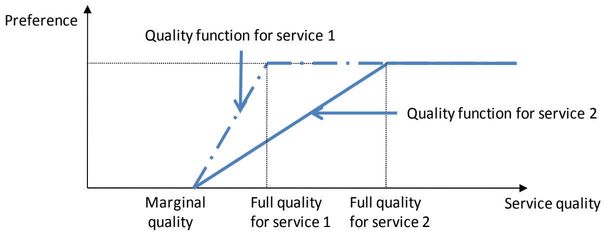

Figure 4: Relationship between preference and service quality for a product

We assume that the quality of a product consists of service qualities. To determine the value of customers' reference related to the service quality, Q_s, we assume that customers in the market are categorized into two homogenous groups, normal and specific. The value of the preference, $U(Q_s)$, can be represented by a utility function shown as follows:

$$U(Q_s) = \begin{cases} 0, & \text{if } Q_s \le Q_M \\ \dfrac{f_{n,q}(Q_s) + f_{s,q}(Q_s)}{2}, & \text{if } Q_M < Q_s \le Q_F^N \\ \dfrac{1 + f_{s,q}(Q_s)}{2}, & \text{if } Q_F^N < Q_s \le Q_F^S \\ 1, & \text{if } Q_F^S < Q_s \end{cases} \quad (4)$$

where Q_M is the marginal quality of a product, Q_F^N is the full quality of a product for a normal customer group, Q_F^S is the full quality of a product for a specific customer group, $f_{n,q}$ is a normal quality function and $f_{s,q}$ is a specific quality function. The specific quality represents the interaction of product functions and services: it is a measure that indicates what services are needed to make product functions for the specific customer group. In terms of product family design, this measure allows us to explore how a particular product platform can best be used to develop a family that provides high services to customer groups. The next section discusses a game theoretic approach for determining a platform design strategy.

3.4 Phase 4: Determine a Design Strategy

A coalitional game is designed to model situations wherein some of players have cooperation for seeking a goal [14]. A coalitional model focuses on the potential benefits of the groups of players rather than individual players. In the coalitional model, the sets of payoff vectors are used to represent the value or worth that each group of individuals can achieve through cooperation.

A platform level problem can be considered as a module selection problem under a collaborative situation. Additionally, the game theoretic framework provides a useful technique for evaluating strategies in dynamic market environments. To determine a product platform, we decide which modules provide more benefit based on the marginal contribution of each module.

We assume that each module in a product is modeled as a player. Then, we consider the following module selection problem. Each potential coalition can be represented as a platform design strategy and be independent of the remaining players. To determine modules for platform design, we consider the set of all possible coalitions and evaluate the benefits of different coalitions.

In order to formulate the proposed scenario as a coalitional game, we must first identify the set of all players, *N*, and a function, *v*, that associates with every nonempty subset *S* of *N* (a coalition) [14]. A real number *v(S)* represents the worth of S and the total payoff that is available for division among the members of S. The function v satisfies the following two conditions: (1) $v(\varnothing) = 0$, and (2) (superadditivity) If $S, T \subset N$ and $S \cap T = \varnothing$, then $v(S \cup T) \ge v(S) + v(T)$. Based on the definition of the coalitional game [14], the proposed game can be defined as:

- *N*: players who represent (variant) modules
- $v(S)$: the benefit of a coalition, $S \subset N$

where a coalition, *S*, represents a potential platform design strategy that consists of several modules.

Here, we use the Shapley value to analyze the benefits of a product family and determine the product platform [26]. The Shapley value is a solution concept for coalitional games and is interpreted as the expected marginal contribution of each player in the set of coalitions [26]. Shapley value is defined as follows:

$$\varphi_i(N,v) = \sum_{T \subseteq N, i \in T} \frac{(|T|-1)!\,(n-|T|)!}{n!}[v(T) - v(T \setminus \{i\})] \quad (5)$$

where $\varphi_i(N,v)$ is the payoff of player *i*, $|T|$ is the players' number in the coalition *T*, $T \setminus \{i\}$ is the players' coalition excepted player *i*, *n* is all players' numbers, and $v(T)$ is the payoff of the coalition *T*. Through the Shapley value, we can determine a platform design strategy based on the payoff of each varietal module by the marginal contribution it makes to the platform.

In the proposed approach, we use profits to evaluate players' coalitional benefits. We assume that the price of a product can increase with increasing quality. Then, for product i profit, π_i, can be formulated based on the overall design strategy quality and product cost as follows:

$$\pi_i = \mathrm{Pr}_i\,\alpha_i - \alpha_i C_i = (Pc_i Q_i)\alpha_i - \alpha_i C_i \qquad (6)$$

where, Pr_i is the price of product i, C_i is the product cost of product i, α_i is the sales quantity of product i, Pc_i is the coefficient of the price for product i, and Q_i is the service quality of product i. Hence, the payoffs of coalitions, v, can be calculated by difference between the expected profit and the current profit. The coalitional benefits for a product family based on a platform strategy, s_y, are formulated as follows:

$$v(s_y) = \sum_{i \in I} \pi_i(s_y) - \sum_{i \in I} \pi_i(s_0)$$
$$= \sum_{i \in I} (Pc_i Q_i(s_y)\alpha_i - \alpha_i(C_i + c(s_y)) - \sum_{i \in I} (Pc_i Q_i(s_0)\alpha_i - \alpha_i C_i) \qquad (7)$$

where s_0 is the current design strategy. The terms $c(s_y)$ and $Q_i(s_y)$ are estimated by the expected strategy cost function and the quality function as mentioned in Sections 3.2.2 and 3.3, respectively.

To determine the product sales quantities, we use the proportion of market segmentation grids that are covered by a product. The sales quantity of product i, α_i is formulated as follows:

$$\alpha_i = \sum_{d,e \in M_i} (\beta_{i,d} \times \gamma_{i,e} \times TD) \qquad (8)$$

where M_i is the set of the market segmentation grids of product i, $\beta_{i,d}$ is the proportion of the market segmentation grids at x-axis (d=1,2,…,D) for product i, $\gamma_{i,e}$ is the proportion of the market segmentation grids at y-axis (e=1,2,…,E) for product i, and TD is the amount of total demands for products in the market. If several products are involved in the same segments, the segment ratio of each product is calculated by the proportion of the number of the products in the same segment.

Based on the results of marginal contributions for different modules, we can determine a platform strategy based on consideration of better product sales depending on services in market segmentations. The proposed method can provide designers with candidate modules for improvement and opportunities for re-design in dynamic market environments. In the next section, the proposed method is applied to determine a platform design strategy using a case study of a family of mobile phone products.

4 CASE STUDY

To demonstrate implementation of the proposed method, a family of mobile products consisting of N73, N76, N78-1, and N79-1 is investigated from the Nokia N70 phone family. These items are shown in Figure 5. The Nokia N70 series family products provide a good example of common and variant functions for services related to vision accessibilities as shown in Table 1. These products offer the opportunity to create a product family with the vision services as common functions that constitutes the product platform.

The objective in this case study is to determine a platform design strategy represented by vision accessible services for the mobile product family subject to a dynamic market environment. This case study focuses on how to determine the marginal contributions of modules related to vision accessible services for the new platform design of the mobile product family using the proposed game at the conceptual design stage of development.

Figure 5: Nokia N70 series products [27]

Table 1: Vision accessible services for four products[1]

	Vision Services	N73	N76	N78-1	N79-1
F1	**Tactile key markers**	**Yes**	**No**	**Yes**	**Yes**
F2	Standard key layouts	Yes	Yes	Yes	Yes
F3	Key feedback - tactile	Yes	Yes	Yes	Yes
F4	Key feedback - audible	Yes	Yes	Yes	Yes
F5	Audible identification of Keys - when pressed	No	No	No	No
F6	Audible identification of Keys - feedback	Yes	Yes	Yes	Yes
F7	**Adjustable font style**	**No**	**Yes**	**Yes**	**No**
F8	**Adjustable character size**	**No**	**Yes**	**Yes**	**Yes**
F9	Display Characteristics (color display)	Yes	Yes	Yes	Yes

4.1 Phase 1: Identify Market Segments

Figure 6 shows current market segmentation grids for the mobile products with respect to vision services and market prices. The products have different vision accessibility services and market prices depending on market segments as shown in Table 1. For example, N73 covers no vision impairment and low price market. In Table 2, we can consider F2, F3, F4, F6, and F9 as common modules for the phone family. And, F1, F7, and F8 are considered as variant modules.

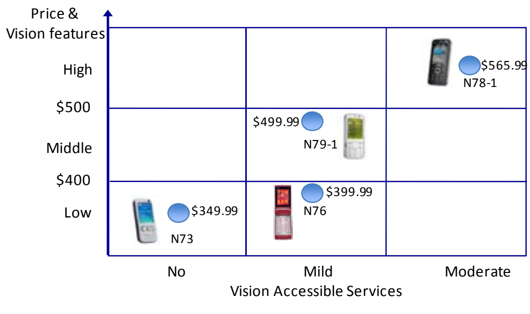

Figure 6: Market segmentation grids for the four products

4.2 Phase 2: Develop Platform Design Strategies

In Phase 2, we facilitate function configuration for developing platform design strategies by identifying relationships between functions and market segments at a conceptual design phase. Using Service and Component Matrix, we can determine the relationship between vision services and components as shown in Table 2. We consider that a cell phone consists of eleven components [28]. Among the components, we assume that a main board includes a program for supporting services.

[1] http://www.nokiaaccessibility.com

Table 2: Service component matrix for the products

Vision Services	Power converter	Power cable	Upper case	Lower case	Speaker	Display unit	Keypad	Microphone	Antenna	Main board	Battery	Components #
F1			x				x					2
F2			x				x					2
F3			x				x					2
F4			x		x		x			x		4
F5			x		x		x			x		4
F6			x		x		x			x		4
F7			x			x	x			x		4
F8			x			x	x			x		4
F9			x			x	x			x		4

To develop a new platform consisting of common modules and variant modules, we need to determine marginal contributions of the variant modules (F1, F7, and F8). The marginal contributions of modules can help decide which the services are included to a new platform for increasing benefits and accessible services in product family design. Table 3 shows service configuration strategies that consist of the variant modules for the phone product family. To determine the expected strategy cost as mentioned in Section 3.2.2, we considered the number of components that are related to vision services and use a unit additional cost, C^a, for each component. For example, since the Tactile key marker is related to two components, Upper case and Keypad, the additional cost of the Tactile key marker is $2C^a$. We assume that a factor of overhead cost and a volume penalty factor are 2 and 1, respectively. The expected strategy cost for the product family can be calculated by Equation (1). Table 3 shows the results of the expected strategy cost for the platform strategies.

Table 3: The Expected additional strategy cost for the platform strategies

Strategy	Additional component design cost					Expected additional strategy cost
	N73	N76	N78-1	N79-1	Total	
S1-F1F7	$4C^a$	$2C^a$	-	$4C^a$	$10C^a$	$5C^a$
S2-F1F8	$4C^a$	$2C^a$	-	-	$6C^a$	$3C^a$
S3-F7F8	$8C^a$	-	-	$4C^a$	$12C^a$	$6C^a$
S4-F1F7F8	$8C^a$	$2C^a$	-	$4C^a$	$14C^a$	$7C^a$

In the vision service point of view, Table 4 shows a comparison of current market segments and the expected market segments for new platform design strategies.

Table 4: Comparison to current market segments and the expected market segments

Platform strategy	N73	N76	N78-1	N79-1
Current	No	Mild	Moderate	Mild,
S1	No, Mild	Mild	Moderate	Mild, Moderate
S2	No, Mild	Mild	Moderate	Mild
S3	No, Mild, Moderate	Mild	Moderate	Mild, Moderate
S4	No, Mild, Moderate	Mild, Moderate	Moderate	Mild, Moderate

4.3 Phase 3: Identify Service Quality

Based on the platform design strategies, the expected service qualities for the products can be calculated by the value of preference as mentioned in Section 3.3. We assume that the service quality of a product is depended on the number of vision services in the product. We consider customers with vision impairment as the specific group. Figure 7 shows the functions of service quality for two customer groups. The marginal quality was determined by the number of common vision services. The full quality of the normal group was determined by the service quality of N73. While the full quality of the specific group was the maximum number of vision services.

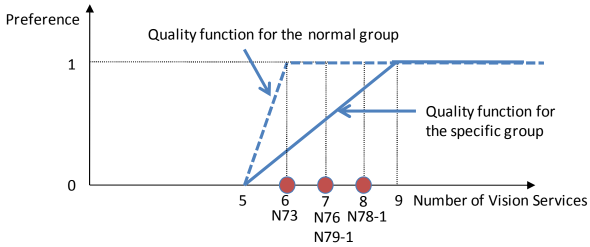

Figure 7: Preference and service quality for the phones

Table 5 shows the expected service qualities of the products with respect to vision services. The expected preference values of the products for the platform strategies are calculated by Equation (4) as mentioned in Section 3.3. For example, the expected service quality of N73 in S1 is 0.75, because the functions of N73 consist of F1, F2, F3, F4, F6, F7, and F9, and the preference values of the normal and specific groups are 1 and 0.5, respectively. We performed normalization of the value of the expected strategy quality for a product to compare current quality with strategy qualities as shown in Table 5.

Table 5: The expected service qualities of the products (normalization)

Strategy	N73	N76	N78-1	N79-1
Current	0.625 (1.0)	0.75 (1.0)	0.875 (1.0)	0.75 (1.0)
S1	0.75 (1.2)	0.875 (1.17)	0.875 (1.0)	0.875 (1.17)
S2	0.75 (1.2)	0.875 (1.17)	0.875 (1.0)	0.75 (1.0)
S3	0.875 (1.4)	0.75 (1.0)	0.875 (1.0)	0.875 (1.17)
S4	0.875(1.4)	0.875 (1.17)	0.875 (1.0)	0.875 (1.17)

4.4 Phase 4: Determine a Platform Strategy

For the case study, we assume that the expected demands for the products are determined by the result of market analysis as shown in Figure 8 and the amount of total demands for the cell phone products is 100,000. For example, the market demands of Low Price and No Impairment are is 50% and 50%, respectively. And then, the amount of demands for the product is 25,000. We also assume that the product cost of each product is 80% of the market price in Figure 6. We consider the current price of the product as the coefficient of the price to obtain a new product' price along with the normalized service quality. Revenue for each product family based on platform strategies and the expected service qualities can be calculated by Equation (7) as shown in Table 6. To determine a platform strategy, the proposed coalitional game was applied to obtain the marginal contributions of vision services.

Table 6: Revenue of current and the proposed product families (unit: $)

Strategy	N73	N76	N78-1	N79-1	Additional Cost	Total
Current	1,750,000	1,200,000	452,800	900,000		4,302,800
S1	4,550,000	1,110,000	452,800	2,775,000	$295,000C^a$	$8,887,800 - 295,000C^a$
S2	4,550,00	1,110,000	452,800	900,000	$157,500C^a$	$7,012,800 -157,000C^a$
S3	8,925,000	600,000	452,800	2,775,000	$414,000C^a$	$12,752,800 -414,000C^a$
S4	7,875,000	1,850,000	452,800	2,775,000	$483,000C^a$	$12,952,800 -483,000C^a$

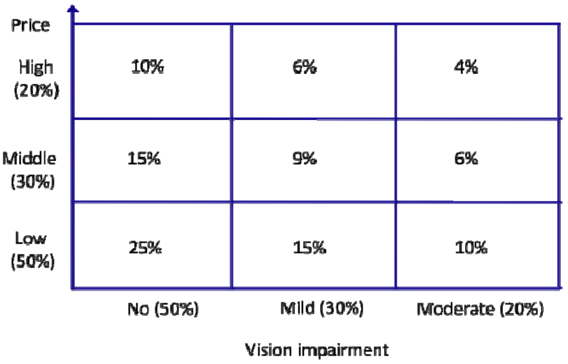

Figure 8: The Expected market demands for market segments

The game between three variant modules for platform design of this product family is defined as the proposed coalitional game that is described in Section 3.4. Table 7 summarizes the coalitional game for determining vision services with three players. To determine marginal contributions for each variant module, the coalitional benefits of the design strategies were calculated by Equation (7). Since there is no benefit in a single module design strategy according to the definition of a coalitional game, we defined four collaborations as the combination of three variant modules for design strategies. Therefore, the payoff vector of the game is $\boldsymbol{v}$(0, 0, 0, 0, 4585000-295000C^a, 2710000-157500C^a, 8450000-414000C^a, 8650000-483000C^a).

Table 7: The Proposed coalitional game for platform design

Game	Modules for vision services
Players (N)	F1, F7, F8
Coalition (G)	G1(ϕ), G2(F1), G3(F7), G4(F8), G5(F1, F7), G6(F1, F8), G7(F7, F8), G8(F1, F7, F8)

To determine the marginal contribution of each variant module, we used the Shapley value as mentioned in Section 3.4. The Shapley values of the variant modules (F1, F7, F8) are (1282500-986416C^a, 4152500-226666.67C^a, 3215000-157916.67C^a).

Based on the marginal contributions of the variant modules, we can decide a platform strategy for a family according to company's service strategy and market situations. Figure 9 shows the results of sensitivity analysis based on various additional design cost for marginal benefits with respect to vision services. Since the contributions of F1, F7, and F8 are depended on the redesign cost, C^a, additional vision services for a new platform can be selected by design constraints. For example, if C^a is less than \$13.64, we can consider the Adjustable Font Style Service as the first candidate that will be included in a new platform to increase vision services based on common components.

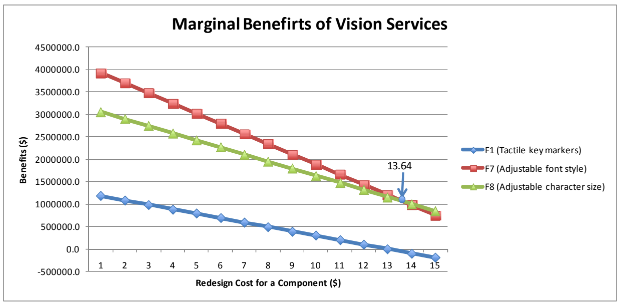

Figure 9: Marginal benefits of vision services with respect to redesign cost

Through the case study, we demonstrated that the proposed coalitional game could be used to determine a platform strategy by selecting functions that provide more benefits with respect to vision services in product family design.

5 CLOSING REMARKS AND FUTURE WORK

This research present the foundational knowledge of the field providing an economical and strategic view based on engineering design for product family and mass customization in dynamic market environments. By extending concepts from product design to service design, we have introduced a method for developing a service based platform through a game theoretic approach in a dynamic market environment. We considered a platform level selection problem as a strategic module selection problem under collaboration situation. In this game, strategies for players represent various platform design methods depending on common and variant services in a product family. Therefore, functions for designing a platform can be determined by selecting service strategies with respect to customers' preferences. We have applied the proposed method to determine a platform for a family of mobile phones in a case study. Through the case study, we demonstrated that the proposed method could be used to determine appropriate functions for a platform according to services. Therefore, we expect that the method can help to facilitate product family design based on services for different market segments in dynamic market environments.

To improve the proposed method, we need to develop a technique that can identify functional module configuration based on services and customers' requirements for establishing design strategies effectively. Since the product cost and the expected strategy cost are sensitive to estimate players' payoffs in a game, cost models are developed by product and service characteristics, company's strategies, and a market environment. Future research efforts will be focused on improving the efficiency of the method, developing product and service cost models for design strategies in various product family environments, and comparing to the proposed game with other decision-making methods for determining a design strategy in a product family.

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