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A Framework on Customer Involvement in Product Design on Product Family Platform: Customer Perspectives

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Abstract: *As knowledge workers, customers can be involved in product design on product family platform with customer knowledge to inspire product innovation ideas, design customization products and improve the success rate. Customer knowledge derives from customer needs and their contact with products. This paper analyzes customer needs with the method of PRE model and discusses customer knowledge on studying the cognitive factors within customer's contact with products. Anchored on the platform of knowledge-intensive collaborative product family design, this paper presents the framework on customer involvement in product design by analyzing customer knowledge and comparing between enterprises and customers. The framework of product design intended for customers, collaborated with customers, and developed by customers, transforms enterprise dominating design into customer involvement design to fulfill the real needs and wants of customers.*

Keywords: *product design, customer involvement, customer needs, customer knowledge*

1. Introduction

Enterprises make profits by satisfying customer needs (CNs) (Dominici, 2010). Improving customer loyalty, which is a major contributor to sustainable profit growth, achieves competitive advantage. A product design that satisfies CNs is crucial to the survival of enterprises. A survey done by Product Development and Management Association (PDMA) reveals that more than 50% of the sales in successful companies come from new products and that the percentage is over 60% in most successful companies (Balbontin et al., 2000). Today, CNs-driven product design is becoming knowledge-intensive and collaboratively supported by the product family platform (Ouertani et al., 2011). The profit of industrial products also increasingly depends on knowledge content.

Successful product designs are those that meet CNs. Different methodologies are proposed to explore CNs. The mathematical description approach of semi-structured CNs has been proposed to acquire precise product functional requirements (You-guo et al., 2011). Bruce (2010) identified hidden consumer needs through market research activities supporting product development. Hasdogan (1996) elucidated the role of user models in the household product design process to assess user needs.

As CNs are key factors in product design, many researchers on product design have considered customer opinions, such as developing product designs that are customer driven (Jin et al., 2011; Liao, 2011), customer-oriented (Elliott, 2000), and customer-centered (Montignies et al., 2010; Miaskiewicz & Kozar, 2011; Clifton et al., 2011). Researchers focus on how to utilize the information of CNs extracted from websites, customer interviews, or reused design experiences to improve customer satisfaction, while employing different expressions. Attempts have also been made to develop the frameworks of product design based on appropriate appreciation of customer voice. That is, enterprises should design CNs-driven products for customers.

The personalization of CNs consequently leads to product variety. Initially, variety does improve sales because the products are more attractive; but as variety increases, the law of diminishing returns suggests that the benefits do not keep pace (Jianxin et al., 2007). The design of platform-based product family has been recognized as an efficient and effective means to realize sufficient product variety and satisfy a range of CNs-supported mass customization (Jiao et al., 1998). Designing and manufacturing product families immediately respond to customer requests, reduce design and manufacturing costs, and shorten the time to market the product (Farrell & Simpson, 2003).

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However, product design on the platform-based product family is still dominated by enterprises and done by enterprises using market volume and tendency forecast. Enterprises develop product models from their point of view on CNs. Product design failure is attributed to the lack of attention paid to the real needs and wants of the marketplace (Calantone & Cooper, 1981). Because the real needs and wants are brought forward by customers (Tseng & Du, 1998; Agost & Vergara, 2010; Alajoutsijärvi et al., 2011), customer involvement in product design is necessary. With the advent of modern manufacturing systems and the development of the Internet, more flexibility is seen in product design and production systems. Web-based open-source software allow users to design and act as innovators to transform industries (Thomke & von Hippel, 2002), and make customers can get involved in product design.

In practice, IBM's User-Centered Design (UCD) is a method for incorporating ease of use into the total user experience. Software products are easy to buy, easy to set up, easy to learn, easy to use, and easy to upgrade (IBM, 2009). The UCD system recruits and compensates research participants from users who play a critical role in the design of easy-to-use products. IBM collects user information in the most effective and efficient manner through online surveys, phone interviews, remote Web-based product evaluations, usability lab studies, and on-site visits. Furthermore, user input is taken into consideration in rapid prototyping of alternative designs. In addition, the company uses the collected information to carry out hands-on tests of their products in order to meet customers' expectations and improve time to market.

Product design processes comprise highly creative and knowledge-intensive tasks in geographically distributed collaborative teams, and customer knowledge (CK) is an important input in product design. In practice, enterprises pay much more attention to CNs, while CNs are only a part of CK. CK includes CNs and product knowledge. In another words, it comprises not only CNs, but also usage knowledge, preference knowledge, and originality knowledge. Customers learn from their purchase and usage of products and acquire product information from other people, from the Internet, television, and others. Because they know how products could be made to satisfy their needs, customers can participate in product design.

On product family platform, this paper is mainly focused on the framework on customer involvement in product design and pays attention to utilize CK to design customization products. Based on the reviews of product design system on product family platform and with the recognition of CNs and their knowledge about products, a framework is presented in this paper. The framework covers three scenarios of customer involvement in product design, namely "design for customer", "design with customer" and "design by customer" to utilize CK and design customization products, and finally its application is discussed.

2. Platform of knowledge-intensive collaborative product family design

A product family is a group of related products that share common features, components, and subsystems satisfying a variety of market niches. A product family comprises a set of variables, features, and components that remain constant from product to product (product platform), or vary from product to product (Simpson et al., 2001). The driving force behind product family design and development is the enterprise positioning of customers at the center of value creation and involvement of customers in the product fulfillment process (Jianxin et al., 2007). Fig.1 shows the architecture of a product family illustrated by Zha and Sriram (2006). The conceptual architecture represents logical organization of product families from viewpoints of customers and designers, and combines recent developments in product representation into a hybrid approach. In the architecture, a product family is composed of products or systems, modules and attributes, and product variety can be implemented at different levels.

Designing and developing product families are recognized to be effective means to achieve the economy of scale to accommodate increasing product variety across diverse market niches (Jianxin et al., 2007). The Product Platform Concept Exploration Method has been developed to facilitate the design of a family of products focusing on scale-based product platforms, which can be exploited from both a functional and a manufacturing standpoint (Simpson et al., 2001). Discovering product design knowledge related to the product family could be done by integrating an ontology with data mining techniques through fuzzy clustering (Ki et al., 2010).

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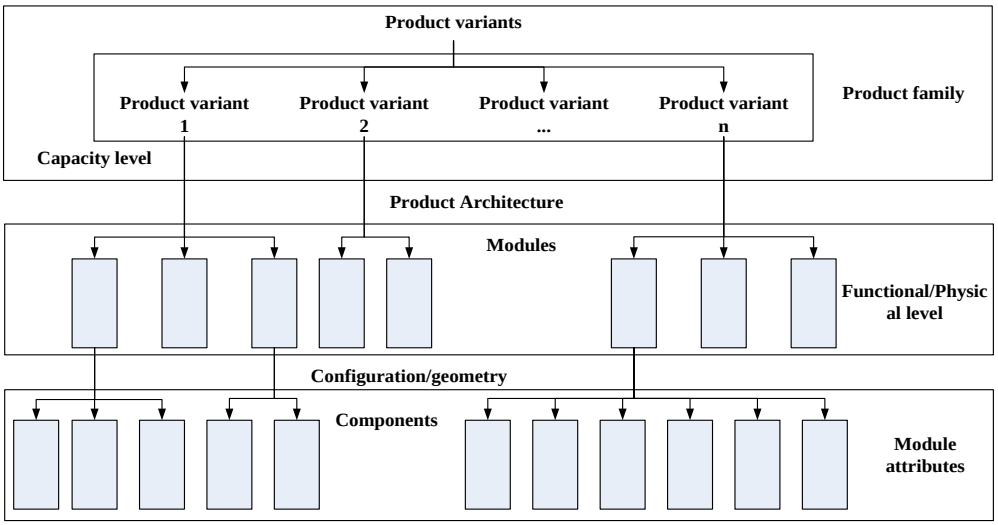

Figure 1: Product family (Zha & Sriram, 2006)

Modularity and standardization are promising tools in product family development (Alba and Hutchinson, 1987; Jianxin et al., 2007). The basic idea of modular design is to organize products as a set of distinct components, which can be designed independently, and develop a variety of products through the combination and standardization of components. By disassembling the functions of products into independent sub-functions, modules make the reuse of functions in different products easier.

The knowledge-intensive support in cyber-infrastructure becomes critical in a collaborative design task, and this has been recognized as a key solution toward future competitive advantages in product development. Zha and Du (2006a, 2006b) developed knowledge-intensive distributed design models and a framework for collaborative design modeling and decision support explaining system implementation and application. Rodriguez and Al-Ashaab (2005) introduced a knowledge-driven collaborative product development that addresses the requirements, as defined by both the research and industrial communities. Zha et al. (2008) proposed a hybrid decision support model within a multi-agent framework to facilitate integration and collaboration for design decisions. Newell et al. (2003) pointed out that Enterprise Resource Planning and Knowledge Management can be implemented together to foster efficiency and innovation complementarities.

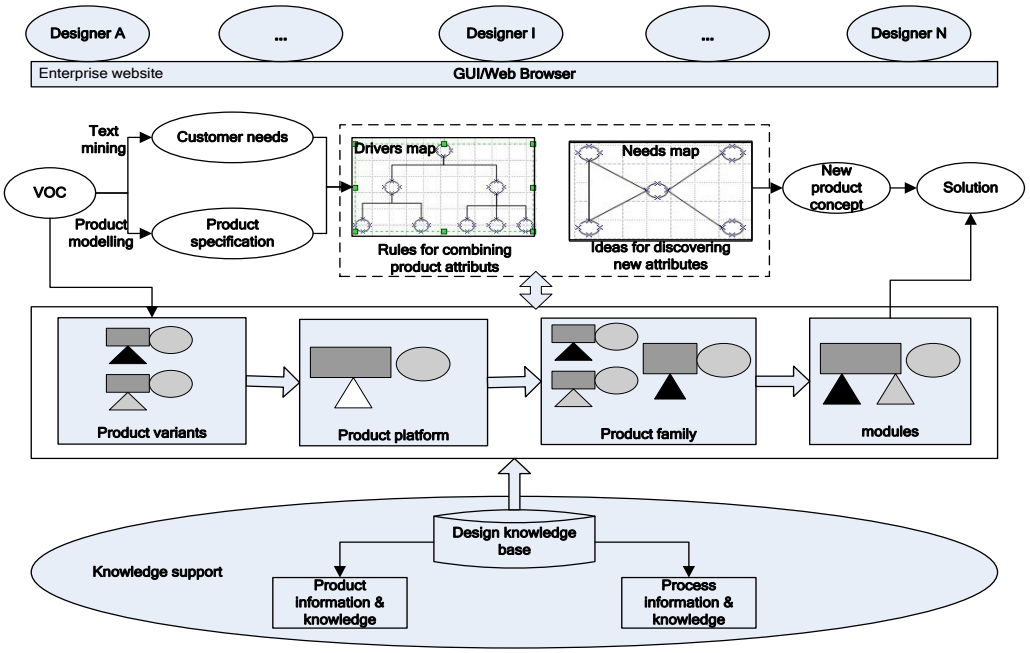

Figure 2: Platform of the knowledge-intensive collaborative product family design

This study draws a conclusion from previous research and proposes the platform of product family design among enterprises, as shown in Fig. 2. In the platform, distributed designers work together through

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a web-browser-based graphical user interface (GUI). The voice of customers (VOC) representing CNs includes queries, claims on public mediation institutes, complaints, commendations, or praises, which enterprises can collect through call centers, company website, Dealer Management System, and others. VOCs are transformed into structured vector form by text-mining analysis and into product specifications by product modeling (Park & Lee, 2011). With the information on product family management, designers define the rules for combining product attributes and discovering new attributes in CNs map. A new product concept is generated. Once the VOC is close to some product family with the analysis of key characteristic fuzzy clustering, designers can modify the product's functional modules and attributes to satisfy CNs and achieve solutions. To accomplish the solutions of VOC, designers need the support of the knowledge database, including product information and knowledge as well as design process information and knowledge.

The product design platform from the perspective of enterprise is mainly to enhance enterprise's innovation ability. And it will provide a more realistic foundation for a framework on customer involvement in product design. However, researches on customer involvement on product design platform with the support of Internet are not to be found, especially form customer perspective.

3. Customer knowledge in product design

From enterprise's perspective, market knowledge which includes CNs, customer relationship, market share and credit standing (Fu et al., 2006) is acquired from marketing channels, customer relationships etc. From customers' perspective, CK can be divided into CNs and product knowledge generated from the activities of communications among them and with enterprises, product purchases, product usages, and innovative ideas. Customers can play more important roles in product design, designing what they want and transforming "push" design to "pull" design. Customers, especially proactive customers, want to design products using their knowledge to enhance their abilities, test their one-up needs, and satisfy their personality needs. Customers also frequently modify products, and some modified products could have potential commercial interest (Morrison et al., 2000).

3.1 Customer needs

Customers make their purchase decisions as driven by functional and emotional needs. Functional needs are those satisfied by product functions, whereas emotional needs are associated with the psychological aspects of product ownership (see Table 1). Functional needs are connected with product functional modules, whereas emotional needs are reflected by product quality, appearance, brand, and others. Product development and design require an accurate understanding of CNs expressed by customers themselves. The standard structured expression of distributed customers is important to product design. By carefully clarifying and defining CNs and demands in the early phases of product development, large and time-consuming changes can be avoided at the later stages of the development work, which can significantly reduce the total time required by development activities (Urban & Hauser, 1993). Clearly expressed CNs are important in product design; customers involved in product design are expected to express their needs proactively.

Table 1: Understanding CNs (Stringfellow et al., 2004)

Customer needs	Information characteristics	Communication requirements	Data collection methods
Functional needs	Well-defined, explicit, tangible	Lean channels	Transaction records and click stream data, survey
Emotional needs	Latent, fuzzy, subconscious, hard to articulate, intangible	Rich channels	Semi-structured interviews, archetype research, story-telling, picture drawing

Product requirement express (PRE) comprises product character, assemblage, and regulation. Product character includes product function, performance, appearance, structure, and dimension. Assemblage refers to the product assemblage structure, which can be divided into functional modules and components based on product families. Regulation is the logical connection and restriction among product modules and components. The recognition of customers needs is influenced by local policies, culture, and technologies. Fig. 3 shows the PRE model.

With the development of the Internet, enterprises can collect VOC, extract customer opinions from online customer centers, and transform CNs into product specifications with the methodology of text-mining and product model (Park & Lee, 2011). Enterprises can design for customers according to VOC. Customers are required to visit enterprises' websites to actively express CNs on product models and also provide information needed by product design on the PRE.

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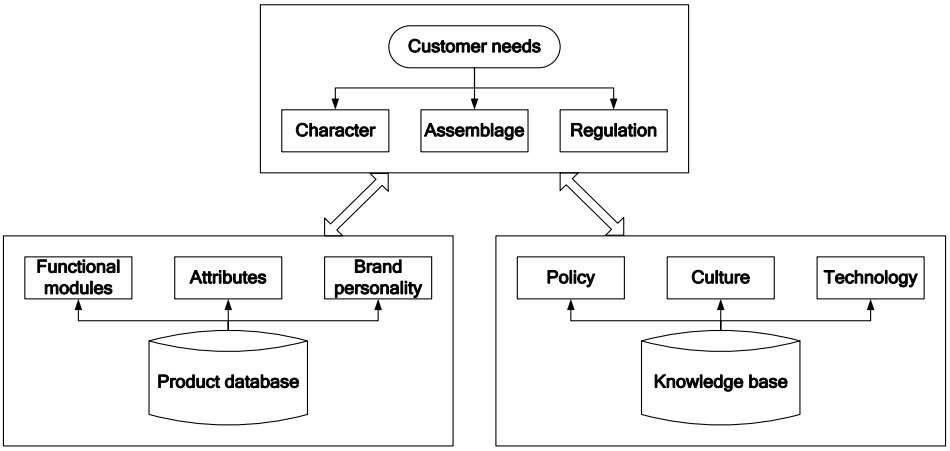

Figure 3: PRE model

3.2 Customer knowledge about products

During the purchase and usage of products, customers obtain useful experiences with the product or information about the product. CK about products is not only related to their behavioral motivation, but it also facilitates the acquisition of new information and knowledge. Different knowledge bases affect CNs and behavior, and CK about products enhances the personalization of product strategies. Familiarity and expertise are two major components in the construct of CK on any particular product or service (Alba & Hutchinson, 1987). Familiarity is defined as "the number of product-related experiences that have been accumulated by customers," whereas expertise is "the ability to perform product-related tasks successfully". Increased product familiarity results in increased customer expertise.

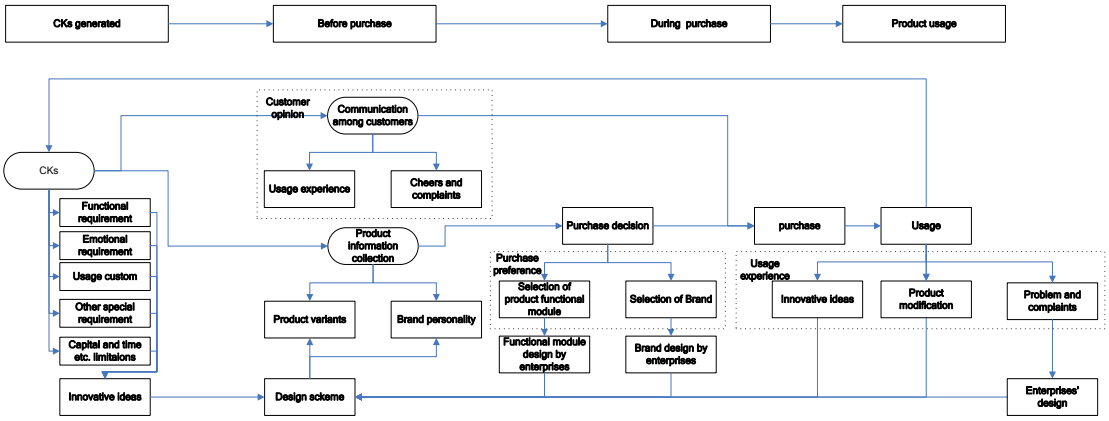

Figure 4: Knowledge and information during product purchase and usage considered in product design

CK about products includes customer opinions, purchase preference, and usage experience of product attributes and brands. Customers have different impressions on product functions and configurations, as well as brand perceived value, which they communicate among themselves. Thus, they purchase products according to their preferences. Customers can easily detect product defects when they use it, and they can provide suggestions on how to improve the product. Fig. 4 shows the knowledge and information generated during product purchase and usage that can be used in product design. In the figure, we divide customer's contact with product into three phases: before purchase, during purchase and product usage including product scrap. Once CNs generated, customer begins to collect information of products and enterprises to find out suitable products which satisfy their functional and emotional needs. During purchase refers to customer's purchase decision with consideration of her/his special requirements, usage custom and other limitation. During product usage, customer can generate innovative ideas, usage problem and complaints and need to modify products to better satisfy her/his needs. Customer innovative ideas of CNs and product usage, problems and complaints which she/he finds out during product usage may make great contribution to product design.

In the mode of Engineering-to-Order, either customers select functional modules according to CNs or enterprises choose functional modules of different brands for customers based on their understanding

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of CNs. Customers can select product functional modules of different brands to assemble products using their preferences and their specific knowledge of the product. Designing with customers could be widely used in product design and development. Customers using their knowledge about product are allowed to specify some requirements outside the predefined parameters of enterprises but within the limits set by product specification constraints (Briere-Cote et al., 2010). Thus, customer specific design solution is formed to satisfy personalization needs, and customers design product parameters within the limits set in product models. Personalized product design can be done by customers independently using their CK.

3.3 Comparison of customers and enterprises

Customers and enterprises have different advantages and disadvantages in product design. Both play different roles in the product design system to achieve good results.

Customers know best with regard to their needs because they consume or use the products. A successful design scheme also relies on marketing. Customers' personalization preferences, such as interest, emotion, custom, and others, influence product design schemes and selection decisions. During the purchase and usage, the problems and complaints which customers make are the main sources of product optimization and different usage environment is the motivation of product improvement. Customers can have trouble imagining and feedback something never experienced which triggers innovative thinking and breakthrough products (Matthing et al., 2004) and create new product design scenarios using their regional culture. As the most frequent source of product design (Lagrosen, 2005), customers can effectively involve product design processes, for example, idea generation, product optimization and prediction et al. However, customers are restricted to limited resources, such as professional information, knowledge, and time.

In contrast, enterprises ensure they own enough resources of product design so that the developed products increase profit and can improve market competence. They design products equipped with knowledge and information, capable employees, and others. They also have the option to outsource product design. Some also establish many multinational companies to capture a larger market and gain more profit. They integrate their resources and abilities using a web-based knowledge-intensive system to develop collaborative product design. They design products based on the forecast and investigation of CNs and market information, although the information could sometimes be inaccurate. The function of the designed products can be tested by enterprises, but the market response is decided by customers.

Through the analysis of customers and enterprises, the advantages and disadvantages of customer and enterprise product design could be determined. Combining the advantageous features of customers and enterprises in product design is important.

4. Framework of customer involvement in product design

Customers can be involved in product design at different levels. Depending upon how an enterprise engages customers in their design process, three approaches may be taken: Design for customers (DFC), design with customers (DWC), and design by customers (DBC). In DFC, enterprises design and make products once customers provide the needs and requirements on the online product models of different product families. DWC refers to enterprises collaborating with customers on the selection of functional modules of different brands and the set of some personality parameters on the platform-based product family design. DBC implies that customers design products by themselves with the support of the knowledge database. A framework for customer involvement in product design is proposed and it has different format for each approach as described as follows.

4.1 Design for customers

After enterprises make CNs clear, they can begin to design products using their resources according to CNs. Fig. 5 shows the framework of DFC.

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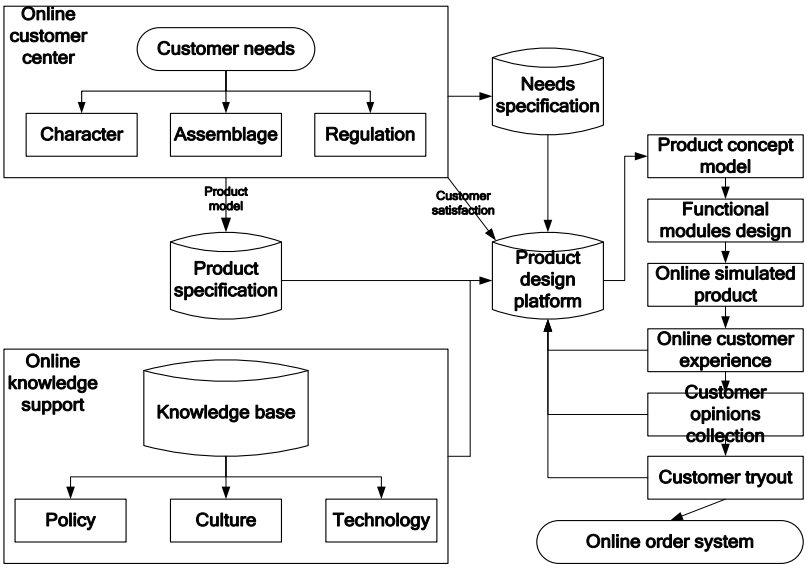

Figure 5: Framework of DFC

Customers express their needs and preferences through an online customer center in the company's website where enterprises extract customer related information. According to product characters, enterprises can make standard sheets which customers could download from the Internet and fill out and upload. Table 2 illustrates the product character sheet. Customers can also express their demands in their own words, although this method may add difficulty in perfectly expressing preferences in detail. Online communication between designers and customers is necessary to clarify CNs. During the communication, enterprises should build a product model elaborating on customer requirements and record product specifications according to customer demands.

Table 2: Product character sheet

Product character					
Name/function	Material	Application place	Color	Dimension	Shape
Assembled product picture: Related description:					
Other requirement:					

After customers confirm the needs specification, enterprises can begin product design on the product design platform with the support of the online knowledge base. Product development and design are becoming increasingly knowledge-intensive, and enterprises do not possess all the knowledge they need. Instead, enterprises rely on buying technology or services through contractual and cooperative partnerships with other organizations (Rodriguez & Al-Ashaab, 2005). Park and Kim (2006) proposed the online framework of knowledge management system for product design in detail.

During the design phase, telecommunication between designers and customers helps designers know more about CNs, and customer satisfaction is the key factor which designers should consider. Online simulation of products improve customers' impressions and makes customers experience such products before the product is completed. Thus, customers can evaluate the design scheme online. If customers like the product trial, they can order the product online.

4.2 Design with customers

Customers can design products with their preferences by selecting the functional modules and redefining some limited functional modules' parameters despite lacking in design resources. The key factor that will encourage customers to participate in product design is the foundation of online product management. Fig. 6 shows the framework of online DWC. Enterprises work on product design, including functional module design, product comparison system, and product configuration management. The customers design the product using their personalization needs and product knowledge.

The online information system is related to company information, which influences customer selection of product functional modules. Brand personalization is the set of human personalization traits that are both applicable and relevant to brands (Azoulay & Kapferer, 2003). Brand personalization

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involves assigning human personalization traits/characteristics to a brand to achieve differentiation. Brand personalization is expressed through the individuals representing the brand (i.e., its employees) as well as through advertising, packaging, and others. Brand personalization indicates emotional associations of the brand and influences customers' purchase decision and brand loyalty. Product comparison system compares different product functional modules of different enterprises and brings forth the functional differences, which guide customer selection. When customers make their choice, price and service are also key factors included in the information system.

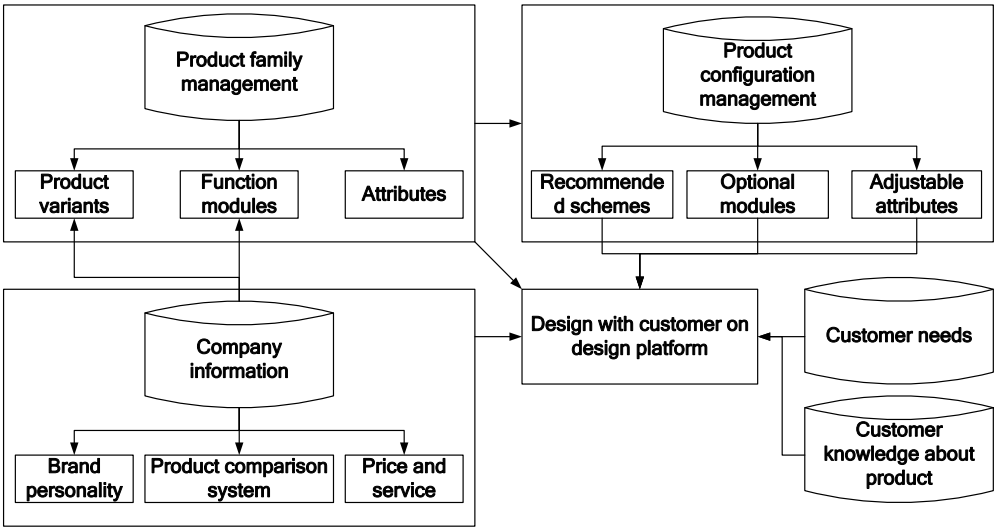

Figure 6: Framework of DWC

Product family management is often used in product design by enterprises to satisfy customer personalization needs (see Fig. 1). A product family includes product variants, functional modules, and attributes; this reveals the structure of products and the relationships among products, functional modules, and attributes. In product family management, integral and optional modules are distinguished according to product functions. Inconvertible attributes protect the intellectual property rights of enterprises, and revisable attributes can respond to customers' personalization needs. However, in the framework of design with customers, the users of product families are not only enterprises but also customers. Brand personalization, such as product variants and functional module brands, should be taken into account in product family management because they influence customers' design.

Product configuration management supports the scheme of product design. Recommended schemes are given by enterprises, which are designed by professional designers or designs popular with customers. Enterprises propose the optional modules of different brands based on comparative information of key characteristics; the comparison provides customers some advice when they make their selection. For adjustable attributes, the two factors considered are the range and the relation with other attributes. Enterprises decide on the ranges of adjustable attributes, which are quantitative and easy to understand for customers. Customers make their choice on the numerical value of adjustable attributes based on their preferences. The relation is also set by enterprises, and the related attributes vary with the customers' choices.

Customers can employ online product configuration information to assemble the functional modules into a product. Customers make their preference selection according to product configuration using the functional and knowledge information provided.

4.3 Design by customers

Customers may have some ideas about product design when they use the product. They also have some special ideas about their needs. Under these conditions, customers need to design products independently. Information and knowledge system support are needed because customers often lack professional knowledge. The framework is as shown in Fig. 7.

Customers can identify product problems when the product is used. Understanding and appreciating the problems may be very important to product design because enterprises can germinate new product concepts based on the customers' findings. Product originality, driven by the special needs of customers, can become a new product in the market. Design schemes are formed by customers drawing from their

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preferences. The intellectual property of product design by customers belongs to customers. However, unless a design by a customer is patented, the ownership of the design is usually not fully recognized and protected legally. As such, general public is not incented to become designers for an enterprise; therefore the involvement of customers in product design should be encouraged. Determining the means to gather social intellectual resource needs further research.

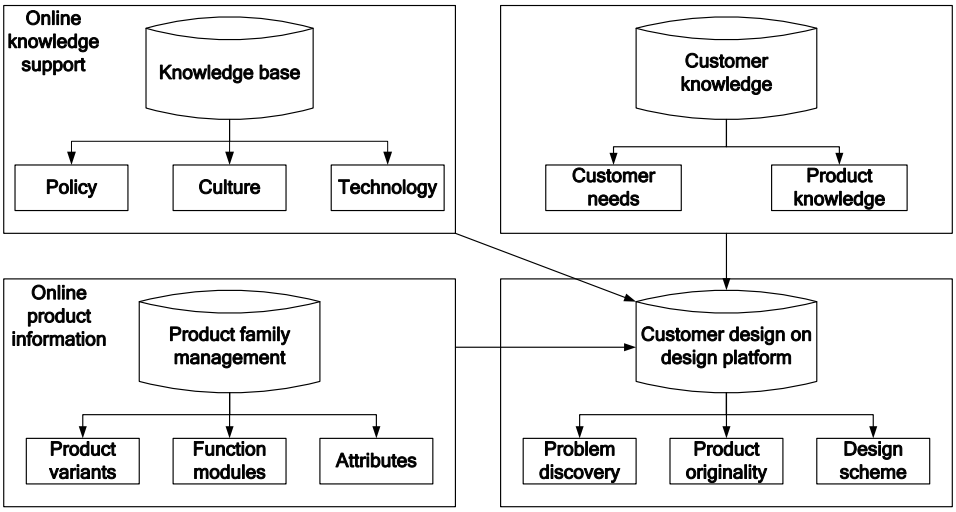

Figure 7: Framework of DBC

5. Application of the framework

Platform-based collaborative product design is an effective way to satisfy diverse market demands and modular design on product family platform is positively correlated with customer involvement, leading to better new product performance (Lau, 2011). In the framework of customer involvement on product design platform, DFC, DWC, and DBC can be solely used or mixed in product design when considering product characteristics. The key factors influencing customer involvement in product design are professional knowledge, CK, function, and personalization. Fig. 8 shows that the more professional knowledge is in product design, the more products have emphasis on functions; consequently, enterprises play the more important roles. Otherwise, customer involvement assumes the more dominant role in product design using CK and personalization. When professional knowledge predominates in product design, which pays attention to function design, enterprises display their advantages in product design, and they can design products for customers who lack the competence to design products using the VOC. When professional knowledge still predominates in product design, focusing on product personalization, or when CK plays a key role in product design, paying attention to function design, enterprises design products with customers. If CK and personalization dominate in product design, customers will design products with the support of enterprises.

Customer involvement does not imply the reduced importance of enterprises and technologies in product design. Instead, enterprises still play a key role in the design of product function modules, which customers can navigate through product families and define according to their preferences. With customer involvement, enterprises can design better products to satisfy CNs.

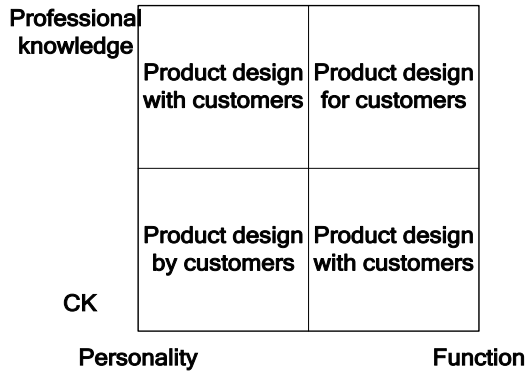

Figure 8: Influence of customer involvement on product design

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A brief example is given to explain the implement of the framework. As an aerospace fastener manufacturer with three distributed branches, Company A has kept a long-term business relationship with Chengdu Aircraft Corp., XAC group etc al., and mainly supplies aerospace fasteners which include standard fasteners, non-standard fasteners, shaped fasteners and assembling units. In order to efficiently utilize design resources of three branches, collaborative design platform on product family platform is built up between Company A and its branches make quick response to VOC with the Internet support. However, more than three thousands kinds of non-standard fasteners and shaped fasteners make its R&D department endure heavy workload and often design products which don't meet customer requirements and demands.

In order to keep pace with the change of CNs and shorten design time, Company A implements the framework of customer involvement on the fastener design platform. The company first permits some long-term strategic partner (for example, Chengdu Aircraft Corp., XAC group etc.) to involve product design and gradually permits other distributed customers to involve. From customer's perspective, the company carefully classifies its products and provides online fasteners information to its customers on the fastener design platform, so that its customers can know about its fasteners in details including usage and function, price, module, attribution, material and even some design parameters etc. Company A supplies online knowledge support including policy (national and industry policies etc.), culture (social and quality culture etc.) and technology (design method and development of fastener technology etc.) to its customers.

Customers can describe their needs on fastener character sheet including character, assemblage and regulation, and Company A designs for customers using design resources of three branches. If customers need to change the function modules, shape, color, material and other personalization design parameters of fasteners, customers can select one similar fastener and design with designers with the support of knowledge base. Some fasteners with one or few pieces of production need customers to design by themselves with the support of knowledge and information system, and long-term strategic partners often design by themselves with the support of Company A. Six months later, according to Company A's statistics, design errors were reduced by 28%, design time was shorten with short 15% designers, and customer satisfaction was improved from 72% to 91%.

6. Conclusion

Customer involved in product design is important to an enterprise and the development of information technology enables customer involve in product design. On the platform of the knowledge-intensive collaborative product family design, the framework of customer involvement in product design is brought forward in this paper.

The framework works well for three scenarios: DFC, DWC, and DBC. It is found that closer cooperation between customers and enterprises in product design on Product Family Platform can greatly improve customer satisfaction and reduce design workload as illustrated by the application of the frameworks to an aerospace fastener manufacturer. Customer involvement with initiative expression of CNs, empirical research, and protection of intellectual property rights of enterprises and customers are out of scope in this research and could be a focus in further studies.

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Li Hui: Lecturer of Business School, Shandong University of Technology, has research interests, including new methods and theories of new product development, Knowledge Management especially customer knowledge and Industry Engineering.

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