# Customer Requirement Management in Product Development: A Review of Research Issues

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**Abstract:** The importance of customer requirement management in product development has been well recognized in both academia and industries alike. This paper provides a comprehensive review of the state-of-the-art research in this field. Customer requirement management entails various issues related to requirement elicitation, analysis and specification, as well as the requirement management process. With respect to a holistic view of customer requirement management, key challenges and future research directions are identified.

*Keywords: Requirement management, customer engineering, product definition, product design, customer relationship management.*

## 1. INTRODUCTION

Understanding and fulfilling each individual customer's requirements has been recognized as a pressing challenge for companies across industries. Apart from offering market-focused products, which corresponds to an average satisfaction of customer requirements, companies are pursuing a strategy of offering customer-focused products with a large degree of individuality (Tseng and Piller, 2003). Customer requirement management thus becomes one of principal factors for product development to succeed in the marketplace (McKay et al., 2001). Poor understanding of customer requirements and inaccurate assumptions made during the elicitation and analysis of requirement information have significant negative implications on design and manufacturing of the product in terms of quality, the lead time and cost.

Over the last two decades, it has been witnessed an exponentially increasing number of consensus and publications in the field of customer satisfaction and requirement management, along with many endeavors in industrial applications. Customer requirement management bears a multidisciplinary characteristic involving such fields as business studies, marketing research, psychological studies, human factors, software engineering, and of course product design. More recently, the importance of front-end issues of product design has been catalyzed by enormous e-commerce applications. This review is dedicated to the state-of-the-art research regarding customer requirement management. While requirement engineering has been studied intensively in the field of software and information systems, the focus of this paper is devoted to product design and development of consumer or capital products. To proceed, the general process of customer requirement management is sketched, encompassing requirement elicitation, analysis and specification. The literature review is organized in the subsequent sections in accordance with various topics in relation to customer requirement management. Key challenges and future research directions are identified in relation to the state-of-the-art research.

## 2. General Process of Customer Requirement Management

The journey of achieving customer satisfaction starts with effective capturing, analyzing and understanding customers' genuine requirements. Customer attributes, sometimes called the Voice of Customers (VoC), tend to be linguistic and usually non-technical in nature. It is deemed to be difficult for engineers to translate the VoC into concrete product and engineering specifications. Customer requirement management involves a tedious iterative process enacted among customers, marketing folks, and designers. Figure 1 presents a holistic view of the customer requirement management process. It essentially embodies the mapping of customer needs (CNs) in the customer domain to functional requirements (FRs) in the functional domain, while leveraging a number of marketing and engineering concerns.

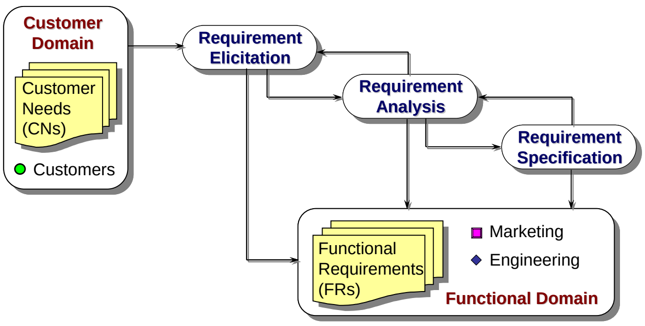


Figure 1: Customer requirement management process

### 2.1 Tasks of Requirement Management

Transformation of CNs to product specifications (FRs) implies a time-consuming and error-prone effort. Despite much advance in computer-aided design and engineering, there is relatively little progress in providing analogous support for requirement management (Prasad et al., 1993). As a result, Fiksel and Hayes-Roth (1993) point out that requirement information must be managed throughout the entire product definition process, involving such tasks as creating, disseminating, maintaining and verifying requirements. As shown in Figure 1, customer requirement management in general is mainly concerned with requirement elicitation, analysis and specification.

*(1) Requirement elicitation.* It is to systematically extract and inventory the requirements of customers and a combination of stakeholders including the environment, feasibility studies, market analyses, business plans, benchmarks of competing products, etc.

*(2) Requirement analysis.* It is to interpret the VoC and derive explicit requirements that can be understood by marketing and engineering. This task always involves classification, prioritization and negotiation of CNs.

*(3) Requirement specification.* While requirement elicitation and analysis more explicitly deal with CNs in the customer domain, requirement specification is about the definition of concrete product specifications (FRs) in the functional domain. In particular, it involves continuous interchange and negotiation within a project team regarding conflicting and changing objectives.

Darlington and Culley (2002) compare the requirement management processes for software and product design. Although quite similar, they differ at the requirement specification stage. In product design, the design requirement evolution process ends up with a complete specification of FRs, from which a successful design can result. However, requirement management does not stop at the requirement specification stage in software design. But rather it proceeds to provide a further metamorphosis and keeps elaborated to guide through the downstream solution development process.

### 2.2 Difficulties in Requirement Management

Tseng and Jiao (1998) point out the difficulties inherent in the customer requirement management process. First, customer requirements are normally qualitative and tend to be imprecise and ambiguous due to their linguistic origins. In most cases, requirements are negotiable and may conflict with one another, and thus tradeoffs are often necessary. Frequently, customers, marketing folks and designers employ different sets of context to express the requirements. Differences in semantics and terminology always impair the ability to convey requirement information effectively from customers to designers. Distinguishing requirements in terms of CNs and FRs is of practical significance (Tarasewich and Nair, 2001). An organization should put considerable efforts in capturing the genuine or "real" needs of the customers (CNs), rather than too much focus on the technological specifications (FRs) during early stage of product development (Yan et al., 2002; Chen et al., 2002a).

Second, there rarely exists any definitive structure of requirement information. Variables used to describe requirements are often poorly understood and expressed in abstract, fuzzy, or conceptual terms, leading to work on the basis of vague assumptions and implicit inference. A number of researchers have enforced a hierarchical structure or an AND/OR tree structure for the articulation of customer requirements, for example, the requirement taxonomy (Hauge and Stauffer, 1993), the customer attribute hierarchy (Yan et al., 2001), and the FR topology (Tseng and Jiao, 1998). Nevertheless, the non-structure nature of requirement information itself coincides with those findings in nature language processing (Shaw and Gaines, 1996).

Third, the mapping relationships between CNs and FRs are often not clearly available at an early stage of design. Customers are often not aware of the underlying coupling and interrelationships among various requirements with regard to product performance. It is difficult, if not impossible, to estimate the consequences of specifying different requirements. Clausing (1994) discerns customer needs and product specifications and point out the mapping problem between them is the key issue in "design for customers".

Fourth, the specification of requirements results from not only the transformation of customer requirements from those end-users, but also considerations of many engineering concerns (Du et al., 2003). In practice, product development teams must keep track of a myriad of requirement information derived from different perspectives of the product life-cycle, such as product technologies, manufacturability, reliability, maintainability, and environmental safety, to name but a few (Prudhomme et al., 2003). This is consistent with the principle of viewpoint-oriented software requirement engineering, where multiple viewpoints encapsulate different types of requirement models natural to different stakeholders (Kotonya and Sommerville, 1996).

## 3. REQUIREMENT ELICITATION

The elicitation of customer requirements emphasizes on the transformation process that converts customer verbatim constructs, which are often tacit and subjective, into an explicit and objective statement of customer needs. Appropriate elicitation techniques that are able to offer a compromised solution between the extensiveness of expertise and the genuineness of the VoC are necessary for effective acquisition of customer needs (Yan et al., 2002).

There are a number of research issues surrounding the acquisition of requirements from different perspectives of the engineers who are developing a product and the customers who eventually use the product. A wide range of research has been geared toward investigating means by which the needs of customers can be captured more effectively (Stauffer and Morris, 1992). Customer requirement may originate from diverse customer groups in various market sectors through different channels, such as interviews, questionnaires, feedback from sales agents and retailers, customer comments and complaints, as well as field maintenance reports. Kano et al. (1984) distinguish between three types of requirements which affect customer satisfaction in different ways, including must-be requirements, one-dimensional requirements, and attractive requirements. Such a differentiation of customer satisfaction helps identify the customers' expected, high-impact, low-impact or hidden requirements, and thus guides through their fulfillment process.

**3.1 Psychology-based Approaches**

A number of complex customer behaviors such as perceptions, motivations, attitudes and personality can be grouped under psychological factors for making rational decisions (Lancaster and Massingham, 1994). These factors influence the way in which customers select, organize and interpret a company and its product offerings. Kansei engineering (Nagamachi, 1989) is a technique for the translation of consumers' psychological feeling about a product into perceptual design elements (JSKE, 2003). Burchill and Fine (1997) apply the Kawakita Jiro (KJ) method and affinity diagrams as a contextual link between the initial and well-understood customer requirements. As a structured questioning methodology built upon Kelly's personal construct theory, the laddering technique has been widely used to transform customers' psychological factors into useful inputs for design applications (Rugg and McGeorge, 1995).

Many methods and tools in the field of knowledge acquisition have demonstrated their applicability in requirement elicitation for product development (Shaw and Gaines, 1996). These methods and tools can be categorized into two major types (Maiden and Rugg, 1996), viz. "contrived" techniques, e.g. sorting, laddering, and repertory grids, and traditional or "non-contrived" techniques, e.g. observation, survey, ethnographic approaches, self-report, and interview. It is claimed that the "contrived" type refers to techniques that are not so heavily dependent on natural language dialogue but good at reducing systematic bias, eliciting implicit knowledge, representing declarative and procedural knowledge. Maiden and Rugg (1996) propose a framework called acquisition of requirements (ACRE) to assist practitioners in understanding the strengths and weaknesses of each of the methods for requirement elicitation.

**3.2 AI-based Approaches**

The subjective factors and the intensive statistical analysis involved during customer requirements acquisition may complicate the problem and even lead the elicitors astray. Many techniques, such as fuzzy systems (Turksen and Willson, 1992), regression analysis (Jenkins, 1995), and expert systems (Hauge and Stauffer, 1993), have been developed for eliciting customer requirements more accurately and objectively. Finch (1999) explores the potential of Internet discussions for enhancing customer involvement in the requirement acquisition process.

Hauge and Stauffer (1993) develop the taxonomy of customer requirements as an initial concept graph structure to assist in traditional qualitative market research for question probe. Chen et al. (2001) develop an expert system for concurrent product design by organizing requirement information using a graph decomposition algorithm (Chen and Occeña, 2000) and a knowledge hierarchical sorting process (Chen and Occeña, 1999). Chen et al. (2002a; 2002b) and Yan et al. (2002) investigate integrated approaches to the elicitation of customer requirements by combining picture sorts and laddering, fuzzy evaluation and neural network techniques.

### 3.3 Knowledge Recovery

Due to the difficulties inherent in the requirement elicitation process, reusing knowledge from historical data suggests itself as a natural means to facilitate the handling of requirement information and tradeoffs among many customer, marketing and engineering concerns (Shahin et al., 1999). Tseng and Jiao (1998) propose to identify FR patterns from previous product designs for addressing a broad spectrum of domain-specific customer requirements. In their model, various FRs are grouped according to the similarity among customers (i.e., market segments). The focus is on the functional domain. Du et al. (2003) extend the idea to study the patterns of CNs for better customization and personalization. Chen et al. (2002b) apply neural network techniques to construct a customer attribute hierarchy for improving customer requirement elicitation. Both ideas emphasize on the customer domain. While these proposed solutions emphasize on the identification of either CN or FR patterns, the mapping relationship between CNs and FRs should also be taken into account. In this regard, Jiao and Zhang (2005a) apply the association rule mining technique to exploit the patterns of CN-FR mappings.

## 4. REQUIREMENT ANALYSIS

Extensive studies have indicated the significance of careful assessment of market and customer requirements for the success of product development (Karkkainen and Elfvengren, 2002). Analysis of customer requirements involves the understanding of customer preference and relevant target markets, along with requirement prioritization and classification, as elaborated below.

**4.1 Understanding Market and Customer Needs**

A number of customer-related marketing approaches have been reported in response to the increasing importance of customers in today's business environment. These approaches include, for instance, customer satisfaction, customer marketing, customer-based method, customer-driven evolutionary systems, and customer loyalty. Customer relationship management has become a focus in today's marketing research (Barness, 1997). A number of theories have been proposed to study the potential values of relationship marketing in customer markets, such as neoclassical microeconomics, transaction costing, relational contracting, social exchange, the equality theory, and the resource dependency theory.

Curry (1991) advocates a customer marketing strategy for identifying, acquiring, keeping and developing customers through formulating a customer pyramid. While a clear understanding of customers and markets through marketing research is of paramount importance, there are other factors to consider as well for managing customer requirements in product development (Lancaster and Massingham, 1994). Bennett (1996) argues that customer group segmentation should be emphasized under the intensifying competition pressures. Barness (1997) points out the necessity of quantitative customer evaluation and argues that individual customers should be put in a more direct contact with manufacturers or organizations via a channel using information technologies. In this regard, Khoo et al. (2002) develop a customer-oriented information system to establish a closer link between product re-innovation and customer involvement in product conceptualization.

Kotler (1991) proposes the micro and macro perspectives to explain the different ways in which customer requirements are evaluated. From the micro perspective, the functional correlation between customer requirements and design specifications is largely influenced by engineering considerations. The macro perspective takes into account a broad range of socio-cultural factors. It emphasizes the fact that customer requirements elicited from one customer group may conflict considerably with another. Nielson (1998) analyzes multicultural customer factors to support organizations to recognize individual customer needs better and to interact with customers directly. Lancaster and Massingham (1994) argue that precise evaluation for major customer groups and markets with respect to competition situations is imperative

**4.2 Customer Preference**

Market researchers have emphasized customer profiling by applying regression analysis to compare customer characteristics and to determine their overall ranking in contribution toward profitability (Jenkins, 1995). Traditionally, market analysis techniques are adopted for investigating customers' responses to design options. For example, conjoint analysis is widely used to measure preferences for different product profiles and to build market simulation models (Green and DeSarbo, 1978). Louviere et al. (1990) use discrete choice experiments to predict customer choices pertaining to design options. Turksen and Willson (1992) employ fuzzy systems to interpret the linguistic meaning regarding customer preferences as an alternative to conjoint analysis. Others have taken a qualitative approach and used focus groups to provide a reality check on the usefulness of a new product design (LaChance-Porter, 1993). Similar techniques include one-on-one interviews and similarity-dissimilarity attribute rankings (Griffin and Hauser, 1993).

D'Ambrosio and Birmingham (1995) emphasize on preference-directed design that is based on an imprecise value function generated from a set of preference statements reflecting the relative importance of each customer attribute. Tseng and Du (1998) employ conjoint analysis to acquire customer preference on product functionality. Wan and Krishnamurty (2001) develop a learning-based preference model that is based on a lottery questions-based elicitation process. McAdams et al. (1999) propose to perform functional exploration to support the mapping among customer needs, functions and forms in accordance with an interdependent product hierarchy. Yan et al. (2006) establish an environment, based on a four-domain modeling paradigm and a three-phase process, for identifying different demographical customer preferences.

### 4.3 Requirement Prioritization

Prioritizing customer preference with respect to a set of customer requirements is essential (Griffin and Hauser, 1993). This is always achieved through assigning different importance weights for customer requirements. Such an indication of relative importance of requirements significantly affects the target values to be set for the engineering characteristics. Kwong and Bai (2003) posit customer requirement prioritization as a multiple criteria decision-making problem. Ho et al. (1999) propose to determine the importance weights of customer requirements based on group decision making, where a set of criteria agreeable to all individuals are formulated to aggregate individual preferences into group consensus. Chen et al. (2003) propose to derive the relative importance of customer requirements using supervised learning with a radial basis function (RBF) neural network. Gustafsson and Gustafsson (1994) apply conjoint analysis to prioritize customer requirements through pairwise comparisons. To deal with vagueness and imprecision inherent in requirement information, Chan et al. (1999) convert the importance assessment of the customer requirements from crisp values into fuzzy numbers, based on which the importance weights of customer requirements are derived using an entropy method.

*(1) AHP.* Owing to its strength in qualitative decision making with multiple criteria, the analytic hierarchy process (AHP) has been widely used to determine the degree of importance of the customer needs (Saaty, 1990). Akao (1990) applies the AHP to determine tradeoff weights for customer requirements based on pairwise comparisons for each level of customer requirements toward customer satisfaction. Armacost et al. (1994) employ a nine-point scale for applying the AHP to generate the importance weights of customer requirements. Fukuda and Matsuura (1993) also propose to prioritize the customer requirements by AHP for concurrent design. Zakarian and Kusiak (1999) adopt the AHP in determining the importance of individual team members based on the customer and engineering requirements of a product. Larichev and Moshkovich (1995) deal with the AHP from a multi-attribute utility theory perspective with focus on indirect elicitation of customer preference through comparison of real alternatives.

*(2) Fuzzy AHP.* Van Laarhoven and Pedrycz (1983) extend the AHP to consider fuzziness inherent in linguistic assessment of customer requirements. They propose to compare fuzzy ratios in terms of membership functions, based on which the local fuzzy priorities are derived. Vanegas and Labib (2001) propose to convert the weights obtained from the AHP into fuzzy numbers using fuzzy line segments. Fung et al. (1998) incorporate fuzzy inference into the AHP for analyzing and prioritizing customer requirements. Kwong and Bai (2003) demonstrate how to determine the importance weights of customer requirements based on extent analysis of fuzzy AHP.

### 4.4 Requirement Classification

A classification of requirements helps guide the designer in compiling, organizing, and analyzing product design issues (Rounds and Cooper, 2002). Fung et al. (1998) propose to categorize customer requirements based on the concept of affinity diagram. The advantage is its creative properties, rather than solely relying on logical or intellectual reasoning as with other statistical methods. Lin et al. (1996) propose an ontology for representing requirements that supports a generic requirement management process. The requirement ontology defines such objects as parts, features, requirements, and constraints by specifying their attributes using first-order logic and identifying the axioms capturing the constraints and relationships among the objects.

The taxonomic approach to requirement management has attracted much attention (Morris and Stauffer, 1994). Information collected in a taxonomy is easy to manage and can ultimately be capitalized upon to improve product definition. Rounds and Cooper (2002) develop a set of taxonomies to assist in gathering, storing, using, and reusing requirements. Stauffer and Slaughterbeck-Hyde (1989) formulate a taxonomy that includes lifecycle design considerations.

With focus on the needs of corporation customers, Gershenson and Stauffer (1999a) develop a taxonomy for gathering, managing, and retrieving requirement information. They demonstrate that the taxonomy provides a generic template with which to create taxonomies for a given product within a given company or industry. Gershenson and Stauffer (1999b) introduce the assignment of relative weights to taxons in order to assist in prioritizing various requirements during the design process in a manner similar to the wisdom of customer importance ratings. The application of such a weighted decision-matrix approach assumes mutual exclusiveness of individual requirements.

## 5. REQUIREMENT SPECIFICATION

The requirement specification task is mainly concerned with the creation of a structurally concrete and precise specification of product requirements based on functional knowledge that has been elicited from customers and other key stakeholders (Stauffer and Morris, 1992). Fung et al. (1998) refer product specifications to the voice of designers (VoD) that takes the form of product attributes or design features. McAdams et al. (1999) propose a matrix approach to the identification of relationships between product functions and customer needs. Brahim et al. (1993) propose a neural network model for relating product specifications with the results of performance tests. Karsak et al. (2002) propose an integrated approach for determining the design requirements based on the analytic network process and zero-one goal programming. With a laddering-based design knowledge hierarchy, Yan et al. (2005) develop a restricted Coulomb energy (RCE) neural network for organizing design requirements.

### 5.1 Requirement Transformation

To support the mapping from VoC to VoD, Fung et al. (1998) develop a fuzzy customer requirement inference system that is capable of performing approximate reasoning in specific domains based on the knowledge and experience available in the company. Mousavi et al. (2001) present a customer optimization route and evaluation (CORE) model to translate customers' qualitative requirements into design technical attributes while considering interactions between design and market needs. Shoji et al. (1993) propose a method for transforming the VoC to product specifications, in which semantics methods, such as the KJ method (affinity diagram) and multi-pickup method, are applied as the basis for discovering underlying facts from affective language.

Morris and Stauffer (1994) develop a methodology of organizing specifications in engineering (MOOSE) to assist design teams in organizing and managing requirement information during product definition. The MOOSE taxonomy provides a hierarchy of design issues that are used to translate qualitative requirements into design specifications. Gershenson and Stauffer (1999b) extend the MOOSE taxonomy to assist designers in considering the corporate requirements regarding manufacturing during product development. Such a categorization culminates with both product and process attributes.

A number of efforts have been devoted to the correlation of customer requirements with design issues. Tseng et al. (1997) outline a virtual design architecture for satisfying individual customer needs by assisting customers in selecting preferred product alternatives from product families. Huang and Mak (1999) develop a standalone computerized design tool to support redesign using information of customers obtained from an established functional or sub-functional tree-like architecture. Tseng and Jiao (1998) establish a computer-aided design tool kit to support requirement specification for product variants based on previous functional requirement patterns. Otto and Wood (1998) investigate a redesign methodology that is based on the recognition of design specifications by historical data projection. Chen et al. (2005) construct a laddering-based design knowledge hierarchy to transform customer preferences into specific product concepts, and exploit conjoint analysis and Kohonen association for product customization.

**5.2 QFD**

Quality function deployment (QFD) has been widely used to translate customer requirements to technical design requirements (Prasad, 1998). QFD utilizes a house of quality (HOQ) - a matrix providing a conceptual map for the design process - as a construct for understanding CNs and establishing priorities of FRs to satisfy them (Clausing, 1994). A key component of QFD is the customer requirement analysis framework to facilitate the designer’s view in defining product specifications. To empower QFD with market aspects, Fung et al. (1998) propose to pre-process the VoC prior to its being entered as customer attributes into the HoQ. Researchers at IBM have applied structured brainstorming techniques to incorporate customer requirements into the QFD process (Byrne and Barlow, 1993). Tang et al. (2002) propose a QFD planning approach for examining the impacts of the relevant financial factors in product development. Fung et al. (2003) extend this concept with resources constraints and allocation within the QFD process.

**5.3 Fuzzy QFD**

Besides addressing the relationships between CNs and FRs, representing the imprecision inherent in the QFD process is a challenging task. To enhance handling of ambiguous requirement information and evaluative inputs, conventional QFD approaches have been extended to fuzzy QFD (Vanegas and Labib, 2001), where subjective crisp variables are expressed as fuzzy numbers (Wang, 1999). Fung et al. (2002) extend QFD-based customer requirement analysis to a non-linear fuzzy inference model. Karsak (2004) develops a fuzzy multiple objective programming approach that incorporates imprecise and subjective information inherent in the QFD planning process to determine the level of fulfillment of design requirements. Temponi et al. (1999) present a fuzzy logic-based methodology to facilitate communication between members of the QFD team regarding requirement specification. Chen et al. (2004) develop a fuzzy regression-based mathematical programming model to extend the scope and to increase the flexibility of QFD planning.

**5.4 Prioritization of Design Requirements**

The importance rating among engineering characteristics (i.e., FRs) has been recognized as crucial in the QFD process (Chan and Wu, 2002). Wasserman (1993) develops a linear programming model for the prioritization of design requirements in the QFD planning process. Bode and Fung (1998) stress the importance of achieving maximum customer satisfaction under resource constraints and advocate to perform the prioritization of design requirements. Wang (1999) employs a fuzzy outranking approach to prioritize the design requirements recognized in QFD based on the assumption that design requirements are independent. Taking into account the effect of CNs on FR priorities, Ramasamy and Selladurai (2004) propose a fuzzy logic-quality function deployment model for determining optimal rating of FRs by simulating the QFD matrix for randomized CN rating in a fuzzy range.

Büyüközkan et al. (2004) employ a general form of the AHP - the analytic network process - to prioritize FRs by considering inter-dependence between CNs and FRs as well as the intra-dependence among them. Khoo and Ho (1996) develop a correlation matrix of CNs for deriving the priorities of FRs. Trappey et al. (1996) propose a quality attribute ranking algorithm for rating CNs and FRs simultaneously. Masud and Dean (1993) propose an approach for prioritizing FRs by compute the relationships between CNs and FRs as a fuzzy weighted average. Kalargeros and Gao (1998) calculate

FR priorities by modifying CN weights based on the actual customer satisfaction, the market position and sales considerations. Park and Kim (1998) present a decision model for prioritizing FRs using crisp data.

**5.5 Targets of Design Requirements**

A number of studies on QFD have emphasized on the calculation of optimal levels of satisfaction to be achieved by a certain set of FR targets. Targets of FRs, or their improvements, are usually defined by design team subjectively and empirically (Zhou 1998). Formal decision model is important to assist them in ranking FRs (Wang 1999). Vanegas and Labib (2001) apply a fuzzy set theoretic approach to determine optimum target values of engineering characteristics in QFD with consideration of the relevant constraints. Zhou (1998) proposes to capture the influences of FRs on CNs as fuzzy numbers, based on which the improvement of FRs are optimized in terms of the amount of change to be made to each FR. Moskowitz and Kim (1997) propose a mathematical programming approach for determining the targets of FRs, where the level of satisfaction produced by an FR value per CN is expressed as a function.

Dawson and Askin (1999) develop a nonlinear mathematical program for determining the optimum of FRs, subject to costs and development time constraints. Fung et al. (1998) develop a fuzzy inference system to map the qualitative and imprecise customer needs to the relevant design requirements and accordingly determine the respective target values. Fung et al. (2005) further put forward a fuzzy expected value-based goal programming model to facilitate product planning with QFD. Chen et al. (2005) apply this goal programming model to calculate target values of the engineering characteristics in the planning matrix of a HOQ. Kim et al. (2000) propose a procedure for determining target levels for engineering characteristics using fuzzy regression and fuzzy optimization.

## 6. PROSPECTS FOR FUTURE RESEARCH

As witnessed in this comprehensive review, customer requirements has been tackled from a broad scope of product definition involving many disciplines. Owing to the flurry of various research efforts, this field of research has emerged rapidly in the past two decades. From a holistic view, there is still much to be desired in order to achieve system-wide solutions and decision support for customer requirement management. In this regard, the following areas are suggested as the avenue for further research efforts.

### 6.1 Requirement Management Process

The requirement management process itself generally involves a number of issues such as process models, process actors, process support and management, process quality and improvement, etc. While a generic requirement management process may not be possible, it is imperative to formulate systematic procedures and models for managing this process throughout. For example, what are the major steps in a requirement management process? What are the roles and responsibilities in requirement management? How about interactions among roles at each step of the process? How to validate requirements in terms of consistency, completeness and accuracy? How about change management and requirement traceability, which is concerned with maintaining links among requirements, between requirements and design, as well as between requirements and stakeholders?

Requirement modeling constitutes an important area of study. Harding et al. (2001) point out the need for effectively modeling and decision support during the process of translating imprecise non-technical customer wishes into useful design specifications within an extended design team. A number of modeling formalisms have been developed for software design. For example use cases entail a scenario-based technique in the UML for identifying the actors and interactions among requirements (Schneider and Winters, 2001). However, so far there exist few formal approaches or any standard for customer requirement modeling in relation to product design.

Another challenging topic is regarding collaborative negotiation among multiple stakeholders and actors involved in the requirement management process (Chen and Tseng, 2005). Bailetti and Litva (1995) foresee the importance of creating mechanisms for ensuring that customer requirement information from various sources is internally consistent. This calls for a synergy of customer requirement information acquired by marketing and the information processing requirements of the design community. As a result, the knowledge that designers actually apply to produce a design must incorporate customer requirement information endorsed by marketing and product management at all stages of product development. In this regard, we believe that future research on customer requirement management should progress along the route of intelligent knowledge management, so that customer requirement profile patterns, as well as the resulting functional relationships between product features, can be systematically maintained in knowledge repositories for retrieval, analysis, projection and forecasting of the VoC (Fung et al., 2006).

### 6.2 Customer Interaction and User Innovation

Of primary importance in requirement management is the interaction with customers. On the technical side, designers have always assumed that customers' satisfaction with the designed product is sufficiently high as long as the product meets the prescribed technical specifications; however, what customers appreciate is not the enhancement of the solution capability but the functionality of the product per se. This means that the traditional dimensions of customer satisfaction may deserve scrutiny, for example, identifying those product characteristics that cause different degrees of satisfaction among customers; understanding the interrelation between the buying process and product satisfaction; determining the key factors regarding the value perception of customers; and justifying an appropriate number of choices from the customers' perspective.

Equally important is the customer decision-making process when interacting with the product. This coincides with consumer behaviors in business systems based on customer involvement in the product fulfillment process (Huffman and Kahn, 1998). Many questions are pending. For example, what are the incentives for integrating customers into value creation? And what factors drive customers to interact with product functionality? Toward this end, customer requirement management must incorporate with marketing engineering interactions (Michalek et al., 2005; Jiao and Zhang, 2005b), along with customer perceptions (Jiao et al., 2006).

Customer input has become a valuable source of product innovation (von Hippel, 2001). While early studies in user innovation have limited to industrial markets and professional users, recent focus is moving toward consumer markets and customer integration (Franke and Shah, 2003). General findings also suggest the same patterns as their industrial counterparts, which means, end users are willing and able to develop substantial ideas, concepts and prototypes for new products (Tietz et al., 2005). Therefore, user innovation lends itself to be a promising dimension of the requirement process.

**6.3 Customer Requirement Management in E-Commerce**

In light of new capabilities implied by e-commerce, customers will be able to involve more interactively and directly in product design. Advanced information and communication technologies (ICT) offer great potential for improving the requirement management process. For instance, data warehousing and data mining techniques may help explore hypotheses that hides useful patterns of customer requirements. Web service and web mining techniques have received much attention to enhance customer experience toward total customer relationship management.

Within e-commerce, the fulfillment of customer needs is implemented as a three-stage process consisting of requirement elicitation, product search and product presentation. The search of the product space, however, may take place in tandem with the requirement elicitation process. Such a coupling requires for advanced support for information retrieval and problem solving throughout the requirement management process. For example, the interaction of customers with virtual sales agents may become a notable scenario. Bergmann and Cunningham (2002) investigate into a navigation-by-asking model for customer requirement acquisition in e-commerce. Blecker et al. (2004) advocate to develop advisory systems for supporting customers during the requirement elicitation process. In addition, the need for constructing and utilizing electronic catalogs may bring in new challenges for customer requirement management. For example, requirement taxonomies naturally indicate a hint of navigating electronic catalogs within existing templates.

## 7. SUMMARY

Substantial progress has been achieved in the areas of customer requirement elicitation, analysis and specification. Future research lies in the holistic view and system-wide solutions to the entire requirement management process, in conjunction with advanced ICT support. Despite the diligent efforts of many researchers, there are still a number of relatively unexplored topics that offers numerous opportunities for scholarly inquiry. As discussed in this review, the unanswered questions may be examined through a wide variety of approaches, both theoretically and methodologically. It is anticipated that the review will serve as a basic frame of reference and will spur more research to examine this important and fascinating field.

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