Technical Correspondence

Mining Demand Chain Knowledge for New Product Development and Marketing

Shu-Hsien Liao and Chih-Hao Wen

***Abstract*—Many enterprises devote a significant portion of their budget to new product development (NPD) and marketing to make their products distinctive from those of competitors, and better fit the needs and wants of consumers. Hence, knowledge and feedback on customer demand and consumption experience has become an important information and asset for enterprises. This paper investigates the following research issues in a world leading bicycle brand/manufacture company, GIANT of Taiwan: what exactly are the customers' "functional needs" and "wants" for bicycles? Does knowledge of the customers and the product itself reflect the needs of the market? Can product design and planning for production lines be integrated with the knowledge of customers and market channels? Can the knowledge of customers and market channels be transformed into knowledge assets of the enterprises during the stage of NPD? The *a priori* algorithm is a methodology of association rule for data mining, which is implemented for mining demand chain knowledge from channels (sales and maintenance) and customers. Knowledge extraction from data mining results is illustrated as knowledge patterns and rules in order to propose suggestions and solutions to the case firm for NPD and marketing.**

***Index Terms*—Association rule, data mining, demand chain management, knowledge extraction, marketing segmentation, new product development (NPD).**

I. Introduction

IN manufacturing and business processes, the transmission between information flow, money flow, and logistics flow generally follows supply chain management (SCM). SCM focuses on using the aforementioned information to optimize the material flow through the successive steps of inbound logistics, operations, and outbound logistics across the supply chain [1]. Essentially, SCM is a set of practices aimed at managing and coordinating the supply chain from raw material suppliers to the ultimate customer [2]. Upstream firms in a supply chain usually face a higher degree of order fluctuations than downstream firms, which are closer to the end customers. This is the so-called bullwhip effect [3]. However, with rising living standards and advances in production capacity, the traditional "mass production" mode of operation can no longer effectively meet the needs of customers, who are looking for uniqueness, innovation, and novelty. The motivation behind a purchase originates from the affective domain and goes beyond the mere desire for the functional purpose of the product. It seems that customer requirements increasingly drive the performance of the overall supply chain [4], [5]. Thus, a demand chain is a supply chain that emphasizes market mediation more than ensuring efficient physical supply of the product [6].

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In the demand chain, the focus is clearly customer-centered, as defined early by Brace [7], in explaining the concept of a demand chain as "... the whole manufacturing and distribution process may be seen as a sequence of events with but one end in view: it exists to serve the ultimate consumer." DCM is a set of practices aimed at managing and coordinating the whole demand chain, starting from the end customer and working backward to raw material suppliers [8]. The main stimulus behind this has been the shift in power away from the supplier and toward the customer [9]. Thus, DCM is the management of supply production systems designed to promote higher customer satisfaction levels through electronic commerce (EC) that facilitates physical flow and information transfer, both forwards and backwards between suppliers, manufacturers, and customers [10]. The generation of consumer product ideas is usually "manufacturer-active," rather than "customer-active" [11]. Demand chain management tries to obtain more reliable and detailed information about (prospective) consumers [1], which is the practice that manages and coordinates the supply chain from end customers backwards to suppliers [2], [12], [13].

In addition, inefficient customer knowledge utilization would render the data collected useless, causing databases to become "data dumps" [14]. How to effectively process and use data is becoming increasingly important. This calls for new techniques to help analyze, understand, or even visualize the huge amounts of stored data gathered from business and scientific applications [15]. Among the new techniques developed, data mining is the process of discovering significant knowledge, such as patterns, associations, changes, anomalies, and significant structures from large amounts of data stored in databases, data warehouses, or other information repositories [14], [16]. Customer knowledge extracted through data mining can be integrated with product and marketing knowledge from research and be provided to upstream suppliers as well as downstream retailers. Thus, it can serve as a reference for product development, product promotion, and customer relationship management [17].

II. NPD of Case Firm

A. Case Firm

There is intense competition in the bicycle industry, and product development is among the essential processes for success, survival, and renewal of organizations, particularly for firms in fast-paced or competitive markets [18]. In the case of product change, it is well known that incremental product innovation is well managed by the cooperation between marketing knowledge and technology knowledge [19], [20]. In Taiwan, the bicycle industry includes upstream, midstream, and downstream firms. The case firm, GIANT, began as a downstream original equipment manufacturing (OEM) factory, and has grown to become the largest bicycle manufacturer in the world with the capabilities of order design manufacturing (ODM) and owner branding manufacturing (OBM). It is considered the best brand in both Taiwan and Mainland China, the second in the USA, and a widely popular brand in Europe, Japan, and Australia. It has factories in Taiwan, Mainland China, and The Netherlands. Its annual production amounts to 1.1 billion bicycles, around 5% of the global bicycle production. GIANT has over 10 000 marketing and distribution outlets providing fast and comprehensive service to customers. Forbes selected it as one of the most successful small-scale enterprises in 2002.

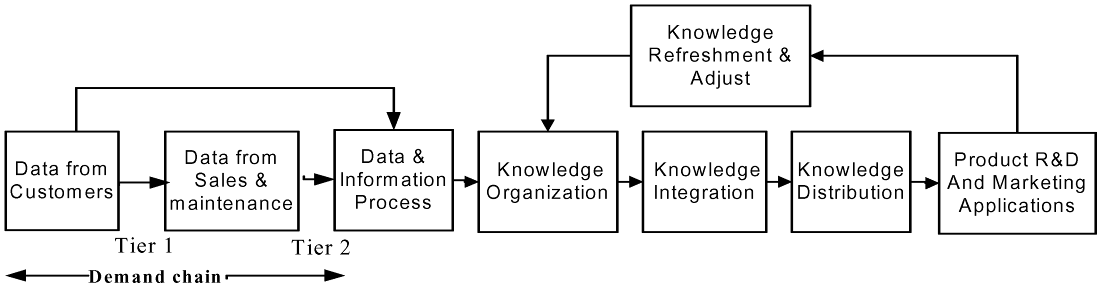

Fig. 1. Demand chain information and knowledge flow.

B. NPD of the Case Firm

As mentioned earlier, the case firm originally manufactured and sold bicycles in the downstream of supply chain system of this industry. Apart from the production of parts and accessories, it is now mainly involved in new product development (NPD). For new products designed by its R&D team, the parts and accessories are manufactured by collaborating firms in the upper and middle streams, and are then assembled and delivered to the distribution outlets for sale worldwide.

Bicycle manufacturing is a traditional labor-intensive industry. Ongoing NPD or slight modifications of the design are necessary because competition is keen and the competitors are adept at imitation. In general, the NPD process involves five stages, namely idea conception, product design and development, manufacturing and market testing, commercialization and product launch, and market development [21]. According to interview data with the Chief Executive Officer (CEO) and Managers of the R&D Department from the case firm headquarters in Taiwan, its NPD problems are described as follows.

C. NPD and Marketing Problems of Case Firm-–From Supply Chain Perspective

Traditional NPD involves professional engineers and designers responsible for exploring novelty in manufacturing processes and product designs. However, their emphasis is more on enhancing the functionality of the products to meet customers' needs, and much less attention has been paid to the use and maintenance of the newly designed products. As a result, these innovations may fall short of meeting the practical tastes and wants of customers. When customers buy a certain product or use a certain service, they may have some purposes to achieve or some experience to realize through such consumption. Hence, to tap into such hidden agendas of consumption can narrow the gap between new products developed and the expectations of potential customers. Thus, techniques such as data mining are much needed and can be of significant help to both R&D and marketing departments.

D. Innovative Thinking of the Case Firm-–From the Demand Chain Perspective

In a survey of over 100 U.S. managers in 2002, Schmitt [22] identified customer focus as the single most important differentiator between the best and worst companies in an industry. To focus on customers would imply providing the right product and service to the right customer at the right time through the right channel.

1) Who Are Our Customers?: In this research, the customer unit is a household, and over time, the household may have different needs that demand different products. Providing appropriate products and services to meet the changing needs of customers over time can help sustain the transaction relationship and maintain interaction.

2) How Can Customers Contribute to Product Design?: In the past, feedback from customers was mainly collected by the service department, which handles complaint calls from customers. In other words, the enterprises played a passive role in waiting for feedback from customers. Hence, enterprises should be more active in soliciting the opinions of customers. Storing knowledge related to the needs and consumption experience of the customers in the database can enable the enterprise to produce products and services that meet the demand of the customers.

3) What Are the Advantages Acquired by the Customers?: Consumers often view innovation in terms of whether a new product, service, or communication helps them improve how they live [22]. Hence, to involve customers in the design of new products can make the newly designed products better meet the customers' expectations and needs. Quality products and services obtained through proper marketing channels and tailor-made to fit customer needs can be distinctive in the view of the customers.

4) What Are the Advantages Acquired by the Case Firm?: Since internal information of this industry mainly concerns changing the market demand and cost consideration, NPD made on the basis of such information is not likely to result in much innovation but rather greater competition.

Previous collaborative designs have only integrated knowledge from the supply chain partners. Adding customer knowledge to NPD can result in distinctive products and services that can ensure greater profits. Involving customers in the design stage can foster knowledge exchange, while involving them in the marketing stage can ensure that needs of different customer segments are met, bringing in greater profits. However, the knowledge extracted in these collaborative product design process is an essential resource of successful competition in the market [23]. As summarized in Fig. 1, through information and data processing, knowledge is organized, integrated, and finally distributed to R&D and marketing departments for applications, while feedback from these applications can refresh and adjust the organization of knowledge.

III. Data Mining

A. Data Source

Data are collected from customers and channel/maintenance stores based on NPD and marketing questionnaire design, including: 1) customer/channel basic data table; 2) customer product involvement data table; 3) customer product preference data table; 4) customer behavior and attitudes data table; 5) maintenance data table; 6) customer complaint data table; 7) sales experience data table; 8) product, part, and accessory data table; and 9) transaction data table. Customer data were collected by interviewing customers who have purchased bicycles with help from channel/maintenance stores. Channel data are gathered by collecting questionnaire replies from channel/maintenance stores as well. Data collection was then conducted between May and August

TABLE I
FRAMES PART ASSOCIATION RULE (MIN SUP(X)9%; MIN CONF($X \rightarrow Y$)50%)

Rule	Lift	Sup(X)	Sup(Y)	Conf (X→Y)	Consequent	Antecedent			
R_{A1}	1.17	11.50	42.73	50.00	Saddle & Seat post	Area= North	Low product involvement	Age = 20~29	Women's Bike

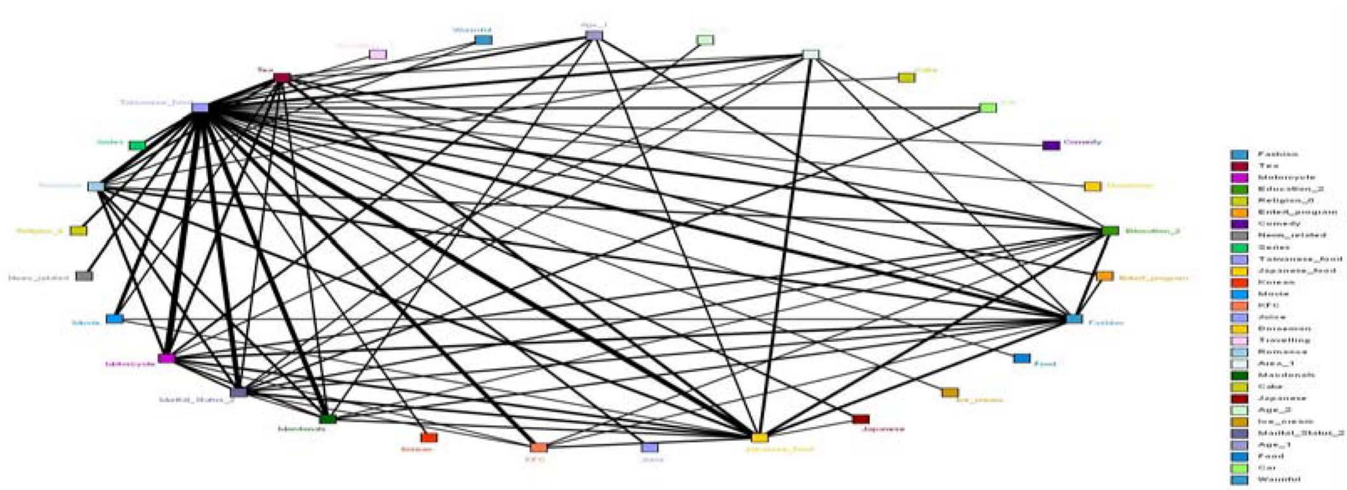

Fig. 2. Bike fault-frames association diagram.

2004 on channel/maintenance locations in 23 counties of Taiwan. A total of 1019 customers and 329 channel/maintenance stores participated in completing questionnaires, and relational database construction was completed in October 2004.

B. Association Rule and A Priori Algorithm

As stated by Agrawal *et al.* [24], discovering association rules is an important data mining problem, and there has been considerable research on using association rules in the field of data mining problems. The association rules algorithm is mainly used to determine the relationships between items or features that occur synchronously in the database. For example, if people who buy item X also buy item Y, there is a relationship between item X and item Y, and this information is useful for decision makers. The association rules are defined as follows [25].

Make $I = \{i_1, i_2, \ldots, i_m\}$ as the item set in which each item represents a specific literal. D stands for a set of transactions in a database in which each transaction T represents an item set such that $T \subseteq I$, i.e., each item set T is a nonempty subitem set of I. The *association rules* are an implication of the form $X \rightarrow Y$, where $X \subset I, Y \subset I$, and $X \cap Y = \Phi$. The rule $X \rightarrow Y$ holds in the transaction set D according to two measure standards—*support* and *confidence*. Support [denoted as $\mathrm{Sup}(X, D)$] to represent the rate of transactions in D containing the item set X. *Support* is used to evaluate the statistical importance of D, and the higher its value, the more important the transaction set D is. Therefore, the rule $X \rightarrow Y$ has *support* $\mathrm{Sup}(X \cup Y, D)$ represent the rate of transactions in D containing $X \cup Y$. Each rule $X \rightarrow Y$ also has the other measuring standard called confidence [denoted as $\mathrm{Conf}(X \rightarrow Y)$], representing the rate of transactions in D that contain$X$ and also Y, i.e., $\mathrm{Conf}(X \rightarrow Y) = \mathrm{Sup}(X \cap Y)/\mathrm{Sup}(X, D)$ [26], [27].

C. Mining Knowledge for NPD

The analysis lift value should be set at greater than one, while the minimum support and confidence values are set at least 9% and 50%, respectively, and then adjusted accordingly, if necessary, during the analysis process. Four different selections are presented for the bicycle problems: frame, wheel, transmission, and steering. Among these, the one that appears least frequently, a total of 74 times, is the "bicycle frame—rear part," which accounts for 9.23% of the frames in total; therefore, the minimum support value is set at that and the minimum confidence value is set at greater than 50%. At the same time, if association rule A is one type of association rule B's arrangement compositions, then association rule A is unnecessary. This means that the association rule emphasizes the ability to include all the large item association rules.

1) Frames Part (Pattern A): From Table I, it can be predicted that the group of consumers that damage the frames the most are the women's bike users from the northern area, with less involvement in the product, and ages ranging from 20 to 29. Therefore, inspecting the cushion chair shaft of the women's bike is the most important task to prevent consumers from being injured because of problems with parts. The association graph in Fig. 2 shows the association relationships between all the decision variables. The combinations of all the decision variables can be shown with this type of graph. All the lines in the graph represent the sign on records of the customers in the database; the thickness of the lines represents whether the extent of the relationship between the two decision variables is high or low.

2) Wheel Part (Pattern B): No matter what the level of involvement, wheel faults will occur, and the relationships between the patterns will be stronger; so it is necessary to increase our attention toward the product material or the purchasing source of the wheels.

3) Transmission Part (Pattern C): According to pattern C, it can be seen that more chain faults are likely to occur, but these relationships are weaker than the women's bike consumers.

4) Steering Part (Pattern D): In order to overcome these two faults, there must be more careful design and manufacturing process inspections or a high rate of examination and repair to prevent consumers from being injured from using these products.

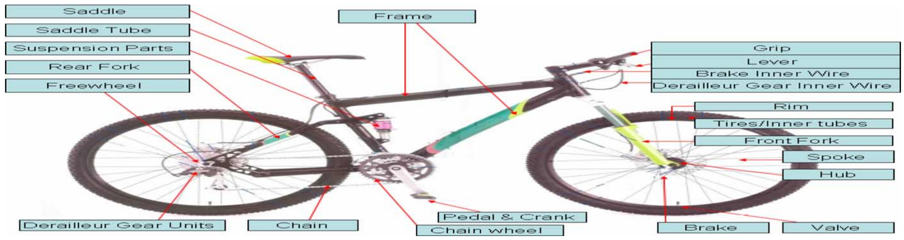

Fig. 3. NPD.

TABLE II
CUSTOMER SATISFACTION ASSOCIATION RULE (MIN SUP(X)10%; MIN CONF($X \to Y$)60%)

Rule	Lift	Sup(X)	Sup(Y)	Conf (X→Y)	Consequent	Antecedent		
R_{G1}	1.97	10.60	37.2	73.10	Current price NT 3001~6000	Preferred price NT 3001~6000	MTB	Women's Bike
R_{G2}	1.94	11.70	37.2	72.30	Current price NT 3001~6000	Preferred price NT 3001~6000	Age = 20~29	Women's Bike
R_{G3}	1.77	13.50	39.92	70.80	Preferred price NT 2001~3000	Current price NT 2001~3000	MTB	Age = 20~29
R_{G4}	1.70	13.40	39.92	67.60	Preferred price NT 2001~3000	Current price NT 2001~3000	Age = 20~29	Women's Bike

Since customers are affected most directly by damaged parts, the psychological or physical injuries they suffer are the deepest. We should take more initiative to discover problems and remedy them, also reviewing why they occurred so that customers will be more loyal to the GIANT brand and products.

As shown in Fig. 3, after data mining for NPD has been done, the case firm can design and develop a type of bicycle based on the mined knowledge through pattern A to pattern D by using 16 knowledge rules. By doing so, GIANT has more capability to improve its NPD by extracting and implementing channels and customer knowledge on the demand chain. In addition, this demand chain knowledge mining could bring the case firm closer to the market from the side of manufacture on the supply chain.

D. *Mining Knowledge for Marketing*

The price of the products that customers use now represents the price that customers are willing to pay before they purchase the product. This is because before using the product, customers tend to give product evaluation in advance, and together with the price that they are willing to pay, this will be the price that customers are currently willing to pay to use the product. The price that customers are willing to pay in the future depends on the current experience that the customers gain from using the product (see Table II). Customers for the mountain bikes and women's bikes all tend to have paid a relatively low price for their current product, and price that they will be willing to pay for their next product will also be low.

IV. DISCUSSIONS AND FUTURE WORKS

Human needs are states of felt deprivation, for example, physical needs for food, clothing, shelter, and safety. Individual needs seek for knowledge, esteem, and self-expression. These needs were not created by manufactures or marketers; they are a basic part of the human makeup. Human wants are the form human needs take as they are shaped by culture and individual personality. They are shaped by one's society and are described in terms of objects that will satisfy needs. Therefore, manufactures or marketers can seek what object of customers' wants in order to satisfy their needs. In this regard, how to find the object of customers' wants becomes a critical task for businesses. Bicycle is an object of some customers' wants due to different individual needs. Thus, this paper investigates what functionalities and style are the customers' functional needs and wants for bicycles by extracting specific knowledge pattern and rules from customers. By doing so, this paper demonstrates a knowledge extraction approach in order to examine that knowledge of the customers and the product itself reflects the needs of the market.

In addition, this paper describes a case study of NPD on a bicycle enterprise by implementing data mining approach and integrating different source of demand chain knowledge. By doing so, this paper presents an example that product design and planning for production lines can be integrated with the knowledge of customers and market channels. Also, the knowledge of customers and market channels can be transformed into knowledge assets of the enterprises during the stage of NPD. This might not be a new approach on NPD or marketing. However, this research suggests that case firm should consider both inside and outside sources of knowledge in order to investigate its operation, product/service, market, customers, suppliers, competitors, etc., from different aspects. By doing so, a knowledge resource could be an intellectual asset and competence to the case firm.

Demand chain management is increasingly being used to meet the needs of enterprises, such as automotive retailing, U.K. manufacturers and services, aerospace firms, U.K. lighting manufacturers, logistics/distribution business, multiechelon spare parts supply chain, etc. [2], [10], [12]. Demand chain management, including customer satisfaction, involvement, and customization, is attained through identifying specific needs of groups of customers and developing appropriate offers to certain groups of customers or market segments on products and service [2]. This paper suggests that the case firm should extract customer and channel knowledge from the demand chain and place them as a knowledge resource on its supply chain. This integration of demand chain and SCM might not only have better capabilities on understanding its market, but also enhances its manufacturing and product innovation capabilities on extending its product lines.

Generally, enterprises do not collect customer data for a database in order to make market analysis. Because information technology investment and manipulation are a threshold not only to small and medium enterprises, but also to some large enterprises unless business owners can be aware that it is really helpful to their businesses [28]. The case firm has not yet built its data warehouse. This research suggests that case firm should build warehouse, integrating some other information technology solutions in order to provide a well-structured database platform on its domestic and abroad system environment. By doing so, all of data can be integrated together and implement for analysis [29].

Does the case firm accept this data mining approach and results? Indeed, the case firm is actually doing the data mining method proposed in this paper. For example, mining specific groups of customers who would like to provide their data (including their friends and family) constantly via Internet and join a customer club so that they can purchase custom-make bicycles. In addition, electronic catalogs are mailed to customers according to customer and market segmentation and paper catalogs are mailed to new customers or presented to general customers in the sales/maintenance stores. Thus, this paper not only presents the practical development of a data mining system, but it is also an academic study to explore the bicycle industry through NPD and marketing based on database technology and data mining methodology.

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