
A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle Analysis based on QFD, AHP/ANP and TRIZ

Jiachen Hou, Daizhong Su

Advanced Design and Manufacturing Engineering Center,
Nottingham Trent University, Burton Street, Nottingham,
NG1 4BU, UK

E-mail: jiachen.hou@ntu.ac.uk, daizhong.su@ntu.ac.uk

Abstract: With the rapid development of technologies and turbulent market environment, manufacturing industry is challenged with the task of managing products in each stage of product life cycle (PLC). A customer-manufacturer-competitor (CMC) model is developed, which helps manufacturers to analyse customer's, competitor's and manufacturer's orientation and related issues within the PLC. The CMC model consists of three evaluation processes, namely, customer-based evaluation, manufacturer-based evaluation and ideal formulation. In this paper, the characteristics of PLC and the *six evaluation sets* for assessing the performance of a manufacturer and its competitors in each PLC stage are presented; the advantages of integrating Quality Function Deployment (QFD), Theory of Inventive Problem Solving (TRIZ), and Analytical Hierarchy Process/Analytical Network Process (AHP/ANP) into the CMC model are discussed; and then the CMC model is described, followed by a case study illustrating how the CMC model can be applied in the PLC analysis.

Keywords: Product life cycle, Quality function deployment, Analytical hierarchy process, Analytical network process, TRIZ, Ideal formulation, Evaluation sets

Reference to this paper should be made as follows: Jiachen Hou, Daizhong Su. (xxxx) 'A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle Analysis Based on QFD, AHP/ANP and TRIZ', *Int. J. Design Engineering*, Vol. X, No. Y, pp.000-000.

Biographical notes: Jiachen Hou received her MA degree of Marketing Management in 2000, MSc degree of Engineering Multimedia in 2002 and PhD degree of Product Design in 2007. Her research interests include value chain management, decision making in complex and uncertain environments, Web/Internet enabled virtual enterprise and mass customisation.

Professor Daizhong Su received his Master degree in 1980 and PhD degree in 1990. He is Professor of Design Engineering and leads the Advanced Design and Manufacturing Engineering Centre at Nottingham Trent University, UK. His research interests include product design, engineering design, integrated manufacturing, CAD/CAM/CAE, and Web/Internet based engineering. His research has been supported by grants from various founding organisations including European Union, UK government and research council,

Jiachen Hou and Daizhong Su

Royal Society, East Midlands Development Agents, international organisations and industries. He has been involved in organising more than 20 international conferences as Conference Chair, Co-chair, international chair and committee members. He has got about 170 referees publications.

1 Introduction

Product life cycle (PLC) is used to map the lifespan of a product. In general, a PLC consists of four stages, including introduction, growth, maturity and decline. Knowing which stage where a product stands in the PLC allows manufacturers to anticipate and effectively plan for the next stage (Friend and Zehle, 2004); whereas failure to understand the differences between PLC stages might result in downfall of a product (Onkvisit and Shaw, 1989). Within nowadays global environment, product life cycle could be affected by many factors, such as customer requirements, unpredictable markets, intensive competitions, etc. The most prevalent failure mode of product development is the deficiencies in understanding the value of the customers needs (Chao and Ishii, 2004). Customers' requirements must be deployed to the manufacturing processes in order to win the customers (Plumlee and Little, 2006). It is important to explore the customers' preferences in each PLC stage. Meanwhile, analyzing capabilities of manufacturers and their competitors is also an inevitable step to compete with the rivals. Systematically transforming the customer's, competitor's and manufacturer's orientation into various product development stages is becoming vital for a manufacturer to stay in a competitive position.

The purpose of this research is to provide an approach for efficiently analyzing customers' preferences and the capabilities of a manufacturer and its competitors, in order to provide appropriate solutions based on the information gained from each particular PLC stage. To achieve this, a model named 'Customer-Manufacture-Competitor (CMC) orientation analysis for PLC' is developed. It is applicable for any stage within the entire product cycle from the initial introduction to the final decline stage, which provides a structure to analyze the influences affecting the product development. The model would help manufacturers discover the overlooked issues during PLC. To effectively analyze information and to provide solutions, Quality Function Deployment (QFD), Theory of Inventive Problem Solving (TRIZ) and Analytical Hierarchy Process/Analytical Network Process (AHP/ANP) have been applied to implement the model. The issues such as market intelligence, core competence, organizational strength, market attractiveness, strategic strategy, and product market position are concerned in each stage of PLC.

In the following sections, the characteristics of PLC and the *six evaluation sets* for assessing the performance of a manufacturer and its competitors in each PLC stage are presented, the advantages of integrating QFD, AHP/ANP and TRIZ in the CMC model are discussed, and then the CMC model is described, followed by a case study illustrating how the CMC model is applied in the PLC analysis.

2 Characteristics of PLC and Six Evaluation Sets

It is essential to understand the nature of each PLC stage because the competitive characteristics vary from one stage to another. The fundamental characteristics of PLC have been addressed by researchers from different perspectives, for example, in the life cycle/portfolio matrix developed by Little (Johnson and Scholes, 1999), the whole concept is to assess whether a strategy is likely to be appropriate in a given stage of the

A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle Analysis based on QFD, AHP/ANP and TRIZ

PLC, the key point is to find out the organisation's position within an industrial environment and therefore to decide the types of strategies for the situation. The Marketing mix based analysis in each stage of PLC has been categorised which concentrated on adjusting the marketing effort to conform to the changing environment (Onkvisit and Shaw, 1989). Even the five forces analysis model is not directly concentrated on life cycle in the industry environment, its popularity is shown that organisations can utilise the model to predict the opportunities and the threats for a particular period (Porter, 1985; 2004).

Characteristics of PLC

Characteristics Stages	Generic conditions					External Conditions			
	Sales (Increasing Level)	Target Market (Income)	Product Modification (Frequency)	Brand Loyalty (Level)	Profit	Consumer	Competitor		
Introduction	Slowly	High	Frequent	None	Loss	Few	Few		
Growth	Rapidly	Middle	Major	Start	Good	Selected Purchase	Undifferentiated Products		
Maturity	Stable	Mass	Annual	Strong	Stable	Repeat Purchase	Difficulties in gaining share		
Decline	Decreasing	Low	Few	Decline	Reasonable	Drop off	Few		
	Portfolio Management & Analysis					Marketing Mix			
	Dominant	Strong	Favourable	Tenable	Weak	Product	Place	Promotion	Price
Introduction	Fast grow start up	Start up differentiate Fast grow	Start up Differentiate Focus Fast grow	Start up Grow with industry Focus	Find niche catch up Grow with industry	Shallow product line	Exclusive	Primary demand	Highest
Growth	Fast Grow Attain cost leadership Renew Defend position	Fast Grow Catch up Attain cost leadership differentiate	Differentiate, focus Catch up Grow with industry	Harvest, catch up hold niche, Grow with industry	Turnaround Retrench	Segmentation	Selective	Selective demand	Declining
Maturity	Defend position Attain cost leadership Renew Fast Grow	Attain cost leadership Renew, focus differentiate Grow with industry	Harvest, hang in find niche, hold niche Renew, turnaround differentiate	Harvest Turnaround Find Niche Retrench	Withdraw Divest	Highly segmented market	Intensive	Selective demand	Stable
Decline	Defend position focus Renew Grow with industry	Find niche Hold niche Hang in Grow with industry Harvest	Retrench Turnaround	Divest Retrench	Withdraw	Shallow product line	Selective	Primary demand	Declining, then stable

Six Evaluation Sets

Organisational Strength	Market Intelligence	Core competences	Market Attractiveness	Strategy	Position
Marketing R&D Manufacturing Distribution Sales force Technology Financial Resources Managerial Competences Competitive Position	Demographic Geographic Behavioralistic Purchasing Channel User Groups	Market sensing Customer linking Channelbonding Technology development Cost control Integrated logistics Human Resources Environmental health and safety Relationships-Contracts Reputation-brands Knowledge Capabilities	Market Size Market grow rate Competitive structure Barriers to entry Industry profitability Work force Bargaining power PEST issues	Unique Cost Speed Hybrid	New Product in New Market New Product in Existing Market Existing Product in New Market Existing Product in Existing Market

Figure 1: Characteristics of PLC and Six Evaluation Sets

It is crucial to structure the related PLC issues in a strategic manner. This research pays special attention on the issues of PLC at the strategic business unit (SBU) level. A SBU is a part of the organisation for which there is a distinct external market for its products. At this level, the basis of strategic decisions is how customer needs can best be met, usually to achieve a sort of competitive advantages for the organisation (Johnson

and Scholes, 1999). It is important to clarify the issues that need to be addressed for PLC at this level. In this research, a total of six evaluation sets are proposed. The six evaluation sets are derived from the survey results. Due to the restriction of the paper length, the details of the survey procedures and sampling selection can not be illustrated here. The six evaluation sets are combined with QFD, ANP and TRIZ approaches for extracting customer information and evaluating the performance of manufacturer and its competitors. The six sets work as a base for the CMC model, which are Integration set, Core competences set, Marketing intelligence set, benchmarking set, strategy set and position set, respectively.

Figure 1 shows the characteristics of PLC and the six evaluation sets, where the vital aspects of characteristics of PLC are summarized and their direct connections with the six evaluation sets are presented. The criteria that are contained in the six evaluation sets reflect the issues that need to be explored in a particular stage. The most up part is the summary of the characteristics of PLC in each stage which are based on fundamental theories of PLC (Johnson and Scholes, 1999; Onkvisit and Shaw, 1989; and Porter, 2004), while the bottom part is the evaluation sets which can be used as criteria for CMC information analysis.

3. Features of Utilising QFD, TRIZ and AHP/ANP in this Research

QFD is a structured approach for translating customer requirements into design specification (Revelle, Moron and Cox, 1988; Terninko, 1997). The approach has been widely utilised by many distinguished International companies, such as IBM, Ford, Toyota, etc. However, QFD focused on identifying problems, but not on resolving the problems. It is important to find a way solving the problems which have already been identified by QFD. Theory of Inventive Problem Solving (TRIZ) is derived from the study of global patents, which is a high efficiency tool with strong capability for solving both technical and physical problems (Altshuller, 1984; Altshuller, Shulyak and Rodman, 1997; Terninko, Zusman and Zlotin, 1998). TRIZ is useful in many fields because it is a unique method of problem resolution. With several decades of development, TRIZ has been well applied in a wide range of areas from engineering, medical, education to business management (Clausing, 2001; Marsh, Waters and Mann, 2002; Ruchti and Livotov, 2001). Utilising arithmetic calculations to rank the issues having influences in each PLC stage and the weight of priorities are an integral part of QFD and TRIZ. The AHP/ANP, which are developed by Satty (1985, 2004), use paired comparisons to represent judgments and highlight the role of inconsistency in the decision making process. The AHP/ANP are based on a multi-criteria measurement theory that provides a general framework to deal with decisions without making assumptions about the independence of higher-level elements from lower level elements.

Integration of QFD, TRIZ and AHP/ANP approaches would help manufacturers to capture customers' needs and to analyze the capabilities of manufacturers themselves and their competitors. As a result of the integration, the functions of the CMC model are enhanced and appropriate utilization of the model in PLC analysis can enhance the manufactures' competitive positions in the markets.

3.1 QFD

QFD focuses on delivering values by understanding the customer's requirements and needs and then deploying these expectations throughout the development process. The procedure of QFD in various development phases is to apply matrices to identify the

*A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle
Analysis based on QFD, AHP/ANP and TRIZ*

correlation between inputs and outputs.

In using QFD, not only an organisation can manage engineering knowledge in a systematic way in which the future similar design can be applied easily, but also it can identify competitive advantages and win an emulous position (Akao, 1990). With many years' development, QFD has been integrated with other approaches to improve organizations' efficiency (Kumar, Antony and Dhakar, 2006; Pramod, et. al, 2006). An advanced product definition methodology based on QFD principles to manage risk and improve product definitions and resource allocation has been developed by Chao and Ishii (2004). To challenge the conventional QFD, a QFD strategy house, which links marketing and manufacturing strategies by focused upon the QFD from operational and organisational perspectives has been proposed (Gonzalez, Quesada and Mueller, 2004.). Although QFD has attracted great attention, the major lack of integration business with product design environment has not been successfully transforming the voice of customers into product design environment (Han, Chen, Ebrahimpour and Sodhi, 2001).

The purpose of applying QFD in this research is to exploring customer's preferences from different directions in each stage of PLC. Conventionally, the core of QFD is the House of Quality, which is represented by a set of matrices for identifying customer needs with technical characteristics; the primary matrices includes Demanded Quality, Quality Planning, Performance Measure, Product Planning and Measured Performance. Unlike most of QFD based applications, applying QFD in this research is mainly focused on defining customers' preference from operational perspective; therefore, the Product Planning and Measured Performance are ignored in this research. However, detailed manufacturer and competitor analysis from manufacturers' perspective will be explored by using ANP.

3.2 TRIZ

Unlike QFD, TRIZ provides a faster and shorter way for solving problems. TRIZ is based on consolidated findings from extensive research of patents, and it offers well defined methods for developing new ideas (Akao,1990). TRIZ is initially for solving the engineering problems, in recently years; many researchers have paid great attentions to apply TRIZ to different fields, such as education, biology, and business management.

With the development in the past several decades, several tools and methods have been designed that can be either used separately or in combination with others based on the original TRIZ. Some of the tools are for analysis, such as Ideal design, Su-field analysis; the others provide knowledge, such as Contradictions analysis, and Patterns of Evolution. Considering that the issues concerned in this research, the technique so called Problem Formulation is utilised to solve the problems which have been identified using QFD and ANP. The formulation process offers a complete list of problem statements once they are clearly identified, and a variety of directions can be followed for developing the best solution (Rantanen and Domb, 2002; Yuri, 1999). The terms of harmful function and useful function are the fundamental concepts of problem formulation, which have been indicated in TRIZ to represent drawback and primary function, respectively. To identify the interaction between useful and harmful functions and to formulate them in precise phrase three links between harmful and useful functions are defined in the following (Terninko, Zusman and Zlotin, 1998):

- **Useful Function is required** \rightleftarrows **Useful Function**
- **Useful Function is introduced to eliminate** \rightleftarrows **Harmful Function**
- **Useful Function causes** \longrightarrow **Harmful Function**

These essential links will be used for finding the solutions for an ink cartridge manufacturer in case study which will be presented later in this paper.

3.3 AHP/ANP

The AHP/ANP use paired comparisons to represent judgments and are able to handle the inconsistency in a decision making process. The methods are based on a multi-criteria measurement theory which provides a general framework for decisions making without assumptions about the independence between higher-level elements and lower level elements (Satty, 2004). In addition to AHP/ANP, several multi-criteria decision making (MCDM) methods exist (Anderson, 2003; Curwin and Slark, 2002; Fishburn, 1996; Miller, 1969; Bowen, 1990), such as Weighted Sum Model (WSM), Weighted Product Model (WPM), ELECTRE Method, TOPSIS Method, etc. The comparisons between AHP/ANP and the other MCDM methods carried out by researchers revealed that AHP/ANP possess a number of benefits over other methods (Triantaphyllou, 2002; Bhutta and Huq, 2002).

In this research, the AHP/ANP approach is adopted. Apart from its successful records of accomplishment in industries, AHP/ANP approach is more appropriate in relation to the nature of the CMC model and associated methods developed by this research. For example, the proposed manufacturer based evaluation process involves tangible and intangible criteria, which required a measurement that have the following functions: providing a realistic description of the problem, structuring the decision-making process, incorporating both quantitative and qualitative factors, expressing the relative importance factors, analyzing alternatives, more importantly, supporting group decision-making and allowing the decision makers to focus on each small part of the problem.

4 The CMC Model

The model covers three evaluation processes, namely, Customer-based Evaluation, Manufacturer-based Evaluation and Ideal Formulation, which provides an efficient approach for manufacturers to constantly dissect the product in each stage of PLC and to look for potential advancements. Its main competences differ from one stage to another depending on how the manufacturer is positioned and the strategies that may take.

Within the Customer-based Investigation, the customer-based evaluation between rivals is the first step towards positing the target in which they are oriented. Followed by the customer orientation analysis, where the AHP and QFD are employed to evaluate the rivals' performance from customers' point of view and to investigate customer orientation from manufacturer's perspectives. For the Manufacturer-based Evaluation process, the analysis is concentrated on evaluating vital issues that influence on product development in each stage from manufacturers' points of view, it addresses the gaps that have been identified from Customer-based Evaluation sector before embarking upon an improvement process. Therefore, the previously completed analysis for customer orientation in different stages will be taken into account, and the ANP approaches are employed in this sector. The Ideal Formulation process is focused on addressing the gaps identified from both Customer-based Evaluation and Manufacturer-based Evaluation before embarking upon an improvement process, therefore, the previously completed analyses for the all elements in the product development stage are reviewed, and then categorised by the factors of pros and cons, and a set of elements to remedy the deficiencies is identified. TRIZ's problem formulation has been applied in this sector. The first two sectors can be analysed separately, and the final sector is established based on the results that gained from formal two analysis results. The customer and competitor's information needs to be structured in a strategic manner, and hence operational issues should be dealt with alongside in the entire PLC.

5. Application of the CMC Model for PLC Analysis: a Case Study

To demonstrate the CMC model, a printer manufacturer is chosen to illustrate the model. For a confidential reason, the manufacturer is referred to Manufacturer Y in this paper.

5.1 Background Information

Manufacturer Y is a medium-size Chinese domestic manufacturer who manufactures printers. The manufacturer also produces own-brand printer consumables for both local and overseas markets. Ink cartridge is one of the products which are designed for a wide range of printers. Compared to its rivals, Manufacturer Y has remained as a fair player in the industry. To keep the existing market position and to expand potential markets, Manufacturer Y needs to pay attention to each stage of product development in order to swiftly alter its development directions to win a competitive position. The office equipments have been updated very fast, and the more intelligent features are required for printer products. The manufacturer currently promotes a type of disposable ink cartridge with a smart-chip. The function of this intelligent smart-chip is to measure the amount of ink that is being used in the prints and it also keeps track on the level of ink that is contained in the cartridge. It is still in an earlier stage for manufacturing intelligent ink cartridge, because of the high costs and technique requirements. The product is currently in its introduction stage. Applying the CMC model would be of assistance for the manufacturer to clarify the product position in the market and to find the appreciate countermeasures for further improvement. For the research purpose, three competitors who manufactured similar products are chosen to compare with the manufacturer. The three competitors held similar position in the ink cartridge industry.

5.2 Customer based evaluation Process

It covers two major steps: the first step involves understanding the differences between manufacturers and its competitors from customers' perspectives; the second step includes activity for analysing customers' characteristics and preferences based on the results obtained from the first step. This process enables assessment of the existing products and determines the potential positioning of the product development directions against the competition. Because the model spans the entire product life cycle, the primary focuses from stage to stage. Unlike the conventional QFD method, collecting voice of customer is not focused on gathering technical data, but analysing current situation from operational perspectives. The aim of the CMC model in this sector is to find out the product's state and competitors' position from customers' perspective, thus it does not need to go further for finding the detailed measured performance as traditional QFD. In this case, the desired evaluation results are concentrated on figuring out the customers' performances and the gaps between the manufacturer and its competitors from the customers' points of view. AHP and QFD have been integrated for the quantitative analysis.

The first priority of this process is to find out the comparison results between the manufacturer and its competitors from customers' perspectives. The criteria for evaluating product's performance are the central point. The Market Intelligence set has been employed in order to get a clear idea about its customer orientation. Establishing an appropriate matrix is the first step in this sector. Table 1 shows a process for customer-based investigation. It consists of three parts with each representing a different facet of

the development process, including *Demanded monitoring*, *Rival evaluation* and *Monitoring planning*. The detailed explanations for calculating results are covered in Section 5.2.1, Section 5.2.2, Section 5.2.3 and Section 5.2.4.

Table 1: Customer-Based Rival Comparisons

Demanded Monitoring	Important Rate	Rival Evaluation				Monitoring Planning			
		Manufacturer Y	Competitor 1	Competitor 2	Competitor 3	Target	Ratio of Improvement	Unique Points	Synthetic Importance
Price	0.177	3	4	5	4	5	1.67	1.2	0.35
Quality	0.139	4	4	3	5	5	1.25	1.5	0.26
Service	0.189	5	4	3	4	5	1.00	1.2	0.23
Distribution Channel	0.127	5	5	4	4	5	1.00	1.2	0.15
Features	0.146	4	5	3	5	5	1.25	1.5	0.27
Brand loyalty	0.222	3	3	4	2	5	1.67	1.2	0.44
Weighted Satisfaction		3.92	4.05	3.70	3.84				

Table 2: Customer-Orientation Analysis

Demographic (Income)				Geographic				Purchasing Channel				User Groups		
H	M	L	Sub-total	Region A	Region B	Region C	Sub-total	Online	Traditional-Retail	Traditional-Wholesale	Sub-total	Student	Professional	Sub-total
▲▲▲	▲▲▲	▲▲		▲▲▲▲	▲▲	▲▲▲		▲▲	▲▲▲	▲▲		▲▲▲	▲▲	
▲	▲	▲		▲	▲	▲		▲	▲	▲		▲	▲	
▲	▲	▲		▲	▲	▲		▲	▲	▲		▲	▲	
▲	▲	▲		▲	▲	▲		▲	▲	▲		▲	▲	
8.17	9.74	7.61	25.52	5.13	7.29	11.49	23.91	8.03	9.74	7.61	25.38	7.41	7.92	15.33
32	38	30	100	21	30	48	100	32	38	30	100	48	52	100

5.2.1 Demanded Monitoring

The most left side of Table 1 shows the *Demanded Monitoring* which is the first stage in Customer-based Investigation process. Its purpose is to further understand the critical factors that customer concerned in different product stages. As mentioned before, different organisations have particular preferences for collecting customer information; in this example, the important rate for demanded monitoring is oriented from past experiences, however, the evaluation procedure remains the same even the different

A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle Analysis based on QFD, AHP/ANP and TRIZ

collection methods are applied. The criteria of *quality, cost, technology, distribution channel, delivery, location, service, branding and product diversity* are included in this step; the results are shown in Table 3 have been computed by applying AHP approach which will be used as measurements to rank the importance of each demanded criteria among the manufacturer and its competitors.

Table 3: Important Rate is derived from AHP

	Price	Quality	Service	Distribution Channel	Features	Brand Loyalty	Rating
Price	0.136	0.057	0.041	0.222	0.277	0.329	0.177
Quality	0.273	0.113	0.061	0.056	0.277	0.055	0.139
Service	0.409	0.226	0.122	0.056	0.277	0.041	0.189
Distribution Channel	0.068	0.226	0.245	0.111	0.031	0.082	0.127
Features	0.045	0.038	0.041	0.333	0.092	0.329	0.146
Brand Loyalty	0.068	0.340	0.490	0.222	0.046	0.164	0.222

5.2.2 Rival Evaluation

The *Rival Evaluation* shows the customers' weighting rates for the *Demanded Monitoring* between a manufacturer and its competitors. To easily understand the performance a measure, a five-point scale is used which makes relative position clear. The numerical number 5 indicates outstanding performance and a 1 for poor performance.

5.2.3 Monitoring Planning

The Monitoring Planning provides a structure for analysing the *Demanded Monitoring* and *Customer Evaluation*. Starting with the importance for each demanded Monitoring, and the subjective evaluation of product performance for several competitors. This information is used to establish a composite importance for each demanded monitoring. The *Target Performance, Ratio of Importance, Unique Points* and *Synthetical Importance* are included in this part.

5.2.3.1 Target Performance

The target performance is selected for each demanded monitoring, which presents the desired level for each *Demanded Monitoring* criterion. Target is influenced by manufacturer's performance in relation to competitors' and the customer's demanded quality importance. It also considers the organisational strength and Market Attractive sets between rivals.

5.2.3.2 Ratio of Improvement

The purpose for calculating the ratio of improvement is for comparisons between the desired target and the performance rating of the manufacturer. The ratio of Improvement is equal to the Target divided by the current judgment for the manufacturer.

$$\text{Ratio of Improvement} = \frac{\text{Target}}{\text{Manufacturer}}$$

5.2.3.3 Unique Points

Unique Points is the core of the product that distinguish from the competitors, the value of 1.5, 1.2 and 1.0 are selected based on the fundamental of QFD, the value of 1.5 means the shining points of the product differs from competitors, and value 1.2 is reserved for the nice to have but not critical. The Unique points greater than 1.0 are seen as an opportunity for management to influence the design. Akao (1990) suggested a maximum value of three Unique Points greater than 1.0 to emphasize the unique impact of those demanded qualities.

5.2.3.4 Synthetical Importance

Synthetical Importance is equal to *Demanded Monitoring Importance* times *Ratio of Improvement* times *Unique points*. The *Synthetical Importance* will be used for weighting the priority for the performance measures. The customers' satisfaction weight can be found by multiplying the rating by the level of customer satisfaction. This process is repeated for all the demanded qualities.

$$\text{Synthetical Importance} = \text{Important Rate} * \text{Ratio of Improvement} * \text{Unique point}$$

5.2.3.5 Weighted Satisfaction

It is important to find the customer satisfaction levels between the manufacturer and its competitors, this is found by multiplying Important Rate by the results taken from the column within the customer evaluation, and each individual weight will be summed to get the Weighted Satisfaction.

$$\text{Weighted Satisfaction} = \text{Important Rate} * \text{Customer Evaluation for the rivals (The manufacturer and its competitors)}$$

5.2.4 Customer Orientation

A further improvement can be made by analysing the customer orientation in various stages. It is not necessary to have values for each criterion within all performance measurements if there is no close relationship between them. The relationship between demand criteria and customer orientation is the important measurement to find out priorities of each criterion within different segments. Currently, the manufacturer only made the distribution in three regions in China. For demonstration purpose, Table 2 shows the measurement from each sub-set, including Income factor from Demographic, Country from Geographic factor, Channel factor from the Channel purchasing and the User State factor from Buyer Behavior. Symbols are used to represent the customer satisfaction level with the demanded monitoring. For example, a high satisfaction is represented with a ▲ which equals 9, medium relationship is represented with a © which equals 3, low relationship is shown as a Ω with value 1, and value 0 represents no relationship which is displayed as —. The priority for each criterion measurement is calculated by adding the weight of the criteria in each cell and multiplying the *Synthetical importance*. Converting the final weights to % is easy for getting clear picture about the priorities for each criterion for the performance measurement. For example, median income in the Income group is 38 which is gained by it's weight 9.74 divided by the sub-

A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle Analysis based on QFD, AHP/ANP and TRIZ

total of 25.5. The results show that in the Demographic part, people with median income have the highest satisfaction rate, followed by high income and low income. In the Geographic part, Region A has the lowest satisfaction rate; on the contrary, people in Region C show a great satisfaction for the product. In the Purchasing Channel, people who purchased the product from retailers are happier than online shopping and purchasing wholesalers; the first time users seem had high satisfaction rate than the regulars in the Buyer Behavior set.

5.3 Manufacturer based Evaluation Process

It is vital to define a problem well before it can be solved. Understanding how to structure the issues that could affect each design stage is an essential step for solving the problem. The mainstream of this process is to compare the manufacturer and its competitors based on the six evaluation sets from the manufacturer's perspectives. This helps to place the manufacturer's resources and performance into perspective locations and reflects the fact that it is the relative position of a manufacturer which matters in assessing its strategic capability. There are two major goals need to be achieved in this process, the first is to explore what are the critical factors that affect PLC stages; the second is to help identify who are the most direct competitors, and on what basis competitive rivalry is likely to take place. This process is particularly important in finding the weaknesses or strength within and around a manufacturer and its competitors. AHP/ANP, the multiple decision making method, has been utilised in this process.

5.3.1 Overview of the evaluation sets using AHP/ANP

Manufacturer-based evaluation is a complicated process due to six evaluation sets with all sub-sets involved in this procedure and the interacting nature of ANP. As mentioned in Section 3.3, ANP is the extending of the AHP to deal with problems with dependence and feedback. As in the AHP, dominance or the relative importance of influence is a central concept, which is a liner top down structure with no feedback from lower to higher levels; while the ANP uses a network without the need to specify levels, which has a loop at the bottom level to indicate that each alternative in that level only depends on itself and thus the elements are considered to be independent from each other. Figure 2 shows the three level hierarchies for the manufacturer based evaluation by applying AHP.

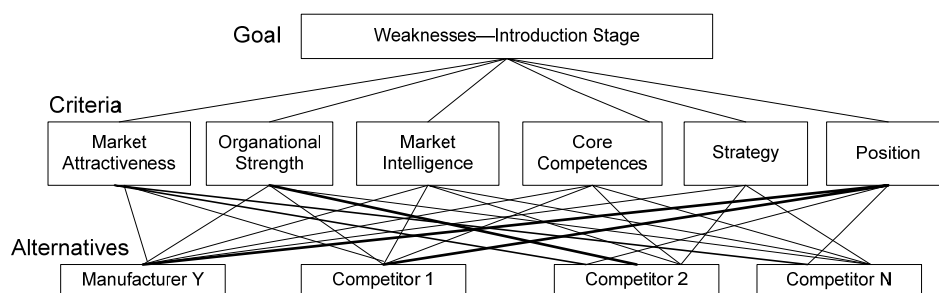


Figure 2: Three level decision hierarchy for analysing weaknesses/strength in introduction stage

The goal of the manufacturer based evaluation is to find out the weaknesses which prevent the manufacturer's further developments within the Introduction stage, and to

eventually overcome the barriers. The criteria can be any of the six evaluation sets or whole sets which depend on the areas that the manufacturer is looking for; the alternatives are the manufacturer and its competitors. The network can be generated from a hierarchy by increasing the hierarchy's connections gradually so that pairs of components are connected as desired and some components have an inner dependence loop. Different from the AHP approach, applying ANP for this evaluation process is more meaningful, because the comparison made between the clusters with respect to control criteria and to compare the elements with respect to sub-criteria of the control criteria. Figure 3 shows an ANP based network decision hierarchy for the manufacturer based evaluation: unlike a hierarchy, a network spreads out in all directions and its clusters of elements are not arranged in a particular order.

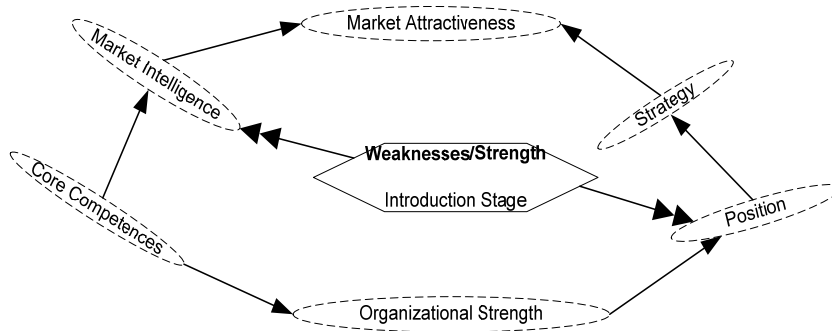


Figure 3: A network decision hierarchy for analysing weaknesses/strength in a PLC stage

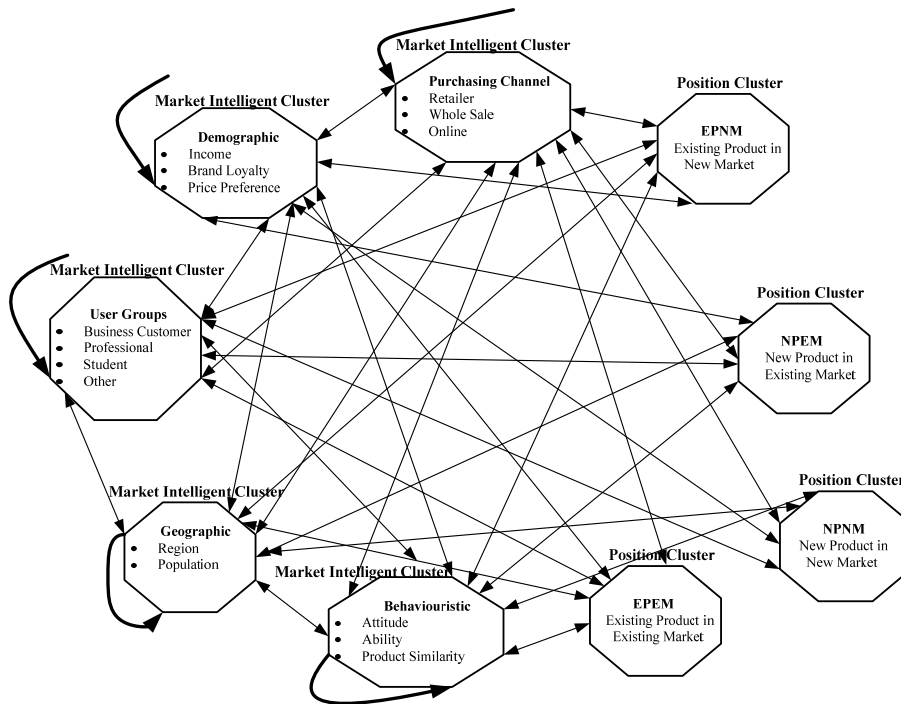


Figure 4: The Connection between Market Intelligent Clusters and Position Clusters

It would be not necessary to illustrate all the procedures, and the Marketing Intelligence set and Position set are selected to demonstrate the method. Figure 4 shows the connections between clusters within the Market Intelligence set and Position set, respectively. The demographic cluster is connected to the geographic cluster when one of the elements within the demographic cluster is connected to at least two elements in the geographic cluster. For example, the criteria such as Income, Brand Loyalty and Price Preference within the demographic set are used for comparing the components which are major parent criteria whose sub-criteria are used to compare the elements in the components. Thus the criteria for comparison of the components need to be more general than those of the elements because of the greater functional complexity of the components. Figure 4 shows the connection between clusters and elements within the two sets and the inner dependence exists for all the clusters, which indicates the flow of influence between the elements. There are five and four clusters included in the market intelligence set and position cluster, respectively.

5.3.2 Paired comparisons

Paired comparisons are needed for all the connections. The paired comparisons use Satty's scale for the comparative judgment (Satty, 1985). In making paired comparisons, ratios are estimated using fundamental scales 1 to 9 of absolute numbers to compare two alternatives with respect to an attribute.

The importance of the comparison is based on the connection of the elements, for example, the wholesale with Distribution channel cluster is connected to the elements within the region cluster, in particular, the Region A, Region B and Region C within the Geographic cluster. Therefore, such kind of questions can be risen, 'with respect to the wholesale, is Region A more or less dominate than Region B? and 'if so, by how much?'

The following step is to construct a matrix using the relative importance of the alternative in terms of each criterion. The reciprocal matrix shown in Figure 5 represents a set of numerical judgments and the derived rating from these judgments. In Figure 5, the derived rating in the last column is computed by raising the reciprocal matrix to arbitrarily large powers and then normalizing their row sums. The rating vector's sum to one and will be placed in their appropriate location in the supermatrix.

	NPNM	NPEM	EPNM	EPEM
NPNM	1.000	2.000	3.000	4.000
NPEM	0.500	1.000	2.000	3.000
EPNM	0.333	0.500	1.000	2.000
EPEM	0.250	0.333	0.500	1.000
Rating	0.466	0.277	0.161	0.096

Figure 5: Initial Comparison

5.3.3 Supermatrix

The representation of a hierarchy with three levels is shown in Figure 6, where W_{21} and W_{32} are matrices; W_{21} is actually a vector that represents the impact of the Goal on the criteria, and W_{32} represents the impact of the criteria on each of the alternatives; W is

referred to as a supermatrix because its entries are matrices.

$$W = \begin{matrix} & \begin{matrix} G & C & A \end{matrix} \\ \begin{matrix} \text{Goal (G)} \\ \text{Criteria (C)} \\ \text{Alternatives (A)} \end{matrix} & \begin{pmatrix} 0 & 0 & 0 \\ W_{21} & 0 & 0 \\ 0 & W_{32} & I \end{pmatrix} \end{matrix}$$

Figure 6: Three Level Comparisons

Supermatrix is introduced with purpose of handling the interdependence characteristics among elements and components which is similar to Markov chain (Issacson and Madsen, 1976; Gilks, Richardson, and Spiegelhalter, 1995). For example, the elements within the region cluster have influences on or are themselves influenced by some or all of the elements of the region cluster or of another cluster. A priority vector derived from paired comparisons matrices are each entered as a part of some column of a supermatrix, which represents the influence priority of an element on the left of the matrix on an element at the top of the matrix. If an element has no influence on other elements, its influence priority is assigned as zero. To get the final relative importance weights of each of the alternatives, it is vital to make certain that the columns of the super-matrix are stochastic, which means the weights of each column for the super-matrix are summed to 1. Figure 7 shows the interdependence happened between Market Intelligence and Position clusters that are derived from paired comparisons. NPNM stands for new product in new market, NPEM stands for new product in existing market, EPNM stands for existing product in new market, and EPEM stands for existing product in existing market.

	NPNM	NPEM	EPNM	EPEM	PC	Dem	Geo	UG	Beh
NPNM	x	x	x	x	x	0	0	0	0
NPEM	x	x	x	x	x	0	0	0	0
EPNM	x	x	x	x	x	0	0	0	0
EPEM	x	x	x	x	x	0	0	0	0
PurchasingChannel	0	0	0	0	0	x	x	x	x
Demographic	0	0	0	0	0	x	x	x	x
Geographic	0	0	0	0	0	x	x	x	x
UserGroups	0	0	0	0	0	x	x	x	x
Behaviourstics	0	0	0	0	0	x	x	x	x
Sum	1	1	1	1	1	1	1	1	1

Figure 7: Supermatrix

5.3.4 Limiting Supermatrix

It is important to capture all possible influences for the supermatrix. Satty (2004) pointed out that through the entries of the weighted supermatrix itself gave the direct influence of any element on any other element. An element can influence a second element indirectly through its influence on some third element and then by the influence of that element on the second. Such kind of influences is gained from the cubic power of the matrix, and so on. The reducibility, primitivity, and cyclicity determine the limiting priorities of a stochastic supermatrix. To get relative importance weight for evaluation purpose, a markovian-based analysis is completed to achieve a convergent set of weights.

*A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle
Analysis based on QFD, AHP/ANP and TRIZ*

According to the markowian analysis, raising the matrix to powers gives the limiting matrix that represents all possible interaction in the system.

5.3.5 Weighted supermatrix

The weighted supermatrix is resulted from the supermatrix of impacts for each criterion, and in terms of that criterion the components are compared according to their relative impact on each other component at the top of the supermatrix. The process is to take the final results of the converged supermatrix and the eigenvector values from the earlier paired comparisons and calculate the relative importance weight for each criterion.

5.3.6 Exploring the Weaknesses/Strength

The criteria need to be evaluated based on the results obtained from above mentioned procedures. For this manufacturer based evaluation process, the relative importance of the evaluation factors depend upon the types of stage of PLC, the requirements for various clusters and their attributes in different stages. As shown in Figure 3, the reason for Manufacturer Y to take this process is to find the weaknesses or strength in the introduction stage; therefore, the evaluating areas would not be the same as in the growth stage. Depending on the development direction in each stage, the manufacturer can utilize the method to adapt the appropriate tackle for future improvement.

5.4 Ideal Formulation

The essential idea in this process is to analyse and structure the innovative issues in terms of evaluation results generated by customers and the manufacturer.

This process addresses the pros and cons in which the manufacturer found from the former two processes. This is achieved by developing a proactive approach to analyse customers' and the manufacturer's evaluation results. It begins to clarify the useful and harmful elements that have already identified from the previous processes, and, afterward, to provide the structure for gathering information necessary to reformulate a problem and then break it down into several smaller problems.

After analysing the results obtained from the previous processes, the technique of problem formulator was used to eliminate unnecessary even harmful factors and to develop useful factors. The conclusions for the previous processes have already been drawn in the end of each process, so it is no need to repeat again. Based on those defined problems, formulation procedure in this sector offers a complete list of problem statement. The unique point of this Ideal Formulation process is to elaborate the detailed findings from the customer and manufacturer based evaluations. Ideal Formulation analysis gives the problem-solving team a variety of directions for developing the best solution. In reality, the analysis for the entire problems that were addressed from the previous sectors is needed in order to guide the future development. For the demonstration purpose, Region A within the demographic issue is taken to illustrate the problem formulation process. Table 2 in Customer-based Evaluation sector indicates that As a result of comparison of the customer satisfaction issue between Region A, Region B and Region C, Region A has the lowest scores. It is important to find out the reasons that hampered the customer satisfaction level in Region A and to find appropriate ways to solve the problems. In order to visually identify harmful functions and useful functions, Figure 8 shows the linkage of cause and effect relationships between the factors.

The procedure begins with the useful information, namely, customer satisfaction in Region A. As identified in Customer-based Evaluation process, the Demanded

Monitoring issues have been measured for tasting customer satisfaction level, in particular, price, service, distribution channel, quality, features and brand loyalty. Figure 8 displays visual clues for understanding the relationships between these criteria and customer satisfaction. It would be too wordy to describe the problem statements for the all criteria, the Price factor is chosen for detailed explanation problem statement by using TRIZ's Ideal Formulation technique.

Figure 8 indicates that the price issue needs to be considered in order to satisfy the customers in Region A. It is important to clarify that the consumers have buying power to afford the product. The following function indicates the relationship between price and buying power: (Buying power) is required for (Price). However, with the higher buying power, the consumers will have more options to purchase the product from the manufacturer's competitors; therefore, (Buying power) causes [Competition]. Since [Competition] is a harmful function, it is necessary to eliminate the competition. There are many reasons cause consumers to prefer competitors' products, such as lower price, good service, high quality, etc. One of the reasons for customers' favorite rivals' products in this example is caused by the price which can be found from Table 2, which showed that the manufacturer has the lowest rating mark compared with the three competitors. (Dropping price) is required to eliminate the [competition], consequently, (Low material costs) is required for (Dropping price), the way for having lower material costs is to select new suppliers who can provide same quality material with a lower price; therefore, (New supplier) is required for (Low material costs). Based on the customers' rating for the price factor, the solution for improving Region A's customer satisfaction level is to have new suppliers; however, this conclusion is not comprehensive because the other factors within the Customer-based Evaluation also need to be taken into account, meanwhile the Manufacturer-based evaluation has not been investigated in this example.

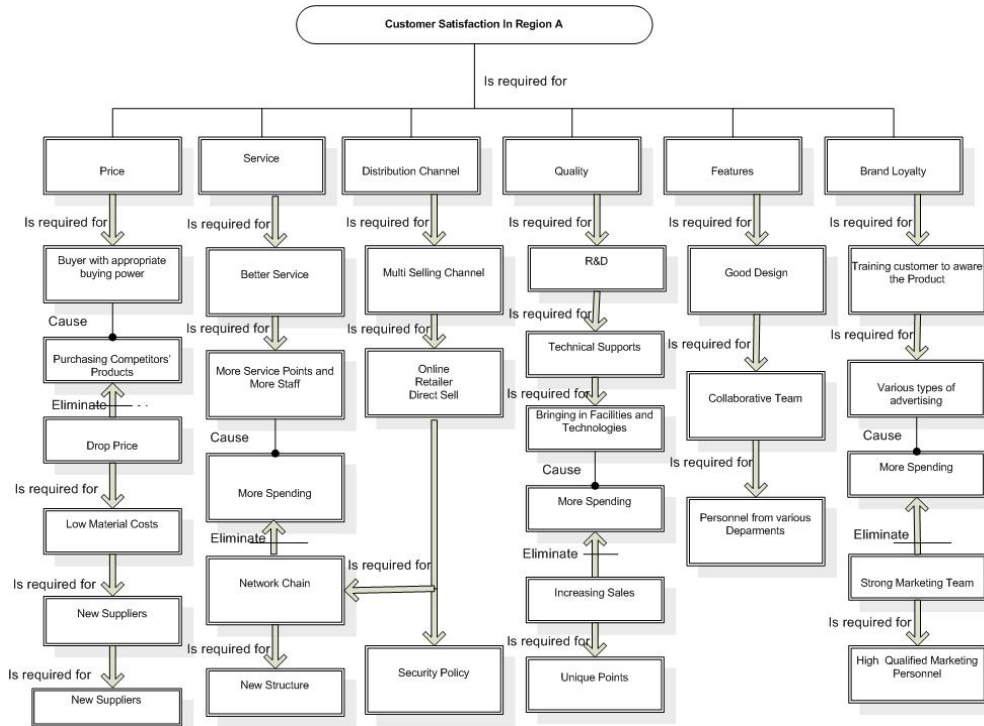


Figure 8: Barriers Analysis for Customer Satisfaction in Region A based on TRIZ

Table 4: Summary of the Customer-based Evaluation

Customer-based Evaluation	
Evaluation	Rating Marks
Rival Competition	
Competitor 1	4.05
Company Y	3.92
Competitor 3	3.70
Competitor 2	3.84
Demographic(Income)	
High	32
Medium	38
Low	30
Geographic	
Region A	21
Region B	30
Region C	48
Purchasing Channel	
Online	32
Wholesale	38
Retailer	30
User Groups	
Professional	52
Student	48

Table 4 shows the results which are gained from the customer-based evaluation for Manufacturer Y.

Table 5 shows Ideal Formulation based analysis which is focused on exploring the reasons why Region A had the lowest the satisfaction rate. To improve Region A's satisfaction Level, the following actions are needed from Manufacturer Y. New suppliers are required for reducing the expenses in materials; to strengthen service level, establishing an new structure is inevitable trend; the security policy needs to be consolidated to ensure to have a secure purchasing channel; Unique point is a major breakthrough for Manufacturer Y to win a market from quality aspect; High qualified personnel are demanded which could help the manufacturer in the aspects of improving product features and customer brand loyalty.

Table 5: Ideal Formulation based Region A Analysis

Ideal Formulation (The factors that affected the Region A)	
Demanded Monitoring	Solution
Price	New Supplier
Service	New Structure
Distribution channel	Security Policy
Quality	Unique Points
Features	High Qualified personnel from various departments
Brand Loyalty	High Qualified Marketing Personnel

6. Conclusions

A well designed PLC analysis approach is crucial for a manufacturing company to adjust its product development direction and to achieve competitive position in the market. A CMC model for PLC analysis has been developed and reported in this paper. The CMC model and associated methods developed provide useful tools for efficiently analysing the customers' preferences and the capabilities of manufacturers and their competitors in each particular PLC stage, and to derive appropriate solutions based on the analysis results obtained.

The CMC model consists of three evaluation processes, namely, Customer-based Evaluation, Manufacturer-based Evaluation and Ideal Formulation. Their major features and functions within the CMC could be highlighted as follows:

- Within the *Customer-based Evaluation* process, the QFD and AHP techniques are integrated for the Market Intelligence set analysis. It enables direct assessment of the existing product's market position and determines the potential product development directions against the competition.
- *Manufacturer-based Evaluation* is a complicated process due to the involvement of six evaluation sets and their sub-sets and the intricate nature of ANP. It is particularly important in exploring the weakness around the manufacturer, and consequently in finding solutions to decomposes the problems which could affect the product advancement in each PLC stage.
- *Ideal Formulation* provides solutions for the problems that have been explored from the above two processes. It is a flexible method that decomposes the issues could affect the advancement of the product in each single stage, and makes the clear pictures for analysing related information. It gives the problem-solving team alternatives of directions from which the best solution could be developed.

Multiple techniques of QFD, TRIZ and AHP/ANP have been integrated into the CMC model. The integration shows great benefits for the CMC to provide solutions and to process information in a systematically way to help manufacturers to efficiently analyse issues related to each PLC stage.

References

- Akao, Y. (1990) *QFD: Integrating Customer Requirements into Product Design*, Productivity Press.
- Altshuller, G. S. (1984) *Creativity as an Exact Science: The Theory of the Solution Inventive Problems*, Gordon&Breach Science Publishing

A Customer-Manufacturer-Competitor Orientation Model for Product Life Cycle Analysis based on QFD, AHP/ANP and TRIZ

Altshuller, G., Shulyak, L., and Rodman, S., (1997) *40 Principles: Triz Keys to Technical Innovation*. Technical Innovation

Anderson, D., Sweeney, D., and Williams, T., (2003) *An introduction to Management Science—Qualitative Approaches to Decision Making*, South-Western

Bhutta, K. and Huq, F. (2002) ‘Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches’. *Supply Chain Management* Vol7, No3, pp:126-135

Bowen, W. M., (1990) ‘Subjective judgements and data envelopment analysis in site selection’, *Computers, Environment and Urban Systems*, Vol.14, No 2, pp. 133-144.

Chao, L. P., and Ishii, K. (2004) ‘Project Quality Function Deployment’, *International Journal of Quality&Reliability Management*, Vo.21 No.9, pp.938-958

Clausing, D., P., (2001) “The Role of TRIZ in Technology Development”, *Triz Journal*, August

Curwin, J., and Slak, R., (2002) *Quantitative Methods for Business Decisions*, Thomson Learning

Fishburn, P.C. (1996) ‘Decision theory and discrete mathematics’, *Discrete Applied Mathematics*, vol.68, No. 3, July, pp209-221

Friend, G. and Zehle, S. (2004) *Guide to Business Planning*, London : The Economist in association with Profile

Gilks, W.R., Richardson, S., and Spiegelhalter, D., J, (1995) *Markov Chain Monte Carlo in Practice-Interdisciplinary Statistics*, Chapman & Hall/CRC

Gonzalez, M.E., Quesada, G., and Mueller, R. (2004) ‘QFD Strategy House: An Innovative tool for Linking Marketing and Manufacturing Strategies’, *Marketing Intelligence&Planning*, Vol. 22, No.3, pp.335-348

Han, S, B., Chen, S, K., Ebrahimpour, M., and Sodhi, M, S. (2001) ‘A Conceptual QFD Planning Model’, *International Journal of Quality&Reliability Management*, Vol18 No. 8, pp. 796-812

Isaacson, D. and Madsen, R.(1976) *Markov Chains: Theory and Applications*, New York: John Wiley & Sons

Johnson, G., and Scholes, K.,(1999) *Exploring Corporate Strategy*, Prentice Hall, pp. 307-393

Kumar, A., Antony, J., and Dhakar. T. S., (2006) ‘Integrating quality function deployment and benchmarking to achieve greater profitability’, *Benchmarking: An International Journal*, Vol. 13, No. 3, pp 290-310

Marsh, D., Waters, F., and Mann, D. (2002) ‘Using TRIZ to Resolve Education

Jiachen Hou and Daizhong Su

Delivery Conflicts Inherent to Expelled Students in Pennsylvania', TRIZ Journal, November

Miller, D.W., (1969) *Executive decisions and operations research* (Prentice-Hall international series in management), 2nd, Prentice-Hall

Onkvisit, S., and Shaw, J. J. (1989) *Product life cycles and product management*, cQuorum Books

Plumlee, T. M., and Little, T. J., (2006) ' Proactive product development integrating consumer requirements', International Journal of Clothing Science and Technology, Vol. 18, No.1, pp 53-66

Pramod, V. R., Devadasan, S. R., Muthu, S., Jagathyraj, V.P., and Moorthy G. D., (2006) Integrating TPM and QFD for improving quality in maintenance engineering', Journal of Quality in Maintenance Engineering, Vol. 12, No. 2, pp 150 – 171

Porter M.(1985) *Competitive Advantage -- Creating and Sustaining Superior Performance*. New York: The Free Press

Porter, M., (2004) *Competitive Advantage*. London: Free Press

Rantanen, K., and Domb, E., (2002) *Simplified TRIZ: New Problem-Solving Applications for Engineers and Manufacturing Professionals*. St. Lucie Press

Revelle, J., Moron, J., and Cox, C., (1988) *The QFD Handbook*, John Wiley&Sons, Inc

Rucht, B., and Livotov, P., (2001) 'TRIZ-based Innovation Principles and a Process for Problem Solving in Business and Management', TRIZ Journal, December

Saaty, T. (1985) *Analytical Planning-the Organisation of Systems*, Pergamon Press

Saaty, T(2004) 'Fundamentals of The Analytic Network Process—Dependence and Feedback in Decision-Making With a Single Network', Journal of System Science and System Engineering, Vol. 13, No.2, pp129-157.

Terninko, J., Zusman, A., and Zlotin, B. (1998) *Systematic Innovation-An Introduction to TRIZ*, St.Lucie Press

Terninko, J., (1997) *Step-by-Step QFD: Customer-Driven Product Design*, St. Lucie Press

Triantaphyllou, E. (2002) *Multi-Criteria Decision Making Methods: A comparative Study*, 2nd, .KluwerAcademic Publishers.

Yuri, S., (1999) *TRIZ: the Right Solution at the Right Time: a Guide to Innovative Problem Solving*. Insytec