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Collaboration in the Design-Manufacturing Chain: A Key to Improve Product Quality

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1. Introduction

Supply china management (SCM) is a well-established discipline that involves the coordination of an organization's internal planning, designing, manufacturing, and procurement efforts with those of its external partners (i.e. designer, manufacturer, supplier, retailers, etc.). To reduce inefficiencies in a supply chain, organizations are increasingly using information systems to integrate the systems and processes throughout their supply chain. Effective supply chain integration and synchronization among partners can eliminate excess inventory, reduce lead times, improve customer satisfaction, reduce cost and increase sales (Mclaren et al, 2002).

Collaboration is a trend in SCM that focuses on joint planning, joint designing, coordination, and process integration between suppliers, customers, and other partners in a supply chain. Its competitive benefits in include cost reductions and increased return on assets, and increased reliability and responsiveness to market needs. During the past 10 years there has been a significant trend of companies externalizing a wide range of functions that formerly might have been carried out in-house. There are many reasons for this trend, including increasing global competition, more rapid technical advance and the need for faster development of products with higher quality and reliability. It is almost impossible for any one firm to possess all of knowledge and technological capability needed to develop a complex product. This means that organisation has to focus on their core competencies and draw on the best expertise available world-wide to access specialties outside that core competence (Jagdev & Thoben 2001, Chung *et al.* 2004). Increasingly, companies are concentrating on core businesses and outsourcing other non-core activities. Consequently, quality management should be carried out across the supply chain, instead of only within the company. It is vital for companies to make the best of external resources and to cooperate with their partners on the supply chain in order to enhance their end-product quality (Wang *et al.* 2006). In leading-edge firms, management of the supply chain is regarded as one important way to gain a competitive advantage. Major American corporations such as Whirlpool, Boeing and Chrysler have shifted many of their design activities to key suppliers (Hartley 1997, Utterback 1974). To be effective, supply chain quality improvement must start from the design stage because design specifications have a major effect on a product's performance, quality and cost.

Currently, as a result of the fragmented global value chain, technology also has become an independent commodity (Guo 2006). Quality management in design and manufacturing phases are normally not implemented in the same company, but from the perspective of the whole supply chain. In increasingly competitive global markets, enterprises must maintain core competitiveness by shortening time-to-market, reducing costs, improving quality and integrating the resources of other partners on the supply chain (Chung *et al.* 2004). Strengthening product design capability is therefore becoming a key target of various companies（Lyu & Chang 2007）.

To a great extent, product quality depends on design and manufacturing processes, therefore studying how to improve product quality through collaboration between designing and manufacturing companies is quite significant, from both theoretical and practical perspectives. This is one of the objectives of the, Design Chain-Supply Chain-Management (DC-SC-M) project, focusing on the coordination issues between western designers and Chinese manufacturers (suppliers). To be successful in highly competitive global marketplaces where product quality is a vital criterion, the designer and manufacturer should improve the end-product quality cooperatively.

The major purpose of this study is to analyze the impact of design and manufacturing on final product quality, and to measure the importance of design quality in product quality. The design-manufacture chain model is illustrated since it is a decisive phase for determining product quality in many industries. Finally, we developed conceptual framework and formula for our Quality Relationship Model (QRM) to identify and elucidate the relationships between design quality, manufacturing quality and product quality.

2. Literature review

2.1 Product quality

Quality has emerged as a strategic factor, making quality management a necessity for overall operational effectiveness and global competence (Desai 2008). Quality is defined to be conformance to requirements (Crosby 1984). Previous research shows that, while product design may account for only 5 per cent of the product cost, it has a critical influence on 75 per cent or even more of manufacturing costs, and influences up to 80 per cent of product quality (Huthwaite 1988). Some have asserted that more than 40 per cent of all quality problems can be directly traced back to inferior product design (Leonard *et al.* 1982, Raia 1989). Moreover, the product design phase drives 70 to 80 per cent of the final production cost, 70 per cent of life cycle cost of product, and 80 per cent of product quality (Dowlatshahi 1992) (Figure.1).

The fact that quality must be designed into the product – as well as being "built-in" by downstream operations – has added to the recent emphasis on the new product development (NPD) process. According to the NDP concept product design, which drives a product's "innate" quality, is the key to overall product quality, and the design phase of the design-manufacturing chain (D-MC) is the most important phase in enhancing quality and reducing cost.

Increasing competitive parity in the areas of cost and quality has forced global manufacturers to seek other sources of competitive advantage with new product development rapidly becoming the focal point in the quest for sustained growth and

profitability. The implementation of the integrated product development (IPD) process has come to depend on the use of multi-functional teams (Birou & Fawcett 1994). Manufacturing management indicates what is possible in terms of manufacturability and works to combine the shortest possible response time with a high degree of quality and dependability. Getting these management functions to work together to develop superior products and reduce concept-to-market time remains a challenge for many organisations (Hayes *et al*. 1988).
'Soft' technical skills such as JIT,TQM, Management methods and level of collaboration have been found to be more influential in developing products and increasing supplier collaboration than 'hard' or technically complex capabilities (O'Sullivan 2003, Von Corswant & Tuna'lv 2002). Well trained technical liaison staff, administrative standards and collaboration will lead to greater levels of supplier involvement in design coupled with increased motivation to make larger investments in the design process (McIvor *et al,* 2006).

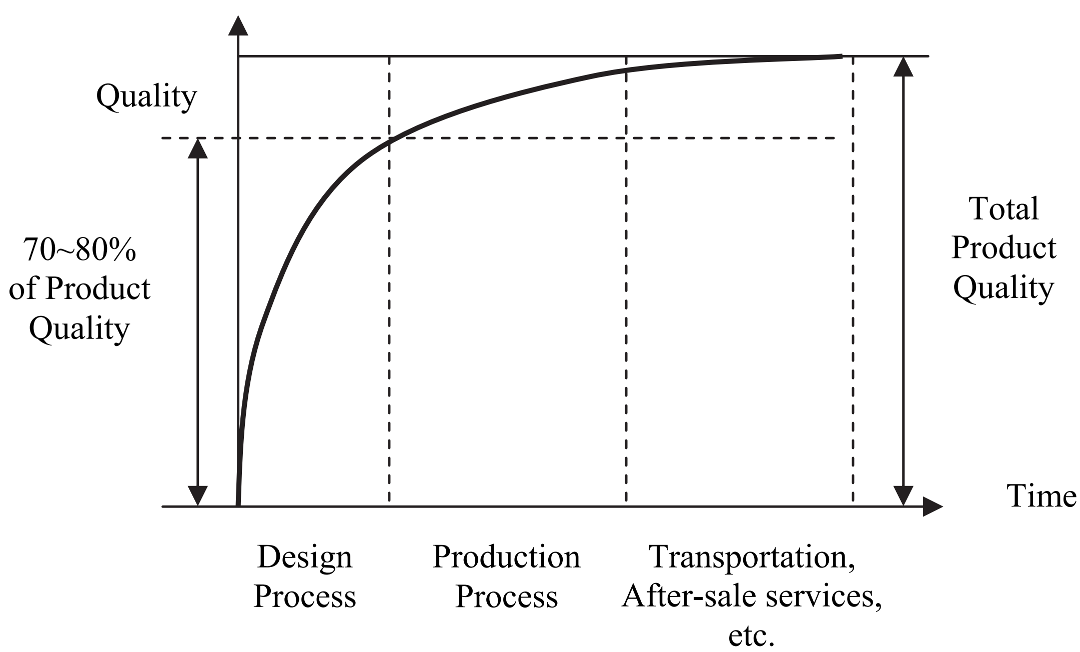

Fig. 1. Incline of Quality (Source: Dowlatshahi 1992)

2.2 Design chain

Firms in many industries are facing increased global competition and are operating in markets that demand more frequent innovation and higher quality. These firms are looking for ways to improve quality and reduce product cost. A large body of literature now exists which has identified new product development as a core process that has a major role to play in achieving success in the global economy (McIvor, Humphreys & Cadden 2006, Taps & Steger-Jensen 2007). A number of studies have identified a wide range of variables critical to successful product development.
The design chain is defined as the collection of business activities associated with all phases of product engineering, including research and development (Wognum *et al.* 2002). The design chain includes four stages: specification, concept design, detailed design, and production design (Hartley *et al*. 1997). The members in a design chain can aim to optimize the mechanical functions of a product, minimize the total production costs or achieve other settled targets (Lee & Gilleard 2002, McIvor & Humphreys 2004, Baglieri & Secchi 2007).

Design chain management is the management of the participants, both internal and external to a focal firm, that contribute the capabilities (knowledge and expertise) necessary for the design and development of a product which, on completion, will enable full-scale manufacture to commence (Twigg 1997). Thus, the design chain involves participants throughout the product development process, from concept, detail engineering, process engineering, prototype manufacturing, through to post-launch activities.
As operations become leaner (Lamming 1993), the focus of quality management will necessarily shift to earlier phases in the product development process, and especially to design relationships that a company forges with its outside suppliers. Each relationship may be considered part of a design chain (Clark & Starkey 1988, Twigg 1997) within a network of firms. Under total quality management (TQM) systems, product design efforts have two primary objectives: to design easily manufacturable products (Kitapci & Sezen 2007) and to design better quality products while minimizing costs.

2.3 Early supplier involvement

In many industries, firms are seeking to improve quality, reduce the cost of products and facilitate the smooth launch of new products. Early supplier involvement is a key coordinating process in supply chain design, product design and process design. Researchers have found that a number of benefits are attained though Early Supplier Involvement (ESI) in the product development process. Incorporating suppliers into project teams enhances the information and expertise regarding new ideas and technology (Smith & Reinertsen 1991, McIvor R. Humphreys P. & Huang, G., 2000.). In addition, it allows early identification of potential problems, thus improving the quality of the final product, eliminating rework and reducing costs (Dowlatshahi 1997, Meyer 1993, Handfield 1994).
ESI refers to customers and suppliers providing their ideas and resources in the early stages of the new product development process. It consists of two parts - early supplier involvement and early customer involvement. Many firms are also aware of the importance of the key suppliers in the early stages of their product development processes and in shortening the time-to-market. An earlier work has reviewed the involvement of suppliers in the earlier stages of a company's product development process to reduce considerably the lead-time and manufacturing costs. Today, manufacturers commonly strive for early supplier involvement in product development. Effective integration of suppliers into the product value chain is a key factor in the improving competitiveness of many manufacturers. Early involvement can occur in any of the stages of product development, as summarized in Table 1 (Dowlatshahi 1997, Hartley *et al*. 1997, Twigg 1998, Lyu & Chang. 2007).
Increasingly, suppliers are becoming involved much earlier (Appleby & Twigg 1988; O'Neal 1993, Sleigh 1993, Twigg 1998, Liker et al. 1996). Today, outside suppliers represent increasingly important members of the new product development team. Supplier involvement promotes better resource utilization, the development and sharing of technological expertise, and network effectiveness (Birou & Fawcett 1994, Wadhwa & Saxena 2007).
There is evidence that the early involvement of suppliers in product development is instrumental in reducing lead time and avoiding costly downstream production problems (Clark& Fujimoto 1991). Japanese supplier management methods involve intense and frequent communication during the product development cycle, particularly in the early stages when the product is being defined (Dyer & Ouchi 1993). This includes the in-depth

and regular sharing of technical information to improve performance and reduce cost. The suppliers send 'guest engineers' to work full-time for extended periods in their customer's design offices along side the customer's design engineers (Dyer & Ouchi 1993, Liker *et al.* 1996).

Design stages	Concept design	Specification	Detailed design	Production design
ESI	Target markets Key product and process technologies Product architecture Contribute key ideas/concepts/ critical components Establish interfaces between product subsystem	Establish specification Avoid ambiguity and information distortion Identify early changes Identify key components required	Selection of proprietary parts and components Tolerance design Prototype testing and demonstration Design for manufacturability Materials selection Process design	Tooling design Design for Manufacturability Quality control and assurance Raw materials

Table 1. Early Supplier Involvement in various design stages

3. Design-Manufacturing Chain（D-MC）

Competitive pressures are forcing companies to design new products - or new versions of products - better, faster and cheaper. It is now generally understood that this can be accomplished through Concurrent Engineering (CE) (Schönsleben 2003) of the product and the manufacturing processes that make the product. From the emergence of market demand to finished-product delivery to the end consumer, the product goes through several phases including design, manufacturing, transportation, distribution and so on. The, design phase includes product planning, concept design, design specification and revision, while manufacturing includes prototyping, testing, production planning, and full-scale production. A Design-Manufacturing Chain (D-MC) (Zhu & Alard 2005, Zhu *et al.* 2006, Zhu 2007, Zhu & You 2009) is a chain or network made up of design and manufacturing companies, in which the final product is designed and produced within different companies. The simplest D-MC consists of only two companies: the designer / designing company (e.g. an Original Equipment Manufacturer, OEM) and the manufacturing company.

Manufacturers are included in the development process because they frequently possess design and technology expertise which designers usually do not know very well. Therefore, product time-to-market reduction and substantial cost savings from higher productivity, lower maintenance and fewer recalls are possible benefits of early supplier (or manufacturer) involvement in product design and development stages. A common method for accomplishing this is through cross-functional teams that bring product developers into direct communication with manufacturing engineers, marketing executives, and others whose input is important to the product development effort (Liker *et al.* 1996).

The essence of today's product development strategies is simultaneous development of the new product – also known as CE and/or design for manufacturability – such as product quality improvement, cost reduction, and lead-time shortening. CE carried out in the early stages of product and system design can bring out a series of benefits, by considering and including various product design attributes such as maintainability, marketability, manufacturability, safety, reliability and transportability.
As Design-Manufacturing Chain (D-MC) (Figure.2) shows, manufacturing process can start prototyping and tooling from the detailed design stage, not waiting until the whole design phase is completely finished.

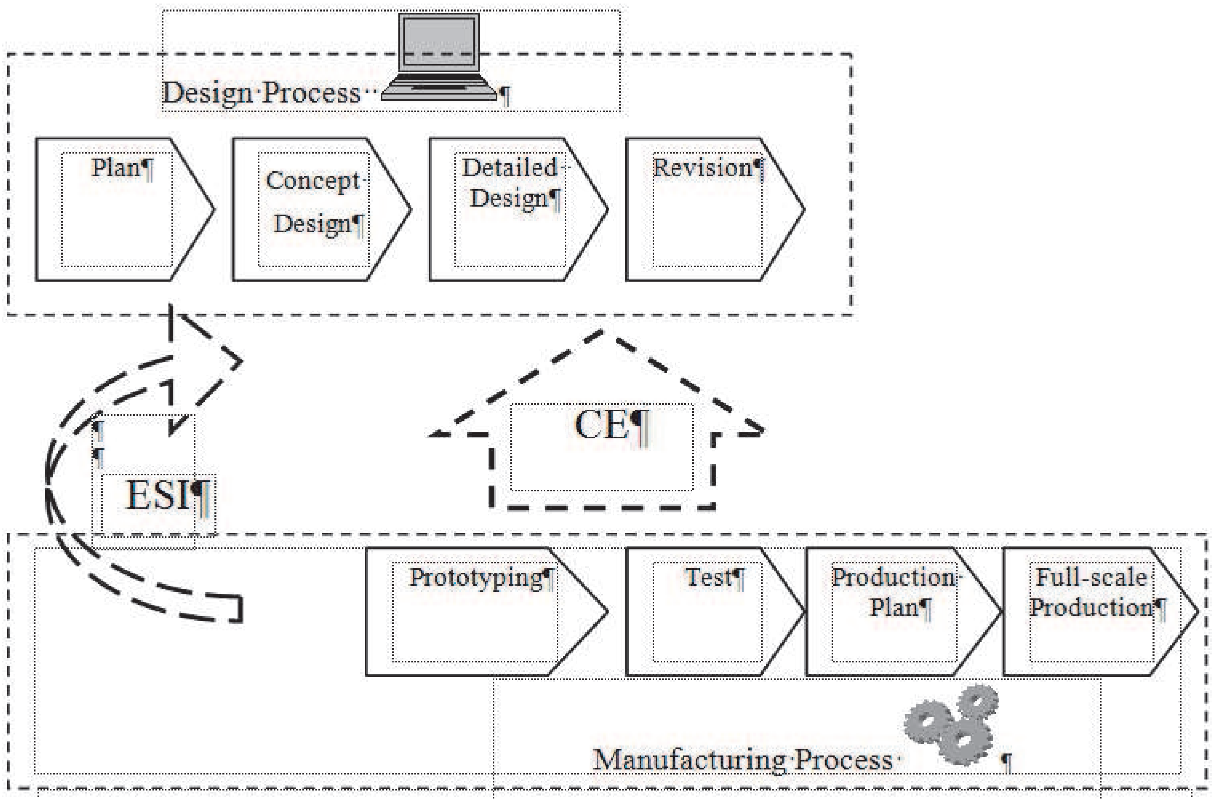

Fig. 2. Design-Manufacturing Chain（D-MC）

The philosophy of D-MC quality management is to control product quality from its roots and emphasizes early supplier (manufacturer) involvement in the process of product design and development, which may accelerate product innovation and optimize product quality. D-MC quality management is also based on win-win relationship of supply chain partners. Partners in D-MC should focus on quality information/resource sharing and on exchanges of manufacturing and testing information, rather than on bargaining.
There are many opportunities for manufacturers to be involved in major stages of the product development process. At the concept design phase, manufacturers help to identify up-to-date technologies to be incorporated into a new product. In the detailed design process, manufacturers can provide solutions for component or sub-assembly design and the selection of most suitable materials and components. Manufacturers have capabilities or know-how to provide the most effective tooling, fixtures and equipment. Throughout the product design and development processes, manufacturers may be involved in design

teams to achieve DFM (Design for Manufacturability) and ensure the product will be delivered effectively and efficiently.
It is necessary to develop a methodology for better supplier involvement in the new product design and development process through a prototype web-based platform on the internet/intranets using web technology. A web-based framework can promote and facilitate early manufacturer involvement in the design stage, in practice.

4. Design-Manufacturing Chain Quality

According to the definition of quality, "quality of design process" means that design specifications should conform to the requirements of customers, and "quality of manufacturing process" means that manufacturing should conform to the design specifications. Although product quality is related to product delivery, after-sales service, maintenance, recyclability, etc., it is mainly shaped in the design and manufacturing processes, i.e., product quality depends on D-MC quality.
Based on a review of the literature and on interviews with expert partners from design, production and logistics departements as part of a research project with eight European industrial companies that cooperate on an international level, we will demonstrate the key determining factors for the final product quality . According to our research there are two primary factors influencing the final product quality: the design process of the product and the manufacturing process. Therefore, to a great extent, final-product quality lies on the quality of Design-Manufacturing Chain. Design-Manufacturing Chain Quality（D-MCQ）includes two parts, design quality and manufacturing quality. Design quality means that design requirements reflect the Voice of Customer (VoC) or the demands of market. Manufacturing quality means that the end-product conforms to the product design requirement and specification, where it is the conformance to quality. If design does not reflect the market requirements, the product can not meet the demands of market even though manufacturing conforms to the design completely, and if manufacturing does not conform to the design specifications, the finished product has poor quality and can not satisfy customers' needs.
Design-Manufacturing Chain Quality Management (D-MCQM) indicates supervision and control the quality of all activities on D-MC. D-MCQM can be depicted by three simple definitions that follow:
Design-Manufacturing Chain (D-MC) is defined as the chain or network made up of design and manufacturing companies and processes;
Quality (Q) means conformance to requirements;
Management (M) refers to the activities for design and manufacturing quality improvement.
Poor quality of D-MC includes poor quality of design and poor quality of manufacturing. Poor quality of design means that design requirements do not reflect the demands of customer adequately at the right cost, and/or at the right time. Poor quality of manufacturing means that manufacturing has not completely conformed to the design requirements/ specifications so that the final product can not meet market demands at the right cost and at the right time. Designs with technological deficiencies lead to inferior products, as do late stage design changes such as products that need to be recalled or re-manufactured. All of those are examples of poor quality.
Technological deficiencies in design, which is "innate" deficiency of product quality, may result in huge quality costs in many areas such as quality-related maintenance, warranty repairs and severe exterior (e.g. product safety liability, product returns, retail channel loss)

loss (Guo 2003). Manufacturing quality control usually can not solve the problems which are rooted in design deficiency. Therefore, design quality is decisive to product quality, so in order to create more customer value it is crucial to manage quality starting from the design process instead of focusing on the manufacturing process only.

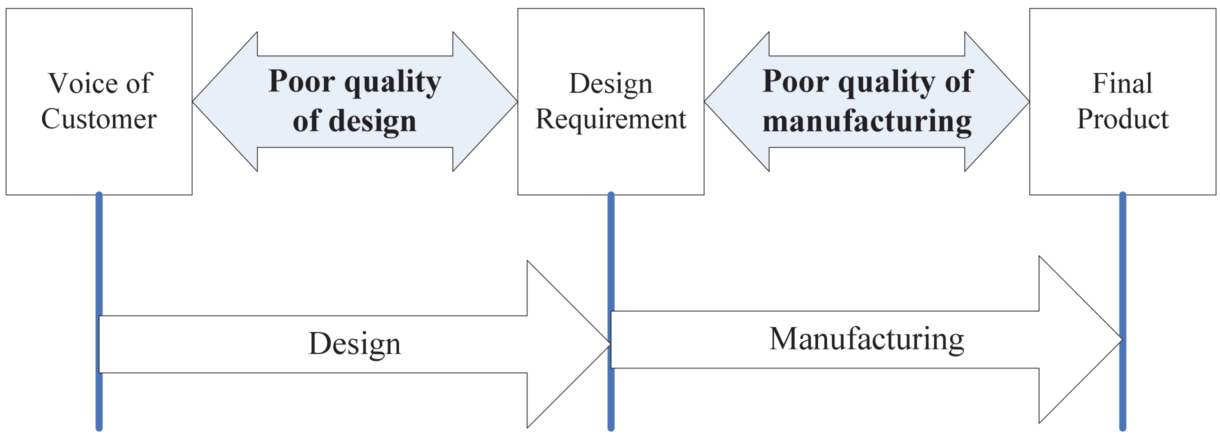

Fig. 3. Poor Quality of D-MC

An overwhelming majority of product failure costs and design iterations come from the ignorance of noise factors during the early design stage. The noise factors which crop up one by one in the subsequent product delivery stages cause costly failures. The Taguchi Method (TM) presented by Taguchi G. (1989) may help designers to select appropriate controllable factors so that the deviation from the ideal value is minimized at a low cost. Variation reduction is universally recognized as a key to quality reliability and improvement in D-MC.
Product design decisions are affected by many controllable and uncontrollable factors including technological, environmental and organisational issues.The number of controllable factors and noise factors for quality reliability change upstream (design process) and downstream (manufacturing process) in the D-MC (Figure.4). Generally, uncontrollable noise factors increase and controllable factors decrease along the D-MC. Accordingly, quality control from start or upstream is more efficient than downstream.

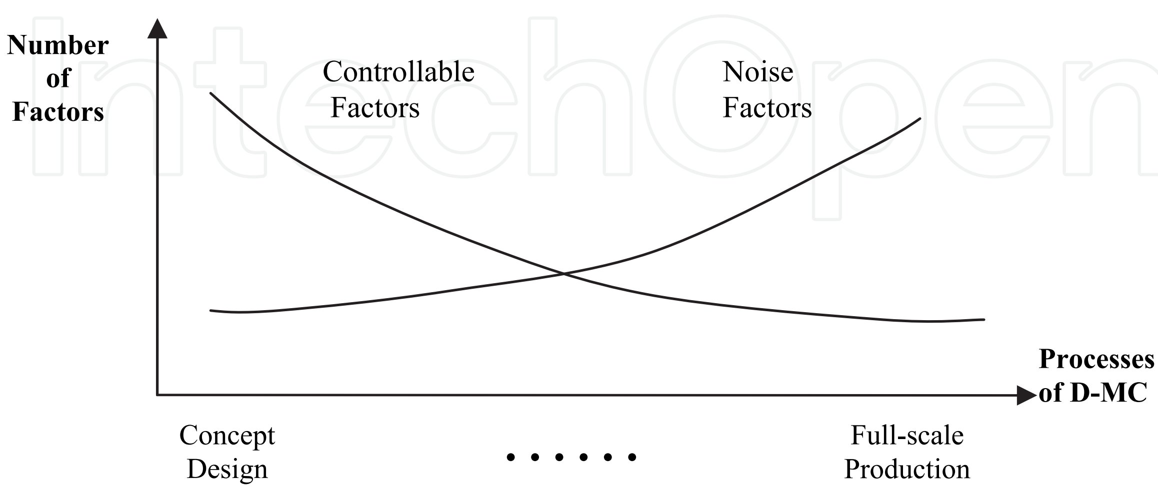

Fig. 4. Controllable Factors and Noise Factors on D-MC

5. Quality Relationship Model (QRM)

Therefore, the impact of design on product quality is much stronger than that of manufacturing. The Quality Relationship Model (QRM) can be illustrated with the leverage relationships between design quality, manufacturing quality and product quality (Figure.5).

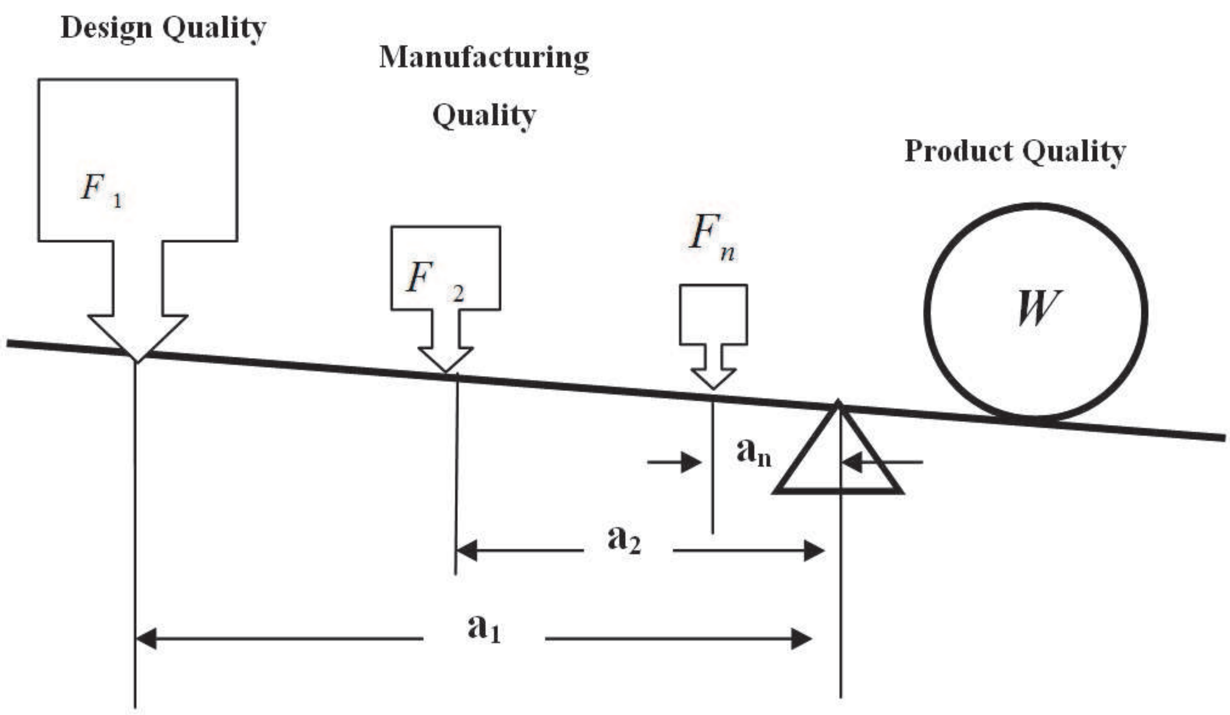

Fig. 5. Quality Relationship Model (QRM)

The followed formula expresses the leverage relationship of QRM in Figure 5.

$$W = F_1 \bullet a_1 + F_2 \bullet a_2 + \cdots + F_n \bullet a_n \quad (1)$$

where:
W denotes final product quality, the bigger W the better the final product quality;
F_1: Design quality;
F_2: Manufacturing quality；
F_3 --- F_n : The quality of every other process, e.g. delivery, after-sales service, etc.
If F_3 --- F_n are all of the processes influencing product quality, then

$$a_1 + a_2 + \cdots + a_n = 1 \quad (2)$$

a_1: The impact factor of design quality on final product quality. According to Figure 1, the product design phase drives 70 to 80 percent of the product quality (Huthwaite 1988, Dowlatshahi 1992), so design influences 70 to 80 percent of the product quality (repetitive), and the impact factor of design quality is between 0.70 and 0.80,

$$0.70 \le a_1 \le 0.80 \quad (3)$$

a_2 : The impact factor of manufacturing quality on final product quality. If the impact factor of design quality is represented in formula 2, then

$$0 < a_2 \leq 0.30 \quad (4)$$

Larger numerical values of a_1, a_2 shows stronger impacts of the process on final product quality.
Certainly, the quality of other processes other than design and manufacturing, i.e. $F_3 \cdots F_n$, also has an influence on product quality. Their impact factors are $a_3 \cdots a_n$ respectively.
$F_1 \cdot a_1$ and $F_2 \cdot a_2$ respectively express the influence of design quality and manufacturing quality on product quality.
Based on an analysis of the formulae, in order to improve product quality, it is imperative to enhance design quality (F_1). A collection of tools for design engineering (e.g. QFD, DFMA, Tolerance Analysis, Robust Design, DOE, etc.) should be implemented in the product development process in order to avoid huge costs for re-design after a new product has launched. To avoid the expensive re-design activities and improve the manufacturability of the design, it is necessary to establish cross-functional teams to facilitate early supplier or/and manufacturer involvement to initiate the product research and development. The cross-functional team is made up of representatives from such groups as engineering, manufacturing and marketing. Meanwhile, it is also necessary to control manufacturing quality (F_2) to avoid manufacturing defects that arise from a manufacturer's negligence. This chapter advocates supplier involvement in the early phases of product design and development in a concurrent engineering environment. Early manufacturer involvement efforts will lead to better manufacturability, easier assembly and better quality.

6. Two cases from the toy and automobile industries

The Toy industry is a good case for a study of design and manufacturing quality because many "Made in China" toys are designed by foreign companies (brand owners, such as Mattel Inc.) but are manufactured by overseas suppliers, and especially by Chinese factories. Design problem would result in a poor-quality or unsafe toy irrespective of where the toy was manufactured. On the other hand, a manufacturing defect arises due to manufacturer errors or negligence. Toy manufacturers produce toys according to design specifications from toy designers; if the design itself has defects, the toys will definitely be faulty.
The recall of an estimated 20 million Chinese-made toys by Mattel on August 14, 2007 shocked the world. To explore the essence of this event, we have to examine deeply what the problems are and where they arose. The fault may occur due to design or due to manufacturing. The distinction between design and manufacturing is particularly important in the context of the toy industry because the design of toys is performed by toy brand owners whereas manufacturing is done by overseas manufacturers. Therefore, the effort to improve product quality and avoid recalls should be targeted at where the problems exist. Table 2 clearly shows that the number of toy recalls by flaw type over the last two decades (1988–2007) and the causes of recalls (Bapuji & Beamish 2007).
A design problem would result in a poor-quality or unsafe toy irrespective of where it was manufactured. On the other hand, a manufacturing defect arises from a manufacturer's

negligence. Toy companies develop designs and then send them to the manufacturers in China along with specifications. If a toy's design is good, it does not necessarily mean that the final toy product will be good. By contrast, if the design is poor, the final toy product will definitely not be good. In other words, only toy companies can prevent problems associated with design. On the other hand, manufacturing defects can be prevented by both manufacturers and by toy designers (brand owners).
Therefore, as Table 2 shows, the recalls of toys over the last two decades (1988~2007) are analyzed to examine if the number of recalls had systematically increased and what kind of problems resulted in recalls (Bapuji & Beamish 2007).

Year	Total Number of Recalls	Number of Recalls due to Design Flaws	Number of Recalls due to Manufacturing Flaws
1988	29	25	2
1989	52	42	2
1990	31	25	3
1991	31	29	1
1992	25	16	0
1993	20	15	1
1994	29	21	4
1995	35	32	0
1996	26	15	5
1997	22	17	1
1998	29	23	1
1999	20	15	2
2000	31	25	2
2001	23	15	4
2002	25	20	3
2003	15	14	0
2004	15	8	4
2005	19	14	3
2006	33	23	6
2007	40	26	10
Total	**550**	**420**	**54**
Percentage	**100%**	**76%**	**10%**

Table 2. Toy Recalls by Flaw Type (1988 – 2007) (Source: Bapuji & Beamish 2007)

Of the 550 recalls from 1988 to 2007, 420 of that (76 per cent) were caused by design flaws, in contrast, only 54 recalls (10 per cent) were due to manufacturing flaws. Therefore only 14 per cent of recalls stem from other reasons, e.g. transportation, storage. In other words, the majority of recalls were due to design-related problems, not manufacturing. Certainly, it is true that the percent of recalls by manufacturing flaws sequentially rose over the last three years, and Chinese manufacturers should consider this seriously, although this is not the topic of this chapter. Of the 550 recalls from 1988 to 2007, 76 per cent were caused by design flaws, in contrast, only 10 per cent by manufacturing flaws. Then other 14 per cent of recalls stem from other causes, e.g. transportation, storage.

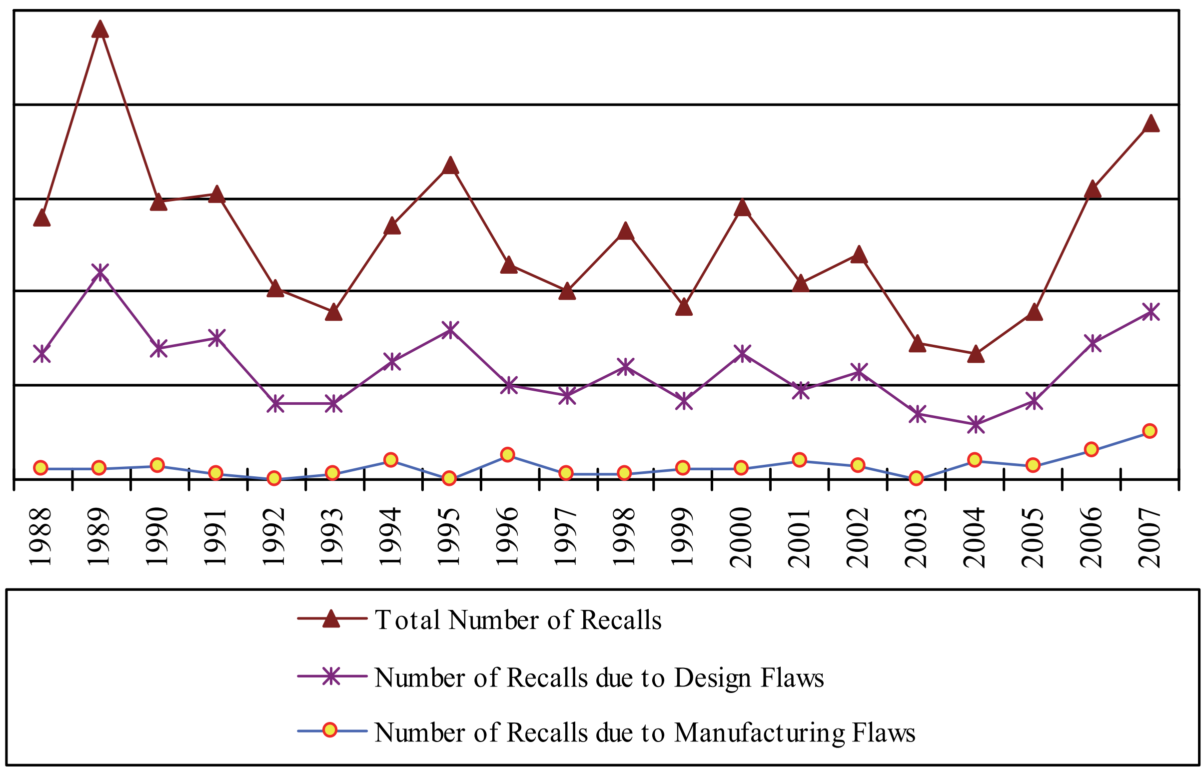

Fig. 6. Recalls by Flaw Type (1988-2007)

Applying the formula of the Quality-Relationship Model to the toy industry, if the impact factors a_1 and a_2 can be evaluated. If W_T shows the quality of toy, then the formula of QRM is as follows:

$$W_T = F_{1T} \bullet a_{1T} + F_{2T} \bullet a_{2T} + \cdots + F_{nT} \bullet a_{nT} = F_{1T} \bullet 0.76 + F_{2T} \bullet 0.10 + \cdots + F_{nT} \bullet a_{nT} \quad (5)$$

$$0.70 < a_{1T} = 0.76 < 0.80 \quad (6)$$

$$0 < a_{2T} = 0.10 < 0.30 \quad (7)$$

The formulae (6) and (7) validate the formulae (3) and (4), and accurately value the impact factors in the toy industry.

Figure.6 shows that design flaws are the crucial factor in toy recalls in the last two decades which caused severe injuries to child end-users. Toy companies must learn lesson and focus their efforts on improving the design quality. The analysis reveals that design flaws resulted in the overwhelmingly majority of toy recalls over the last two decades. Not only have design problems been more numerous but they also seriously damaged consumers. An overwhelming majority of the recalls could have been avoided with better design, and it is important to focus our efforts on learning from the recalls that occurred in the past and minimize their recurrence.

The second D-MC case is taken from the automobile industry. A survey from Mckinsey, named *The Roadmap of Chinese Automobile Companies Going Global* (Gao 2008), shows that the quality problems in assembly accounts for about 10 percent of the quality problems of all stages of automobile production. Most of quality problems originate in design. For example, one assembly company found that the excessive noise in brakes resulted from brake material which had been selected during the design stage. Some quality problems stem from process design or from design specifications. As a whole, out of the top 50 defects mentioned by the assembly company, 85 per cent were introduced prior to the assembly process (Figure.7).

According to Figure.1, about 80 per cent the quality problems of suppliers are derived from problems with component design. So, out of the "Suppliers" section in Figure.4, 80 per cent of quality problems of suppliers, i.e.36 per cent (80% multiplied by 45%) of final product problems, are derived from design. Then, in total, 76 percent (40% plus 36%) of the problems come from the whole vehicle design and the component design. This figure (76%) exactly coincides with the percentage observed in the toy industry. Certainly, it is a mere coincidence between these two different industries, but at least, these two cases indicate that the impact factors in the Quality Relationship Model (QRM) are reasonable.

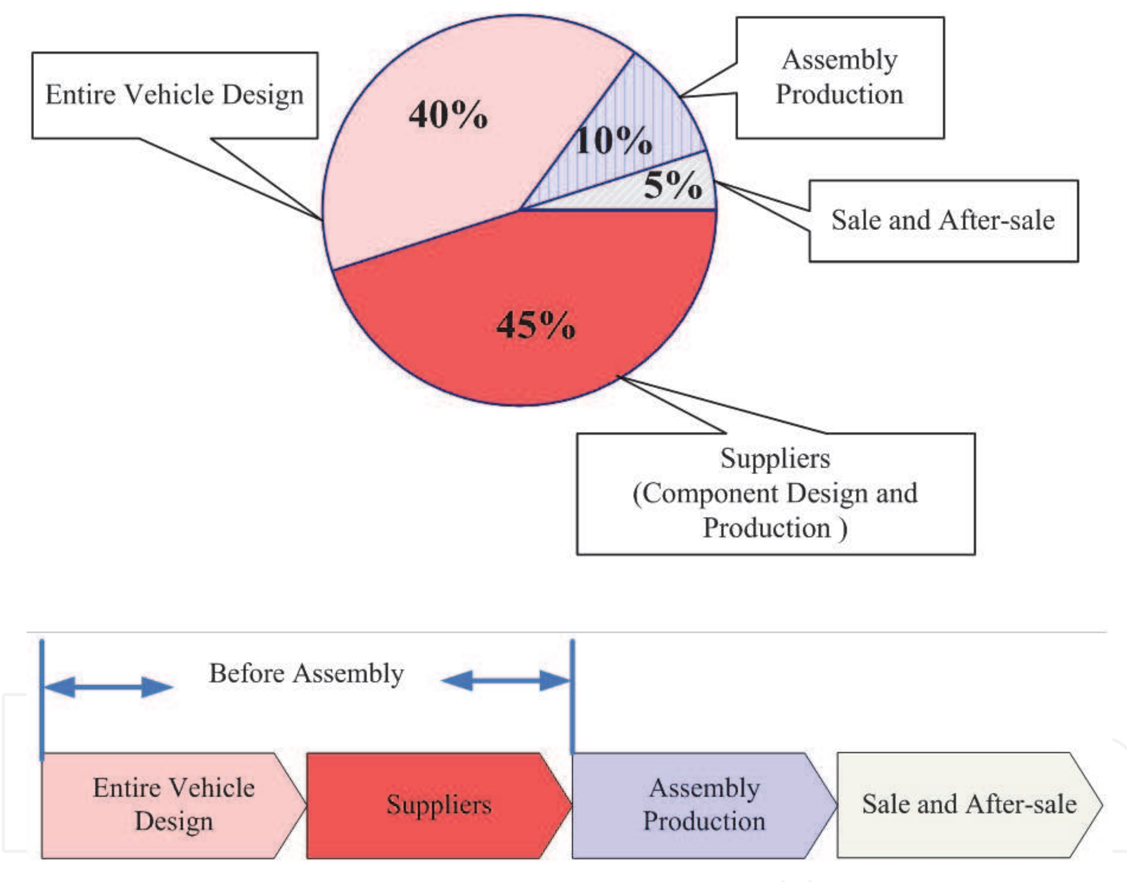

Fig. 7. Total Quality Control in Automobile Production

7. Conclusion

Compared with others phases of production, design has a crucial influence on final-product quality; in other words, the quality of design is more important than that of other quality issues on the supply chain. This study presents a formula showing a leverage relationship among design quality, manufacturing quality and final product quality, which shows clearly that improving the design process is the most effective path to improving final product quality. Based on the QRM formula and the case studies of two different industries (toy and automobile), this chapter explains and explores the impact factors of design and manufacturing on final product quality. In summary, to optimize product quality, it is crucial to manage the D-MC successfully by collaboration of the partner companies throughout the whole supply chain.

Although the impact of design on quality in various companies and industries may be different, through the analysis of the empirical cases from two different industries, the findings of this study have important implications for managers responsible for integrating suppliers into product development projects. Our findings emphasize the importance of design on the final product quality. These results should be encouraging to companies trying to decide whether involving suppliers in their new product development efforts is worth the effort required. This study reminds quality managers to turn their attention to design process to improve product quality and performance, instead of keeping their eyes solely on manufacturing.

Finally, from the view of technology and innovation management in supply chain, process or organisational innovations will tend to relate to supply chain (e.g. reducing costs, improving production quality and capabilities, shortening the time-to-market). Some barriers relate to all types of innovation (e.g. cost factors) while others relate to a subset of innovation types. There a clear need to make further investigation and validate the models put forward in this study.

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Over the past few decades the rapid spread of information and knowledge, the increasing expectations of customers and stakeholders, intensified competition, and searching for superior performance and low costs at the same time have made supply chain a critical management area. Since supply chain is the network of organizations that are involved in moving materials, documents and information through on their journey from initial suppliers to final customers, it encompasses a number of key flows: physical flow of materials, flows of information, and tangible and intangible resources which enable supply chain members to operate effectively. This book gives an up-to-date view of supply chain, emphasizing current trends and developments in the area of supply chain management.