INFORMATION SHARING IN A HIGH UNCERTAINTY ENVIRONMENT: LESSONS FROM CASE STUDIES IN THE DIVERGENT DIFFERENTIATION SUPPLY CHAIN

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ABSTRACT

Information distortion and incapability of sharing information simultaneously between the production sides and demand sides make the major uncertainty of the supply chain. This study tends to understand how to share information effectively in a high uncertainty environment based on case studies on three Printed Circuit Board (PCB) companies in the divergent differentiation supply chain, in Taiwan. The results show that PCB industry is with high uncertainties across the demand, manufacturer, and distribution sides. Trust can increase information sharing while risk is considered the main factor impeding information sharing. Information sharing content through the sharing of "demand forecast information" can improve the OFP's performance. Furthermore, information sharing with VMI mechanisms can reduce supply chain uncertainty, especially in the divergent differentiation supply chains. The inter-organizational coordination can be coordinated through the VMI system to reduce the bullwhip effect and risks.

Keywords: Information sharing, uncertainty, VMI, coordination, trust.

INTRODUCTION

The supply chain is a complex network, and it is even difficult to analyze [9]. Among the supply chain issues, uncertainty and information sharing are common research topics [7] [16]. Uncertainty is one of the crucial issues discussed frequently in the supply chain management [4] [10] [14]. Davis pointed out that numerous factors in a complex Supply Chain Network (SCN) can cause uncertainty, and any factor has the potential to affect the whole supply chain network, especially the efficiency [4]. Seeking an effective management on the supply chain requires companies to identify what uncertainty factors are, and then try to minimize consequent results and impacts. The so-called "Bullwhip Effect" is considered as one of the major factors that cause the uncertainty among supply chain nodes. This is mainly resulted from information distortion and incapability of sharing information simultaneously between the production sides and demand sides of each node connection in a supply chain, and in term reduces the overall supply chain performance.

Strader et al. argued that it is almost impossible to eradicate all uncertainty factors, yet the impact made from them can be reduced when proper managerial strategies are in place. Information sharing is one of them [22]. According to Tan et al., information sharing can reduce uncertainty factors, and increase the efficiency of a supply chain [23]. Information sharing aims to capture and disseminate timely and relevant information for decision makers to plan and control supply chain operations [21] [25]. Strader et al. believed that effective information sharing can reduce the errors made during the decision making processes in supply chains, and therefore enables a proper control on the uncertainty factors, so that the business risk can be reduced [22]. In addition, exchanging information between supply chain partners can lead to operational efficiencies and new knowledge creation in supply chains, even when learning from partners may not be an explicit goal [18].

Although sharing information is advantageous, it is a difficult task in a supply chain due to several challenges. Lee and Whang revealed that sharing information in a supply chain needs to overcome several challenges lying in the implementation, e.g. lack of willingness of sharing sensitive information among different partners; information confidentiality issues; how to share the cost and risk of implementing information equipments required for achieving information sharing; and how to improve the negotiation and planning activities within a supply chain in order to achieve the goal of information sharing [15]. Apart from that, the challenges faced from the execution of information sharing (such as the profit distribution issues regarding information sharing) also make enterprises feel intimidated of sharing. For certain supply chain members, information sharing does not necessarily bring positive results for their business profits, and might even incur more operating costs. This is the reason which causes these supply chain members showing a lower willingness to share sensitive information such as cost, productivity and pricing information, or causes them to use the these types of sensitive information as a bargaining chip when negotiating the distribution of profits. Therefore, how to evenly distribute the profits and possible risks resulted from information sharing is an important consideration for determining whether a long-term cooperative relationship is maintained among these supply chain members.

Several kinds of models have been used to assist in the analysis of supply chain related strategies. For example, push and pull model is used when focusing on the analysis of production and replenishment of inventory management related issues [24]. The replenishment in the push strategy is based on the forecast whereas the actual consumption volume is the focal point in the pull strategy. Make to Order (MTO) and Make to Stock (MTS) models are used for discussing production strategies in the relationships between customers and suppliers [1]. However, most previous models pay more attentions to the dyadic parties in the whole supply chain including the sender and receiver. Lin and Shaw suggested another model which includes three types of supply chain, and it is more appropriate to oversee the issues across the entire supply chain form the upstream to the midstream and downstream [17]. Among the three types, Divergent Differentiation Supply Chain is with the highest uncertainty, and is more challenging to manage. Relatively, fewer studies

focus on the divergent differentiation supply chain. Due to these characteristics, this study has chosen divergent Differentiation Supply Chain for research object.

Most of the past studies on information sharing in the divergent differentiation supply chain are based on simulations method (e.g., [22] [26]), and the study on real world situation of the supply chain is demanded. This study tends to fill this gap by performing three case studies on three Printed Circuit Board (PCB) companies PCB industry, a type of divergent differentiation supply chain, in Taiwan. This study particularly aims at understanding the following questions: first, how organizations deal with the uncertainty in divergent differentiation supply chains through information sharing; second, whether the supply chain uncertainty can be reduced through cross-organizational coordination and the content of information sharing; and third, what key factors affect them to perform information sharing.

The rest of the paper is organized as follows. The next section describes the supply chain types, factors causing uncertainty, and factors that affect information sharing in a supply chain. Then, a framework of four main dimensions and nine variables is discussed as well as the research designs. After that, case results of studying three PCB manufacturers are supplied that also include the cross cases comparison and research Lessons. Finally, the conclusion, limitations, and future research are presented.

THEORETICAL BACKGROUNDS

Supply Chain Types

A supply chain network is mainly comprised of a series of autonomous and semi-autonomous organizational entities from upstream to downstream, interconnected to fulfill the order request from customer through various processes and activities [3] [14] [17]. In terms of product demand, Fisher divided products into functional and innovative types [6]. The demand on functional products is more stable, and it is required efficient supply chain strategies to reduce inventory accumulations in the overall channel. In contrast, the market of innovative products is faced with unpredictable changes in demand, and need to adopt the supply chain strategies that can rapidly respond to the market so as to seize profit opportunities in the early stages of the product lifecycle.

Lamming et al. revised Fisher's categorization and suggested two dimensions to define the types of supply network – the characteristics and complexity of the final products [6] [12]. According to Lamming et al., the characteristics of products can be divided into two categories – innovative-unique and functional depending on the innovation degree of the product, while the product complexity can be categorized based on the sensitivity of the technology used for product manufacturer and the number of the components used in the product [12]. For innovative-unique products with high and low complexities, the key for supply chain development is on the speed of product development, productive elasticity, innovation degree and quality control. For a functional product with high complexity, the key for supply chain development lies in reducing manufacturer costs and enhancing the service quality. For a functional product with low complexity, the key for supply chain development lies in reducing manufacturer costs through mass production, and enhancing the service quality.

In terms of product manufacturer, Lin and Shaw divided supply chain structures into three types - Convergent Assembly, Divergent Assembly and Divergent Differentiation - according to the attributes of manufacturer processes, business objectives, product segmentations, product categories, assembly processes, product lifecycles, inventory categories and so on. As far as convergent assembly supply chains are concerned, the products from this type of networked organizations are comprised of numerous components, and the final products are established through many steps of assembly. Since different components might comes from different suppliers, convergent assembly supply chains may have numerous suppliers. In addition, products of this type are difficult to modify even in the early stages of the product life cycle due to the differences between each part, and hence more difficulties to satisfy specific requirements from customers. For this type of products, the greatest uncertainty is in market demands, and the major inventory cost is from final products. Therefore, the key for convergent assembly supply chain networks lies in the synchronization of the arrival of each raw material, which can reduce inventory and transaction costs as well as increase order fulfillment rate. Typical industries belonging to this category include the automotive industry and the airline industry [17].

As far as divergent assembly supply chains are concerned, the networked organizations of this type usually have their own final assembly factories and distribution systems. To fulfill a high volume of order requests that demand customization, these networked organizations usually turn to delayed differentiation to divide their product assembly processes into two stages: complex semi-finished products are assembled in factories, and easier customized assembly processes are later completed at distribution centers. In addition, since the raw materials required by their products possess the feature of generalization, these raw materials can become parts for different products, and can be assembled into numerous different products through different production lines. This is also the very feature that makes semi-finished products become their major inventories. Therefore, the key for divergent assembly supply chain networks lies in the rapid delivery of products which can meet special requirements from customers, or in other words, shortening the lead time of customized assembly. Typical industries belonging to this category include the PC, mobile phone and other related electronic equipment industries [3] [17].

As far as Divergent differentiation supply chains are concerned; the final products of this type are usually finished goods before the customers place their purchase orders. This feature often results in late response or oversupply to customer demands from the overall supply chain due to inaccurate forecast of the demand information, and might generate other issues such as high rates of inventory accumulations, overstocking of capitals, or purchasing order transfers to other suppliers. According to this feature, the networked organizations of this type usually have their own final assembly factories and distribution systems. In addition, due to a great variation in product specifications, the life cycles for products can be as short as a few months, or even just a few weeks. Therefore, the differences for products

mainly come from manufacturer factories, and hence the ability to respond rapidly has become a key factor for this type of supply-chain organizations. Typical industries belonging to this category include the clothing industry and the toy industry [17].

Based on the three different supply chain types and their respective objectives, Lin and Shaw proposed corresponding information sharing contents for each supply chain type [17], as can be seen in Table 1.

Table 1. Supply chain types and information sharing strategies

Manufacture Procedures	Convergent Assembly	Divergent Assembly	Divergent Differentiation
Supply Chain Goals	Lean Production-to supply goods with the lowest possible costs	Customization-to supply customized goods to customers	Agile Production to instantly supply products that can meet market demands
Information Sharing Contents	Productivity negotiation and planning Inventory changes Production schedules	Demand and ordering information Customer ordering quantity	Market demands Customer sales Customer responses

In line with above discussions, it is suggested that there are great differences between the supply chain structures of different industries, and the supply chain structures may have impact on their relevant information sharing contents.

Factors Cause Uncertainty

The most important issue of supply chain management is to comprehend and manage the uncertainty factors of a supply chain in order to alleviate their influences. From the viewpoint of the interactions between upstream and downstream vendors in a supply chain, Davis concluded that the uncertainty factors from three dimensions - demand, supply and manufacture - are the major reasons that cause the delay of the final product delivery date or the degradation of customer service level [4]. If uncertainty-related information with respect to these three dimensions can be obtained more, their influences can then be understood better. Each of these factors is elaborated as below: first, uncertainty factors in demand: the average demand and the demand variations should be evaluated. Second, uncertainty factors in supply: the punctual delivery rate, average delay time and delay time variations of suppliers as well as the quality of their delivered goods should be evaluated. Third, uncertainty factors in manufacturer: information needing evaluation include downtime frequency, repair time, repair time variations, reliability of the manufacture process, etc.

When investigating supply chain uncertainty, Lee and Billington also divided it into the same three dimensions - supply, manufacturer, and demand and considered the sources of supply chain uncertainty as: (1) supplier lead time and delivery performances; (2) feedstock quality in the future; (3) manufacturer process time; (4) delivery time, and (5) demand [13] [14].

Based on above discussions, this research agrees that the uncertainty factors involved in the operation of supply chain processes can be divided into three dimensions, i.e. demand, supply and manufacturer.

Factors Affect Information Sharing

Researchers who investigated inter-organizational partnerships tended to utilize characteristics like trust, commitment, and power to describe the relationships and phenomena between organizations. According to Morgan and Hunt, trust and commitment are two important factors for the successful maintenance of a long-term partner relationship. The stronger the mutual trust is the more reassured the partners will be when cooperating with each other. Commitment means partners are consistently investing a certain amount of resources, and are showing willingness of continual cooperation. The stronger the mutual trust and commitment between partners are, the more the uncertainty of cooperation can be reduced, and the better the coordination between partners can become [20]. Anderson and Narus defined trust as "the belief of a vendor that its cooperative vendors will take actions in favor of its interests, or at least will not take actions against it" [2]. According to Morgan and Hunt [20], trust happens when a group has confidence in the reliability and morality of its trading partners, has faith in the authenticity of words and promises from its members, and believes its members will fulfill their duties in this trading relationship. Mayer et al. points out that trust are composed of three dimensions: Ability, Good will and Honesty [19].

Inter-organizational coordination and information sharing are necessary and beneficial for a business seeking growth. However, the negotiations between different parties are usually hindered by various obstructions which might in the end cause the failure of inter-organizational coordination and information sharing. Besides, different organizations may have different goals, cultures, operation processes, risk considerations, demands and willingness of cooperation and these may all become factors that can have impact on inter-organizational coordination and information sharing in addition to the technological aspect. Lee and Whang pointed out that information sharing in a supply chain is faced with several challenges lying in its implementation, e.g. lack of willingness of different partners to share sensitive information with each other, information confidentiality issues, how to pool the cost and risk of implementing information equipments required for achieving information sharing, as well as how to improve the negotiation and planning within a supply chain through information sharing so as to achieve the goal of information sharing [15].

When considering the risk of information sharing, Kumar and Dissel divided the risk of inter-organizational information sharing into three aspects: first, economic aspect: inter-organizational information cooperation can help participants to share huge investment amounts, to increase their resource utilization rates, to reduce supply-chain uncertainty, and to increase their economic scales. However, from a practical standpoint, the results depend upon whether this kind of cooperative relationship can last long, and whether each participant can always be aware of the fairness and benefit of their cooperation. Second, technical aspect: Information and communication technologies have been generally acknowledged as inter-organizational enablers. On the contrary, lack of a stable, mature and reliable technology

connection will also hinder and suppress inter-organizational connections. Third, socio-political aspect: Inter-organizational cooperation may be established through some strategies or negotiations [11]. But this cooperative relationship can be breached by some socio-political factors, such as researching for new advantages, conflicts in execution, different cultures and values between different organizations. Concluding the above discussion on the three aspects, this research will lay emphasis on the economic and technical aspects proposed by Kumar and Dissel [11], and will temporarily disregard the socio-political aspect since it is more difficult for an organization to control, comprehend or effectively handle on its own.

Research Designs

This research has chosen the PCB industry, the industry with high uncertainty, to investigate information sharing issues and supply chain uncertainty factors. Since PCBs are critical parts for consumer electronic products, PCB manufacturer factories are in the upstream of the whole product supply chains and are distant from the consumer market. Most PCB manufacturer factories are OEMs, so they receive orders from various final-product manufacturers or contract assembly factories. However, each PCB manufacturer factory has different product structures and customer groups. A preliminary study on the PCB industry showed that the communication boards (mobile phone boards) are their major products. Since the functions of communication products are renovated frequently, the product life cycles of the communication boards used to implement these functions are shortened accordingly. Nowadays, mobile phones are gradually transforming from communication electronic products into consumer electronic products, mobile phone boards have even shorter life cycles, facing customer revision or cease or production in no longer than 6 months. In addition, since the demand for the final products in the mobile phone market are more unstable and more difficult to predict, it is common for customers seeking optimal product launch times to change their ordered quantities or delivery dates. The production plans of the PCB manufacturer factories will be jointly affected by the customers' changes in demand, so the production schedules have to respond instantly. Therefore, innovative products contribute a very high percentage to the PCB industry, which contains numerous uncertainty factors.

To avoid the possibility of being biased by single case design, this research adopts a multiple case design with embedded multiple units of analysis. This research chose three of the top ten PCB manufacturer factories as studying cases. All of them belong to supply chain networks categorized as divergent differentiation supply chain, and their customer-end products are mostly communication electronic products. They have passed ISO 9002, ISO 14000, QS 9000 certification, capitals range from NT 4 to 6 billion or so, and are listed in the stock market. Their characteristics are listed in Table 2.

Table 2. Characteristics of case companies

Focal Companies	PCB Manufacturer Factory
Profit Sources	Foreign major communication companies
Life cycles for Final Products	6-12 months on average
Demand Stability	Difficult to predict
Lifecycles for PCB Products	Less than 6 months
Product features	Innovative products
Supply Chain Type	Divergent differentiation
Variety of Final Products	Large
Main Types of Inventory	Raw materials
Supply Chain Goals	To instantly supply products that can meet market demands (rapid response)

The chosen interviewees are the directors of procurement, sales, production, manufacturer, and information departments. Moreover, the information sharing issues to be investigated include not only general trading information, but also higher-level management information. The data gathered by this research are mainly through face-to-face interviews, supplied with other documents and related archives (from internal reports of the case companies, newspapers/magazines and seminar data). For the triangulation purpose, this research adopts the method of multiple data source analysis. This research has tried to include as many data sources as possible in order to ensure the accuracy of the information obtained. This research designed its data collection items and interview guides based on the issues to be investigated, and sorted the issues out in advance to serve as a reference for data collection in order to ensure the data collected is relevant. In addition, the interviewers took notes during the interviews for further analysis. The analysis results generate seven major useful lessons.

With the aim to investigate issues relating to information sharing, this research needs to gain a perspective that can view a supply chain as a whole so as to discover where the problems are. Therefore, this research takes the whole supply chain as its main unit of analysis. This study uses four main dimensions and nine variables to study more complicated and detailed relationships between the variables and how to reduce the uncertainty generated, as can be seen in Table 3.

Table 3. Analysis dimensions and variables

Analysis Dimension	Analysis Variable
Supply Chain Uncertainty	Demand side
	Supply side
	Manufacturer side
Information Sharing	Inter-organizational coordination
	Information sharing content
Information Sharing Factors	Trust
	Motivation
	Risk
Supply Chain Performance	Effectiveness assess

This study approached managers from the departments of sales, procurement, production control, and IT, and sought information about the interactions with suppliers and customers as well as detailed information about the decision making of senior management. To ensure collecting reliable data, face-to-face interviews were employed as primary method for data collection while company documents were used to provide supplementary information and triangulate the final analyses.

CASE STUDY RESULTS

Organizational Context of the Three Cases

Company A, the large printed circuit board (PCB) manufacturer, was established in 1979 and its current annual turnover is approximately 5.1 billion Taiwan dollars. Its products are used by a wide range of electronic products, but the major focus is on consumer electronics, telecommunication electronics, and electronics in cars. Company B, also the large PCB manufacturer, was established in 1974 with the capital of 4.6 billion Taiwan dollars. The main product categories are electronics in cars and telecommunication electronics. Company C is the third large PCB manufacturer, and its current annual turnover is approximately 5.7 billion Taiwan dollars. Most of its products are main board in mobile phones and the liquid crystal display (LCD). Organizational context of the three cases are presented in Table 4.

Table 4. The cases backgrounds

Backgrounds	Manufacturer Company A	Manufacturer Company B	Manufacturer Company C
Year Established	1979	1974	1978
Annual Turnover (Billion NT)	5.1	4.6	5.7
Product Portfolios	Communication boards (>50%); Consumer electronic boards	Mobil phone boards (50%); Automobile part boards	Mobil phone boards (50%); LCD boards

Comparison of Cases A, B, C

The supply chain of PCB industry is categorized as divergent differentiation supply chains. The three cases are the manufacturers of consumer products, automotive electronics and communications category mostly covers a wide range, including: air conditioning, TV, refrigerator, phone, telephone, car panels, LCD board, network board, the base station board printed circuit board. The electronic products have the characteristics of diversified product ranges, short product life cycles, and unpredictable demands. In addition, PCB manufacturers are mostly recognized as OEM. Yet, the circuit designs of products requested by customers are highly customized and contain various levels of diversification, and such diversification of product designs makes each kind of plastic board has its unique specification and cannot be used by other customers. To deal with the high uncertainty, presently, PCB manufacturer factories are adopting the MTO approach to speed up their order fulfillment processes by utilizing the demand forecast information shared by their customers to map out their productivity and raw material demands in advance. Furthermore, the PCB cases performed information sharing activities in their SCM processes accompanied with VMI mechanisms. The information sharing initiatives and VMI mechanisms of the three cases are presented in Table 5.

Table 5. The information sharing initiatives and VMI mechanisms of the three cases

Comparison	Manufacturer Company A	Manufacturer Company B	Manufacturer Company C
Information Shared	Information of transactions, demand forecast, and stock.	Information of transactions, demand forecast, and demand forecast of raw materials.	Information of transactions, demand forecast, and products outflow.
Information Kept	1. Manufacturer costs 2. Distribution of outsourced production capabilities 3. Stock of major raw materials 4. Secrets about sales	1. Manufacturer costs 2. Distribution of outsourced production capabilities 3. Stock of major raw materials 4. Secrets about sales	1. New products and their costs 2. Manufacturer costs 3. Names of new agents 4. Commercial and sales secrets
Information Sharing Practices	1. Give more trust to the customers who use VMI. 2. Perform more inter-organizational coordination and data exchanges with the customers who use VMI. 3. Most information sharing practices are to satisfy basic level transactions, and less to perform strategic thinking. 4. The intention to share only depends on the needs of customers and suppliers. 5. Sharing sensitive information is restricted.		
VMI Mechanism	1. Rent VMI warehouses 2. Supply stocks for customers based on the forecast given by them.	1 Establish VMI warehouses 2. Develop production plans based on demand forecasts	1. Rent VMI warehouses 2. Supply stocks for customers based on the orders placed by them.

This study found that the uncertainty of the divergent differentiation supply chain of PCB industry is mainly from demand and manufacturer sides. Dealing with the orders placed by customers is critical, especially the ways to increase customer satisfaction on the orders effectively, such as ensuring the just in time (JIT) practices, and ensuring high product quality. The case companies adopted the approach of sharing order and manufacturer information which means letting customers check the status of the production of their orders, product delivery, and yield rate in order to enhance customer service quality and reduce product return rate. Moreover, in the divergent differentiation supply chain of PCB industry, sharing order and manufacturer information with their customers can also improve the efficiency of order fulfillment.

In terms of the degree of information sharing, the case results show that the requirements posed by supply chain partners will determine what to share and to what extent. The parties in the chain try hardly to gain a mutual trust in order to exchange information. Also, the willingness of sharing information between partners depends on the risk of sharing the particular information and whether the information will affect the bargaining and negotiation powers. Furthermore, due to the

concern of organizational secret and interests, the companies tend not to share information that will let their customers know the production techniques, yield rate, materials stock, and production costs.

Apart from sharing information to reduce uncertainty, PCB manufacturers also adopt VMI mechanisms in the sharing practices to maintain minimum level of stocks and ensure the effectiveness of information sharing. Most of the cases, they try their best to obtain the latest stock information from customers and provide update information on order fulfillment process in order to ensure the accurate demand for helping perform demand forecast and carry out production plans. The use of VMI mechanisms allows customers to modify their orders so that the risks of being out of stock on raw materials and holding excessive stocks can be reduced. Thus, this study found that the use of VMI mechanisms in information sharing practices in the divergent differentiation supply chain can improve the coordination and reduce the bullwhip effect.

LESSONS LEARNED

Based the viewpoint of coping with uncertainty issues, this research has utilized case study method to investigate the uncertainty factors that might exist in the demand, supply and manufacturer dimensions and how manufacturer factories should manage and adapt to these uncertainty factors through information sharing, as well as the key factors that might have impact on information sharing between partners. Through the above investigations, this research deduced seven l.

Lesson 1

The uncertainty in the divergent differentiation supply chain is largely originated from the demand and manufacturer sides due to the features of simple raw materials, highly-customized products, and shorter product life cycles.

Due to a wide range of product categories, PCB manufacturer factories frequently receive the contract orders for producing the products that are highly diversified, have short life cycles, have demands which are difficult to predict, and they need to incorporate product design changes frequently. Based on the viewpoint of product manufacturer, PCBs do not require many kinds of raw materials, and the product differentiation occurs in the early stages of the manufacturer process. Based on these characteristics, this research deems that most PCB manufacturer factories belong to divergent differentiation supply chain networks [17]. The case analysis results also show that most of the factors that can result in the manufacturer uncertainty of a divergent differentiation supply chain are caused by the instability of the demand and manufacturer side. For example, the changes in demand (such as unexpected orders) can result in schedule disorder accordingly.

Lesson 2

In a divergent differentiation supply chain, sharing information with the demand side helps improve the performances of the order fulfillment process (OFP).

Products from the PCB manufacturer factories are mostly innovative products. Their supply chain strategies mainly focus on timeliness so as to rapidly respond to the market demands [6]. Time to market is the most critical factor for attaining this goal. Therefore, PCB manufacturer factories, most of which belong to divergent differentiation supply chains, focus more on how to cope with the dynamic demands from the downstream customers, and how to enhance their on-time delivery fulfillment rates. To supply products which can meet customer requirements while keeping their inventory at the lowest level, PCB manufacturer factories tend to adopt the MTO approach, or in other words, to manufacture according to the contents and specifications of the orders placed by their customers. Through the sharing of product demand forecast, PCB manufacturer factories can map out the demands for raw materials, production plans, and even their productivity in advance, because the enhancement of information transparency can facilitate the execution of production and management decisions, shorten the order processing time of the MTO approach, and therefore improve the OFP performances.

Lesson 3

The supply chain uncertainty can be reduced through inter-organizational coordination.

Inter-organizational coordination between organizations can reduce the costs of information search and coordination, reduce organizational uncertainty, shorten delivery time, and control strategic market information. Due to the frequent customization of PCB products, PCB manufacturers are adopting MTO production strategies and maintaining minimum inventory cost while achieving the diverse needs from customers. Furthermore, the differentiation on PCB products occurs in the early stage of production process. Thus, the demand uncertainty derived from requirement changes can be reduced through signing agreements with customers to secure that customers can cover the costs of raw materials for unfinished products in a certain period of time. The case results show if the actual order amount is much larger than demand forecast, the manufacturer will coordinate with the customer to delay the delivery date in order to give more time for the supplier to prepare extra raw materials for supply. Such coordination can reduce the effect caused from demand change greatly. In addition, to reduce the uncertainty of lead time when purchasing special raw materials is needed, the manufacturer coordinates with the customer, if possible, to replace substitutive materials or to provide demand forecast of the product earlier.

Lesson 4

In a divergent differentiation supply chain, sharing information through the VMI mechanism helps improve supply chain coordination and reduce the bullwhip effect.

Even if information sharing is conducted, most of the forecast information may become inaccurate when the changes in demands grow too large. Thus, simply conducting information sharing is of no great help to the reduction of the bullwhip effect [8]. This research found that the studied PCB manufacturer factories have established Vendor Managed Inventory (VMI) mechanisms with their customers. Therefore, through efficient sharing of inventory information, PCB manufacturer factories are able to adjust their supply

according to the actual demand from the customers so as to reduce the chance of oversupply or under-supply. Meanwhile, customers can use the inventory information as a reference to clear their orders or to modify their demand forecast information. Therefore, this research deems that information sharing can facilitate the establishment of a inter-organizational coordination mechanism, and also reduce the significant impact that the bullwhip effect might bring to upstream suppliers.

Lesson 5

The stronger the trust between partners is, the higher the level of their information sharing will be.

Between the three PCB manufacturer factories and the customers who have created higher degree of trust with them, the information shared include not only their transactions information, but also the demand forecast and inventory information. When the suppliers have acquired higher degree of trust with these three PCB manufacturer factories, these factories are more willing to share information that can assist these suppliers in making production decisions, such as the latest market information. We also found that the three PCB manufacturer factories have more trust toward their VMI customers. Nevertheless, the trust from these PCB manufacturer factories toward their supply chain partners only emerges after a long period of cooperation. During the long-term cooperation, the PCB manufacturer factories were constantly observing and evaluating whether their customers can provide stable orders and exhibit positive trading behaviors, and whether their suppliers can display trustworthy delivery performances, so as to establish strong trust with them. This research confirmed that the higher the degree of information sharing is, the more enhanced the trust between them will become, bringing them into a benign cycle.

Lesson 6

The willingness of information sharing will be affected when organizations are driven by risk considerations and use information as a bargaining chip.

This research found that the motivations that drive the three PCB manufacturer factories to share information with their partners are mainly operational rather than strategic. In other words, they are only willing to provide information that is required by their partners, and tend not to share the more sensitive information (such as process yields, procurement distribution percentages, etc.) with their partners. The reason that causes these situations in the PCB industry is that downstream customers tend to rely on several suppliers to be their supply sources, so the chances for them to develop strategic partner relationships are slim. Therefore, in the PCB industry where cost is the most important competitive advantage, companies are unwilling to share with their customers the process yield information which is indirectly related to their costs, or other information related to their business confidentiality, such as the WIP (Work in Process) or the contractor productivity distribution information. This is because these PCB companies worry that once they share their internal procurement and bargaining information with their customers, their dominant position in the bargaining process may be deprived.

Lesson 7

Once inter-organizational coordination mechanisms are established, sharing information through the use of VMI can effectively disperse risks.

The PCB customers tend to maintain appropriate amount of stock when supplying products to the market. In order to prevent the loss caused from short supply or over supply, the VMI mechanism is built between the manufacturer and customer. Both parties also agree to share necessary information in the coordination process and disperse risks through such information sharing practices. Based on the case results, when the channel of sharing stock information is established and the coordination mechanism is functioning, PCB manufacturers can reduce the cases of short supply or over supply. Both parties can therefore reduce the risks in the transactions.

CONCLUSION

This study investigated how information sharing can reduce the uncertainty in the divergent differentiation supply chain and increase supply chain performance. The critical factors that affect information sharing are also extracted. This study found that in a divergent differentiation supply chain, the stronger the trust between partners is, the higher the level of their information sharing will be. Based on inter-organizational coordination mechanisms, sharing information through the use of VMI can effectively disperse risks, help improve supply chain coordination, reduce the bullwhip effect, and improve the performances of OFP. The supply chain uncertainty can be reduced through inter-organizational coordination. The research results are summarized as Figure 1, and more elaboration of the figure are provided afterward.

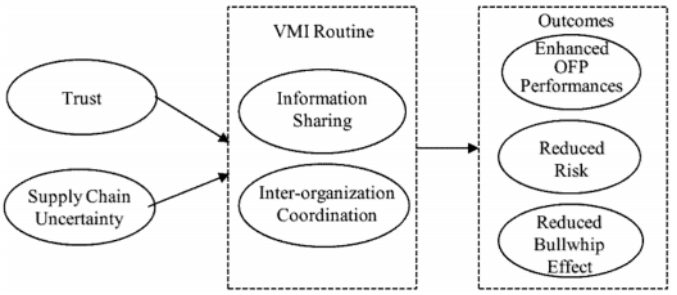

Figure 1. Research results of this study.

This research found that trust and uncertainty are two key factors that might stimulate information sharing. Currently, most relationships between PCB manufacturers and their upstream and downstream partners are still in a type of general transaction relationships. Due to risk considerations, organizations tend not to share sensitive information that they can use as bargaining chips. Through the sharing of product demand forecast, however, PCB manufacturers can map out the demands of raw materials, production plans, and even their productivity in advance, because the increased information transparency can facilitate the execution of production and management decisions, shorten the order fulfilment time in the MTO approach, and therefore improve the efficiency of OFP.

Bullwhip Effect refers to the scenario where the orders to the supplier tend to have larger fluctuations than sales to the buyer, and the distortion propagates upstream in an amplified form [5]. If the customers are providing their demand information only in the form of orders, these PCB manufacturers are more likely to be affected by the bullwhip effect. However, through VMI approaches, the PCB manufacturer factories and their customers are able to establish more effective information sharing and inter-organizational coordination mechanisms that will assist in dealing with negotiation activities (e.g. on prices and specifications), product design revision, and order change in a timely basis. The bullwhip effect can therefore be reduced.

Limitations and Future research

This research has committed to bridge the gap between theory and practice. However, no different to others, this research still has its limitations. There are three limitations; first, the PCB industry is a rapidly-changing environment. Therefore, different data collection time points may yield different results which may influence the analysis of a PCB supply chain's current status. Second, during the process of data collection, the knowledge backgrounds of the interviewees may have impact on their understanding of the interview questions. Third, this research only selected three manufacturer factories as the PCB industry's individual cases. However, the main objective of this research is not to generalize, but to investigate and comprehend the PCB industry's current status of information sharing. Therefore, the conclusions of this research may provide a foundation for further verification by subsequent researchers. Below are three future research directions: first, the objects investigated by this research are limited to PCB vendors. However, the demand for IC package substrates is also booming in recent years. Therefore, the IC package substrate industry may also be worthy of subsequent researches. Second, for the present, upward or downward integration is rarely seen in the PCB industry. However, if any trends of vertical integration or strategic alliance emerge in the future, the demand, supply and manufacturer uncertainty factors of PCB supply chains will have to be reexamined then. Third, this research is based on a small number of cases only. Thus, the generalization of its lessons may be limited. Future researchers can statistically test these lessons through a larger sample base.

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