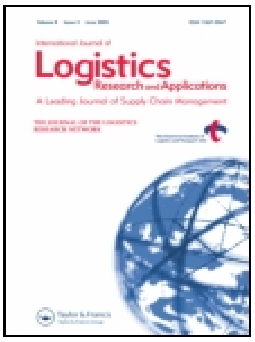


Taylor & Francis
Taylor & Francis Group

International Journal of Logistics Research and Applications
A Leading Journal of Supply Chain Management

ISSN: 1367-5567 (Print) 1469-848X (Online) Journal homepage: http://www.tandfonline.com/loi/cjol20


# Sharing information in a high uncertainty environment: lessons from the divergent differentiation supply chain


**Wei-Hsi Hung, Chieh-Pin Lin & Chin-Fu Ho**



**To cite this article:** Wei-Hsi Hung, Chieh-Pin Lin & Chin-Fu Ho (2014) Sharing information in a high uncertainty environment: lessons from the divergent differentiation supply chain, International Journal of Logistics Research and Applications, 17:1, 46-63, DOI: 10.1080/13675567.2013.837156

**To link to this article:** http://dx.doi.org/10.1080/13675567.2013.837156

Published online: 10 Oct 2013.

*International Journal of Logistics: Research and Applications*, 2014
Vol. 17, No. 1, 46–63, http://dx.doi.org/10.1080/13675567.2013.837156

Taylor & Francis
Taylor & Francis Group

# Sharing information in a high uncertainty environment: lessons from the divergent differentiation supply chain

Wei-Hsi Hung[a], Chieh-Pin Lin[a] and Chin-Fu Ho[b*]

[a]*Department of Information Management, National Chung Cheng University, Taiwan, Republic of China;* [b]*Program of Chain Stores Management, Takming University of Science and Technology, Taiwan, Republic of China*

(*Received 7 February 2012; accepted 17 August 2013*)

Information sharing is one of the most important topics in supply chain management, but it is not an easy task due to the numerous challenges. This study aims to investigate how uncertainty can be reduced through the proper sharing of information, and it also endeavours to discover what factors play a key role in its success. The printed circuit board industry in Taiwan, which was chosen for this study, is a type of divergent differentiation supply chain and operates in a highly uncertain environment. The results show that trust between partners in the chain can increase information sharing while uncertainty is considered the main factor impeding it. Information sharing on such as 'demand forecast information' could improve the performance of order fulfilment process. Information sharing with vendor-managed inventory mechanisms could reduce supply chain uncertainty and bullwhip effects with the result that inter-organisational coordination could be strengthened.

**Keywords:** uncertainty; information sharing; vendor-managed inventory; inter-organisational coordination; supply chain management



## 1. Introduction

The supply chain is a complex network, and it is even more difficult to analyse (Huang, Lau, and Mak 2003). Among supply chain issues, uncertainty and information sharing are common research topics (Fynes, Burca, and Marshall 2004; Li and Lin 2006), uncertainty being one of the critical issues that is frequently discussed (Davis 1993; Ireland and Webb 2007; Lee and Billington 1993). There are numerous factors in a complex supply chain network that can cause uncertainty, and any one factor has the potential to either positively or negatively affect the whole network (Davis 1993). The so-called bullwhip effect is considered one of the major factors causing uncertainty between supply chain nodes (Anne, Chedjou, and Kyamakya 2009). Although it is virtually impossible to eradicate all the uncertainty factors, the negative impact can be reduced by putting proper managerial strategies in place (Strader, Lin, and Shaw 1999). Information sharing is one factor that can reduce uncertainty and increase the efficiency of a supply chain (Hung et al. 2011; Tan, Kannan, and Handfield 1998; Wagner et al. 2005). Effective information sharing decreases errors made during decision-making processes, enabling better control of the uncertainty factors, thus reducing risks (Strader, Lin, and Shaw 1999). In addition, exchanging information between

*Corresponding author. Email: cfho@mis.nsysu.edu.tw

supply chain partners can lead to operational efficiencies and new knowledge creation, even when learning from partners may not be an explicit goal (Malhotra, Gosain, and El Sawy 2005).

Although sharing information is advantageous, Lee and Whang (2000) revealed that several challenges inherent in the implementation need to be overcome, for example, a lack of willingness to share sensitive information among different partners; confidentiality issues; how to share the cost and risk of implementing the information equipment required; and how to improve the negotiation and planning activities within a supply chain. Apart from that, the challenges faced in the execution of information sharing (such as the profit distribution issues regarding information sharing) tend to be rather intimidating and somewhat threatening.

This study has chosen a divergent differentiation supply chain for its research. Such chains often come with a high degree of uncertainty and therefore are very much in need of information sharing (Lin and Shaw 1998). This study will present three case studies in the printed circuit board (PCB) industry, a type of divergent differentiation supply chain, in Taiwan. Due to the extremely short life cycle of its high-tech products, the actual ordering of them is hard to manage. PCB companies frequently face a shortfall in forecasted demand or the risk of an excessive inventory. Hence, demand uncertainty exposes these firms to a state of high risk. A remedy should be proposed for dispersing these risks to other supply chain partners. This study particularly aims at understanding the following questions: firstly, how do organisations deal with the uncertainty in a supply chain through information sharing; secondly, can the uncertainty be reduced through specific mechanisms of information sharing; and thirdly, what key factors influence them to share information.

## 2. Literature review

### 2.1. *Divergent differentiation supply chains*

Lin and Shaw (1998) divided supply chain structures into three types – convergent assembly, divergent assembly, and divergent differentiation – according to the attributes of manufacturing processes, business objectives, product segmentations, product categories, assembly processes, product life cycles, inventory categories, and so on. In regard to the divergent differentiation supply chain, the final products are usually completed before the customers place their order. Accordingly the downstream firms of PCB manufacturers need to have their own final assembly factories and distribution systems. In addition, due to the great variation in product specification, the life cycle of products can be as short as a few months, or even just a few weeks. Therefore, the ability to respond quickly has become a key factor for this type of supply chain organisation or manufacturing factory. Typical industries belonging to this category include the clothing and toy industries (Lin and Shaw 1998). Most of the past studies on information sharing in the divergent differentiation supply chain were based on the simulation method (e.g. Disney and Towill 2003; Ryu, Tsukishima, and Onari 2009; Sohn and Lim 2008; Sterman 2006; Strader, Lin, and Shaw1999), so a study in the real world of supply chains is undoubtedly challenging and demanding.

With convergent assembly supply chains, the products comprise numerous components, and so the final products are produced as a result of many assembly line steps. Typical industries belonging to this category include the automobile and aerospace industries (Lin and Shaw 1998). However, with the divergent assembly supply chain, organisations usually have their own final assembly factories and distribution systems. To fulfil orders of mass customisation, organisations usually turn to the 'Delay Differentiation' strategy (Lin and Shaw 1998) to divide their product assembly processes into two stages (corresponding to two models): complex assembly processes for semi-products (generic model) are carried out in factories and simple assembly processes for fulfilling customised orders (customised model) are completed later at distribution centres. Typical industries belonging to this category include the personal computer (PC), mobile phone, and other related electronic equipment industries (Chan 2003; Lin and Shaw 1998).

### 2.2. *Factors causing uncertainty*

One of the most important issues in supply chain management (SCM) is in the comprehending and managing of the uncertain factors in order to lessen their impact. From the viewpoint of the interactions between upstream and downstream vendors in a supply chain, Davis (1993) 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 the level) of customer service. In terms of the uncertainty related to demand, the average demand and the demand variations should be evaluated. Concerning uncertainty related to supply, a punctual delivery date, the average time delay, and time delay variations of suppliers, as well as the quality of their delivered goods should be evaluated. In regard to uncertainty in manufacturing, factors including downtime frequency, repair time, repair time variations, and the reliability of the manufacturing process need to be evaluated. The more uncertainty-related information can be obtained, the better their influences can be understood.

When investigating supply chain uncertainty, Lee and Billington (1992, 1993) also divided it into the same three dimensions: supply, manufacturing, 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) manufacturing process time; (4) delivery time; and (5) demand. Based on prior literature, this research also categorises the uncertainty factors into the three dimensions, that is, demand, supply, and manufacturing.

### 2.3. *Factors affecting information sharing*

Inter-organisational coordination (IOC) 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 may eventuate in the whole process breaking down. Besides, different organisations may have different goals, cultures, operational processes, risk considerations, demands and levels of cooperation and these may all become factors that can have an impact on IOC and information sharing besides the technological aspects. Lee and Whang (2000) pointed out that information sharing in a supply chain is faced with several challenges based on its implementation, for example, a lack of willingness among different partners to share sensitive information with each other, information confidentiality issues, how to pool the cost and risk of implementing the information equipment required for achieving it, as well as how to improve the negotiation and planning within a supply chain.

When considering the risks, Kumar and Dissel (1996) divided inter-organisational information sharing into three aspects: first, the economic aspect: information cooperation can help participants to share huge investment amounts to increase their resource utilisation rates, to reduce supply chain uncertainty, and to increase their interdependencies for profitability. However, from a practical standpoint, the results depend on how long this kind of cooperative relationship can last, and whether each participant is aware of the benefits of such cooperation. Second, the technical aspect: information and communication technologies have generally been acknowledged as inter-organisational enablers. Conversely, the lack of a stable and reliable technological connection can also be a hindrance and suppressant of inter-organisational relationships. Third, the socio-political aspect: inter-organisational cooperation may be established through some strategies or negotiations, but it can also be breached by socio-political factors, such as researching for new advantages, conflicts in execution, diverse cultures, and differing values among organisations.

In conclusion, this research will emphasise the economic and technical aspects proposed by Kumar and Dissel (1996) and will disregard the socio-political aspect since it is too complicated and difficult for an organisation to control, comprehend, or effectively handle this aspect on its own.

### 2.4. *Vender-managed inventory*

Vendor-managed inventory (VMI) is a collaborative arrangement typically between a vendor and its customers. In a VMI, the vendor takes over the task of replenishment for its partners (Liu and Kumar 2009). The purpose of the VMI is to replenish the customer's inventory before the downstream firm faces a shortage. Since the original concept of VMI was proposed by Magee in 1958, more and more successful retailers have integrated it into their business model, such as Wal-Mart (Andel 1996; Disney and Towill 2003; Stalk, Evans, and Shulman 1992). Nowadays, VMI is a popular practice in SCM and is prevailing in the information technology (IT) industry.

VMI can be categorised into three types according to the location of the physical warehouse: the hub, the consignment stock hub, and the customer stock hub (Valentini and Zavanella 2003). In the hub mode, the supplier sets up a dedicated warehouse close by the manufacturer for the obvious reason of convenience: to meet demands quickly. In the consignment stock hub mode, the customer holds the consignment stock while the ownership still legally belongs to that of the supplier. Ownership transfer only occurs after the stock is used. Unused stock can be returned to the manufacturer, and the customer will be charged only for the actual consumption of items. In the customer stock hub mode, the customer owns the stock in the hub and the supplier will work on storage replenishment only. Liu and Kumar (2009) suggested several major steps in VMI. Firstly, that customers share their actual demand or usage with the vendor; secondly, the vendor generates the demand forecast and places replenishment orders for customers; thirdly, customers review replenishment orders and confirm them; fourthly, the vendor sends shipping notices after receiving the customer's confirmation of replenishment orders; fifthly, customers acknowledge the actual receipt or return of goods; and finally, problems are dealt with when the performance is not as expected.

Since the vendor has to be responsible for the management and replenishment of the downstream in a VMI model, a partner's inventory becomes of the utmost importance (Houshyar et al. 2011). This means that the vendor has to manage its customers' inventory throughout the whole supply chain as it has been defined in the VMI management process. With information sharing activities, suppliers can manage the customers' inventory efficiently (Yao, Philip, and Martin 2007). Within a decentralised supply chain, an increase in information sharing among members will improve the performance of the entire chain especially in terms of cost saving, resulting in much benefit to all the members in the entire chain (Bernstein and Chen 2006; Yao, Philip, and Martin 2007; Yu, Yu, Yan, and Cheng 2001).

## 3. Research designs

To avoid the possibility of being biased by a single case scenario, this research adopted a multiple case design with embedded units of analysis. Three of the top 10 PCB manufacturing factories were chosen. All of them belong to supply chain networks categorised as divergent differentiation supply chains, and their customer-end products are mostly communication electronic products. They have obtained ISO 9002, ISO 14000, and QS 9000 certification; their current annual turnovers range from four to six billion (Taiwanese dollars), and they are listed on the stock market. Their characteristics are listed in Table 1.

The chosen interviewees were directors of procurement, sales, production, manufacturing, and information departments. Moreover, the information sharing issues investigated included not only general trading information, but also higher level management information. The data gathered by this research were mainly through face-to-face interviews, supplied documents, and related archives (from internal reports, newspapers/magazines, and seminar data). For triangulation purposes, multiple data source analysis was adopted and has tried to include as many sources as possible in order to ensure accuracy. Data collection items and interview guides were designed based on the issues to be investigated and were sorted out in advance to serve as a reference in order to ensure relevancy. In addition, the interviewers took notes for further analysis. The results have generated seven useful lessons.

With the aim to investigate issues relating to information sharing, a perspective was needed that could view a supply chain as a whole so as to discover where the problems existed. The whole supply chain was therefore chosen as the main unit of analysis. Four main dimensions and nine variables were used to study complicated and detailed relationships between the variables and to deduce how to reduce supply chain uncertainty, as can be seen in Table 2.

The study approached managers from the departments of sales, procurement, production control, and IT, and sought information about their interactions with suppliers and customers as well as detailed information about the decision-making of senior management. To ensure the collection of reliable data, face-to-face interviews were used, while company documents provided supplementary information enabling triangulation of the final analyses.



Table 1. Characteristics of case companies.

| Focal companies | PCB manufacturing factory |
|---|---|
| Profit sources | Foreign major communication companies |
| Life cycles for final products | 6–12 months on average |
| Demand stability | Difficult to predict |
| Life cycles 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) |

Table 2. Analysis dimensions and variables.

| Analysis dimension | Analysis variable |
|---|---|
| Supply chain uncertainty | Demand side |
| | Supply side |
| | Manufacturing side |
| Information sharing | IOC |
| | Information sharing content |
| Information sharing factors | Trust |
| | Motivation |
| | Risk |
| Supply chain performance | Effectiveness assessment |

## 4. Case study results

### 4.1. *Industrial backgrounds*

Since PCBs are critical components for consumer electronic products, their manufacturing factories are in the upstream of the whole product supply chain and are distant from the consumer market. Most factories are original equipment manufacturers (OEM), so they receive orders from various final product manufacturers or contract assembly factories. However, each factory has different product structures and customer groups. A preliminary study of the PCB industry showed that communication boards (mobile phone boards) are their major product. Since the functions of communication products are redesigned frequently, the life cycle of the boards (used to implement these functions) is shortened accordingly. Nowadays, mobile phones are changing from being communication products into being consumer products, so the boards have an even shorter life cycle, facing constant customer revision or of ceasing production altogether perhaps within six months. In addition, since the demand for the final products in this particular market are unstable and thus very 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 manufacturing factories are affected by the customers' changes in demand, so the production schedules have to respond immediately. Therefore, innovative products constitute a very high percentage of the PCB industry.

### 4.2. *Organisational and information sharing contexts*

Manufacturing factory A, a large PCB manufacturer, was established in 1979 and its current annual turnover is approximately 5.1 billion (Taiwanese dollars). Its products are used in a wide range of electronics, but its major focus is on consumer, telecommunication, and automotive electronic products. Manufacturing factory B, also a large PCB manufacturer, was established in 1974, its current annual turnover being approximately 4.6 billion (Taiwanese dollars). Its main product categories are automotive and telecommunication electronics. Manufacturing factory C is also a well-known PCB manufacturer in Taiwan, and its current annual turnover is approximately 5.7 billion (Taiwanese dollars). Most of its products are the circuit boards in mobile phones and the liquid crystal displays (LCD). The organisational context of the three cases is presented in Table 3.

The first PCB manufacturing factory of Case A receives orders from downstream assemblers but not directly from sale orders in the marketing channel. The products are very broad in their scope and they have various types and numbers of customers, so management demands for the factories are difficult. Their products include three major categories: consumer electronics (e.g. television, air conditioning, etc.), communication electronics (e.g. mobile phone, telephone, etc.), and automotive electronics (e.g. automotive control panels). Although the order quantity is massive, the customers' specifications and circuit designs are very different. This means that they cannot use a common panel mould to produce all the products. While demand uncertainty is a critical issue, they must still consider how to ensure customers are supplied quickly, how to avoid

Table 3. The cases' backgrounds.

| Backgrounds | Manufacturing factory A | Manufacturing factory B | Manufacturing factory C |
|---|---|---|---|
| Year established | 1979 | 1974 | 1978 |
| Annual turnover (billion NT) | 5.1 | 4.6 | 5.7 |
| Product portfolios | Communication boards (>50%); consumer electronic boards | Mobile phone boards (50%); automobile part boards | Mobile phone boards (50%); LCD boards |

overproduction caused by excessive inventories, and how to deal with raw material suppliers for timely production. Hence, they are beginning to see the advantages of supply chain information sharing between upstream and downstream.

In terms of their upstream suppliers, Case A classified them based on the importance of raw materials and tended to cooperate more with those suppliers with whom they had a long-term friendship. For these trusted agents, a higher quantity of procurement was assigned. At the same time, the suppliers gave a higher priority to them in order to stabilise sources of supply and lower procurement and transaction costs. To reduce the problem of overstocking derived from demand uncertainty, the case company utilises IOC and uses the approach of make-to-order (MTO). Furthermore, it promotes the implementation of VMI (with customers) in order to maintain optimal safety stock volumes. The demand forecast and customer inventory information are, respectively, used to replenish PCBs in the customer and consignment stock hubs. Through the information shared, customers clearly understand the status of orders and can be flexible with order changes. They can also carry out information sharing derived from general orders, delivery, and accounting activities. More IOC and information exchange activities are carried out with VMI customers who enjoy a higher degree of trust.

The information sharing in Case A has ensured that delivery delay from the suppliers is rare. They are able to deliver products on time, make required changes as requested by customers, enhance product and service quality, and reduce the customer refund rate. Since customers can maintain a lower safety stock volume of raw materials, their inventory costs are reduced. However, some limitations still exist in the process of information sharing. Due to differing levels of trust, the degree of information sharing also varies. Especially when sharing organisational secrets, the supply chain partners tend to withhold certain kinds of information, which include the stock level of raw materials, sales numbers, production costs, production technologies, and profit rates.

With the second PCB manufacturing factory, Case B, since the product specifications and circuit designs provided by the customers are very different, the products in the later part of the supply chain are highly diversified and customised. This means that they are not interchangeable between customers. Moreover, the electronic product itself has a short life cycle; thus, the fluctuations in demand are intensified. Therefore, in regard to correct quantity and delivery date, it is important to accurately forecast demand and to satisfy customer orders.

In response to this high uncertainty, Case B is aware of the importance of information sharing between supply chain partners and is selective about the degree of information and the content shared based on suppliers and customers' demands and the level of cooperation of their partners. They provide order information if the customer needs it, so he can obtain the production status and track other information on the order. Responding to rapid changes in market demand, they allow customers to modify the content of orders in a flexible fashion. Moreover, they have also advocated VMI to large customers to help them avoid the shortage of input for the production line or an excessive inventory. They also replenish the consignment stock hub based on demand forecasts in order to maintain the optimum level of inventory.

Because of practising IOC, they attach much importance to the procurement system. Suppliers are assessed and graded in terms of their abilities, and the results are used for adjusting the quantity of procurement. Thus, the chance of facing a shortage of raw materials is reduced and the capability of the suppliers is enhanced. Through procurement contracts, the raw materials can be obtained on time. The adoption of the MTO strategy allows Case B to develop production plans based on the content of customers' orders. Also, it allows them to keep the diversity and unique design of their products and to reduce the inventory to a minimum.

Because of its information sharing practices, Case B's low inventory policy on raw materials is actualised, and its turnover rate is increased. With a stabilised supply of raw materials from upstream suppliers, the production schedules and plans are in order. Thus, they can share shipment information with the customers as well as increase the accuracy of product delivery in terms of quantity and time. Although more IOC and information exchange activities are used with VMI customers (those with a higher level of trust), the information about its production technologies and yield rate are shared less in order to preclude customers from knowing their cost savings and profit margins.

Case C receives customers' design requests and manufactures the products accordingly. However, since the specifications and circuit designs of products requested are various, the PCBs cannot be used interchangeably. So, the uncertainty of demand is an important issue for them. They must produce on time despite changes in customers' orders yet avoid overproduction and high levels of stock. Hence, they began to focus on sharing information with customers, based on suppliers and customers' needs.

In practice, Case C chooses the best fit suppliers and does not screen them based on their track records. In comparison with the other cases, the use of procurement contract is absent here. Their raw material procurement is based on type, deadline, and price criteria, and the best supplier is selected each time from a list in order to ensure lower material inventories and costs. Also, quality materials are acquired for each production and product quality is ensured while low inventory and costs savings are achieved. The order management and scheduling is focused on the delivery time. According to the strategy of production management, they adopt MTO which enables them to satisfy diversified demands from various customers, at the same time reducing overstock and avoiding the uncertainty resulting from order changes.

Due to these mechanisms being put in place, the rate of on-time delivery and order fulfilment have improved significantly. Through sharing the delivery information with customers, the accuracy of product delivery is enhanced in terms of item content and quantity and the product return rate is reduced. Case C also implemented VMI mechanisms with their customers to enable them to give orders and check the production status of them (via the SCM system). The order feedback mechanism and replenishment based on official orders made their production process smoother. A quick response to orders enhances customer satisfaction and consequently gains more orders. There is more IOC and information exchange with VMI customers who have a higher level of trust. However, they decided to withhold certain kinds of information such as manufacturing costs and gross profit due to sensitivity.

### 4.3. *Cross-case comparison*

The supply chain type of these three cases is divergent differentiation, and they are the manufacturers of consumer products, automotive electronics, and communications covering a wide range, including air conditioning, TVs, refrigerators, phones, telephones, car panels, LCD boards, network boards, and base station PCBs. Their production is a step-by-step process, which means it is hard to change it and there is a standard operation procedure so any changes happening in front-end-of-line will largely affect back-end-of-line. The electronic products have the characteristics of diversified product ranges, short product life cycles, and unpredictable demands. In addition, PCB manufacturers are mostly recognised as OEM. Furthermore, the whole PCB production can consist of up to 50 stages and any change in the aspect of product design can lead to a redesigning of the whole product.

The major problem the three cases face is that the circuit designs of products requested by the customers are highly customised and contain various levels of diversification giving each kind of plastic board a unique specification which is therefore not interchangeable. This means manufacturers have to produce products based on the requirements in customers' orders. The surplus products cannot be sold to other customers and thus can easily become dead inventory. To deal with this high uncertainty, presently, the three manufacturing factories are adopting the MTO approach to speed up their order fulfilment processes (OFPs) utilising the demand forecast

Table 4. The information sharing initiatives and VMI mechanisms of the three cases.

| Comparison | Manufacturing factory A | Manufacturing factory B | Manufacturing factory C |
|---|---|---|---|
| Information Shared | Information on transactions, demand forecast, and stock | Information on transactions, demand forecast, and demand forecast of raw materials | Information on transactions, demand forecast, and product outflow |
| Information sharing methods | (1) E-mail<br>(2) One-way review | On-line customers can check through the system | (1) E-mail<br>(2) Telephone |
| Information retained from partners | (1) Manufacturing costs<br>(2) Distribution of outsourced production capabilities<br>(3) Stock of major raw materials<br>(4) Secrets about sales | (1) Manufacturing costs<br>(2) Distribution of outsourced production capabilities<br>(3) Stock of major raw materials<br>(4) Secrets about sales | (1) New products and their costs<br>(2) Manufacturing costs<br>(3) Names of new agents<br>(4) Commercial and sales secrets |
| Information sharing practices | (1) Most information sharing practices are to satisfy basic level transactions, and less to perform strategic thinking<br>(2) The intention to share depends only on the needs of customers and suppliers<br>(3) Sharing sensitive information is restricted | | |

information shared by their customers. By so doing they can map out their productivity and raw material demands in advance. The information sharing practices of the three cases are presented in Table 4.

To deal with supply chain uncertainty, all three cases practised information sharing. In terms of the degree, 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 hard to gain mutual trust in order to exchange information. Also, the willingness to share information depends on the risks involved and whether the bargaining and negotiation powers will be affected by it. Furthermore, due to the concern of organisational secrets and interests, the companies tend not to share information that will let their customers know the production techniques, yield rate, stock materials, and production costs.

This study also found that the uncertainty of the divergent differentiation supply chains comes mainly from the demand and manufacturing sides. Dealing with the orders placed by customers is critical; ways must be found to increase customer satisfaction, such as implementing just-in-time practices and ensuring high product quality. The case companies adopted the approach of sharing order and manufacturing information which means letting customers check the status of the production of their orders, product delivery date, and yield rate in order to enhance customer service quality and reduce product return rates. Sharing order and manufacturing information with their customers can also improve the efficiency of order fulfilment.

Apart from sharing information to reduce uncertainty, PCB manufacturers have also adopted VMI mechanisms to maintain minimum levels of stock. Since the manufacturing of PCBs can take several weeks, customers tend to keep a certain amount of stock on hand. Yet, it can cost customers dearly if the amount is excessive. On the one hand, large customers tend to avoid the situation of being out of stock; on the other hand, they tend not to pay for too much stock. For these reasons, most of the customers prefer to establish VMI mechanisms. This study found that the

Table 5. Comparison of the VMI warehouses of manufacturing factories.

| Comparison | Manufacturing factory A | Manufacturing factory B | Manufacturing factory C |
|---|---|---|---|
| Contracts with VMI customers | Yes | Yes | Yes |
| Order patterns | Order by contracts | Order placed through the ordering systems | Formal order |
| Relationship with VMI customers | High trust, high IOC, and more information sharing | High trust and does not cover accidents | High trust, high IOC, and more information sharing |
| VMI warehouse types | Adopting Customer Stock Hub as the major approach and consignment stock hub as the supplementary (rent VMI warehouses) | Consignment stock hub (establish VMI warehouses) | Customer stock hub (rent VMI warehouses) |
| Approaches of customers' receiving products | (1) Customer stock hub: receive directly from the warehouse (2) Consignment stock hub: needs to place orders for the receiving | Needs to place orders to take in inventory | Receive stock directly from the warehouse |
| Stocks ownership | Stock in VMI warehouses belong to customers | Stock in consignment stock hub belong to customers | After a negotiated time frame, stock in customer stock hub belongs to customers |
| Replenishment approaches | (1) Customer stock hub: supply stock based on demand forecasts and customer stock information (2) Consignment stock hub: supply customers based on demand forecasts | Supply stock based on demand forecasts | Supply stock based on the formal orders placed by them |

use of VMI mechanisms improves coordination and reduces the bullwhip effect. Most of them try their best to obtain the latest stock information from customers and provide updated information on OFPs. The use of VMI mechanisms allows customers to modify their orders so that the risks of being out of stock of raw materials and holding excessive stocks can be reduced, as can be seen in Table 5.

The key benefit of VMI for PCB manufacturers is the information transparency regarding the customers' inventory as they bear the major responsibility for its (customers' inventory) management. In this paper, both A and B share a similar VMI pattern, while C is different. When setting production schedules, A and B take their customer forecast into account, whereas C only treats the customer forecast as a reference in capacity planning and conducts production scheduling based mainly on customer orders.

The difference lies in their risk distribution strategy. A and B incorporate customers' forecasts into formal production schedules, but this practice is subject to a frequently observed risk that customers' orders may not be large enough to cover the amount of product produced based on those forecasts. The reason for noting this risk is that a forecast is often larger than an order. Hence A and B negotiate with customers to guarantee that the size of their orders over one or two months will be large enough to cover the current forecasted demand. In other words, if the ordered quantity falls short of what was forecasted earlier, the customers need to make orders on the extra parts so as to reduce the stocks of A and B.

By comparison, C does not consider customer forecasts in its production schedule. Thus, the level of safety stock is relatively low, but the response time to market changes is relatively high.

In comparison with the forecast-based approach employed by A and B, C needs to produce and deliver the product faster after it has received an order. To ensure on-time delivery for overseas customers, Case C delivers products by air, the extra freight cost being negotiated with customers.

The above comparison shows that the sharing of demand forecasts and stock information between PCB manufacturers and their customers provides much help in implementing VMI mechanisms, and undoubtedly the key motivation for adopting VMI is to enjoy the benefit of the transparency of demand change information among suppliers. Our results found that the stock information shared from the customer stock hub can give the PCB manufacturers more accurate information on the actual usage of raw materials and meaningful information on the demand change. Where products have a short life cycle, such practice is more powerful and can greatly reduce the effects of inaccurate demand forecasts.

Another crucial characteristic of the three cases was the necessary relationship of IOC with customers for reducing uncertainty in the supply chain. A successful SCM needs good cross-functional integration (Lambert, Cooper, and Pagh 1998). An efficient SCM practice can increase customer responsiveness as well as satisfaction. In this study, the manufacturers practise more IOC and data exchanges with the customers and they tend to trust more those who use VMI. Hence, it is possible for hostile relationships which have traditionally existed between manufacturers and suppliers regarding costs to be gradually transformed into a cooperative and mutually reliable relationship (Angeles and Nath 2001; Hoyt and Huq 2000; McCutcheon and Stuart 2000). The IOC practices of the three cases are presented in Table 6.



## 5. Lessons learned

To understand how organisations cope with uncertainty, this research has utilised the case study method to investigate the factors that may exist in the demand, supply, and manufacturing dimensions and to consider how factories can manage and adapt to these uncertainty factors through information sharing. The key factors that might have an impact on this sharing between partners have also been discussed. Through the above investigation, seven lessons have been deduced.

### 5.1. *Lesson 1*

*The uncertainty in the divergent differentiation supply chain largely originates from the demand and manufacturing sides due to the features of simple raw materials, highly customised products, and shorter product life cycles.*

Due to a wide range of product categories, PCB manufacturing factories frequently receive contract orders for producing products that are highly diversified, have short life cycles, have demands which are difficult to predict, and need design changes frequently. However, PCBs do not require many raw materials, and product differentiation occurs in the early stages of the manufacturing process. Based on these characteristics, this research deems that most PCB manufacturing factories belong to divergent differentiation supply chain networks (Lin and Shaw 1998). The case analysis results also show that most of the factors that result in the manufacturing uncertainty of a divergent differentiation supply chain are caused by the instability of the demand. For example, the changes in demand (such as unexpected orders) can result in schedule disorder accordingly.

### 5.2. *Lesson 2*

*In a divergent differentiation supply chain, sharing information with the demand side helps improve the OFP.*

Table 6. IOC of manufacturing factories A–C.

| Coordination mechanism | IOC |
|---|---|
| *Manufacturing factory A* | |
| Partnership management | (1) Distinguishing the customers who are contract based and only order once, and give no priority to urgent orders<br>(2) The ownership of the in-process products belongs to the customers<br>(3) Classifying the suppliers based on how important their materials are to the companies<br>(4) Owning domestic transportation vehicles, and cooperating with foreign logistic companies for delivering overseas products |
| Production management strategy | (1) Adopting the approach of MTO<br>(2) Providing suggestions or assistance to customers regarding practical operations |
| Mechanism of partner cooperation | (1) Cooperating with customers to set up VMI mechanisms<br>(2) Renting consignment stock hub for the larger customers in order to improve the efficiency for real-time product replenishment<br>(3) Customers can check the production status of their orders through emails or telephones |
| Adjustments between partners | (1) Lowering material inventory through information sharing with suppliers<br>(2) The material order may be dispatched to other suppliers when current suppliers cannot satisfy the purchasing quantities or delivery dates<br>(3) Customers have to cover the expenses for extra work if they pose modifications after the initiation of production<br>(4) For the orders of special materials, an inquiry about customers' demand forecast will be made to ensure proper purchase |
| *Manufacturing factory B* | |
| Partnership management | (1) Large customers provide their demand forecasts and make orders through the ordering systems. Urgent orders for certain customers will be dealt with<br>(2) The customer classification and purchasing quantity are based on the qualities and delivery dates of suppliers<br>(3) Listing and managing long-term suppliers, and examining materials through random sampling<br>(4) Cooperating with logistic companies for product delivery |
| Production management strategy | Adopting the approach of MTO |
| Mechanism of partner cooperation | (1) Customers are allowed to check the current production status of their orders<br>(2) Setting up consignment stock hub of VMI in order to satisfy the customers' demands on short delivery products going overseas<br>(3) Collaborating with customers to improve the production processes in factories<br>(4) Carrying out stock replenishment on consignment stock hub of VMI based on the contract, and the backlog on orders to be credited |
| Adjustments between partners | (1) Reducing material inventory through information sharing with suppliers<br>(2) The material order may be dispatched to other suppliers when current suppliers cannot satisfy the purchasing quantities or delivery dates<br>(3) Coordinating with customers on delivery dates when large differences occur between the actual orders and prior forecasts or the quality check fails for the products during production<br>(4) After the production, customers have to share the costs resulting from cancellation or modification (totally or partially) on their orders according to contracts<br>(5) Negotiations with customers are possible for purchasing surplus qualified products resulting from high yield rate |
| *Manufacturing factory C* | |
| Partnership management | (1) Large customers provide their demand forecasts and make urgent orders through the ordering systems. These customers have priority of production for their urgent orders<br>(2) No classification on suppliers, and making purchases according to contracts<br>(3) The products will be delivered by the logistic companies<br>(4) Freight is charged to the customers for air delivery |

(*Continued*)

Table 6. Continued

| Coordination mechanism | IOC |
|---|---|
| Production management strategy | (1) Adopting the approach of MTO |
| | (2) Making production based on confirmed orders, not forecasts |
| Mechanism of partner cooperation | (1) Customers are allowed to check the current production status of their orders |
| | (2) Cooperating with customers to carry out the trading approach of VMI, and customers prepare their own warehouses |
| Adjustments between partners | (1) Purchasing materials based on each order, and the suppliers promising to deliver within due dates in order to reduce material inventory |
| | (2) The orders will be shared to other suppliers when the chosen suppliers cannot meet the demands |
| | (3) Customers must cover the costs of materials and the production process resulting from cancellation of their orders after production |
| | (4) When facing underproduction problems caused from excessive defective products or unexpected orders, partial products will be delivered first, and the other delivery dates will be negotiated or postponed |
| | (5) For orders needing special materials, either a prior confirmation will be made by customers or substitute materials will be recommended |
| | (6) For surplus products, customers will be negotiated with for delivering them together |

Products from PCB manufacturing factories are mostly innovative products. Their supply chain strategies focus on timeliness so as to rapidly respond to market demands (Fisher 1997). The time to the market is the most critical factor for attaining this goal. Therefore, PCB factories, most of which belong to divergent differentiation supply chains, focus more on how to cope with the dynamic demands from downstream customers, and how to enhance their on-time delivery fulfilment rates. All three PCB manufacturing factories have adopted the MTO approach according to the contents and specifications of the orders placed by their customers. By adopting this approach, they can supply products which meet customer requirements while keeping their inventory at the lowest level. Through the sharing of product demand forecasts, factories can map out in advance the demand for raw materials, production plans, and even their productivity, because the enhancement of information transparency can facilitate the execution of production and management decisions, shorten the order processing time, and therefore improve the OFP performances.

### 5.3. *Lesson 3*

*Supply chain uncertainty can be reduced through IOC.*

IOC can reduce the costs of information searching and coordination, reduce organisational uncertainty, shorten delivery time, and control strategic market information. Due to the frequent customisation of PCB products, manufacturers are adopting MTO production strategies and maintaining minimum inventory costs while achieving the diverse needs of customers. Furthermore, the differentiation of PCB products occurs in the early stage of the production process. Thus, the demand uncertainty derived from requirement changes can be reduced through signing agreements with customers to ensure that they can cover the costs of raw materials for unfinished products in a certain period of time. The case results show that if the actual order amount is much larger than the 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. Such coordination can greatly reduce the effect caused by the demand change. In addition, to reduce the uncertainty of lead time, the manufacturer can coordinate with the customer to use, if possible, substitute materials or to provide a demand forecast of the product earlier.

### 5.4. *Lesson 4*

*In a divergent differentiation supply chain, sharing information through VMI mechanisms helps improve supply chain coordination and reduces the bullwhip effect.*

Even if information sharing is conducted, much of the forecast information may become inaccurate when changes in demand increase greatly. Thus, simply conducting information sharing is of no great help in reducing the bullwhip effect (Gavirneni, Kapuscinski, and Tayur 1999). This research found that the studied PCB manufacturing factories have established VMI mechanisms with their customers. Therefore, through efficient sharing of inventory information, they 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 an IOC mechanism and also reduce significantly the impact that the bullwhip effect might bring to upstream suppliers.

### 5.5. *Lesson 5*

*The stronger the mutual trust between partners, the higher the level of their information sharing.*

Within a high uncertainty environment, a mutual trust between supply chain partners is critical to sharing information. On the one hand, where suppliers had acquired a high degree of trust with the three PCB manufacturing factories, we found that these factories were more willing to share information with them. This in turn could assist them in production making decisions, such as the latest market information. It was also found that the three PCB manufacturing factories had more trust in their VMI customers. However, building a strong relationship is not an easy task since the trust in their supply chain partners only emerged after a long period of cooperation. During this lengthy period, the factories were constantly observing and evaluating whether their customers would provide stable orders and display positive trading behaviours.

On the other hand, for those customers who have created a high degree of trust, the information shared included not only their transaction information, but also the demand forecasts and inventory information. Furthermore, the customer trusted those suppliers that were displaying trustworthy delivery performances. This research also found that the higher the degree of information sharing, the more enhanced the mutual trust between them becomes, bringing them into a favourable cycle. Once mutual trust is established between supply chain partners, they are more likely to establish a long-term relationship (Morgan and Hunt 1994).

### 5.6. *Lesson 6*

*The willingness to share information will increase when organisations are driven by risk considerations and can use information as a bargaining chip.*

This study based on the economic and technical aspects proposed by Kumar and Dissel (1996) researched at risk circumstances in the inter-organisational information sharing activities in the supply chain. It was found that 'motivation' played a critical role in such sharing and cooperative commitment to supply chain partners, and that this motivation is largely 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.). The reason for this is that downstream customers tend to rely on several suppliers, so the chances of them developing strategic partner relationships are slim.

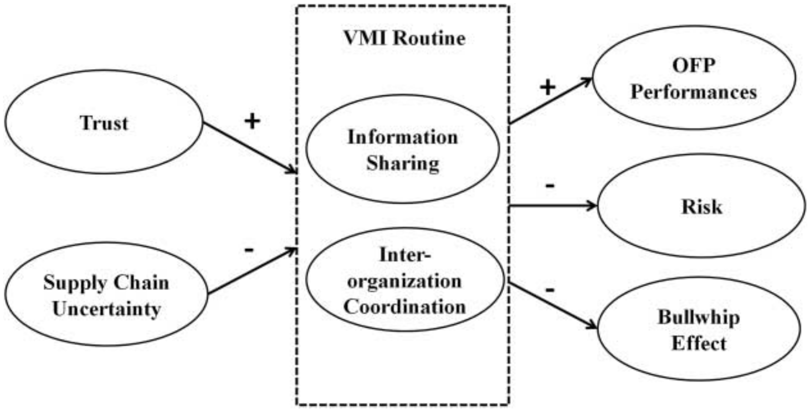


Figure 1. Research results of this study.

Therefore, in the PCB industry where cost is the most important competitive advantage, companies are unwilling to share information which is indirectly related to their costs, or other information related to their business confidentiality, such as the work in process or the contractor productivity distribution information. This is because these PCB companies are concerned that once they share their internal procurement and bargaining information with their customers, their dominant position in the bargaining process may be vulnerable.

### 5.7. *Lesson 7*

*Once IOC mechanisms are established, sharing information through the use of VMI can effectively disperse risks.*

Based on traditional supply chains, the simulation (Disney and Towill 2003) and modelling (Yao, Philip, and Martin 2007) studies prove that the VMI system can enhance supply chain efficiencies and reduce possible negative effects. This study also found similar results from the investigation in a more dynamic supply chain – the one in the PCB industry. PCB customers tend to maintain an appropriate amount of stock when supplying products to the market. In order to prevent the loss caused from short supply or oversupply, the VMI mechanism is built between the manufacturer and customer.

Based on the premise of the bullwhip effect, the coordination in a supply chain between partners is seen when one party would like to pass on the cost or risk burden to the upper stream partner, such as the costs of excessive manufacturing. On the other hand, the upper stream partner tends to reduce such a burden through coordination with the lower stream partner. This study found that VMI is a valid solution to find a balance between both sides in terms of dispersing risks. With such a mechanism, if one party wants to gain sweet rewards, bearing considerable risks is needed. If companies treat SCM as an investment for developing their own process, they would be willing to accept reasonable risks in order to achieve continuous improvement and change. It is prudent to share the risks and to share information with others in order to achieve the common goals of the supply chain. Both parties would also agree to share necessary information in the coordination process so as to disperse risks. Based on the case results, when the channel for sharing stock information is established and the coordination mechanism is functioning, PCB manufacturers are able to reduce situations of short supply or oversupply. Both parties can therefore reduce risks in their business transactions.

## 6. Conclusion

This study investigated how information sharing could reduce uncertainty in the divergent differentiation supply chain and increase performance. The critical factors that affect information sharing have also been extracted. This study found that the stronger the mutual trust between partners, the higher is the level of information sharing. Based on IOC 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. Supply chain uncertainty can be reduced through IOC. The research results are summarised in Figure 1, and more elaboration of the figure is provided afterwards.

This research found that mutual trust and uncertainty are two key factors that can stimulate information sharing. Currently, most relationships between PCB manufacturers and their upstream and downstream partners are still of a general transactional type. Due to risk considerations, organisations tend not to share sensitive information that they can use as bargaining chips. Through the sharing of product demand forecasts, however, PCB manufacturers can map out the demand for 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 with the MTO approach, and therefore, improve the efficiency of OFP.

The bullwhip effect refers to the scenario where the orders to the supplier tend to have larger fluctuations than the sales to the buyer, and the distortion propagates upstream in an amplified form (Disney and Towill 2003). 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 manufacturing factories and their customers are able to establish more effective information sharing and IOC mechanisms that assist in dealing with negotiation activities (e.g. on prices and specifications), product design revision, and order changes on a timely basis. The bullwhip effect can therefore be reduced.

### 6.1. *Limitations and future research*

This research has attempted to bridge the gap between theory and practice. However, no different from others, it still has its limitations. Firstly, the PCB industry is a rapidly changing environment. Therefore, different data collection time points may yield different results which in turn may influence the analysis of a PCB supply chain's current status. Secondly, during the process of data collection, the background knowledge of the interviewees may have an impact on their understanding of the questions. Thirdly, this research selected only three PCB manufacturing factories. However, the main objective of this research was not to generalise, but to investigate and to 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 subjects investigated by this research are limited to PCB vendors. However, the demand for integrated circuit package substrates is currently booming so this industry may well be worthy of further research. 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 manufacturing uncertainty factors of PCB supply chains will have to be re-examined. Third, this research is based on a small number of cases only. Thus, the generalisation of its lessons is limited. Future researchers can statistically test these propositions by using a larger sample base.

## References


Andel, T. 1996. “Manage Inventory, Own Information.” *Transport and Distribution* 37 (5): 54–58.

Angeles, R., and R. Nath. 2001. “Partner Congruence in Electronic Data Interchange–Enabled Relationships.” *Journal of Business Logistics* 22 (2): 109–128.

Anne, K. R., J. C. Chedjou, and K. Kyamakya. 2009. “Bifurcation Analysis and Synchronisation Issues in a Three-Echelon Supply Chain.” *International Journal of Logistics Research and Applications* 12 (5): 347–362.

Bernstein, F., and F. Chen. 2006. “Coordinating Supply Chains with Simple Pricing Schemes: The Role of Vendor-Managed Inventories.” *Management Science (INFORMS)* 52 (10): 1483–1492.

Chan, F. T. S. 2003. “Performance Measurement in a Supply Chain.” *The International Journal of Advanced Manufacturing Technology* 21 (7): 534–548.

Davis, T. 1993. “Effective Supply Chain Management.” *Sloan Management Review* 34 (2): 35–46.

Disney, S. M., and D. R. Towill. 2003. “The Effect of Vendor Managed Inventory (VMI) Dynamics on the Bullwhip Effect in Supply Chains.” *International Journal of Production Economics* 85 (2): 199–215.

Fisher, M. L. 1997. “What is the Right Supply Chain for Your Product?” *Harvard Business Review* 75 (2): 105–116.

Fynes, B., S. Burca, and D. Marshall. 2004. Environmental Uncertainty, Supply Chain Relationship Quality and Performance.” *Journal of Purchasing & Supply Management* 10 (4–5): 179–190.

Gavirneni, S., R. Kapuscinski, and S. Tayur. 1999. “Value of Information in Capacitated Supply Chains.” *Management Science* 45 (1): 6–24.

Houshyar, A. N., S. A. Darestani, A. N. Hoshyar, M. Mukhtar, and R. Sulaiman. 2011. “A Simulation Investigation on Impacts of Transportation Disruption for Vendor Managed Inventory Model and Traditional Inventory System.” *Journal of American Science* 7 (4): 115–133.

Hoyt, J., and F. Huq. 2000. “From Arms-Length to Collaborative Relationships in the Supply Chain: an Evolutionary Process.” *International Journal of Physical Distribution & Logistics Management* 30 (9): 750–764.

Huang, G. Q., S. K. Lau, and K. L. Mak. 2003. “The Impacts of Sharing Production Information on Supply Chain Dynamics: A Review of the Literature.” *International Journal of Production Research* 41 (7): 1483–1517.

Hung, W. H., C. F. Ho, J. J. Jou, and Y. M. Tai. 2011. Sharing Information Strategically in a Supply Chain: Antecedents, Content and Impact.” *International Journal of Logistics Research and Applications* 14 (2): 111–133.

Ireland, R. D., and J. W. Webb. 2007. A Multi-theoretic Perspective on Trust and Power in Strategic Supply Chains. *Journal of Operations Management* 25 (2): 482–497.

Kumar, K., and H. G. van Dissel. 1996. “Sustainable Collaboration: Managing Conflict and Cooperation in Interorganizational Systems.” *MIS Quarterly* 20 (3): 279–300.

Lambert, D. M., M. C. Cooper, and J. D. Pagh. 1998. “Supply Chain Management: Implementation Issues and Research Opportunities.” *The International Journal of Logistics Management* 9 (2): 1–19.

Lee, H. L., and C. Billington. 1992. “Managing Supply Chain Inventory: Pitfalls and Opportunities.” *Solan Management Review* 33 (3): 65–73.

Lee, H. L., and C. Billington. 1993. “Material Management in Decentralized Supply Chains.” *Operations Research* 41 (5): 835–847.

Lee, H. L., and S. Whang. 2000. “Information Sharing in a Supply Chain.” *International Journal of Technology Management* 20 (3/4): 373–387.

Li, S., and B. Lin. 2006. “Accessing Information Sharing and Information Quality in Supply Chain Management.” *Decision Support Systems* 42 (3): 1641–1656.

Lin, F. R., and M. J. Shaw. 1998. “Reengineering the Order Fulfillment Process in Supply Chain Networks.” *The Information Journal of Flexible Manufacturing Systems* 10 (3): 197–229.

Liu, R., and A. Kumar. 2009. “Leveraging Information Sharing to Configure Supply Chains.” *Information Systems Frontiers* 13 (1): 139–151.

Magee, J. F. 1958. *Production Planning and Inventory Control*, 80–83. New York: McGraw-Hill Book Company.

Malhotra, A., S. Gosain, and O. A. El Sawy. 2005. “Absorptive Capacity Configurations in Supply Chains: Gearing for Partner Enabled Market Knowledge Creation.” *MIS Quarterly* 29 (1): 145–187.

McCutcheon, D., and F. I. Stuart. 2000. “Issues in the Choice of Supplier Alliance Partners.” *Journal of Operation Management* 18 (3): 279–302.

Morgan, R. M., and S. D. Hunt. 1994. “The Commitment-Trust Theory for Relationship Marketing.” *Journal of Marketing* 58 (3): 20–38.

Ryu, S. J., T. Tsukishima, and H. Onari. 2009. “A Study on Evaluation of Demand Information-Sharing Methods in Supply Chain.” *International Journal of Production Economics* 120 (1): 162–175.

Sohn, S. Y., and M. Lim. 2008. “The Effect of Forecasting and Information Sharing in SCM for Multi-generation Products.” *European Journal of Operational Research* 186 (1): 276–287.

Stalk, G., P. Evans, and L. E. Shulman. 1992. “Competing on Capabilities: The New Rules of Corporate Strategy.” *Harvard Business Review* 70 (2): 57–70.

Sterman, J. D. 2006. “Operational and Behavioral Causes of Supply Chain Instability.” In *The Bullwhip Effect in Supply Chain*, edited by O. Carranza and F. Villegas. New York: Palgrave Macmillan.

Strader, T. J., F. Lin, and M. J. Shaw. 1999. “The Impact of Information Sharing on Order Fulfillment in Divergent Differentiation Supply Chain.” *Journal of Global Information System* 7 (1): 17–25.

Tan, K. C., V. R. Kannan, and R. B. Handfield. 1998. “Supply Chain Management: Supplier Performance and Firm Performance.” *International Journal of Purchasing and Materials Management* 34 (3): 2–9.

Valentini, G., and L. Zavanella. 2003. “The Consignment Stock of Inventories: Industrial Case and Performance Analysis.” *International Journal of Production Economics* 81–82: 215–224.
Wagner, C. M., B. Huber, E. Sweeney, and A. Smyth. 2005. “B2B e-marketplaces in the Airline Industry: Process Drivers and Performance Indicators.” *International Journal of Logistics: Research and Applications* 8 (4): 283–297.
Yao, Y., T. E. Philip, and E. D. Martin. 2007. “Supply Chain Integration in Vendor-Managed Inventory.” *Decision Support Systems* 43 (2): 663–674.
Yu, Z., H. Yan, and T. C. E. Cheng. 2001. “Benefits of Information Sharing with Supply Chain Partnerships.” *Industrial Management & Data Systems* 101 (3): 114–119.