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Evaluating the supply chain performance of IT-based inter-enterprise collaboration

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Abstract

With the use of IT, the nature of business processes has changed from intra- to cross-enterprise. This has significantly altered enterprise interactions with suppliers and customers. Collaboration is essential for successful supply chain performance. In recent years a variety of initiatives have been adopted by industries. These attempted to create efficiency and effectiveness through integration of the activities and processes. However, enterprises can only gain significant benefits by mass collaboration. Collaborative Planning, Forecasting and Replenishment (CPFR), which result in deeper partnerships, have become an important factor in supply chains. We investigated the performance of CPFR; it possesses formalized guidelines and is a relatively new initiative. By using simulation, we investigated four CPFR alternatives that are used in the adoption of collaboration strategies in industries. Retailers have traditionally played the hub role in supply chains in order to reduce the bullwhip effect, but our simulation confirmed that shifting the retailer (buyer-driven) collaboration to a manufacturer (supplier-driven) approach was a more viable option.

Keywords: Supply chain management; Collaboration; Information technology; Collaborative Planning Forecasting and Replenishment; Simulation

1. Introduction

Several collaboration initiatives have been identified as important in improving supply chain performance. These aim at increasing efficiency and effectiveness through integration of cross-enterprise activities and processes [5,23]. Collaboration may share large investments, pool risks, and share resources, causing growth and return on investments [10] and has led to new strategies, such as Quick Response (QR), Efficient Consumer Response (ECR), and Vendor Managed Inventory (VMI), and Collaborative Planning, Forecasting and Replenishment (CPFR) has been increasingly adopted in industry [4,13].

Mentzer et al. [18] defined supply chain collaboration as integrating all partners into one virtual network with common goals. It is important in achieving competitive advantage [11]. Simatupang and Sridharan [21] showed a linkage between collaborative performance metrics and collaborative enablers. Simatupang and Sridharan [22] and Holweg et al. demonstrated that collaboration between partners resulted in better performance.

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The increasing complexity of organizations and the scale of information activities require greater cooperation between enterprises [29]. IT department technical quality, IT plan utilization, and top management support all influence on the effectiveness of supply chains [2]. IT centralizes the information, providing shorter lead time and smaller batch size in the supply chains [8] and can significantly reduce the bullwhip effect, which causes poor supply chain performance. Organizational culture, the effect of trust, teamwork and reward systems, etc., can also help achieve a positive exchange of information. Collaboration between trading partners creates greater benefits than those with superficial collaboration [12,24,27]. Supply chain collaboration has become a critical element in the complex manufacturing environment [26]. However, some companies still feel anxious and uncertain about a benefit from its use.

CPFR (See the discussion below) [7] provides information about the collaborative process according to formal guidelines, which elicit details of the collaborative processes and involved partners. However, since CPFR is a relatively new initiative, little research has been carried out on its use, though it apparently has had positive effects on supply chain performance. Because of this dearth of information, we decided to evaluate the benefits of four primary scenarios of CPFR to ascertain their effect on collaborative and cross-enterprise activities. In addition, because retailers have traditionally been playing the major role in supply chains in order to reduce bullwhip effects, we also investigated the suitability of retailer- or buyer-driven collaboration and manufacturer- or supplier-driven collaboration in CPFR programs.

2. Collaborative Planning Forecasting and Replenishment

2.1. Basics of CPFR

Collaborative Planning, Forecasting, and Replenishment (CPFR) was defined by the Voluntary Interindustry Commerce Standards (VICS) committee as a way of describing supply chain collaboration [28]. It defined CPFR as "*a collection of new business practices that leverage the Internet and EDI in order to radically reduce inventories and expenses while improving customer service*." Compared with previous strategic alliances, CPFR concentrated on strongly linking business planning, forecasting, and replenishment through deeper information sharing.

Most CPFR applications so far have concentrated on the grocery industry [9]. The primary driving forces for CPFR adoptions there included fierce competition, a shorter product life cycle, offshore production, and the supply chain cost structure. In particular, retailers expected to cut costs through implementing the CPFR initiative [19].

Table 1
Key CPFR scenario leads defined by VICS

	Sales forecast	Order forecast	Order generation
Scenario A	Buyer	Buyer	Buyer
Scenario B	Buyer	Seller	Seller
Scenario C	Buyer	Buyer	Seller
Scenario D	Seller	Seller	Seller

2.2. CPFR process

CPFR has three stages: planning, forecasting, and replenishment proposed by VICS. These are further divided into nine steps, which apply an iterative approach to developing collaborative business planning, forecasting and replenishment between partners. The details of steps depend on the capability of the partners, the role of the supply chain, the information source, and consensus between partners. CPFR steps and details of the supply chain collaboration will normally be decided by mutual discussion. Retailer or vendor may play a lead role in sales forecasting, order forecasting, and order generation. Therefore, the model can be divided into four scenarios termed A–D, as shown in Table 1. In scenario A, the buyer leads the sales forecast, the order forecast and the order generation. In scenarios B–D, the order generation is assigned to the seller, similar to VMI strategy.

The nine steps of CPFR proposed by VICS are:

1. Develop Collaboration Arrangement
2. Create Joint Business Plan
3. Create Sales Forecast
4. Identify Exceptions for Sales Forecast
5. Resolve/Collaborate on Exception Items for Sales Forecast
6. Create Order Forecast
7. Identify Exceptions for Order Forecast
8. Resolve/Collaborate on Exception Items for Order Forecast
9. Generate Order.

2.3. Inhibitors and enablers of CPFR implementation

By improving the relationship with customers, CPFR has provided some typical benefits such as: increased profitability, reduced inventory, shortened cycle time, more efficient transportation planning, decrease of shortages, better promotion planning, and improved customer service [17]; three collaborative enablers (information sharing, decision synchronization and incentive alignment) were proposed by Simatupang and Sridharan as ways to improve fulfillment, inventory, and responsiveness.

In 1990s, several supply chain initiatives were developed in the grocery industry. In these, category management by the retailer and efficient replenishment depending on actual consumption were two mechanisms indicated by Holmström et al. Category management, efficient replenishment and scalable IT architecture were taken as the primary solutions for mass collaboration in order to obtain economics of scale.

Traditionally the business exchange was dependent upon transactional relations centering on a single product transaction and restricted information sharing [14]. Recently, the exchange was extended to passive information sharing, and a more proactive collaboration through joint planning and synchronization in supply chains. Stank et al. stated that the CPFR implementation was related to business process changes and IT. Furthermore, that it was still not known whether the supply chain performance was correlated with CPFR adoption. A successful CPFR implementation needed to involve a deeper involvement between partners and incorporate collaboration initiatives with operational changes to help gain efficiency. VICS suggested that CPFR could be followed with a step-by-step model. However, Skjoett-Larsen et al. argued that CPFR should be taken as a general collaboration approach between supply chain partners.

Stank et al. stated that the invisibility of actual customer demand and deficiency of collaborative relationships for joint decision making were major barriers to achieving the performance objectives of supply chain integration. Skjoett-Larsen et al. indicated that the collaborative partners should have trusted one another when starting the CPFR implementation. Managing CPFR steps in a supply chain needed discussion on the sharing of responsibilities between partners, and on how coordination mechanisms should be improved to align the activities [6].

Barratt and Oliveira [1] identified the critical inhibitors and enablers of CPFR implementation for the widespread adoption of CPFR in industry. The main inhibitors included lack of visibility, lack of trust, and lack of collaborative objectives in the supply chain. The enablers suggested by them involved improved collaboration by stabilizing the objectives and broadening the complexity and scope, with mutual trust and information sharing.

McCarthy and Golicic [16] also confirmed that CPFR was able to improve the supply chain performance by responsiveness intensification, product availability, inventory and associated cost reduction, and revenue growth. Based on the inhibitors and enablers of CPFR, McCarthy and Golicic proposed guidelines for implementing collaborative forecasting. They included internal forecasting process auditing, top management support, collaborative forecasting training, initially targeting key companies and creating a single demand projection.

Holmström et al. revealed that, in CPFR implementation, making good forecasts is critical to the operations of the suppliers, particularly when it was not previously necessary. Retailer category management processes could be taken as the basis for forecasting, which allowed retailers to upgrade collaboration with a large number of suppliers without increasing planning resources. The benefit of using category management was that retailers could scale up collaboration with many suppliers without increasing planning resources. Additionally, suppliers could jointly perform the forecast and assortment decisions by using actual customer demand from the retailer's point of sales (POS) system. Collaborative planning was thus more successful, provided that a little additional work input from retailers was provided.

Exception items in sales and order forecasts are normally explored according to agreements between partners. Caridi et al. [3] developed an agents-driven negotiation process to resolve the exception items that arose in implementing CPFR. The agents-driven negotiation process could then reduce costs, inventory and stock-out level, as well as increase sales.

3. Model development

To investigate the impacts of collaboration on supply chain performance, we modeled five scenarios: a non-collaboration model and CPFR scenarios A–D. The complexity and stochastic nature of CPFR activities required a powerful tool to model them. ARENA [15] is a powerful discrete-event commercial software simulator. Models were built using ARENA and executed to collect the performance measures for analysis and comparison.

3.1. Model settings

The supply chain structure was a two-echelon model: manufacturer (seller) and retailer (buyer). The primary

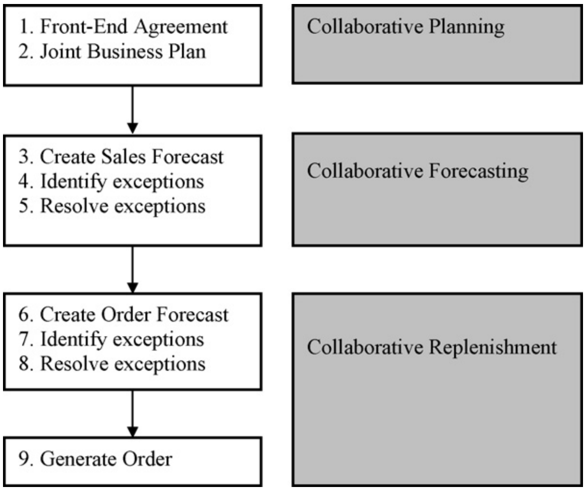

Fig. 1. CPFR process model.

process of CPFR proposed by VICS is illustrated in Fig. 1. The five scenarios were compared by analyzing the performance measures at the customer service level: order fulfillment rates, order cycle time, and supply chain cost.

The basic activities in the two-echelon supply chain were:

1. *Retailer*: facing different customer demand rates,
   - Fills customer orders according to the order quantity.
   - If the order quantity is more than the current stock, offers all the inventories to the customer.
   - The insufficient part is back-ordered.
   - After receiving the replenishment from manufacturer, retailer fills these orders.
   - At the start of each review period, retailer proceeds with ordering replenishment according to the established inventory policy.
2. *Manufacturer*: After receiving the retailer's orders,
   - Fills the orders according to its inventory status and the order quantity.
   - If the order quantity is more than current stock, manufacturer offers all of the inventories (finished products) to the retailer.
   - The insufficient part is back-ordered.
   - After receiving the replenishment of required materials from the supplier, manufacturer proceeds with manufacturing according to the production plan, assuming that the supplier of raw materials possesses an infinite capacity.

Parameters in the two-echelon supply chain model are:

1. *Customer demand rate*: The arrival of customer orders and order quantities follow some empirical probability distributions.
2. *Lead time*: When delivering raw materials from supplier to manufacturer and delivering finished products from manufacturer to retailer, there is a delivery transportation lead time. In addition, the production lead time of the manufacturer depends on the batch size.
3. *Inventory policy*: Manufacturer and retailer must establish their inventory policies. In our study, these members were with an (s, S) inventory policy, in which s represents the reorder point and S represents the order up-to-level. For calculating the total cost, the unit shortage cost, unit inventory handling cost, and unit order cost must all be known.
4. *Exception criteria*: Two exception criteria were assumed. For the sales forecast exception, the deviation between retailer's and manufacturer's sales forecasts being above or below the 20% margin is an exception, and this was adjusted by the lead side was 10%. For an order forecast exception, the deviation between retailer's and manufacturer's order forecasts being over or below 20% was taken as another exception, and it was adjusted by the lead side with 10%.

For CPFR initiatives, the following information may be shared between partners according the scenario chosen:

1. *Promotion information*: The retailer's promotion calendar covered one season. It was assumed that promotion campaigns could increase sales. Promotion information could be used to adjust the sales forecasts.
2. *Sales information*: Without sharing sales information, manufacturer proceeded with the sales forecasts according to orders from retailer. When sharing sales information, the manufacturer could obtain the demand information of end customers to establish the inventory policy.
3. *Inventory information*: The information about current inventory levels and inventory policy was shared between involved members to adjust the order releases.
4. *Capacity information*: Without sharing production capacity information, the manufacturer could only fulfill the retailer's orders with its own production capacity. This information could be used to adjust the order forecasts. When sharing capacity information, the manufacturer was assumed to have the additional

Table 2
The scenario settings

Scenarios	Lead side	Shared information	Exception resolving lead side
Non-collaboration	No lead side	Non-information sharing	Non-exception resolving
CPFR A	Sales forecast, order forecast and order generation lead by retailer	Promotion and sales information	Sales forecast exception resolving and order forecast exception resolving lead by retailer
CPFR B	Sales forecast lead by retailer, order forecast and order generation lead by manufacturer	Promotion, sales, inventory, and capacity information	Sales forecast exception resolving lead by retailer, order forecast exception resolving lead by retailer
CPFR C	Sales forecast and order forecast lead by retailer, order generation lead by manufacturer	Promotion, inventory and information	Sales forecast exception resolving and order forecast exception resolving lead by retailer
CPFR D	Sales forecast, order forecast and order generation lead by manufacturer	Inventory and capacity information	Sales forecast exception resolving and order forecast exception resolving lead by manufacturer

capacity to fulfill the retailer's orders by using an outsourcing strategy.

3.2. Scenario settings

The five scenarios were generated. The lead sides for sales forecast, order forecast, and order generation were determined according to the settings of Table 1. The lead side also controlled the resolution of exception items. The information sharing settings of the five scenarios are shown in Table 2. For the non-collaboration scenario, there was neither lead-side nor information sharing; manufacturer and retailer made their forecasting and ordering decisions, and the manufacturer made the replenishment decision based on the retailer's orders. As indicated by VICS, scenario A tended to be the retailer- or buyer-driven collaboration approach, whereas scenarios B–D were the manufacturer (supplier)-driven ones.

3.3. Performance measures

The performance measures were:

1. *Average service level*: The supply chain service level represented the average service level of manufacture and retailer.

Table 3
Simulation parameter settings

Parameters	Settings
Simulation replications	30
Simulation run length	470 days
Customer order inter-arrival time distribution	Exponential distribution with mean 0.15
Customer order size (X)	$P(X) = \begin{cases} 0.167, & \text{if } X = 1 \\ 0.333, & \text{if } X = 2 \\ 0.333, & \text{if } X = 3 \\ 0.167, & \text{if } X = 4 \end{cases}$
Replenishment review period	1 week
Transportation lead time	1 day for materials transported from supplier to manufacturer, 20 days for finished products transported from manufacturer to retailer
Manufacturing lead time	50 days
Inventory holding cost	$1.0 per piece
Shortage cost	$5.0 per piece
Order cost	$10.0 per order for retailer, $100.0 per order for manufacturer
Production capacity	180 units per day for manufacturer, 180 units per day for outsourcing
Sales forecast exception item	The deviation between retailer's and manufacturer's sales forecasts is over or below 20%, and this exception item is adjusted by the lead side with 10%
Order forecast exception item	The deviation between retailer's and manufacturer's order forecasts is over or below 20%, and this exception item is adjusted by the lead side with 10%

2. *Average fulfillment rate*: The supply chain fulfillment rate represented the average order fulfillment rate of manufacturer and retailer.
3. Average order cycle time: This represented the average order cycle time of the manufacturer and retailer.
4. *Total system cost*: The total supply chain cost was the sum of the average costs of both manufacturer and retailer. The cost items consisted of inventory holding cost, shortage cost, and order cost.

4. Simulation results and discussions

4.1. Simulation results

The parameter settings for the five scenarios are shown in Table 3. The model parameters were reasonably set in order to reflect the CPFR programs, and to make steady simulation for analysis. If the steady state could not be achieved, the simulation results were not useful for analysis. A simulation length of 470 days was tested to generate results with relative small variations. Simulation models of the scenarios were constructed to generate the performance measures for analysis and comparison. Notice that the results were computed from a set of simulation runs; in reality the monetary numbers could not be justified as precisely as those presented in the tables of results.

4.1.1. Performance of non-collaboration scenario

The performance without collaboration between manufacturer and retailer is summarized in Table 4. Without information sharing, the retailer's sales and order forecasts were based on its own sales data, promotion calendar, and inventory policy. Retailer's sales may radically fluctuate because a promotion campaign can unexpectedly increase sales. A retailer therefore tries to satisfy increasing sales by raising the order size to the manufacturer. However, the manufacturer may not immediately respond to any unusual request. Such situations can result in a large increase in shortage costs and order cycle time, and a serious fall-in the service level and fulfillment rate for both the retailer and manufacturer. After the promotion campaign, the variations of sales and orders may be amplified and the retailer's inventory level increased due to the bullwhip effect. In a non-collaboration scenario, there is great opportunity to improve the supply chain performance.

Table 4
Performance of non-collaboration scenario

	Retailer–customer	Manufacturer–retailer
Service level	0.70	0.43
Order fulfillment rate	0.58	0.79
Order cycle time (day)	8.17	23.04
Shortage cost ($)	1791.97	3219.09
Holding cost ($)	599.83	0.00
Order cost ($)	66.00	14.00

Table 5
Performance of CPFR scenario A

	Retailer–customer	Manufacturer–retailer
Service level	0.92	0.91
Order fulfill rate	0.89	0.89
Order cycle time (day)	1.25	8.13
Shortage cost ($)	61.61	726.27
Holding cost ($)	879.68	145.98
Order cost ($)	66.00	14.00

4.1.2. Performance of CPFR scenario A

In this, the retailer is the lead and takes the responsibility for the sales forecast, the order forecasts, and order generation. Table 5 summarizes the performance in this scenario. By taking the promotion calendar into consideration in advance, the service level and order fulfillment rate can maintain a much better level. But without sharing the information of its production capacity, the retailer's order fulfillment is restricted by the manufacturer's capacity, thus the stock-out and order cycle time in the manufacturer side continuously increase to a relatively high level. There is also a need to improve the order cycle time on the manufacturer side.

4.1.3. Performance of CPFR scenario B

In this the sales forecast is controlled by the retailer whereas the order forecast and order generation are controlled by the manufacturer. Table 6 lists its performance. With information sharing, the retailer performs the sales forecasting by jointly considering the

Table 6
Performance of CPFR scenario B

	Retailer–customer	Manufacturer–retailer
Service level	0.98	0.93
Order fulfillment rate	0.97	0.99
Order cycle time (day)	1.05	1.75
Shortage cost ($)	12.50	69.78
Holding cost ($)	1292.77	151.58
Order cost ($)	66.00	28.00

Table 7
Performance of CPFR scenario C

	Retailer–customer	Manufacturer–retailer
Service level	0.94	0.94
Order fulfillment rate	0.92	0.89
Order cycle time (day)	1.14	7.72
Shortage cost ($)	35.61	712.21
Holding cost ($)	907.15	146.51
Ordering cost ($)	66.00	14.00

Table 8
Performance of CPFR scenario D

	Retailer–customer	Manufacturer–retailer
Service level	0.78	0.94
Order fulfillment rate	0.69	0.99
Order cycle time (day)	4.09	1.64
Shortage cost ($)	821.45	64.51
Holding cost ($)	834.65	117.24
Order cost ($)	66.00	28.00

actual sales data, promotion calendar, inventory policy, and production capacity. The manufacturer can increase the replenishment to the retailer through information sharing and collaboration. Then, due to the production capacity information sharing, the manufacturer can increase capacity by outsourcing to respond effectively to the retailer's promotion events, which cause sales fluctuations. Therefore, the stock-outs of both trading partners decrease, resulting in cost reduction and service level improvement.

4.1.4. Performance of CPFR scenario C

In CPFR scenario C, the retailer controls the sales and order forecasts, and manufacturer controls the order generation. The performance is summarized in Table 7: it is similar to that of scenario A. The manufacturer can add the replenishment to the retailer according to the retailer's stock-out status while the production capacity limitation is met. Therefore, the service level and order fulfill rate of this scenario are better than those of scenario A for the retailer side.

4.1.5. Performance of CPFR scenario D

Here, the manufacturer controls all the partnership issues of the sales forecast, order forecast and order generation. The performance is summarized in Table 8. Here the retailer's promotion calendar is not shared with the manufacturer, and this results in a reduction of service level and fulfillment rate for the retailer side due to the manufacturer's lowered replenishment.

4.2. Comparisons and discussions

Table 9 and Fig. 2 summarize the synergic supply chain performance of the five scenarios. From Table 9 and Fig. 2, it is obvious that supply chain collaboration strategies result in much better performance than those in non-collaboration.

4.2.1. Average system service level

There are ways of improving the average system service levels in the non-collaboration and CPFR scenario D. The average system service levels of CPFR scenarios A and C are relatively inferior to that of scenario B because production capacity information is not shared. However, in CPFR scenarios A and C, retailer takes the promotion calendar into consideration in advance, and this results in a sound service level for customers. The average system service level of scenario C was relatively superior to that of scenario A because the order generation was made by manufacturer in scenario C. In such a situation, the manufacturer can continuously enhance the replenishment to the retailer by observing the inventory level of the retailer. In scenario D, the manufacturer does not have the promotion calendar of the retailer, which causes reduction in the service level.

4.2.2. Average system fulfillment rate

Similar to the average system service level, there are opportunities to improve the average system fulfillment rates in both the non-collaboration and CPFR scenario D. The average system fulfillment rate of scenario C was relatively superior to that of scenario A also because the order generation was made by the

Table 9
The average supply chain performance

	Non-collaboration	CPFR A	CPFR B	CPFR C	CPFR D
Average system service level	0.69	0.92	0.98	0.94	0.78
Average system fulfillment rate	0.58	0.89	0.97	0.92	0.70
Average system cycle time (day)	15.61	4.69	1.40	4.43	2.87
Total system cost ($)	5690.89	1893.54	1620.63	1881.48	1931.84

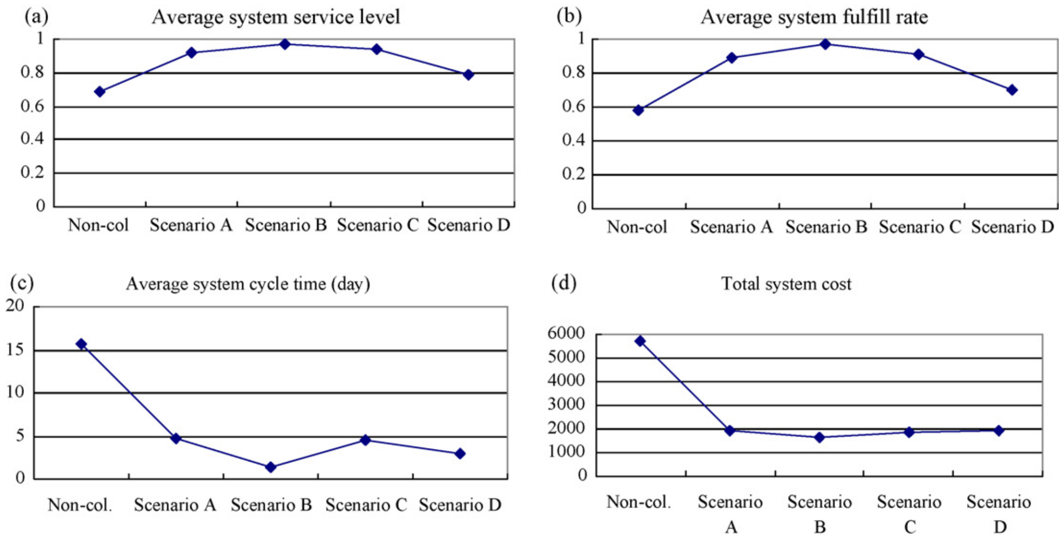

Fig. 2. The average performance of supply chain: (a) average system service level; (b) average system fulfill rate; (c) Average system cycle time; (d) total system cost.

manufacturer in scenario C. For CPFR scenarios, there was room to improve the fulfillment rate in scenario D as the promotion calendar of the retailer was not shared between trading partners.

4.2.3. Average system cycle time

The average system cycle time of non-collaboration was much longer than that of CPFR. In scenarios A and C, the retailer increased the order to manufacturer by considering the influence of any promotion campaigns. However, due to the non-sharing of production capacity information, order fulfillment was restricted by the capacity level, which lengthened the manufacture's order cycle time. In scenario D, the manufacturer, who did not receive the retailer's promotion calendar, made the replenishment decision. The average system cycle time was still within a reasonable range because the order cycle time of the manufacturer was stable. However, there was an opportunity to improve the order cycle time in the retailer side.

4.2.4. Total system cost

Similar to the average cycle time, the total system cost of non-collaboration was much higher than that of CPFR. Because of no information sharing and non-collaboration, the stock-out had a significant impact on the total cost proliferation. Compared to CPFR scenario B, there were opportunities for scenarios A, C and D to reduce the supply chain cost. In scenario C, the total system cost was relatively lower because the replenishment decision was made by the manufacturer, which caused a reduction in shortage cost.

From the simulation results, the holding costs of collaboration scenarios were substantially higher than those of the non-collaboration scenario. The increase of the holding costs was compensated by reduction of shortage costs. In the non-collaboration scenario, the inventory level was overly low. Therefore, even though the holding cost was very low, shortages frequently happened and these caused a proliferation of shortage costs.

Of all these comparisons, the CPFR scenario B was the best even though it did possess a more complicated collaboration and information sharing mechanism. Such performance results are consistent with the observations of Fiala and Sahin and Robinson [20], in which supply chain partners with the higher corporate performance possessed a higher level of information sharing and communication. Furthermore, the related studies of Holmström et al., Simatupang and Sridharan, Skjoett-Larsen et al. and Stank et al. indicated that mass collaboration would be more beneficial for partners. In CPFR scenarios A and D, the forecasting and replenishment decisions were guided either by the retailer or manufacturer side. CPFR scenarios B and C however, covered a deeper collaboration on both sides. Holweg et al. indicated that the effectiveness of supply chain collaboration depended on the integration of internal and external operations.

Suppliers encounter a critical challenge in making retailers perform sales and order forecasts when they

Table 10
The first set of perturbed model parameters

Parameters	Settings
Customer order inter-arrival time distribution	Exponential distribution with mean 0.1
Customer order size (X)	$P(X) = \begin{cases} 0.25, & \text{if } X = 1 \\ 0.25, & \text{if } X = 2 \\ 0.25, & \text{if } X = 3 \\ 0.25, & \text{if } X = 4 \end{cases}$
Transportation lead time	5 days for materials transported from supplier to manufacturer
Production capacity	300 units per day (manufacturer), 300 units per day (outsourcing)

Table 11
The average supply chain performance for first perturbation

	Non-collaboration	CPFR A	CPFR B	CPFR C	CPFR D
Average system service level	0.63	0.63	0.84	0.65	0.64
Average system fulfillment rate	0.46	0.47	0.78	0.50	0.49
Average system cycle time (day)	22.49	19.34	7.72	19.16	8.10
Total system cost ($)	10231.86	8496.45	2409.04	8227.48	2519.64

have not previously done so. In such situations, the retailer's category management process can be incorporated into CPFR to develop deeper collaboration with lower costs. Holmström et al. concluded that collaboration could be more successful provided that a little, not excessive, additional work by retailers was involved.

Soliman and Janz [25] indicated that several factors such as pressures felt from trading partners, or from competitors, etc., and trust between trading partners significantly affected the intention to apply inter-organizational IS. Fliedner indicated that the extended ERP system could be developed to connect the partners' planning mechanisms through cross-enterprise IT systems.

In practice, supply chain collaboration usually starts with an uncomplicated scenario due to low mutual trust between trading partners. Mutual trust can gradually increase, causing a boost in confidence to a complicated and profound collaboration mechanism.

Nowadays, large retailers such as Wal-Mart and Kmart are quite able to make planning, forecasting and replenishment decisions with their own knowledge and well integrated IS. For Taiwan's industry, companies generally start with CPFR scenario A. After mutual trust and benefits have increased, they may go forward to CPFR scenarios B, C or D.

Table 12
The second set of perturbed model parameters

Parameters	Settings
Transportation lead time	5 days for materials transported from supplier to manufacturer
Inventory holding cost	$2.5 per piece
Shortage cost	$3.5 per piece

4.3. Further results

We finally perturbed some model parameters to investigate the performance of CPFR scenarios. First, we increased the customer demand rate (i.e., shortened the customer order inter-arrival time), the lead-time of materials transported from supplier to manufacturer, and the production capacity. The distribution of the four part types was also modified. Table 10 shows the first set of perturbed model parameters. The simulation results are summarized in Table 11. From this it can be seen

Table 13
The average supply chain performance for second perturbation

	Non-collaboration	CPFR A	CPFR B	CPFR C	CPFR D
Average system service level	0.67	0.79	0.97	0.72	0.81
Average system fulfillment rate	0.53	0.71	0.99	0.60	0.72
Average system cycle time (day)	21.96	17.70	6.96	20.22	5.72
Total system cost ($)	8161.87	6815.62	4367.51	7900.36	3912.62

that the total system cost significantly rose due to the increase of customer demand. Even the production capacity increased and the customer orders could not be satisfied. However, CPFR scenario B still appeared to be a better scenario for manufacturer–retailer collaboration.

Second, we perturbed the unit holding and shortage costs. Table 12 lists the set of perturbed model parameters. The simulation results are summarized in Table 13. From this it can be seen that the cost parameters may impact on the total system cost. CPFR scenarios B and D are better collaboration scenarios. Here, the manufacturer (supplier)-driven approach was more suitable for CPFR programs.

5. Conclusions

CPFR provides a good collaboration alternative based on integrating internal and external business activities. However, IT cannot alone ensure that partners can gain. Mutual trust plays an essential role in achieving effective implementation.

Apart from information sharing, successful supply chain collaboration requires knowledge sharing, technology sharing, risk sharing, and revenue sharing. The members in the supply chain also need to take the knowledge and technology level of their partners into consideration when selecting the appropriate collaboration scenario.

The primary limitation of our study is that we analyzed the inter-enterprise collaboration based on simulation, not on surveys provided by enterprises.

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