

Simulation modelling of central order processing system under resource sharing strategy in demand-driven garment supply chains

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Abstract. In this paper we proposed a central order processing system under resource sharing strategy for demand-driven garment supply chains to increase supply chain performances. We examined this system by using simulation technology. Simulation results showed that significant improvement in various performance indicators was obtained in new collaborative model with proposed system.

1. Introduction

In recent years, the trend of customization and personalization is increasing tremendously in garment industry. Instead of traditional ready-to-wear garments, customers are seeking to wear customized clothes fitting individual preference and body shape with distinctive materials, styles, pattern or colours. Therefore, the demand of small-series production and quick response become more and more important in today's garment supply chain. To meet this raising trend, demand-driven supply chain (see figure 1) is developed and employed nowadays. According to Verdouw, C.N et al. [1], a demand-driven chain is defined as “a supply chain in which all actors involved are sensitive and responsive to demand information of the end customer and meet those varied and variable demands in a timely and cost-effective manner”. In demand-driven supply chains, only products and services corresponding to customers' demands are produced and it forces stakeholders in the supply chain to collaborate with each other [2]. However, there are still a lot of potentials to improve current demand-driven supply chain, e.g. long lead time and high cost.

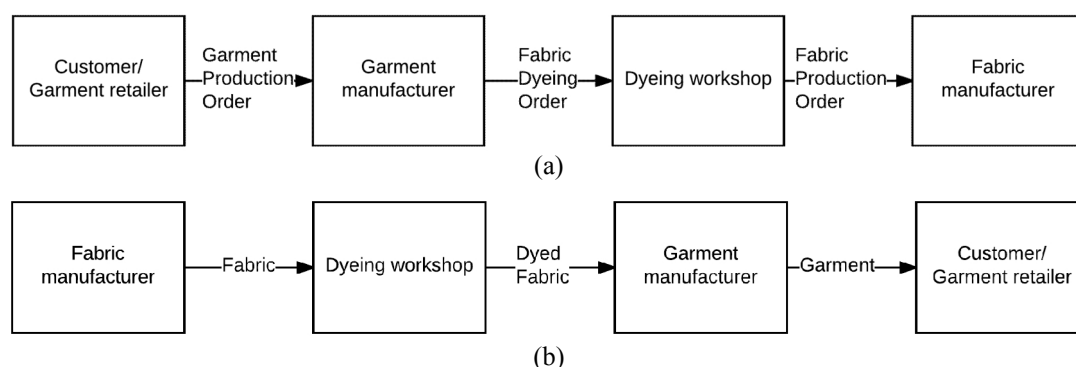


Figure 1. (a) Information flow and (b) material flow in demand-driven garment supply chains



As the increasing of complexity and flexibility in today's supply chain, inter-organizational collaboration between different supply chain echelons becomes an important issue. Companies are tending to find suitable partners to improve supply chain performance as a whole, so that to achieve mutual benefits together. Supply chain collaboration (SCC) becomes a hot research topic in supply chain field. Most of researches concentrated on joint decision making [3], [4], incentive alignment contract [5], [6] or information sharing [7], [8], which are all common strategies employed in vertical SCC. Collaboration in a demand-driven supply chain mainly focused on vertical collaboration as well. In previous research, horizontal collaborations were less addressed in either SCC research or demand-driven supply chain. Therefore, we are thinking to implement horizontal collaboration into current demand-driven garment supply chains, so that to combine vertical collaboration and horizontal collaboration together. Resource sharing (RS) is also a common SCC strategy and it was utilized more frequently in horizontal collaboration. The principle of RS is that resources or assets, e.g. machines and techniques, could be shared and leveraged among supply chain partners [9]. To the best of our knowledge, no previous research considered or discussed RS in garment supply chain. So, in this study, we explored the application of RS for horizontal collaboration in a four-echelon demand-driven garment supply chain. We compared a traditional demand-driven garment supply chain model to a new collaborative supply chain model with a central order processing system under designed RS strategy. We used simulation technology to see whether the whole supply chain can obtain significant performance improvement in the new model by applying proposed novel system.

2. Methodology

2.1 Conceptual model

As shown in figure 1, in a demand-driven garment supply chain, garment retailer or customer places a demand to a garment manufacturer, then garment manufacturer calculates material (dyed fabric) it needs for the production and send corresponding order to its supplier. Dyeing workshop estimates number of fabrics needed based on this demand and sends another order for fabric production to its fabric supplier. Although this model has advantages such as decreasing wasteful overproduction of garments, it still has several defects, such as long lead-time or delay between two echelons of supply chain.

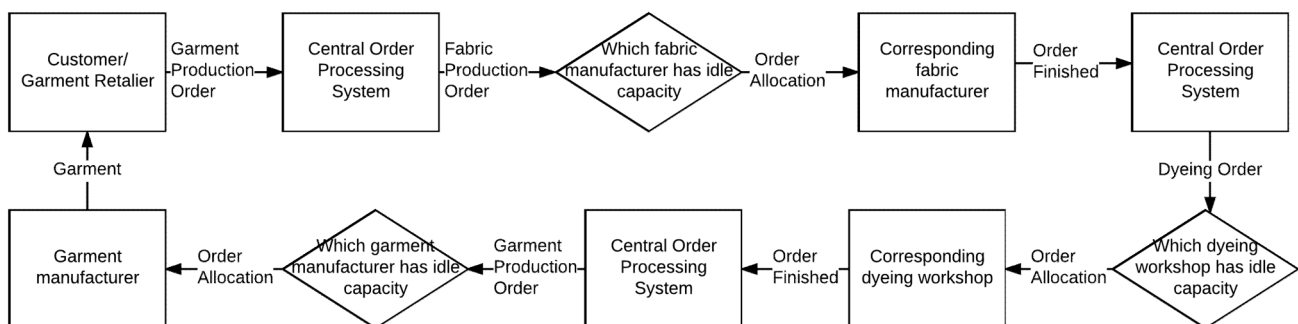


Figure 2. Information flow of central order processing system under RS strategy

We designed a central order processing system (COPS) in this study as shown in figure 2. Instead of fixed one-to-one or multiple-to-one relationships between suppliers from different echelons in a traditional demand-driven supply chain, collaborative relationships between suppliers are dynamic in our collaborative model with COPS. All members in COPS are potential collaborative partners with each other; no matter they are from the same echelon or different echelons. Production capacity status of each supplier for different types of products is updated in the system. Resources could be shared among suppliers from the same echelon in supply chain (horizontal collaboration). COPS is responsible for all demand estimation and order distribution to suitable suppliers, starting from raw material to final garment product. In our collaborative model, end consumers make a request of

garments to the system. COPS would calculate raw materials (fabrics) needed for production and create an order. The status of all fabric manufacturers would be checked in the system and the order would be delivered to the first fabric manufacturer with idle resource. Once the fabric production finished, fabric manufacturer would inform COPS, COPS would create another order for fabric dyeing and check capacity status of all dyeing workshops. Once a dyeing workshop has idle resource, then COPS would inform fabric manufacturer to transport the fabrics for corresponding dyeing workshop. Same principle is applied to the garment production stage. A suitable garment manufacturer would be selected for fabric cutting and sewing process and it would deliver final products to corresponding garment retailer or customer.

2.2 Simulation model

As it is impossible to run the experiment on our designed system in real-world system, also considering the complexity and stochastic nature of supply chain model discussed in this study, traditional analytical method, e.g. mathematical modelling, is not feasible. Therefore, we employed discrete-event simulation (DES) technology to evaluate RS model in this study. DES concern the modelling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time [10]. In this study, SIMIO (Simulation Modelling framework based on Intelligent Objects) was utilized as the simulation engine for building our simulation model. We initially developed a simulation model based on the traditional demand-driven garment supply chain model shown in figure 1. As mentioned previously, we simulated four echelons in garment supply chains, including fabric manufacturer, dyeing workshop, garment manufacturer and garment retailer. In each echelon, three individual small and medium-sized companies were available and could provide same service. Therefore, in total of twelve companies and three separate garment supply chains were modelled. Garment retailer demanded three types of garments, viz. dress, trousers and jacket. Input parameters (order size, order type, processing time etc.) were collected based on one-year historical data provided by a garment manufacturer and also through interviewing professionals in garment industry or reading relevant literatures [11], [12].

Then we created COPS in the simulation model. In general, three main functions were realized in COPS: (1) production capacity update and check, (2) order reception, creation, monitor and distribution, and (3) supplier selection for each supply chain echelon. They were respectively set and programmed in the simulation model. Production capacity of each process (general scripts in Simio: *MachineX.Capacity.Remaining*) was updated and checked during working hours in COPS. COPS received garment production orders from all three garment retailers. It also created corresponding orders for each echelon in supply chain. Once an order was completed in certain supplier, corresponding products were stored in the warehouse of supplier (wait process in Simio). COPS would monitor the status of each created order and is responsible for its distribution. Each order has three potential suppliers in next echelon in this model; COPS determined the selection of supplier responsible for the order. Once there is available capacity in supplier of next stage (general scripts in Simio: *MachineX.Capacity.Remaining*>0), COPS would send this order to selected supplier and also send signal (fire process in Simio) to current supplier holding raw material for delivering them to selected supplier (assign specific path to true, others to false in Simio).

3. Results

Two simulation scenarios (traditional demand-driven supply chain and supply chain with COPS under RS) were run for a duration of 20 weeks with 50 replications respectively. Average value of several supply chain performance indicators were checked, including order completion rate (*number of completed order/number of all received order*), facility utilization (*machine run time/total working time*), lead time (*average time from receiving an order to order completion*) and productivity (*throughput of garments per day*). They were compared between two models as shown in table 1. All checked indicators were improved in terms of their average value of 50 replications. Independent samples T-test (confidence interval = 95%) was performed to output data to verify whether there is a significant difference of each performance indicator between two models, as shown in table 2.

Significant improvements were obtained in terms of productivity, order completion rate and facility utilization respectively. Therefore, the experiment results can reflect the improvement of these three performance indicators of the model. COPS can bring overall benefits to companies operating in the system.

Table 1. Comparison of checked performance indicators

	Scenario	Number of replications	Mean	Std. Deviation
Productivity (pieces/day)	Traditional	50	1195.10	27.0748
	New	50	1222.52	29.7452
Lead Time (days)	Traditional	50	15.29	1.4018
	New	50	14.86	2.5470
Order Completion Rate	Traditional	50	83.38%	0.0256
	New	50	87.01%	0.0318
Facility Utilization	Traditional	50	82.86%	0.0159
	New	50	84.79%	0.0201

Table 2. T-test results

	T value	Degree of freedom	Sig. (2-tailed)	Mean Difference	Difference percentage
Productivity	-4.821	97.145	0.000	27.4204	2.29%
Lead Time	1.032	98	0.305	-0.4243	-2.78%
Order Completion Rate	-6.276	93.775	0.000	0.0363	4.35%
Facility Utilization	-5.331	92.925	0.000	0.0193	2.33%

4. Conclusion

In this study, we proposed COPS for garment supply chains. RS strategy was employed in the system, which is a less researched but important domain in supply chain collaboration. Simulation experiment results showed that, compared to traditional demand-driven supply chain model, the new proposed model with COPS got significant improvements in multiple supply chain performance indicators. COPS could help collaborative partners gain more benefits as a whole, converting so-called competitors to collaborators in garment supply chains. The system provided a platform for small and medium-sized companies in garment industry to increase their competences while facing the trend of customization and small-series production. This new model also could be a potential direction for solving current issues in small-series production, e.g. long lead-time or delay between two supply chain echelons, in other industries with similar supply chain process. It is expected to have more researches on this direction in future.

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