SIMULATION MODELLING OF RESOURCE SHARING IN INTER-ORGANIZATIONAL SUPPLY CHAIN COLLABORATION WITHIN GARMENT INDUSTRY

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Resource sharing (RS) is an important method in inter-organizational supply chain collaboration (SCC). However, it is still an under-explored area in research of SCC compared to other subjects (e.g. coordinating contract and information sharing). The aim of this paper is to examine the feasibility of applying RS model in the manufacturing stage of garment supply chain and to determine the suitable type of garment for RS in production. Eight scenarios of RS were designed. Discrete-event simulation was used for running experiment of each scenario. The comparison of different scenarios shows that garment manufacturers could get great benefits by applying RS model.

1. Introduction

Collaboration in supply chain becomes more and more common nowadays; while research regarding supply chain collaboration (SCC) keeps increasing as well. In existing literatures regarding SCC, most of them focused on discussing coordinating contract, information sharing, and joint decision making strategies. In practice, there is an increasing trend of sharing economy in recent years, more and more companies became successful by doing business regarding resource sharing (RS). RS is the process of leveraging capabilities and assets and investing in capabilities and assets with supply chain partners [1]. Partners could share resources (e.g. human or facility resources) if they share same or similar process in e.g. manufacturing or transportation process to improve supply chain performance. RS has been existing in various industries and businesses, e.g. car platform sharing strategy in automobile manufacturing [2], inventory pooling in retailing industry [3] and carriers sharing in logistics [4]. It is not a new concept but is relatively not paid sufficient attention in studies regarding SCC [5].

Studies regarding SCC in garment industry are scarce. Most of them concentrated on coordinating contracts and information sharing by using mathematical modelling, like Xiao and Jin [6], Wang, et al. [7] and Kuo, et al. [8]. To best knowledge, there is no study specifically discussing RS in garment supply chain. Therefore, there is a gap of research regarding RS in garment

industry. Those successful experiences from other industries imply RS could be a potential new model applying in garment industry so that to improve garment supply chain performance. In practice, current garment manufacturers often desire to keep orders by themselves even if they do not have sufficient resource to finish the order in time under some circumstances. Still, some of them are applying RS within organization itself, resources are shared between different teams or departments for increased productivity and facility utilization. Moreover, RS is applied cross organizations in some garment manufacturers when they are facing special cases, e.g. fluctuation in market expectation or inadequate production capacity. But if this strategy is treated as a common strategy in garment supply chain, RS partners may obtain increased productivity and utilization of facility, resulting in reduced costs and lead time. However, manufacturers who apply RS may incur delay of own production, which could result in a negative effect. Therefore, the objective of this paper is, by building a simulation model of manufacturing stage in garment supply chain and comparing key performance indicator (KPI) of different scenarios in RS model, to examine and analyze whether garment manufacturers can really get benefits by applying RS and which type of garment is more suitable for this model in production.
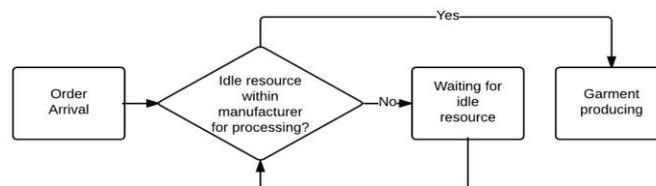
2. Methodology

2.1. Conceptual model

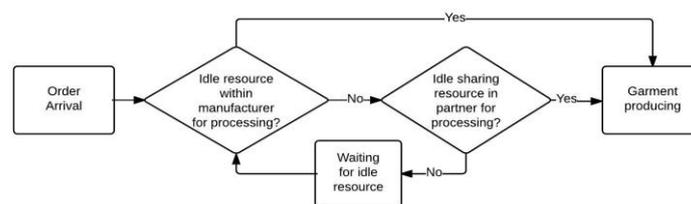Figure 1. Flowchart of traditional model in garment production

Figure 2. Flowchart of RS model in garment production

In traditional model of garment production, manufacturers received orders from customers and processed the order based on current resource capacity and production schedule. If there is no idle resource left, then the order should be waited until idle resource is available. The RS model in this study is simple but can make the whole flow and output totally different. If one manufacturer (M1) has no idle resource for processing the order currently, then the resource status of partner (M2) will be checked. The order will be delivered to M2 if it has idle sharing resource for production and no order is waiting for production in M2. A flowchart of the traditional model and the RS model are shown in figure 1 and 2.

2.2. *Simulation model*

As it is almost impossible to run different experiments regarding RS in real-world system, discrete-event simulation (DES) modelling technology was used in this study to evaluate performance of traditional model and different scenarios of RS model. DES, which is one of the most widely used operations research and management techniques, concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time [9].

2.2.1. *DES model building*

The simulation model was built in Simio according to the conceptual model introduced in section 2.1. Two medium-sized garment manufacturers (M1 and M2) with similar production type but different resource capacities were modelled. The simulation model starts with the order arrival to the manufacturers and ends with the finish of garment production. As there are hundreds of types of products in garment production, it is not feasible to build the model on this basis. By analyzing relevant data and considering the objective of this study, garments were categorized based on their order frequency (OF), order size (OS) and production time (PT). PT is directly influenced by the type of garment; therefore three types of PT were defined, viz. long, medium and short. In garment industry, orders are rare to be in high OF with large OS or in low OF with small OS, therefore only the combination of high OF with small OS and low OF with large OS were considered in the DES model. Finally, six typical types of garments (P1-P6) were selected and defined for this model as indicated in table 1. All data were defined based on interviewing professionals in garment manufacturing industry. In the model, there are 40 units of resources (operators and machines) for garment production in M1 and 60 units in M2. To reduce the complexity of the model, the simulation model was developed under following assumptions:

1. All process in the model followed a First-In-First-Out principle;

2. The influence of raw materials supply was ignored;

3. Breakdown/failure for each process was ignored;

4. Production of each type of garment required same resource in the model;

5. Order was processed immediately if it was processed within the manufacturer; however, a two-hour delay was implemented in RS if the order is sent to partner.

Table 1: Product list and distribution

	P1	P2	P3	P4	P5	P6
OF (day)	High Un(5,15)	Low Un(30,50)	High Un(5,15)	Low Un(30,50)	High Un(5,15)	Low Un(30,50)
OS (piece)	Small Un(50, 1000)	Large Un(3000, 10000)	Small Un(50, 1000)	Large Un(3000, 10000)	Small Un(50, 1000)	Large Un(3000, 10000)
PT (minute)	Long Tri(80, 90,100)	Long Tri(50, 60, 70)	Medium Tri(35, 40, 45)	Medium Tri(25, 30, 35)	Short Tri(13, 15, 17)	Short Tri(8,10, 12)

* Un = Uniform distribution, Tri = Triangular distribution

2.2.2. *Experiment design and its realization in DES model*

As the initial objective of this study is to explore whether RS is beneficial, a traditional model (scenario 1) and a total RS model (scenario 2) were designed. Another objective of this study is to explore suitable type of garment for applying RS in manufacturing stage. Therefore, another six scenarios (scenario 3-8) were designed, where RS was applied in production of P1-P6 respectively. A complete experiment design is illustrated in table 2.

Table 2: Experiment design

Scenario	RS for P1	RS for P2	RS for P3	RS for P4	RS for P5	RS for P6
1	No	No	No	No	No	No
2	Yes	Yes	Yes	Yes	Yes	Yes
3	Yes	No	No	No	No	No
4	No	Yes	No	No	No	No
5	No	No	Yes	No	No	No
6	No	No	No	Yes	No	No
7	No	No	No	No	Yes	No
8	No	No	No	No	No	Yes

In this study, six types of garment have different PT. Therefore, it is not reasonable to compare the total yield (Y_T) of six products. In most cases, garment manufacturer can make more profits from products with longer PT. To neutralize the effect of PT, a factor K_p, which is calculated by the mean PT of

product p divided by minimum mean PT among all products, was introduced. Then, a benefit index (BI) = $\sum (Y_p * K_p)$, performed as KPI to show the potential overall benefit in each scenario, was designed for this study, where Y_p is the yield of product p in two manufacturers.

To realize different RS scenarios in DES model, a general script for programming in Simio is indicated as following:

M1.Capacity.Remaining= =0 && M2.Capacity.Remaining >(1-R_p)*M2.Capacity && $\sum$ M2.Order.Buffer.NumberWaiting = =0

R_p= 0, Traditional model for production of product p

R_p= 1, RS model for production of product p

3. Results

Based upon the DES model described in section 2.2.1, eight scenarios were run for duration of 20 weeks with 50 replications respectively. A standard working schedule of five days per week and eight hours per day was employed. An overview of experiment results is shown in table 3 and figure 3.

Table 3: Yield of P1-P6 and Total Yield

Scenario		Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_T
1	Mean	11079.40	32570.34	10895.80	32073.22	11385.82	34409.70	132414.28
	SD	1472.453	3843.222	1392.261	4943.929	1612.821	5135.975	6497.554
2	Mean	11050.98	34299.76	11219.28	33092.58	11592.10	35315.84	136570.54
	SD	1276.691	3578.985	1646.031	5544.957	1797.247	6390.337	6274.972
3	Mean	11215.78	33452.70	11339.40	33310.94	11236.94	34636.34	135192.10
	SD	1501.174	3564.356	1447.861	4408.345	1716.016	6509.319	6482.208
4	Mean	10993.82	33286.10	10933.88	32139.02	11359.58	33850.36	132562.76
	SD	1397.608	3459.663	1558.631	5027.385	1622.016	5609.459	6918.646
5	Mean	10833.08	33988.90	10962.80	32685.18	11256.08	33313.78	133039.82
	SD	1580.126	3990.618	1600.255	4914.563	1701.846	5284.038	5865.334
6	Mean	11124.98	32819.92	11055.78	33055.54	11375.00	34403.20	133834.42
	SD	1335.891	3705.145	1519.647	4722.491	1711.465	6111.260	6273.813
7	Mean	10862.26	32843.26	11246.62	33446.22	11744.12	32357.68	132500.16
	SD	1407.240	3921.118	1606.443	5235.339	1819.983	6225.637	7213.046
8	Mean	11121.64	32665.24	11165.46	32979.94	11474.10	35736.64	135143.02
	SD	1444.780	3997.147	1539.352	4651.606	1366.536	7320.659	7251.972

Scenario 1 played a benchmark role in the experiment. Firstly, the outcome of scenario 1 and 2 were compared to generally illustrate whether RS have a positive effect on Y_T and BI of all six types products. An independent sample T-Test (confidence interval (CI) = 95%) was conducted to show that there is significant difference in total yield (t(98)=3.254, p=0.002) and BI

(t(62.004)=7.344, p=0.000) between scenario 1 and 2. By comparing the mean value, a 3.14% increase of Y_T and a 3.23% increase of BI were obtained in scenario 2. It shows that RS, in terms of Y_T and BI, has an advantage than traditional model. Scenarios 3 to 6 were then respectively compared to scenario 1 to explore the effects when RS applied in different type of products. An increasing (decreasing) percentage of mean value of Y_p, Y_T and BI in each scenario compared to traditional model (scenario 1) is indicated in table 4. Surprisingly, based on the comparison of scenarios 3-8 to 1, there is no significant difference on Y_p, even on the yield of product applied RS. However, compared to scenario 1, scenario 3, 5, 6 and 8 have significant difference on BI, which means the overall benefit is influenced. Besides, significant effect on Y_T is obtained in scenario 3 and 8.
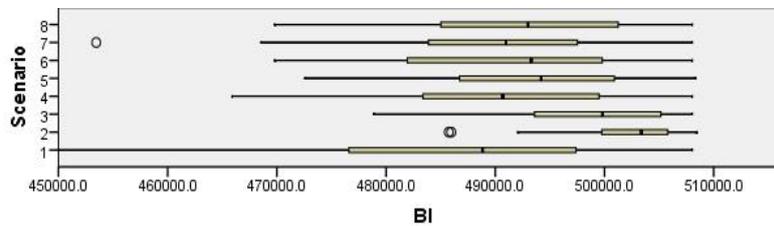

Figure 3. Boxplot of BI

Table 4: Increasing (decreasing) percentage

Comparison	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_T	BI
2 vs.1	-0.26%	**5.31%**	2.97%	3.18%	1.81%	2.63%	**3.14%**	**3.23%**
3 vs.1	1.23%	2.71%	4.07%	3.86%	-1.31%	0.66%	**2.10%**	**2.47%**
4 vs.1	-0.77%	2.20%	0.35%	0.21%	-0.23%	-1.63%	0.11%	0.67%
5 vs.1	-2.22%	4.36%	0.61%	1.91%	-1.14%	-3.18%	0.47%	**1.46%**
6 vs.1	0.41%	0.77%	1.47%	3.06%	-0.10%	-0.02%	1.07%	**1.12%**
7 vs.1	-1.96%	0.84%	3.22%	4.28%	3.15%	-5.96%	0.06%	0.76%
8 vs.1	0.38%	0.29%	2.47%	2.83%	0.78%	3.86%	**2.06%**	**1.28%**

* Bold represents significant difference by independent sample T-Test (CI = 95%, $p < 0.05$)

4. Discussion and conclusion

This study examined RS model in garment manufacturing stage of inter-organizational supply chain collaboration through a simulation model. The experiment results show that RS has a significant effect on increasing total yield and potential benefits of involved manufacturers. An extended investigation reveals that RS has no significant effect on the production of garment type P2 and P5. The total RS model presents the highest increase in overall benefit compared to other scenarios. However, if it is infeasible for manufacturers to

apply a total RS model, it is recommended to apply RS in production of garment type P1, as it shows the highest increase in terms of BI. Although the increasing percentage is not sufficiently high, RS model still reveals the potential of bringing great benefits to involved partners, as 1% increase of BI means approximately 10000 euros profit increase under the condition that $K_P=1$ stands for only 2 euros profit. Based on the case in this study, two medium-sized garment manufacturers may obtain a profit increase of over 30000 euros in 20 weeks if a total RS model is applied.

The results of this study also implicates that RS may be applied in other industries which have similar product type and process in production. The simulation in this study was developed on the basis of five assumptions in section 2.2.1; it is expected to develop a more complex and accurate model. There are still several interesting questions to be explored based on the model in this paper, e.g. the optimal combination of products for RS, the effect when more than two manufacturers are involved in RS model, the effect when RS is applied in other stage of supply chain. These are expected to be discussed in future study.

Acknowledgements

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