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Shifting orders among suppliers considering risk, price and transportation cost

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Abstract. Supplier order allocation is an important supply chain decision for an enterprise. It is related to the supplier's function as a raw material provider and other supporting materials that will be used in production process. Most of works on order allocation has been based on costs and other supply chain performance, but very limited of them taking risks into consideration. In this paper we address the problem of order allocation of a single commodity sourced from multiple suppliers considering supply risks in addition to the attempt of minimizing transportation costs. The supply chain risk was investigated and a procedure was proposed in the risk mitigation phase as a form of risk profile. The objective including risk profile in order allocation is to maximize the product flow from a risky supplier to a relatively less risky supplier. The proposed procedure is applied to a sugar company. The result suggests that order allocations should be maximized to suppliers that have a relatively low risk and minimized to suppliers that have a relatively larger risks.

1. Introduction

In today's competitive environment, companies have to optimize their business processes and improve overall performance of their supply chain. Every company is attempting to meet demand, improving the quality and reducing costs to optimize the business processes [1]. In most industries, cost of raw materials and components formed as a major part of production cost until up to 70% [2]. An efficient and effective supply chain depends on how good the company in selecting the suppliers that will provide materials. The right decisions would result in supplier being able to supply quality materials at the right time, and thus would be able to reduce not only purchasing cost but also enhance the competitiveness of the company [3]. This is related to the function of the supplier itself as a provider of raw materials and supporting materials that will be used in the production process. In procurement, companies have to pay attention on various costs including the procurement cost as well as transportation cost [4]. Transportation costs should be considered in determining the amount of the order and also the removal of order to improve the efficiency of the overall supply chain [5].

Some published works only focused on creating an optimal order allocation for each supplier to fulfill demands of each manufacturer [6][3][4][7][2]. Most of these works however only focus on minimizing overall supply chain cost, but neglect the importance of reducing risks. Among the few authors, Oguzhan and Erol [8] proposed a model that takes risk into account when allocating orders to suppliers. Risk factors are used to determine an optimal order allocation that can maximize orders to suppliers that have a relatively low risks. Each supplier has different risks, therefore it is necessary to analyze risk for each supplier, then optimize the order allocation by entering the risk factor in the model [9].

In this paper we present a model that take into account supply chain risks when making order allocation to suppliers. A two-stage model is applied. First, the optimization model is developed for order allocation without considering risk. The model is simply to optimize order allocation with an objective function of cost minimization. Second, a risk profile for each supplier is assessed. These risk profile values will then become the basis for shifting order allocation, mainly from higher risk suppliers to lower risk suppliers as long as the capacity is still available. To do risk assessment, a simple risk assessment tool is developed. This includes such risk as delivery delay, quality problems, etc. There are various risks that could happen in the supply chain. For an example of risk associated with supply chain, see for example Pujawan and Geraldin [10] who list various supply chain risks in a fertilizer company and Parenreng et al. [11] that present risks of tuna supply chain. We apply the procedure to a sugar company.

2. Proposed Procedure of Procurement Plan and Shifting Orders Among Suppliers

In this research, a case study has been conducted in a company producing sugar. One of the materials needed is soda caustic which is used in this paper as a case example. Tables 1 – 4 present some basic data that we will need as input parameters for the model. Table 1 presents capacity and unit price. Table 2 is demand data which represents three manufacturers. Table 3 presents' transportation costs and table 4 is the results of risk assessments. The higher the risk profile values, the higher is the risk associated with the corresponding supplier.

Table 1. Capacity and unit purchasing price of each supplier

Suppliers	1	2	3	4	Total
Capacity (C_i) per kg	31800	30200	29450	28800	120250
Unit Price (P_i) per kg	8300	8100	8400	8650	33450

Table 2. Demand of each manufacturer/ assembler

Manufacturers/assemblers	1	2	3	Total
Demand (D_i) –kg	38400	34600	29650	102650

Table 3. Unit Transportation Costs from suppliers to manufacturers/assemblers (T_{ij})

		Manufacturers/assemblers (j)		
		1	2	3
Suppliers (i)	1	63.64	55.45	70.45
	2	97.73	102.27	95.45
	3	65.91	56.82	72.73
	4	59.09	56.82	68.18

Table 4. Risk Profile of each supplier.

	Supplier 1	Supplier 2	Supplier 3	Supplier 4
Risk profiles(R_{Ti})	58	24	44	32

2.1 Initial Procurement Plan

The first stage is optimizing the procurement plan without consideration of risk profile. The procurement quantity of each supplier is obtained by the cost criterion.

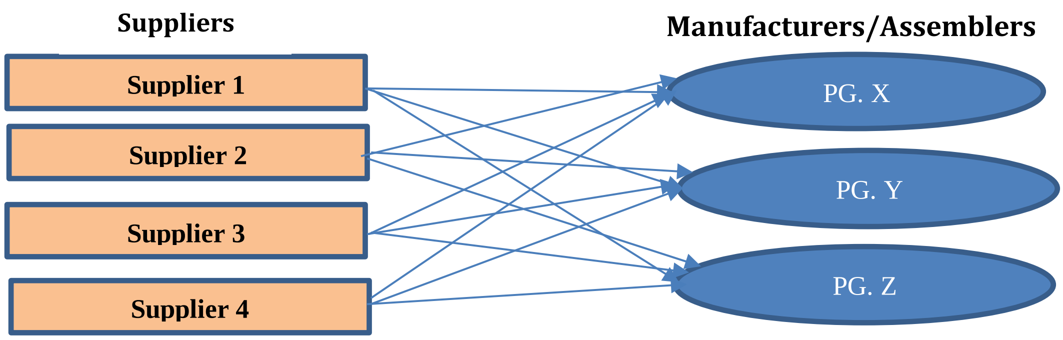

Figure 1. Supply Chain Network

Figure 1 shows the network where suppliers can supply any plant and each plant may allocate orders to the available suppliers. The optimization model below is used to find the optimum allocation decision. The objective function is to minimize the total cost which consists of purchasing costs and transportation costs. The constraints include consideration of capacity and demand. Supply from a supplier to any plant is limited by the capacity (2) and supply will not exceed the demand.

$$Mincost = \sum_{ieV_1} P_i \sum_{jeV_2} y_{ij} + \sum_{ieV_i} \sum_{jeV_2} T_{ij} * y_{ij} \quad (1)$$
$$\sum_{jeV_2} y_{ij} \leq C_i i \in V_1 \quad (2)$$
$$\sum_{ieV_1} y_{ij} \geq D_j i \in V_2 \quad (3)$$
$$y_{ij} \geq 0 \quad (4)$$

Where :

i	: suppliers	P_i	: unit purchasing price of supplier i
T_{ij}	: unit transportation cost from supplier i to manufacturer j	y_{ij}	: quantity to be transported from supplier i to manufacturer j
P_i	: unit purchasing price of supplier i	C_i	: capacity of supplier i
J	: manufacturers/assemblers	Dj	: demand of manufacturer j

After imposing the input parameters for both objective function and constraints, the model will have the following form.

Mincost = $8364y_{11} + 8355y_{12} + 8370y_{13} + 8198y_{21} + 8202y_{22} + 8195y_{23} + 8466y_{31} + 8457y_{32} + 8473y_{33} + 8709y_{41} + 8707y_{42} + 8718y_{43}$

Subject To

- $y_{11} + y_{12} + y_{13} \leq 31800$
- $y_{21} + y_{22} + y_{23} \leq 30200$
- $y_{31} + y_{32} + y_{33} \leq 29450$
- $y_{41} + y_{42} + y_{43} \leq 28800$
- $y_{11} + y_{21} + y_{31} + y_{41} \leq 38400$
- $y_{12} + y_{22} + y_{32} + y_{42} \leq 34600$
- $y_{13} + y_{23} + y_{33} + y_{43} \leq 29650$
- $y_{ij} \geq 0$

Optimal Solution of processing the formulation using LINGO software, as follows.

Table 5. Optimal Solution that minimizes total costs

	Manufacturers/Assemblers (j)			
Suppliers (i)	**1**	**2**	**3**	**Total (kg)**
1	0	31800	0	31800
2	550	0	29650	30200
3	26650	2800	0	29450
4	11200	0	0	11200
Total (kg)	38400	34600	29650	102650

Table 5 shows the optimal order allocation for each supplier to each manufacturer in accordance to the objective function, constrains and data of the case company. However, the order allocation in Table 4 has not considered the risk factor. In this study, risk factor is included in the procurement plan to reduce risk that will happen in the order allocation decision between supplier and manufacturer. Shifting of orders from higher risk suppliers to lower risk suppliers will be described in the following section.

2.2 Shifting Orders Based on Risk Profile Value

According to Table 4, Supplier 2 is most reliable and Supplier 1 is the most risky supplier. Product Transfer will be performed from a risky supplier to a relatively less risky supplier by using value in Table 4. As shown in Table 4, supplier 2 has the risk profile value of 24, which is the lowest. This value is then used to subtract risk profile values of other suppliers. The remaining risk profile values are then normalized as shown in Table 6. Since there will be no product transfer from supplier 1 to others, zero is the base value and the differences between the risk profiles of suppliers remain the same.

The product transfer network based on risk profiles of suppliers is presented in Figure 2 and parameters used in the model are presented in Table 6 and Table 7.

Table 6. Normalized Risk Value

Suppliers	**Total Risk Value**	**Relative total risk values**	**Normalized values**
Suppliers - 1	58	58-24=34	$R_{N1} =$ (34-0)/63=0.54
Suppliers - 2	24	0	$R_{N2} = 0$
Suppliers - 3	44	44-24=20	$R_{N3} =$ (20-0)/63=0.32
Suppliers - 4	32	32-24 = 9	$R_{N4} =$ (9-0)//63= 0.14
	Total	63	1

Table 7. Parameters used in the model

Suppliers	Number of Product procured according to min cost	Normalized risk Values	Number of Product to be transferred	Product to be kept in the supplier	Remaining capacity of the supplier
Suppliers -1	31800	0.54	17172	14628	0
Suppliers -2	30200	0	0	30200	0
Suppliers -3	29450	0.32	9424	20026	0
Suppliers -4	11200	0.14	1568	9632	17600

Illustration in Figure 2 below was made based on value and calculation in Table 6 which is the existing parameters on the model that including the risk. Shifting order illustration began from maximizing order for supplier that has the lowest risk profile value (Supplier 2). The same steps repeated for reallocating the excess supply order from Supplier 2 to the next supplier that has larger value of risk profile than Supplier 2 (in this case supplier 4).

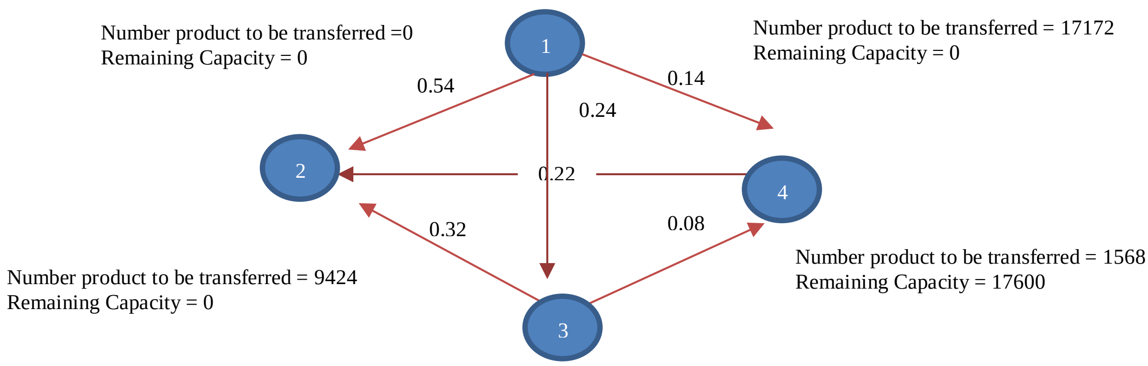

Figure 2. Illustration of shifting order between suppliers

Table 8. Recapitulation The Difference between the normalized risk values of suppliers (R_{ij})

R_{12}	R_{32}	R_{42}	R_{14}	R_{34}	R_{13}
0.54	0.32	0.24	0.14	0.08	0.22

The objective function of formulation (5) does not represent any quantity but since the objective function is maximization, it determines condition of transfer from a risky supplier to a less risky supplier. It is basically to maximize the transfer quantity based on the normalized risk value. The model to transfer the product from a risky supplier to a relatively less risky supplier is given by the model below. Constraint (6) is to determine the lowest and highest risky nodes for each supplier and (7) is condition that the difference between the quantity entering and leaving the node cannot be greater than the remained capacity of that supplier.

$$Max z = \sum_{ij} N_{ij} * Y_{ij} \quad (5)$$

$$\sum_{j}^{J} X_{ij} \leq Q_{Ti} \forall i \neq j \quad (6)$$

$$\sum_{k}^{K} X_{ki} - \sum_{j}^{J} X_{ij} \leq C_{Ri} \quad (7)$$

Where :

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N_{ij}	: Positive difference between the normalized risk		C_{Ri}	: remained capacity of supplier i
J	: indicates all suppliers less risky than supplier i		X_{ij}	: number of products to be transferred from supplier i to supplier j
Q_n	: quantity to be transferred less risky than supplier i			
K	: all suppliers more risky than supplier i			

Below is the transfer model incorporating the parameter values from the case company.

Max Z = $0.54*X_{12} + 0.32X_{32} + 0.24*X_{42} + 0.14*X_{14} + 0.08*X_{34} + 0.22*X_{13}$

Subject To

- $X_{12} + X_{13} + X_{14} \leq 17172$
- $X_{12} + X_{32} + X_{42} \leq 0$
- $X_{13} - X_{32} - X_{34} \leq 0$
- $X_{32} + X_{34} \leq 9424$
- $X_{14} + X_{34} - X_{42} \leq 17600$
- $X_{42} \leq 1568$
- $X_{ij} \geq 0$

The formulation is solved via LINGO and the optimal solution is presented in Table 9 below.

Table 9. Optimal Solution

R_{12}	R_{32}	R_{42}	R_{14}	R_{34}	R_{13}
0	0	0	17172	9424	0

Modified procurement plan in Table 10 was a comparison between optimal solution of data processing that not considering risk and optimal solution of data processing that including risk. Table 10 also shown order allocation changing in supplier 1, 3 and 4. Supplier 1 should decrease 54% of total supply order, supplier 3 should decrease 32% of their supply order; while supplier 4 should increase 42% of supply order. This condition occurred because supplier 1 and supplier 3 has relatively higher risk profile value so both of supplier 1 and 3 have to decrease their order allocation and reallocate their order to the supplier that has relatively less risk profile value (supplier 4), therefore supplier 4 should increase their supply order. There was no changing order allocation for suppliers 2 because the number of supply is already reach the maximum capacity.

Table 10. Modified Procurement Plan

Current Procurement Plan		Modified Procurement Plan		Decrease	Increase	Percentage (%)
Supplier 1	31800 kg	**Supplier 1**	14628 kg	17172 kg	0	(–) 54%
Supplier 2	30200 kg	**Supplier 2**	30200 kg	0	0	0%
Supplier 3	29450 kg	**Supplier 3**	20026 kg	9424 kg	0	(–) 32%
Supplier 4	11200 kg	**Supplier 4**	37796 kg	0	26596 kg	(+) 42%
Total	102650 kg	**Total**	102650 kg			

3. Model Verification

In this research, verification process was done by analyzing the output of the lingo. Referring to formula (1) until (7), the validity was obtained if the output of the model meets two criteria below:

1. The number of orders to be delivered by each supplier does not exceed the capacity of suppliers.
2. The number of orders for each supplier have to fulfill the demand of each manufacturer.

4. Conclusions

In this paper we present a model that can be used to allocate order to suppliers by considering both total costs and the risk. The first step is to allocate order to minimize cost. This initial solution is then used as a basis for transferring orders to lower risk suppliers by looking at both capacity constraints and risk profile of each supplier. The model was applied to a case study. The results suggest that the model has been able to include both objectives in making allocation decisions.

This procedure can be extended to multi-period, multi commodity and multi-echelon Supply Chain in further research. Risk analysis as parameter in determining order allocation for suppliers can use more parameters as supporting data to determine risk profile value. Processing data and analysis of order allocation can be further developed by using the integration of fuzzy method, AHP, revised analytic hierarchy process or TOPSIS fuzzy.

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