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Mixed Integer Linear Programming Model for Optimizing Batik Palembang Supply Chain Network

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The role of supply chain management or SCM (Supply Chain Management) is strategic for a company or industry in winning the competition. In order to face the competitive in the global market, businesses must improve the quality of the supplay chain operating performance, including the small and medium enteprises (SME) such as craftsmen *Batik* Palembang or *Jumputan*. We need to improve the performance of the supply chain, from raw materials up to the flow of product to the consumer. In this paper, we analyze and develop a mixed integer linear model to improve the performance of the craft industry supply chain network of *batik* Palembang. The concept of multi-product multi-multi-period facilities has been the author mentioned above, where the issue to be analyzed are arranged in the form of network flow problem with main purpose i.e. minimising total cost of supply chains. From our experiments we yield several managerial insights. First, networks with higher capacity can expect better reduction in total network cost. Second, networks with high fixed cost tend to increase the production level to maximum capacity.

Keywords: Batik Palembang, Supply Chain Management, Mixed Integer Linear Programming, Network Optimisation

1. INTRODUCTION

The modern business environment continues changing and become more competitive in term of network management, network design and product development as well as its distribution[1]. Supply chain management (SCM) has become an important competitive advantage aspect for the enterprise and the industry in winning the competition[2,3,4]. SCM is a set of techniques that are coordinated in planning and acquiring raw materials from suppliers, transforming them into final product, and delivering both products and services to the consumer. In SCM there are also activity of sharing information in a business network and logistics, planning and synchronizing the various resources and global performance measurement[4,5].

The main component of SCM is a collection of various business functions, i.e. procurement, manufacturing or servicing, and distribution. In industry, the activities of SCM are very crucial and important as supply chain ia a backbone of its activities. The chain could be seen as an interconnected network or supply chain network, which consists of suppliers, manufacturing centers, distribution centers, and retail outlets. In addition there are also a flow of raw materials, inventories, and finished goods at various supply chain and logistics network facilities[6].

Efforts to improve and optimize the supply chain network performance have been addressed by many researchers over the past few decades, and many classifications of problems have appeared in the literature as well as the approach used to solve the problems. Integrated supply chain system as well as the various

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techniques have been considered by a number of authors[7,8,9]. Recently, Bilir et.al. presented an integrated multi-objective supply chain network optimization model that involves facility location, transportation, and inventory decisions to minimize the supply chain risks as well as to maximize profit and sales[10].

More over, the optimal implementation of SCM have been proven to have significant and positive effect on customer satisfaction at relatively minimum cost[11,12,13]. This aspect is crucial in today's business operations. Mathematical optimization models are often used and was proven to find the optimal solution (e.g. least-cost) in supply chain operation as well as design. Optimization models can determine the optimal supply chain design while simultaneously considering a large array of possible supply chain configurations, production locations, supplier locations, production scales, transport modes or production locations[14].

The need to improve the performance of supply chain and logistics network is also in line with fastest business growth today as well as information and communication technology (ICT). The business paradigm has change to achieve a higher efficiency in process while their main objective is still give priority for customer satisfaction. Businesses today are operating in an integrated colaborative network. This achievement strongly affected by the application of information technology (IT) in SCM. IT is defined as a critical factor to enhance the supply chain performance and has proven to have a direct and indirect impact on the supply chain performance[15]. IT facilitates the process of enterprise integration, with businesses as well as other companies in the worldwide supply chain network [13,16].

For small and medium enterprises (SME), such as *jumputan* or *batik* fabric craftsmen Palembang, the implementation of SCM in their day-to-day operation is not as simple as easy process. There are various obstacles appear, such as: product quality issue, flexibility, and variety of products that they could make[12]. The implementation of SCM along with the application of IT in SME could increase their ability to innovate, either process or product innovation[17].

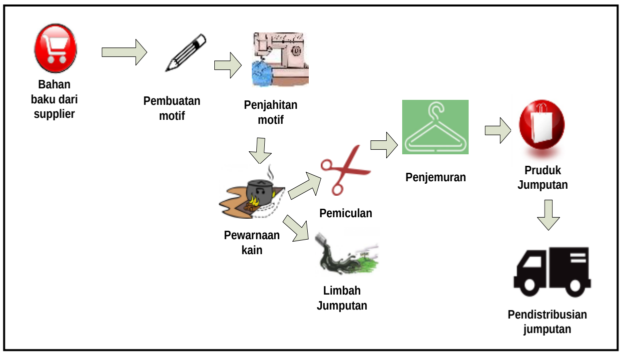

Fig 1. Flow process of *jumputan* production

The production of *batik jumputan* is categorized as a home industry, which consists of several processes (Fig 1.) namely: preparation of raw material, pattern making, coloring, drying, and finishing process. After the fabric is painted and given a motive by binding it, we put it into a color solution. After finishing all proceses, there are 2 product resulted, finished jumputan fabric and wasstewater. The production process is generally done on a regular basis i.e. once a week.

The craftsmen get raw materials from local suppliers. They are typically signed as the regular suppliers. Based on our survey in *Tuan Kentang Seberang Ulu I* Palembang, a craftsmen typically have more than three suppliers. Using this strategy, they could find an economist supplier who sell the ceapest price. Beside that also to anticipate if scarcity of raw materials occur.

Marketing process of jumputan as the final product is done through various channels, such as: local distributors, local stores at modern market, or buyers from outside of Palembang city. In addition, craftsmen also sell their products directly in the center of the production or in their home. Currently, some of them try to sell their product over the internet typically using social media applications, for example at Instagram Batiq_Colet_Jumputan.

From the observations and interviews at the jumputan production center, generaly the craftsmen want to develop their business, to increase the profit through efficiency processes, and to enhance their customer service quality. *Batik* craftsmen currently is not handle and manage some important information properly, such as information of product flow, cash or cost flow, and information flow. They often had difficulty in managing the order and estimating the availability of raw materials, as well as enhancing process efficiency. The selection of optimal supplier has not been made. They effort just simply to keep product available and order fulfillment without estimating the proper amount of raw materials purchased.

This paper discusses the concept and model of *jumputan* supply chain network optimization using SCM framework for minimising the total cost of the network in the form of mixed integer linear programming models. The main contribution of this paper is to examine the application of the concept of integrated SCM in optimizing and resolve the issue of SCM on batik jumputan Palembang.

2. PROBLEM DESCRIPTION

We consider a multi-product, multi-facilities, multi-periods supply chain network with the following features:

- l suppliers $S_1, S_2, \ldots, S_l$ where the product can be produced.
- m producers $P_1, P_2, \ldots, P_m$ where the product can be produced.
- n customer locations $C_1, C_2, \ldots, C_n$ where the jumputan product is required.
- Supplier capacities, producer capacities and storage capacities at producer points are known.
- Customer requirements at each centre are deterministic and known for each period. Furthermore, they must be met, that is backorders are not permitted.
- A planning horizon of T periods.
- A homogeneous fleet of vehicles to transport the product through the network.
- The transport capacity in this model is the limitation of the maximum quantity of product that can be carried out by the vehicle in period T.

- The limitation is due to physical constraints and availability of transport facilities, and
- The capacity of each transportation lines could be identical or different.

Figure 2 depicts the situation. In this model, it is assumed that there are a number of suppliers that supply the raw materials for batik jumputan production with a specific capacity over a period of time. There are also a number of producers, the craftmens, that produce multi product with a specific capacity of each product over a period of time. The set-up cost is a fixed cost on a lot-for lot basis, not dependent on the realized volume. Typically in each one production cycle. It is incurred at each production facility whenever the production runs. All products are assumed directly to be delivered to retail outlet. Products are delivered using a homogeneous vehicle fleet. The movement of vehicle incurs a variable transportation cost only.

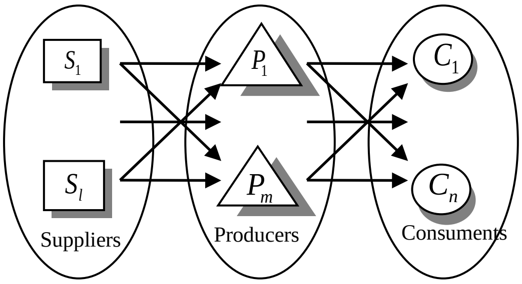

Fig. 2. Network flow model

The demand for batik jumputan in a period at each craftmens side is expressed as a forecasted real demand. It is assumed that the demands are given and backordering is not allowed. Each facility must keep a limited amount of inventory, with higher holding cost.

The problem is to determine a production and distribution plan over the planning horizon that meets the customer demands, satisfies the capacity restrictions and minimizes the total costs. The costs include: raw material supply, production, transportation, and inventory holding.

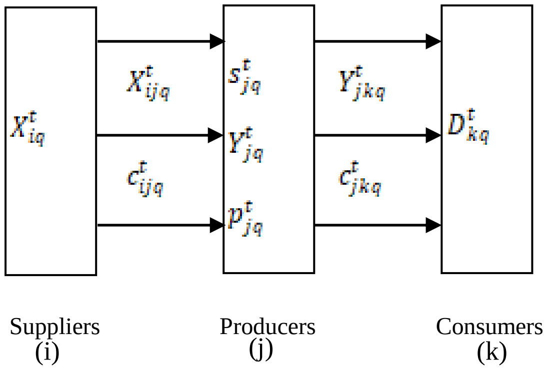

Fig. 3. Network model representative for single item problem

The above problem is represented in the form of a network (Figure 3). The network for the flow of products from their suppliers to production points and finally to customers is defined. This model then refers to three components: the suppliers sites, indexed by i, the craftmens, indexed by j, and the customers, indexed by k. A mixed integer linear programming (MILP) model is developed to address the problem. The model comprises cost components from Suppliers to Producers, Craftsmens, and cost components from Producers to Customers.

2.1. Model Parameters

Supply chain network problem studied in this paper are formulated using the following notation:

- T: number of periods in the planning horizon.,
- *l* : number of suppliers where product can be supplied.
- *m* : number of producers where the product can be produced.
- *n* : number of customer locations where the product is required.
- *q* : number of type product which can be produced in producers in period of time

For each product q, we define the following notation:

- R_{iq}: capacity of supplier i to supply material for product q in period t, i = 1,2, …, l; q = 1,2, …, q; t = 1,2, …,T.
- P_{jq} : capacity of producer craftsmens j to produce product q in period t, j = 1,2, …, m; q = 1,2, …, q; t = 1,2, …,T.
- D_{kq}^t: demand for product q of customer k in period t, k = 1,2, …, n; t = 1,2, …,T; q = 1,2, …, q.
- s_{jq}^t: set-up cost for product q at producers j in period t, j = 1,2, …, m ; t = 1,2, …, T; q = 1,2, …, q.
- p_{jq}^t: unit cost of production for product q of producer j in period t, j = 1,2, …, m; t = 1,2, …, T; q = 1,2, …, q.
- c_{ijq}^t : unit cost of transportation to deliver product q from supplier i to producer j in period t, i = 1,2, …, l; j = 1,2, …, m; t = 1,2, …, T; q = 1,2, …, q.
- c_{jkq}^t : unit cost of transportation to deliver product q from producer j to customer k in period t, j = 1,2, …, m; k = 1,2, …, n; t = 1,2, …, T; q = 1,2, …, q.

2.2. Decision Variables

Decision variabels of our model are as follows:

- X_{iq}^t: amount of product q supplied from supplier i in period t,
- Y_{jq}^t: amount of product q produced at producers j in period t,
- X_{ijq}^t: amount of raw material of product q transported from supplier i to producer j in period t.
- Y_{jkq}^t: amount of product q transported from producer j to customer k in period t.
- z_{jq}^t: a binary variable that equal to 1 if there is a production set-up for product q at producer j in period t.

2. PROBLEM FORMULATION

Our problem is to minimize the total cost of supply, production, transportation, and distribution over the T periods. The model assumes no starting inventory. The problem can be expressed as follows:

Minimize:

$$\sum_{t=1}^{T}\sum_{j=1}^{m}\sum_{q=1}^{q}\left(Y_{jq}^{t}p_{jq}^{t}+s_{jq}^{t}z_{jq}^{t}\right)+\sum_{t=1}^{T}\sum_{i=1}^{l}\sum_{j=1}^{m}\sum_{q=1}^{q}X_{ijq}^{t}c_{ijq}^{t}+\sum_{t=1}^{T}\sum_{j=1}^{m}\sum_{k=1}^{n}\sum_{q=1}^{q}Y_{jkq}^{t}c_{jkq}^{t} \quad (1)$$

where:

$$z_{jq}^{t}=\begin{cases}1, & if\ Y_{jq}^{t}>0\\ 0, & else.\end{cases}$$

Subject to:

$$Y_{jq}^{t}\le D_{kqT}^{t}z_{jq}^{t} \quad , \quad \forall j,q,t \quad (2)$$
$$\sum_{jq}Y_{jq}^{t}\le P_{j} \quad , \quad \forall j,t \quad (3)$$
$$\sum_{jq}Y_{jkq}^{t}\le Y_{jq}^{t} \quad , \quad \forall j,t \quad (4)$$
$$D_{kq}^{t}\le\sum_{jq}Y_{jkq}^{t} \quad , \quad \forall k,t \quad (5)$$
$$D_{k}^{t}\le\sum_{q}D_{kq}^{t} \quad , \quad \forall k,t \quad (6)$$
$$\sum_{jq}X_{ijq}^{t}\ge Y_{jq}^{t} \quad , \quad \forall j,t \quad (7)$$
$$\sum_{q}X_{ijq}^{t}\le T_{ij}^{t} \quad , \quad \forall i,j,t \quad (8)$$
$$\sum_{q}Y_{jkq}^{t}\le U_{jk}^{t} \quad , \quad \forall i,j,t \quad (9)$$
$$Y_{jq}^{t},X_{ijq}^{t},Y_{jkq}^{t}\ge 0 \quad (10)$$
$$P_{j}\ ,R_{i}\ \ \ge 0 \quad (11)$$
$$z_{jq}^{t}=0\text{ or }1. \quad (12)$$

The objective function (1) represents the total costs over the T periods. In our model, we combine fixed cost and variable cost as a decision trade-off in satisfying the consumer demand.

Constraint (2) assures that a setup cost will be incurred if there is product type q produced in producer j. Note that D_{kq}^{t} is the total demand for commodity q from period 1 to T. Constraint (2) will assure the value of z_{jq}^{t} equal to 1 if Y_{jq}^{t} positive.

Constraint (3) and (4) restrict the maximum number of product jumputan q produced at producers j in period t, and the maximum amount of jumputan delivered prom producer j to consument k in period t.

Product flow from producer j to consument k must satisfy total demand as indicated by (5). Constraint (6) indicate the total product flow from various producers j to consument k. Total product sent by producers must satisfy consumer demands.

Constraint (7) requires that total row material from sipplier i must satisfy the production requirement at producers j in period time t. Constraints (8) and (9) indicate transportation capacity restrictions which are the maximum number of raw materials can be transferred from supplier i to producer j and from producer j to customer k.

Constraints (10) and (11) is the non-negative values. Constraint (12) is 0-1 variable where the value of z_{jq}^{t} will be 1 if Y_{jq}^{t} is positive.

4 COMPUTATIONAL RESULT

In this section, we describe the computational experience in solving our models. We generate several test data to demonstrate the applicability of the mathematical formulations above. We used small sample data sets and simulate production data in object, ie: 7 network points comprises 2 suppliers, 3 producers and 2 consuments. T period observation is 12 period. There are 2 type of batik jumputan product. Production capacity, supplier capacity and consumer demand are set random. Setup cost, production and transportation cost are random also.

Analysis was done using CPLEX solver by performing sensitivitas analysis using several schenario. We observe the effect of capacity constraints changing in supplier and production facilities in handling various demand models, with transportation capacity and also without.

Our first observation is the total network cost change as the capacities of producers change with no transportation capacity contraint (constraint (8) and (9)). By setting the value of setup cost low and satisfying low demand, it is observed that the total cost reduces by 0.38% as the production capacity increase. On the other hand, when satisfying high demand the total cost reduces by 0.40%. The effect of total cost reduction is getting higher when the value of setup cost is high.

The other observation is using transportation capacity contraint in our model. The impact of transportation capacity on total network cost and product movement from producers to distributors as well as suppliers is observed. The transportation capacity used is a maximum amount of products that are allowed to flow in transportation network per period. From computational result it is observed that as the capacity of the transportation line decreases the total network cost increases. Our models tend to create more productions.

Tabel 1 and Tabel 2 show that total network cost is affected by transportation capacity. The lower trancportation capacity the higher total network cost. On the other side, value of setup cost will affect the producers decision to find an eficient processes with eficicent cost also. Using this model, the craftsmens will have better capacility in handling fluctuative raw material price and production cost.

Tabel 1. Effect of setup cost and transportation capacity on the average value of total network cost increment

Setup cost	Transportation capacity	Producer Type 1	Producer Type 2
	LOW	1.62%	2.02%
LOW	MEDIUM	0.08%	0.13%

	HIGH	0.00%	0.01%
HIGH	LOW	4.36%	5.38%
	MEDIUM	0.07%	0.13%
	HIGH	0.00%	0.03%

Table 2. Total cost increment when handling demand variation

Transportation capacity	LOW SETUP COST		HIGH SETUP COST	
	Producer Type 1	Producer Type 2	Producer Type 1	Producer Type 2
LOW	2.45%	2.45%	3.27%	3.10%
MEDIUM	2.81%	2.78%	2.02%	2.21%
HIGH	2.83%	2.79%	2.07%	2.25%

Tables 2 shows the value of total cost change as a result of demand changing and producer capacity increment. Various total cost reduction are observed as a result of producer capacity increases. On the other hand, it is also observed that the effect on using low production setup cost in handling increasing demand is better than using a high setup cost facillities, if the transportation capacity is low. When the transportation capacity set medium or high, using higher setup cost in production plants is prefer than lower setup cost as resulting lower total cost increment.

5. CONCLUSIONS

In this paper chapter we discussed the capacitated multi-items, multi-facilities, multi-periods supply chain network problems. We considered fixed-charge production costs with supply, production, distributiion, and linear transportation costs. We also studied the problems associated with capacities. Mixed integer linear programming models were developed for these problems. The models that we studied provide useful tools for addressing questions that arise in managing supply chain networks. In order to study the problems, we generated small test problems in scenarios. We did our experiments by varying the capacity and cost.

From our experiments we yield several managerial insights. First, networks with higher capacity can expect better reduction in total network cost. Second, networks with high fixed cost tend to increase the production level to maximum capacity

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