Chemical Supply Chain Network Optimization

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ABSTRACT

The chemical company, Apollo (fictitious name) is a multinational company specializing in chemical manufacturing. Due to the complexity of the chemical manufacturing industry, the company aims to develop a network optimization model considering factories that operate with multiple suppliers, multi-products, multiple bill of materials, multi-stage facilities, and unique product classifications. The main objective of this project is to develop a Linear Programming based optimization model to help the company in their decision making and assist the company to minimize cost while fulfilling customer demand. Electronic spreadsheets have been developed to assist the company in decision making based on data provided by the company.

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KEY LESSONS

1. We capture the complexity of chemical manufacturing industry with substitutable products and multiple bill of materials.
2. We develop a supply chain network optimization model to address the complexity of the chemical manufacturing process.
3. We examine and analyse the model using Excel Solver.

INTRODUCTION

The research draws attention following Steve (2017) who observes that the chemical industry is estimated to spend more than $150 million on supply chain planning software like SAP and Aspen Tech. Supply chain planning in chemical industry is more complicated as compared to other industries as a consequence of different manufacturing approaches such as separation, blending, reaction and packaging of finished goods. Apollo Corporation is a multinational company aiming to develop a supply chain network optimization model. Network optimization is challenging as the operations are characterized by several types of raw materials (multi-source), varying bill of materials (BOM), multiple processes such as activation, drying, milling, packing, and multiple facilities which transform the semi-finished goods to finished goods and deliver to markets. Both product and process complexities lead to challenges in allocating production quantities to each plant and obtaining optimal raw materials from various suppliers.

Given this complexity, the company aims to answer questions such as what is the optimal network set up considering supply, manufacturing, distribution capabilities, and transportation costs. What is the optimal BOM to use in order to minimize costs by comparing costs and capacities of different supply alternatives?

To address the above questions, we formulate the problem as a supply chain network optimization model. The output of the model addresses the above research questions, in addition to providing tactical solutions to simulate different scenarios for the company. The implementation of the optimization model is to assist the company to have minimum cost to serve while fulfilling customer demand.

EXTANT KNOWLEDGE

Chopra and Meindl (2016) note that supply chain is the process of transforming raw materials into finished products and getting them to the customers. Supply chain planning is critical as the main objective is to balance the supply and demand by coordinating assets to optimize the delivery of goods, services and information from supplier to customer. System optimization is often adopted to address supply chain issues such as planning, multi-stage, and multi-product optimization and determine the lowest cost of the network by considering plant capacity constraints.

RESEARCH APPROACH

The research approach involves mapping of factory processes, data collection, model formulation, cleansing and fitting data to the model, developing optimization model, validating pilot model, and model implementation. In our problem, the company has 4 different plants namely, IDCD, IDCE, IDCF, IDCH and the material flow from supplier to customer is shown in Figure 1. It is important to note that semi-finished products move from IDCD to IDCF or IDCH and IDCE to IDCF or IDCH. The optimization model considers cost at each stage of material movement from supplier to customer to provide lowest cost to serve to customer in order to satisfy the demand. Objective function in the optimization model is formed by including raw material cost, processing cost, intercompany transportation cost for semi-finished products and finished goods transportation costs to customer. Pilot cost minimization optimization model results are shown in Table 1 and Profit maximization optimization model results are shown in Table 2. Both Cost minimization and Profit maximization model are tested in two scenarios. 1st model is without plant capacity constraint and 2nd model tests a scenario with a production line closed. 2nd model is constructed to understand the criticality of capacity of a plant.

Figure 1: Apollo Corporation Network Diagram

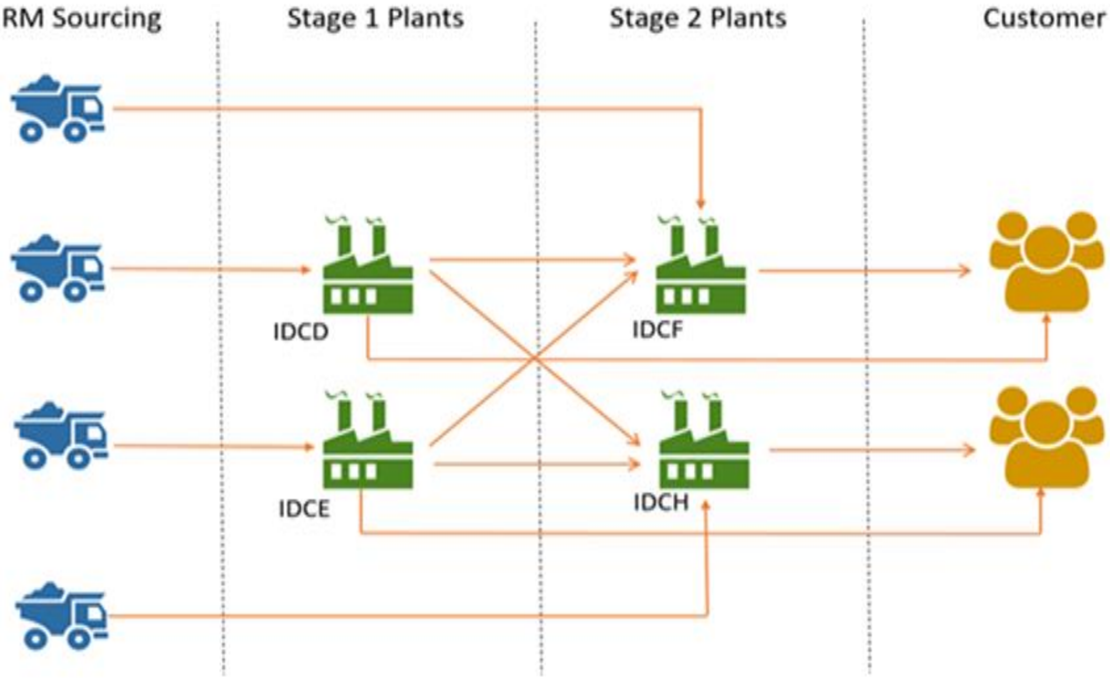

Table 1: Cost Minimization model result

Cost Minimization	Model 1		Model 2	
Total Cost to Serve	**4,192,450,319**	**100%**	**5,402,249,990**	**100%**
Cost Breakup	**IDR (Currency)**	**% contribution**	**IDR (Currency)**	**% contribution**
RM Cost	1,667,140,000	40%	4,265,030,000	79%
FG Processing Cost	469,576,000	11%	469,799,500	9%
FG Transportation Cost	550,225,000	13%	550,225,000	10%
SFG Processing Cost	1,263,943,694	30%	58,132,990	1%
SFG Transportation Cost	241,565,625	6%	59,062,500	1%
Total Cost	**4,192,450,319**	**100%**	**5,402,249,990**	**100%**

Table 2: Profit Maximization model result

Profit Maximization	Model 3		Model 4	
Max. Profit	**2,187,384,734**		**1,580,125,036**	
Total Revenue	4,601,575,000		3,550,075,000	
Total Cost	2,414,190,266	100%	1,969,949,964	100%
Cost Breakup	**IDR (Currency)**	**% Contribution**	**IDR (Currency)**	**% Contribution**
RM Cost	1,082,671,613	45%	1,470,765,452	75%
FG Processing Cost	319,908,307	13%	255,755,092	11%
FG Transportation Cost	273,446,000	11%	214,311,000	9%
SFG Processing Cost	626,353,972	26%	29,118,420	1%
SFG Transportation Cost	111,810,375	5%		0%

RESULTS

In the pilot model, we notice that 4.1 billion IDR is the lowest cost to meet the demand without any production line capacity constraint and 5.4 Billion IDR is the lowest cost with production plant capacity constraint as shown in Table 1. The RM cost is 40% of the total cost and semi-finished goods processing cost is 30% and model chooses the bill of materials with semi-finished goods so that it can be processed in house to have total lowest cost possible.

In Model 2 the total cost to serve increases to 5.4 billion IDR once production line is closed in the model. We notice that raw material cost contribution increases significantly to 79% and semi-finished goods processing cost is reduced to almost 1%. This is because the model suggests to go with different BOM which does not require internal processing of raw materials and reduces the processing time in plant but increases costs in terms of purchasing raw materials.

So the total cost to serve is increased by net 1.2 billion IDR. Similarly, in Profit maximization base model is without any production line capacity constraint which is Model 3 and Model 4 is with a line closed. We note that profit is reduced in Model 4 than in Model 3. All other cost contributions remain similar to cost minimization model. Company can take this information forward for S&OP and discuss the importance of servicing the customer vs generating profit for the company.

While the model is built in MS Excel, the scalability of the model with large data remains challenging as solver engine takes a long time to generate optimization results.

This cost minimization model will help the company to reduce their operational cost significantly by providing prescriptive network setup for fulfilling customer demand while using resources effectively.

REFERENCES

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