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An LP Model for Optimizing a Supply Chain Management System for Steel Company

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***Abstract*— In this research, we have developed a linear programming formulation to describe Qatar steel manufacturing supply chain from suppliers to consumers. The purpose of the model is to provide answers regarding the optimal amount of raw materials to be requested from suppliers, the optimal amount of finished products to be delivered to each customer and the optimal inventory level of raw materials. The model is validated and solved using GAMS software. Sensitivity analysis on the proposed model is conducted in order to draw useful conclusions regarding the factors that play the most important role in the efficiency of the supply chain.**

***Index Terms*— Supply chain management, Linear programming, GAMS software, Sensitivity analysis**

I. INTRODUCTION

Supply chain management (SCM) has attracted ever increasing attention over the last two decades in response to a highly competitive and globalized marketplace and the pressure to cut the cost of creating and delivering value to customers. A supply chain is an integrated system which synchronizes a series of inter-related business processes in order to:

1) Acquire raw materials and parts.
2) Transform these raw materials and parts into finished products.
3) Add value to these products.
4) Distribute and promote these products to either retailers or customers.
5) Facilitate information exchange among various business entities, e.g. suppliers, manufacturers, distributors, third-party logistics providers, and retailers.

Figure 1 shows the main elements/stages in a supply chain network from raw materials' sources to customers.

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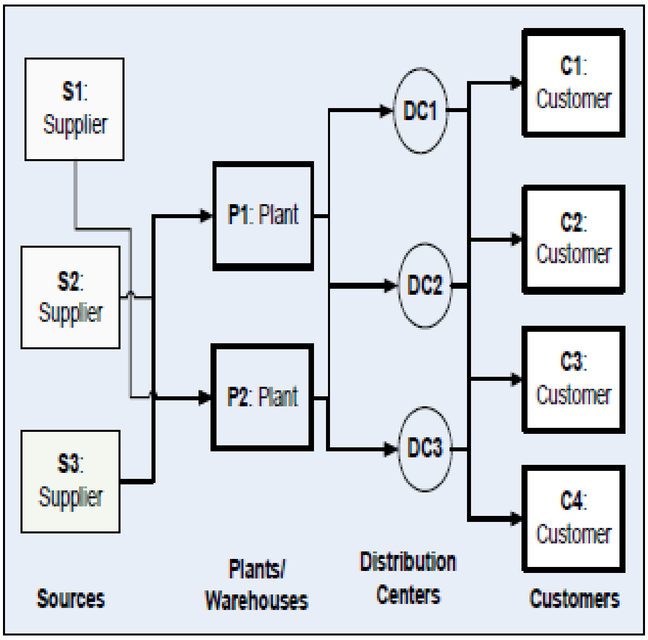

Figure 1: A generic framework for a supply chain network

The proposed approach develops a comprehensive deterministic LP model to minimize the annual cost of the steel company's supply chain including transportation, inventory, and distribution. The viability of decision variables resulted from the solution of the LP model is verified in a dynamic and stochastic Discrete Event Simulation (DES) model of the supply chain. The model is set to produce a specific set of Key Performance Indicators (KPIs) that are developed to characterize the supply chain performance in terms of responsiveness, efficiency, and utilization. Finally, simulated annealing is used to set values to model variables that achieve a multi-criteria tradeoff of the defined supply chain KPIs.

II. LINEAR PROGRAMING MODEL

A linear programming model representing Qatar steel manufacturing supply chain from suppliers to consumers is formulated. The model is validated and solved using GAMS software. Sensitivity analysis on the proposed model is conducted in order to draw useful conclusions regarding the factors that play the most important role in the efficiency of the supply chain.

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The sequences of processes that are performed to manufacture the final products sold by Qatar Steel to its consumers are shown in Figure 2.

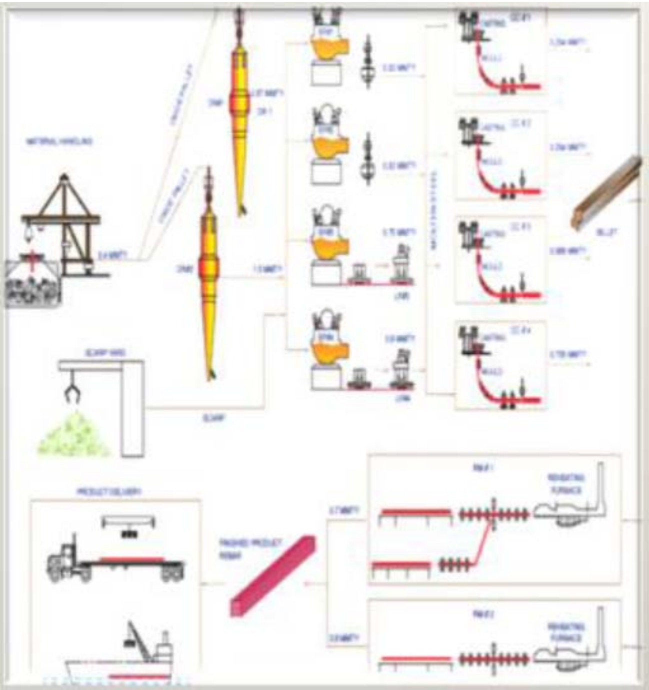

Figure 2: An overview of QS site operations

The representation of the entire supply chain is based on a linear programming formulation, which decides on the amounts of raw materials to be requested from each supplier, as well as the optimal distribution of finished products to consumers, based on product delivery time, maximum demand and price for each consumer. The aim of the model is the maximization of the company's profit.

To formulate the linear programming model, we considered 4 product types; namely DR, HB, Billets and rebar, 6 customer sites; Qatar, UAE, Oman, Bahrain, Saudi Arabia and Kuwait, 5 suppliers including Sweden, Brazil, Bahrain, Canada and Oman and 2 scrap suppliers cites from Qatar. Furthermore, the processing units are integrated by type, adding up to 4 units, namely the Direct Reduction (DR), the electric Furnace (EF), the Continuous Casting (CC) and the Rolling Mill (RM).

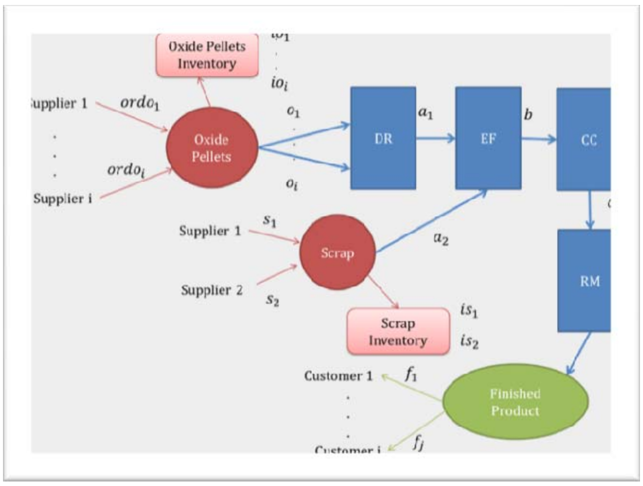

Figure 3: Relationship between the involved parties

Objective function:

$$\max profit = \sum_{j=1}^{6} p_i \cdot f_i - \sum_{i=1}^{5} c_i \cdot ordo_i - [s_1 \cdot cs_1 + s_2 \cdot cs_2] - \sum_{i=1}^{5} ic_i \cdot io_i - [ic_3 \cdot is_1 + ic_4 \cdot is_2]$$

Subject to the following constraints:

$$minpurchasedoxidepellets \leq \sum_t ordo_i \leq maxpurchasedoxidepellets \quad (1)$$

$$minpurchasedscrap \leq \sum_t ords_i \leq maxpurchasedscrap \quad (2)$$

$$a_1 = \sum_{i=1}^{5} dr_{1i} \cdot o_i + dr_{13} \cdot s_1 + dr_{14} \cdot s_2 \quad (3)$$

$$a_2 = \sum_{i=1}^{5} dr_{2i} \cdot o_i + dr_{23} \cdot s_1 + dr_{24} \cdot s_2 \quad (4)$$

$$b = ef_1 \cdot a_1 + ef_2 \cdot a_2 \quad (5)$$

$$d = cc \cdot b \quad (6)$$

$$fp = rm \cdot d \quad (7)$$

$$f_1 + f_2 \leq fp \quad (8)$$

$$io_i = o_i - ordo_i \quad (9)$$

$$is_i = s_i - ords_i \quad (10)$$

$$\sum_t o_1 + o_2 \leq capacity\ DR \quad (11)$$

$$\sum_t a_1 + a_2 \leq capacity\ EF \quad (12)$$

$$\sum_t b \leq capacity\ CC \quad (13)$$

$$\sum_t d \leq capacity\ RM \quad (14)$$

The objective function aims at maximizing the profit over one year, which consists of the following terms: the income from selling the final products to consumers, minus the cost of purchasing the raw materials, minus the cost of holding raw materials in inventory. The first two constraints guarantee that the orders placed for raw materials from all suppliers will be within the given range of minimum and maximum quantities. Constraints (3) – (7) provide the output levels of materials from every processing unit, based on the input. Constraint (8) guarantees that the amount of final product sent to customers will not exceed the existing amount at that time. Constraints (9) and (10) define inventory levels for raw materials. Finally, constraints (11) – (14) ensure that capacity of every processing unit is not violated.

III. PRELIMINARY RESULTS AND ANALYSIS

The initial model is implemented in the GAMS software using the available data as parameters. It is possible to conduct an analysis regarding the optimal levels of raw materials to be purchased and finished products to be

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supplied to customers. As a preliminary analysis, a fixed demand is assumed for each customer and based on this demand the amount of raw materials to be supplied will be decided on, taking into consideration the processes and the capacity of the units.

In the following analysis, the amount to be purchased from each supplier is determined from the model, based on an alternating level of demand from each customer. This is expected to yield useful results, due to the difference in costs from different suppliers and prices for different consumers. Three cases are presented; the first case reflects a low demand, the second case an average demand, while the third case reflects a high demand. Note that the graphs refer to oxide pellets as supply and product rebar as demand. Other raw materials have been included in the model, but for only oxide pellets are demonstrated for sake of simplicity.

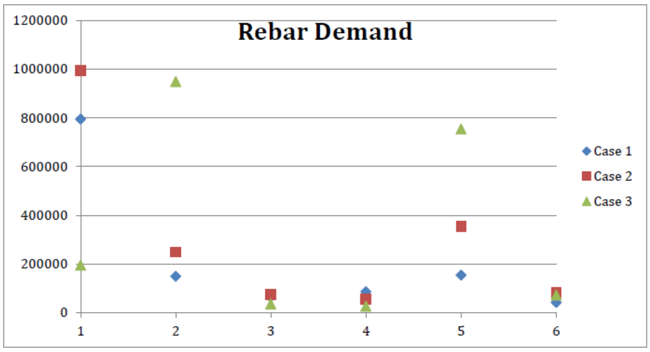

Figure 4: Rebar Demand

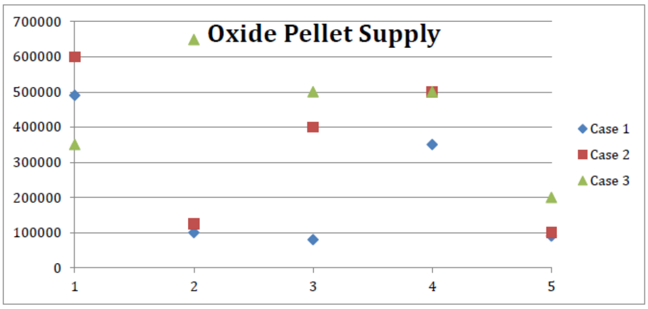

Figure 5: Oxide Pellet Supply

The total demand in each case, as well as the profit, is summarized in the following table:

Table I: The total demand and profit

	Total Demand	Profit(in billions of units)
Case 1	1287926	20.5
Case 2	1707926	54.3
Case 3	2027926	31.6

It is worth noting, that while in case 3 the highest amount is sold, the profit is not greater than in case 2, because the higher the demand, the higher the need to purchase the raw materials in large quantities even from the costliest suppliers. However, these values for the levels of raw materials constitute the optimal values, meaning that other levels would potentially lead to lower profit.

IV. CONCLUSION

We have presented an approach for optimizing a supply chain management system for a Steel Company. The proposed approach develops a comprehensive deterministic LP model to minimize the annual cost of the steel company's supply chain including transportation, inventory, and distribution.

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