Optimal Production and Distribution for Efficient Supply Chains

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ABSTRACT

This paper determines the optimal configuration of a production and distribution network which is subjected to economic constraints. The network has restrictions on production and facility capacity. The economic constraints are inclusive of production costs and transportation costs. The total costs of these two areas i.e. production and distribution need to be optimized and the demand has to be satisfied. The optimal production will be determined by the total number of these products produced at the factory and the production cost of each product. To optimize the costs, a mathematical model was designed and solved with the help of a software package. Each customer base is required to only receive their products from one warehouse. Before a case study can be done, randomly generated data had to be used to check for the effectiveness of the model. To optimize the costs, a mathematical model was designed and solved with the help of a software package. The problem is to be solved using a mixed integer linear program (MILP) which requires a binary.21 different scenarios will be were investigated in order to check for effectiveness.

Keywords Production, Distribution, MILP

1. Introduction

There has been a growth in markets and sourcing options. A lot of companies have decided to focus on their core businesses as a result of this. Strategic decisions can have a great impact on the company. A supply chain network consists of existing or potential manufacturing facilities that is factories, warehouses and customer/distribution centers. Supply chain are becoming increasingly complex.

Transportation costs, warehouse contracting and safety stock handling were the main features of the problem. De Laporte et al. (2019) stated that policy initiatives in agricultural prices have led farmers to consider alternatives to current cropping practices. In the context of land quality and feedstock supply, the authors assessed the impacts of site selection, transportation and opportunity costs on a bioethanol production plant. other models of biomass production and transport.

Tshivhase and Vilakazi 2018) focused on the mining industry which is also a strong contributor of carbon emissions. Tshivhase and Kainuma (2019) addressed the emissions of carbon into the atmosphere by proposing a single period, multi-supplier low carbon mixed integer model. This model was proven to reduce carbon emissions in the supply chain and also find the optimum distribution levels among different facilities including factories. Tshivhase and Kainuma (2018) identified the existing literature gaps and possible future research focus with respect to carbon emission reduction by looking at literature done between 1995 1nd 2018. In the 1990s due to improved computer models a consensus was formed that stated that greenhouses gases were deeply involved in most climate changes and emissions were bringing discernable global warming. During the same decade, scientific research in emissions has included multiple disciplines.Miranda et al (2018) stated that the number and location of visited docks at the islands have a relevant effect on maritime transportation costs. They additionally impact transportation costs incurred for moving the household waste or freight from within the islands to the selected docks. Baller et al. (2019) stated that suppliers manage the inventory of its customers and arranges for the transportation of the replenishmnets. So the supplier bears both the inventory holding and transportation costs. They strive to minimize the costs by optimizing inventory and shipping decisions. Tshivhase and Kainuma (2019) reviewed the literature of what has been studied with respect to carbon emissions and also identify the gaps in the literature using a systematic literature review approach. Content analysis was used to categorize existing literature on the various topics and methods over time in the area of carbon emissions in the supply chain.

Hanbazazah et. al. (2019) states that a key challenge in management is to minimize costs while meeting customer satisfaction levels. This challenge is greater in transportation where costs tend to increase with reduced delivery lead times.

The rest of the sections in this paper are: Section 2 for Model Development. Section 3 which represents Results. Section 4 is the conclusions.

2. Model Development

2.1. Description of the model

A simple supply chain is considered and it consists of the plant, warehouses and the customer outlets. Only one type of transportation option is considered. This network conspires optimal operation of a production and distribution network. The network consists of a number of factory sites at various locations, a number of warehouses and customer centers. The description of the mathematical model is explained in this section. A simple supply chain is considered and it consists of the plant, warehouses and the customer outlets. Only one type of transportation option is considered. Operational costs include those associated with production and handling at the centers. Products are produced at the plant. There is also a certain amount of demand at the at the customer centers. The plan is to optimize the model such that the total costs including transportation costs are minimized.

The model is shown using the parameters below:

Table 1: Parameters

dem_s	Demand at the customer outlet
dem_x	Demand of facility x϶{p,w}
rc_p	Unit raw material costs from supplier to the plant
tc_{pw}	Unit transportation cost from the plant to the warehouse
tc_{ws}	Unit transportation cost from warehouse to the customer outlet
dis_{xy}	Distance between facility x϶{p,w} and facility y ϵ{w,s}
fc_x	Fixed cost of opening facility x϶{p,w}
vc_x	Unit variable cost per unit at facility x϶{p,w}
in_w	Expected inventory at the warehouse w
r_{num}	Number of units of raw material a required for one product
cap_x	Capacity of facility x
cap_y	Capacity of transportation option
$h_p \in \begin{cases}1\\0\end{cases}$	Binary, 1 if plant p is open otherwise its 0
$h_w \in \begin{cases}1\\0\end{cases}$	Binary, 1 if warehouse w is open otherwise its 0
pr_q_{pw}	Quantity of products transported between the plant and the warehouse
pr_q_{ws}	Quantity of products transported between the warehouse and the customer outlet

The objective model is formulated in the next steps:

$$Obj_1 = CP + CT + CH \tag{1}$$

$$CP = CF + CV \tag{2}$$

$$CF = \sum_p fc_p h_p + \sum_w fc_w h_w \tag{3}$$

$$CV = \sum_p vc_p dem_p + \sum_w vc_w dem_w \tag{4}$$

$$CT = \sum_p \sum_w pr\_q_{pw} tc_{pw} dis_{pw} + \sum_w \sum_s pr\_q_{ws} tc_{ws} dis_{ws} \tag{5}$$

$$CH = \sum_{w.} h_w in_w \tag{6}$$

$$dem_p = \sum_w pr\_q_{pw} \qquad \forall\, p \tag{7}$$

$$dem_w = \sum_w pr\_q_{ws} \qquad \forall\, w \tag{8}$$

$$in_w = \frac{dem_w}{2} + \sigma_w \left(\frac{\sum_w pr\_q_{pw}}{dem_w} \right) \tag{9}$$

$$\sigma_w = \frac{\sum_w \sum_s \sigma_s pr\_q_{ws}}{dem_w} \tag{10}$$

$$\sum_w pr\_q_{pw} \le cap_p h_p \qquad \forall\, p \tag{11}$$

$$\sum_s pr\_q_{ws} \le cap_w h_w \qquad \forall\, w \tag{12}$$

$$\sum_m pr\_q_{pw} = dem_w \forall\, w \tag{13}$$

$$\sum_m pr\_q_{ws} = dem_s \forall\, s \tag{14}$$

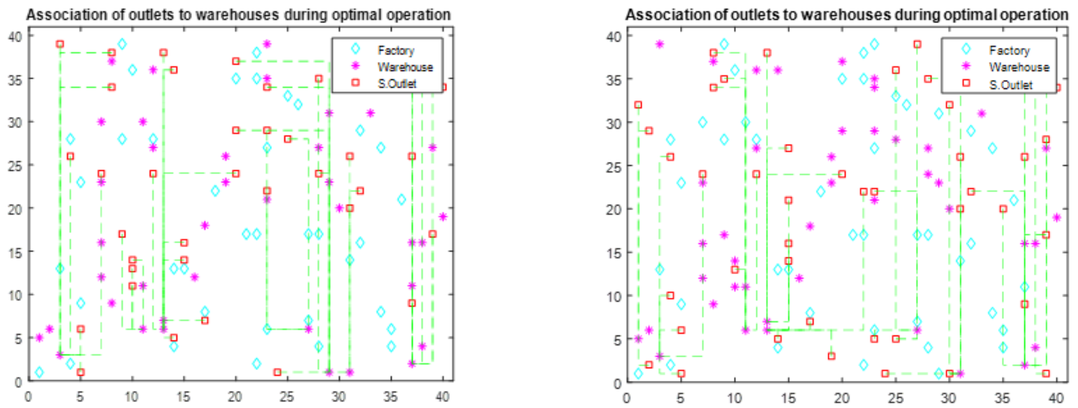
$$\sum_p \sum_w pr\_q_{pw} \le cap_y \tag{15}$$

$$\sum_w \sum_s pr\_q_{ws} \le cap_y \tag{16}$$

Objective function 1 (1) minimizes the total costs that we are looking at in a typical supply chain. The plant costs (2) comprises of the variable and fixed costs. Equation (3) determines the fixed costs of this supply chain when the facilities are in operation. Equation (4) calculates the amount of variable costs according to the facilities' demands. Equation (5) Computes the transportation cost according to the distance and amount of transported product Equation (6) Determines the inventory holding cost at the warehouses. Equation (7) and (8) determines the demand at each facility. Equation (9) calculates the inventory level at the warehouse and ensures that demand is always lower than the facility's capacity. The standard deviation of demand (10) is defined as the weighted average of the standard deviation of other facilities' demand. The capacity of a facility is always higher (11) and (12) than the demand in the next facility Equation (13) and (14) ensures that the amount of products from facility A to facility B must be equal to facility B's demand Equation (15) and (16) ensures that transportation is not overloaded.

3. Results

These 21 data sets are evaluated to examine the model. These sets were randomly generated using uniform distribution. Initially, a model is developed and then performance evaluation and illustration is done. The example first generate facility random locations. This is just to show solution techniques using random data. The number of each type of facility is completely arbitrary. The problem is solved; a plot function is included as a way of monitoring the solution as shown. The demand at the customer centers depends on the number of available customer centers and products. The number of outlets that are associated with each warehouse are shown by the green dotted lines. Some of these warehouses are not necessary since there are not use during optimal operation.



P=42
W=42
C=42

P=44
W=44
C=44

Figure 1: 2 of the 21 data sets

From the fig.1 above it can also be seen that not all warehouses are in use during optimal operation. Numerical computations are done with 21 randomly generated data from matlab. These are used to examine the performance of a typical supply chain organization.The model is applied to these 21 data sets. These data sets are uniformly increased from 12 to 64 facilities i.e. the factories, warehouses and centers are of equal numbers of 12 to 64 facilities.

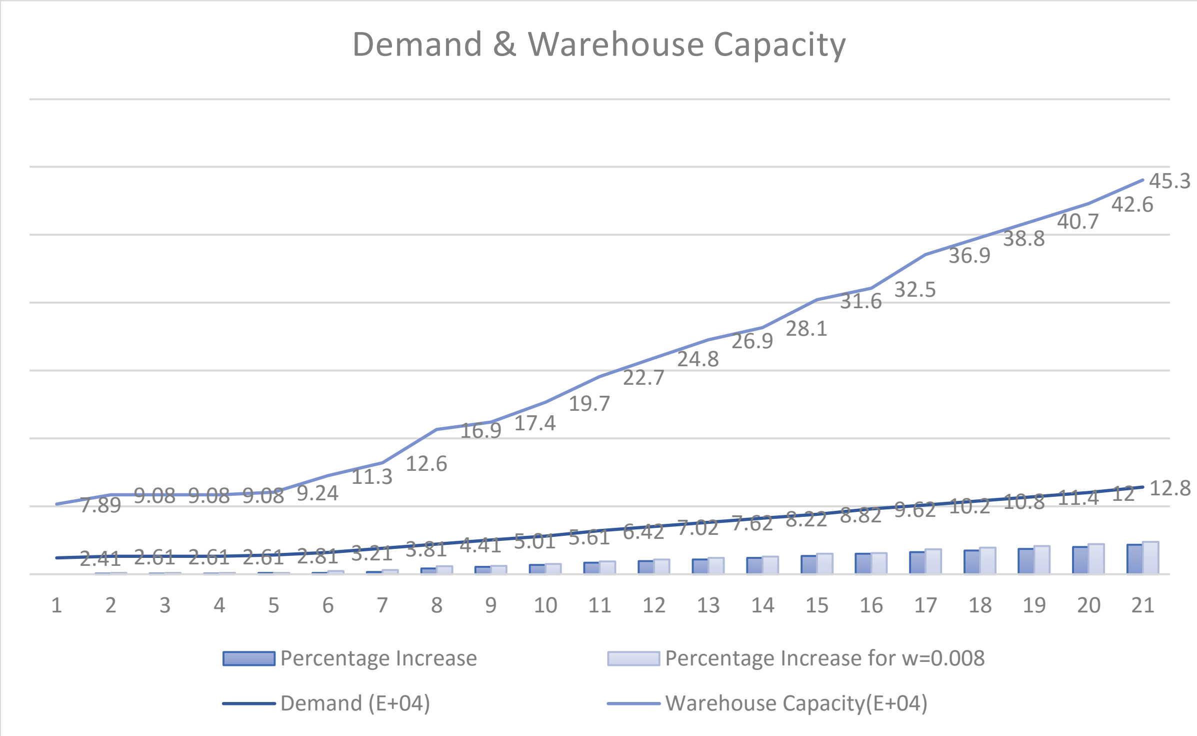


Figure 2: Demand and corresponding warehouse capacity for the data sets

The demand is always calculated at less than the warehouse capacity in all the 21 cases as shown in Figure 2. This is a more realistic view since, it is always required that customer demands be met. As the number of facilities increases so does the demand and also the warehouse capacities. These are the warehouses that are not necessary so they should never be constructed. At very low facilities number that is low warehouses, there is a very low difference between the number of warehouses that are in use compared to the number of warehouses out of use. This shows that the lesser the number of warehouses constructed the better.

The MILP requires that only one warehouse should be connected to one customer outlet. The top six connections are shown in Figure 3. Since all the customer centers for each data set are in use during optimal operation the total number of connections for each data set will be equal to the original randomly generated data. So for 12 facilities there would be 12 total connections. Data set 17 has visibly higher number of connections for the first six connections. For the 21 data sets the total number of connections are in agreement with the total number of facilities as shown in Figure 3. This just shows that customer/distribution centers are very important in the supply chain as this is the required for customer demand requirements.

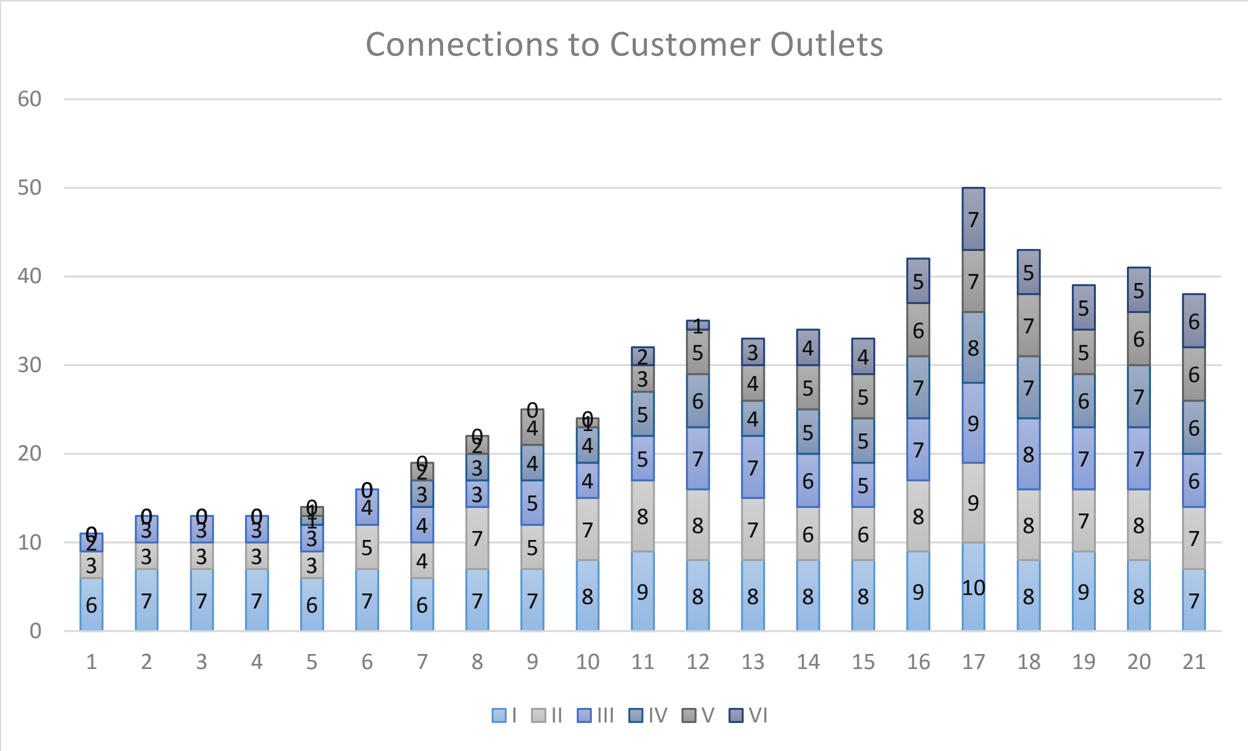


Figure 3: Top 6 connections to customer outlets

The results obtained demonstrate the cost savings of optimization. The cost benefits are a result of a selection of the best factory sites. It is always beneficial for organizations to operate only specified plants for optimality. The results also show that a lot of warehouses are not needed for optimal operation.

4. Conclusion

A model was used to determine the optimal distribution schedules. This research proposed an integrated model that addresses some issues related to the operation of a complex supply chain network. The focus is on economic operational aspects within the organization. The data are randomly generated in MATLAB. The MILP model may help in managerial decisions. With respect to production allocation, raw material, etc. The model was tested with MATLAB generated data. As the number of facilities such as the factories and warehouses increases, this leads to an increase in the total costs.

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