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Development of an Operational Decision Making Model for Transportation of Goods into a New Demand Area

Khan Md. Ariful Haque, Md. Mosharraf Hossain, Ripon Kumar Chakrabortty, Shakh Alauddin and Ripon Haydar

A supply chain is dynamic and involves in constant flow of production, information, service, and funds from supplier to customer. In this paper a strategic design model for two-echelon distribution system is being formulated & analyzed, where the first echelon is the customer order fulfillment stage. In this stage customer order is placed to the distribution center and distribution center immediately replenish the order to the customer. Here the customer order distribution is considered as normal distribution. Also the second echelon is the procurement of goods to distribution center (DC). In this stage, to fulfill the customer requirement the goods are stored in the distribution center which is replenished from plant. Here a standard level is maintained to fulfill the retailer requirement. The key decision considered here is to decide how any ordered lot is being supplied to a particular new demand area. A heuristic mathematical model is developed to minimize the cost of supply a goods into a new demand area. For the purpose of finding the optimal cost of transferring goods, an excel calculation sheet have been formulated. Solution is in two phase, at first phase optimal stock level have been calculated to satisfy the demand by excel Add-ins called "SOLVER". In second phase, the optimal cost of transportation is calculated by manually changing the location decision factor.

Keyword: Supply chain management (SCM), Distribution Systems, Multi-echelon inventory Stock level, Transportation.

1. Introduction

The purpose of this paper is to formulate and analyze a model for single product two-echelon distribution system where significant economy of scale is transportation. In this model the distribution network is "distributor storage with career delivery". The key operational decision considered is how to supply lots to new demand area retailers, the Inventory level of product to be held at the distribution centers, and the routine of transportation between plants and distribution centers.

The operational decision is made by calculating the minimum cost of transporting per unit form the available option of transporting. In our model plant locations, capacity and capabilities are assumed known and fixed. Retail outlet locations are also assumed known and variable, with known parameters of stochastic demand process at each location. Also our distribution center location is also known as fixed and its capacity is known. It is considered that, a company's plant produce a single type of

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Khan Md. Ariful Haque, Email : arif99ipe@yahoo.com
Dr. Md. Mosharraf Hossain*, Corresponding Author, Email : mosharraf80@yahoo.com
Ripon Kumar Chakrabortty, Email: ripon_ipebuet@yahoo.com
Shakh Alauddin,
Ripon Hayder,
Department of Industrial and Production Engineering (IPE), Rajshahi University of Engineering and Technology, Rajshahi 6204, Bangladesh,

product. This company has some distribution centers (DC) and they supply their product to the retailer. Here the product flow is through DC to retailer. But sometime it transported to a retailer directly from plant according to its order. When they construct their supply network, they locate their DC close to their retailer to facilitate to collect the order and transporting goods to the retailer. At that time, they did not consider that after certain time duration there will grow a new demand area for their product. After that time duration they see that, because of their familiarity of product, a new demand area for their product is developed. But the problem is that there is no distribution center beside that retailer to deliver their demanded product to that area. But the number of retailer is very few (one or two) and the demand of their product is not too high that they allocate a new DC at that area. Though, the company transports their product directly to the retailer, but the distance is not too close to the plant to transport directly their product from plant to the retailer. The objective is to find the optimum way to transport the product to that demand area, where total cost is minimized. The inventory cost here is very important. The plant may be hold inventory and transport goods directly to the retail site. In this case the inventory is centralized, reducing inventory costs as a result of lower safety stock requirements, but here the retail outlet may not have sufficient safety stock to respond uncertain demand. It increases the efficiency but decreases the responsiveness as well as decrease the quality of service provided to the customer. To increase the responsiveness the inventory may be shift quickly to the retailer. In this case if the lot size is very small it causes the higher transportation cost when the lot is transported from plant to retail outlet. DC's allow potential centralization of inventory. Network of DC's allow larger transportation from plant to the DC's, it decreasing unit transportation costs as a result of economies-of-scale is transportation. However, additional cost for constructing and operating the DC's will be incurred; there may be an increase in transportation cost.

From the previous studies the authors found some salient features. Most of the works overlook some others factors such as geological matters, human perceptions, Socio-economical condition etc for setting up a distribution centre. Rather they were optimistic enough for all those cases & strict themselves in the mathematical models. The authors proposed some new factors along with a revised mathematical model for transporting goods to new demand areas. On Bangladeshi perspective it is certain that this work & its results will bring some beneficial ways for the manufacturer as well as for the retailers

Thus, the introduction of DC's create an opportunity to shift the balance among the fixed and variable cost of DC's, the inventory cost, the transportation cost, and the service quality. The optimal design decision of this distribution system requires and integrated view of transportation cost, facility cost and service level. The key contribution of these works are: the creation of a formal model that provide an integrated view of the transportation problem where the economy of scale is transportation, product demand is uncertain and inventory cost impacts are very significant; develop and effective solution procedure for realistic problem.

2. Literature Review

Supply chain management is the integration of the activities that procure materials and services, transform them into intermediate goods and final products, and deliver them to customers (Chase et al. 2008). Again Chopra & Meindl (2004) have mentioned four major drivers of supply chain which are facility, inventory, Transportation & Network which affect overall supply chain performance. In this regard Transportation cost is becoming one of the major motivation (Melkote & Daskin 2001) .For sustaining in this competitive era, a manufacturing firm should have some unique approaches as well as responsive enough to meet customer demand which results decreasing supply chain effectiveness. Supply chain management has captured a wide variety of researchers in the recent decade. Melkote & Daskin (2001) investigated a model that simultaneously optimizes facility locations & the design of the underlying transportation network. Zhou & Liu (2003) proposed three types of stochastic programming mode such as Expected Value Model, Chance Constrained Programming and Dependent Chance Programming model for capacitated LA problem for the first time which is different from the traditional stochastic programming models. The problem of locating facilities and allocating customers covers the core topics of distribution system design. Model formulations and solution algorithms which address the issue varies widely in terms of fundamental assumptions, mathematical complexity and computational performance (Klose & Drexl 2005).

However, when any of the available solution methods and/or algorithms is used to solve integrated production/distribution problems in supply chains, the objectives and model inputs are frequently assumed to be deterministic/ crisp and the environmental coefficients and related parameters, including available labor levels, machine capacities, market demand and cost/time coefficients, are normally fuzzy/imprecise because of some information being incomplete or unobtainable over the planning horizon. Gebennini, Gamberini & Manzini (2009) recently have developed an integrated production–distribution model for the dynamic location and allocation problem with safety stock optimization. In their model they have mentioned a cost-based and mixed-integer programming model to support management in making the following decisions: the number of facilities (e.g. warehousing systems, distribution centers), the choice of their locations and the assignment of customer demand to them, and also incorporate tactical decisions regarding inventory control, production rates, and service-level determination in a stochastic environment. Considering the limitation of the traditional stochastic models Baohua and Shiwei (2009) have proposed a new Robust Optimization Model and Algorithm for Logistics Center Location and Allocation under Uncertain Environment which one is remarkably better than the stochastic optimization model, wherein the total cost does not change a lot under all scenarios, thus the risk of decision can be effectively reduced. Murata, Verter, and Laporte (2010) proposed another new solution method which provides framework which is a local search heuristic (steepest-descent algorithm) and is applicable to problems where the allocation decisions are in the form of polygons, e.g., with Euclidean distances.The standard approach to solving location–allocation problems is to model alternative location sites and customers as discrete entities. Many problem instances in practice involve dense demand data and uncertainties about the cost and locations of the potential sites (Murata, Verter, and Laporte 2010). Yim et.al. (2011) in their work, considered a transportation network with a set of origins and a set of destinations for allocating the resources within the system, so that the probability of overloading the links in the network is minimized under a given set of budgets for the residential and employment developments, and network enhancement.

For transporting goods in new market area it is must for the marketer to be prudent enough. For a successful market penetration, the manufacturer have to be respondent enough mostly for its forward supply chains. Transporting or conveying goods to some new demand areas, where the customers have a little knowledge regarding all the features of new product is not always an easy job. From the above literature review, it is anticipated that the distribution or transportation system of goods is very important topics now a days. It also give annotations to the authors regarding some overlook things after reviewing some powerful previous works. They rarely consider any psychological factors which affect a lot for designing & allocating a new distribution centre. Since for new demand areas the factors affect alarmingly, the authors were pretty much intended to give some ideas regarding those issues. The motivation behind this work was to provide a sound idea regarding the selection of new distribution centre's locations first. After that the target was to provide a new mathematical formulation for designing & allocating their location considering the distance matrix, demand volatility, environmental affects so on. So in this paper, a heuristic mathematical model for describing the cost structure of transportation is being developed where prime function is to minimize the total transportation cost by considering the safety stock of the product in the distribution center.

The remainder of this paper is organized as follows. Section 3 & 4 defines & illustrates the problem & the proposed model along with its detailed mathematical formulations. Section 5 gives a short idea about the solution approach. The experimental design & all the results are shown in Section 6 with some analysis. Finally, the results are concluded in Section 7.

3. Problem Definition

The problem can be summarized as follows. Given a set of plants, DC's and retail outlets with specific demand processes, a new demand area/retailers is developed suddenly. Now it is to determine how the finished goods should be supplied to those new demand area/retailers, what are the factors to consider for allocating a new distribution centre and the required inventory stock level of the product at each DC. Here the main focus is on single products, in which case the demand at any retail outlet for the product is variable. Under these conditions, it is reasonable to assume that the demand process at each retail outlet is Normal distribution, and also further assumed that the mean rate is known. The inventory policy adopted at each DC is a continuous review policy; that is, as soon as an item is demanded, an order is immediately placed for its replenishment (Lin, Nozick & Turnquist 2006). DCs must carry enough safety stock to ensure a specified fill rate during product's replenishment lead time. Inventories at the plants do not change with the transportation decisions made in the model, so they are excluded from consideration. The replenishment lead time from the plants to the DC's includes the manufacturing lead time and transit time. Economies-of-scale in transportation imply that the average transportation cost decreases as the volume increases. The average transportation cost of each echelon depends on the overall echelon volume, which is the sum of volumes across all products (Lin, Nozick & Turnquist 2006). Service quality in the distribution system is represented by two measures: the Customer Service Level (*CSL*) for product at each DC, and the amount of total demand that is covered within a specified distance or travel time from at least one DC. Both the required Customer Service Level (*CSL*) and the distance or travel time standards that define coverage are input parameters specified by the model user. If a higher Customer Service Level (*CSL*) is specified, it creates a need for additional safety stock in the DC inventory, and shifts the overall system cost calculation. If coverage standards are changed, it affects the computation of penalty costs (for uncovered demand) in the model, and can cause replenishment decisions to be changed.

4. Model Formulation

Here most of the subscripts sets along with their key decision variables are being cited from the work of Lin, Nozick & Turnquist (2006). The author tried to modify the old model & bearing in mind some more factors such as geological matters, human perceptions, Socio-economical condition etc.

Subscripts and sets:
$p \in P$ indicate the plants.
$d \in D$ indicate the distribution centers (DC's).
$r \in R$ indicate the retailers.

Decision variables:
X_d equals 1 if distribution center *d* is opened and 0 otherwise.
S_d stock level of product at DC *d*

Input parameters:
l_{dr} is the distance from DC d to retailer r.
l_{pd} is the distance from plant p to DC d.
ω_{dr} is the per-mile cost to transport a unit of product *i* from DC d to retailer *r*.
λ_r is the mean demand for product at retailer *r*.
h_d is the inventory holding cost for product at DC *d*.
q_{dr} equals 1 if a DC located at candidate site *d* cannot cover demand at retail outlet *r*, and is 0 otherwise.
f_d is the fixed cost for the DC *d*
L is the replenishment lead time for the distribution center *d*
CSL is the Customer Service Level for the product at DC *d*.
γ is the per unit penalty cost for uncovered demands.
Φ_{dc} is the cost per mile for transporting products from plant *p* to DC *d*
Z_{dr} is the volume of product transported from DC *d* to retailer *r* including new demand area volume
Z_{dr}^{n} is the volume of product transported from DC *d* to new demand area retailer *r*
Z_{dr}^{u} is the volume of uncovered demanded product transported from DC *d* to retailer *r*
X_d equals 1 if distribution center *d* is opened and 0 otherwise.
Z^{n} is the ratio of Z_{dr}^{n} & Z_{dr}

Based on the notation the following mathematical formula can be developed,
The objective is to minimize the sum of transportation costs, fixed cost DC's, inventory cost and penalty costs for uncovered demands. Let, total cost C_T.

$$\min C_T = \sum_{d\in D}\sum_{r\in R} l_{dr}\,\omega_{dr}\,X_d Z_{dr}{}^n + \sum_{p\in P}\sum_{d\in D} l_{pd}\varphi_{pd}X_d Z_{dr}{}^n + \sum_{d\in D} f_d X_d Z^n + \sum_{d\in D} h_d\,S_d X_d Z^n + \gamma\sum_{d\in D}\sum_{r\in R} q_{dr}\,Z_{dr}{}^u \quad (1)$$

subject to,

$$\sum_{d\in D} Z_{dr} = \lambda_r \qquad \forall r \in R \quad (2)$$

Equation (2) assures that, all the demands are satisfied.

$$Z_{dr} \leq X_d\lambda_r \qquad \forall d \in D, \qquad \forall r \in R, \quad (3)$$

Equation (3) ensures that, only facilities that are opened are used in the solution.

$$\Lambda_d = \sum_{r\in R} Z_{dr} \qquad \forall d \in D \quad (4)$$

It was assumed that each DC replenish inventory on a one-for-one basis and that the demand at each retailer follows a normal distribution with mean λ_r. Therefore, the demand at each DC follows a normal distribution with mean Λ_d, defined by (4).

The DC must carry enough inventory to ensure a low probability (1 − *CSL)* of stocking out during replenishment lead time, *L*. This simplification allows us to evaluate the inventory level at a DC without regard to the transportation strategy. However, in some cases this may slightly underestimate the actual inventory cost at a DC.

Stock level = Demand + Safety stock

$$s_d = \Lambda_d + ss \quad (5)$$

Where, safety stock ss = F_s^{-1}(*CSL*)*σ_L

CSL= NORMDIST (ROP, Λ_d, σ_L)

σ_L = Standard deviation of demand during lead time.

= $\sqrt{L} * \sigma_D$

L = Lead time

σ_D= Standard deviation of weekly demand

$$s_d \geq 0 \text{ and integer } \forall d \in D \quad (6)$$

$$Z_{dr} \geq 0 \quad \forall d \in D, \qquad \forall r \in R \quad (7)$$

$$X_d = \{0,1\} \quad \forall d \in D \quad (8)$$

Therefore, constraint (5) and (6) define the computation of the minimum inventory of product at DC *d* to meet the require service level, *CSL*. Constraint (6) and (7) ensure that the flow and inventory variable are nonnegative. Constraint (8) is integrality requirements on the location variables.

5. Solution Approach

In this study there are two type of decision making criterion as described before. There are two steps for solving the problem. First step is to calculate the stock level for the distribution centers. And in the second step it is decided that how the goods transport into the new demand area.

Step 1: Stock level calculation and optimization

Phase 1: Stock level calculation
- Calculation of the reorder point
- Calculation of the standard deviation of demand
- Calculation of the CSL
- Calculation of the safety stock and
- Calculation of the stock level

Phase 2: Optimization

Step 2: Decision making for the goods shift to the new demand area

Phase 1: Allocation of the supply of new demand area demand from Khulna
Phase 2: Allocation of the supply of new demand area demand from Rajshahi
Phase 3: Allocation of the supply of new demand area demand from Jessore
Phase 4: Decision making of minimizing cost.

6. Result Analysis

Hypothetical data are generated here by the random number by calculator. The random number here are used is more than 500 units and less than 750 units. The supply data are also generated by random number as the previous approach. But it is stated that there exist a demand and supply gap. So, random numbers are between 500 units and 750 units. The demand and supply data for new demand area is generated by random number greater than 500 units and 750 units. Total capacity of the transportation truck = 800 Units/ truck. Penalty cost per unit of product = 20 Tk/unit.

Table 6.1: Comparison of stock level before optimizing and after optimizing

DCs	Stock level	Supply	Supply and stock level after optimizing	Stock level	Supply	supply and stock level before optimizing
Khulna	3964	3540	7504	3666	3275	6941
Rajshahi	4239	3785	8024	3800	3395	7195
Jessore	4246	3792	8038	4069	3634	7703

Figure 6.1: Supply and stock level after and before optimizing

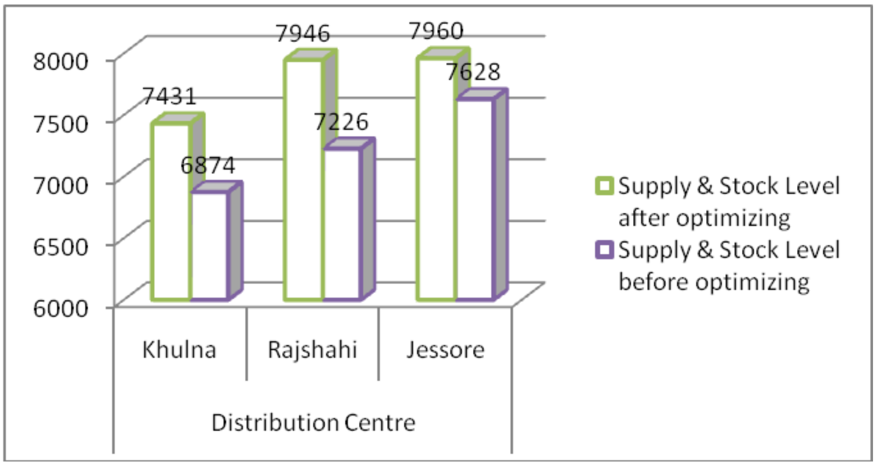
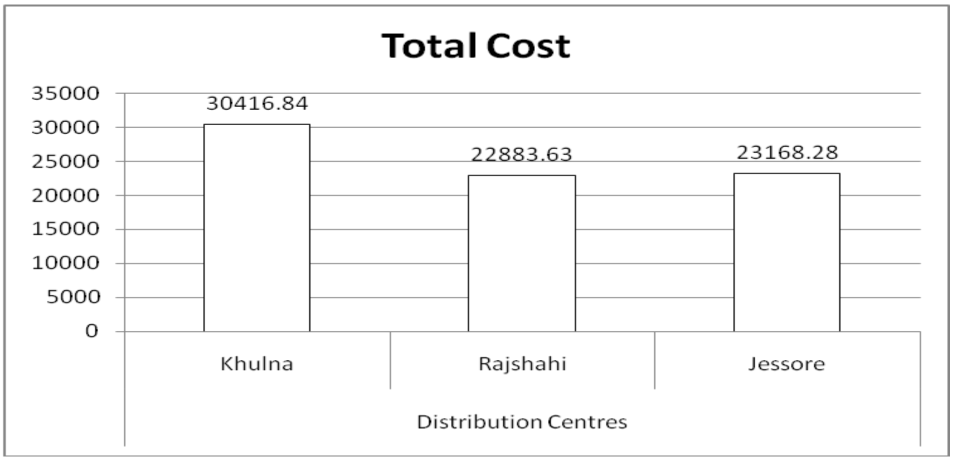


Figure 6.2: Total cost chart for transferring goods into new demand



Above bar chart shows the result of calculation before optimization of stock level for supply of goods into the retailers and new demand area. When all supply are less than its demand. Also the result of stock level after optimization were observed, where prime concern is to fulfill the all demand of customer outlet. The bar chart bellow show the minimum cost of transportation of product into the new demand area. Which cost is minimum, that distribution center is chosen for holding inventory and transportation for the new demand area. The achieved results were convincing enough which give a clear provision for the manufacturer. Results justified that by using the above mentioned mathematical model while considering the three major psychological factors (geological matters, human perceptions, and socio-economical condition) provides a better stock of inventory which allows the manufacturer to be responsive enough for achieving supply chain strategic fit.

7. Conclusion

The purpose of this paper was to find the minimum cost of transportation of goods into new demand areas and maintain the inventory level to fulfillment of all demand including new demand areas for achieving the supply chain strategic fit. For any developing countries the socio economical condition is often undulated for some several reasons. Among them geological matters, human perceptions, socio-economical condition is mostly governed. This work has been conducted by taking some realistic data as well as some hypothetical data. All the factors was properly cultivated & implicated while taking the information. After all this, the author has modified a mathematical model that provides such an integrated view as well as a computationally feasible method for obtaining solutions in realistic situations. Solution procedure has two major steps. The first step is stock level calculation and optimization. The second step is decision making how to shift goods to new demand area. In this paper optimization is done by excels' third party Add-Ins "SOLVER" package, the solution procedure identifies a solution very close to optimality. The product consider for calculation is cement good.

Future research would be useful in following directions. First, in the current procedure, A third party excel Add-Ins is used to optimized the cost. Here, all constrains are not able to input correctly. Using business optimization package helps to reduce this problem. Second, a simple routing heuristic is used to find optimal routes. Since this may not yield the true lowest cost routes, developing a more complex routing heuristic for finding better route decisions would be useful. Third, here normal distribution for handling customer demand uncertainty is being considered. But in reality if the service of product is good it will be exponential distribution. Fourth, the capacity of distribution center is not considered here. If the capacity of distribution center is excited to handle the customer demand uncertainty, the model should change.

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