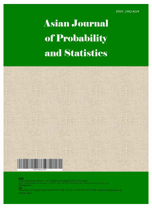

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Mathematical Modeling and Distribution Design for Agricultural Products in Bangladesh

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Authors' contributions

This work was carried out in collaboration among all authors. Author MFU put the basic idea of the research. Authors MKI and GMOF designed the study, performed the statistical analysis, wrote the protocol and wrote first draft of the manuscript. Author MMA managed the analyses and the literature searches of the study. All authors read and approved the final manuscript.

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Abstract

In this paper, we have formulated a mixed integer linear programming (MILP) model for the distribution design of Agricultural products in Bangladesh. The scheme of distribution is very important for the supply chain network (SCN), which is choosing the suitable distribution center (DC) for the distribution of the products. This study is a real life distribution problem. To developed this model, we have collected data from various market players who are directly or indirectly involved in Agriculture sector. We have to solve this model, by using a mathematical programming language (AMPL). We have verified a multi-stage SCN, which includes producer, DC and customer. Also this model is to optimize profit, allocations of the products and most useable DC which satisfied most of the customer demands. Finally, we can analyze the profit for the uncertainty parameters.

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Keywords: Supply chain; agricultural products; distribution center; optimization; mixed integer linear program.

1 Introduction

At present, Worldwide trading and producing is improving very quickly. With this quickly improvement, competition among all kinds of market players becomes more intense. The producing products serve all kind of market players (producers to consumers) is very difficult. Therefore every market players or company is looking for individual supplies system to equilibrium in the total supply chain of the market players. Selecting locations of DCs are very difficult portion in SCN for the reason of invalid locations where the market players convey over plus cost. So every businessman should have to know the oncoming agreement when formation suitable location decision. Multi-product distribution system is a observation of suitable location problem where the model serve various goods and shipment from producer to consumer happens via DC.

Hung et al. delineate to optimizing a supply distribution network with leveling needs among DC [1]. They developed a bi-level programming model to reduce the entire value of the distribution network, and balanced the work load of every DC for the delivery of product to its client, finding the model by the genetic formula.

A mixed whole number programming model was developed by Geoffrion et al. that was one among the foremost necessary makes an attempt for the multi-product facilities location drawback. DC locations, DCs capacities, consumers, and transportation network model for all products were determined [2]. Here the developed MILP model is solved by applying Charnes and Cooper transformation.

Charnes A. and Cooper described a MILFP model which is solved by a suitable transformation technique [3]. Applying this transformation technique, they converted MILFP model into similar MILP and get an optimal solution to the problem could be obtained easily. This technique is very easy but to obtain the optimal solution, we have to needs two-transformed model. This type of problems have become a subject of comprehensive interest in many fields like production location planning, financial analysis of industrial sector, budget related problem, SCN problem, stock market selection problem, cutting stock problem, stochastic processes problem. Many researcher developed time to time survey papers on applications and algorithms of MILP model.

Also, Agarwal et al. has provided with an integrated model to minimize total transportation cost by determining the optimal locations, flows, shipment composition, and shipment cycle time [4]. A Model has formulated for a two tier distribution network. Agarwal has made following assumptions to formulate the mathematical model; each distribution receives the goods only from the warehouses or directly from plants, the average monthly demand at various nodes has been taken as independent of each other, manufacturing location always has the material ready when the order arrives, major safety stock is maintained at the warehouses for its direct sale and for the distributors which are replenished at regular intervals by the warehouse. But the operating cost at each warehouse is not considered.

A large number of literatures available on SCN research, which deals with the different aspects of the topic. There are many models such as facilities location, production, inventory and transportation considering these areas for combined optimization. Present study includes combination of two, or more of these areas. Also take into account, Azad et al. developed a two-stage distribution model [5]. In addition, Jakor and Seifbarghy explained a two-stage inventory system, where they consider the independent Poisson demand with constant transportation [6]. In the same time, Nagurney, A. described the relationship between SCN network equilibrium and transportation network equilibrium: super network equivalence with computations [7].

Papageorgiou et al. Explained and used Strategic supply chain optimization for the pharmaceutical industries of the mixed integer programming model for large scale problems [8]. Alonso-Ayuso et al. described a two-stage MILP model for strategic planning under uncertainty of the SCN and stochastic methods [9]. Shen mentioned 'A multi-commodity SCN design problem' which includes economy of scale in the SCN relating costs [10]. Ma & Suo described a three-stages multiple products logistics networks model [11]. Li et al. explained lower and upper bounds for a capacitated plan location problem with several products [12].

In Bangladesh, SCN distribution center markets are becoming quality day by day like several alternative developed countries. Because of the right management system and quality of merchandise peoples are becoming interested regarding SCN distribution center. During this study, we've developed a true life MILP model by grouping information from some market players of agricultural merchandise. The planned downside may be a giant scale downside, therefore it's terribly troublesome to research the model by hand calculation. That's why we tend to develop a code by exploitation AMPL to research the model.

Most of the reference problems are real life aspects and described mathematically. The present study, formulated MILP model is solved by AMPL, using Charnes and Cooper transformation, also focuses to optimize profit, allocations of the products and how many DC to use, with most of the customer demands are fulfill. Finally, we can analyze the profit under uncertainty parameters.

This study is organized as follows: section 2 discusses data ingathering. In section 3 presents a mathematical formulation of MILP model which deals with the stage of research methodology. In section 4, discuss the solution procedure. In section 5, contains a numerical example and discuss the sensitivity of the MILP model. Finally, in section 6, presents the conclusions and suggestions for the future work.

2 Data Ingathering

We tend to developed our MILP model by ingathering information for Agricultural product optimization in at random elite samples of 235 market players who are directly or indirectly concerned in agricultural business from three districts (Mymensingh, Kishorgonj and Jamalpur) in Bangladesh, additionally ingathering information from some super shop market like Agora, Shwapno and some big size Agricultural products distributor in Dhaka town. We've collected total prices of SCN style like fixed prices, labor prices, holding prices, transportation prices, packing prices and personnel prices. Subsequently calculated profit dividing total come back by total investment. We've additionally collected secondary information from East Pakistan Bureau of Statistics (BBS), Directorate of Agricultural Marketing (DAM), Statistics Department of Bangladesh Bank (SDBB), Bangladesh Journal of Agricultural Economics (BJAE), NGOs reports and Newspapers.

3 Formulation of Multi-Product Milp Model

Before mathematical formulation of MILP model, we have discussed basic notations, parameters and decision variables that are relevant with our work in this study.

Sets:

- L: Set of production locations indexed by l;
- C: Set of customers indexed by j;
- P: Set of products indexed by i;
- D: Set of distribution center indexed by k.

Parameters:

- U^1_{ki}: Annual fixed cost for k^{th} DC operation of i^{th} product;
- U^2_{k}: Annual fixed cost for k^{th}DC operation;
- U^3_{ki}: Unit producing cost of i^{th} product for k^{th} DC;
- U^2_{kji}: Unit shipment cost of i^{th} product for $j^{\ th}$ customer through k^{th} DC;
- U^5_{ki}: Unit holding cost of i^{th} product for k^{th} DC;

U^3_{kji}: Unit transportation cost of i^{th} product for j^{th} customer through k^{th} DC;
D_{ji}: Unit demand of i^{th} product from j^{th} customer;
Ca_{ki}: Products capacity of i^{th} product for k^{th} DC;
T_{ki}: Unit transportation time from k^{th} DC to j^{th} customer;
Pu_i: Probability uncertainty of i^{th} product;
γ any positive constant.

X_{kjil}: Total amount of i^{th} product shipped from l^{th} production location to j^{th} customer via k^{th} distribution center.

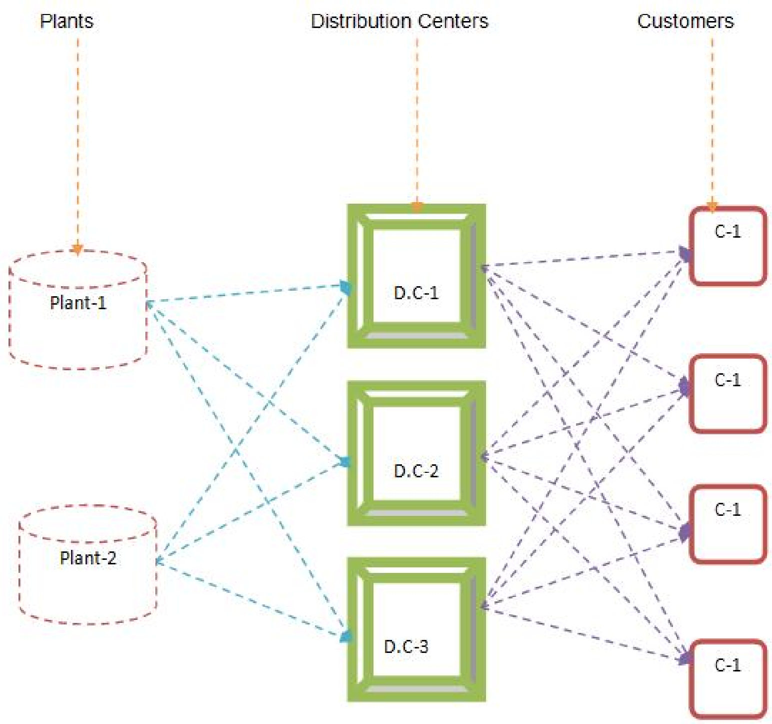

Fig. 1. Multi-product distribution network

Decision Variables

$$y_k = \begin{cases} 1, \textit{if distribution center is used} \\ 0, \textit{otherwise} \end{cases}$$

$$w_{kj} = \begin{cases} 1, \textit{if customer j is assign to distribution center k} \\ 0, \textit{otherwise} \end{cases}$$

3.1 Mixed integer linear programming problems

In mathematical optimization, linear programming maximizes (or minimizes) a linear objective function subject to at least one or a lot of constraints. Mixed number programming adds one further condition that a minimum of one in every of the variables will solely whole number values. The technique finds broad use in research.

Mathematically the MIP problem can be written as follows:

Maximize (or minimize), $Z = CX$

Subject to constraint:

$Ax \leq b,$

$x \geq 0,$ some x_i are restricted to integer values.

Where,

$X = (x_1, x_2, \dots, x_n)^T$

$C = (c_1, c_2, \dots, c_n)$

$b = (b_1, b_2, \dots, b_m)^T$

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix}$$

The $x_i's$ are the decision variables, the first equation is called the objective function and the m^{th} inequalities are called constraints. The constraint bounds, the$b_i's$, are often called right-hand side.

MILP Model,

Objective function of the model is:

$$Maximize, Z = J_1 - J_2 \tag{1}$$

Where x_1 is the total income and x_2 is the total cost.

$$J_1 = \sum_{k=1}^{D}\sum_{j=1}^{C}\sum_{i=1}^{P}\sum_{l=1}^{L} x_{kjil} s_{ki}$$

$$J_2 = \sum_{k=1}^{D}\sum_{i=1}^{P} y_k u_{ki}^{1} + \sum_{k=1}^{D}\sum_{j=1}^{C}\sum_{i=1}^{P}\sum_{l=1}^{L} x_{kjil} u_{kji}^{2} + \sum_{k=1}^{D}\sum_{j=1}^{C}\sum_{i=1}^{P}\sum_{l=1}^{L} x_{kjil} u_{kji}^{3} + \sum_{k=1}^{D} x_k u_k^{4} +$$
$$\sum_{k=1}^{D}\sum_{j=1}^{C}\sum_{i=1}^{P}\sum_{l=1}^{L} x_{kjil} u_{kji}^{5} / 2 + \sum_{k=1}^{D}\sum_{j=1}^{C}\sum_{i=1}^{P} rw_{kj} u_{kji}^{6}$$

Subject to constraints:

$$\sum_{k=1}^{D}\sum_{l=1}^{L} x_{kjil} = d_{ij} \;\; , \forall i, j \tag{2}$$

$$\sum_{j=1}^{C}\sum_{l=1}^{L} x_{kjil} <= Ca_{ki} \;\; , \forall k, i \tag{3}$$

$$\sum_{j=1}^{C}\sum_{i=1}^{P}\sum_{l=1}^{L} x_{kjil} <= \beta y_k \;\; , \forall k \tag{4}$$

$$\sum_{k=1}^{D} w_{kj} = 1 \;\; , \forall, j \tag{5}$$

X_{kjil}, S_{ki}, U_k^1, U_{kji}^2, U_{kji}^3, U_k^4, U_{kji}^5, U_{kji}^6, d_{ij}, Ca_{ki}, β>=0, and y_k, w_{kj} are binary $\forall$ *k,j,i,l*

The objective function is to optimize the maximum profit as well as optimal distribution center which satisfy most of the customer demands. Constraint (2) assurance that the total amount of specific product shipped from l^{th} production location for a particular customer via k^{th} distribution center is equal to the total demand of the specific product from that customer. Constraint (3) ensure that the total amount of specific product shipped from l^{th} production location via all distribution center for all customer is not greater than total capacity of all distribution center. Constraint (4) presents that a distribution center is used when and only if there is a demand for any product. Constraint (5) guarantees that each customer is allocated to exactly one distribution center.

4 Solution Procedures with Numerical Example

To find the solution of the formulated MILP model, we have solved the required model by using AMPL (AMPL Student Version 20121021) with appropriate solver MINOS. We have developed an AMPL code, which consists of an (a) AMPL model file, containing the actual program, (b) AMPL data file, containing data for the various parameters and (c) AMPL run file. This program has accomplished on a Core-I3 machine with a 3.60 GHz processor and 4.0 GB RAM.

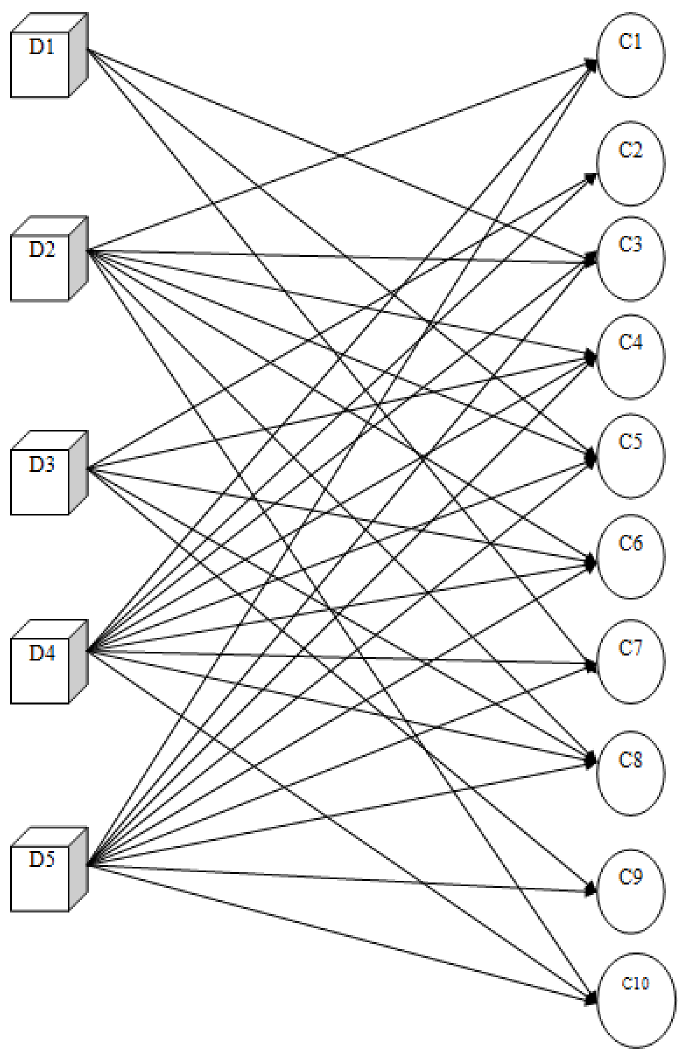

Fig. 2. Selection distribution center, customer allocations for all products

To analyze the effectiveness of the proposed models, we consider a numerical example, which consisting 1 production locations, 5 products, 5 distribution centers and 10 customers (1L-5P-5DC-10C). The deterministic demand of unit products of customers are (1480 1731 1342 1400 1655), (1390 1845 1445 1300 1758), (1380 1930 1533 1300 1857), (1450 1745 1348 1310 1952), (1390 1830 1646 1220 1650), (1450 1948 1323 1400 1758), (1320 1740 1337 1330 1859), (1450 1840 1549 1300 1955), (1380 1935 1432 1420 1656) and (1340 1730 1538 1400 1757), fixed costs of per unit products (in BDT) for each distribution centers are (5, 6 ,8, 2 ,3), (6 ,7, 6 ,3, 4), (7, 7, 8,2 ,4), (8, 6, 9, 2, 3), and (6, 6, 8, 2, 3), selling price of per unit products (in BDT) for each distribution centers are (19.5, 19.4, 17.5, 12.5, 15), (22.5, 18.7, 20.8, 11.1, 14.5), (22, 19.7, 20.8, 13.7, 14), (20.9, 21.1, 18.2, 15, 15) and (23.5, 21.6, 21.5, 11.1, 14.5), holding costs of per unit products (in BDT) for each distribution centers are (1.5, 1.5, 1.2, 1.5, 1.2), (1.2 , 1.9 ,1.3, 1.6 , 2.1), (1.7, 1.2, 1.5 ,1.7 , 1.5), (1.0, 1.4 ,1.8, 1.6,1.6) and (1.2, 1.2, 1.7, 1.6, 2.2) respectively. We have thought-about some unsure state of affairs, like natural cataclysm and political conditions. This unsure event hampers to gather and distribute product and lacks of shoppers satisfy. All types of information don't existent here because of its giant volume.

The solution for example problem, one production location, five products, five distribution center and ten customers (1L-5P-5DC-10C) is shown in Fig. 2.

From this Fig. 2, it is clear that the distribution centers 4 and 5 are most profitable than other distribution centers, because this two distribution centers are satisfied most of the customer demands.

4.1 Profit comparisons for various uncertainties

In this section, we have presented profits comparison for different uncertainty parameters. Due to the volume details optimal solution are not presented in this paper. If readers are interested then they can contact with the corresponding authors. Various uncertainties profit comparisons has presented in Fig. 3.

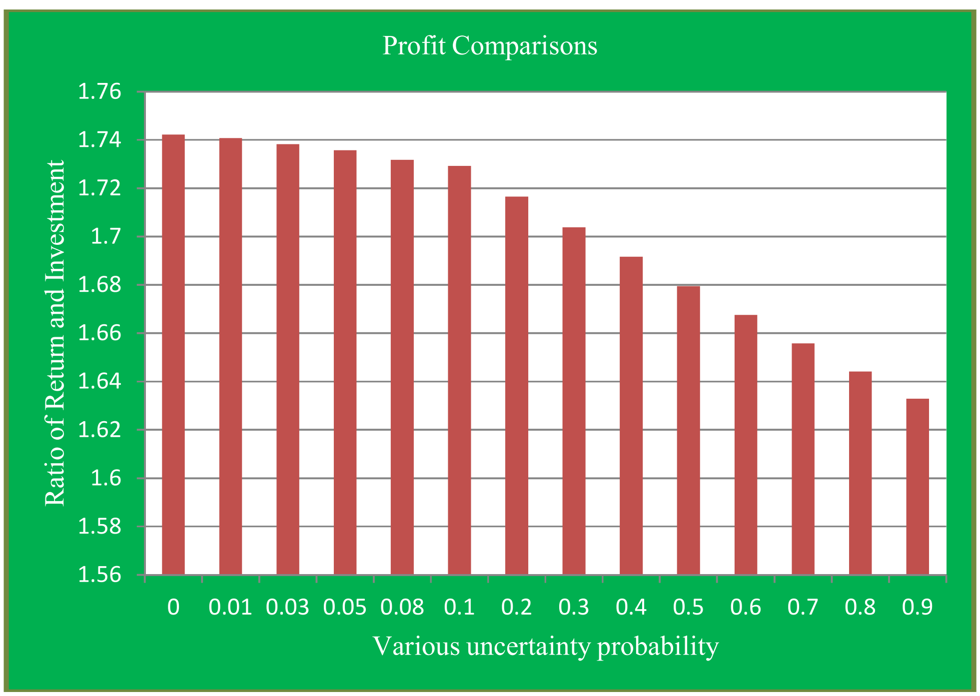

Fig. 3. Profit comparison with uncertainty probability

From Fig. 3, it is clear that, if we increase uncertainty probability then profit has decreased gradually. The amount has been calculated in Bangladeshi Currency. Naturally natural cataclysm is a key factor for a business organization. It has direct impact on its profit or loss. The effect of natural cataclysm and it's seemed to us that it will be very terrible for the company if profit decreases in such a way. We see from the figure that rate of modification of profit isn't too high for little natural cataclysm however it's quite sensible and if natural cataclysm remains like that overall in an exceedingly year the corporate has to not create a loss. Finally, we are able to create a forecast that the corporate should be wariness for the large natural cataclysm and have to be compelled to take some plans like advance assortment of merchandise that don't seem to be raw or increase range of inventories within the standard locations etc so they need to not fall in risk in such things and haven't to delay in deliveries ordered by customers. Within the next section, we've got drawn a conclusion regarding our work.

5 Conclusion

In this paper, the MILP model is developed for the integrated SCN design which is solved by the well-known branch and bound Algorithm applying A Mathematical Programming Language (AMPL). MINOS optimization solver was applied to optimize the problem and find the optimal solution. We developed an MILP model and analyzed the business policy of agricultural products in Bangladesh. We collected one year data to develop this model. The formulated MILP model is to maximize the total profit, allocations of the products and also to optimize most useable DC which satisfied most of the customer demands. Finally, we can analyze the profit for the uncertainty parameters. Some of the significance findings can be summarized as follows:

Firstly, the illustrated numerical example apparently shows that the MILP model shows (Fig. 2) the distribution centers 4 and 5 are most profitable than other distribution centers, because this two distribution centers are satisfied most of the customer demands. Secondly, for the increase of uncertainty probability then the profit has decreased gradually (Fig. 3). We are confident that this is the first work with agricultural products business policy in Bangladesh. We hope that this work will be helpful to the researchers, businessman of agricultural products and common readers to know about the system of profitable agricultural products marketing.

The future research of our interest is to optimize the whole system of the SCN design of agricultural products in Bangladesh, like a producer- local wholesaler-urban wholesaler-retailer and consumer. Also, formulate the coordination model among the participants of SCN. Further, comparison this MILP model with MILFP model for various parameters.

Competing Interests

Authors have declared that no competing interests exist.

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