Journal of Agriculture and Sustainability

ISSN 2201-4357

Volume 13, **2020**, 9

INFINITY PRESS

www.infinitypress.info

Coordination and Supply Chain Optimization of Agricultural Products in Bangladesh under Uncertainty

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Abstract: In this study, we developed four different mathematical formulations for the coordination and three stage supply chain optimization of agricultural products in Bangladesh. This research, we assumed that the farmers-retailers-distributors are coordinated by jointly participation their information. To developed a Mixed Integer Linear Programming (MILP) model and analyze the situation of inadequate production

https://doi.org/10.28924/ip/jas.1943

capacity for the producer as the reason for shortages. The producers will coverage these shortages by outsourcing, which decided very beginning of the SCN. This plays a very important role in deciding so as to mitigate these challenges and to extend the system performance and individual gain of the SCN. The coordinated mechanism among the participants of the market has been prominent to realize the best answer. The SCN was modeled using a formulation in MILP that maximizes the total profit and also to validate our proposed model, analyzed the total profit for real data and normal distribution data for various parameters. The formulated MILP model were solved by a mathematical programming language (AMPL) and results obtained by appropriate solver MINOS. Numerical example with the sensitivity of several parameters has been deployed to validate the models. We conclude from this study, profit of all participants increased by SCN coordination system without ant additional investment.

Keywords: Supply chain, Optimization, Mixed integer linear program, Coordination, Agricultural products

Introduction

The supply chain network (SCN) of a company consists of various functions at every drafting board. The SCN functions will be loosely classified by Ganeshan et al. [1] in the following four classes – location, production, inventory, and transportation. Each function plays important role the entire SCN activities. Pourakbar et al. [2] descried an integrated four-stage SCN, considering single provider, multiple producers, distributors and retailers.Brandenburg et al. [3], define SCN is the coordination of the physical, logical and money flows system among the entire network whole final goal is to deliver the whole system properly. The SCN may be a complicated method presented by Nickel et al. [4], though Papageorgiou [5] proved that associate economical SCN style and resource allocation over the network is crucial for a decent performance of the SCN.

Coordination among the members of supply chain network in business activities is one of the vital issues to overcome the new challenges of the comprehensive enterprise. I n the entire SCN, each party always attempt to enhance his own profits only, so implementation of coordination system is very essential for optimal solution. That is why to ensure the optimal system and satisfy customer demands in today's competitive markets; significant information needs to be shared along the supply chain Network. Ahumada et al. [6], Rong et al. [7] and Aung et al. [8] presents SCN coordination and optimization of production planning, products distribution and profit sharing among them. Vander Vorst et al. and Shukla et al. [9-10] described SCN for the environmental impacts like operational activities, transportation etc.

A large quantity of literature obtainable on SCN analyzed many researchers with various aspects of the topic. Huge number of models considering the combined optimization areas for various business functions location, production, inventory and transportation. Due to high customer expectation, all kind of business effort have been solidified their SCN for feasible business operations. Goyal [11] described a single vendor-buyer inventory models which optimist the total cost. Sajadieh, M.S. et al. [12] optimize shipment, ordering and pricing policies for two stages SCN with price sensitive demand. Drezner et al. [13] described Facility Location Problems (FLP) under the situation of producing plants. Hung et al. [14] presented the situation allocation with reconciliation needs among Distribution Centre (DC). Jose et al. [15] presented MILP model to minimizing time and number of auto for a capacitated vehicle routing drawback and they solved it numerically. Yamada et al. [16] investigated super network equilibrium model. They also investigated the interaction between transport networks and SCN.

In this study, producer-retailer-distributor multi-product, multi-distribution center and multi-customer location production problem is formulated as a MILP model which maximizes the total profit, and at the same time optimizes production land, profitable distribution center. We have incorporated the possibility of external procurement by the producer when it faces shortages and extended the model by considering the interested of the wholesaler also as long term partnership is described by the business entities in today's business environment. The wholesalers purchase the item from the producer and sell it in the market. To solve these formulated MILP model using AMPL with appropriate solver MINOS. Finally, a numerical example along with the sensitivity of relevant parameters is considered to estimate the achievement of the models.

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

Data Collection

Data collecting may be a crucial step, since the actual information influences the results of the study. If the results accuracy defines the problem under study, those results enable deeper information of the problem. Typically this stage consumes a long time, and contributes to correct information and to supply input to the mathematical model.

We tend to developed our MILP model by collecting actual information for agricultural product optimization in at random elite samples of 235 market players who are directly or indirectly involved in agricultural business from four districts of Bangladesh, additionally the data gathered for this study area unit associated with customers and suppliers; types of products; fixed and variable prices associated to installation of plants, warehouses, distribution centers and agricultural products hub facilities; transportation prices, process and transportation times associated to transportation modes. The mathematical model consists in an exceedingly ancient SC, during which flows area unit initiated from suppliers and finish in customers. Thus, the SCN consists within the following entities: suppliers, productions facilities, DC, WH, agricultural products hubs and markets. Every entity is delineated by its geographical location and therefore the entities area unit connected through the fabric flows between them.

Model Formulation

This section describes the proposed mathematical formulation. Before mathematical formulation of MILP models, we have discussed indices, sets, 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;

Parameters for producer model:

u_{il} The price of i^{th} product at l^{th} location ($/kg)

l_{il} Labor Requirement of i^{th} product at l^{th} location (ha)

v_{il} Labor cost of i^{th} product at l^{th} location ($/unit)

w_{il} The amount of water need of i^{th} product at l^{th} location (ha)

g_{il} Water cost of i^{th} product at l^{th} location ($/unit)

f_{il} Fertilizer Requirement of i^{th} product at l^{th} location (kg/ha)

c_{il} The price of unit raw materials for i^{th} product at l^{th} location ($/unit)

r_{il} The amounts of raw materials need to produce i^{th} product at l^{th} location ($/unit).

t_{il} Unit transportation cost of raw materials for i^{th} product at l^{th} location ($/unit)

p_{il} The production cost of i^{th} product to l^{th} location at ($/unit).

h_{il} Unit holding cost of i^{th} product from l^{th} location for some given unit of time ($/unit-time)

${g^*}_{il}$ Fertilizer cost of i^{th} product at l^{th} location ($/unit).

p_i Uncertainty probability of i^{th} product

d_{ij} Unit demand of i^{th} product for j^{th} customer

$TCLA$, is the total cultivated land available

TWA, is the total amount of water available

Parameters for wholesaler model:

U^1_{li} Annual fixed cost for l^{th} DC operation of i^{th} product

U^2_l Annual fixed cost for l^{th}DC operation

U^3_{li} Unit producing cost of i^{th} product for l^{th} DC

U^4_{liJ} Unit shipment cost of i^{th} product for $j^{\ th}$ customer through l^{th} DC

U^5_{li} Unit holding cost of i^{th} product for l^{th} DC

U^6_{liJ} Unit transportation cost of i^{th} product for $j^{\ th}$ customer through l^{th} DC

D_{IJ} Unit demand of i^{th} product from $j^{\ th}$customer

Ca_{lI} Products capacity of i^{th} product for l^{th} DC

T_{lj} Unit transportation time from l^{th} DC to $j^{\ th}$customer

Parameters for retailer model:

f_{li} Retailer fixed cost of i^{th} product at l^{th} location ($/kg)

p_{lij} Retailer production cost of i^{th} product at l^{th} location for j^{th} customer ($/kg)

H_{lij} Retailer holding cost of i^{th} product at l^{th} location for j^{th} customer ($/kg)

pc_{li} Retailer production capacity of i^{th} product at l^{th} location (kg)

tt_{lj} Retailer unit time transportation at l^{th} location for j^{th} customer (h)

rt_{lj} Retailer required delivery time transportation at l^{th} location for j^{th} customer (h)

$rt^*{}_{lj}$ Retailer obligatory time transportation at l^{th} location for j^{th} customer (h)

p_{ij} Retailer penalty cost of i^{th} product for j^{th} customer ($/kg)

Tc_{ij} Retailer unit transportation cost at l^{th} location for j^{th} customer ($/kg)

mc_l Retailer unit maintenance cost at l^{th} location ($/kg)

d_{ij} Unit demand of i^{th} product from j^{th} customer (kg)

pp_{li} Retailer purchasing price of i^{th} product at l^{th} location ($/kg)

Decision variables for producer:

$\boldsymbol{x_{li}}$ **O**rdered quantity of i^{th} product for location l (unit)

$\boldsymbol{n_i}$ **N**umber of shipment of i^{th} product (unit)

x_{lij}, is the total amount of i^{th} product shipped from l^{th} location/distribution center for j^{th} customer (kg)

$$x_l = \begin{cases} 1, if \ location\ l\ is\ used, \\ 0, else \end{cases}$$

$$w_{lj} = \begin{cases} 1, if \ customer \ \ j\ is\ used\ distribution\ center\ l, \\ 0, else \end{cases}$$

Producer Model:

Objective function,

$Maximize, Z = Z_1 - Z_2$

After knowing the distributor's order quantity, producer's income is obtained by the multiplication of the selling price and demand quantity. It is assumed that producer's selling price, s_{li} is fixed for each product i. Therefore producer's total income (z_1) is defined by,

$$Z_1 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} s_{li} x_{lij}$$

Producer's investment:

The total investment of producer is required to satisfy order quantity of distributor as well as customer's demand for all products. In this model, fixed opening cost, labor cost, fertilizer cost, water cost, holding cost and transportation cost are considered as producer's costs.

Therefore, mathematically producer's total investment (z_2) is defined as,

$$z_2 = \sum_{l=1}^{L} \alpha_l x_l + \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} ((t_{li} + c_{li}) r_{li} + (p_{il} + h_{il}) x_{lij} + v_{li} l_{li} + w_{li} g_{il} + f_{li} g^{*}_{li})$$

Subject to constraints,

$$\sum_{l=1}^{L}\sum_{i=1}^{m} x_{lij} \le TCLA$$

$$\sum_{l=1}^{L}\sum_{i=1}^{m} L_{li}\, x_{lij} \le TLA$$

$$\sum_{l=1}^{L}\sum_{i=1}^{m} W_{li}\, x_{lij} \le TWA$$

$$\sum_{l=1}^{L}\sum_{i=1}^{m} F_{li}\, x_{lij} \le TFA$$

$$\sum_{l=1}^{L} x_{lij} \le d_{ij} \quad ,\forall i,j$$

x_{lij}, F_{li}, W_{li}, L_{li}, h_{li}, p_{li}, c_{li}, r_{li}, v_{li}, f_{li}, w_{li}, l_{li}, g_{li}, g^{*}_{li}, t_{li}, ud_{lij}, TCLA, TLA, TWA, TFA are non-negative and x_l is binary.

Distributor Model:

The objective function of the model is difference between total income and total cost:

$$Maximize,\ z^{*} = z_3 - z_4$$

Where z_3 is the total income and z_4 is the total cost.

$$z_3 = \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij}\, s^{**}_{li}$$

$$z_4 = \sum_{l=1}^{L}\sum_{i=1}^{m} y_l\, u^{1}_{li} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij}\, u^{2}_{lji} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij}\, u^{3}_{lji} + \sum_{l=1}^{L} x_l\, u^{4}_{l} +$$
$$\sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij}\, u^{5}_{lji} / 2 + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} w_{lj}\, u^{6}_{lji}$$

Subject to constraints:

$$\sum_{l=1}^{L} x_{lij} \le d_{ij} \quad ,\forall i,j$$

$$\sum_{j=1}^{n} x_{lij} \le ca_{li},\ \forall i,l$$

$$\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} \le \alpha\, y_l \quad ,\forall l$$

$$\sum_{l=1}^{L} w_{lj} = 1 \ , \forall, j$$

X_{lji}, $s^{**}{}_{li}$, U^{1}_{l}, U^{2}_{lji}, U^{3}_{lji}, U^{4}_{l}, U^{5}_{lji}, U^{6}_{lji}, d_{ij}, Ca_{li}, α **are non-negative and** y_l, w_{lj} **are binary** $\forall\, j, i, l$

Decision variables for retailer:

x_{lij}, is the total amount of i^{th} product shipped from l^{th} location for j^{th} customer (kg)

Z_3, is the total income

Z_4, is the total cost

Z^*, is the maximum profit

$S^*{}_{li}$, is the retailer selling price of i^{th} product at l^{th} location (\$/kg)

$$z_l = \begin{cases} 1, if\ \ location\ l\ is\ used, \\ 0, else \end{cases}$$

$$y_{lj} = \begin{cases} 1, if\ \ customer\ \ j\ \ is\ assaign\ \ to\ \ producer\ l\ , \\ 0, else \end{cases}$$

Retailer Model:

Objective function,

$$Maximize,\ z^* = z_3 - z_4$$

Where,

$$z_3 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} s^*_{li}\, x_{lij}$$

$$z_4 = \sum_{l=1}^{L} x_l\, y_{li} + \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n} (Tc_{ij}\, x_{lij} + (p_{ilj} + h_{ilj} + mc_l)\, x_{lij} + d_{ij}\, p_{ij} (rt_{ij} - rt^*_{ij}))$$

Subject to constraints,

$$\sum_{l=1}^{L}\sum_{i=1}^{m} x_{lij} \le \sum_{i=1}^{m} d_{ij} \ ,\forall j$$

$$\sum_{l=1}^{L}\sum_{j}^{n} x_{lij} \le \sum_{j=1}^{n} d_{ij} , \forall i$$

$$\sum_{l=1}^{L} x_{lij} \leq d_{ij} \quad ,\forall i,j$$

$$\sum_{j=1}^{n} x_{lij} \leq ca_{li}, \forall i,l$$

$$\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij} \leq \alpha\, x_l \quad ,\forall l$$

$$\sum_{l=1}^{L} y_{lj} = 1, \forall j$$

$\boldsymbol{x_{lij}}$, $\boldsymbol{Tc_{ij}}$, $\boldsymbol{d_{ij}}$, $\boldsymbol{h_{lij}}$, $\boldsymbol{p_{lij}}$, $\boldsymbol{mc_l}$, $\boldsymbol{d_{ij}}$, $\boldsymbol{p_{ij}}$, $\boldsymbol{rt_{ij}}$, $\boldsymbol{rt^*{}_{ij}}$ **are non-negative and** $\boldsymbol{x_l}$ **,** $\boldsymbol{y_{li}}$ **are binary** $\forall$ $\boldsymbol{l, i, j}$.

Producer-Distributor-Retailer coordinated model

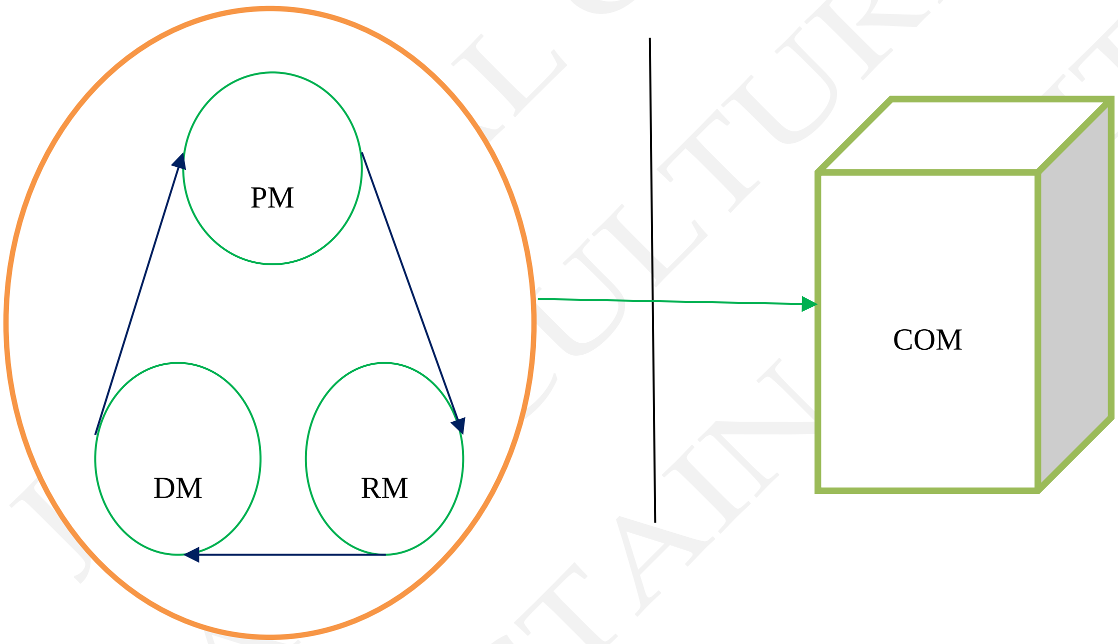

Fig.1 Supply chain coordination model among the participants

Now we study the previous non-coordinated model convert into a supply chain coordination model where we assume that among the distributor, the retailer and the farmers take decisions jointly and the farmers and retailers decides to go for recover the deficit demand by anyhow. If $\beta 1$ ($0 <= \beta 1 <= 1$) is the deficit demand which recovered by other sources. The modified profit equations of the farmer, retailer and the distributor are respectively as follows:

$$z_1 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}[x_{lij} + \beta 1(d_{ij} - x_{lij})]c_{li}$$

$$z_3 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}[x_{lij} + \beta 1(d_{ij} - x_{lij})](s_{li} - c_{li})$$

$$z_5 = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}[x_{lij} + \beta 1(d_{ij} - x_{lij})](s^*_{li} - s_{li})$$

Hence the coordination return is given by,

$$Z = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}[\{x_{lij} + \beta 1(d_{ij} - x_{lij})\}c_{li} + \{x_{lij} + \beta 1(d_{ij} - x_{lij})\}(s_{li} - c_{li}) +$$
$$\{x_{lij} + \beta 1(d_{ij} - x_{lij})\}(s^*_{li} - s_{li})]$$

Which simplified, we have

$$Z = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}[(1-\beta 1)x_{lij} + \beta 1 d_{ij}]s^*_{li}$$

Therefore the coordination profit is given by

$$Maximize, Z = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}[(1-\beta 1)x_{lij} + \beta 1 d_{ij}]s^*_{li} - [\sum_{l=1}^{L}\sum_{j=1}^{n}\{\alpha_l w_{lj} + (c_{li} + t_{li})r_{li}\} +$$
$$\sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}(p_{lij} + h_{lij} + mc_l)x_{lij} + \sum_{l=1}^{L}\sum_{i=1}^{m} l_{li}v_{li} + f_{li}g^*_{li} + w^*_{li}g_{li} +$$
$$\sum_{l=1}^{L}\sum_{i=1}^{m} y_l u^1_{li} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij}(u^2_{lij} + u^3_{lij})x_{lij} + \sum_{l=1}^{L} x_l u^4_l +$$
$$\sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} x_{lij}\frac{u^5_{lij}}{2} + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} w_{lj}u^6_{lij}$$

Remaining set of constraints are described in the above three non-coordinated models.

Solution Approach and Numerical Example

By using AMPL (AMPL Student Version 20121021) with appropriate solver MINOS, to find the solution of proposed model. 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.

For the purpose of sensitivity analysis of our mentioned MILP model, we supposed a numerical example. Let us assume a firm has 2 locations, 5 types product Boro rice, Wheat, Green pepper, Cucumber, Carrot and three customers with 4 cycle of time. Consider the unit production capacity, selling price, fixed cost, transportation cost, holding cost, and production capacity of each locations are normal distribution with mean $\mu \geq 0$ and variance $\sigma > 0, < \mu/2$. Normal distribution is defined by maximum {normal distribution (μ, σ, 0)}, Robert Fourer et al. (second edition), "A Modeling Language for Mathematical Programming". Here the expression maximum (μ, σ, 0) is encircled to manage the infrequent event, which gives the positive mean value for normal distribution giving back a negative value. Also, the trade of each production limit per cycle of time in each locations are {(10000, 11000), (11000, 12000), (8000, 9000), (9000, 7000)}; {(12000, 10000), (10000, 11000), (7000, 8000), (8000, 6000)}; {(12000, 10000), (10000, 11000), (7000, 8000), (8000, 6000)}; {(7000, 8000), (4000, 5000), (5000, 6000), (6000, 5000)}; {(8000, 9000), (5000, 6000), (6000, 4000), (5000, 6000)}; {(8000, 9000), (5000, 6000), (6000, 4000), (5000, 6000)}; {(7500, 7000), (6500, 6000), (6500, 5500), (5500, 5000)}; {(8500, 6000), (7500, 7000), (5500, 5000), (5000, 6000)}; {(6500, 7000), (7000, 5000), (5500, 6500), (5000, 6000)}; {(7500, 8000), (6000, 5000), (5500, 6000), (5000, 5000)}; {(7500, 6000), (6500, 5000), (5500, 6500), (5000, 4000)}; {(7500, 7000), (5000, 8000), (6500, 7000), (7000, 6000)}; {(7500, 7000), (6000, 5000), (6500, 5000), (5000, 7000)}; {(5500, 6000), (7000, 8000), (5500, 6000), (7000, 5000)}; {(4500, 7000), (5000, 7000), (8500, 6000), (6000, 5000)}. Rate of produce per cycle (tons): (100, 150), (140, 150), (200, 185), (250, 190), (100, 200). Initial stock: (10, 15), (20, 00), (15, 10), (30, 12), (15, 25). Required delivery time: (12, 11, 12), (14, 12, 13). Obligatory time: (11, 10, 14), (15, 11, 12). Delay defining function: (1, 1, 1), (1, 1, 1). Penalty cost: (0.0, 0.3, 0.1), (0.1, 0.0, 0.2), (0.0, 0.1, 0.1), (0.1, 0.2, 0.1), (0.3, 0.1, 0.0) and per unit cost price: (33, 38), (30, 28), (40, 35), (38, 33), (30, 32). In addition, we consider the rate of perishable products is 10%.

Result Analysis and Discussion

In this section, fundamental findings regarding the numerical example of the proposed models as described below:

Now, we have to analyze the profit sensitivity between real data and random data for various parameter related to our model. Solutions are obtained for the selling price of real data against for a wide range of random values of selling price when all other parameters are unchanged. Similarly, we have to analyze for the parameters of labor cost, raw material cost, fertilizer cost, holding cost, transportation cost and per unit demand.

From figure 2, it is illustrated that the random point 6 and 8 are very close to the real line, but the random point 10, 15, 17, 19 are more distance from the real line. Only three random points moves above the real line and rest of the random points below the real line. Therefore, for the selling price of normal random distribution data, the required profit line moves near about 12% below to the real line.

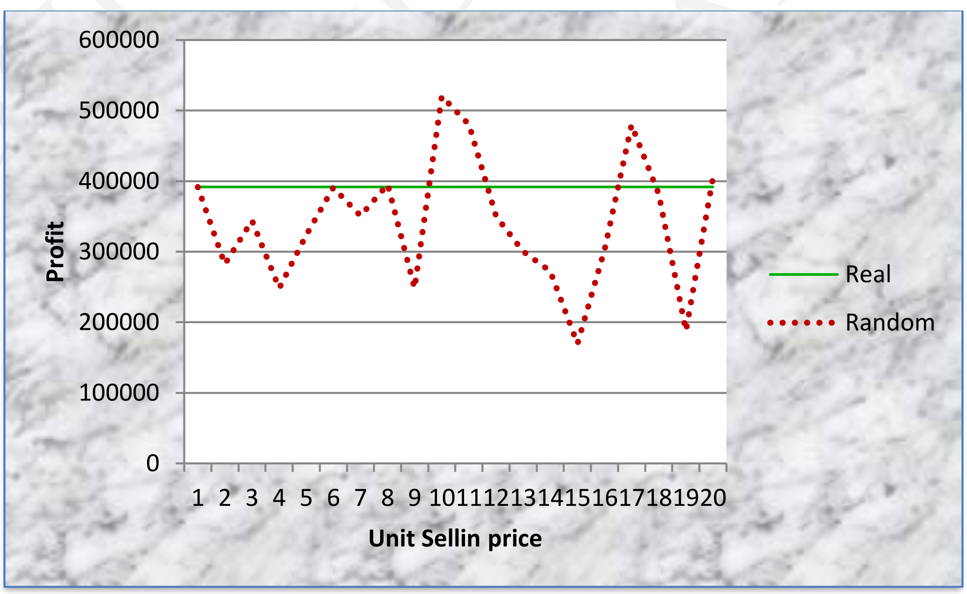

Fig.2 Profit comparison for the parameter selling price with real data and random data

From figure 3, it is observed that the random point 4 and 10 are very close to the real line, but the random point 9, 12, 15, 16, 18, 20 are more distance from the real line. Six random points moves above the real line and others random points below the real line. Therefore, for the labor cost of normal random distribution data, the required profit line moves near about 0.56% below to the real line.

From figure 4, it is seen that the random point 3, 4, 10 and 11 are very close to the real line, but the random point 12, 15, 16,17, 18,19, 20 are more distance from the real line. Five random points moves above the real line and others random points below the real line. Therefore, for the raw material cost of normal random distribution data, the required profit line moves near about 0.51% below to the real line.

Figure 5, indicate that the random point 18 and 19 are very close to the real line, but the random point 2, 6, 7, 9, 15, 20 are more distance from the real line. Random point 7, 9, 12, 13 moves below the real line and other random points moves above the real line. Hence, for the holding cost of normal random distribution data, the required profit line moves near about 0.05% above to the real line.

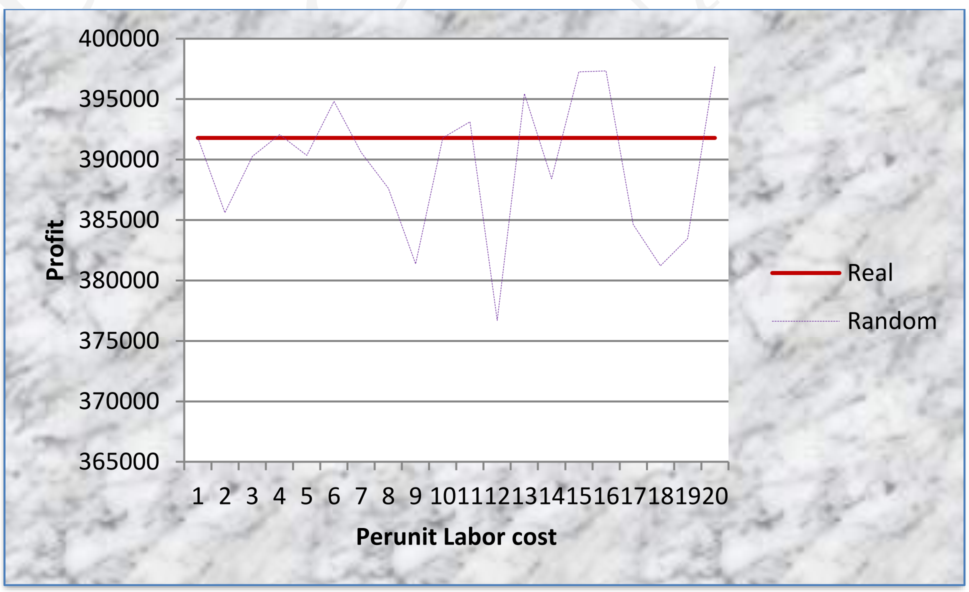

Fig.3 Profit comparison for the parameter labor cost with real data and random data

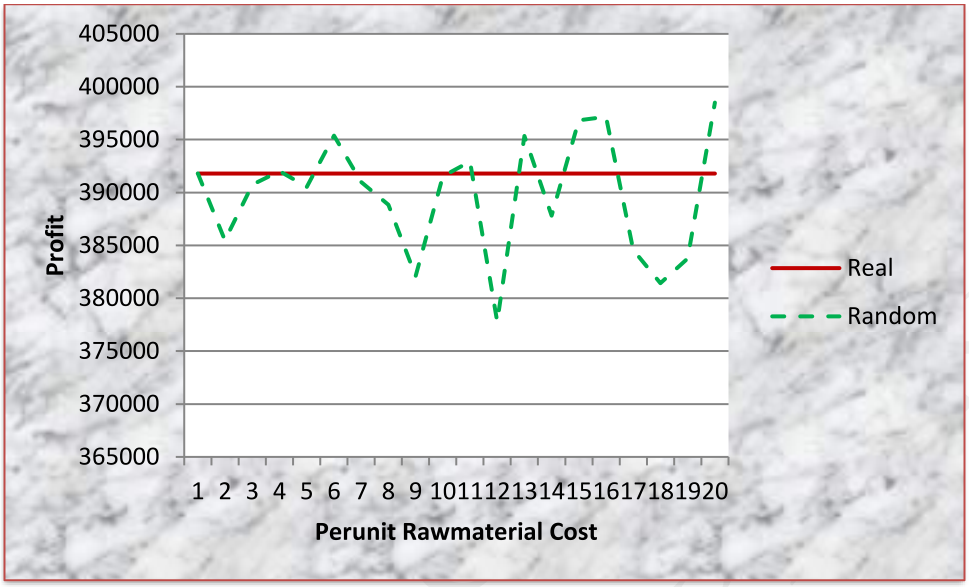

Fig.4 Profit comparison for the parameter raw material cost with real data and random data

Figure 6, described that the random point 6, 13 and 15 are very close to the real line, but the random point 2, 9, 12, 18 are more distance from the real line. Only two random points moves above the real line and rest of the others random point moves below the real line. Here, it is observed that for the transportation cost of normal random distribution data, the required profit line moves near about 0.98% below to the real line.

Figure 7, represent that the random point 3, 4, 13 and 18 are very close to the real line, but the random point 8, 9, 10 are more distance from the real line. Seven random points moves above the real line and rest of the others random point moves below the real line. Therefore, for the unit demand of normal random distribution data, the required profit line moves very close to the real line which is near about 0.004% below to the real line.

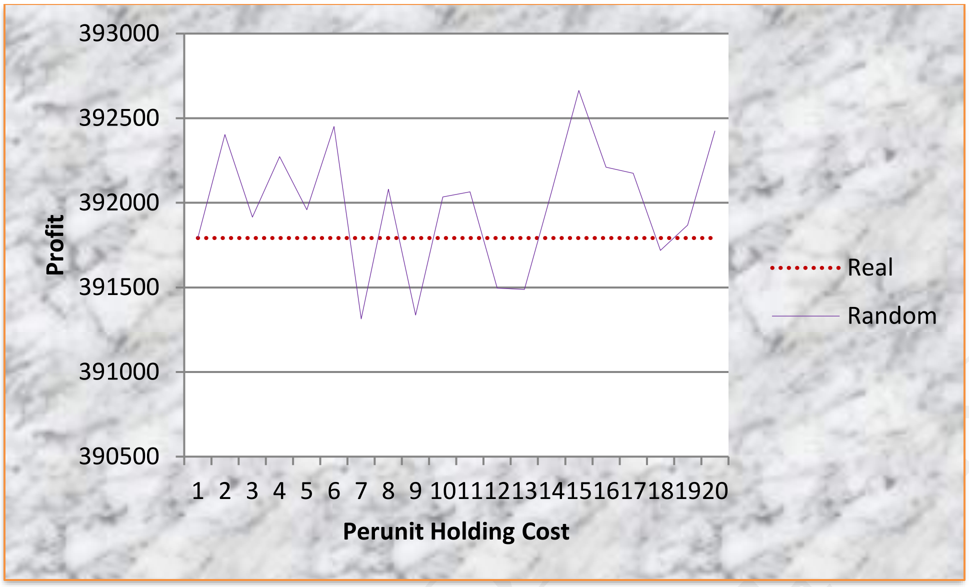

Fig.5 Profit comparison for the parameter holding cost with real data and random data

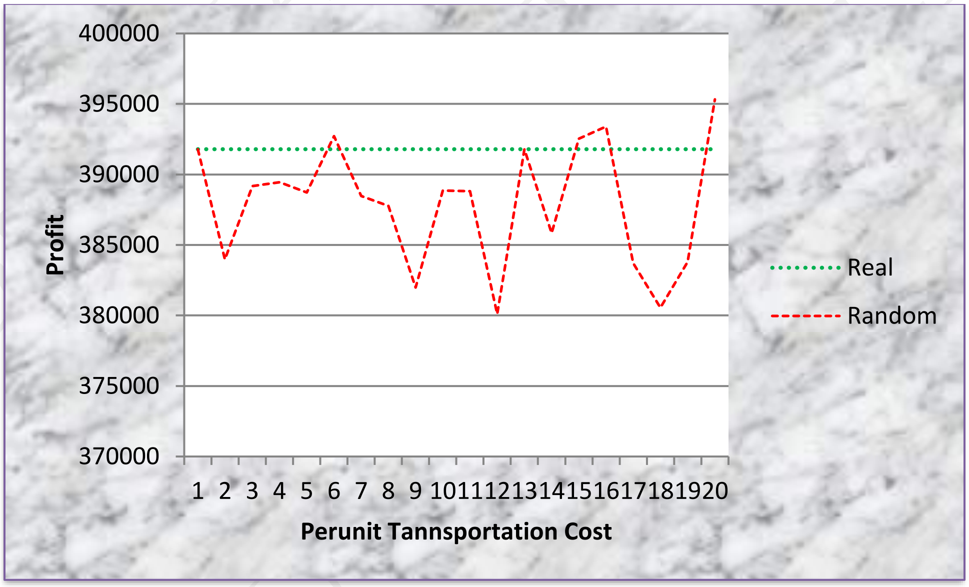

Fig.6 Profit comparison for the parameter transportation cost with real data and random data

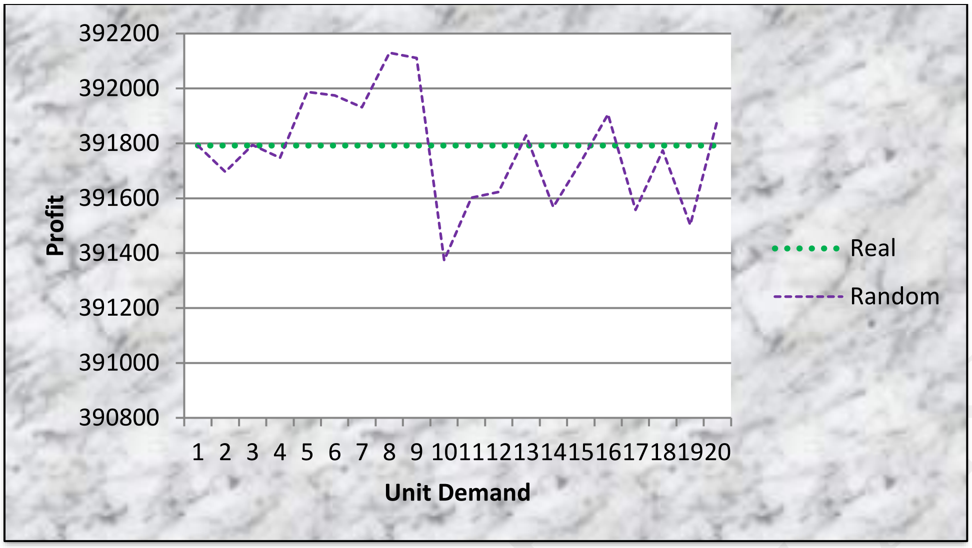

Fig.7 Profit comparison for the parameter unit demand with real data and random data

In Table1, Which provide the comparative analysis of the decision variables before and after coordination for totally recovered of deficit products by external sources. The percentage of the change of profit for various cases is obtained by the following formula:

$$PI(\%) = \frac{(Total\ return - Total\ investment)}{Total\ investment} \times 100$$

The individual profit of producer, retailer and distributor is calculated using the formula of described by Sajadieh and Jokag [12] and Goyal [11].

The individual profit before coordination of the producer, retailer and distributor are: Producer profit= 32.41%, Retailer profit= 14.12%, Distributor profit=18.25% and net profit= 64.78%.

If the deficit value of $\beta 1$ is assumed and the problem is solved, after coordination we have the following results are in Table 1.

Table 1: Coordinated policy with various outsourcing

S. No.	$\beta 1$	Producer profit%	Retailer profit%	Distributor profit%	Net profit%
1	0.01	**32.96**	23.42	**30.06**	**86.44**
2	0.03	30.91	25.99	34.43	91.33
3	0.05	29.70	27.42	36.95	94.07
4	0.07	28.92	28.45	38.60	95.97
5	0.09	28.35	29.20	39.75	97.30
6	0.10	28.14	29.50	40.21	97.85
7	0.30	26.40	31.95	43.79	102.14
8	0.50	29.98	32.68	44.74	103.39
9	0.70	29.73	32.97	45.18	103.88
10	1.00	**25.55**	33.21	**45.52**	**104.28**

From table1, we have the coordinated profit is maximum when the producer fully recovered the deficit of products, that is $\beta 1 = 1$, in that situation the producer profit is decrease. It is also observed that as the value of $\beta 1$ is increased the coordinated benefit is also increased.

Profit comparison before and after coordination of the different market participants of the SCN are shown in Table 2.

Table 2: Net profit of the different market participants

Market participants	Profit% after coordination	Profit% before coordination	Comparison before and after coordination(percentage)
Distributor	45.52	18.25	27.27
Retailer	33.21	14.12	19.08
Producer	**25.55**	**32.41**	-6.86
Coordinated benefit	**104.28**	**64.78**	39.50

The producer loss will be recovered by the retailer and distributor larger gain. After recover the producer losses the coordination profit has 39.50% for 100% deficit product recover, this profit could be shared all of the SCN participants. Therefore, after coordination the coordinated profit is increased by 39.50%.

Figure.8, shows that the profit before and after coordination for various market players in the relevant field. At first time, the producer profit increase in coordination method without outsourcing, but decrease with complete outsourcing. In the same time the total profit increase after coordination for both cases without and with outsourcing may be completely compensated by the retailer and distributor larger profit.

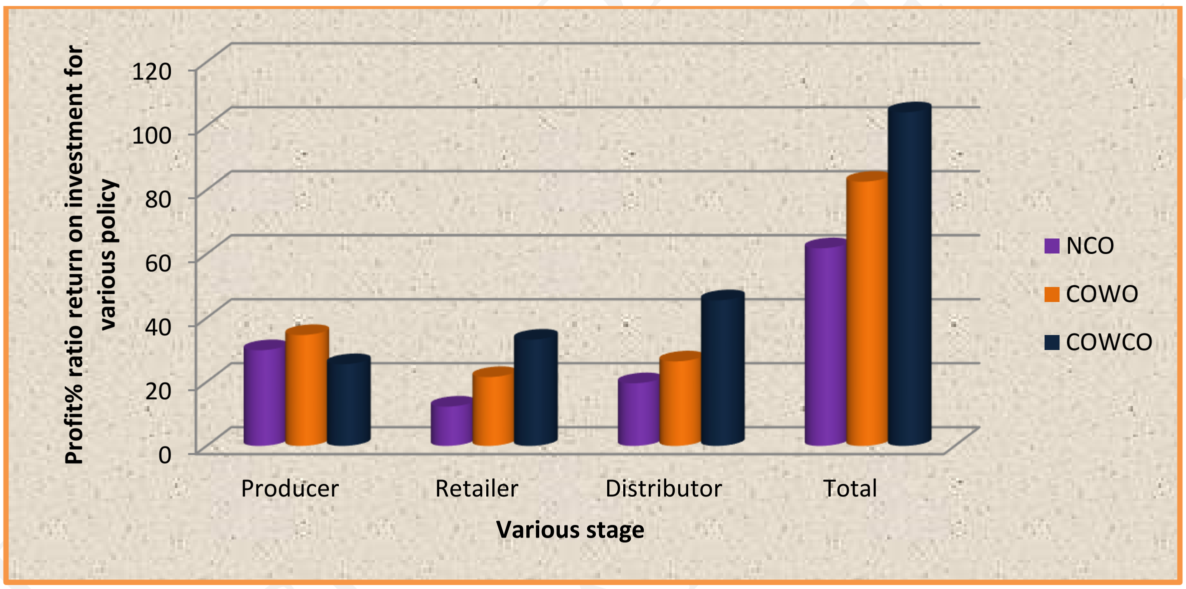

Fig.8 Profit of various market players before and after coordination

Therefore, coordination policy is the best policy for stable situation of agricultural sector in Bangladesh.

Sensitivity analysis was performed on the supply chain coordination model with supply and demand that uses the joint pricing policy. Decision variables were kept constant at the optimal level. When demand decrease and supply increase then profit decrease (Fig.9). Therefore, for supply chain coordination policy, each market players must have to satisfy their supply-demand condition.

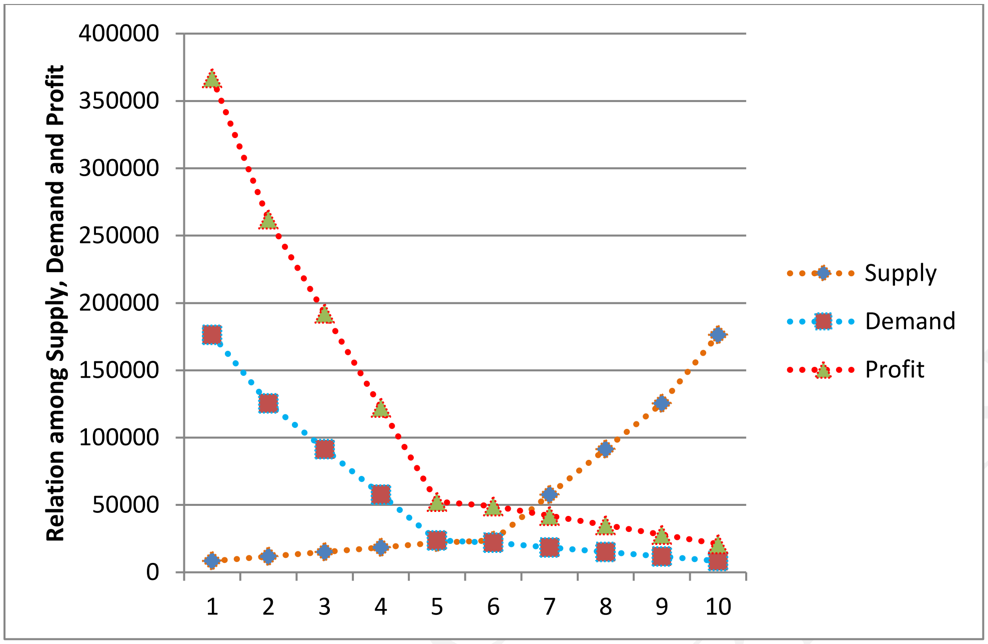

Fig.9 Profit sensitivity between supply demand

Conclusions

In this research, four mathematical MILP based models are developed for the coordinated SCN and solved these models by using AMPL with appropriate solver MINOS. In this paper, we assumed the insufficient production capacity of the producer recovered by external sources; it has been shown that total coordinated profit may be improved by recovering the deficit products. The formulated models simultaneously maximize the profit. Some of the significance findings can be summarized as follows:

The illustrated numerical example shows that, using the real data and normal distribution data for various parameters, results are not far difference. In addition, maximum profit is obtained for the coordinate policy when $\beta 1 = 1$ that is for fully recovered of deficit products. The external loss of the producer may be fully make amends by the retailer and distributor larger profit and therefore the coordination profit 39.50% for total recover of deficit products, which may be further, shared to raise the individual profit higher than that of their earlier non-coordinated approach. It is also observed that as the value of $\beta 1$ is increased the coordinated benefit is also increased. On the other hand, for stable situation the relation of supply and demand is very important. The work may also be expanded along a more progressive environment considering production and demand uncertainty.

Acknowledgements

I am highly thankful to the University Grants Commission of Bangladesh, for the provided financial support during my research work.

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