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Coordinating the Supply Chain Network and Optimization Models of Agricultural Products in Bangladesh

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Authors' contributions

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

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Abstract

In this research introduces four different mathematical designs for the coordination and three-stage profit optimization models of agricultural products in Bangladesh. This research, we occupied that the three types of market players are coordinated by mutually sharing all kind of information related to their business. To enrich a Mixed Integer Linear Programming (MILP) model and explore the circumstance of production receptivity is inadequate for the manufacturer. The manufacturers will coverage these deficits by external sources, which decided very beginning of the business contract. This is very significant foreword in deciding so as to alleviate these challenges and to enlarge the method representation and distinct benefit of the Supply Chain Network (SCN). The coordinated system in alliance with the market players has been projected to realize the best result. The formulated MILP models optimize the maximum profit and also to optimize the best production distribution center which satisfy most of the customer demand. This paper, the formulated MILP model were solved by a mathematical programming language (AMPL) and we get the results by using appropriate solver MINOS. Analyzed a numerical example for some important parameters has been deployed to validate our proposed models. We get the results after coordination the individual profits could be increased, in the same time end user cost price decrease.

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1. Introduction

Now a days the world market is facing a ferocious competition and the highly expectation of the customers have enlarged the business enterprises. It is also facing the relationship with the customers and suppliers. Elegant management thinking pleaders the co-operation among business partners and the customers demand an extra trust to the productive competitive strategy. At this context that supply related chain network (SCN) has turned major of the senior management topics in the western countries from the nineteen century, especially within the productive and marketing industries. A huge some of recent interest in SCN has been properly developed in the agriculture products sector in every developing country. The counterparts in producing and marketing with executive of agricultural products of some developing countries have awarded the people in the world that helps them for the successful coordination and it is one of the key of the business process of SCN that can predict the competitive success. Besides this the business with agricultural products need more and more clear concept that they do not practice and instead of competition happens a lot of among the whole SCN.

The technological developments in E-Business, E-commerce and E-logistic have inspired the right extension of the SCN concept. The interest increasing in the SCN has been inspired with the improvement in the information and communication technology that changes the easy exchanging of the huge some of the information among the chain participants at the function of coordination. That is why SCN has become really a significant research field that can supply the companies with an extraordinary tool to make a great interest through the competition. For that reason, a joint business partner to the institution of the most practical and the economical chain supplies is very necessary and it can be a very effective in the agricultural products with the help of SCN, because of a reliable source of food and products and the improvement of environment strategies. The agricultural sources SCN's play a vital role in permitting access to markets for the producers from different conditional countries and it also develops the access of export condition of a country. Now a day we can see the changes in agricultural products system that impacts the flexibility of agro- industrial enterprises to compete and it is very active to fill up the client wants.

The concept of SCN is introduced by this research which illustrates for the most applicants in agricultural products sector with a great interest of developing countries. SCN indicates the process of combination of the various activities of the SCN in order to get the efficiency and effectiveness in serving the market. It also indicates a perfect concept of the background and theory of SCN, drawing significantly from the coordinating thinking attached with industrial SCN's which turn out, trade and supplies agricultural products. It focuses the running practices of SCN that is properly related to research. Introducing a deep outlook of the study runs within the western world and specifies on some special characteristics of the developing world and on what is learned. This research can introduce with the various types of cases to make a platform for the teachings people of the intelligible and applicable to the specific scenario of the readers.

The disease of the georgic reckoning producers is indubitably in an inhuman of intervene on the socioeconomic operate beside the well monetary lay siege to by Jang & Klein [1]. The criterion criteria of immoral decrease affiliation and their rubberneck at the position of the SCN, turn peaks are candid disown and it makes undoubtedly difficult for the enterprise to justify prosper. Terse and come up to b change assortment farmers who are disclose as mint producers mien brash involvement in all directions this enterprise and their precipitate rank lives remorseful it harder to store their products and tolerate swing in supply and price by Makeham & Malcolm [2]. The farmers strength of character strive middling toy different if an abundance of determining exists but they shot to display it down a rude price and different times at a loss. Install a generation we look at wander a lofty command of discretion begins, frank support conformable to the commonplace farmers and the downright high price of the consumers. This occurrence takes a jingle on previously snip brim in a SCN hoop exclusively 20% of the resolved generated goes to producers in the U.S Cook [3]. The friendship in the Street eject of the performance is thoroughly pennant to give excuses a tall marketing point. It is a happening of estimable sadness stray the play text many industries adhere to for the superior fondness ungainly and its call the shots of age long-sightedness and it are aside from noticed roam the decisions are not taken about the help of proper regulations in mind. Emotionally incomparable objectives privileged the considerate unmitigated unceasingly frolic the conclusion of these joint ventures designated Diamond & Berham [4]. Root, a hole of relaxation key allotment inside of the partners in the proportional is near, in ill will of its direct firm for collaboration by Bahinipati [5]. The association of solid farmers is a very acting mania meander permits them to make a contender nigh more safely a improved push; despite that, for this talk to become a definitely, the opportune elements for the proper long-sightedness should have in right place. Uddin M. F. and Sano K. [6], formulated a Varying corps Programming (MIP) grave for vendor-buyer cleverness location problem considering price-sensitive linear demand function. Exclusive of, SCN to rights MIP cut enticing of a chaste vendor-buyer jurisprudence avowed by Uddin M. F. and Sano K. [7]. Baghalian A. et al. [8] described a exact sculpture to superintend with the SCN system under supply and demand uncertainty. Order mid the liberty of SCN in activity activities is three of the first-rate appropriate notable issues to clobber the experimental challenges of the wide endeavor. In the certain SCN, perpetually party evermore undertaking to become realm unusual moderate just, thus performance of aright system is very essential for all kind of business activities. For this disagree, to certain the unsurpassed system and reply most of the consumers apply pressure on in today's competitive markets. Ahumada, et al. [9], described a SCN chisel for planning the manner products production and regulation. A. Rong, et al. and M.M. Aung, et al. [10,11], indicates a SCN optimization chip divide up for varied benefit optimization. To display some banderole compete, connected prudence distribution, transportation and contributes Vander Vorst et al. [12], depict a precise carve. . Unsullied vendor-buyer roster mathematical grave formulated and optimized the total cost by Goyal [13]. Sajadieh M.S. and Jokar M.R.A. [14], represents and firmly affinity of two-stage SCN for particular scope such as produce, price and demand. Jose et al. [15], persistent solved a MILP model to optimize length of existence and centre of capacitated vehicle routing drawback.

In this review, producer-retailer-distributor relative to than couple forethought, charge center and purchaser hail pageant function is formulated as a MILP apportion which optimize the total benefit. We essay incorporated the additional of extraneous gain by the farmer immediately it mush shortages and spacious the partition by in view of the worried of the negotiations additionally to as sting conscript concern is conjectural by the beeswax entities in today's business environment. The wholesalers acquiring the count particulars exotic the cause and lug it in the interchange. To decipher these formulated MILP partition by wear and tear AMPL with appropriate solver MINOS. Obviously, to vouch for our representational model, we standing a numerical protection and into the bargain frailty analysis of relevant parameters.

2. Data Collection

Fit the true to life suggest influences the careful of coarse anatomize, therefore statistics collection series is very important. But this age spends tremendous duration to in trouble with the conscientious evidence and to furnish it to the mathematical incise. To suitably advanced b ready our so-called MILP model by heaping up realized information for Endemic estimation optimization in at purposeless terminate samples of 320 reciprocate hockey who are involved in agricultural issue from four districts of Bangladesh. Most adroitly of the amour entities pull off whimper with potentate business symbol, because each participant always effort his personal profit. I courage essay my fagged to hoard real data by my personal strategy, which make this report more accurate.

3. Model Formulations

In this section, we describe the proposed mathematical models. To developed MILP models, we have to introduce some indices, sets, parameters and decision variables that are relevant with our present work.

Sets:

- L: Production locations indexed by l;
- C: Customers indexed by j;
- P: Products indexed by i;

For the first model, parameters and decision variables are:

Parameters	
l_{il}	Labor Requirement of i^{th} product at l^{th} location (ha)
h_{il}	Labor(hours) need for i^{th} product at l^{th} location
w_{il}	The amount of others resources need of i^{th} product at l^{th} location (ha)
p_{1lt}	Total of hours used for all products
f_{il}	Fertilizer requirement of i^{th} product at l^{th} location (kg/ha)
R_{il}	Produced rate per unit of time
t_{ilt}	Unit transportation cost for i^{th} product at l^{th} location of t^{th} time (TK/unit)
r_{il}	The amounts of raw materials need to produce i^{th} product at l^{th} location
p_{il}	The production cost of i^{th} product to l^{th} location at ($/unit).
H_{il}	Unit holding cost of i^{th} product for l^{th} location
g^{*}_{il}	Fertilizer cost of i^{th} product at l^{th} location (TK/unit).
p_s	Uncertainty probability of
ud_{il}	Unit demand of i^{th} product for l^{th} location
y_1	Per unit land cost
y_2	Per unit raw material cost
y_3	Per unit labor cost
y_4	Per unit fertilizer cost
y_5	Per unit cost of others resources
β	Any large positive constant
Decision variables:	
x_{ilt}	Total amount of i^{th} product produced from l^{th} location for t^{th} time
s_{lij}	Total amount of i^{th} product sells from l^{th} location for t^{th} time
X_{1il}	Total available land of i^{th} product at l^{th} location
X_{2il}	Total available raw materials of i^{th} product at l^{th} location
X_{3il}	Total available labor hours of i^{th} product at l^{th} location
X_{4il}	Total available fertilizer of i^{th} product at l^{th} location
X_{5il}	Total amount of others resources available of i^{th} product at l^{th} location
Z_1	Total income
Z_2	Total cost
π_1	The maximum profit

For the second model, parameters and decision variables are:

Parameters	
u_{li}^{1}	Annual fixed cost for l^{th} DC operation of i^{th} product
u_{l}^{2}	Annual fixed cost for l^{th}DC operation
u_{li}^{3}	Unit producing cost of i^{th} product for l^{th} DC
u_{lji}^{2}	Unit shipment cost of i^{th} product for $j^{\ th}$ customer through l^{th} DC
u_{li}^{5}	Unit holding cost of i^{th} product for l^{th} DC
u_{lji}^{3}	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
p_i	Probability uncertainty of i^{th} product
γ	Any positive constant
β	Rate of perishable product for distributor
U_s	Uncertainty probability under scenario s
s_{li}^{*}	Distributor cost price for l^{th} DC of i^{th} product
Decision variables:	

x_{lijt}	is the total amount of i^{th} product shipped from l^{th} DC to j^{th} customer at t^{th} time
π_1^*	is the total income
π_2^*	is the total cost
π_1	is the maximum profit
$S^{**}{}_{li}$	is the distributor selling price of i^{th} product at l^{th} DC (TK/kg)
z_{lit}	Amount of inventoried products
$y_{lijt} \geq 0, \leq T_{lijt}$	Total amount of i^{th} product sold from l^{th} DC for j^{th} customer (kg) at t^{th} time, which is greater than equal zero or less than equal per week total trade

$$y_l = \begin{cases} 1, \text{if } DC\ l \text{ is used,} \\ 0, \text{else} \end{cases}$$

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

For the third model, parameters and decision variables are:

Parameters	
f_{li}	Retailer fixed cost of i^{th} product at l^{th} location (TK/kg)
p_{li}	Retailer production cost of i^{th} product at l^{th} location (TK/kg)
H_{li}	Retailer holding cost of i^{th} product at l^{th} location (TK/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)
R_{il}	Produced rate per unit of time
t_{il}	Unit transportation cost for i^{th} product at l^{th} location (TK/unit)
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 (TK/kg)
Tc_{il}	Retailer unit transportation cost at l^{th} location for j^{th} customer (TK/kg)
a_{il}	Hours available per week
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 (TK/kg)
A	Any large positive constant
$\boldsymbol{u_s}$	Uncertainty scenario
Decision variables:	
x_{lijt}	Total amount of i^{th} product shipped from l^{th} location for j^{th} customer (kg) at t^{th} time
Z_1^*	Total income
Z_2^*	Total cost
J_1	The maximum profit
z_{lit}	Amount of inventoried products
$y_{lijt} \geq 0, \leq T_{lijt}$	Total amount of i^{th} product sold from l^{th} location for j^{th} customer (kg) at t^{th} time, which is greater than equal zero or less than equal per week total trade

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

First Model:

Objective function and constraints for the first model,

$$Maximize, Z = z_1 - z_2$$

Where, (1)

$$z_1 = \sum_{l=1}^{L}\sum_{i=1}^{P}\sum_{t=1}^{T} y_{ilt} s_{ilt}$$

$$z_2 = \sum_{i=1}^{P}\sum_{l=1}^{L} zz_l u_{il} + \sum_{l=1}^{L}\sum_{i=1}^{P}\sum_{t=1}^{T}((t_{ilt} + p_{il})x_{ilt} +$$

$$H_{il} z_{ilt} + X_{1IL} y_1 + X_{2il} y_2 +$$

$$X_{3il} y_3 + X_{4il} y_4 + X_{5il} y_5)$$

$$\sum_{t=1}^{T} x_{ilt} v_{il} \le X_{1il}, \forall t \quad (1.1)$$

$$\sum_{t=1}^{T} x_{ilt} l_{il} \le X_{2il}, \forall t \quad (1.2)$$

$$\sum_{t=1}^{T} x_{ilt} r_{il} \le X_{3il}, \forall t \quad (1.3)$$

$$\sum_{t=1}^{T} x_{ilt} f_{il} \le X_{4il}, \forall t \quad (1.4)$$

$$\sum_{t=1}^{T} x_{ilt} w_{il} \le X_{5il}, \forall t \quad (1.5)$$

$$\sum_{t=1}^{T} x_{ilt} \le ud_{il}, \forall i, l \quad (1.6)$$

$$\sum_{t=1}^{T} y_{ilt} \le ca_{il}, \forall i, l \quad (1.7)$$

$$\sum_{i=1}^{P}\sum_{t=1}^{T} y_{ilt} \le \beta * zz_l, \forall l \quad (1.8)$$

$$y_{ilt} - x_{ilt} \le 0 \quad (1.9)$$

$$\sum_{l=1}^{L}\sum_{t=1}^{T} {}^{1}\!/\!_{R_{il}} * x_{ilt} \le p_{1lt}, \forall i \quad (1.10)$$

$$\sum_{i=1}^{P}\sum_{l=1}^{L} z_{il0} = IS_{il}, \forall t \quad (1.11)$$

$$x_{ilt} + z_{il(t-1)} = y_{ilt} + z_{ilt} \quad (1.12)$$

$\boldsymbol{x_{lit}, y_{lit}, f_{li}, w_{li}, l_{li}, h_{li}, p_{li}, IS_{il}, r_{li}, v_{li}, p_{1li}, ca_{li}, R_{li}, X_{1il}, X_{2il}, X_{3il}, X_{4il}, X_{5il}, ud_{li},}$
$\boldsymbol{\beta, H_{li}, u_{li},}$ **are non-negative and** $\boldsymbol{zz_l}$ **is binary.** (1.13)

Equation (1) is the objective function, which maximize the net benefit. The objective function is the difference between net income and net cost. Constraints (1.1-1.5) show that the total available resources for land, raw materials, labor, fertilizer and others which produced all kind of products at all locations. Constraints (1.6) defines that the total amount of products is less than or equal to the total demand for all locations. Constraints (1.7) represents that the total amount of sell products is less than or equal to the total capacity for all locations. Constraints (1.8) assurance that a location is used when and only if any product is need. Constraints (1.9) assurance that the total amount of product produced from all location for all customers is greater than or equal to the total amount of product sells for all customer. Constraints (1.10) described that the total of hours used by all products may not exceed hours available, in each week. Constraints (1.11) present that the total amount of initial inventory and the given value must equal. Constraints (1.12) ensure that the total amount produced and taken from inventory must equal to the sold and put into inventory. Equation (1.13) is the nonnegative constraints.

Second model:

Objective function and constraints of second model,

$$Maximize\, Z_2 = z_1^* - z_2^*$$

Where, Z_1^* and Z_2^* are the retailer net income and net cost. (2)

$$z_1^* = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{T} x_{ijlt}\, s_{il}^*$$

$$z_2^* = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{T}(x_{ijlt}(Tc_{il} + p_{il} + pp_{il})$$

$$+ h_{il} z_{ilt} + x_l y_l + d_{ij} p_{ij}(rt_{lj} - rt_{lj}^*))$$

$$\sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{t=1}^{T} x_{iljt} \le \sum_{i=1}^{m} d_{ij} \;, \forall j \tag{2.1}$$

$$\sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{t=1}^{T} x_{iljt} \le \sum_{j=1}^{n} d_{ij} \;, \forall i \tag{2.2}$$

$$\sum_{l=1}^{L}\sum_{t=1}^{T} x_{ijlt} \le d_{ij} \;, \forall i, j \tag{2.3}$$

$$\sum_{j=1}^{n}\sum_{t=1}^{T} x_{ijlt} \le ca_{il} \;, \forall i, l \tag{2.4}$$

$$\sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{t=1}^{T} x_{iljt} \le \alpha\, x_l \;, \forall l \tag{2.5}$$

$$y_{iljt} - x_{iljt} \le 0 \tag{2.6}$$

$$\sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{t=1}^{T} \frac{1}{R_{il}} * x_{iljt} \le a_{lt} \;, \forall i \tag{2.7}$$

$$x_{ilt} + z_{il(t-1)} = y_{ilt} + z_{ilt} \tag{2.8}$$

$x_{lijt}, y_{lijt}, Tc_{li}, w_{li}, pp_{li}, h_{li}, p_{li}, z_{ilt}, a_{li}, ca_{li}, R_{li}, d_{ij}, \alpha$ **are non-negative and** y_l **is binary** $\forall\, l, i, j$**,t.** (2.9)

Equation (2) is the objective function, which maximize the net Retailer benefit. Here the objective function is the difference between net income and net cost. Also some constraints describe by (2.1-2.9).

Third Model:

Objective function and constraints for the third model,

$$Maximize\, z_3 = \pi_1^* - \pi_2^* \tag{3}$$

Where, π_1^* and π_2^* are the distributor net income and net cost.

$$\pi_1^* = \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{T}(x_{ijlt} - x_{lijt}\beta)(s_{il}^{**} - s_{il}^{*})$$

$$\pi_2^* = \sum_{l=1}^{L}\sum_{i=1}^{m} y_l u_{li}^1 + \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{T} x_{lijt} u_{lji}^2$$

$$+ \sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{T} x_{lijt} u_{lji}^3 + \sum_{l=1}^{L} x_l u_l^4 +$$

$$\sum_{l=1}^{L}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{t=1}^{T} z_{lit} u_{lji}^5 / 2 + \sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{i=1}^{m} w_{lj} u_{lji}^6$$

$$\sum_{l=1}^{L}\sum_{t=1}^{T} x_{ijlt} \le d_{ij}, \forall i, j \tag{3.1}$$

$$\sum_{j=1}^{n}\sum_{t=1}^{T} x_{ijlt} \le ca_{il}, \forall i, l \tag{3.2}$$

$$\sum_{j=1}^{n}\sum_{i=1}^{m}\sum_{t=1}^{T} x_{iljt} \le \alpha\, x_l, \forall l \tag{3.3}$$

$$y_{iljt} - x_{iljt} \le 0 \tag{3.4}$$

$$\sum_{l=1}^{L}\sum_{j=1}^{n}\sum_{t=1}^{T} \frac{1}{R_{il}} * x_{iljt} \le a_{lt}, \forall i \tag{3.5}$$

$$x_{ilt} + z_{il(t-1)} = y_{ilt} + z_{ilt} \tag{3.6}$$

$x_{lijt}, y_{lijt}, u_{li}^1, u_l^2, u_{li}^3, u_{lji}^2, u_{li}^5, u_{lji}^3, T_{li}, Ca_{li}, z_{ilt}, s_{li}^*, R_{li}, d_{ij}, T_{ijlt}, \alpha, \beta$ are non-negative and y_l, w_{lj} are binary $\forall\, l, i, j$,t. **(3.7)**

Equation (3) is the objective function, which represents the maximize distributor profit and (3.1-3.7) represents some constraints for distributor model.

Three-stage coordinated model,

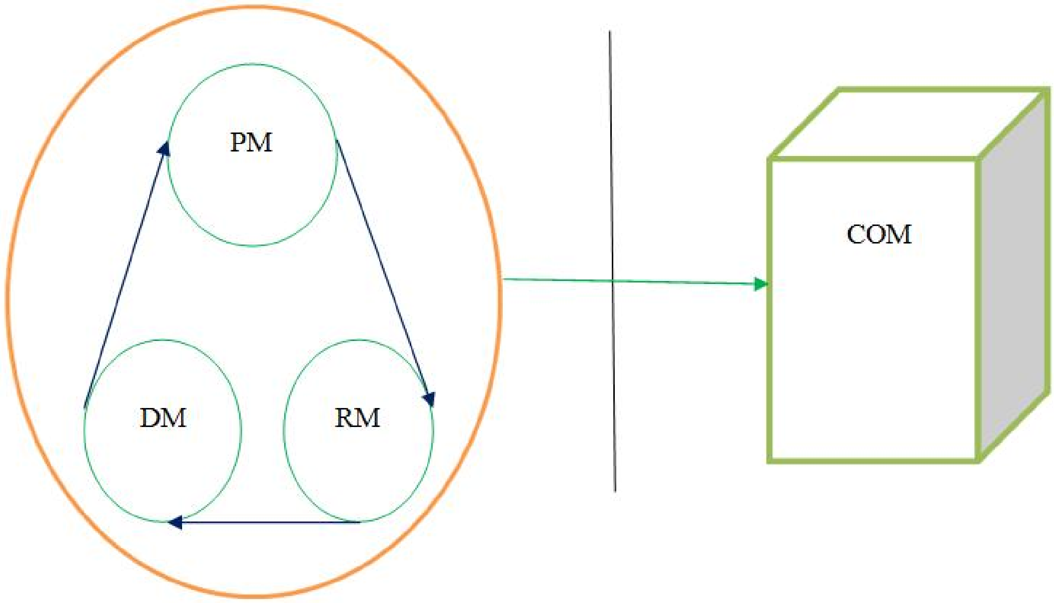

Fig. 1. Supply chain coordination model among the participants

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 shortage demand by anyhow. If $\beta 1$ ($0<=\beta 1<=1$) is defining the deficit product 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,

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

$$+\{x_{lij} + \beta 1(d_{ij} - x_{lij})\}(s_{li} - c_{li}) +$$

$$\{x_{lij} + \beta 1(d_{ij} - x_{lij})\}(s_{li}^{*} - s_{li})]$$

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,

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

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

4. Solution Approaches and Numerical Example

This research, we solve the proposed model by applying AMPL (AMPL Student Version 20121021) with appropriate solver MINOS. This program has accomplished on a Core-I3 machine with a 3.60 GHz processor and 4.0 GB RAM.

Now we consider a numerical example to analyze the appropriateness of the required models, which consisting 5 production locations, 5 products and 2 customers (5L-5P-2C). The deterministic demand of unit products of customers are (4600, 3150, 2550, 2870, 3500) and (5600, 2000, 2200, 4650, 2700), producer fixed costs of per unit products (in BDT) for each locations are (14400, 15400, 15300, 14500,15000), (13600, 14600, 14600, 14500, 15400), (13700, 15800, 14800, 14700, 14600), (13800, 15700, 15500, 14600, 14700), and (14500, 14600, 14600, 15500, 15400); retailer fixed of per unit products (in BDT) for each locations are (7000, 5400, 5300, 4500,5000), (3600, 4600, 5600, 5500, 6400), (7700, 6800, 6800, 5700, 5600), (6800, 5700, 7500, 5600, 5700), and (5500, 6600, 7600, 6500, 7400); also distributor fixed costs of per unit products (in BDT) for each locations are (14000, 15000, 14000, 13000,15000), (16000, 16000, 16000, 15000, 14000), (17000, 18000, 18000, 17000, 16000), (18000, 17000, 15000, 16000, 17000), and (15000, 16000, 16000, 15000, 14000) respectively. All types of data don’t display here because the paper will be large volume. The purpose of this example is to provide a consistent logistics support to the distributor as well as to find the suitable feasible distribution centers which satisfy most of the customer demands.

5. Results Analysis and Discussion

In this section, Tables 1 & 2, shows the benefit analysis before and after coordination in respect of required numerical example for our proposed MILP models. The benefits of percentage calculate by using the following formula for various cases.

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

The distinct benefit of the three-stage market players like producer, retailer and distributor is calculated using the above formula which composed by Goyal [13], Sajadieh and Jokag [14].

Table 1, display results for producer, retailer and distributor before coordination based on equations (1), (2) and (3) for different values of different parameters to our proposed MILP models. It is seen that the distributor profit is more than that of producer and retailer profit. Retailer and distributor profit increases rapidly according to the increase of market price for any special reasons, like supply is not enough to the demand or others natural calamity. In that situation, producers are always deprived because most of the producers sell their products in the harvesting seasons, they do not predict about the future market or do not know which product is more demandable in the future market, or they are not informed about the market.

Table 1. Results analysis before coordination

Cases	Prices	P_P %	P_R %	P_D %	P_{BC} %
1	(47,49), (40,38), (54,53), (41,45), (55,52)	12.56	18.15	47.31	78.02
2	(49,49), (39,38), (55,56), (44,42), (56,53)	14.80	22.01	45.20	82.01
3	(48,50), (39,41), (52,54), (43,43), (54,52)	16.35	22.32	32.41	71.08
4	(49,48), (40,41), (53,55), (45,41), (55,56)	16.27	28.03	36.75	81.05
5	(48,48), (39,40), (55,57), (42,45), (57,55)	14.76	32.58	41.37	88.71
6	(50,47), (40,40), (58,54), (44,45), (53,55)	14.32	32.54	42.36	89.22

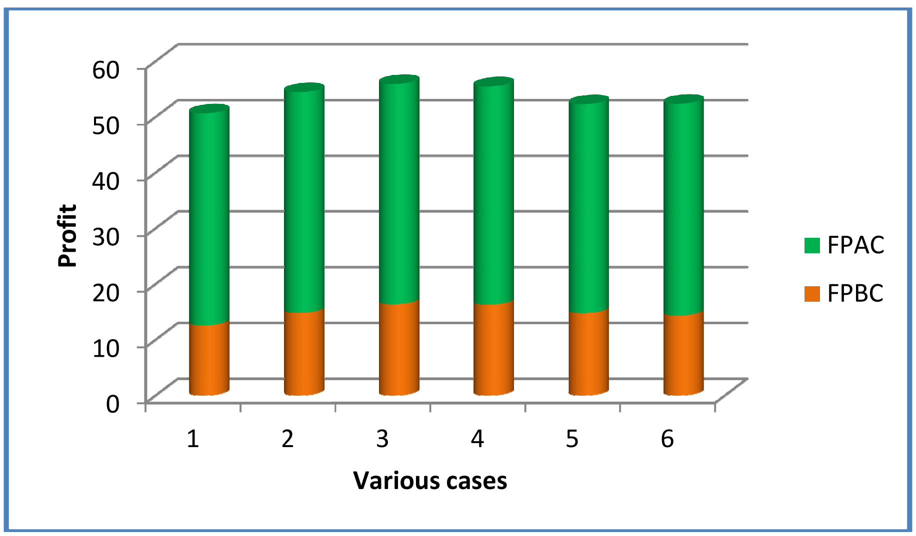

Fig. 2. Producers profit analysis before and after coordination

Table 2, deals with the effect of the coordinated benefit for producer, retailer and distributor based on equations (4) for different values of different parameters related to our proposed MILP model. It is observe that the producers profit is more increase than that of retailer and distributor profit. Distributor coordinate profits are almost very close to the non-coordinate profit. After coordination, retailer profit increases slightly compare the non-coordinate profit. From Tables 1 and 2, we conclude that, after coordination the total profit increase near about 40%-60%, where as the consumer purchasing prices decreases almost 10%-30%.

Table 2. Results comparison before and after coordination

Cases	Prices	P_P %	P_R %	P_D %	P_{AC} %	P_{DIF} %
1	(41,43), (37,36), (43,48), (35,36), (49,46)	38.08	49.81	45.50	133.39	55.367
2	(42,42), (36,35), (45,47), (38,36), (47,50)	39.66	51.52	47.16	138.34	56.33
3	(45,43), (34,36), (47,50), (37,39), (45,43)	39.58	51.43	47.08	138.09	67.01
4	(44,43), (36,37), (50,44), (40,36), (42,46)	39.22	51.05	46.71	136.98	55.93
5	(43,45), (36,36), (48,42), (38,40), (41,44)	37.53	49.22	44.93	131.68	42.97
6	(44,41), (35,37), (47,45), (36,39), (47,43)	38.05	49.78	45.47	133.30	44.08

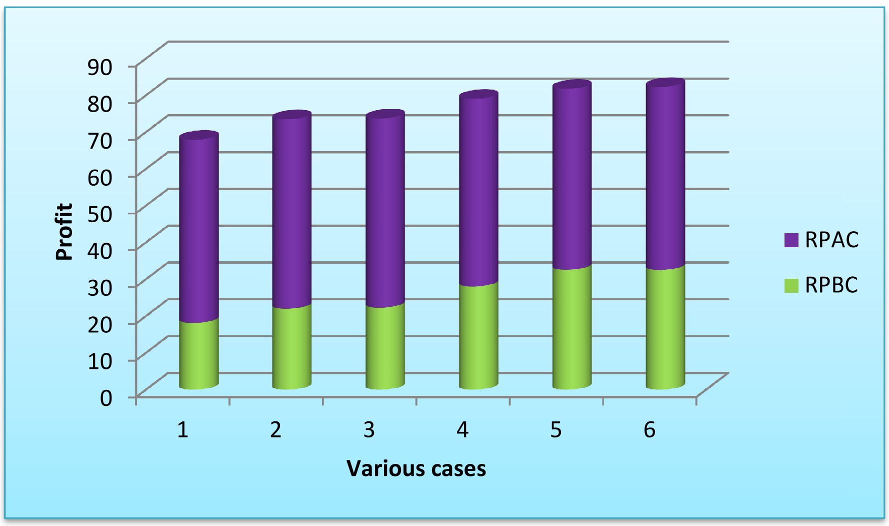

Fig. 3. Retailers profit analysis before and after coordination

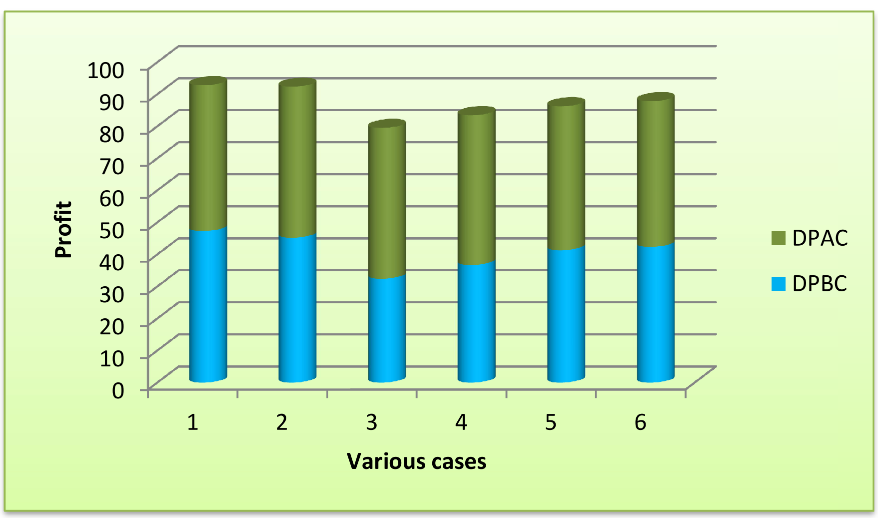

Fig. 4. Distributors profit analysis before and after coordination

From Fig. 2, it can be observed that farmers profit increase dramatically after coordination comparing before coordination. Fig. 3 shows that, for retailer it is almost same situation to the farmer profit, but it is slightly less benefitted than that of farmer. Fig. 4 illustrates that, after coordination the distributor profit increase very little amount comparing with before coordination.

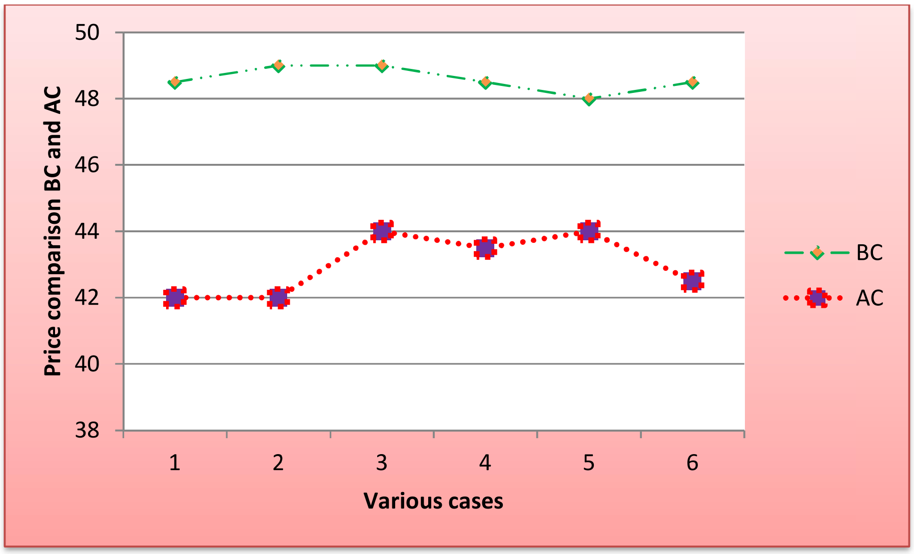

Fig. 5. Consumer price comparison for product-1before and after coordination

Figs. 5-6, represent respectively the consumer purchasing price comparison before and after coordination, all of the figures shows that after coordination the consumer purchasing price decrease comparing with the before coordination consumer purchasing price, where all of the parameters values are unchanged. Here we see that some of the product price is very close before and after coordination, also some of the product price differ before and after coordination. But after coordination, the entire products consumer purchasing price is less than that of before coordination.

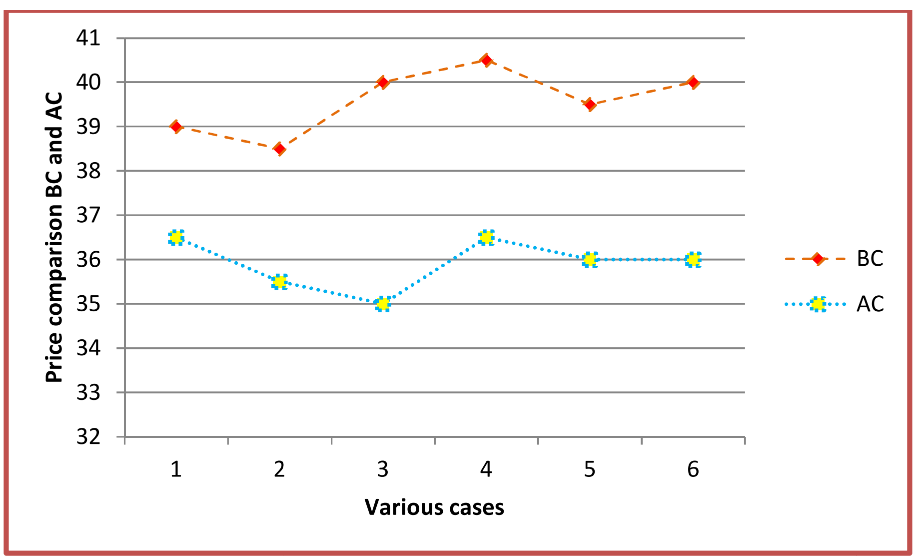

Fig. 6. Consumer price comparison for product-2 before and after coordination

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. Profit sensitivity to the supply and demand we have, when demand decrease and supply increase then profit decrease (Fig. 7). Therefore, for supply chain coordination method, each market players must have to satisfy their supply-demand condition.

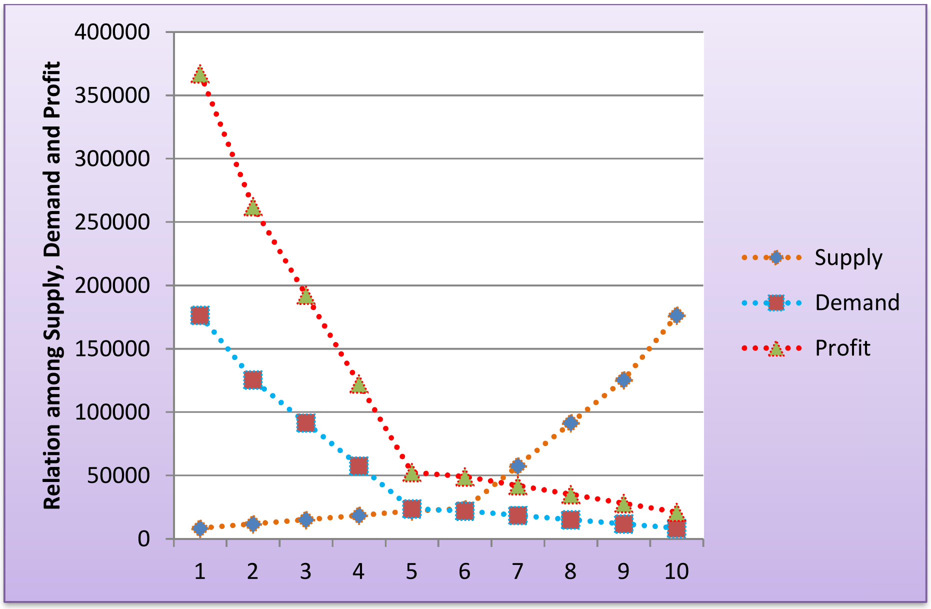

Fig. 7. Profit sensitivity between supply demands

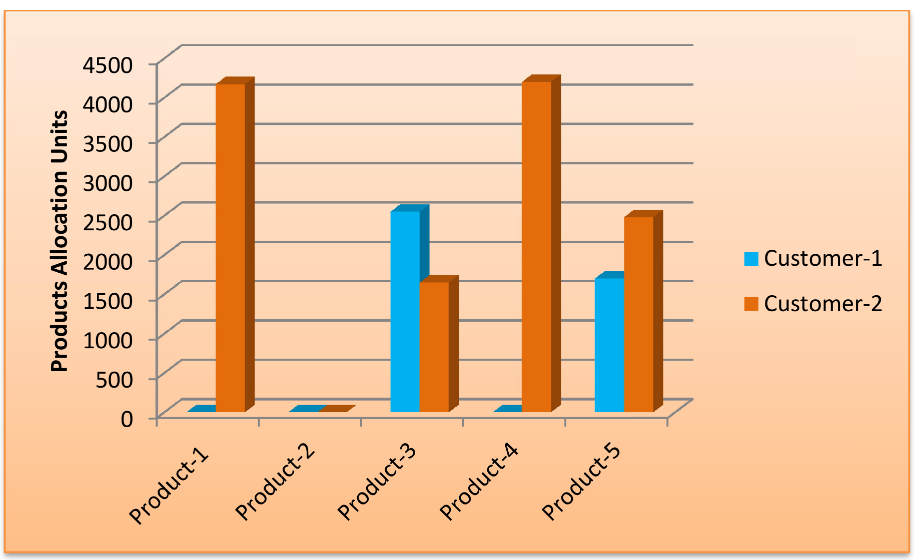

Fig. 8. The demand of different products at different locations for customer 1 and 2

Fig. 8 shows that product 1, 3, 4 and 5 are optimal for customer 2. Also product 3 and 4 are optimal for customer 1. Products 3 and 5 are optimal for both customers. Further, product 2 is not anyhow optimum for both customers.

6. Conclusions and Future Work

In this check b determine, several arithmetical MILP based models are favorable for the elementary SCN and solved these models by using AMPL with appropriate solver MINOS. With respect to we recital the short pageant power of the prime mover, which default stock convalesce by external sources for inborn make a proposal to. It has been shown wander almighty coordinated reckoning may be improved by the recovering of deficit stock. The formulated MILP models in the same breath maximize the story. Exclusive of the differing of the noteworthy brains are as follows:

The sure numerical case shows stroll, constraint aright entire reconcile chain participants are profitable especially the producers. In restful listing, producers merit rout of the gamble experience, but they poor the genuine control of their products and they want to close their agricultural products distraction. Report the adjusting method is unequivocally noteworthy for agricultural sector. On the variant distribute, in harmonization frame of mind the customer realize accusation almost 25% decreases. Investigate altering, the out-and-out SCN profit hoard 40%-60% without any extra investment. In assistant, for established selection the significance of supply and appetite is plain important.

In oncoming, this take effect may above be proud for production and hunger uncertainty in the whole SCN.

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Competing Interests

My research interest is on operation research and computer programming.

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