



## Supply Chain Optimization for Farmer-Bepari System of Agricultural Products in Bangladesh

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### Authors' contributions

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

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## Abstract

This study, for the Farmer-Bepari system of agricultural products in Bangladesh, can be formulated as a mixed integer linear programming (MILP) model. Further, it will be investigated that the significant impact of profit the attributes such as labour cost, fertilizer cost, the raw material cost of different firms and also to estimate the product distribution in different locations. To solve this MILP model, with the help of a branch and bound algorithm by using A Mathematical Programming Language (AMPL). To investigate the model we have to collect data from seven locations of three districts in Bangladesh. Also, a numerical example presented this study, which objectives illustrate the models. From the sensitivity of the production, if the raw material cost, labour cost and fertilizer cost increase is about 5%, then decrease

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the profit by MILP model have 0.004%, 1.6% and 1.2% respectively. Labour cost is a significant factor in profit, which changes the profit more than the raw material cost and fertilizer cost of the product. The results are helping decision-makers to identify the desired agricultural production and distribution structure optimization strategy.

*Keywords: Mixed Integer Linear Programming (MILP); agriculture products; supply chain; marketing; Bangladesh.*

## 1 Introduction

Bangladesh is an agricultural country. Most of the people directly or indirectly involved in agriculture. Agriculture has played a key role in reducing Bangladesh's poverty from 48.9% in 2000 to 31.5% by 2010 with over 87% of rural people part of their some income from agricultural activities (World Bank, 2016). Agriculture remains the most important sector of Bangladesh economy, contributing 71% to the national GDP in 1971, which has naturally declined. During the fiscal year 2013 to 2017, the broad agriculture sector contributed 15.47%, 15.32%, 14.58%, 14.02% and 13.41% respectively to the total GDP (BBS and GoB) [1,2]. Even in the agricultural sector, the corresponding contribution to GDP has fallen over time (currently 13.41%) but the unconditional contribution is still on the rise. Although the economy of Bangladesh is primarily dependent on agriculture in terms of employment, the living condition of small-scale farmers is not in good. They provide hard labour for the production of the agricultural product but do not get the fair price of their products. The price what the consumers pay and the farmers get are very much gap. This means that farmers of the country are not getting that price at which products are sold in the market Abdullah and Hossain [3]. Present government and non-government organizations (NGO) have taken many programs and initiatives for the development of agriculture sectors, from which fertilizer and seed distribution is very important along with ensuring other facilities for the farmers. For appropriate initiative by the government and NGO, crop production has increased by two to three times in the last few economic years (Abdullah and Hossain 2013). But the high crop production cannot be productive for farmers because without an effective agricultural marketing system; they cannot involve themselves for a long time in the agriculture production sector. If the farmers do not get the fair price for their products they must disagree to continue to produce the agricultural products and change their occupation. In due course, the supply of agricultural products, inputs and services is very important to target groups, like farmers, distributors and consumers. Agricultural marketing is not just a means of distributing agricultural product but also a way of stimulating new forms of production Abbott, [4]. Agricultural marketing is the supply chain moving from agricultural products from the farmers to the bepari, paiker, retailer and consumer. Agricultural products production and marketing are inter-connected activities, like planning, production, growing and harvesting, grading, packaging, transport, storage distribution and sale Sultana, [5]. In our country most of the farmers are uneducated and they are not skilled for proper agricultural marketing system. Agriculture marketing business of Bangladesh, intermediaries are playing a prominent role and they get a major portion of the benefits. But they create artificially interrupted the supply of agricultural products. Actually, they are not the major players in the agricultural sectors. They create one kind of business syndicate and maintained by the intermediaries have a huge impact on the ability of small-scale farmers that creates barriers in getting a fair price for their products The farmers are bound to the business syndicate decision. The absence of adequate institutional network persists to deal with the marketing channel of all major commodities such as rice, jute, vegetables, poultry, fish, and tea in the country. The business syndicate is reduced farmers bargaining power, so the farmers do not get the right price for their products. Farmers are bound to sell their products at the harvest time when the prices are minimal, so they get a very low return for their produced products. For the lack of coordination, small-scale farmers do not know the current market price, trends, demand and supply of their products in the market which create barriers for the farmers in getting a fair price of their products. In the whole business chain, the farmers are bearing maximum risks, but they are deprived of the major benefits of their products.

In the widespread enterprise, succeed of new demand; supply chain is a very important argument for agriculture business. It is ordinary each party always try to Mark Up his own profits, so without a supply

chain system for comprehensive business could not be optimal. That is why significant information needs to be shared along the supply chain to ensure the optimal system and to satisfy customer demands in today's competitive markets. To get the optimal result, proper coordination between Farmers- Baperi's decision makings is also required.

For single vendor-buyer model, optimizing the joint total cost was first introduced by Goyal [6]. Then developed the model by incorporating a finite production rate and following a lot-for-lot policy for the vendor Banerjee [7]. By relaxing Banerjee's lot-for-lot assumption, proposed a more general joint economic lot-sizing model Goyal [8].

Further, the effectiveness of price-sensitive demand, quantity discounts and volume discounts as a coordination mechanism in distribution channels described Viswanathan and Wang [9]. They decided that, if the sensitivity of demand to price changes higher then the effectiveness of volume discounts as a coordination mechanism is higher and the sensitivity of demand to price changes lower then the effectiveness of quantity discounts is higher. Again for a single supplier and single buyer price-sensitive demand with volume discounts and franchise fees as a coordination mechanism in a system of supply chain constructed Qin et al. [10]. Subsequently, they showed that when demand is price sensitive, channel profits achieved by employing volume discounts and franchise fees are larger than achieved by quantity discounts and franchise fees.

Moreover, for one supplier, multiple producers, distributors and retailers four-stage integrated supply chain model described Pourakbar et al. [11]. Then by applying supply chain system, they determined the optimal order quantity of each stage and the shortage level of each stage to minimize the cost. In the meantime, the Joint Economic Lot Sizing (JELS) model has described Sajadieh and Jokar [12] where they optimize the number of shipment, pricing and ordering strategy. Also considering JELS policy a vendor-buyer integrated production inventory model with price-sensitive demand of the customer have described Jokar and Sajadieh [13].

Also, operations research and management science community have led to a strong interest in location analysis and modelling with location decision making. It is very natural, humankind has been analyzing the effectiveness of location decisions since they inhabited their very beginning. Solving incapacitated facility location problems, a method has proposed Holmberg [14], where the term 'facility' is used in its magnificent sense.

Consequently, the integrating transportation and infinite horizon multi-echelon problem and an inventory cost function have studied Teo and Shu [15]. The formulated set-partitioning integer-programming model has solved by using column generation algorithm which develops a pricing sub-problem. In fine, they prove that the subproblem of price is NP-complete. To determine the location distribution facilities problem of integrated decision models have described Ko [16]. Also, he proposed the process of hierarchy and analyzed the research findings from data based on the location selection measure and displayed the practical applicability. To determine the number of the warehouse for locating an economic facility to set up a model has investigated Eroglu and Keskindürk [17]. For the warehouse location problem, they considered a genetic algorithm for minimizing the warehouse construct distribution costs. Also for discontinuous piecewise linear cost function, a transportation model has investigated Sheng et al. [18]. "Challenges and Prospects of the Poultry Industry in Bangladesh" have analyzed Islam et al. [19]. Also "Supply Chain Optimization by Mixed Integer Program for Manufacturer and Retailer System of Poultry Firms in Bangladesh" has described Islam et al. [20]. In the same time "Comparison and Supply Chain Optimization of Poultry Firms in Bangladesh Using Mixed Integer and Linear Fractional Program" have provided Islam et al. [21].

For the purpose of this study, production, marketing and supply chain surety the optional condition for the farmers and beparis system, every model has select the best location for the warehouses. Here we have considered transportation cost, raw material cost, inventory holding cost, production cost and under a set of constraints for land, labour, fertilizer, water and available capitals. The sensitivity on the farmers and

bepari's cost price, selling price and profit are discussed and hence make a conclusion in support of the marketing chain that could be applied to solve the facility location problem.

In this paper the organized as follows: section 1 presents the literature review, to develop the model the methodology, notations and assumptions are discussed in section 2. In section 3, construct two MILP model for farmers and beparis and discussed in detail. Findings from the two models are discussed in section 4.

## 2 Methodology

This study, data were collected from primary and secondary sources. The data were collected to achieve the result for the purpose and scope of this study. Primary data was collected by questionnaire survey and direct interview with the farmers and beparis in seven different locations districts of Mymensingh, Kishorgonj, Gazipur and Manikgonj of Bangladesh. The main question to the farmers is the production cost of their products and profit margin. Most of the small-scale farmers had given actual and valuable data to complete the study. The secondary data were collected from Bangladesh Agriculture University (BAU), Bangladesh Rice Research Institute (BRRI), Bangladesh Bureau of Statistics (BBS), Directorate of Agricultural Marketing (DAM), Food and Agricultural Organization (FAO), Statistics Department of Bangladesh Bank, The Bangladesh Journal of Agricultural Economics, The Indian Journal of Agricultural Economics, Bangladesh Economic Review, Asian Vegetables Research Development Center (AVRDC), NGOs reports, Newspapers and Internet Files.

Data were collected from some farmers and some market players who are directly or indirectly involved in the sub-sector of agricultural organization in the study area. There are many limitations to the data collection such as time, location, funds, a wider range of commodity etc. Also, the honesty of the interviewees of the farmers and beparis opinion and answer is very important for better result of this study. Every businessman has some business strategies and practices which are very confidential, so they do not disclose the actual information in order to maintain the secrecy of the business and which give the more authentic result of this study. Again some major marketing players of agricultural farms disagree to disclosing the information and some of them do not understand to answer the questions. Small-scale farmers get the actual data to compare with large farmers or educated farmers. But actual data is very important to get the optimal result, here applying my personal strategy to get actual data from agricultural products production and marketing players.

### 2.1 Notation and assumption

In order to get the formulation of the model several assumptions, parameters declaration, decision variables and notations are required. In this subsection, we have described the notations, assumptions, parameters declaration and decision variables for the MILP based individual Farmers and Beparis model. The notations are as follows.

It is considered an agricultural firm consists of a single farmer and single bepari with a set of feasible locations. The farmers produced the products and deliver to bepari's. Again beparis delivers the products to the customers at different locations. The red colour arrows represent the commodity flow and the green colour arrows represent the information flow.

### 2.2 Penalty function

The penalty function can be written as

$$g_{lj} = \begin{cases} 1, & \text{if } t_{lj} > t_{lj}^* \\ 0, & \text{else} \end{cases}, \text{ where the required time of delivery is } t_{lj} \text{ of products from location } l \text{ to bepari } j$$

and should be delivery time is  $t_{lj}^*$  from location  $l$  to bepari  $j$ .



Fig. 1. Study area

### 2.3 Decision variables

$$y_{ij} = \begin{cases} 1, & \text{if customer } j \text{ is assigned to manufacturer } l, \\ 0, & \text{else} \end{cases}$$

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

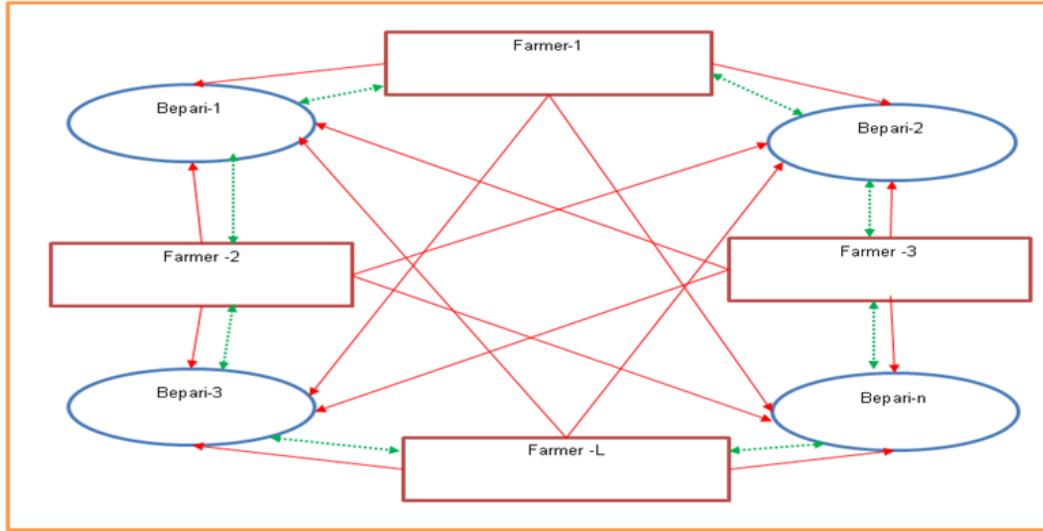
Variable  $x_{li}$  is the optimal area of product  $i$  for location  $l$  (ha).

Variable  $x_{lij}$  is the production quantity of product  $i$  for bepari  $j$  at location  $l$  (unit).

Let us consider the following assumptions:

- i. Every farming area facility is capable to produce all of the products (rice, wheat, potato, vegetables etc.)

- ii. The selling price and purchasing price for any product vary from seller to customer and customer to seller depending on their negotiations, location facility, order sizes, discounts, historical relationships, etc.
- iii. The objective function and all constraints are linear.



**Fig. 2. Coordination model of the supply chain**

**Table 1. Notation for the multiproduct multi-customer and multi-facility Farmer-Bepari system**

Notation	Parameters
$i$	Number of product indexed by $i$ for all $i=1, 2, \dots, m$ .
$j$	Number of bepari indexed by $j$ for all $j=1, 2, \dots, n$ .
$l$	Number of farmer location indexed by $l$ for all $l=1, 2, \dots, L$ .
$s_{ij}$	The selling price of product $i$ to bepari $j$ (\$/unit).
$\alpha_l$	The fixed opening cost for the farmer at location $l$ (\$).
$\alpha$	Any positive scalar.
$TT_{li}$	Unit cost of transportation of raw materials from location $l$ to bepari $j$ (\$/unit).
$TC_{li}$	Unit cost of transportation of product $i$ from location $l$ to bepari $j$ (\$/unit).
$h_{li}$	Unit cost of holding of product $i$ from location $l$ (\$/unit).
$f_{li}$	Fertilizer cost for product $i$ at location $l$ (\$/unit).
$l_{li}$	Labour cost for product $i$ at location $l$ (\$/unit).
$w_{li}$	Water cost for product $i$ at location $l$ (\$/unit).
$u_{li}$	Return for product $i$ at location $l$ (\$/ha).
$A$	Total feasible area for production.
$L$	Available labour for production.
$F$	Available fertilizer for production.
$W$	Available water for production
$c_{ij}$	Bepari's purchasing price of product $i$ to location $l$ (\$/unit).
$M_{lji}$	Maintenance cost of product $i$ to bepari $j$ at location $l$ (\$/unit).
$H_{lji}$	Unit cost of holding of product $i$ from location $l$ to bepari $j$ (\$/unit-time).
$S_{lji}$	Unit cost of shipment of product $i$ from location $l$ to bepari $j$ (\$/unit).
$d_{ij}$	The total demand of product $i$ to bepari $j$ (unit).
$w_{li}$	Production capacity for product $i$ at location $l$ (unit).
$t_{ij}$	Delivery time required of products from location $l$ to bepari $j$ (unit).
$t^*_{ij}$	Required time which should be delivery from location $l$ to bepari $j$ (unit).
$p$	Delay delivery penalty cost (\$/unit).

### 3 Model Formulation

#### 3.1 MILP model for farmers

In this subsection, we formulated farmers mixed integer linear programming model which estimates the total profit and optimal locations and distributions. Therefore the optimization functions are as follows:

$$\text{Maximize} = r_1 - r_2 \tag{1}$$

Where  $r_1$  is the total return and  $r_2$  is the total investment.

$$\sum_{i=1}^m \sum_{j=1}^n u_{ij} * x_{ij} = r_1 \tag{1a}$$

Farmers total cost:

Farmer total cost is the summation of fixed opening cost, labour cost; water cost, fertilizer cost, transportation cost and holding cost are as follows:

$$\sum_{l=1}^L \alpha_l * x_l + \sum_{l=1}^L \sum_{i=1}^m (F_{li} + L_{li} + W_{li} + H_{li} + T_{li}) * x_{li} = r_2 \tag{1 b}$$

Constraints:

These constraints restrict the use of available resources such as land, labour, fertilizer and water. For the utilization of available resources, the following relationships are used:

$$\sum_{i=1}^m \sum_{j=1}^n x_{ij} \leq A \tag{1.2}$$

$$\sum_{l=1}^L \sum_{i=1}^m L_{li} x_{li} \leq L \tag{1.3}$$

$$\sum_{l=1}^L \sum_{i=1}^m W_{li} x_{li} \leq W \tag{1.4}$$

$$\sum_{l=1}^L \sum_{i=1}^m F_{li} x_{li} \leq F \tag{1.5}$$

$$x_{li}, F_{li}, c_{li}, W_{li}, L_{li}, u_{li}, h_{li}, t_{li}, L, W, F, A, \alpha_l \geq 0, x_l \text{ is binary} \tag{1.6}$$

Where ‘ $i$ ’ is the type of products, ‘ $l$ ’ is the produce location of that product.  $A$  is the total farmland available,  $L$  is the total labour available,  $W$  is the total water available and  $F$  is the total fertilizer available for the product of location  $l$ .

In this paper, to solve the above two model by using the branch and bound algorithm strategy. Branch and bound algorithm are generally used to get the optimal solution to the optimization type problems. This study, to optimize the profit, production allocations, distributions and minimizes the cost of products.

The constraints help define the interrelationships among the decision variables and the agriculture production conditions. In detail, constraints (1a) express the total return and (1b) express the total investment production of the total products; constraint (1.2) indicate the total land allocated to different products which are not greater than to the total land area available; constraints (1.3), (1.4), (1.5) indicate that the maximum requirement of such factors of production as labour, water and fertilizer not greater than to the regional resource available. The last equation (1.6) is the nonnegative constraints.

### 3.2 MILP model for Beparis

In this subsection, we formulated beparis mixed integer linear programming model which estimates the total profit according to the optimal products allocation and distribution. Therefore the optimization functions are as follows:

$$\text{Maximize} = R_1 - R_2 \quad (2)$$

Where,  $R_1$  is the total return and  $R_2$  is the total investment.

$$\sum_{l=1}^L \sum_{j=1}^n \sum_{i=1}^m Q_{lji} * (s_{li} - c_{li}) = R_1 \quad (2a)$$

Baperi's total cost is the summation of fixed cost, shipment cost, maintenance cost, holding cost, penalty cost and transportation cost are as follows:

$$\begin{aligned} & \sum_{l=1}^L x_l * \alpha_l + \sum_{l=1}^L \sum_{j=1}^n \sum_{i=1}^m (S_{lji} + M_{lji} + H_{lji}) * x_{lji} + \sum_{l=1}^L \sum_{j=1}^n \sum_{i=1}^m p d_{ji} y_{lj} (t_{lj} - t_{lj}^*) g_{lj} \\ & + \sum_{l=1}^L \sum_{j=1}^n TT_{lj} * TC_{lj} = R_2 \end{aligned} \quad (2b)$$

Constraints:

$$\sum_{l=1}^L \sum_{i=1}^m x_{lji} = \sum_{i=1}^m d_{ji}, \forall j \quad (2.2)$$

$$\sum_{l=1}^L \sum_{j=1}^n x_{lji} = \sum_{j=1}^n d_{ji}, \forall i \quad (2.3)$$

$$\sum_{l=1}^L x_{lji} = d_{ji}, \forall i, j \quad (2.4)$$

$$w_{li} \geq \sum_{j=1}^n x_{lji}, \forall i, l \quad (2.5)$$

$$m_{li} \geq \sum_{j=1}^n x_{lji}, \forall i, l \quad (2.6)$$

$$\sum_{j=1}^n \sum_{i=1}^m x_{lji} \leq \alpha * x_l, \forall l \quad (2.7)$$



$$\sum_{l=1}^L y_{lj} = 1, \forall j \tag{2.8}$$

$$x_{lji}, d_{ji}, y_{li}, w_{li}, m_{li}, S_{lji}, M_{lji}, H_{lji}, y_{jl}, TT_{lj}, TC_{lj}, t_{lj}, t^*_{lj}, g_{lj}, p, \alpha_l \geq 0, x_l \text{ is binary} \tag{2.9}$$

The constraints help define the interrelationships among the decision variables and the agriculture production and distribution conditions. The objective function (2a) express the total return and (2b) express the total investment. Constraints (2.2) represent the total amount of products being produced at all locations for a particular buyer must be equal to the total that buyer demand. Similarly, constraints (2.3) indicate that a particular product being produced all locations in the study area is equal to the buyer's total demand for that product. It is important to note here that the first two constraints are stated separately to show better accountability of the total demands from all buyers and for all products respectively. Constraints (2.4) assurance that the sum of the finite product being produced for a particular buyer at all locations is satisfied the buyer's demand for the specific product from that buyer. Constraints (2.5) represent the capacity constraint. Constraints (2.6) represent the maintenance cost constraint. Constraints (2.7) premise that a location is located if the demand for any product. Constraints (2.8) show that each buyer is assigned to exactly one location. The last constraint (2.9) is the nonnegative constraints.

### 4 Results and Discussion

Here we consider a numerical example to analyze the effectiveness of the formulated two models. Let us consider a farmer has 7 locations, 3 products and 2 beparis. For both beparis the unit demand of products are (3200, 2700, 2300) and (2900, 2500, 2600), unit cost of transportation in (\$) for farmers are (0.2, 0.3), (0.3, 0.2), (0.2, 0.3), (0.3, 0.2), (0.2, 0.2), (0.3, 0.3) and (0.3, 0.2), unit time transportation in (h) (10, 12), (11, 13), (12, 10), (10, 11), (12, 10), (10, 14) and (11, 12), unit cost of penalty in (\$) for products are (0.10, 0.15, 0.10) and (0.2, 0.10, 0.20) respectively. Also, for both MILP model the following Table-2, represent the others information about the parameters of MILP models.

**Table 2. Parameters of the MILP models**

Parameters	Locations for the Bepari's						
	1	2	3	4	5	6	7
Selling price(unit)	(17,18,19)	(18,17,17)	(19,18,18)	(17,18,18)	(18,18,19)	(17,19,17)	(19,178,18)
Purchasing price(unit)	(10,11,12)	(10,10,11)	(12,11,11)	(10,10,11)	(11,11,12)	(10,12,11)	(12,10,11)
Shipment cost(unit)	(0.1,0.2,0.1)	(0.1,0.1,0.1)	(0.1,0.2,0.3)	(0.2,0.1,0.1)	(0.1,0.2,0.3)	(0.3,0.3,0.3)	(0.2,0.3,0.1)
Holding cost(unit)	(0.2,0.1,0.3)	(0.3,0.1,0.2)	(0.2,0.3,0.1)	(0.2,0.1,0.2)	(0.1,0.1,0.1)	(0.1,0.1,0.1)	(0.1,0.1,0.3)
Capacity (in hun. Unit)	(21,15,10)	(12,14,18)	(15,13,18)	(12,18,13)	(18,13,10)	(11,15,18)	(16,11,15)
Maintenance cost(unit)	(0.3,0.2,0.1)	(0.1,0.1,0.2)	(0.2,0.1,0.1)	(0.1,0.2,0.1)	(0.1,0.1,0.2)	(0.2,0.2,0.1)	(0.2,0.1,0.1)
Required delivery time	(11,12)	(10,12)	(12,11)	(11,12)	(12,11)	(13,13)	(10,12)
Obligatory delivery time	(10,7)	(8,10)	(10,9)	(9,10)	(10,8)	(10,10)	(9,11)

To analyze the effectiveness of the key parameters, we consider five sets of the bepari's opening costs (\$) with same average value such as (6000,8000, 5000,6000, 7000,8000,7000), (8000,6000, 6000, 5000, 8000,7000,7000), (7000, 5000, 8000, 7000, 6000,8000,6000), (5000, 7000, 8000, 6000, 7000, 6000, 8000) and (8000,8000, 7000,7000, 6000,6000,5000), while all other remaining parameters unchanged as shown in Table 2 are included. From numerical example, Tables 3 and 4 are briefly summarized the significant

outcomes of the proposed farmers and beparis MILP model as well as the allocations and the distribution of the produced products for bepari-1 and bepari-2.

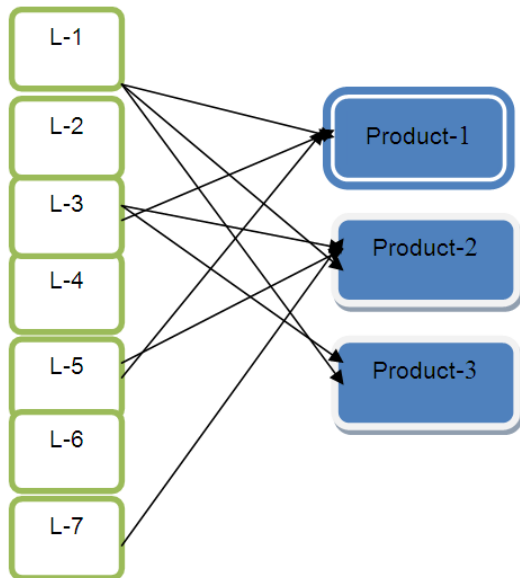
**Table 3. The sensitivity of the fixed opening cost for Bepari-1**

MILP						
Location-1	Location-2	Location-3	Location-4	Location-5	Location-6	Location-7
(500,1500,100)	(00,00,00)	(1500,200,1300)	(00,00,00)	(1200,1000,00)	(00,00,00)	(00,00,00)
(00,1500,800)	(00,00,00)	(1500,00,1500)	(00,00,00)	(1700,1200,00)	(00,00,00)	(00,00,00)
(1200,800,1000)	(00,700,00)	(1200,00,1300)	(00,00,00)	(1800,1200,00)	(00,00,00)	(00,00,00)
(500,1500,1000)	(00,00,00)	(1000,00,1300)	(00,00,00)	(1700,1200,00)	(00,00,00)	(00,00,00)
(00,1500,1000)	(00,00,00)	(1500,00,1300)	(00,00,00)	(1700,1200,00)	(00,00,00)	(00,00,00)

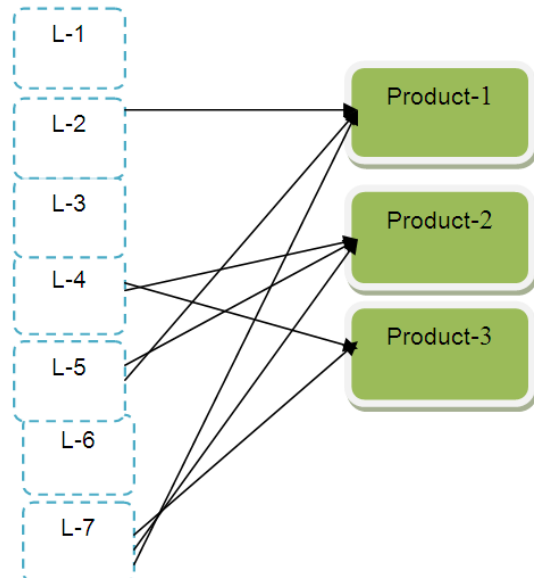
**Table 4. The sensitivity of the fixed opening cost for Bepari-2**

MILP						
Location-1	Location-2	Location-3	Location-4	Location-5	Location-6	Location-7
(00,00,00)	(1200,00,00)	(00,00,00)	(00,1800,1200)	(600,2000,00)	(00,00,00)	(1100,500,1400)
(00,00,00)	(1200,700,00)	(00,00,00)	(00,1800,1200)	(100,00,00)	(00,00,00)	(1600,00,1400)
(00,00,00)	(1200,700,100)	(00,00,00)	(100,1800,1100)	(00,00,00)	(00,00,00)	(1600,00,1400)
(00,00,00)	(1200,700,00)	(00,00,00)	(00,1800,1200)	(100,00,00)	(00,00,00)	(1600,00,1400)
(00,00,00)	(1200,700,00)	(00,00,00)	(00,1800,1200)	(100,00,00)	(00,00,00)	(1600,00,1400)

Figs. 2 and 3 describe the optimum allocation of different products for both bepari’s. From the distribution pattern of different products, it is clear that MILP provides optimal locations of the Farmer for Bepari-1 are 1, 3, 5 and 7. The optimal locations are achieved by MILP model of the Farmer for Bepari-2 are 2, 4, 5 and 7. Hence, by using this model the distribution of different products, it is explicitly recommended that for both bepari location-6 is not remained optimal, which shows the following Figs. 3 and 4.



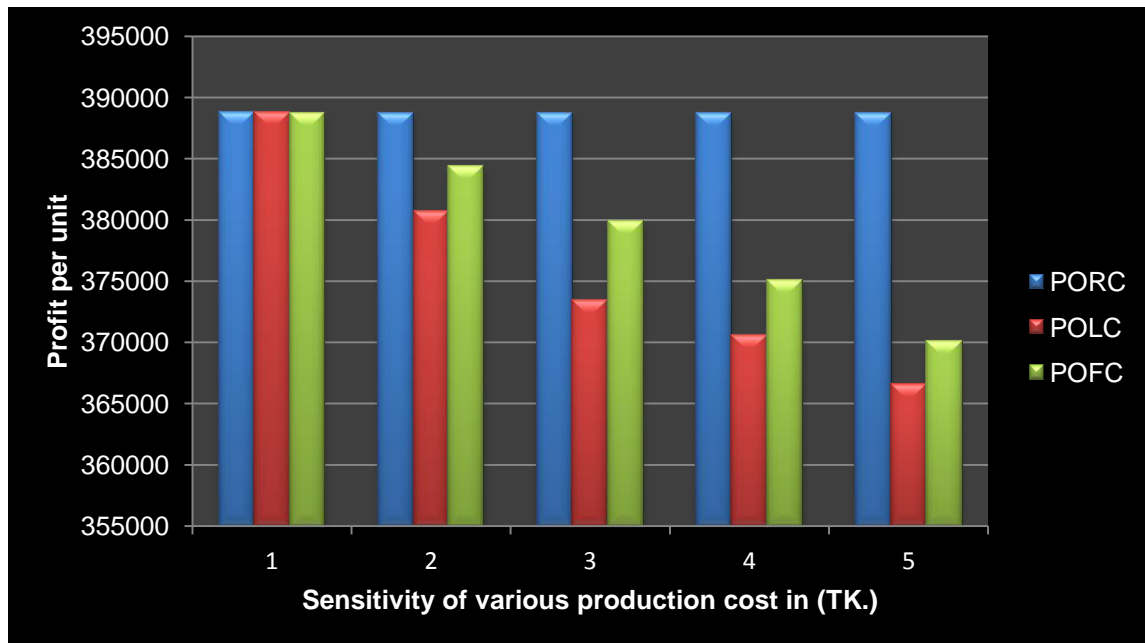
**Fig. 3. Allocatios for baperi-1 by MILP Mode**



**Fig. 4. Allocations for baperi-2 by MILP Model**

Analyzed this study, it is clear that the production cost, raw material cost, fertilizer cost, labor cost and fixed opening cost proof that all the cases, if the raw material cost, labour cost and fertilizer cost increment is about 5%, then the profit decrease by MILP model have 0.004%, 1.2% and 1.6% respectively. The fertilizer

cost more effect on profit than the raw material cost. Also the labour cost of the product more effect on profit than the raw material cost and fertilizer cost of the product which shows in Fig. 5.



**Fig. 5. The sensitivity analysis of raw material price, fertilizer cost and labour cost on profit**

In this study, to optimize the best locations for the warehouse is to yield all kind of related support to the farmers and beparis. The formulated beparis MILP model has been solved by the method of the branch and cut algorithm by using AMPL with Gurobi. Further, the farmers MILP model has been solved by the method of the branch and bound algorithm by using AMPL with Cplex. Here, I have used two solver Cplex, Gurobi and comparison the result. This study, Cplex solves the problem quicker than Gurobi. Example: using ‘Cplex’ a problem has solved by 520 simplex iterations with 59 branch-and-bound nodes, where using ‘Gurobi’ this problem has solved by 785 simplex iterations with 124 branch-and-cut nodes. In this paper, every optimization program has two parts which represent the objective function and some constraints. Also, by using AMPL, every program formulation has two main parts; the actual program file which contains formulation for various constraints and the data file which contains data for different parameters. This program has accomplished on a Core-I3 machine with a 3.60 GHz processor and 4.0 GB RAM.

## 5 Conclusion

In this study, the MILP model is solved by AMPL using branch and bound algorithm is to develop for the integrated supply chain network. MILP model is to minimize the total costs of distribution, storage and other operations, with production levels high enough to satisfy customer demand. Also, this MILP model has maximized the total profit on investment. Again, analyzed various parameters like the raw material cost, fertilizer cost and labour cost, it is concluded that fertilizer cost and labour cost is very significant factors to farmers profit. Also, if the raw material cost, fertilizer cost and labour cost have increased by 5%, then the total profit decrease by 0.003%, 1.2% and 1.5% respectively. This model describes, how can increase the farmers and beparis income. Moreover, transformation cost is very important factors for beparis profit of agricultural products. By decreasing the transportation cost and increasing supply capacity, each business payers will more profitable way to satisfy more customers’ demands. The developed model is useful to supply chain optimization of agricultural production planning and distribution planning. MILP model is one

of the best logistic models to achieve the profit maximization and cost minimization, with find the optimum producer and optimum distribution.

The future research of my interest is to optimize the whole system of the supply chain of agricultural products in Bangladesh, like a farmer- bepari-paiker-retailer and consumer. Also, formulate the coordination model among the market players. Further, comparison this MILP model with MILFP model for various parameters.

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## Competing Interests

My research interest is on Mathematical Programming and different areas of Optimization.

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