JARIE

Journal of Applied Research on Industrial Engineering
www.journal-aprie.com

Determining Optimal Production Plant Location and Vehicle Route in Upstream Supply Chain Network for Date Sap Processing Industry

Golam Sakaline; Md. Aqib Aman; Md. Mahraj Uddin; Kaushik Debnath; Md. Abu Shahed; Tanver Rahman

PAPER INFO

Chronicle:
Received: x Month xx Reviewed: x Month xx
Revised: x Month xx
Accepted: x Month xx

Keywords:
Agro-based Natural Resources. Nutrition Content. Mixed Integer Linear Programming. Large Neighborhood Search.

ABSTRACT

Bangladesh is blessed with various agro-based natural resources like Date sap, extracted from date trees. As this date sap is found in rural areas in large quantities annually but a very small fraction is converted into some value-added delicious foods at a domestic level while a large portion is left underutilized due to negligence, improper collection, and preservation system from the industry level. The processed delicious foods have conspicuous demand in the national market due to their nutritious value and the growth of the national economy. Despite its economic importance, very little researches have been conducted in this field for its industrial processing. So, this research implies to improve this straggled sector providing much attention for collecting raw sap from source and processing into value-added products from industrial level cost-effectively. The key objectives of this paper are to determine optimal facility location for processing date sap and set vehicle routes that can pick up date sap from source to processing plant simultaneously curtailing operational transportation costs. Initially, a Mixed Integer Linear Programming (MILP) model is introduced to determine optimal facility location. Besides, the Large Neighborhood Search (LNS) algorithm has been used to find the optimal set of vehicle routes. This paper outlines a summary of final results that Jessore (A south-western city in Bangladesh) is an optimal plant location and 10 vehicles are necessary for covering 15 areas which ultimately optimize the total supply time, respecting constraints concerning routing, timing, capacity, and supply as well transportation costs.

1. Introduction

The world population has been growing rapidly for the past few decades. If the growth rate continues at this rate, the total number of populations will be doubled within next couple of decades. Therefore, the world will face challenges to meet up the food and nutrition for this increasing number of populations. Indeed, this shows the needs of proper preservation and utilization of natural resources which has also been a great concern of the world recently [1]. Bangladesh is blessed with a lot of natural resources and commonly considered as agricultural land among other South Asian countries. One of the greatest concerning issues of the country is to make the proper use of its natural resources. Among different natural resources, date sap (Khejur Rosh) is widely found in rural and suburban areas of the country. Date Sap is extracted from date palm trees during winter season specifically saying, December and January. It is also a popular drink among the Bangladeshi people of all ages. The sap is high in nutritious value as it contains natural sugar which can be used for various popular delicious foods for instance, Palm sugar, Date Jaggery and Rasgulla (A South Asian dessert). The sap can also be used as natural drugs for some common diseases like diabetes among the Bangladeshi general people. Moreover, this sap carries an economic value for many of the rural people. A particular group of people extract this natural sap from Palm trees and sell them in local markets which make a marginal profit for their livelihood. This also has a correlation with the pottery business as they need pitchers made of clay

DOI: 10.22105/jarie.2021.278857.1280

to market the sap from local to urban market. Despite its significant market value, this natural resource got little attention to our policy makers due to the lack of enough research.

So, this sector necessitates much more focus on the optimal strategic and operational decisions to manage and maintain the logistics efficiently since the profitability and economic value is intertwined with the proper distribution and transportation of goods. The improved efficiency of transportation of goods leads to a considerable savings to the ultimate costs and the competition in the rural economy [2], [3]. As far as the optimal routes reduce cost and improve the service quality, the date sap collection and molasses: the final product of date sap, processing can be considered as vehicle routing problem (VRP), which is indeed the generalized version of the traveling salesman problem (TSP) [4-6]. Therefore, the transportation cost of a particular good incurs a significant portion of total cost. So, choosing an optimal date sap processing plant can decrease transportation costs by determining a set of required vehicles which is very important and that constitutes the main objective of this paper. To find out the objective, Mixed Integer Linear Programming (MILP) model has been implemented that enables the optimum plant location where the raw materials can easily be supplied and molasses be delivered to the market soon. Then, the total travelling cost i.e., total number of vehicles and total amount of distance is minimized while the customers' demands are met up sorting out the supply and demand constraints [2]. So, the whole supply chain policy can significantly change the traditional system of transportation and resource mobilization if the model is implemented establishing the optimum plant location which surely decreases the number of vehicles and increases the consumers' response at a larger scale.

2. Literature Review

Various research works have been studied to identify the possible scopes that can be utilized to fulfill our objectives. Goli et al. (2019) developed an integer linear model for routing relief vehicles and using the covering tour approach with the aim of minimizing the last arrival time of vehicles to the damaged areas [7]. Tirkolaee et al. (2020) worked on a novel bi-objective Mixed-Integer Linear Programming (MILP) model proposed for Flow Shop Scheduling (FSS) with an outsourcing option and Just-in-Time (JIT) delivery in order to simultaneously minimize total cost of the production system and total energy consumption [8]. Also, Tirkolaee et al. (2020) applied a novel mixed-integer linear programming (MILP) model which is developed to formulate the sustainable periodic capacitated arc routing problem (PCARP) for municipal solid waste (MSW) management [9]. Tirkolaee et al. (2019) established a novel multi-objective mixed-integer linear programming model (MOMILP) for a two-echelon green capacitated vehicle routing problem (2E-CVRP) in which environmental issues and time windows constraints are considered for perishable products delivery phase [10]. Another research of Tirkolaee et al. (2018) addressed a novel model for the multi-trip Green Capacitated Arc Routing Problem (G-CARP) to minimize total cost including the cost of generation and emission of greenhouse gases, the cost of vehicle usage and routing cost [11]. Another study conducted on a novel mathematical model which is developed for robust periodic capacitated arc routing problem (PCARP) considering multiple trips and drivers and crew's working time to study the uncertain nature of demand parameter by Tirkolaee et al. (2018) [12]. L. Yantong et al. (2016) worked on the perishable food where they formulated the production inventory routing planning with an integrated mixed integer linear programming (MILP) model where the food quality level was explicitly traced throughout the supply chain [13]. Through implementation of vehicle routing problem (VRP) solution for developing the optimized trip number and vehicle can reduce the transportation cost. A recent detailed extensive work done by Erdogan G. (2021) which generated VRP (Vehicle Routing Problem) Spreadsheet solver using depot and customer location, vehicle details and the most important costing of different routes and customer [14]. Erdogan G. (2017) aimed to find out the optimize way to pick up and deliver product

from depot to customer by using different types of analytical parameter and formula [15]. P. Singamsettya and J. Thenepalleb (2021) researched on modelling an optimal route for the distribution chain of a rural LPG delivery system where they used CVRP for solving many challenging constraint [3]. L. Hong (2012) worked on vehicle routing problem for time windows (VRPTW) based on an improved large neighborhood search (LNS) algorithm for dynamic vehicle routing problem with time windows [16]. Musavi and A. Bozorgi Amiri’s (2017) findings and analysis on the perishable products like date molasses showed how a multi-objective sustainable hub location-scheduling problem developed sustainable supply chain solution in this date sector [17]. A. Expósito et al. (2018) exploited VRP with time windows to deal with milk collection [18]. Also, H. Mei et al. (2017) conducted a thesis on the modeling of milk-run vehicle routing problem to minimize overall cost in the network [19].
Table 1 summarizes the reviewed studies in order to demonstrate the research's uniqueness. After reviewing the current state of this field's literature research, Mixed Integer Linear Programming (MILP) is used for choosing the optimum plant location from where the raw materials can be easily processed and finished date molasses products can easily be supplied to the domestic market alongside with vehicle routing problem (VRP) for developing a concrete solution for the agriculture (date) industry which eventually enhance the cost efficiency. To the best of our knowledge, very few research works are conducted to develop a comprehensive methodology of supply chain network optimization for the collection and conversion of this valuable natural resource. The proposed mathematical model is presented in the third section; the proposed solution method is introduced in the fourth section; the computational results from the implementation of the algorithm are presented in the fifth section; and finally, conclusions and recommendations for future work are presented in the sixth section.

Table 1. *Comparison Table of recent relevant studies along with present study*

No	Author	Approach	Objective	Algorithm	Data	Solution Method	Sector/Field
1	(Kim et al., 2011) [20]	Optimization	Cost efficiency	MILP	Observational	Exact	Energy
2	(Pauls-Worm et al., 2014) [21]	Prediction	Cost efficiency	MILP	Experimental	Approximation	Food
3	(Li et al., 2016) [13]	Optimization	Return maximize	MILP	Observational	Exact	Food
4	(Singamsetty et al.,2021) [3]	Optimization	Cost efficiency	VRP based algorithm	Simulation	Exact	Energy
5	(Mei et al., 2017)[19]	Optimization	Cost efficiency	VRP based algorithm	Observational	Exact	Food
6	(Hong et al., 2011) [16]	Optimization	Cost efficiency	VRP based algorithm	Compiled	Exact	Transportation
7	(Sangaiah et al., 2019)[4]	Optimization	Cost efficiency	MILP	Simulation	Exact	Energy
8	(Tirkolaee et al., 2019)[2]	Optimization	Cost efficiency	VRP based algorithm	Simulation	Exact	Food
9	(Goli et al., 2018) [5]	Optimization	Cost efficiency	VRP based algorithm	Compiled	Approximation	Transportation
10	(Tirkolaee et al., 2018)[1]	Optimization	Cost efficiency	VRP based algorithm	Simulation	Exact	Waste Management

11	(Tirkolaee et al., 2018)[6]	Optimization	Cost efficiency	MILP	Simulation	Exact	Waste Management
12	(Tirkolaee et al., 2020)[22]	Optimization	Minimize cost and maximize supply reliability	BOMILP	Simulation	Exact	Transportation
13	**This Paper**	**Optimization**	**Cost efficiency**	**Both MILP & VRP**	**Compiled**	**Exact**	**Agricultural**

3. Problem statement and modeling

In the date industry, there exists a common problem in the upstream network of supply chain as the production process and its associated distribution system is so much disorganized. Besides, a vehicle routing system is a must need in this industry for returning back the farmers from a huge chunk of loss. That's why maintaining this mixed model of centralized and decentralized system which eventually we can say as a hub and spoke model developed where raw materials of date industry, date sap will be routing in an optimal vehicle routing system and the cost of the transportation will be minimal. That's why a mixed Integer Linear Programming (MILP) is implemented to develop the most optimal transportation costing plant and the vehicle routing problem (VRP) which also helps to design the optimal vehicle routing system. Here in this VRP algorithm we applied Tucker-Zemlin sub tour elimination constraints which helps us to designing the optimal routing system where the truck number is reduced drastically and the process is more robust to apply in the date industry. So, in this process subtour is an arc tour of two point of a tour that start and return back to same point after visiting another single point. This process is helpful for only two point of a tour. But if there is more than two point, there occurred a long distance and time lengthy tour. Because of the tour will be start from the start point (0) to the second point (1) then back to start point (0) again. After doing this subtour it starts there another subtour from start point (0) to third point (2) and return back to start point (0) and continues in same process again and again for more tour point. So there anticipate subtour elimination process to eliminate this long-distance process and save times. In subtour elimination process the tour will be start from the start point (0) to second point (1) then second point (1) to third point (2) and it continues until the tour enter and leave every single point (0) of the total tour point. After visiting every point then it returns back to the start point [23]. To optimize this tour process there used subtour elimination process on the basis of the capacity of transportation vehicles capacity. In where, when the vehicle capacity is full by collecting raw material from different location point by mini subtour elimination process it will end up their first sub tour and start another subtour process in same mini subtour elimination process. Here the picturize form of four tour point of subtour, subtour elimination process, and the mini sub tour elimination process for the restriction of transportation vehicle capacity are given below:

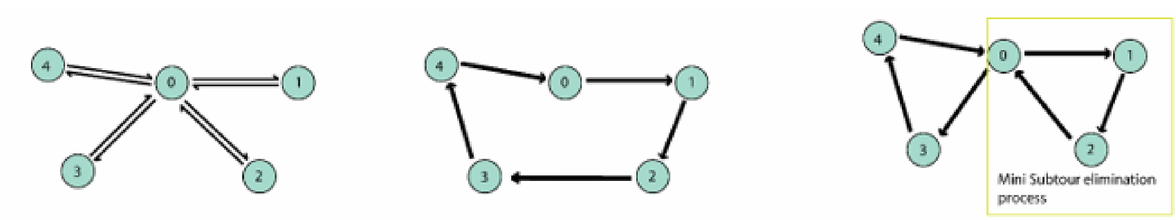

Figure 1. *Subtour Elimination Process*

3.1. Assumptions

1. The data such as the pickup and delivery demands, number of vehicles, vehicle capacities and the distance between the delivery centers are predetermined.
2. No split pickups, partial deliveries, and transshipments are allowed.
3. No on the spot (instantaneous) pickups and deliveries are considered.
4. No restriction on overall distance (in units) travelled by any vehicle on any route.
5. No restriction on the number of delivery centers served by any vehicle

3.2 Model Formulation of MILP

Under these assumptions, the sets, parameters and decision variables are the following:

Sets:

i = distributional Warehouse Centers

j = Plant Center

Parameters:

X_{ij} = Flow from distributional warehouse centers to Plant Center j (units)

S_i = Available supply from distributional warehouse centers i (units)

D_j = Demand by Plant Center j (units)

C_{ij} = Cost to serve Plant center j from distributional warehouse centers i

f_i = Fixed cost for distributional warehouse center i

$P_{\min}$ = Minimum number of Plant Center required to open

$P_{\max}$ = Maximum number of Plant Center allowed to open

M = A really big number amongst the whole data sheet

Decision variable:

$$Y_i = \begin{cases} 1 \text{ if distributional warehouse centers is opened} \\ 0 \text{ otherwise} \end{cases}$$

The proposed mathematical model is presented in the following:

Objective function:

$$Min\ Z = \sum_i \sum_j C_{ij} X_{ij} + \sum_i f_i Y_i \text{ ………………….. } (1)$$

Subject to:

$$\sum_j X_{ij} \le S_i \text{ ………………… } (2)$$

$\sum_i X_{ij} \geq D_j$ ………………… (3)

$X_{ij} - M_{ij} Y_i \leq 0$ ………………………. (4)

$\sum_i Y_j \geq P_{\min}$ ………………………. (5)

$\sum_i Y_i \leq P_{\max}$ ………………………. (6)

$X_{ij} \geq 0$ ………………………………. (7)

Here first of all, the objective function of *equation (1)* determines the minimized transportation cost in the optimized route. Here, the first part, $\sum_i \sum_j C_{ij} X_{ij}$ denotes the variable cost of the transportation system and the second part which is $\sum_i f_i Y_i$ denotes the fixed cost in this transportation system. *Equation (2)* shows that the available supply from distributional warehouse centers i (units), must need to be greater than overall flow from all the distributional warehouse centers i to plant Center j. From *constraint (3)*, it clearly indicates that the demand by Plant Center j (units), must need to be equivalent with overall flow from all the distributional warehouse centers i to Plant Center j. Here, the binary linking *constraint (4)* means that it satisfies all the constraints and the area has got the eligibility for being determined as an optimum production plant where transportation cost will be very low. *Constraints (5) and (6)* work on determining only one production plant which will satisfy all other limitations. *Equation (7)* shows that all flows must need to be greater than zero as it can't be roaming with zero resources in it or it can't be negative.

3.3 Model Formulation of VRP

Under these assumptions, the sets, parameters and decision variables are the following:

Sets:

V_D The depots

V_C The customers

$V = V_D \cup V_C$

$V_M \subseteq V_C$ The set of customers that must be visited

$G = (V, A)$ The complete directed network on which we will solve the VRP.

$i \in V_C$ as p_i The profit of servicing a customer

q_i The pickup service amount for the customer

$\hat{q}_i$ The delivery service amount,

s_i The service time required by the customer

$[a_i, b_i]$ The time interval for the customer (Note that there is also a time interval for each depot vertex)

K The set of vehicles

$k \in K$ Each vehicle which is the element of set of vehicles K

$o^k \in V_D$ The origin depot of the vehicle,

τ^k The work starts time of the vehicle

f^k The fixed cost of using the vehicle

Q^k The capacity of the vehicle

D^k The distance limits

$\hat{D}^k$ The driving time limit

W^k The working time limits

r^k The return depot of the vehicle

Parameters:

d_{ij} Distance associated with each arc $(i, j) \in A$

$\hat{d}_{ij}$ Driving duration associated with each arc $(i, j) \in A$

c_{ij}^k Travel cost for each vehicle $k \in K$ on arc (i, j)

w_{ij}^k The amount of the pickup commodity and carried by vehicle k on arc (i, j)

z_{ij}^k The delivery commodity carried by vehicle k on arc (i, j)

t_i^k The time at which vehicle k arrives at vertex i

v_i The amount of violation of the time window of vertex i

Decision variables:

$$\Omega = \begin{cases} 1 \text{ if the vehicles have to return to their specified return depots} \\ 0 \text{ otherwise} \end{cases}$$

$$\beta = \begin{cases} 1 \text{ if there is a backhaul constraint} \\ 0 \text{ otherwise} \end{cases}$$

$$\Theta = \begin{cases} 1 \; if \;\; the \; time \; windows \; can \; be \; violated \; at \; the \; cost \; of \;\; a \; penalty \; \Pi \; per \; unit \; time \\ 0 \; otherwise \end{cases}$$

$$x_{ij}^{k} = \begin{cases} 1 \; if \;\; vehiclektraverses \; arc \;\; (i, j) \\ 0 \; otherwise \end{cases}$$

$$y_{i}^{k} = \begin{cases} 1 \; if \;\; vehiclekvisits \; and \; serves \; vertexi \\ 0 \; otherwise \end{cases}$$

The proposed mathematical model is presented in the following:

Objective function:

$$\text{Maximize} \;\; \sum_{i \in V_C} \sum_{k \in K} p_i y_i^k - \sum_{(i,j) \in A} \sum_{k \in K} c_{ij}^k x_{ij}^k - \sum_{j \in V_C} \sum_{k \in K} f^k x_{o^k,j}^k - \Pi \sum_{i \in V} v_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

$$\text{Subject to} \;\; \sum_{k \in K} y_i^k = 1 \qquad \forall i \in V_M \; ,\ldots\ldots\text{(9)}$$

$$\sum_{k \in K} y_i^k \leq 1 \qquad \forall i \in V_C \setminus V_M \; ,\ldots\ldots\ldots\ldots \text{(10)}$$

$$\sum_{j \in V \setminus \{i\}} x_{ij}^k \leq \sum_{j \in V \setminus \{i\}} x_{ji}^k \qquad \forall j \in V_C, k \in K \; ,\ldots\ldots\ldots\ldots \text{(11)}$$

$$\sum_{p \in S, q \in V \setminus S} x_{pq}^k \geq y_i^k \qquad \forall i \in V_C, k \in K, S \subset V : o^k \in S, i \in V \setminus S \; ,\ldots\ldots\ldots\ldots\ldots\ldots \text{(12)}$$

$$\sum_{p \in S, q \in V \setminus S} x_{pq}^k \geq \Omega y_i^k \qquad \forall i \in V_C, k \in K, S \subset V : i \in S, r^k \in V \setminus S \;\; \ldots\ldots\ldots\ldots\ldots \text{(13)}$$

$$\sum_{j \in V_C} x_{o^k,j}^k \leq 1 \qquad \forall k \in K \;\; \ldots\ldots\ldots\ldots\text{.. (14)}$$

$$\sum_{k \in K} x_{ij}^k \leq 1 - \beta \qquad \forall (i,j) \in A : q_i > 0 \; and \; \hat{q}_j > 0 \;\; \ldots\ldots\ldots\ldots\ldots\text{(15)}$$

$$\sum_{j \in V \setminus \{i\}} w_{ij}^k - \sum_{j \in V \setminus \{i\}} w_{ij}^k = q_i y_i^k \qquad \forall i \in V_C, k \in K \;\; \ldots\ldots\ldots\ldots\text{.. (16)}$$

$$\sum_{i \in V_C} w_{i,r^k}^k = \sum_{j \in V_C} q_j y_j^k \qquad \forall k \in K \;\; \ldots\ldots\ldots \text{(17)}$$

$$\sum_{j \in V \setminus \{i\}} z_{ji}^k - \sum_{j \in V \setminus \{i\}} z_{ij}^k = \hat{q}_i y_i^k \qquad \forall i \in V_C, k \in K \;\; \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(18)}$$

$$\sum_{i \in V_C} z_{o^k,j}^k = \sum_{i \in V_C} \hat{q}_j y_j^k \qquad \forall k \in K \;\; \ldots\ldots\ldots\ldots\text{.. (19)}$$

$$t_i^k + (\hat{d}_{ij} + s_i) x_{ij}^k - W^k (1 - x_{ij}^k) \leq t_j^k \qquad \forall (i,j) \in A : j \in V_C, k \in K \;\; \ldots\ldots\ldots\ldots\ldots\ldots \text{(20)}$$

$$a_i \le t_i^k \le b_i - s_i + v_i \qquad \forall i \in V_C, k \in K \text{ ……….. } (21)$$

$$v_i \le M.\Theta \qquad \forall i \in V_C \text{ ……….. } (22)$$

$$t_{o^k}^k = \tau^k \qquad \forall k \in K \text{ ………. } (23)$$

$$t_i^k + (s_i + \hat{d}_{ij}) x_{i,r^k}^k \le b_{r^k} + v_{r^k} + M(1-\Omega) \qquad \forall (i,j) \in A : i \in V_C, k \in K \text{ ………. } (24)$$

$$w_{ij}^k + z_{ij}^k \le Q^k \qquad \forall (i,j) \in A, k \in K \text{ ……….. } (25)$$

$$\sum_{(i,j)\in A} d_{ij} x_{ij}^k \le D^k \qquad \forall (i,j) \in A, k \in K \text{ ……….. } (26)$$

$$\sum_{(i,j)\in A} \hat{d}_{ij} x_{ij}^k \le \hat{D}^k \qquad \forall (i,j) \in A, k \in K \text{ …………… } (27)$$

$$\sum_{i\in V_C} s_i y_i^k + \sum_{(i,j)\in A} \hat{d}_{ij} x_{ij}^k \le W^k \qquad \forall (i,j) \in A, k \in K \text{ ……………..} (28)$$

$$x_{ij}^k \in \{0,1\} \qquad \forall (i,j) \in A, k \in K \text{ ……….. } (29)$$

$$y_i^k \in \{0,1\} \qquad \forall i \in V_C, k \in K \text{ ……….. } (30)$$

$$v_i \ge 0 \qquad \forall i \in V_C \text{ ………….. } (31)$$

$$w_{ij}^k \ge 0 \qquad \forall (i,j) \in A, k \in K \text{ ………. } (32)$$

$$z_{ij}^k \ge 0 \qquad \forall (i,j) \in A, k \in K \text{ ……….. } (33)$$

The objective function (8) maximizes the total profit collected minus the travel cost of vehicles, fixed cost of using vehicles, and the penalty for violating time windows. We first state the constraints set the visit rules for the customers by the vehicles. Constraint (9) ensures that every customer is visited at most once and Constraint (10) enforces a visit to the customers that must be visited. Constraint set (11) is a weak form of the well-known flow conservation constraints, which require an inflow if there is an outflow, and accommodates the VRP variants in which the vehicle does not have to return to its depot. Constraints (12) provide the connectivity between the origin depot of vehicle *k* and the customers visited by this vehicle, and constraints (13) dictate the vehicle to return to its depot if it is required to. Constraints (14) state that each vehicle can be used at most once, whereas the backhaul constraint is enforced by constraint (15). Next, we present the constraints that set the customer requirements. The flow conservation for the pickup commodity is provided by constraints (16) and (17). Similarly, the flow conservation for the delivery commodity is provided by constraints (18) and (19). Constraints (20) are formulated based on the Miller- Tucker-Zemlin subtour elimination constraints [23] and provide the framework for the time windows. The lower and upper limits of the time window for each customer, and the variable to account for violation are stated in constraints (21) and (22). The final set of constraints state the restrictions related to vehicles. Constraints (23) and (24) set the start of the working time for vehicle *k*, and ensures that the vehicle returns to its depot on time if it is required to. Constraint (25) prohibit the violation of the vehicle capacities. Constraints (26), (27), and (28) state the distance, driving time, and working time limits for each vehicle, respectively. Finally, constraints (29) – (33) are integrality and non-negativity constraints.

4. Proposed Solution Method

First of all, here we developed route costing from the data. Then we worked on Mixed Integer Linear Programming (MILP) which helped us to develop the optimized plant. The plant will optimize transportation costs and reduce the truck number. So, that the process will be more robust under many conditions. Besides, the development of the VRP solution helped us to develop the optimized route with minimal vehicle numbers which will eventually increase average working time, load per vehicle, distance traveled.

4.1 Route Costing

Here, with the help of the world logistics index and the distance of each trip, we calculated the route costing. Here firstly, we developed the distance table and the variable cost table separately. Performing multiplication from both data tables, we develop the cost matrix for different location tables which eventually helps us in developing the MILP model and VRP solution in this paper.

4.2 Flow diagram of Mixed Integer Linear Programming (MILP) model for this paper:

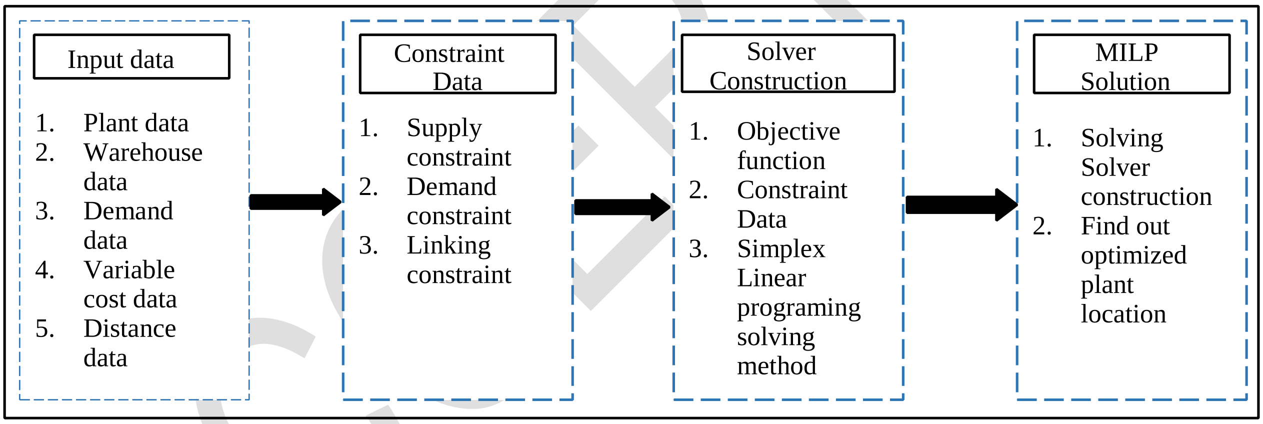

Figure 2. *Flow diagram of MILP algorithm*

In the above diagram, we worked on all the problems in Microsoft Excel where we used Open Solver add-in. Open Solver is an Excel VBA add-in that extends Excel's built-in Solver with more powerful solvers. It is open-source software. It helped by a built-in visualizer that highlights the model's decision variable, objective, and constraints directly on the spreadsheet. It has a fast quick-solve mode that makes it much faster to resolve our model after making changes [24],[25].

Here we used according to the flow diagram in the following steps as described below:

Step 1: Here we worked on inputting the data of plant, warehouse, demand, variable cost, and distance. In this Mixed Integer Linear Programming (MILP) model this input data helps the model to configuring the optimal production plant through the quantity of input data.

Step 2: In this second step, we worked on constraint data of this Mixed Integer Linear Programming (MILP) model which helped us to find the optimal production plant under the bindings of the conditions of constraint data. Here mainly, we used three types of constraints. They are supply constraint, demand constraint, and linking constraint. The supply constraint works on the available supply which is provided by each warehouse, the demand constraint works on the demand fulfilling capacity of the plant and the linking constraint works on the binary decision making which helps us in choosing the optimal production plant.

Step 3: Here, we worked on the construction of the solver. In the solver construction method, we firstly set the objective function and select it for the Mixed Integer Linear Programming (MILP) solution. Then we set the constraint data in the solver console. Finally, we used the simplex linear programming solving method for developing the solution of this Mixed Integer Linear Programming (MILP) model.

Step 4: In this final process, the solver console works on solving solver construction. It finally develops and finds out the optimum production plant for this paper.

4.3 VRP Implementation:

We have used an add-in in Microsoft Excel, which is named "VRP Spreadsheet Solver". This add-in can easily solve VRP with the following flow chart diagram. Developing a VRP solver with the solution algorithm named Large Neighborhood Search (LNS) is a challenging task. The required travel distance and duration data have to be repeatedly retrieved from a Geographical Information System (GIS) and also need to put the input of recurring cost of vehicle transportation with the help of local areas transportation cost special through knowledge and expertise. Then this solver engaged their calculation and computed the best-optimized vehicle routes with demonstrating visualization too. The recent detailed extensive paper has generated for comfortable use of the VRP (Vehicle Routing Problem) Spreadsheet solver using depot and customer location, vehicle details, and the most important costing of different routes and customer which can be found in Erdogan G. (2020) [14].

Steps for implementation of VRP solution using VRP Spreadsheet Solver are:

Step 1: Inputting data on the VRP solver console sheet

Opening of the VRP Spreadsheet solver add-in in Microsoft excel and input the Number of depots, Number of customers, Vehicles types, the solution type including Bing map trial key by getting from "Bing maps" at https://www.bingmapsportal.com (accessed 30 September 2020) to use GIS service in VRP Solver console sheet is developed in this first sheet of solver console [26].

Step 2: Establishing locations on the location sheet

Setting up Location sheet from Location menu and Input the Location name of depot and customer and populate them by using GIS web service to get the coordinates (Latitude and Longitude) of those input locations where we need to input the service time and the time window of the vehicles, CPU time limit (seconds) for better viewing the distance in the next step.

Step 3: Generating distance on the distance sheet

Setting up a distance sheet from the Distance menu and populate the distance from one location to another besides with the depot using GIS web service is the most important thing in this third step.

Step 4: Configuring vehicles on the vehicle sheet

Setting up the vehicle sheet from the Vehicles menu and input the vehicle type, vehicle number, drive distance limit, driving time, the time window of the vehicle, and the return depot location is very necessary for configuring the features related to the vehicles.

Step 5: Developing solution on the solution sheet

Setting up the solution sheet from the Solution menu is the main task. Here, mainly watching which vehicles perform in which area and also knowing the number of loads is being placed from one location to another in this optimized way are the important data that helps in the next stage.

Step 6: Visualizing map on the visualization sheet:

Setting up the visualization sheet from the Visualization menu to see to visualization map of the trips is the main work in this step. Here we can see the whole map based on the solution sheet developed in the previous step. The routes of vehicles and the whole vehicle distribution can be shown easily in the map on this visualization sheet.

Step 7: Engaging VRP Spreadsheet Solver with the solution sheet:

Engaging VRP Spreadsheet Solver from the solver menu to find the outcome result of the trip number and the trip time in the solution sheet is the last important task that helps the LNS algorithm for developing the solution sheet. Here the result of the VRP Spreadsheet Solver gives the result in Vehicles trip services with the help of vehicle time window, drive limit, vehicle capacity. This result can be counted as a trip and also, working with the trip distance, vehicle information is important for generating the result.

4.4 Sensitivity analysis:

Finally, through this sensitivity analysis, we tried to show the comparison of two scenarios of traditional supply chain upstream system of date industry and newly developed supply chain upstream system where we showed the percentage-based computational result through a tornado chart which easily shows how a drastically changing supply chain upstream system will perform both from increasing profitability to reducing cost in date sap industry.

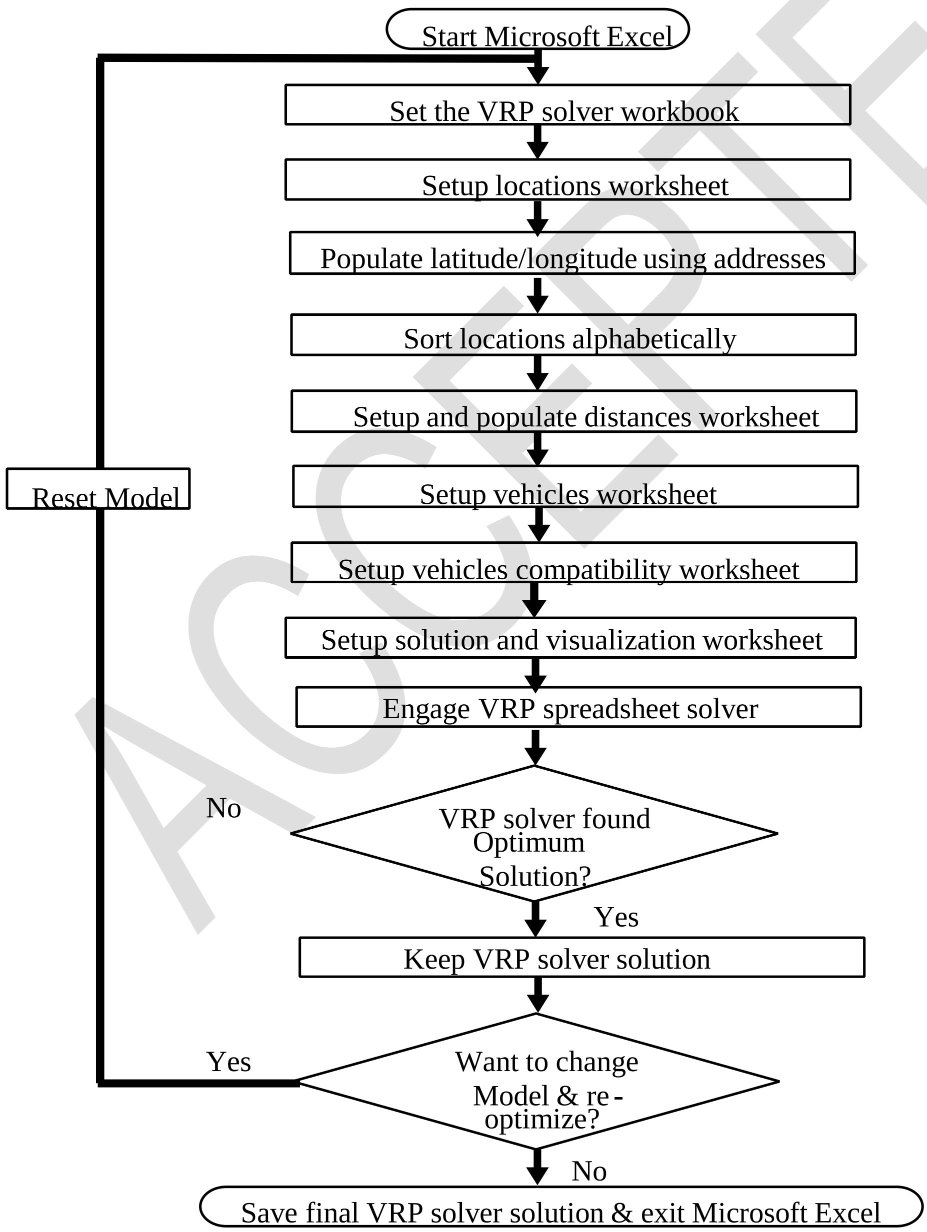

Figure 3. *VRP flowchart in Excel.*

5. Computational Results

5.1 Route Costing

Firstly, the distances from each and every warehouse to other warehouse are calculated. Distances are generated from Microsoft Bing Maps and costing calculations are performed based on it. From the "World Logistics Index 2018", we get that the cost per kilometer in every transportation per kilometer is $0.06 [17]. The generated route cost based on distances from each and every distributional warehouse region to other distributional warehouse region of Bangladesh is given below:

Table 2. *Cost Matrix for different locations*

	Depot-														
Cost	***JES***	***KHU***	***FAR***	***KUS***	***NAT***	***RAJ***	***BAR***	***VAL***	***GAZ***	***CHU***	***JEN***	***MEH***	***MAG***	***MAD***	***NOA***
Depot-															
JES	-														
KHU	*3.5*	-													
FAR	*7.8*	*11.2*	-												
KUS	*6.6*	*10.1*	*9.1*	-											
NAT	*11.0*	*14.4*	*13.4*	*4.4*	-										
RAJ	*13.3*	*16.7*	*15.7*	*6.6*	*2.3*	-									
BAR	*10.7*	*7.3*	*7.5*	*16.6*	*21.0*	*23.2*	-								
VAL	*16.0*	*19.4*	*8.1*	*17.2*	*21.6*	*23.8*	*14.0*	-							
GAZ	*14.6*	*18.0*	*6.8*	*15.8*	*20.2*	*22.5*	*12.6*	*2.1*	-						
CHU	*4.4*	*7.8*	*8.8*	*7.7*	*12.0*	*14.3*	*15.1*	*17.0*	*15.6*	-					
JEN	*3.8*	*7.2*	*6.2*	*5.1*	*9.4*	*11.7*	*13.8*	*14.4*	*13.0*	*4.7*	-				
MEH	*6.6*	*10.0*	*9.0*	*2.7*	*7.0*	*9.3*	*16.6*	*17.2*	*15.8*	*2.0*	*2.8*	-			
MAG	*2.8*	*6.2*	*5.2*	*3.9*	*8.2*	*10.5*	*12.7*	*13.3*	*12.0*	*3.8*	*1.2*	*4.0*	-		
MAD	*12.0*	*10.6*	*4.1*	*13.2*	*17.6*	*19.8*	*3.4*	*10.6*	*9.2*	*13.0*	*10.4*	*13.2*	*9.3*	-	
NOA	*40.0*	*43.5*	*32.2*	*41.3*	*31.8*	*34.1*	*38.0*	*25.6*	*26.2*	*42.2*	*38.5*	*41.3*	*37.4*	*34.6*	-

5.2 Implementation of Mixed Integer Linear Programming (MILP):

Mixed Integer Linear Programming (MILP) has been applied for choosing best production plant amongst 15 distributional warehouse regions. We have developed the MILP solution in the Microsoft Excel software.

Table 3. *MILP Solution with regional demands*

Decision	***Depot-Jessore***	***Khulna***	***Faridpur***	***Kustia***	***Natore***	***Total Demand***	***Binary***
	73.9	*22.2*	*11.8*	*20.0*	*59.7*		
	Rajshahi	*Barishal*	*Valuka*	*Gazipur*	*Chuadanga*		
Depot-Jessore	*66.5*	*10.3*	*9.6*	*18.1*	*18.5*	*369.6*	*1*
	Jenaidah	*Meherpur*	*Magura*	*Madaripur*	*Noakhali*		
	16.6	*11.5*	*10.3*	*10.0*	*10.6*		

Here, first of all we work on the basis of regional demand and fix the supplier limit up to 400 ton in every distributional warehouse. Then the fixed cost is set at approximately 130 USD. From MILP solution, it can be observed that Jessore satisfied all of the supply, demand and binary constraint data. The MILP solution for determining optimum production plant is attached in above table.The fixed cost will be used on different cases such as truck maintenance, repairing etc. All of the constraints above discussed in methodology section and input data is connected for determining the optimum production plant. Here, we can see that in the binary column, only Jessore fulfilled all the constraints and that's why it is called as Depot-Jessore where the cost has reached at the optimality condition for constructing it as a production plant.

5.3 VRP Solution Development:

From the VRP solution, it has been found that how much of vehicles we need for picking up the date sap and delivering all the finished goods. Solution indicates that we need exactly ten vehicles for optimizing the route in the domestic market of Bangladesh. We have used here VRP solver console of Microsoft Excel for evaluating the minimal number of vehicles which fulfill the both the market demand and supply. The solution we achieve from the VRP solver is attached below:

Table 4. *VRP outcome summary*

Vehicle number	**Trip/day**	**Distance travelled (km)/day**	**Driving time (Hour)**	**Working time/day (Hour)**	**Load (ton)**	**Covered area by each vehicle**
V1	*10*	*500*	*6.17*	*16.73*	*104*	*Kustia, Khulna, Magura, Jessore*
V2	*5*	*954.7*	*12.23*	*16.98*	*51.4*	*Khulna, Kustia, Natore, Chuadanga, Jenaidah*
V3	*3*	*1050.6*	*13.53*	*16.53*	*28.9*	*Barishal, Rajshahi, Chuadanga*
V4	*3*	*1101.2*	*12.70*	*15.70*	*36*	*Natore*
V5	*3*	*1061.7*	*13.00*	*16.00*	*33.4*	*Rajshahi, Madaripur, Meherpur*
V6	*3*	*1012.1*	*12.13*	*15.13*	*36*	*Jenaidhah, Rajshahi*
V7	*3*	*1189.2*	*13.95*	*16.95*	*35.8*	*Gazipur, Faridpur, Rajshahi*
V8	*2*	*1017.9*	*11.95*	*13.70*	*15.7*	*Valuka, Gazipur*
V9	*1*	*1334.8*	*16.07*	*16.57*	*10.6*	*Noakhali*
V10	*2*	*809.4*	*9.47*	*11.22*	*24*	*Rajshahi, Natore*
Total	**35**	**10031.6**			**375.8**	

From the above table, it can also be concluded that ten vehicles are capable of supplying total 375.8 tons of date sap processed goods to various city of Bangladesh. The optimized vehicle route mapping provides a clear insight about how many trios should be made to supply demands and covers all the areas needed. Vehicle 4 and Vehicle 9 are dedicated for only Natore and Noakhali respectively. All other vehicles accomplish milk runs for delivering goods in the most efficient way.

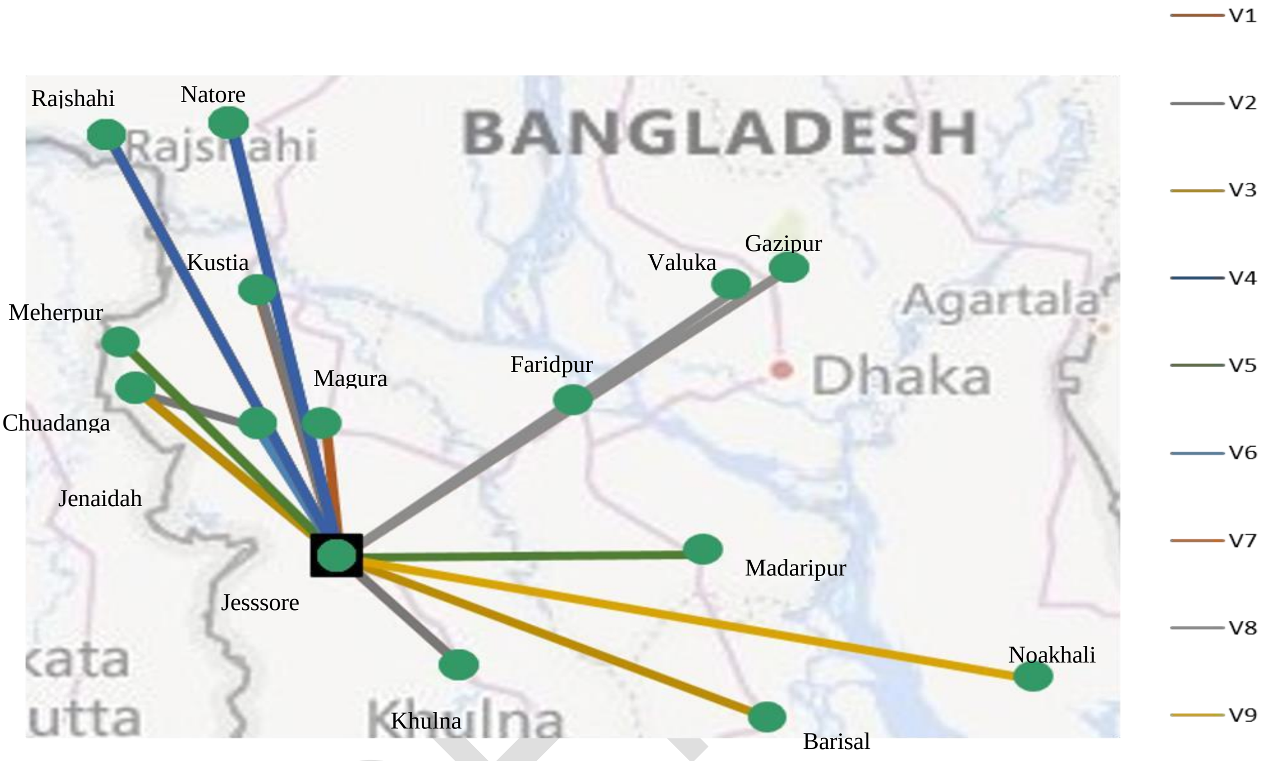

Figure 4. *Vehicle Routing Map*

5.4 Sensitivity Analysis

Here, in this part, we develop a sensitivity analysis based on five parameters between a scenario of a traditional system and the proposed system. This sensitivity analysis will help us to visualize the theme of how the model will optimize the whole situation in the date industry. The sensitivity analysis is attached below:

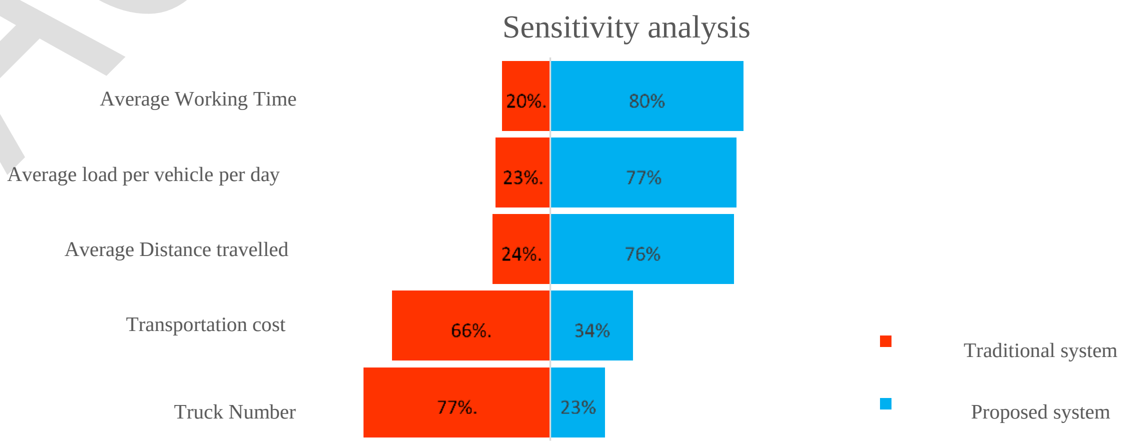

Figure 5. *Sensitivity analysis based on traditional system & proposed system*

Here, in the above sensitivity analysis, we work on the parameters which are average working time, average load per vehicle per day, the average distance traveled, transportation cost, and truck number. From this, we draw a computational result that our suggested supply chain system helps on utilizing the average working hour, average load per vehicle per day, and average distance traveled more efficiently. Moreover, welcoming this new supply chain upstream network system in the upstream network will reduce transportation costs and truck numbers so that the whole system can reduce their cost and increase their productivity which will finally make a great impact on the profitability index of the date industry.

6. Conclusion and Future Work

The primary goal of this study is to determine the best site for a manufacturing plant and the most effective route development employing the fewest number of cars possible. Optimal routing and vehicle allocation are one of the most important decisions of the date sap industry. This article has demonstrated how to reduce transportation costs by using an optimal supply chain network in the data sector. In this paper, a MILP model has been developed for choosing the best plant location to build a robust supply chain network. We selected an optimal production plant location that will eventually help date industry professionals understand how Jessore will affect the domestic Bangladesh market if it is chosen as a production facility. To solve the Vehicle Routing Problem (VRP), the LNS algorithm has been utilized which observed that 10 vehicles are required for covering the demand of 15 areas.

This paper only worked on optimizing the upstream supply chain of the date industry. For future research, a study of downstream stages of the supply chain and its network optimization can be suggested. Moreover, many famous metaheuristics like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Simulated Annealing (SA), etc. can be applied for network optimization. Instead of using Microsoft Solver, C-PLEX and AMPL software can also play an important role in case of finding the optimal solution. Several future projects can be carried out by gathering enormous amounts of data, applying data science to produce more predictive analyses, and creating more interesting visualizations, all of which will benefit the future date industry in general. Scenario analysis will also aid in the construction of more future forecasts, and many future projects will be achievable as a result of overcoming the assumptions and limitations in this study due to a lack of data in this business. In the future, it will need to be improved by correctly collecting data and critically assessing it. Thus, it will drive more resilient supply chain solutions in this date sap processing industry.

Funding Source Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Agreement

The author of this paper affirm that the article is the authors' original work, hasn't received prior publication and isn't under consideration for publication elsewhere.

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Appendix

Depot code	Depot name	Short form
BD-22	Jessore	JES
BD-27	Khulna	KHU
BD-15	Faridpur	FAR
BD-30	Kustia	KUS
BD-44	Natore	NAT
BD-54	Rajshahi	RAJ
BD-06	Barishal	BAR
BD-34	Valuka	VAL
BD-18	Gazipur	GAZ
BD-12	Chuadanga	CHU
BD-23	Jenaidah	JEN
BD-39	Meherpur	MEH
BD-37	Magura	MAG
BD-36	Madaripur	MAD
BD-47	Noakhali	NOA