Determination of Optimal Routes and Delivery Frequency of Vehicles with Minimum Transportation Cost

Armin Ali, Sirajum Munira and Khairun Nahar
Department of Industrial& Production Engineering
Rajshahi University of Engineering & Technology (RUET)
Rajshahi-6204, Bangladesh
ayantiarmin@gmail.com, sirajummunira784@gmail.com, shapla05.ipe@gmail.com

Abstract

Road and traffic problems in Bangladesh are always being barriers to the development of different sectors. This directly impacts on the transportation cost of the industries. An improper transportation system can cause significant damage to any organization. This paper focuses on vehicle routing and travelling cost problem. This paper addresses the routing problem faced by a beverage company in Bangladesh, while delivering products in multiple distant locations in a single trip. The Google sheet and Google map have been used to identify the near optimal solution for the routing by reducing the overall distance of each vehicle. Genetic Algorithm concepts have been used in this paper for cost optimization. The algorithm is constructed to obtain the best feasible solution of optimal number of delivery frequency for rental and organization vehicle with different capacities so that it can minimize the total transportation cost. The optimal route distance travelled by the vehicles was used in the travelling cost optimization problem. The solutions provide clear idea about how optimal routing can be proposed and both types of vehicles are to be selected to get a minimized cost of transportation of the organization.

Keywords
Genetic algorithm, Vehicle routing, Vehicle frequency, Cost optimization and Linear programming.

1. Introduction
Transportation cost is an important part of supply chain logistics costs. It adds to the finished costs of products. In today's competitive market, all the organizations should focus on the maximization of profit and productivity in all the steps of operations such as manufacturing, transportation, handling, marketing etc. For that, organizations are more curious in minimizing these costs. According to studies, 5% to 6% of price of a product occupies the transportation costs. In some cases, the percentage of price can rise up to 30% especially in foods (Hajghasema and shojaie 2015). Focusing on optimal use of resources by using an optimized routing system, the purpose of this paper was to completely give a coverage on vehicle routing and optimize transportation costs so that it minimizes the whole cost of organization's vehicle.These are water, railway, roadway and pipeline. To keep supply chain running efficiently, it is necessary to reduce all the risks related to transportation. Transportation cost is the essential part of any transportation system. They are generally assumed internally for an organization. There are several factors which can influence the transportation cost. These are fuel prices, insufficient routes, distance, and damage. To increase the profit of a company, it is necessary to focus on transportation cost.

Routing is one of the terms used for transportation. It is a process of choosing a pathway between multiple in reach the destination. Planning of the route is generally to minimize the distance and time spent on the road. To develop a proper transportation network route planning should be achieved for the vehicle.One of the main reasons of the increasing transportation cost is not using routes properly for each vehicle. In urban environments, this routing problem is quite common. Often drivers have to choose route when they are assigned to deliver products in various places in a single trip. They tend to choose longer routes for their overall journey. The optimal route sequence not only minimizes the distance but also minimizes cost of the transportation network. Other than that, for moving goods all over the country, the number of transportation need for each company is huge. These huge number of vehicles are the reasons of huge cost for an organization. Also sometimes these organizations also need to rent

vehicle for their work. Optimal use of these vehicles can also play good role in minimizing the cost. So this transportation cost plays a huge role in achieving profit for a company.

In Bangladesh road transport rates are higher than many developing countries. There are several reasons for that. Improper routing and not using optimal number of vehicles are the two of the reasons for this increasing transportation cost. The manufacturing industries generally supply products throughout the whole country by their vehicle. So to deliver the products in different location in a single trip, drivers need to choose optimal route sequence. Due to improper sequence, the distance becomes longer. Also not using the rental and organization vehicles in a suitable number can also increase the cost. So to reduce the cost, solving the problem related to routing and vehicle number in necessary.

1.1 Objectives
The objectives of this study are:
- To optimize route for vehicles
- To obtain delivery frequency with minimum transportation cost

2. Literature Review
Routing and cost optimization problems have a very extensive history. Different researchers around the world have worked on these problems. Some of the papers that have been reviewed for the thesis work are presented below.

Younas and Dawood (2003) presented a routing problem related to road congestion problems faced by the drivers in a city which can be called metropolitan. The study was conducted considering a small time period. For optimizing the routing problem in London they developed a genetic algorithm to provide a near optimum solution to the addressed complication. They also concentrated on the congestion systems of the routes by analyzing the density level of traffic on road during the whole day. It followed the basic genetic algorithm approach to find the answer. They used a lookup table which provides least distance and bearable cost for the measures that were considered.

Lorenzoand and Glisic (2012) have developed a sequential genetic algorithm (SGA) for the optimization of the topology in the networks. The measurement of the contribution they have added a fitness function. The function consists of the output along with the delay and consumption of power. The paper used genetic algorithm approach to form an encoding and controlling ways of fitness, though it depends on the load of the traffic on the road.

Ahmed et al. (2014) developed a method to find Initial Basic Feasible Solution which can be applied for both the balanced transportation problem and unbalanced transportation problem. For competitive scenario of the present market world transportation models help to provide powerful structure for the betterment. They provided a better solution to meet the complication which ensures reduced cost of transportation in these sectors than the traditional ones.

Khan et al. (2015) presented an algorithm with the help of MATLAB code to identify the feasible solution for certain transportation costing problems. A network was formed to show the general problem structure in the research. There were many examples provided to compare the algorithm with traditional ones that it gives relatively better outcome. The efficiency of the method was also examined numerically.

Edokpia and Amiolemhen (2016) developed a solution to the ongoing transportation issues in Nigeria. Their motive was to minimize the cost related to transport and provide a schedule which can be proved as optimal for the problem. The research was performed in a beverage producing company. They considered a few routes and destination depots on which the GA was applied. The GA provided a schedule which is optimal and also decreased the total costs. The data which was collected from the place was analyzed using Linear Programming model combined with Vogel's Approximation Method (VAM) to deliver the optimum solution. The study was relevant in terms of the company was not considering any policy before. The result does not allocate all the depots but they can be made in use to be in a systematic way.

Hajghasema and shojaie (2015) executed a transportation problem which introduced a model considering a certain number of vehicles of different sizes. They intended to provide a minimized cost along with less number of vehicles which are rented. They also provided a decreased time horizon for the stopping of each vehicle. To meet the objectives, the paper introduced an objective function along with some relevant constraints. In the paper they also prepared a registration process where all the requests are to be accepted. The organizational data analysis also produced a network of the locations and vehicles. They considered real time data of the traffic and roads and solved the model using Lingo. They came to a conclusion that the organization vehicles might be used for distanced locations but it could decrease the gain of the company.

There were numerous amounts of research works in the field of transportation. Some of the research paper have presented the routing for different locations considering several factors. They have also provided a minimized cost with vehicle routing. Some of the papers used cost minimization functions to optimize the total cost. Some have used a mixed integer non-linear programming model for multi vehicle situation. A few papers were reviewed that solved the problem by genetic algorithm. The papers which used genetic algorithm suggested that it can help to select the best outcome in a certain time period. If GA is used, then other heuristic algorithms are not necessary to use. It helps to minimize the corresponding functions by applying some search agents. They are mainly crossover and mutation. GA also helps to optimize the functions without the need for any structure of the function. In this paper linear programming and genetic algorithm are used for the traveling cost optimization and optimal routing of the vehicles.

3. Methods
3.1 Methodology
For the solution of the problem of this work, two segments have been introduced. First is route selection and optimal distance determination, other is the cost optimization of the transportation. The methodology of the study is presented below:

Step 1: Obtaining destination points for each vehicle
Step 2: Finding location coordinates for different places
Step 3: Identification of optimal distance along different routes
Step 4: Formulating objective function for optimizing travelling cost
Step 5: Finding the optimized cost by using Genetic Algorithm

3.2 Route Selection
Here, route is optimized for every delivery occurred in the organization. Google spreadsheet with vehicle routing add-in is used to solve this problem. The optimal distance for each delivery is determined here. The data set was created for each vehicle to get the solution. With the help of map co-ordinates, each set of data was formed. The result was analysed in the result analysis portion.

3.3 Notations for Cost Optimization
A model has been formulated in this part. Model Formulation is a technique that develops mathematical representation of a problem with an objective function which goes under operations research. For formulating any model, there are some steps that need to be followed. Firstly the decision variables of the problem should be well defined with explanation, secondly the relevant constraints of the problem should be formed, and lastly the objective function is developed with the help of the previously formed decision variables and constraints.

o	=	Organizational vehicle
r	=	Rental vehicle
c	=	Capacity of the vehicle
kv	=	Minimum capacity of the vehicle required for the vth delivery
CT_{toc}	=	The cost associated with travelling by the c capacity organizational vehicle period t
CTr_{trc}	=	The cost associated with travelling destination by the in c capacity rental vehicle of at period t
D_{ot}	=	Optimal distance for organizational vehicles along routes at period t
d_{rt}		Optimal distance for rental vehicles along routes at period t
t	=	Days of the month

B	=	Required budget for travelling cost
Vmax	=	Maximum number of delivery in a day
Vmin	=	Minimum number of delivery in a day

3.4 Decision Variables

X_{toc}	=	1, if the organizational vehicle m is sent from the origin otherwise, 0
Xr_{trc}	=	1, if the rental vehicle m is sent from the origin otherwise, 0

3.5 Assumptions
• Unit costs are constant. It does not change with seasonal demands or events.
• The demand is considered constant.
• The money values are expressed in BDT.

3.6 Objective Function
The objective function is formed with the help of the constraints and parameters mentioned before. In this problem the minimization occurs for a single month of 31 days and the number of vehicles for this time period is 29 vehicles. Two types of vehicles are presented as organizational and rental. Here the objective function minimizes the total cost of transportation by two types of vehicles as organizational and rental.

$$\text{Min } z = \sum_{t=1}^{T}\left(\sum_{o=1}^{O} CT_{toc} * X_{toc} * D_{ot} + \sum_{r=1}^{R} CTr_{trc} * Xr_{trc} * d_{rt}\right)$$

3.7 Constraints
The travelling costs of vehicles is less than the organization's budget for budgeted cost of organization.

$$\sum_{t=1}^{T}\left(\sum_{o=1}^{O} CT_{toc} * X_{toc} * D_{ot} + \sum_{r=1}^{R} CTr_{trc} * Xr_{trc} * d_{rt}\right) \leq B \forall \; t, o, r, c$$

The capacity of the vehicle selected for a delivery is greater than or equal to the required capacity for the delivery

$$C_o \geq k_v \qquad \forall \; v, o$$

$$C_r \geq k_v \qquad \forall \; v, r$$

The total number of organizational and rental vehicles is less than the maximum number of delivery in a day

$$\sum_{o=1}^{O} X_{toc} + \sum_{r=1}^{R} Xr_{trc} \leq Vmax \qquad \forall \; t, o, r, c$$

The total number of organizational and rental vehicles is greater than the minimum number of delivery in a day

$$\sum_{o=1}^{O} X_{toc} + \sum_{r=1}^{R} Xr_{trc} \leq Vmin \qquad \forall \; t, o, r, c$$

$$X_{toc} \varepsilon \; \{0,1\}; \qquad \forall \; t,o,c \;\; (\text{acts as binary variable})$$

$$Xr_{trc} \varepsilon \; \{0,1\}; \qquad \forall \; t,r,c (\text{acts as binary variable})$$

The model gives an output of the number of organizational and rental vehicles to be used in a day according to the need. The need depends on the capacity of each vehicle. As all the vehicles represent different levels of capacities, the output will identify those vehicles which are needed in that day.

4. Data Collection
In this paper primary data has been used. It was collected from the distribution department of a Beverage Company. It is situated in Sonargaon, Narayanganj. It was acquired from Senior Manager, distribution of the organization. These data were tabulated by using spreadsheet. From the data, route optimization algorithm along with a cost minimization mathematical model is developed. Information about all the travelling routes were collected from vehicle data.

The cost and capacities of rental and organization vehicles were also collected.1 month or 31 days' data were collected from the organization. It has the minimum capacity of vehicles required for each day. Also it has the required delivery data that each vehicle has to travel.

All costs related data was recorded here in the currency of Bangladeshi taka. For travelling cost, it was considered as per kilometer unit. All the vehicles data was collected in tabular form. The travelling cost were obtained for each vehicle.

5. Results and Discussion
5.1 Selection of Routes and Identification of Optimal Distance

It was done with the help of vehicle routing function in Google Spreadsheet. There are different vehicles in the company from where the data was collected. The vehicles deliver products in different locations in the country. The delivery data collected form the company were analyzed. Then it is occurred that the vehicles complete 29 sequences of delivery. So for each delivery the optimal route sequence was developed using the map coordinate with the spreadsheet functions. Then the minimum distance is identified for each delivery.

For example, for the first delivery that was fulfilled by a vehicle has a number of 8 destinations of different places to supply the goods. The origin was Industrial Zone from where the products are picked for delivery. The coordinate location of the origin is 23.649698905858717, 90.58633579872526 which was collected from Google map. Like the origin, the coordinates of other locations were also collected from the map.

Table 1.Different destinations and their location coordinates

Location No	Coordinates
1 (origin)	23.649698905858717, 90.58633579872526
2	23.7342740477753, 90.417932291011
3	23.714618, 90.428461
4	23.743546, 90.387570
5	23.69297810952641, 90.46745747456318
6	23.707212020107384, 90.46204809058834
7	23.726971913526537, 90.4300295353168
8	23.708378093996306, 90.41207052059666
9	23.764018353409625, 90.40665234534573

In Table 1, locations for a delivery is considered. A total number of 9 locations were travelled in this delivery. In this deliveries are completed by a s single vehicle.
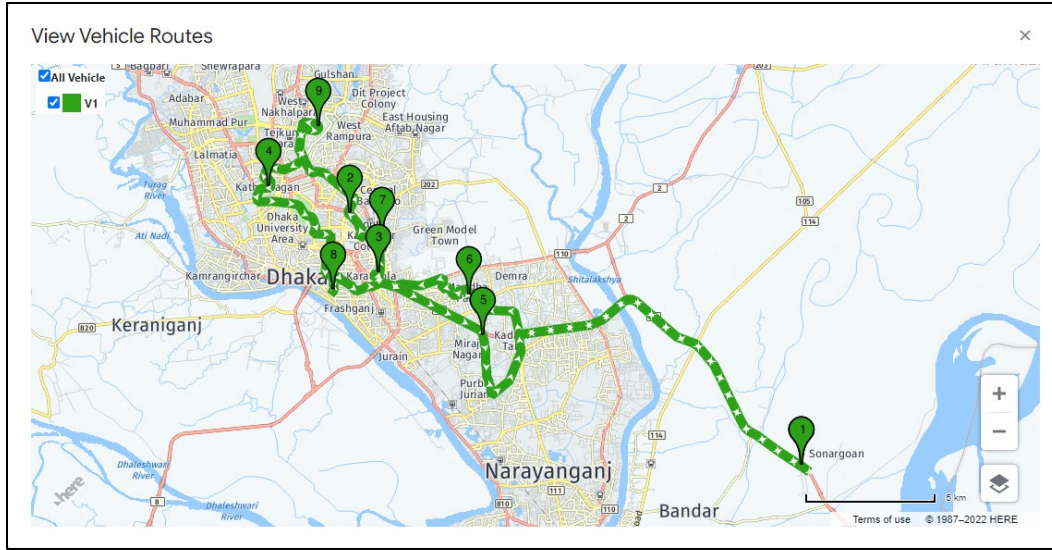
Figure 1: Optimal route for delivery number 1

In Figure1, the route sequence of the delivery no 1 is shown. The result of the route sequence is: 1-6-7-2-9-4-8-3-5-1. The optimal distance from the solution was 72.53 km.

Similarly, the route sequence of 29 deliveries are determined. And the optimal distance of the all the deliveries are found in the same way.

Table 2.Optimal distance for each delivery

Delivery No	Optimal Distance in kilometres	Delivery No	Optimal Distance in kilometres
1	72.53	16	103.82
2	631.36	17	126.59
3	134.49	18	196.06
4	343.66	19	203.17
5	417.84	20	279.97
6	341.58	21	144.68
7	617.95	22	499.65
8	137.85	23	524.76
9	488.8	24	90.95
10	66.03	25	213.51
11	510.73	26	434.41
12	151.00	27	395.04
13	68.06	28	126.64
14	77.24	29	82.01
15	61.03		

In Table 2, Optimal distance for each delivery has been shown. The distance has been calculated in kilometers. These are the optimal distance of the deliveries we found from the optimal route sequence.

5.2 Cost Optimization Result Analysis

By solving the objective function in equation, the optimal number of organizational and rental vehicle was known from the algorithm. The cost for each day was also minimized. The table given here shows the cost for each delivery that was delivered in the days along different locations.

Table 3. Minimum cost for each day

Day	Optimal number of organizational vehicle	Optimal number of rental vehicle	Minimum cost (Tk)	Day	Optimal number of organizational vehicle	Optimal number of rental vehicle	Minimum cost (Tk)
1	10	7	136110	17	5	14	152690
2	9	10	115380	18	5	11	142120
3	2	13	209800	19	8	8	92596
4	4	12	130190	20	7	11	199840
5	7	9	152330	21	7	11	80793
6	5	11	156610	22	6	6	83263
7	6	11	141790	23	4	11	111770
8	4	10	85837	24	8	11	134380
9	4	11	134960	25	3	8	76211
10	6	11	112130	26	6	10	221760
11	2	15	196400	27	9	3	59425
12	8	4	118230	28	8	8	162650
13	5	8	61704	29	4	12	158350
14	5	12	129650	30	9	6	116180
15	8	9	152850	31	6	7	142590
16	6	12	176260	Total Cost			= 4,144,145

In Table 3, the number of organizational and rental vehicles required for each delivery was calculated with the help of genetic algorithm.

Here several organization and rental vehicles were available with different capacities. The number of vehicles are determined by considering required deliveries, available vehicles' capacity and budget for the vehicle cost of the month. Such as, for the first delivery a number of 10 organizational vehicles were required to cover up the demand and a number of 7 rental vehicles were needed to fulfill the demand. For the first day of the month the cost calculated was 136110 Tk. In this similar way, the cost for 31 days was calculated.

5.3 Proposed Improvements
The obtained result from the linear programming model suggests that this model can find optimal solution for reducing the transportation cost. Also by using Google spreadsheet options, optimal routing solution of each delivery is found. From the command window of MATLAB, the optimal number of vehicle and the total cost of vehicle is seen. This indicates the cost of each day is showing separately. Optimized total transportation cost for the month is 4,144,145 TK while existing total transportation cost for the month 4,471,547 TK.From this, it is observed that cost is optimized for the month than the existing cost by using the process. For the data collected from the company route sequence for each delivery was determined. From the sequence the optimal distance was found. By using this distance, the cost optimization part was also calculated showing the optimized result of the transportation cost.

6. Conclusion
The study was based on the route and cost optimization for traveling of a transportation system. In every transportation system there are many locations where the product is to be delivered, also there are multiple number of vehicles available. The route each vehicle follows might not be optimized and favorable with the budget. The goal of the study was to find the optimized routing for each vehicle and the destination sequence. Genetic algorithm was the medium for solution of the problem. The result from route optimization from Google spreadsheet was used in the cost optimization part. The number of organizational and rental vehicle needed each day was found from the algorithm and the minimized cost was calculated as total cost for all periods.

There are some scopes for the future work regarding this work. The demand fluctuations during seasons can be considered with various types of vehicles having different capacities. The algorithms could be considered using more number of iterations for the functions to obtain more evaluated result. A shorter time period has been considered in this work, while longer time periods can be used to get better outcome.

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Biographies

Armin Ali is a graduate in Industrial & Production Engineering from Rajshahi University of Engineering & Technology. Her research interests are supply chain and logistics, supply chain operations, quality control, operations management, project and environment management, management information system, operations research.

Sirajum Munira is a graduate in Industrial & Production Engineering from Rajshahi University of Engineering & Technology. Her research interests are quality control, supply chain and management, industrial and business management, multiple criteria decision analysis, project and environment management, management information system.

Khairun Nahar is an Assistant Professor of Industrial & Production Engineering at Rajshahi University of Engineering & Technology. Her main research interests are in CAD/CAM, quality control, operations research, measurements & instrumentation, engineering economy & multiple criteria decision analysis.