Supply Chain Network Optimization Strategy in Last-Mile Delivery Using Crowdsourced Approach: A Case Study

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Abstract

Last-mile delivery bears a significant impact in today's competitive environment as it contains the major amount of cost in the supply chain. Here Hub and Spoke model is used as network optimization strategy to decrease the delivery cost. Besides the crowdsourced approach is one of the key topics and is continuously being studied to reduce delivery time and costs. This paper proposes a mathematical model for a crowdsourced supply chain network using hub and spoke model to minimize the transportation cost of the system. The analysis tries to test and quantify the performance of the model using the supply chain of a renowned company in Bangladesh. The model generates locations for the echelons and scales a grid in which the factories, warehouses, sales outlets, customer locations, and the drivers reside. In the model, two alternative methods are used for last-mile delivery to make a comparison of the transportation cost. By using a linear programming model in MATLAB, the effects of crowdsourcing on the supply chain are emphasized. The result is evaluated and analyzed for practical use.

Keywords
Supply Chain, Crowdsourced Approach, Hub and Spoke Model, Last-mile delivery, Transportation cost

1. Introduction

A supply chain is a network that includes different activities, individuals, elements, information & resources and represents a series of steps to get the product or service from its primary state to the end customer. There are many different links in this chain that require a lot of strategies to optimize the cost. Here, crowdsourced approach using hub and spoke model is used to allocate the factory, warehouse, sales outlets, and customer location. This model is used to manage the transportation route in a multi-echelon network to reduce the overall transportation cost. For minimizing this cost across echelons, the allocation of the warehouses to meet all of the customer service goals has been described.

Crowdsourcing is a term used to depict the way toward getting work from a large group of people in an online setting. The advantages of crowdsourcing include cost savings, speed, and it works as an alternative to traditional financing options. According to (Arslan et al., 2018), one of the main difficulties faced by internet retailers and logistic service providers is to provide cost-efficient home delivery services. The recent trend towards shorter lead times and delivery on the same day further raises the pressure on transport efficiency. At the same time, mobile internet technology gives rise to new opportunities such as crowdsourced delivery to organize the last mile. This concept entails the use of the excess capacity of private passenger vehicles on journeys that already take place to support delivery operations. By utilizing existing traffic streams, this might empower quicker and cheaper deliveries.

The problem of designing a crowdsourced network through a hub and spoke model consists of origin, hub, and destination nodes. In a hub and spoke network, a set of intermediate nodes are located as the origin (hubs), and destination nodes (spokes) are allocated to these hubs. Hubs are responsible for consolidating, transferring, and distributing flows through the network to gain economic profits. Therefore, it is necessary to design a reliable logistics network that remains available and efficient. In this paper, the supply chain network includes several factories, warehouse, sales outlets, and demand points which need to be located not just randomly but as a result of a careful calculation to minimize the overall cost and increase the supply chain surplus. For this reason, the hub and spoke model is used to make the whole system more robust and agile by receiving products from different origins, consolidating the products, and sending them directly to destinations. According to (Greasley, 2012), the last mile is described as a delivery link which is the link between the distribution system at the spoke terminal and a customer who can be classified as non-retail (trade) or retail.

The main objective of this paper is to select better options to deliver the products to the end customers in a cost-efficient way. So, the models are generated to make necessary differences to the courier delivery and crowdsourced delivery. In specific, the cost between the courier service delivery system and the crowdsourced delivery system are compared where individual travelers share a ride to save on their travel cost. In section 2, a literature review related to the crowdsourced delivery, hub and spoke model and transportation networks are described. The theoretical framework is described in section 3 to define, discuss, and evaluate the theories relevant to the research. In section 4, the problem is described to find the optimal path for the transportation of products from the factories, warehouses, sales outlets, and to the customer location. Besides necessary models are developed and calculations are done to summarize the results in the multi-echelon model, for the optimal number of warehouses and sales outlets. The result and discussion that is explained in section 5 indicate that the location of the sales outlets has a significant impact on the total transportation cost. At last, the paper ends with the limitations and future research so that the improvements can be done in a different context.

2. Literature Review

Advancement of supply chain management and financial engineering research was contributed by (Geunes and Pardalos, 2003) through an examination of network optimization applications. In another research, different ways to set up the point of hub and spoke networks and different impacts were discussed by (Konings et al., 2013) to get the economic feasibility. A mixed-integer programming model was developed by (Zheng et al., 2015) to designs a liner hub and spoke shipping network. In order to optimize the supply chain of a national medical consumer supply company with foreign manufacturers, two mixed-integer programming models were developed by (Krishnan, 2015). In the research, to determine the optimal locations of warehouses and distribution facilities that minimize total transportation cost, p-median single echelon, and hub and spoke multi-echelon models were used. Single and multiple allocation networks were addressed by (Bryan, 1997) with completely interconnected hubs and no direct node-to-node links. According to the research, allowing multiple allocations allows much greater routing flexibility, and hence is expected to have a lower objective cost of operation.

Research related to single allocation and multiple allocation hub location problems was evaluated by (Abdinnour-helm and Abdinnour-helm, 2013). A robust optimization approach was used as a factor for dealing with uncertain parameters such as fixed setup cost and capacity of the hub. In another research, the hub-and-spoke logistics network design problem was considered by (Taylor et al., 2015) for 3rd party logistics companies. To minimize the total logistics costs for the network, the research focused on deciding the number, location, and operation of hub facilities.

Crowdsourced delivery is considered as a response to the increasing expectations of customers for quicker, more customized, and cost-efficient delivery service. The performance of the crowdsourced last-mile delivery to develop a simulation model and to conduct initial simulation experiments was investigated by (Chen and Chankov, 2017) in order to identify the important factors influencing its performance. In the research of (Misra et al., 2014), the use of crowdsourcing has been suggested to include a broad number of stakeholders in transport planning and operations. In the research, crowdsourcing for collecting normally sparse data on facilities such as bike routes and crowdsourcing for requesting feedback on transport quality of service and ongoing data quality were identified.

Variations of crowd logistics with their flow of materials, goods, and information were presented by (Mladenow et al., 2016). In the research, potential advantages and challenges of logistics were discussed with the crowd. The potential benefits of crowdsourcing last-mile delivery were demonstrated by (Devari et al., 2017) by exploiting a social network of the customers. In the research, it is found that to ensure speedy and reliable delivery using the social network to assist in last-mile delivery greatly reduces delivery costs and total emissions. In another research, (Pilloni, 2018) presented the improvements in production efficiency, quality, and cost-effectiveness as well as the quality of working conditions, products' quality, and availability, according to mass customization requirements in the crowdsourced model.

3. Theoretical Framework

Nowadays companies' success and customer satisfaction depend mostly on the management of the supply chain. The approaches being discussed include how a supply chain cost should be optimized to be considered the most efficient to get the optimum result. Supply chain operations include the transformation of raw materials and elements into finished goods shipped to the end customer. It is the network of all the persons, organizations, services, activities, and technologies involved in the production and selling of a product. A typical supply chain may involve a variety of stages, including the following: Customers, Retailers, Wholesalers/distributors, Manufacturers, and Component/raw material suppliers.

Network design in the supply chain is a powerful modeling methodology known to achieve substantial cost savings in the supply chain and service quality improvements by better coordination of supply chain strategies. One of the important methods for studying network design is using modeling techniques, and then solving the modeled issue by the appropriate technique. Different distribution methods are used in the supply chain to move and store a product from the supplier stage to a customer stage. The multi-echelon method optimizes stock across all locations in a supply chain network. Multi-echelon model aims to provide the required level of end-customer service on a minimum network inventory, with the inventory distributed among the different echelons. Often consideration is taken with the main emphasis on production, storage, and warehouse operating costs, as their cost affects the part of the overall optimization.

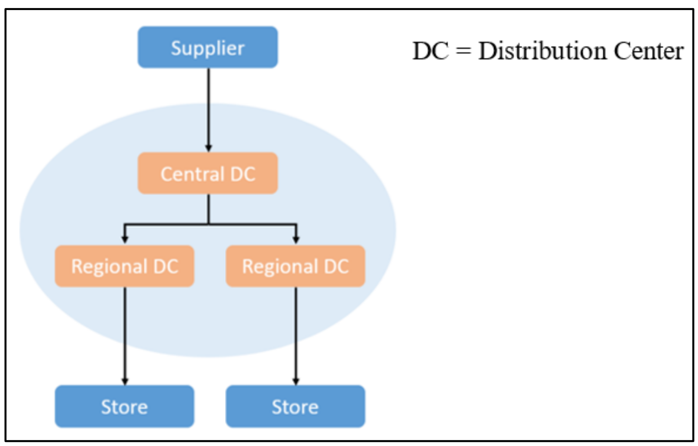

Fig 1:Multi-echelon optimization model

As a wholesaler or retailer exceeds a certain scale, their distribution network typically starts to integrate multiple storage location rates. The hub-and-spoke model has been adopted by the logistics and distribution industries in recent years to accelerate deliveries and reduce costs. In this model, transports gather goods from their point of origin (spokes tips) and take them back to a central processing facility (the hub). The shipment is then either warehoused or directly distributed from the center of the network. Larger companies run several hub-and-spoke networks. One advantage of the hub-and-spoke model is it has enhanced shipment monitoring. There are far too many routes linking them to a large network of other cities as shipments are delivered directly from source city.

For the extended supply chain, social networks offer a place for trading partners to exchange their internal data and add knowledge that affects the supply chain. With increasing online purchases, a majority of retailers are looking out for options to deliver their products more efficiently. The effect of crowdsourcing on supply chain risk reduction is also apparent in technology that enables companies to connect and interact with their suppliers in real-time. This is the process of soliciting input from a significant number of people to get ideas, resources, or information.

Offering last-mile delivery of products to consumer's homes presently takes up the majority of online purchases. The crowdsourced approach is the way to reduce the transportation cost in such online deliveries. The main difference between the crowdsourced delivery and courier delivery is in the first one, there will be an individual driver or traveler who will share the ride to save on their own travel cost. Picking up multiple tasks at one location is more convenient than picking them up at different locations. It also saves the transportation cost. Besides crowdsourcing platforms guarantee that people can be able to work on any project from any place and at any time. This is the way the crowdsourced approach helps in online delivery service.

4. Model Formulation

The study suggests a mathematical model for a crowdsourced supply chain network using the hub and spoke model to reduce the cost of transport, networking, and routing. The system is divided into four main echelons; echelon-1 refers to the factory locations, echelon-2 indicates the warehouses, echelon-3 indicates the sales outlet locations and echelon-4 are the customer locations. Here the multi-mode distribution network is focused, which is solved by linear mixed-integer programming. The model first produces factories, warehouses, and distribution outlets at random locations. One restriction on the model is that demand is met, meaning exactly the quantities in demand are generated and distributed by the system. Another restriction is the capacity constraints on each factory and each warehouse. The rest of the problem is discussed about the determination of the cheapest mapping of sales outlets to warehouses.

4.1 Assumptions

I. The model only presents an example of routes that involve only one stop
II. There is no traffic congestion

4.2 Variables & Parameters

The parameters and the variables used in the cost optimization model formation are as follows.

Index Sets

I Index set of factories
J Index set of candidate warehouse locations
K Index set of customer locations
S Index set of sales outlets
L Index set of products
V Index set of ad hoc drivers

4.3 Parameters

n Number of operating warehouses
r_{kl} Required quantity at customer location k for product (in lbs.)
d_{ij} Distance between factory location i and warehouse location j (in km)
$ḑ_{js}$ Distance between warehouse location j and sales outlet s (in km)
$ḑ_{sk}$ Distance between sales outlet s and customer location k (in km)
d_{jk} Distance between warehouse location j and customer location k (in km)
c_{ij} Cost per truck from factoryi to warehouse j (in Tk/km)
c_{1jk} Cost of courier shipment from warehouse j to customer location k (in Tk)
c_{2jk} Cost of courier shipment from warehouse j to customer location k via crowdsource (in Tk)
m Number of operating sales outlets
c_{js} Cost per truck from warehouse j to sales outlet s (in Tk/km)
c_{1sk} Cost of courier shipment from sales outlet s to customer locations k (in Tk/km)
c_{2sk} Cost of courier shipment from sales outlet s to customer locations k via crowdsource (in Tk)
$a_{il}= \{1, if factory\ produces\ product\ l, otherwise\ 0$

4.4 Decision Variables

f_{ijl} Quantity of product l from factory i to warehouse j (in lbs.)
f_{jkl} Quantity of product l from warehouse j to demand location k (in lbs.)
$ţ_{ij}$ Number of trucks from factory i to warehouse location j (in trucks)

t_{js} Number of trucks from warehouse location j to sales outlet s (in trucks)
f_{jsl} Quantity of product l from warehouse j to sales outlet s (in lbs.)
f_{skl} Quantity of product l from sale outlet s to customer location k (in lbs.)
x_s= {1, *if there is an operating sales outlet at s, otherwise* 0
z_{js}= {1, *if an operating warehouse at j serves an operating sales outlet at s*, *otherwise* 0
y_{sk}= {1, *if the operating sales outlet at s serves customer location k*, *otherwise* 0
x_j= {1, *if there is an operating warehouse at location j*, *otherwise* 0
y_{jk}= {1, *if the operating warehouse at location j serves customer location k*, *otherwise* 0

4.5 Objective Function

The total transportation cost under a particular scenario is directly dependent on the amount of product transferred between the echelons, the type of transportation, the distance between the echelons, and the routing of the process. The transportation cost includes the cost for movement of the materials from factory to warehouse, from warehouse to sales outlet, and from sales outlet to the customer location. Summing up all the costs in a process, the objective function for minimizing total transportation cost is:

$$Min\ (\Sigma_{i\in I} \Sigma_{j\in J} (c_{ij} * d_{ij} * t_{ij}) + \Sigma_{j\in J} \Sigma_{k\in K} (c_{1jk} * d_{jk}) + \Sigma_{j\in J} \Sigma_{k\in K} (c_{2jk} * y_{jk}) + \Sigma_{j\in J} \Sigma_{s\in S} (c_{js} * d_{js} * t_{js}) + \Sigma_{s\in S} \Sigma_{k\in K}(c_{1sk} * d_{sk}) + \Sigma_{s\in S} \Sigma_{k\in K}(c_{2sk} * y_{sk})) \quad (4.1)$$

4.6 Constraints

The objective function is subjected to following constraints:

$\Sigma_{j\in J}\ x_j = n$		(4.2)
$\Sigma_{s\in S}\ x_s = m$		(4.3)
$\Sigma_{s\in S}\ z_{js} \leq m * xj$	$\forall j$	(4.4)
$x_s \leq \Sigma_{\ j\in J}\ z_{js}$	$\forall s$	(4.5)
$\Sigma_{k\in K}\ (y_{jk}) \geq x_j$	$\forall j$	(4.6)
$\Sigma_{k\in K}\ (y_{jk}) \leq x_j * \|K\|$	$\forall j$	(4.7)
$\Sigma_{k\in K}\ (y_{sk}) \geq x_s$	$\forall s$	(4.8)
$\Sigma_{k\in K}\ (y_{sk}) \leq x * \|K\|$	$\forall s$	(4.9)
$y_{jk} \leq x_j$	$\forall j, \forall k$	(4.10)
$z_{js} \leq x_j$	$\forall j, \forall s$	(4.11)
$z_{js} \leq x_s$	$\forall j, \forall s$	(4.12)
$\Sigma_{j\in J}\ z_{js} \leq x_s$	$\forall s$	(4.13)
$y_{sk} \leq x_s$	$\forall s, \forall k$	(4.14)
$\Sigma_{j\in J}\ y_{jk} + \Sigma_{s\in S}\ y_{sk} \leq 1$	$\forall k$	(4.15)
$\Sigma_{j\in J}\ f_{jkl} + \Sigma_{s\in S}\ f_{skl} \geq r_{kl}$	$\forall k, \forall l$	(4.16)
$f_{jkl} \leq r_{kl} * y_{jk}$	$\forall j, \forall k, \forall l$	(4.17)
$f_{skl} \leq r_{kl} * y_{sk}$	$\forall s, \forall k, \forall l$	(4.18)
$f_{ijl} \leq x_j * a_{il} * \Sigma_{k\in K}\ r_{kl}$	$\forall i , \forall j, \forall l$	(4.19)
$\Sigma_{k\in K}\ f_{jkl} + \Sigma_{s\in S}\ f_{jsl} \leq \Sigma_{i\in I}\ f_{ijl}$	$\forall j, \forall l$	(4.20)
$\Sigma_{k\in K}\ f_{skl} \leq \Sigma_{j\in J}\ f_{jsl}$	$\forall s, \forall l$	(4.21)
$f, t \in \mathbb{R}$		(4.22)

$x, y, z \in \{0,1\}$ (4.23)

Objective function 4.1 minimizes the total transportation cost of the network, the terms showing the costs of the shipments. Constraint 4.2 specifies the number of warehouses to be open throughout the whole process. The number of the operating sales outlets are specified by constraint 4.3. Constraint 4.4 ensures that only the open warehouses serve the sales outlets. Constraint 4.5 specifies that each sales outlet is served by at least one warehouse. Constraints 4.6 to 4.9 ensure that only the open sales outlets serve customer locations and all open sales outlets serve at least one customer locations.

Constraints 4.10 & 4.11 ensure possible routes exist only between open warehouse and sales outlets, while constraint 4.12 allows only one warehouse to supply the products to each sales outlet. Constraints 4.13 & 4.14 specify either a warehouse or a sales outlet serve any particular customer location. Constraint 4.15 ensures one incoming route to each location at most, either from a warehouse or a sales outlet and constraint 4.16 specifies that all the customer demands are satisfied. Constraints 4.17 & 4.18 ensure that products are shipped only along the allowed routes.

Constraint 4.19 specifies that shipments to the warehouse only come from factories that produce the needed product. Constraints 4.20 & 4.21 ensure that outbound shipments from warehouses and sales outlets do not exceed the inbound shipment. At last, constraint 4.22 ensures the non-negativity of the product flow to and from all the warehouses and sales outlets and the number of trucks and constraint 4.23 defines the decision variables to be binary.

5. Result

In this chapter, the results of the crowdsourced approach to solving a supply chain network with hub and spoke model are analyzed. A robust supply chain model has been designed by considering a real-life scenario to analyze the different aspects of the network cost and the crowdsourcing approach. The design defines the locations for multiple echelons and scales a grid where the factories, warehouses, sales outlets, customer locations, and drivers are located. To be exact, the study aims to test and quantify the model's viability and efficiency across the supply chain of a renowned Bangladeshi organization. In addition, the recommendations of the model based on the result analysis of the case are explained.

5.1 Case Study

The model is a four-echelon system where the locations of the factories, sales outlets, and the customer are fixed. The location of the warehouse and the drivers are chosen randomly to satisfy the objective. The supply chain is assuming production and transfer of only one type of product. In order to solve the problem and generate results, a variety of data has been used. These data are picked from various sources, some reasonable assumptions are made and necessary calculations are done. The transportation costs are based on distances and pricing of the delivery process has been collected from reliable sources keeping in mind the locations of the echelons.

In designing the problem, several aspects are taken into consideration. The availability of data and the possibility of implementation in a real supply chain system are some of the key factors. The transformation of the data for populating the models is sometimes a highly complex task. The reason for this simplification lays in the complexity of the mathematical model which is a highly delicate procedure where not just using algorithms is a standard way.

5.2 Result Analysis

The program is implemented in MATLAB R2018b, on a pc platform with an intel core i5 processor and 4GB RAM. The program combines the MATLAB scripts and graphic user interfaces script that is potting the results from the generations run. There are some necessary functions that are not in the scripts themselves but in the way of writing the functions in MATLAB language. It is necessary to transform the mathematical formulation of the model into a specific programming language.

In the model, two alternative methods are used for the last-mile delivery of the product from the sales outlets to the customer location. The cost between the courier service delivery system and the crowdsourced delivery system are compared where individual travelers share a ride to save on their travel cost. The shortest path criterion is used to assign the drivers to a particular task. Figure 3 shows a route of the product from the factory to the customer location for a specifically selected node.

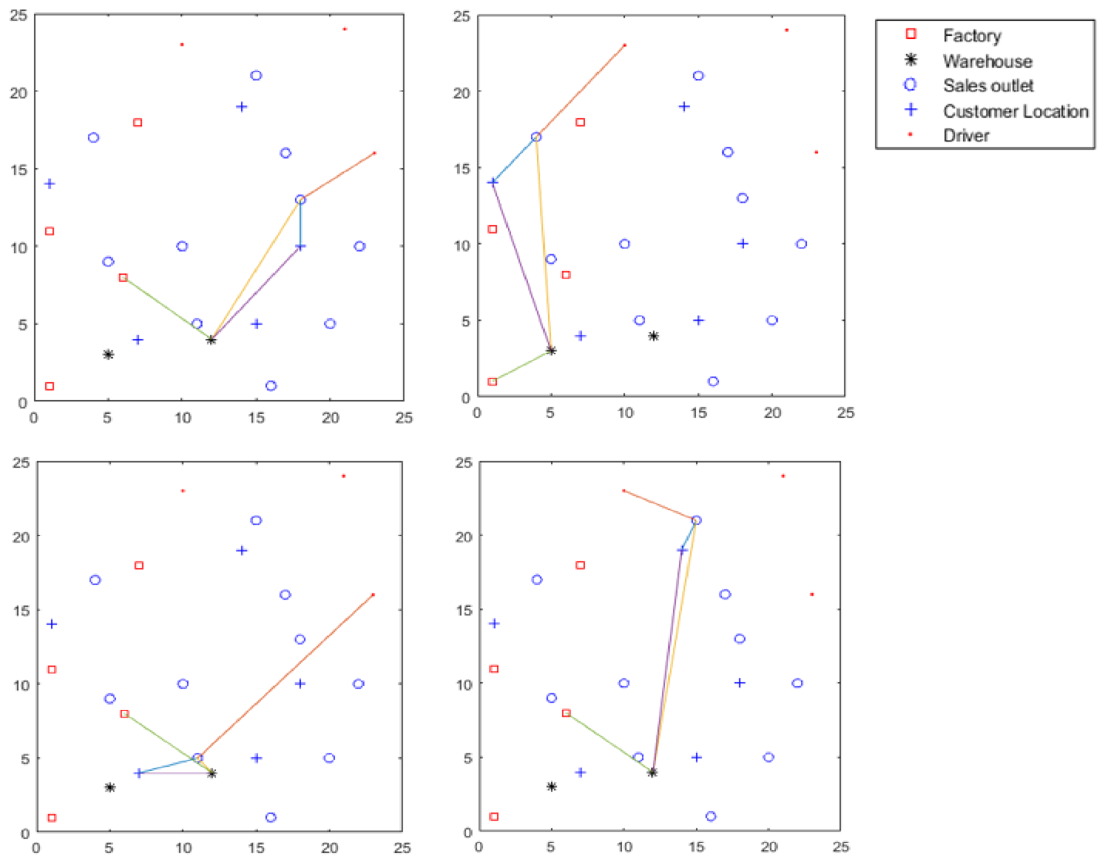

Figure 2: Optimized network for specific customer location 1, 2, 3 and 4 respectively (From left hand side to right hand side)

The figure shows a grid with the factories, warehouses, sales outlets, customer locations, and drivers in it. For a given customer location, the nearest sales outlet will provide the product through the nearest driver. The product is supplied to the sales outlet from the nearest warehouse and the warehouse is fed its supplies from the nearest factory. For a changed customer location, the results are shown below.

Table 1 indicates the different rates of the transportation medium per km. With the help of this cost table, the crowdsourced network has been analyzed and optimized in Table 2 for five specific customer locations in Dhaka, Bangladesh. From the table, the results indicate that a significant percentage of cost is reduced in case of crowdsourced last-mile delivery than the courier service delivery system. An average annual savings of 26.5% is possible if the crowdsourced last-mile delivery system is utilized in the network.

Table 1 : Rate of different transportation medium per km

Medium	**Cost per km**
Trucks	Tk 51
Courier service	Tk 18
Crowdsourcing	Tk 12

Table 2 : Optimization results for the crowdsourced network analysis

	Customer Location				
	1	2	3	4	5
	Mirpur	Uttara	Malibagh	Dhanmondi	Banani
Shipment cost from factory to warehouse	Tk 4,100	Tk 4,100	Tk 5,700	Tk 4,600	Tk 5,200
Shipment cost from warehouse to sales outlets	Tk 1,600	Tk 1,250	Tk 1,700	Tk 1,360	Tk 1,500
Shipment cost via courier service from sales outlet to customer location	Tk 140	Tk 250	Tk 225	Tk 200	Tk 250
Shipment cost via crowdsourcing from sales outlet to customer location	Tk 85	Tk 130	Tk 110	Tk 100	Tk 130
Monthly transportation cost (using courier service)	Tk 87,600	Tk 1,17,800	Tk 1,26,700	Tk 1,07,680	Tk 1,28,600
Monthly transportation cost (using crowdsourcing)	Tk 71,100	Tk 81,800	Tk 92,200	Tk 77,680	Tk 92,600
Savings	Tk 16,500	Tk 36,000	Tk 34,500	Tk 30,000	Tk 36,000
Annual Savings	Tk 1,98,000	Tk 4,32,000	Tk 4,14,000	Tk 3,60,000	Tk 4,32,000
% of savings	18.84%	30.56%	27.22%	27.86%	28%

Table 3 summarizes results for the multi-echelon model, for the optimal number of warehouses and sales outlets. Three specific locations for warehouse and another three specific locations for sales outlets in Dhaka are considered. Substantial savings results by increasing the number of warehouses from one to two, with less percentage of savings beyond that. The results also indicate that warehouse location depends to a greater extent on the location of the factories than the customer locations.

Table 3 : Result for the model network with different number of warehouses

Number of warehouses	1	2				3			
Number of sales outlets	0	0	1	2	3	0	1	2	3
Warehouse locations	Gazipur	Gazipur, Savar	Gazipur, Savar	Gazipur, Savar	Gazipur, Savar	Gazipur, Savar, Kachpur	Gazipur, Savar, Kachpur	Gazipur, Savar, Kachpur	Gazipur, Savar, Kachpur

Sales outlet locations	-	-	Mirpur	Mirpur, Banani	Mirpur, Banani, Uttara	-	Mirpur	Mirpur, Banani	Banani, Uttara
Monthly transportation cost	Tk 1,37,500	Tk 1,21,300	Tk 1,08,600	Tk 1,02,300	Tk 96,600	Tk 1,27,800	Tk 1,17,500	Tk 1,07,000	Tk 1,01,300
Savings	-	Tk 16,200	Tk 28,900	Tk 35,200	Tk 40,900	Tk 9,700	Tk 20,000	Tk 30,500	Tk 36,200
Annual savings	-	Tk 1,94,400	Tk 3,46,800	Tk 4,22,400	Tk 4,90,800	Tk 1,16,000	Tk 2,40,000	Tk 3,66,000	Tk 4,34,400
% of savings	-	11.78%	21.01%	25.6%	29.74%	7.05%	14.54%	22.18%	26.33%

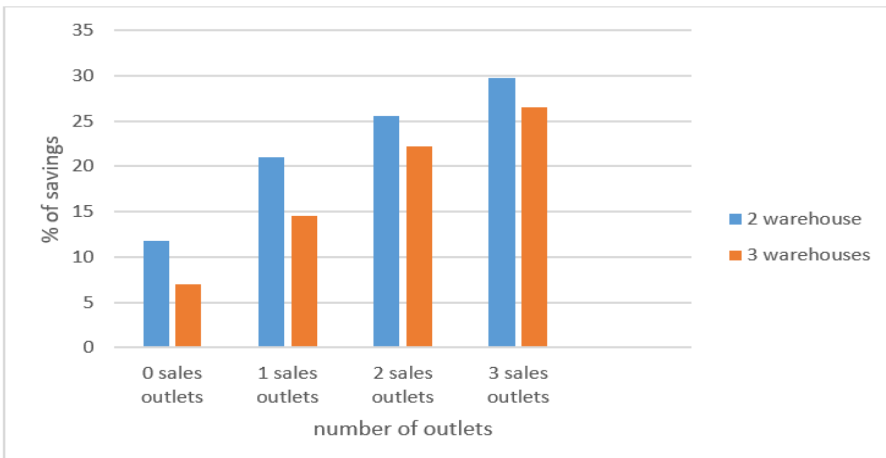

Figure 3: Comparison between % of savings for different number of warehouses & sales outlets

The location of the sales outlets has a significant impact on total transportation costs. Specifically opening a sales outlet at Mirpur location results in yearly savings of Tk 3,46,800, a savings percentage of 21.01%, whereas adding two sales outlets in the system results in yearly savings of Tk 4,22,40. Added warehouses both will reduce total transportation costs and make the supply chain network more robust to a temporary failure of facilities. For example, adding a second warehouse for robustness reduces cost by Tk 16,200, an 11.78% savings, whereas adding a warehouse and a sales outlet results in saving a percentage of 21.01%.

5.3 Sensitivity Analysis

Sensitivity analysis in this model investigates the effect of geographical changes in demand. The current demand patterns have 42% of the customers located in the eastern part of Dhaka, 33% in the southern part, and 25% of the customers in the northern part. As a somewhat extreme case analysis, Table 4 summarizes optimization results if all demands were shifted entirely to the eastern side, northern side, or the southern side of the city.

Table 4 : Two warehouse network model results under changes in demand

	Demand evenly spread in the northern part			Demand evenly spread in the eastern part			Demand evenly spread in the southern part		
Number of sales outlets	1	2	3	1	2	3	1	2	3
Sales outlets location	Uttara	Uttara, Bashund hara	Uttara, Bashundhara, Banani	Malibagh	Malibagh, Khilgaon	Malibagh , Khilgaon , Badda	Motijheel	Motijheel, Dhanmon di	Motijheel, Dhanmon di, Shahbag
Monthly transportation cost	Tk 1,23,300	Tk 1,14,200	Tk 1,04,200	Tk 1,30,100	Tk 1,13,500	Tk 1,00,000	Tk 1,12,800	Tk 1,06,300	Tk 94,900
Monthly transportation cost from network optimization from the demand	Tk 1,17,800	Tk 1,08,400	Tk 1,00,400	Tk 1,26,700	Tk 1,11,000	Tk 98,600	Tk 1,07,600	Tk 98,200	Tk 87,500
Cost increase	Tk 5,500	Tk 5,800	Tk 3,800	Tk 3,400	Tk 2,500	Tk 1,400	Tk 5200	Tk 8,100	Tk 7400
% of increase	4.46%	5.07%	3.64%	2.61%	2.20%	1.4%	4.61%	7.61%	7.79%

As shown in the table, there is almost 4.5% increased cost when the demand shifts to the northern part of the city. The increase in cost is approximately 2.15% when the demand is shifted towards the eastern part and 6.67% when shifted towards the southern part of the city.

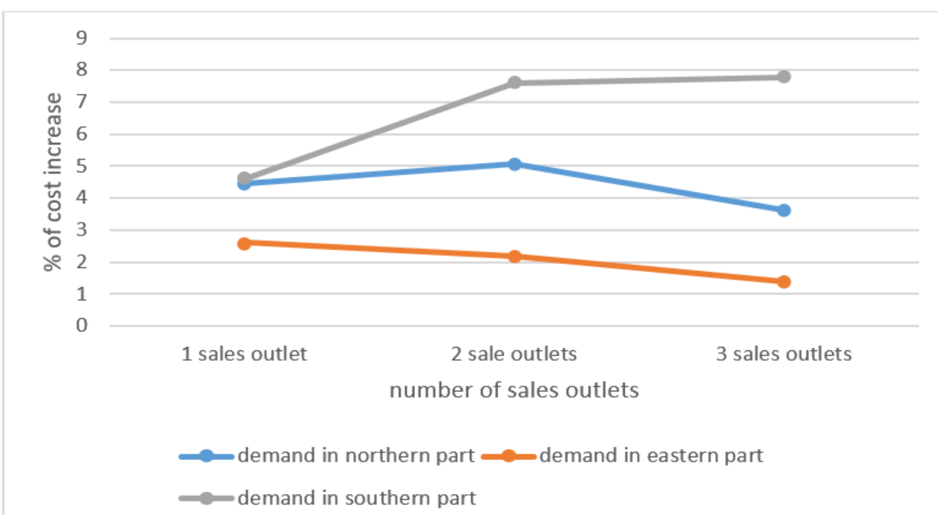

Figure 4: Comparison of % of cost increase for different number of sales outlets in sensitivity analysis

6. Conclusion

This study is aimed specifically at providing research on how the crowdsourced approach can be used with the hub and spoke network to create a network optimization model that will reduce the transportation cost. This includes the optimal placement of the warehouse within the supply chain. The main motivation of the research is to develop a model which has the goal of fulfilling some new research opportunities in the field of supply chain cost optimization. In this study, an online product delivery problem is introduced which is solved by using the crowdsourced approach. Besides, hub and spoke model is used where the warehouses are used as hub. By selecting the customer locations, the shortest distance among the warehouse, distribution centers, and sales outlet is generated. Thus, the cost related to transporting the deliveries are optimized. Besides in the model, the comparison of delivery cost between the courier system and crowdsourced system is shown. The result indicates that there is a good amount of savings by using crowdsourced delivery rather than the courier service. Comparison between the percentage of savings for the different number of warehouses & sales outlets is shown in this research which indicates that the additional warehouses will reduce total transportation cost and make the supply chain network more robust. At last, a sensitivity analysis was done to show the geographical changes in demand. Thus the model is provided with the objective function of total cost minimization to result in delivering the goods.

7. Future Research

In conclusion to this paper, this section proposes some future research directions based on the results obtained from the studies. Despite the successful implementation of the model, there are several ways that this research can be improved further in the future. As the model is presented only for the locations having the same demand. Future research can be done by considering variations of the demands in different locations. In the future research or work of implementing the model, the warehouse capacity can be considered. Most significantly, products must be specifically grouped according to the type of storage needed. This will allow determining the right capacity of static storage requirements within a warehouse. Implementations can be done to simplify this process, allowing warehouse capacity to be modeled and optimized. In future research, traffic congestion can be considered because transportation cost, time, and product service life are related to the time that is needed to deliver the product from the manufacturer to the customer demand locations.

However, from a modeling point of view, applying the model and testing it with the real case data is an important case and confirms the findings and search for new potential ones. As the last step, studying in-depth and developing this specific model for solving this kind of problem is an important challenge. The future improvements are significant for step forward in the supply chain cost optimization for different companies which will certainly improve the model and will aim at identifying new tradeoffs.

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