Development of a Model to Optimize the Supply Chain Management and it's Application

By

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Declaration

This is to certify that the thesis work entitled ***"Development of a Model to Optimize the Supply Chain Management and it's Application"*** has been carried out by **Md. Al Amin** in the Department of Industrial Engineering and Management, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of any degree or diploma.

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Abstract

The main objective of this research is to develop a mathematical model for supply chain transportation costs. This model consider the real time data of the transportation cost incurring elements which helps in achieving optimization. Though it has been case studied for a particular company but it's been generalized for all aspects of supply chain network under some specific conditions. In this research Theory of Constraint (TOC) has been applied to identify the main constraints to its goal. The main constraint are found supply chain transportation cost which significantly impact on supply chain profit. Thinking process has been developed to propose a conceptual model regarding the constraints. The case study has been performed for 30 days and found 32.68% better results for one complete transportation cycle compared to existing transportation modes. The ways the model optimize the transportation cost by managing vehicle route, fleet size and number of moves throughout the transportation network. Finally, this model offering significant results in throughput accounting of supply chain transportation that leads to optimize overall supply chain costs.

Keywords: Optimization, Supply chain, Mathematical model, Transportation cost, Transportation network

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List of Abbreviations

Abbreviations	Descriptions
SCM	Supply Chain Management
TOC	Theory of Constraints
CD	Central Depot
MDC	Main Distribution Center
RDC	Regional Distribution Center
B2B	Business to Business
TL	Truck Load

CHAPTER 1

Introduction

1.1 General

Supply Chain Management is defined as the management of upstream and downstream associations with vendors and customers to provide better customer value by optimizing the supply chain (Dubey *et al*., 2013). Supply chain collaboration amongst independent firms or business units often provides larger benefits from effectively satisfying end customer needs than working in isolation. However, a lack of awareness about the existence of constraints along the supply chain prevents the benefits of collaboration from being fully realized. Their research attempts to apply the Theory of Constraints approach to overcome difficulties in realizing the potential benefits of supply chain collaboration. Specifically, it shows how the Theory of Constraints approach can be used to expose an inherent dilemma of collaboration and establish collaborative replenishment policy and collaborative performance metrics so that the chain members can work together to advance supply chain profitability (Simatupang et al., 2004).

Supply chain optimization is the application of processes and tools to ensure the optimal operation of a manufacturing and distribution supply chain. This includes the optimal placement of inventory within the supply chain, minimizing operating costs. Supply chain optimization addresses the general supply chain problem of delivering products to customers at the lowest total cost and highest profit. This includes trading off the costs of inventory, transportation, distributing and manufacturing. In addition, optimizing storage and transportation costs by means of product or package size is one of the easiest and most cost effective initial implementations available to save money in product distribution. This research work aims to propose a mathematical model for supply chain transportation network. Then the model has been applied in a transportation network for verifying the model to a particular Bangladeshi company named Abdul Monem Ltd. However, this model can be applied for any transportation network under some necessary condition.

1.2 Objectives of the Thesis

The objectives of the thesis are:

1. To develop a model to optimize the supply chain transportation costs.
2. To identify the supply chain constraints using theory of constraints.
3. To apply the model to optimize the supply chain management.

1.3 Organization of the Thesis

The organization of the thesis is as follows: Chapter 2 discusses the background study, research gap and objective of this research work. Chapter 3 describes the theoretical considerations and define some of the key points of the research. Chapter 4 demonstrates model formulation and proposed a mathematical regarding supply chain transportation costs in details. Chapter 5 a case study has been performed for verifying the proposed model. Chapter 6 presents the results and discussion of the proposed model. Chapter 7 includes conclusions, limitations and future scopes of the work.

CHAPTER 2

Background Study and Literature Review

2.1 General

Many past studies have been dedicated to determining how to achieve the lowest possible transportation cost. For example, A Study focused on minimizing the total costs involved in a transportation problem (Pilot.C and Pilot.S, 1999). Chanas and Kuchta (1996) proposed an optimal solution to the transportation problem, which makes use of fuzzy cost coefficients and an algorithm determining the nature of the solution. McCann (2001) addressed two related questions one is the optimum size of a vehicle and the structure of transportation costs. Min and Zhou (2002) synthesizes past supply chain modeling efforts and identifies key challenges and opportunities regarding the supply chain modeling. They also provide various guidelines for the successful development and implementation of supply chain models. Dubey *et al.* (2014) offers a model for sustainable supply chain network where it describes about maximizing the supply chain surplus (economic) and minimizing the carbon emission (environmental). The paper finds that the environmental dimensions were ignored in comparison to the economic criteria in a study conducted in one of the Indian company. Wang *et al.* (2011) introduced a green supply chain network design model for the firm's strategic planning based on the classical facility location problem. The distinguishing feature of our model is its consideration of environmental element which includes environmental level of facility and environmental influence in the handling and transportation process. Parkhi *et al.* (2014) studied on transportation costs optimization in retail distribution. According to them cost factors in supply chain transportation network are truck volume utilization, fleet utilization, route optimization, turnaround time (TAT), backhauling, information technology. Alvarenga *et al.* (2007) proposed a robust heuristic approach to vehicle routing problems with time windows, using travel distance as the main objective through an efficient genetic algorithm and a set partitioning formulation. Ghoseiri and Ghannadpour (2010) presented a new model and solution for multi objective vehicle routing problem with time windows (VRPTW) using goal programming and genetic algorithm, in which decision makers specify optimistic aspiration levels to objectives and deviations from those aspirations are minimized. They used a direct interpretation of VRPTW as a multi objective problem, in which both total required fleet size and total traveling distance were minimized, while capacity and time-window constraints were secured. Al-Khayyal and Hwang (2007) formulated a model for finding the minimum-cost route in a network for a heterogeneous fleet of ships engaged in the pickup and delivery of several liquid bulk products. They showed that the model can be reformulated as an equivalent mixed-integer linear program with a special structure. Yu *et al.* (2011) proposed a hybrid approach, which consists of ant colony optimization (ACO) and Tabu search, to solve VRPTW. Chiang and Hsu (2014) proposed their own approach to solve a multi objective vehicle routing problem with time windows. The objectives were to simultaneously minimize the number of vehicles and the total distance. Their approach was based on an evolutionary algorithm and it aims to find a set of Pareto optimal solutions. Because of the many applications of different vehicle routing problems, a large number of researchers have focused on developing solutions to them. Useful techniques for solving general vehicle routing problems can be found in (Ombuki *et al*., 2006). Dubey *et al.* (2013) Supply Chain Management may be defined as the management of upstream and downstream associations with vendors and customers to provide better customer value at least cost to the supply chain. Chopra (2003) describes a framework for designing the distribution network in a supply chain. In this research various factor influencing the choice of distribution network are described. He identified the distribution networks that are best suited for a variety of customer and product characteristics. Zeng and Rossetti (2003) classified the key logistics cost elements into six categories, namely transportation, inventory holding, administration, customs charges, risk and handling and packaging costs. Simatupang (2004) established the abbreviation that Supply chain collaboration amongst independent firms or business units often provides larger benefits from effectively satisfying end customer needs than working in isolation. However, Chen *et al.* (2004) shown Supply chain management is not only limited to Logistics activities and planning and control of materials and information flow internally within the company or externally between companies. It also deals with the strategic decisions such as inter organizational issues, alternative organizational form to vertical integration. It is also the management of relationship between suppliers and customers. Taylor (2004) provides a manager guides on supply chain in his research. He argued that the main supply chain dilemma in the SCM according to theory of Constraints is the bullwhip effect. Usually, the impact of the decisions made on the above scenario is the demand amplification to upstream SC's partners. This effect is known as bullwhip effect that causes a negative impact by increasing the level of safety in the inventory and/or damage in the service level, increasing the lack of products. Taylor (2004) suggests that managerial systems have parameters or attributes that present a natural variability, even when well administrated. In fact, managers make decisions based on average information about those parameters, such as average daily sales, average delivery time and average productivity.

According to one study, three costs are considered as supply chain transportation costs which are: the holding cost at the supplier end, the holding cost at customer end and the carrying cost (Merzouk *et al.*, 2006). Sahyouni *et al.* (2007) developed three generic facility location models for the integrated distribution and collection of products. The models quantified the value of integrated decision making in the design of logistics networks by focusing on facility and transportation costs throughout different stages of a product's life cycle. Based on the previous literature supply chain cost can be divided in two main categories. a) Distribution costs: which is generally logistics cost. b) Inventory value and inventory holding costs: which mainly consist of cost of inventory and cost of keeping inventory in storage location (Parkan *et al.*, 2009). Dos Santos *et al.* (2010*)* collaboratively applied TOC, VMI and B2B tools to improve the global supply chain performance. Eskigun *et al.* (2005) had showed a large-scale network design model for the outbound supply chain of an automotive company. Since delivering high volume of vehicles through a single VDC (Vehicle distribution centers) might result in inefficiencies and congestion in the system, fixed capacity limits are considered on the number of vehicles delivered through a VDC. However, assumed that the dwell time at plants and VDCs consists of a constant component and a load make-up time component. The integration and visibility of the information among customer, supplier and company is possible through Vendor Managed Inventory (VMI) and Business to Business (B2B). Customer integrated system model brought a reduction in all inventory level with consequent reduction of the logistics costs and provoked an impact directly on the final sale costs (Dos Santos *et al.*, 2010). Jha *et al.* (2012) considered a joint-location inventory problem and minimized the transportation cost involved in a joint inventory location model by using a modified adaptive different evolution algorithm. Nowakowska *et al.* (2013) showed TOC as an effective tool for supply chain management. He has given consent that better results of SCM depend on all involved parties rather working in isolation. According to them "Lack of awareness about the constraints along SC, decreases the benefits of collaboration". According to (Hua *et al.*, 2014) distribution network in retail perspective includes the transportation from distribution center with a multivehicle distribution vehicle delivery to multiple stores. It should satisfy the following conditions: (1) Demand does not exceed the carrying capacity (2) The length of each distribution route delivery vehicles does not exceed the maximum travel distance delivery time (3) Each delivery of goods cannot exceed the time required. Yan *et al.* (2015) developed a bi-objective model for transportation costs. This model considering the time window's constraints that specify the earliest and latest arrival times of customers. The simultaneous minimization of fleet size and total transportation cost are considered as objective functions. Costas *et al.* (2015) applies Goldratt's Theory of Constraints (TOC) to reduce the bullwhip effect of supply chain. KAOS methodology has been used to devise the conceptual model for a multi-agent system, which is used to experiment with the well-known 'Beer Game' supply chain exercise. Their work brings evidence that TOC, with its bottleneck management strategy through the Drum–Buffer–Rope (DBR) methodology, induces significant improvements. Kuldeep *et al.* (2016) working on eliminating the bottlenecks from the constraints resources was the solution to cope up with the increased demand by applying Theory of Constraints to improve the productivity of component under consideration.

Chen *et al.* (2004) worked with the optimization of multi echelon SC networks for uncertain products demands and prices by constructing a SC scheduling model. This model is constructed against some conflicting objectives then it has been case studied and found significant results. Altiparmak *et al.* (2006) shown multi-objective optimization of supply chain network by using genetic algorithm approach. They proposed a set of Pareto-optimal solutions for the multi-objective supply chain network design based on the genetic algorithm. Khan (2014) carried out optimization of transportation costs problem using linear programming. He has formulated a mathematical model based on the real world situation on a particular company. He used excel solver to solve to find out the optimal solutions regarding the model formulated. Govindan *et al.* (2017) reviewed the supply chain network design under uncertainty. They outlined different issues that affect supply chain network design under different paradigms. Finally, they have given a comprehensive study for achieving sustainable, green, responsive and humanitarian supply chain network design. Farjana Nur *et al.* (2014) found Distribution network design options must therefore be compared according to their impact on customer service and the cost to provide this level of service. Meixell *et al.* (2005) stated their research on the design of global supply chains, and assess the fit between the research literature in this area and the practical issues of global supply chain design. The classification scheme for this review is based on ongoing and emerging issues in global supply chain management and includes review dimensions for (1) Decisions addressed in the model (2) Performance metrics (3) The degree to which the model supports integrated decision processes (4) Globalization Considerations.

2.2 Motivation of this thesis

Transportation logistics are considered as an important factors for trade and investment as they facilitate the distribution of products. After going through several literature review transportation costs can be defined as the subsets of transport cost, handling costs, wastage costs and inventory holding costs both supplier and customer ends (Merzouk *et al.*, 2006). Total cost of the supply chain largely depends on the transportation cost. In the supply chain transportation network, extra vehicle may unnecessarily runs from the main distribution center again vehicle may run short to fulfill the customer demand. This is due to not following the proper vehicle management system. The real time data about the demand, capacity of the warehouse, no. of vehicle required are not taken under considerations that result in excess inventory costs along with transport costs. Transportation mode and network play an important role in that case and definitely impacts on supply chain responsiveness. The damage rate of the products depends on the modes of transportation. So this is another most important areas for considerations. The handling part of the supply chain also responsible for the product damage. If we can reduce the handling times it will leads to reduction in overall transportation costs.

From the above discussion, it is clear that there is a trade-off necessary between the cost of the supply chain and transportation costs. Moreover, in different stages of the supply chain it is also necessary to increase the value of the overall supply chain profit. As a result, a general transportation network has been designed under some assumptions identifying transportation cost as a main constraint of the company and given effort to optimize between carrying, handling, wastage and inventory holding costs. Accordingly, a mathematical model has been developed to optimize the supply chain transportation costs. On based on my knowledge, no study has considered together the three distinct elements of the transportation costs and made a linkage among them. The distinguished feature of this model are: (1) this model offer best utilization vehicles that approaches the model to achieve more optimality and (2) applicable for any transportation modes and network under some specific conditions.

CHAPTER 3

Theoretical Considerations

3.1 Logistics vs. Supply Chain Management

Surbhi S. (2015) found the following key differences between logistics and supply chain management:

1. The flow and storage of goods inside and outside the firm are known as Logistics. Whereas the movement and integration of supply chain activities are known as Supply Chain Management.
2. The main goal of Logistics is full customer satisfaction. Conversely, the main goal of SCM is to gain a substantial competitive advantage.
3. Supply Chain Management is a new concept as compared to Logistics.
4. Logistics is an activity of Supply Chain Management.

3.2 Basics of transportation costs

Transportation refers to the movement of item from one locality to another to make the product obtainable to the customer. There are five basic modes of transportation: Rail, Road, Air, Water and Pipeline. Each transportation mode has different cost and service characteristics. Transportation plays a significant role and has impact on overall impact on performance efficiency and effectiveness of reverse logistics (Shaik and Kader, 2013).

Parkhi et al. (2014) defined transportation costs as followings:

- As transportation is the major cost component of logistics, reduction in costs will have great impact of overall logistics cost. This paper explains what are the components of cost involved in retail transportation both fixed and variable cost. It deals with how to reduce logistics cost by building efficient transportation network, improving truck utilization, improving fleet utilization, analyzing the load flow to stores and leveraging information technology.
- The trucks used in distribution network can either be owned by retailer or can be rented from 3rd Party Logistics provider. The fixed costs involved in transportation are time

related cost. Capital costs (vehicle cost), vehicle taxation, vehicle insurance, driver salary and overhead cost fall under fixed costs.

- The variable costs involved in transportation are running costs. Fuel cost, oil & lubricants cost, vehicle repair and maintenance, tires & tubes cost, trip allowance to crew, loading and unloading personnel cost, other operating cost.
- If the truck is owned by the retailer, retailer has to bear all the risks of breakdown, fitness certificate, accidents etc. As 3rd Party Logistics provider will be having large scale of operation, these risks can be avoided based on the credibility of the logistics provider. Depreciation of capital cost should be taken into account if the truck is owned by the retailer.

3.3 Basics of TOC

The Theory of Constraints is a methodology for identifying the most important limiting factor (i.e. constraint) that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor. In manufacturing, the constraint is often referred to as a bottleneck. The Theory of Constraints provides a powerful set of tools for helping to achieve that goal, including:

- The Five Focusing Steps: A methodology for identifying and eliminating constraints
- The Thinking Processes: Tools for analyzing and resolving problems
- Throughput Accounting: A method for measuring performance and guiding management decisions

The philosophy of TOC works under three simple assumptions (tocico.org, 2013):

- *Basic Assumption 1:* Everything within a system is connected by cause and effect relationships.
- *Basic Assumption 2:* All contradictions can be resolved without compromise.
- *Basic Assumption 3:* There is no resistance to improvement.

The working principle of TOC provides a focus to ensure effective ongoing improvements. The principle consists of five focusing steps (Figure 1) according to (Goldratt, 1990).

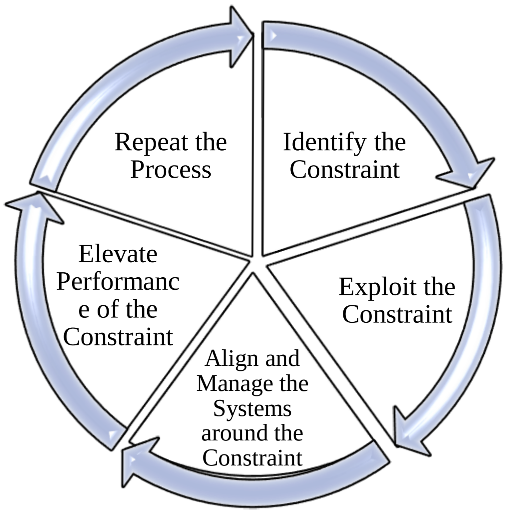

Figure 1: Five focusing Steps of TOC

- **Identify the system's constraint(s).** These may be physical (eg. materials, machines, people, demand level) or managerial. It is important to identify these constraints and also necessary to prioritize them according to their impact on the goal(s) of the organization.
- **Decide how to exploit the system's constraint(s).** If the constraint is physical, then the objective should be to make the constraint as effective as possible. A managerial constraint should not be exploited but be eliminated and replaced with a policy which will support to increase throughput.
- **Subordinate everything else to the above decision.** This means that every other component of the system (non-constraints) must be adjusted to support the maximum effectiveness of the constraint. Because constraints dictate a firm's throughput, resource synchronization with the constraint will lead to more effective resource utilization.
- **Elevate the system's constraint(s).** If existing constraints are still the most critical in the system, rigorous improvement efforts on these constraints will improve their performance. As the performance of the constraints improve, the potential of non-constraint resources can be better realized, leading to improvements in overall system performance. Eventually the system will encounter a new constraint.
- **If in any of the previous steps a constraint is broken, go back to step 1**. Do not let inertia become the next constraint. TOC is a continuous process and no policy will be appropriate for all time or in every situation. It is critical to recognize that business policy has to be refined to take account of environment changes.

Typical thinking process table as shown in following Table 1.

Table 1: Thinking process (Rahman, 2013)

Generic questions	Purpose	TP tools
What to change?	Identify main problems	Current reality tree
What to change to?	Develop a solutions (simple & practical)	Evaporating cloud diagram
How to cause the change?	Implementation of solutions	Prerequisite tree

3.4 Cost Factors & Supply Chain Network Design Validation

Parkhi *et al.* (2014) studied on transportation costs optimization in retail distribution. According to them cost factors in supply chain transportation network are truck volume utilization, fleet utilization, route optimization, turnaround time (TAT), backhauling, information technology. Simchi-Levi *et al.* (2008) provides the 7 Factors of Solid Supply Chain Network Design: Location and distance, current and future demand, service requirements, size and frequency of shipment, warehousing costs, trucking costs, mode of transportation.

3.5 Evaporating Cloud Diagram

Evaporating Cloud Diagram (Figure 2) provides a systematic approach to identifying the conflicting needs or interests of the parties to a conflict. It a process for making explicit the assumptions underlying the conflict and challenging their validity, leading to win win solutions to workplace conflicts (Goldratt, 1990).

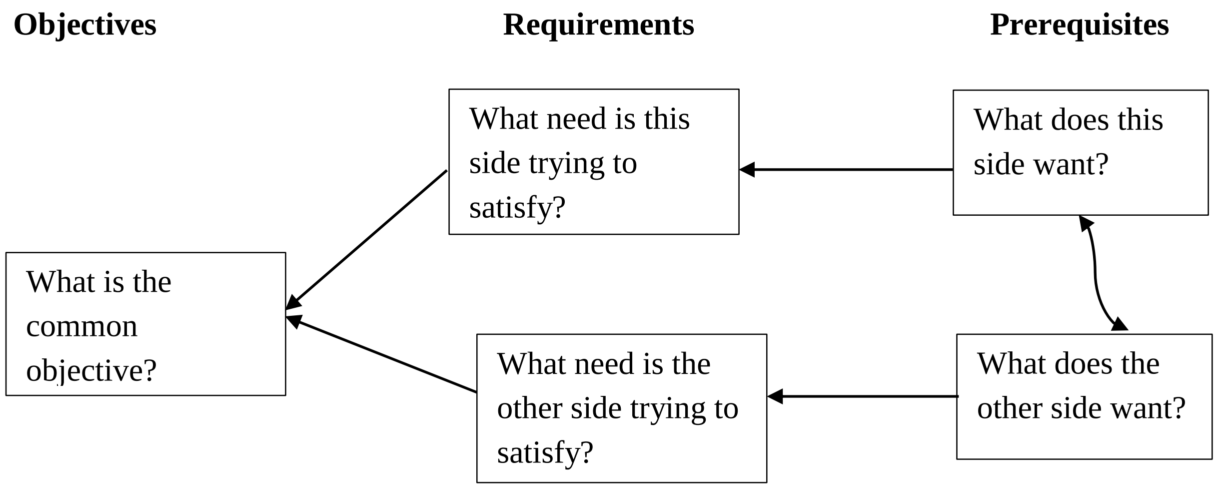

Figure 2: Evaporating Cloud Diagram for supply chain of the company

CHAPTER 4

Model Formulation

4.1 Model Formulation

Model refers to a planned delineate of mechanism which defines the procedures, results or consequences of the activities that guides the steps of operations. Model Formulation is a constructive technique under operations research used to build up the mathematical architecture of problems and issues raised while seeking for an objective function (maximum profit or revenue state or minimum cost level) in the operations of any organizations. Decision variables, Objective function, Constraints and Parameters are components of objective function which constitute the model of operations research. The literal concept of Formulation of Model is the transformational process of real world decision problem into a constructive operation research model. There are several approaches for model formulation which are classified as template approaches and constructive approaches but the most widespread is the linear programming problem formulation of models.

4.2 Model Formulation Steps

4.2.1 Define the Decision Variable

The foremost step is to identify the problems or decision variables and the factors which influence the decision variables along with the right-hand side constants which represent the available resources and specify the objective's level. This aspect raises the issues to be managed.

4.2.2 Formulate Constraints

Constraints imply certain limitations in the system or factors which influence the functions. We develop and consider all possible constraints for formulating the basis or objective functions.

4.2.3 Developing the Objective Functions

Objective function is said to be the result that an organization is looking for, which is maximum profit or revenue state or minimum level of cost. The basic and optimum goal structure must be developed.

4.3 Assumptions of This Model

This research assumes that a single supplier logistics enterprise for transportation process. The assumptions are:

1. The demand is certain or known.
2. The model is not depending on high demand on seasonal time and low demand on non-seasonal time.
3. The possibility of happening abnormal supply chain disruption like political crisis, natural disaster, sudden accident or uncertain delay at any time is not taken under considerations.
4. Every route will start and ends at the central depot.

4.4 Optimization Criteria

Consider a simple transportation network model consisting of one central depot (CD) and two customers i & j respectively which has been depicted by following Figure 3. Assume that every route will starts and ends at the central depot. So there can be two possible routes: i) CD to i to j to CD and ii) CD to j to i to CD. Each of the arrow in the following network represents the transportation between customers.

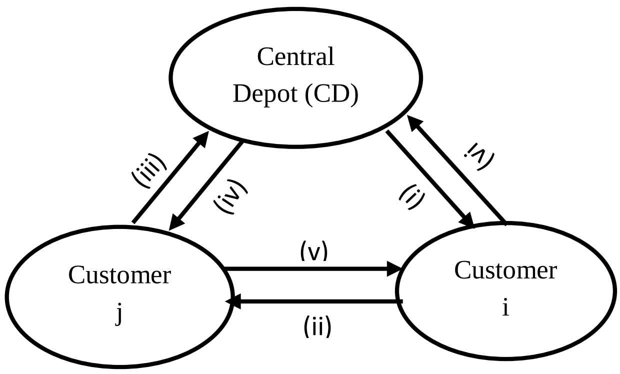

Figure 3: A simple transportation network model

This model follow the real time data of the customers demand, number of vehicle required, capacity of the vehicle, capacity of the customer node, inventory holding status etc. Firstly, this model calculate first the total demand on the customer node and total number of vehicle required considering the vehicle capacity. If the total demand of the customer node exceeds the capacity of the central depot then it will lose customer and proceed to the customer followed by the feasible amount.

Then this model decide which customer node should be visited or not? If yes it will check the next step whether the existing vehicle are capable or not? Besides it will consider the route it will proceed to (forward or backward?). For any transportation between two nodes will incur two costs that is transport cost and handling costs. Inventory holding costs can also be incurred accordingly to the requirements of inventory on that node.

One important thing is that, if any vehicle being empty after a certain period then it will consider unnecessary movement of the vehicle. If the path distance for the vehicle in the forward directions are less and will incur less costs it will proceed to forward. Likewise, it will return backward for the opposite scenario. The more the customer node, the transport cost approaches to more optimality. This is one of the distinguish feature of this model. The conceptual model for transportation mode and network are shown in the following Figure 4.

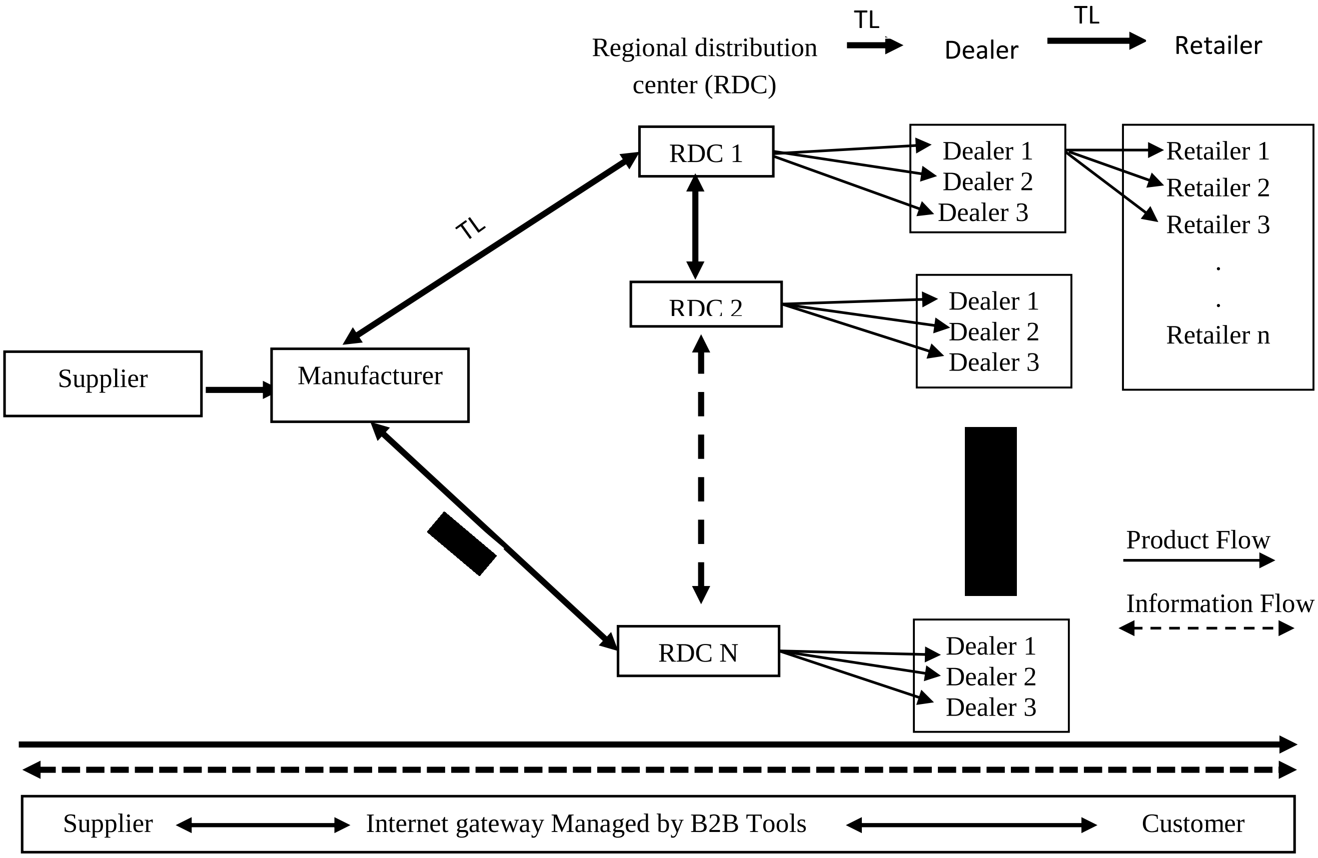

Figure 4: Conceptual Model for Transportation Modes and Networks

4.5 Mathematical Model

For n+1 number of customers and n number of vehicle this model can easily optimize the total transportation cost of supply chain. In order to optimize the transportation cost the vehicle route and capacity must be determined as the customer number for a route is uncertain.

The objective function (equation number1) defines the aggregate costs of the entire chain and consisting of three elements. First one (transport costs): costs associated with transporting goods to customer nodes to nodes. The second element (inventory holding costs): The cost associated with holding/carrying goods on the customer nodes if it is required. The third elements (handling costs): costs associated with overall handling for a complete cycle (average wastages costs, average loading and unloading costs, average packaging, labeling, billing & collecting, administration costs etc.).

Notations:

D_i = Demand per unit

V_{count} = No. of vehicle to dispatch

T_c = Transport cost for each node per vehicle

H_i = Handling cost for each node per unit demand

V_{return} = No. of vehicle to return

V_{inv} = Amount of inventory required

C_{inv} = Inventory holding cost per unit

H_0 = Initial handling cost at central depot

T_0 = Transport cost from last node to central depot

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The main objective of this model is to minimize the SC transportation cost. This model can be written as:

$$Z = \sum_{i=1}^{n} V_{count} \cdot \sum_{i=1}^{n} X_i \cdot \sum_{i=1}^{n} T_c + \sum_{i=1}^{n} V_{return} \cdot \sum_{i=1}^{n} T_c + \sum_{i=1}^{n} D_i \cdot \sum_{i=1}^{n} X_i \cdot \sum_{i=1}^{n} H_i + \sum_{i=1}^{n} V_{inv} \cdot \sum_{i=1}^{n} Y_i \cdot \sum_{i=1}^{n} C_{inv} + (H_0 + T_0) \cdots \quad (1)$$

Constraint-1: Every route starts and ends at the central depot

$$\sum_{i=1}^{n} X_i = \sum_{i=1}^{n} X_i \le 1 \quad (2)$$

Constraint-2: Vehicle capacity constraint

$$\sum_{i=1}^{n} D_i \times \sum_{i=1}^{n} X_i \le \sum_{i=1}^{n} V_i \quad (3)$$

Constraint-3: Warehouse capacity constraint

$$\sum_{i=1}^{n} D_i \times \sum_{i=1}^{n} X_i \le \sum_{i=1}^{n} W_i \quad (4)$$

Constraint-4: Vehicle return constraint

$$\sum_{i=1}^{n} D_i \times \sum_{i=1}^{n} X_i = \sum_{i=1}^{n} V_i \quad (5)$$

4.5.1 Algorithm

Step-1: Start the program
Step-2: Define capacity of central depot (CD)
Step-3: Input number of demands/nodes/stations (D_n) and value of demands on each stations (D_i)
Step-4: If total demand ($\sum_{i=1}^{n} D_i$) ≤ capacity of central depot (CD) go to step-5 or take feasible demands only by reducing no. of stations (D_n), then go to step-5.
Step-5: Input no. of vehicles (V_n) and its capacity (V_i)
Step-6: If total demand ($\sum_{i=1}^{n} D_i$) ≤ ( ) total vehicle capacity go to step-7 or reduce D_n to feasible limit, then go to step-7.
Step-7: Select route

i. Start from first node (CD >1>2>………n>CD)
ii. Start from last node (CD>n>n-1>…….>1>CD)

Step-8: Define warehouse capacity for all nodes/stations (W_i)
Step-9: If ($W_i \ge D_i$) go to the next node. If so, Xi= 1, otherwise Xi=0 & check for all nodes.
Step-10: Calculate optimum number vehicles for dispatch for nodes to pursue (n_i).
Step-11: Input transportation cost (T_{n+1}) for n_i nodes (T_0 included).
Step-12: Input handling cost (H_{n+1}) for n_i nodes (H_0 included).
Step-13: Ask if inventory required for nodes n_i.

i. If Yes, set Yi=1, enter amount of inventory (V_{inv}) and cost per unit inventory required (C_{inv}). Then go to step-14.
ii. If No, Yi=0, go to step-14

Step-14: Calculate optimum transportation cost for vehicles to pursue (V_{count}) for nodes n_i. Take return vehicle cost (V_{return}) into account as well.
Step-15: Calculate total cost

- $= \sum_{i=1}^{n} V_{count} \times \sum_{i=1}^{n} X_i \times \sum_{i=1}^{n} T_c + \sum_{i=1}^{n} V_{return} \times \sum_{i=1}^{n} T_c + \sum_{i=1}^{n} D_i \times \sum_{i=1}^{n} X_i \times \sum_{i=1}^{n} H_i + \sum_{i=1}^{n} V_{inv} \times \sum_{i=1}^{n} Y_i \times \sum_{i=1}^{n} C_{inv} + (H_0 + T_0) \quad (1)$

4.5.2 Flow Chart

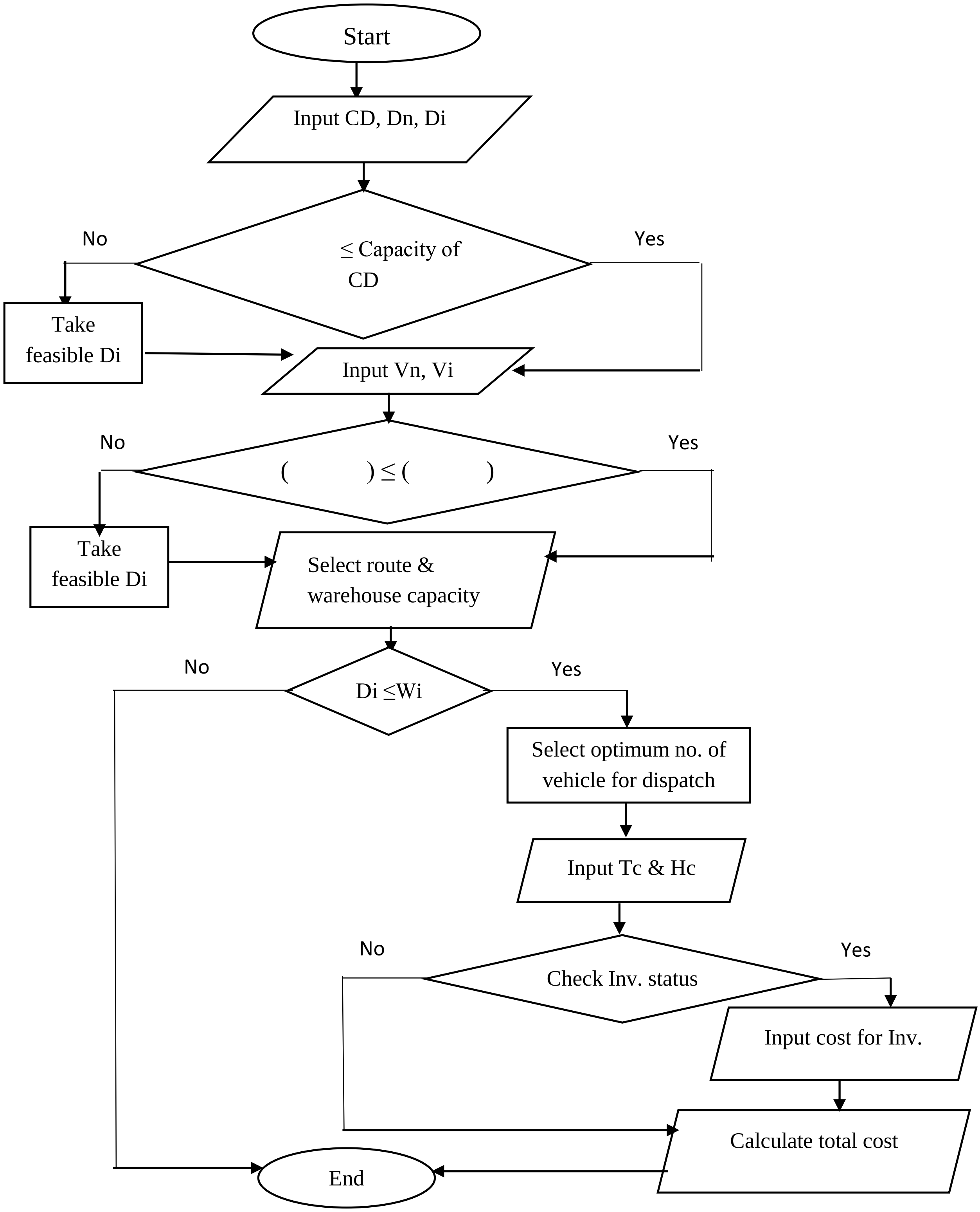

Figure 5: Model solving steps

CHAPTER 5

Application of the Model – A Case Study

5.1 Selection of the Case Company

The company that has been chosen for research case study is Abdul Monem Limited, Bangladesh (Beverage Unit-Coca-Cola). Abdul Monem Limited has become one of the most reliable, reputed and diversified conglomerates in Bangladesh with a broad portfolio of businesses that optimizes opportunities.

The main goal of the company is to reduce costs and make sure the product is available to meet the customer demand. However, recently it has been observed that the company is unable to deliver its product quantity to customers with respect to demand in recent times. The constraints are in severe mode to lose the goodwill of the company at the peak time.

5.2 Existing Transportation Networks

For the case company, they have used the intermodal transportation modes. They transport from the central depot (Comilla) to main distribution center (Khulna) via ship. After that they uses truck ways to deliver their products to the subsequent customer nodes. The existing transportation mode and network of the company is shown in Figure 6:

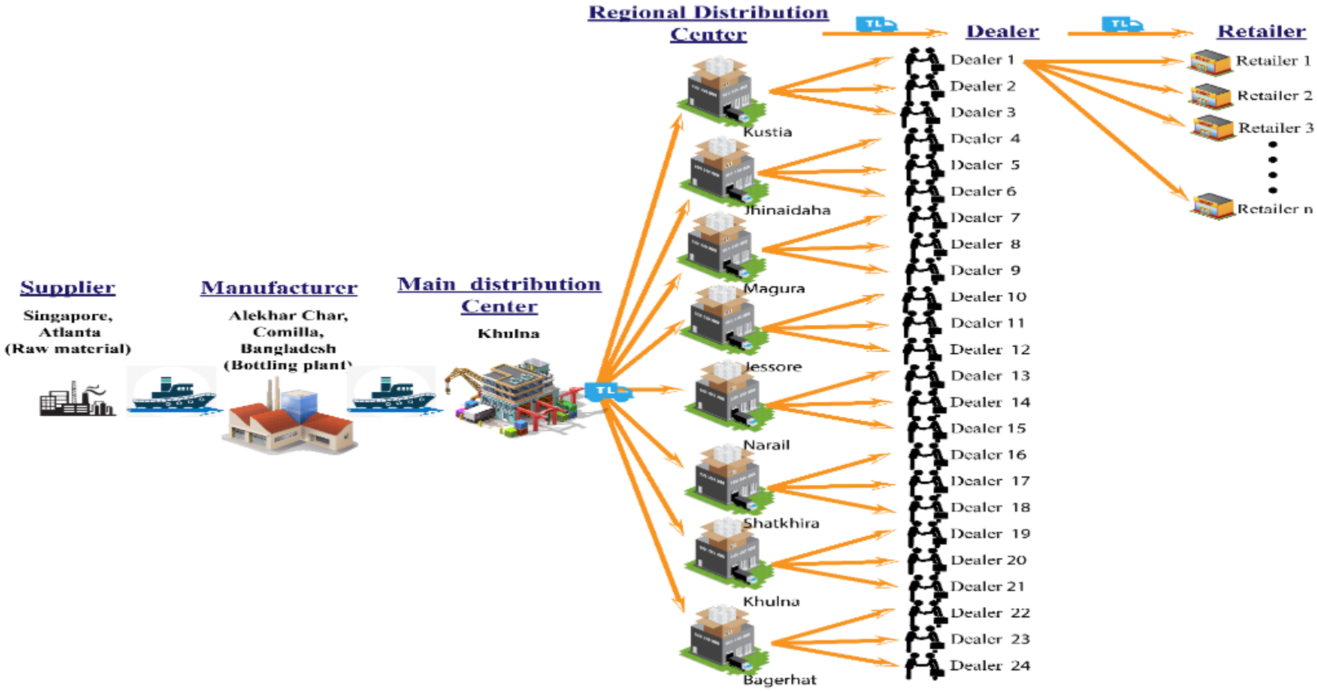

Figure 6: Existing Transportation Mode and Network

5.3 Current Handling Scenario

In the Existing Layout of the company's transportation network no. of handling the product from Manufacturer to Main Distribution Center is 20 times. At first, loading has been carried out from the central depot (Comilla) to the main distribution center (Khulna). After that, it is unloading for different regional distribution center. Details of current handling scenario are given in Table 2.

Table 2: Regional Loading and Unloading

Region (CD, MDC, RDC)	**Loading/ Unloading Status**
Comilla (CD)	Loading (Ship)
Rupsha Ghat, Khulna	Unloading (Ship)
Rupsha Ghat, Khulna	Loading (Truck)
Khulna (MDC)	Unloading (Truck)
Khulna (MDC)	Loading (Truck) for 8 RDC (Khulna, Kushtia, Jhenidah, Magura, Jessore, Narail, Satkhira and Bagerhat)
8 RDC	Unloading (Truck)

5.4 Problem Identification and definition

The five focusing steps along with evaporating cloud diagram are used to identify the constraints. In this case study an evaporating cloud diagram (Figure 7) has been developed for Abdul Monem Group (Coca-Cola) which can clearly specify the conflict between two requirements. To solve the conflict between two requirements the supply chain transportation costs have to optimize.

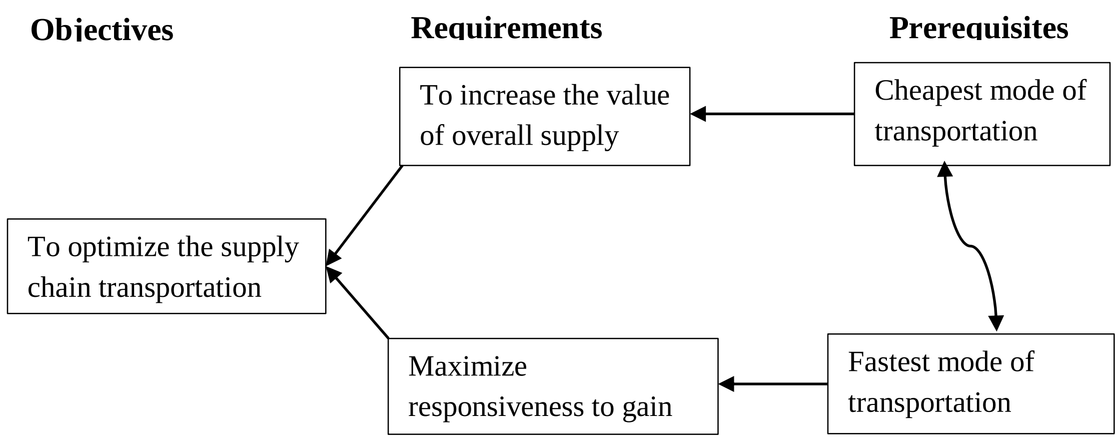

Figure 7: Evaporating Cloud Diagram for supply chain of the company

By analyzing the existing mode of transportation network and handling system being practiced it is obvious that for obtaining the ultimate supply chain goal the main constraints is the high transportation costs. The high transportation cost is found mainly due to the Modes of transportation (Transportation Mode: River ways) and using cargo in the river ways make the delivery time longer.

5.4.1 Transportation Modes and Networks

Transportation modes and networks plays an important role in logistics enterprise. These can be considered as the most influential factors in supply chain logistics. After going through literature review, this research have five different modes of transportation they are Road, Rail, Marine, Air and Intermodal. This option choices depends upon the quantity of the material to be moved, distance required to be covered, capacity of the CD, MDC & RDC and customer demands nodes respectively. Transportation networks design should also be in such way so that the route can be optimized.

In the company Abdul Monem Limited workers have a long idle time due to low tide in River Rupsha. During low tide in river workers cannot go for loading or unloading products delivered from Manufacturer to Distribution Center 1(Located in Khulna). Natural disaster (like flood) could also be the reason for idle time. Floods for example, frequently result in stoppages of loading and unloading of containers at shipping ports or railway terminals. That obviously have a ripple effect on factories that rely on these transportation networks. Factories would be forced to idle both workers and manufacturing facilities until goods started moving again. No business runs at 100% efficiency over long periods of time. Idle time is inevitable, but the goal is to minimize the “transportation cost" of the spply chain of the company.

5.4.2 Using Cargo in the River Ways Make the Delivery Time Longer

Supply chain may have series of negative effects for both the customer and the seller due to loner lead times. Lead time is the single largest factor that influence the performance of the inventory control and supply chain. Lead time includes the order placement, sourcing of materials, manufacturing and delivery of the final product.

However, other factors can increase lead time unnecessarily as well, such as delays in order processing, inefficient capacity management by suppliers, delays at the receiving port and much more. In most of the time using cargo takes a lot of time with loading and unloading the product and makes a severe delay in delivering it to its upper stages. Sometimes due to bad weather condition the ship delivery is compelled to stop. This makes an extensive value loss in overall supply chain. Other factors that is highly affected due to river ways transportation mode are:

- Most of the time workers sit idle and at a time too much pressure on the workers
- High loading and unloading time
- Number of workers associated with the loading and unloading of product is damn high
- Damage of product is high because of large number of handling is needed in cargo

5.5 Thinking Process Development to Propose Solution Regarding the Constraint

5.5.1 Establishing New Transportation Mode and Network

As the main problem is associated with the transportation mode and network, this research have highly proposed that the mode and network must have been changed. This research has proposed the transportation mode of **roadways** like **truckload.** Associated with it this research suggested them **Direct Shipment** from Comilla to other regional distribution center. It will reduce the delivery time as well as the damage of product. Here is the short list of effects concerning with the roadways and direct shipment:

1. The new transportation mode and network will reduce the lead time which results in maximizing product responsiveness.
2. The proposed mode and network will minimize the idle time of workers to a significant level. As a result resource utilization will be high.
3. Loading and Unloading will be easy and will take shorter time. No. of handling times will also be reduced.
4. Number of workers associated with loading and unloading the product will be reduced. This will certainly minimize cost.
5. Less damages of product due to less handling. In roadways, the product handling is highest two times in the whole transportation whereas in River ways it is 6 times.

Along with product availability the company must be concern to the transportation cost. So there is a trade-off necessary between fastest mode of transportation and its cost.

5.5.2 Proper Implementation of B2B Tools

Nowadays the real time data (demand, inventory capacity, safety stock, lead time etc.) of the supply chain partners can easily by be monitored and analyze through the high speed internet. Thus necessary actions can be taken accordingly. Information exchanging system referring to the business in process among the parts become possible. The uses of B2B tools will significantly help in reducing information gap among the supply chains. This research proposed the uses of this tools to reduce the bullwhip effects. Besides the company's other cost incurring areas are highly influenced by the information gap among the partners, real time data of the partners as well. Internet gateway managed by B2B tools for getting complete integration between suppliers, company and customers, coordinating the production processes and inventory levels on the SC. The proposed transportation mode and network are shown in the following Figure 8.

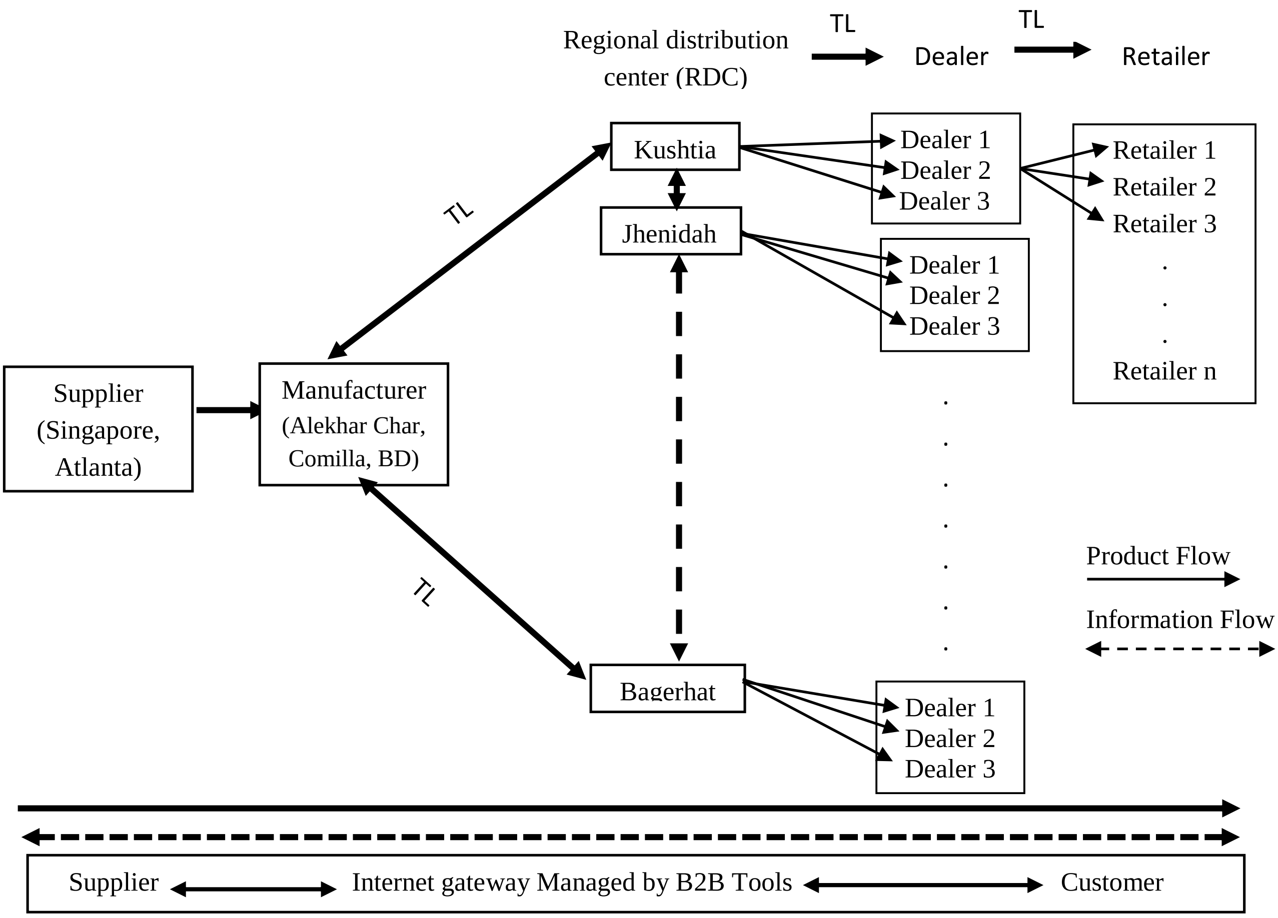

Figure 8: Proposed Transportation Modes and Networks

5.6 Proposed Handling Scenario

In the Proposed Layout of the company's Transportation Network No. of handling the products from manufacturer to Regional Distribution Center is 16 times. The proposed handling configuration are given in Table 3.

Table 3: Proposed Handling

Region (CD, MDC, RDC)	**Loading/ Unloading Status**
Comilla (CD)	Loading (Truck) for 8 RDC (Khulna, Kushtia, Jhenidah, Magura, Jessore, Narail, Satkhira and Bagerhat)
8 RDC	Unloading (Truck)

CHAPTER 6

Result and Discussion

6.1 Supply Chain Transportation Cost Reduction

According to the case company's transportation modes and network there are eight regional distribution center (eight customer nodes). Consider, the company are capable to fulfill the demand of the customer nodes by using their existing facilities. For existing modes of transportation network, first proceed to the main distribution center (Khulna) from central depot (Comilla) via ship. Then proceed to the subsequent regional distribution center via truck according to the demand. On the other hand, in the proposed mode transportation is carried out by Direct Shipment from Comilla to other regional distribution center via truck. The details about the demands (unit) and transport costs between nodes (per unit) and warehouse capacity of the respective nodes (unit) both for existing and proposed modes of network are shown in the following Table 4.

Table 4: Experimental Data

Demands (unit) and transport costs between nodes (per unit) and warehouse capacity of the respective nodes (unit)								
For existing modes and network								
RDC →	Khulna (1)	Kushtia (2)	Jhenidah (3)	Magura (4)	Jessore (5)	Narail (6)	Shatkhira (7)	Bagerhat (8)
Comilla (CD) [10500]	10000 15	0	0	0	0	0	0	0
Khulna (MDC) [10500]	1000 5 2500	1020 15 2500	1050 13 1500	1100 10 2000	1070 12 2200	1200 11 2000	1250 12 1800	1230 8 1600
Demands (unit) and transport costs between nodes (per unit), handling costs at nodes (per unit) and warehouse capacity of the respective nodes (unit)								
For proposed modes and network								
Comilla (CD) [10500]	1000 38 20 2500	1020 35 20 2500	1050 42 20 1500	1100 37 22 2000	1070 44 23 2200	1200 36 25 2000	1250 58 25 1800	1230 45 25 1600
Vehicle capacity	V1=500, V2=700, V3=800, V4=850, V5=940, V6=1000, V7=1150, V8=1240, V9=1300, V10=1500 (Let, 10 Vehicle available to dispatch)							

For complete one cycle, considering all cost factors regarding transportation cost comparative scenario are illustrated in the followings: Assume, T_{ij} & D_{ij} transport costs & demand between nodes i to j

Average handling cost per unit case = 2.5 tk
Average wastage cost per unit case = 25 tk
Total transportation Costs in existing modes of transportation

Min Z = Carrying Costs + Handling Costs + Wastage Costs

=Ã6 Ü@5 Ã< Ý@5 6EFÛ&EF

[D(1,1)+D(1,2)+D(1,3)+D(1,4)+D(1,5)+D(1,6)+D(1,7)+D(1,8)+D(2,1)+D(2,2)+D(2,3)+ D(2,4)+D(2,5)+D(2,6)+D(2,7)+D(2,8)]* loading & unloading* avg. handling costs + [D(1,1)*2%+D(1,2)+D(1,3)+D(1,4)+D(1,5)+D(1,6)+D(1,7)+D(1,8)+D(2,1)*2%+D(2,2)%+D (2,3)*2%+D(2,4)*2%+D(2,5)*2%+D(2,6)*2%+D(2,7)*2%+D(2,8)*2%]*avg. wastage costs

= 245830 + 94600 + 9460

= 349890 tk.

By applying the proposed model and solving by using 'Code: blocks' version 16.01 (Appendix A)

á á á á á á á á
• L Í 8?KQJP ÛÍ :E ÛÍ 6? E Í 8NAPQNJ ÛÍ 6? E Í &EÛÍ :E ÛÍ *E
Ü@5 Ü@5 Ü@5 Ü@5 Ü@5 Ü@5 Ü@5 Ü@5

á á á
E Í 8EJR ÛÍ ;E ÛÍ %EJRE :*4 E 64;
Ü@5 Ü@5 Ü@5

= 235523 tk.

Percentage of cost reduction in total transportation cost

= {(349890-235523)/349890}*100

= 32.68%

6.2 Lead Time Reduction

The proposed transportation networks contributes a great reduction in lead time between manufacturer to distributor which results in higher product availability and lower inventory level. Also, the handling times reduced by 20% by changing existing transportation modes and network. The lead time of the supply chain partners are given in Table 6. Graphical representation of the lead time of existing and proposed transportation mode and network is shown in the following Figure 9.

Table 5: Lead Time of Supply Chain Partners

Supply chain partners	**Average lead time in existing transportation mode and network**	**Average lead time in proposed transportation mode and network**
Manufacturer	30 Days	30 Days
Distributer	14 Days	3 Days
Dealer	3 Hour	3 Hour
Retailer	1 Day	1 day

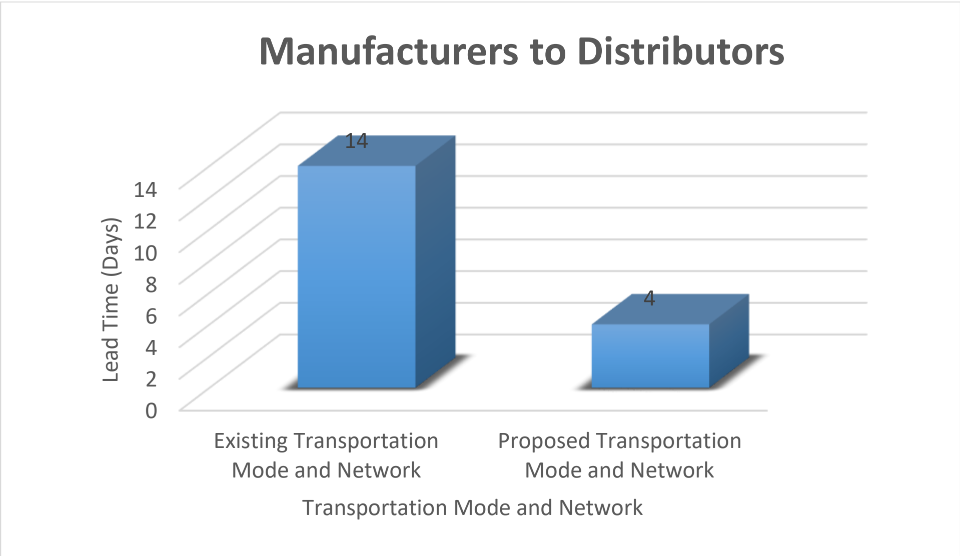

Figure 8: Change of lead time with respect to mode and network

6.3 What Makes Differences?

The vehicle and warehouse are considered as capable for same demand, the actual differences brought by the followings:

- **Route Optimization**

Route optimization has played an important role in optimization of transportation costs. It would be the single largest barriers for optimizing transportation costs. The way the route is being optimized by saving the unnecessary moves, considering the return moves. The details about the route optimization are outlined in the following Tables. Route optimization are shown in the following Table 6.

Table 6: Route optimization

Customer Node (Demand unit)	Vehicle dispatch (Proceed: Return)	Dispatch style	Surplus/remainder
1 (1000)	1^ (9:1)	V1<1000	V1 = 0
2 (1020)	2 (8:0)	V2<1020	V2 = 180
3 (1050)	2^, 3 (8:1)	V2<180 and V3<870	V2 = 0 and V3 = 30
4 (1100)	3^, 4 (7:1)	V3<30 and V4<1070	V3 = 0, V4 = 80
5 (1070)	4, 5 (6:0)	V4<80 and V5<990	V4 = 0 and V5 = 510
6 (1200)	4, 5, 6, 7 (6:0)	V5<510, V6<500 and V7<190	V5 = 0, V6 = 0 and V7 = 660
7 (1250)	4, 5, 6, 7, 8 (6:0)	V7<660 and V8<590	V7 = 0 and V8 = 460
8 (1230)	4, 6, 7, 8, 9 (6:0)	V8<460 and V9<770	V8 = 0 and V9 = 90
Vehicle Capacity: V1=1000, V2=1200, V3=900, V4=1050, V5=1500, V6=500, V7=850, V8=1050, V9=860, V10=1240 **Results:** 9 vehicle required to meet the demand No. of possible moves in forward (without return): 9*(8+1) = 81 No. of moves in forward (with return): 9+8+8+7+6+6+6+6 = 56 No. of moves in backward (with return): (1+1)+ (3+3)+(4+4) = 16 Total no. of moves required = 56+16 = 72 If 10 vehicle run, No. of possible moves in forward (without return) would be: 10*(8+1) = 90 % of moves saved = (90- 72)/90 = 20 %			**Symbols:** < Indicates assign value ^ Indicates return backward

- **Changing the Modes of Transportation**

The change in transportation modes results in reducing per unit costs. For an example, the cost per unit in river ways via ship is larger than the costs per unit in roadways via trucks. Besides, existing modes requires more handling times compared to the proposed modes and networks. This because of unnecessary handling in the regional distribution center. Furthermore, wastage percentages significantly reduces by applying the proposed modes and networks.

Finally, The Proposed Transportation Network in this research work has reduced the total transportation cost including carrying cost, handling cost, inventory holding costs & cost due to wastage from Manufacturer to Distributor. This also contributes a great reduction in Lead time between Manufacturer to Distributor which results in higher product availability and lower inventory level.

CHAPTER 7

Conclusion

7.1 Conclusion

In this research a mathematical model proposed to optimize the supply chain transportation costs. This optimized mathematical model has been developed considering transportation cost elements and real time data of the entities under some specified conditions. For existing supply chain transportation modes and network tools of TOC are applied to find out the constraints. Mitigation strategies regarding that constraints has been proposed using thinking process by developing a conceptual model. According to this tools the proposed modes and network are respectively truck loads and direct shipment network. A case study has been performed to verify the feasibility of the model during 30 days. The result obtained from the developed model compared to the existing modes of network and found better results. This model is solved by using code blocks (version 16.01) and it's very easy to interpret and integrate with any means of software. This model leads to reduction in lead time, reduction in damage, reduction in no. of handling times and thus help in achieving optimum SC transportation costs. This model gives 32.68 % better results under the same facilities compared to existing one though it has been considered in short range. The more the customers, the more the results will approaches to optimality. This model would be more generalized if we consider the variable costs.

7.2 Limitations

There are several limitations of our thesis. They are:

1. Time window constraint is not taken under consideration.
2. The variable costs is not taken under considerations.
3. Demand uncertainty wasn't taken in consideration. This model isn't depend on high demand on seasonal time and low demand on non-seasonal time.
4. There is a possibility of happening abnormal supply chain disruption like political crisis, natural disaster, sudden accident or uncertain delay at any time. This things also haven't considered in our study.

7.3 Future Work and Recommendations

Integration of time window constraint with this model will work better for achieving optimization. Besides, charging penalty cost for the day later arrival and give reward for advance arrival will add another dimension in achieving optimization. The transportation cost optimization can be done in a stochastic environment, in that case the researcher have to handle some extra variable. There are some recommendations regarding the case company-

- Use roadways instead of river ways for short range coverage.
- Use truckload instead of cargo loads for short range coverage
- Use direct shipment network instead of all shipment via distribution network if possible.

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APPENDIX A

```
#include<stdio.h>

#include<stdlib.h>

void main()

{

   int CD,Dn,i,D[1000],SumD,Vn,V[1000],SumV,x1,W[1000],GnG[1000],Tc[1000],

Hc[1000],InR[1000],InC[1000],x2,j,MinZ,c,temp,Go,PRD,PRV,Vcount[1000],DispatchV,V
Return[1000],k;

   SumD=0;

   SumV=0;

   MinZ=0;

   Go=0;

   PRD=0;

   PRV=0;

   temp=0;

printf("\nWelcome to Mathematical Model Formulation for Transportation Network\n");

printf("Enter the capacity of central depot. :");

scanf("%d",&CD);

printf("\nEnter the number of nodes/stations :");

scanf("%d",&Dn);

printf("Enter the value of demands for each nodes :\n");

for(i=0; i<Dn; i++)

   {

      printf("Demand %d :",i+1);
```

```
        scanf("%d",&D[i]);
    }
 c=0;
for(i=0;i<Dn;i++){
        SumD=SumD+D[i];
        if(SumD>CD){
            SumD=SumD-D[i];
            Dn=i;
            c=1;
            break;
        }
    }
if(c==1){
        printf("\nTotal demand exceeds Central Depot's capacity.\n");
        printf("Supply executable up to Station No. %d With total demand of %d
.\n\n",Dn,SumD);
    }
printf("Enter the number of vehicles :");
scanf("%d",&Vn);
printf("Enter the capacity of each vehicles :\n");
    for(i=0; i<Vn; i++)
    {
        printf("Capacity of vehicle %d :",i+1);
        scanf("%d",&V[i]);
        SumV=SumV+V[i];
    }
SumD=0;
```

```
c=0;
for(i=0;i<Dn;i++){
        SumD=SumD+D[i];
        if(SumD>SumV){
            SumD=SumD-D[i];
            Dn=i;
            c=1;
            break;
        }
    }
if(c==1){
        printf("\nTotal demand exceeds Total vehicle capacity.\n");
        printf("Supply executable up to Station No. %d With total demand of %d
.\n\n",Dn,SumD);
    }
printf("Select route :\ni)Press 1 to start from first node\nii)Press 2 to start from last node\n");
scanf("%d",&x1);
if(x1==1||x1==2)
    {
        printf("Route %d selected.\n",x1);
        printf("Enter the warehouse capacity of \n");
        j=Dn+1;
        for(i=0; i<Dn; i++)
        {
            if(x1==1)
            {
                j=i+1;
```

```
            }
            else
            {
               j--;
            }
            printf("Node/Station %d: ",j);
            scanf("%d",&W[i]);
}
printf("Node/Station status(Dependent on demand & warehouse capacity):\n");
j=Dn+1;
        for(i=0; i<Dn; i++)
        {
            if(x1==1)
            {
               j=i+1;
            }
            else
            {
               j--;
            }
            if(D[i]<=W[i])
            {
               GnG[i]=1;
               Go=Go+1;
               PRD=PRD+D[i];
               printf("Node/Station %d status: Proceed\n",j);
```

```
        }
    else
        {
            GnG[i]=0;
            printf("Node/Station %d status: Do not proceed\n",j);
        }
      }
for(i=0; i<Vn; i++)
      {
         PRV=PRV+V[i];
         if(PRV>=PRD){
             break;
        }
}
DispatchV=i+1;
printf("Number of Stations in pathway : %d\n",Go);
printf("Total demand of stations in pathway : %d\n",PRD);
printf("Optimum number of vehicles for dispatch : %d\n",DispatchV);

j=Dn+1;
c=0;
for(i=0; i<Dn; i++)
      {
         if(x1==1)
         {
             j=i+1;
```

```
        }
        else
        {
            j--;
        }
        if(GnG[i]==1)
        {
            if(c==0)
            {
                printf("Enter the transportation cost for each vehicle,\n");
                printf("From Central Depot. to Station %d :",j);
                scanf("%d",&Tc[i]);
                c=1;
                temp=j;
            }
            else
            {
                printf("From Station %d to Station %d :",temp,j);
                scanf("%d",&Tc[i]);
                temp=j;
            }
        }
}
    if(c==1)
    {
        printf("From Station %d to Central Depot. :",temp);
```

```
            scanf("%d",&Tc[Dn]);
}
j=Dn+1;
c=0;
for(i=0; i<Dn; i++)
        {
            if(x1==1)
            {
                j=i+1;
            }
            else
            {
                j--;
            }
if(GnG[i]==1)
            {
                if(c==0)
                {
                    printf("Enter the handling cost per unit for,\n");
                    printf("Central Depot. :");
                    scanf("%d",&Hc[Dn]);
                    c=1;
                }
                if(c==1)
                {
                    printf("Station %d :",j);
```

```
            scanf("%d",&Hc[i]);
          }
     }
}
j=Dn+1;
c=0;
for(i=0; i<Dn; i++)
    {
       if(x1==1)
       {
          j=i+1;
       }
       else
       {
          j--;
    }
     if(GnG[i]==1)
       {
          if(c==0)
          {
             printf("Query of inventory status:\nIf inventory needed press 1,else press any
number\n");
             c=1;
          }
          printf("Station %d :",j);
          scanf("%d",&x2);
          if(x2==1)
```

```
            {
                printf("Amount of inventory required for station %d :",j);
                scanf("%d",&InR[i]);
                printf("Cost per inventory required for station %d :",j);
                scanf("%d",&InC[i]);
            }
            else
            {
                InR[i]=0;
                InC[i]=0;
            }
        }
    }
    PRD=0;
    PRV=0;
    j=0;
    PRV=PRV+V[j];
    temp=DispatchV;
    c=0;
    k=0;
//      if(Go%2==1)
//      {
//          Go=Go+1;
//      }
for(i=0; i<Dn; i++)
    {
```

```
if(GnG[i]==1)
{
    c++;
    PRD=PRD+D[i];
    Vcount[i]=temp;
    VReturn[i-1]=k;
    k=0;
    if(c>=Go/2+1)
    {
        continue;
    }
    while(j<DispatchV)
    {
        if(PRV==PRD)
        {
            temp=temp-1;
            k++;
            Vcount[i+1]=temp;
            j++;
            PRV=PRV+V[j];
        }
        if(PRV>PRD)
        {
            break;
        }
        if(PRV<PRD)
```

```
                {
                    temp=temp-1;
                    k++;
                    Vcount[i+1]=temp;
                    j++;
                    PRV=PRV+V[j];
                }
            }
            PRV=PRV-PRD;
            PRD=0;
        }
    }
for(i=0; i<Dn; i++)
    {
        if(GnG[i]==1)
        {
            printf("\nStation %d : %d\n",i+1,Vcount[i]);
            printf("Vehicle returned  : %d\n",VReturn[i]);
        }
    }
for(i=0; i<Dn; i++)
    {

MinZ=MinZ+Vcount[i]*GnG[i]*Tc[i]+VReturn[i]*Tc[i]+InR[i]*GnG[i]*InC[i]+D[i]*GnG[i
]*Hc[i];
    }
    MinZ=MinZ+Tc[Dn]*temp+Hc[Dn];
```

```
        printf("Total cost : %d",MinZ);
    }
    else
    {
        printf("Wrong input.");
    }
getch();
}
```