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Application of Theory of Constraints in Supply Chain Management

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ABSTRACT
The main objective of this research is to develop a conceptual model for transportation network considering the supply chain constraints. Theory of Constraints (TOC) is a decision-making paradigm that enables focused improvement of a system by thoroughly examining the process to identify the system constraints. These constraints pave the way of finding the focal point of development. The research is focused on the supply chain of a renowned company named Abdul Monem Carbonated Beverage Ltd. in Bangladesh for validating the developed model. At first phase of the study Eli's Five Focusing Steps and Evaporating Cloud Diagram are employed to identify the constraints. Upon developing the constraints for the supply chain being studied, Thinking Process tool has been adopted to propose the conceptual model. This research revealed the main constraint of the studied supply chain is transportation cost. It has also significant impact on supply chain logistics. Finally, a significant constraint mitigation methodology has been proposed which optimized supply chain transportation cost between manufacturer and distributor. The existing transportation network and modes are modified to get rid of unnecessary material handling and storage. The suggested model can reduce the material handling by 20% which in term can significantly alter the current transportation costs.

Keywords: Theory of Constraints, Supply chain, Transportation cost, Transportation network, Transportation modes

1. Introduction

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 [1]. A coordinated effort among autonomous firms or trading units of supply chain frequently gives bigger advantages by successfully fulfilling final consumer needs than working individually. Nonetheless, overlooking the presence of constraints along the supply chain keeps the revenue of a joint effort from fetching full return. Their application of the Theory of Constraints attempts to reduce troubles in producing the expected profit from a coordinated effort. In particular, it unveils how this technique can be utilized to identify internal conundrum of joint effort. The outcome is a bigger supply chain profitability through the establishment of collaborative performance metrics and replenishment policy. [2]. Business-to-Business (B2B) and Vendor Managed Inventory (VMI) tools can be applied along with TOC to increase supply chain profitability. The proposed TOC approach utilizes Vendor Managed Inventory and Business-to-Business to limit the information distortion which in term reduces bullwhip effect and inventory size. The potential performance improvement is conceptualized through a case study in a Brazilian industry. [3]. A research on the design of global supply chains, assess the fit between the research literature and the practical issues of global supply chain design has been performed [4].

Transportation can be defined as 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 distinguished service characteristics [5]. A study on transportation costs optimization in retail distribution has been carried out. According to them cost factors in supply chain transportation network are truck volume utilization, fleet utilization, route optimization, turnaround time (TAT), backhauling, information technology [6]. Researcher's 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 [7]. The key to the success of supply chain network design project is the experienced consultants that help you to gather high quality data, validate model and propose the alternative supply chain structure that matters to your business [8-9]. A model offering sustainable supply chain network where it describes about maximizing the supply chain surplus (economic) and minimizing the carbon emission (environmental) [10]. Green supply chain network design model based on the classical facility location problem for the firm's strategic planning has been developed. 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 [11]. A mathematical model

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for optimizing SC transportation costs also been developed by the researchers. They have considered the transportation costs elements in the deterministic environment and proposed a guideline for the transportation networks of the case company [12].
Framework for designing the distribution network in a supply chain by Chopra in 2003. 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 [13]. Zeng and Rossetti classified the key logistics cost elements into six categories, namely transportation, inventory holding, administration, customs charges, risk and handling and packaging costs [14]. However, the concerns of SCM are not limited to logistic activities and planning, material and information management inside the company or among the partners. Many strategic decisions (organizational disputes, organizational structure to vertical integration etc.) also come under the sphere of SCM. Another vital responsibility of SCM is the relationship management between suppliers and customers. [15]. 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. Generally, the demand booms in the upstream of SC as a result of decisions made in the above scenario. This is known as the bullwhip effect. Bullwhip causes a negative effect due to increase in inventory costs and lessen the service level. Taylor proposes that administrative frameworks have boundaries or attributes that exhibit inherent inconstancy regardless of quality monitoring. As a matter of fact, managers use those average information (average sales, average delivery time, average productivity etc.) to make crucial decisions. [16]. 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 [17]. 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" [18]. 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.
Transportation mode and network play an important role and definitely impacts on supply chain responsiveness. The damage rate of the products depends on the modes of transportation. So, this is one of the 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 product availability. Moreover, in different stages of the supply chain it is also necessary to increase the value of the overall supply chain profit. The identification of the constraint in the different stages of the supply chain is another important issue. Transportation mode and network play an important role in that case and definitely impacts on supply chain responsiveness. As a result, we have designed the transportation mode and network identified as a main constraint of the company and tried to optimize between carrying, handling and wastage cost. The researchers doing this research as a part of their research entitled "Development of a model to optimize the supply chain transportation costs" published in Journal of Engineering Science in 2019 (Volume 10, Issue 1, pages 67-76).

2. Theory of Constraints (TOC)

The Theory of Constraints is a technical method of seeking improvement of a system. TOC assumes that every complex system is an integration of some processes that are linked internally or externally. Among these processes the particular one with lowest throughput acts as the constraint that holds the system's performance stagnant. This affect may either be short-term or long-term. A rich set of analytic tools comprises Theory of Constraints (TOC):

- The Five Focusing Steps
- The Thinking Processes
- Throughput Accounting

2.1 The Five Focusing Steps

This is a methodology for spotting and eradicating system constraint with a view to identifying the most significant constraints. The constraints which are impeding the system performance are spotted through brainstorming and analyzed to its root. Then the performance of this segment is elevated to optimum level. The cycle is repeated afterwards [20].

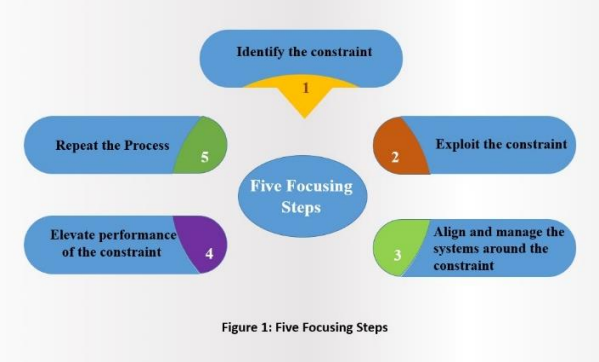

Figure 1: Five Focusing Steps

2.1 The Thinking Process

The Theory of Constraints encompass an advanced problem-solving technique namely Thinking Processes. Its sole purpose is to first finding the principal cause of the UDEs (Undesirable Effects), and afterward eradicating these UDEs without causing a new one [20]. Thinking Processes employs a question-answering approach. The three fundamental questions are:

- What needs to be changed?
- What should it be changed to?
- What actions will cause the change?

2.2 Throughput Accounting

Throughput Accounting aims to eradicate unwanted effects of conventional accounting technique. Otherwise, these deviations can obstruct the aim of increasing profit in long term. Four basic measures of throughput accounting are:

- Net Profit is defined as the difference between throughput and operating expenses.
- Return of Investment (ROI) is the ratio of net profit to the investments.
- Productivity is the ratio of throughput divided by invested amount.
- Investment Turns is a measure of proportion of throughput to investment.

Management decisions are consulted by the effects of achieving the improvements mentioned below.

- Expanding throughput
- Lowering investments
- Diminishing operating expenses

This sequence also indicates priorities. In a nutshell, TOC principally aims to expanding income i.e., sales rather than paying subtle attention on reducing expenses [20].

3. Methodology

3.1 Application of TOC in SCM- A case study

3.1.1 Selection of the Case Company

The beverage unit (Coca-Cola) of renowned Abdul Monem Limited, Bangladesh was chosen for contextual study. The organization has been one of the most prominent and reliable organization in terms of product quality with a broad spectrum of businesses. Additionally, the company has an impressive image of implementing sustainable infrastructure and businesses in the country to supply quality products. Their investments have always been a significant part of the nation's economic prosperity and advancement.

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.

3.1.2 Existing Transportation Networks of the Selected Company

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 2.

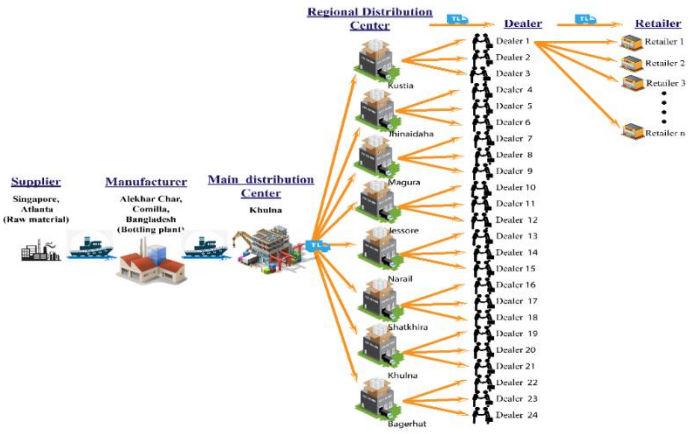

Figure 2: Existing Transportation Mode and Network

3.1.3 Current Handling Scenario

In the Existing Layout of the company's transportation network no. of handling operations of 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 1.

Table 1 Regional Loading and Unloading

Region (CD, MDC, RDC)	Loading/ Unloading Status
Comilla	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) ↓

3.2 Application of Five Focusing Steps

3.2.1 Problem Identification and definition

The five focusing steps are Identify, Exploit, Subordinate, Elevate and Repeat the constraint along with evaporating cloud diagram are used to identify the constraints. In this case study an evaporating cloud diagram (Figure 3) 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 be optimized.

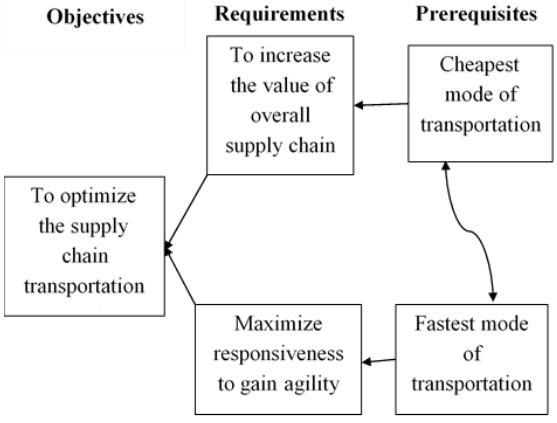

Figure 3: Evaporating Cloud Diagram for supply chain of the company

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 constraint 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.

3.2.2 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 has five different modes of transportation they are Road, Rail, Marine, Air and Intermodal. This choice 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). Idle time can also be caused by natural disasters. As Bangladesh is a flood-prone area, every now and again loading and unloading operations are hampered at shipping ports. Transportation networks, heavily dependent on water-ways face significant troubles in such conditions. Though most distribution centers hold a safety stock, companies are compelled to shut loading and unloading operations until the condition is resolved. As businesses cannot run at full efficiency, the idle time is inescapable. But careful scheduling and coordination among the departments of the organization can reduce transportation cost to profitable extent.

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

The customers and sellers can face a sequence of negative effects due to longer lead time. Lead time indicates the performance level of inventory management and supply chain in large. Thus, managers need to take adequate measures to ensure the shortest possible lead time. In broader sense, lead time is the amount of time elapsed between the initiation and closing of a production process such as material sourcing, manufacturing, order placing and fulfillment of the order. When the raw material required for production are sourced from a distant supplier, the lead time can be exceptionally long. For instance, it is quite common in manufacturing industries to import raw material from abroad or marketing final products in different countries.

Nonetheless, there exists other factors that prolong the lead time unnecessarily. Inefficient management can cause delays in order processing. Unavoidable delays can happen in the transportation phase or receiving ports etc. 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:

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

3.3 Thinking Process Development

3.3.1 Establishing New Transportation Mode and Network

As the main problem is associated with the transportation mode and network, this research has 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 7 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.

3.3.2 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 Figure 4.

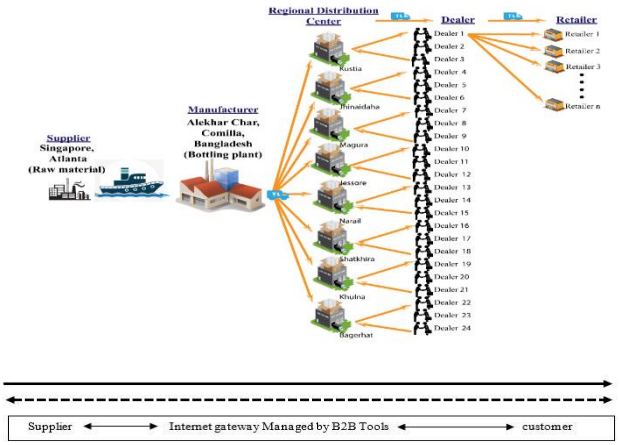

Figure 4: Proposed Transportation Modes and Networks

3.3.3 Proposed Handling

In the previous layout of the company's transportation network, number of handling operations of the products from manufacturer to Regional Distribution Center(RDCs) is 16. The proposed handling configuration is given in Table 2.

Table 2 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) ↓

5. Result and Discussion

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 of transportation is carried out by direct shipment from Comilla to other regional distribution center via truck. Previously there were 20 handling operations compared to proposed 16 operations model.

$$\%\ decrease\ in\ handling\ operations = \frac{20-16}{20} \times 100\% = 20\%$$

As the result shows, the handling operations are reduced by 20% by changing existing transportation modes and network. The lead time of the supply chain partners are given in Table 3.

Table 3 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	**4 Days**
Dealer	3 Hour	3 Hour
Retailer	1 Day	1 day

The proposed transportation networks contribute a great reduction in lead time between manufacturer to distributor which results in higher product availability and lower inventory level. Graphical representation of the lead time of existing and proposed transportation mode and network is shown in the following Figure 5.

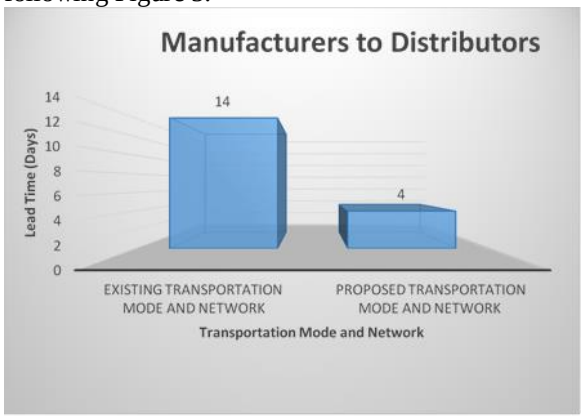

Figure 5: Change of Lead Time with Respect to Mode and Network

6. Conclusion and Recommendations

In this research work we have presented a theoretical approach of applying Theory of Constraints (TOC) tools to supply chain management. By using the TOC tool evaporating cloud diagram, the constraints of supply chain stages have been identified. After that mitigation methodology of the constraints has been proposed by using another tool of TOC called thinking process. Finally, throughput accounting has been used to measure the overall outcomes of the application of TOC to supply chain management. Abdul Monem Limited, Bangladesh (Beverage Unit-Coca-Cola) was chosen for our case study. In this beverage company transportation cost is currently at a higher level that limits the profit. Their current transportation mode and network is respectively river ways and all shipment via distribution center. By using tool thinking process the proposed transportation mode and network is respectively truck loads and direct shipment network. This proposed network and will optimize the transportation cost including carrying cost, handling cost & cost due to wastage. The reduction in lead time between manufacturer and distributor is also presented graphically.

The demand uncertainty and possibility of happening abnormal situation in supply chain disruption like political crisis, natural disaster, sudden accident or uncertain delay at any time does not taken into considerations. In future, the transportation cost optimization can be done in a stochastic environment, in that case the researcher has 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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