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Optimization of a Green Supply Chain Network: A Case Study in a Pharmaceutical Industry

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Abstract

Green Supply Chain Management (GSCM) is defined as the integration of environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes and procurement. Generally, the sustainable supply chain is built on three dimensions: social, economic, and environmental, while the green supply chain emphasizes on the environmental issue considering an economic result. Although many works of sustainable growth heed attention on the profit margin as a first priority, however, the green supply chain focuses on the environmental issue along with an efficacious process, which is a beneficial to the environment as well. There are over 200 papers about GSCM. But among them, very few papers focus on the Pharmaceutical Industry, specially focusing on the supplier. But this paper focuses on implementing GSCM on Pharmaceutical Industry. Multi-objective Optimization Model has been applied here. Performance of the proposed model is evaluated by the Pycharm Solver of Python.

Keywords: Green supply chain, CO_2 emission, Cost, Pharmaceutical company.

1 | Introduction

Climate change is quite obvious at present, and its' impact is falling adversely on population and world economy. Last twelve years have witnessed the worst scenario [1]. As Supply Chain Management (SCM) is a vital part of a business, it should be sustainable, because a significant amount of pollution occurs through it. Hence, optimization needs to be brought in this sector. Carbon Di-oxide emission and cost need to be reduced [2]. This is how the concept of Green Supply Chain Management (GSCM) has been introduced. Manufacturing industries are GSCM in an efficacious way to increase profit. However, pharmaceutical companies are confronting major challenges due to globalization at present [3]. Pharmaceutical supply chain can be considered as a tool for the effective supply of pharmaceutical products [4]. Here in this paper, we suggest a mathematical model which has been solved by Python. Additionally, we attempted to show all stages of a supply chain network, from supplier to manufacturer [5]. Because we believe, considering each stage is crucial to obtain accurate result. By adding a "green" component in the SCM practices, GSCM practices encompass a set of

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green activities in procurement, manufacturing, distribution and reverse logistics. The objectives of this paper are to minimize cost and CO_2 emission in a pharmaceutical company in Bangladesh.

Environmental collaboration includes cooperating with suppliers to achieve environmental objectives and improve waste reduction initiatives, providing suppliers with design specification that include environmental requirements for purchased items, encouraging suppliers to develop new source reduction strategies, working with suppliers, production and helping suppliers to provide materials, equipment, parts and services that support organizational goals. We tried to accumulate data from a pharmaceutical company in Bangladesh and analyze them. Some relationships between costs and carbon di-oxide emission have also been displayed in this paper.

1.1 | Problem Statement

The rate of increase of environmental CO_2 emission was 3.3 ± 0.1 PgC/year between 1980 and 1989 and 3.2 ± 0.1 PgC/year from 1990 to 1999. The pharmaceutical industry is one of the major industrial emitters of greenhouse gases, particularly CO_2 [6]. Medicine production is an energy-intensive process. Additionally, most of the papers did not start their work from the supplier stage of SCM.

1.2 | Research Goals

The optimization of Green Supply Chain in a pharmaceutical industry is our main goal. The optimization will be done by using Mixed Integer Linear Programming (MILP) model. Our goal is to trade-off between the cost of production and reducing the CO_2 emission by optimizing all the steps of supply chain. And our goal will be fulfilled if we can control all the Green House Gas emission rates and make profit better than before. Two models will be used and those are to be traded off. Thus, we will reach our goal.

2 | Literature Review

2.1 | Economic and Environmental Optimization

Optimization of both economic costs and environmental costs and reduction of the industrial wastage has been shown in multiple papers [14] and [15]. The experimental output obtained by GAMS software illustrates the validity of the model. The main objective is to obtain the capability of resisting uncertain conditions. These procedures were Fuzzy Programming, Bi-objective Supply Chain Network design, Multi Objective Differential Evolutionary algorithm (MODE) [14].

2.2 | MILP Model

Two evaluation indicators, namely TC and TE of CO_2, are chosen to create an MO mixed integer linear model [16]. It proposes a new mathematical model to assess and optimize GSC performance. A chance constrained mixed integer programming model is proposed for a single product supply chain [17]. A MILP problem has been formulated considering demand uncertainty [11].

2.3 | Supply Chain in Miscellaneous Sectors

SCM has been implemented in Green Internet of Things (G-IoT) [12]. Supply chain model has been applied in educational institutions [13]. Blood supply chain has been discussed as well [10]. A manufacturing context has been demonstrated clearly [9].

2.4 | Supply Chain in Pharmaceutical Industry

A model for an agile supply chain in the pharmaceutical industry has been developed [18]. The pharmacy supply chain and current managerial practices in a hospital has been demonstrated [19].

2.5 | Research Gap

Very few papers worked with pharmaceutical companies. Additionally, most of them started working with manufacturer stage. Apart from that, in Bangladesh, researchers hardly work with pharmaceutical industry for supply chain optimization. Hence, we tried to work with a pharmaceutical company in Bangladesh, and start with supplier stage.

3 | Methodology

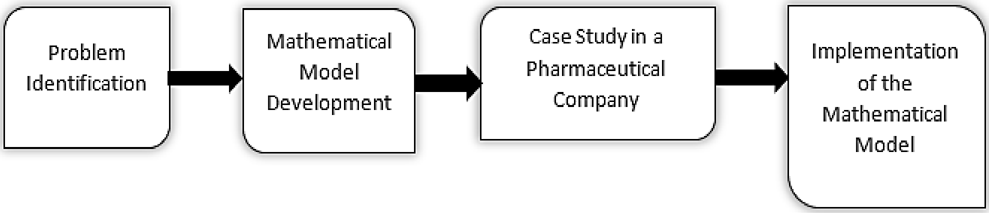

Fig. 1. Steps of research methodology.

The GSCM is a very large field. So, when a planning horizon is tried to be set, we have to consider all the segments of supply chain and apply optimization in each stage. The framework is shown below:

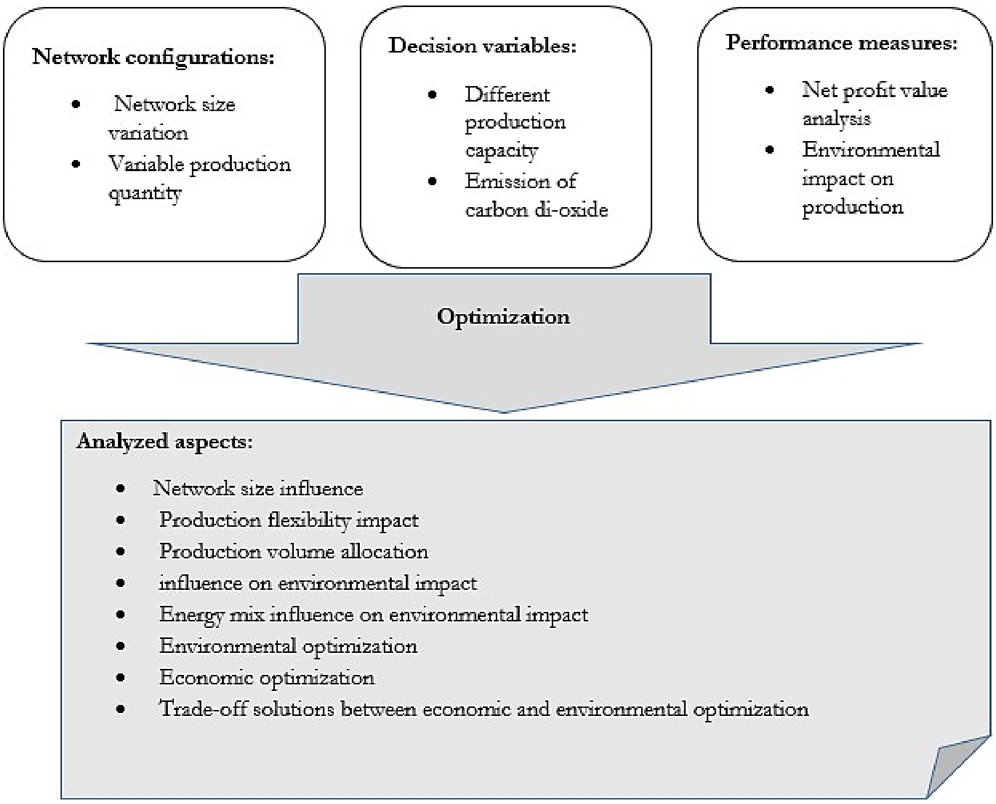

Fig. 2. Conceptual framework for a both economic and ecological GSCM planning horizon.

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4 | Model Design

In a supply chain system, there are five stages. Those are supplier – manufacturer – distributor – dealer or, retailer – customer. So, if the pharmaceutical products such as medicine, insulin etc. need to be reached to customer, we should go through the first four stages. Here, we have proposed a multi-objective model that is a MILP. The proposed model is divided into four level of SCM.

Level-1 is indicated for supplier, Level-2 is indicated for manufacturer, Level-3 is indicated for distributor and Level-4 is indicated for dealer.

Now, some limitations and assumptions arise here. In developing the proposed model, the following assumptions and litigations were found out:

I. The model is designed for multiple suppliers, manufacturers, distributors, dealers, products and multi-periods for the whole production process.
II. The amount of demand was assigned to the suppliers at the beginning of the period.
III. The locations of suppliers, plants, distributors, dealers are fixed.
IV. The capacities of the suppliers, manufacturers, the distributors and the dealers are known.
V. The summation of the production time was equal to the duration of each period.
VI. At the beginning or the end of the planning horizon, no inventory is allocated for the distributors.
VII. All dealers are not free all the time. So, sometimes products are temporarily stored at the distributors.
VIII. Transportation mode is controlled by trucks.
IX. The shortage of dealers is allowed and in addition, more limitations arose when the simulation was done.

So, the consideration of limitation added more assumptions. They are:

I. The demands of all stages must be satisfied during the production planning horizon.
II. The production time is limited.
III. Each products have different capacities in storage and they are limited in quantity.
IV. The capacities of the supplier, manufacturer, distributor and dealers are limited.
V. For each perfect product, the capacity in storage is limited.

4.1 | Parameters

The parameters of the proposed model are listed below:

Hdpt = Holding cost of products p at distributor d in period t.

Rsmpt = Receiving cost from supplier s to manufacturer m per item product p in period t.

Kmpt = Production cost per item p by manufacturer m in period t.

Umdpt = Shipping cost of each product p from manufacturer m to distributor d during period t

Vdrpt = Shipping cost of each product p from DC d to dealers r during period t.

Dmpt = Time required to produce product p by manufacturer m in period t.

Tt = Total production time during period t.

Invpdt = Inventory of product p at distributor d during period t.

Demrpt = Demand of dealer r for product p during period t.

Capmpt = Production capacity of manufacturer m for product p in period t.

Sdt = Total storage capacity of distributor d during period t.

Mdpt = Storage capacity of DC d for product p in period t.

Nrpt = Storage capacity of dealer r for product p in period t.

Jrt = Total storage capacity of dealer r during period t.

Srpt = Shortage cost for each product p at dealer r during period t.

Ap = The penalty cost of early/tardy deliveries per unit of product p.

CO_2mdpt = Unit CO_2 emission per product p from manufacturer m to DC d during period t.

CO_2'drpt = Unit CO_2 emission per product p from DC d to dealer r during period t.

4.2 | Decision Variables

The decision variables of the proposed model are listed here:

asmpt = Number of raw materials transported from supplier s to manufacturer m during period t.

bmdpt = Amount of products p transported from manufacturer m to distributor d during period t.

cdrpt = Amount of products p transported from distributor d to dealer r during period t.

dmpt = Total production of products p by manufacturer m during period t.

erpt = Amount of shortage of products p in dealer r during period t.

fpt = Amount of products p which are not deliver on-time in period t in whole network.

4.3 | Set of Parameters

There are six parameters used here. These parameters will help to take the decisions about the optimization of these two functions. The optimized value of the parameters will have to be minimum. The parameters are:

p = set of product types.

P = maximum number of product types, d = set of distributors.

D = maximum number of distributors, t = set of time periods.

T = maximum number of time periods, s = set of suppliers.

S = maximum number of suppliers, m = set of manufacturers.

M = maximum number of manufacturers, r = set of retailers.

R = maximum number of retailers.

4.4 | Model Formulation

Most of the industries implement linear economic optimization models. Other papers divided the proposed model into three levels: level 1 indicates the manufacturers; level 2 represents the distributors and level 3 denotes the dealers [7] and [8]. However, in this paper, we started working with suppliers instead of manufacturers. In the mathematical model we used, the configurations represent different network designs, which, in diverse scenarios and periods, have to satisfy different demands of the markets. The supplier factories produce the pre- products manufactured in the lines and in the nodes. The pre-products yield in the end product, which are produced in the factory, node and line. Investments can be made on the factories, on the nodes or on the lines. The new dimensions integrated to consider the environmental aspects are the monitored and measured emissions categories, the mean of transport used, the different electricity mix compositions and the fuel and heating sources.

Integrating the above environmental parameters to the economic ones and using the decision variables, two model objective functions are formulated in *Eqs. (1)* and *(2)*. The first corresponds to the total supply chain cost minimization and the second to the total carbon di-oxide minimization.

$$\begin{aligned}\text{Min } Z1 = &\sum_{m=1}^{M}\sum_{p=1}^{P}\sum_{t=1}^{T}K_{mpt}.d_{mpt} + \sum_{d=1}^{D}\sum_{p=1}^{P}\sum_{t=1}^{T}H_{dpt}.\Big(\sum_{\tau=1}^{t}\sum_{m=1}^{M}b_{mdpt} - \sum_{\tau=1}^{t}\sum_{d=1}^{D}c_{drpt}\Big)\\ &+\sum_{s=1}^{S}\sum_{m=1}^{M}\sum_{p=1}^{P}\sum_{t=1}^{T}R_{smpt}.a_{smpt} + \sum_{m=1}^{M}\sum_{d=1}^{D}\sum_{p=1}^{P}\sum_{t=1}^{T}U_{mdpt}.b_{mdpt}\\ &+\sum_{d=1}^{D}\sum_{r=1}^{R}\sum_{p=1}^{P}\sum_{t=1}^{T}V_{drpt}.c_{drpt} + \sum_{r=1}^{R}\sum_{p=1}^{P}\sum_{t=1}^{T}S_{rpt}.e_{rpt} + \sum_{p=1}^{P}\sum_{t=1}^{T}f_{pt}.A_{p}.\end{aligned} \tag{1}$$

Eq. (1) is the first objective function that abates the total costs of the supply chain, along with the costs of supply, production, holding at the distributor, transportation from the supplier to manufacturers, manufacturers to the distributors, transportation from the distributors to the dealers and dealer shortages due to the shortage of the stock situations. In addition, another cost is included. If the production is hampered for any reason, then the amount of delivery will decrease as per demand. Then a penalty cost is considered for ensuring Just-In- Time deliveries.

$$\text{Min } Z2 = \sum_{m=1}^{M}\sum_{d=1}^{D}\sum_{p=1}^{P}\sum_{t=1}^{T}CO2_{mdpt}.b_{mdpt} + \sum_{d=1}^{D}\sum_{r=1}^{R}\sum_{p=1}^{P}\sum_{t=1}^{T}CO2'_{drpt}.c_{drpt}. \tag{2}$$

Eq. (2) denotes the objective function that minimizes total carbon emission in entire supply chain process. Now for calculating the carbon emissions, several methodologies have been applied. Since Greenhouse Gas protocol is the most applied because of its easy application and worldwide scope, we also adopted this methodology in this research. The equivalent carbon emission per product can be calculated as a linear function and it depends on the travelling distance (in kilometers) and the carried vehicle carbon emission (in grams of CO_2 per kilometer). We applied this carbon emission model for a given supplying mode and the carbon emission is proportional to the number of product units that are shipped daily.

4.5 | Constraint Selection

$$d_{mpt} \le Cap_{mpt}, \qquad \forall m,p,t \tag{3}$$

Eq. (3) states that the total products produced by the manufacturer should be equal or less than the production capacity.

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$$\sum_{m=1}^{M}\sum_{p=1}^{P} b_{mdpt} \le S_{dt}, \qquad \forall d,t \tag{4}$$

$$\sum_{m=1}^{M} b_{mdpt} \le M_{dpt}, \qquad \forall d,p,t \tag{5}$$

Eq. (4) denotes the capacity restrictions of the delivery of distribution centers for each type of product. *Eq. (5)* denotes the capacity restrictions of the delivery of distribution centers for all types of products.

$$\sum_{d=1}^{D}\sum_{p=1}^{P} c_{drpt} \le J_{rt}, \qquad \forall r,t \tag{6}$$

$$\sum_{d=1}^{D} c_{drpt} \le N_{rpt}, \qquad \forall r,t \tag{7}$$

Eq. (6) denotes the capacity restrictions of the delivery for the dealers for each type of product. *Eq. (7)* denotes the capacity restrictions of the delivery for the dealers for all types of products.

$$\sum_{r=1}^{R} Dem_{rpt} \le d_{mpt}, \qquad \forall p,t \tag{8}$$

Eq. (8) considers that total production is equal to the total demand required.

$$\sum_{r=1}^{R} e_{rpt} = \sum_{r=1}^{R} Dem_{rpt} - \sum_{r=1}^{R} d_{mpt} \le d_{mpt}, \qquad \forall p,t \tag{9}$$

Eq. (9) states the amounts of shortage rather than demand at the dealers.

$$\sum_{d=1}^{D} c_{drpt} = Dem_{rpt}, \qquad \forall r,p,t \tag{10}$$

Eq. (10) shows how the total demands in the supply chain are supplied and fulfilled.

$$\sum_{r=1}^{R}\sum_{\tau=1}^{t} c_{drp\tau} \le \sum_{m=1}^{M}\sum_{\tau=1}^{t} b_{mdp\tau}, \qquad \forall d,p,t \ne T \tag{11}$$

$$\sum_{d=1}^{D}\sum_{p=1}^{P} c_{drp\tau} \le \sum_{m=1}^{M}\sum_{p=1}^{P} b_{mdp\tau}, \qquad \forall d,p \tag{12}$$

Eqs. (11) and *(12)* show the inventory at the distribution centers. The point to be noted that there is no inventory in the beginning and at the end of the planning horizon at each distributor.

$$\sum_{m=1}^{M}\sum_{\tau=1}^{P} b_{mdp\tau} - \sum_{r=1}^{R}\sum_{\tau=1}^{t} c_{drp\tau} = Inv_{pdt}, \qquad \forall d,p,t \ne T \tag{13}$$

Eq. (13) represents the balance between the total inputs and outputs of goods moving to the distributors from the manufacturers and to the dealers from the distributors during the planning horizon.

$$\sum_{m=1}^{M}\sum_{p=1}^{P} D_{mpt} . d_{mpt} \le T_t, \qquad \forall t \tag{14}$$

Eq. (14) represents the available time limitations of the production facilities for all production processes.

$$b_{mdp\tau},\ c_{drpt},\ d_{mpt},\ e_{rpt},\ a_{smpt} \ge 0,\ \text{integer}. \qquad \forall m,d,r,s,p,t \tag{15}$$

Eq. (15) ensures positive values of the supplies from supplier, production amount, deliveries to warehouses and dealers and dealer shortages. Because, non-negative will affect in the final result.

5 | Result and Discussions

The optimization models contain two functions. Both are minimization functions. One function is about the minimization of total supply chain cost included in all stages of supply chain. And other function is about the minimization of the carbon di–oxide through the product flow from manufacturer to distributor and from distributor to retailer. In this model, there are seven kinds of costs, two types of time periods, five types of capacity and two stages of carbon di-oxide emission are assumed. Six types of decision variables are also assumed. The whole model is solved using Python. Here, we used 'Pycharm' software for coding and solving it. After solving the model, total six outputs we have got for minimum Z1 and five outputs for minimum Z2 value.

6 | Case Study

When the real model is solved then we need to implement it to a real-life scenario. For this purpose, we visited Beximco Pharmaceuticals Limited which is situated in Tongi, Gazipur. In this industry, we mainly took a survey on the production time and the cost incurred with some specific times. We also have taken some data of costing with changing the number of distributors, number of retailers and the number of suppliers. Also, we have took some information about the whole production planning and the duration of the production planning. On basis of these datasets, some analysis has been done. There are many kinds of pharmaceutical products in this industry. Among those, we have chosen "Napa 500mg" for our all kinds of analyses.

6.1 | Sequence of the Whole Production Planning

A tablet is a pharmaceutical Oral Solid Dosage form (OSD) or solid unit dosage form. Tablets are solid single units containing one or more active ingredients prepared either by molding or compression. The solid production unit follows five stages of production normally. These are:

Stage 1. Dispensing.

Stage 2. Granulation.

Stage 3. Compression.

Stage 4. Coating.

Stage 5. Packaging.

In each and every stage there are a lot of activities which follow a specific sequence. For this reason, a specific production time is allocated for a specific product. From analysis and survey, we have known that there are 11 main sequential activities are allocated among these five stages of solid medicine (tablet) production. These 11 activities are analyzed in the Gantt chart and the total production time is calculated which is used in Value Stream Mapping (VSM) before. The Gantt chart is shown below with the assumed identifications of the activities.

a = checking batch size and batch no.

b = checking the quantity of materials.

c = checking tare weight and selecting container, d = drying.

e = milling.

f = addition of lubrication, g = crushing.

h = blending.

i = seal coating, j = polishing.

k = strip packaging.

Table 1. Table for activities, predecessors and time durations.

Predecessor	Activity	Duration (hour)
-	a	2
-	b	2
-	c	3
b	d	4
a	e	3
c, d	f	1
d, e	g	2
f	h	2
g, h	i	3
I	j	3
j	k	4

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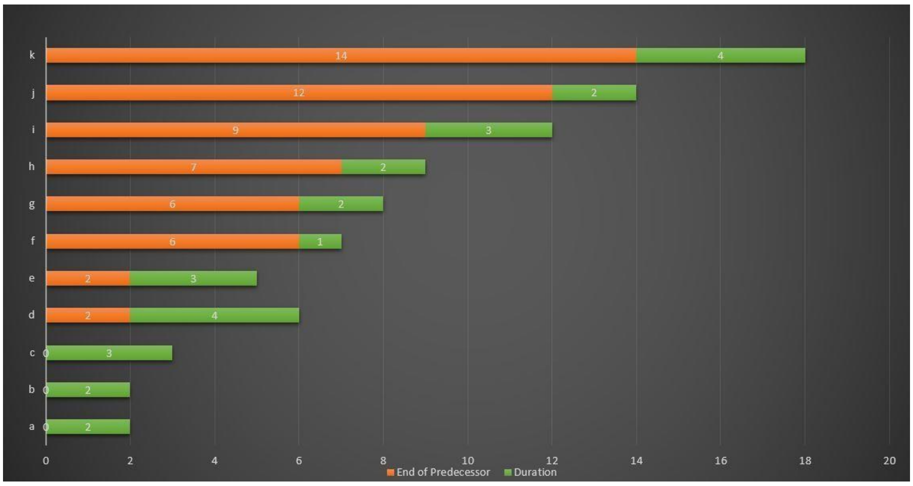

Fig. 3. Gantt chart for total production time.

6.2 | Carbon Di-Oxide Reduction Analysis

Carbon di-oxide emission is a very common issue in any kind of industry. Sometimes, it can be reduced by using different reduction methods. Maximum methods are very costly but highly benefitted. Because our environment is continuously polluted by the emission of this gas.

In our proposed model, two stages of carbon di-oxide emission are incurred. These are:

I. Carbon di-oxide emission with the product flow from manufacturer to distributor.
II. Carbon di-oxide emission with the product flow from distributor to retailer.

In both cases, some specific aspects are responsible for the emission of this gas. For example, transportation, production, packaging is the common source of emission. In this model, we have assumed the total transportation is fixed and the emission during packaging is fixed. Here, we have considered that the carbon di-oxide emission changes over production time. We have set the weightage of emission from 0.1 to 1. The weightage of the lowest emission is 0.1 and the weightage of the highest emission is 1.

Table 2. Carbon di-oxide emission data.

Production Time (Hours)	Cost Incurred	Weightage of CO_2 emission
18	127,50,000 /=	1
17	128,34,000 /=	0.9
16	129,23,000 /=	0.8
15	131,00,000 /=	0.7
14	132,96,000 /=	0.6
13	134,80,000 /=	0.5
12	136,95,000 /=	0.4
11	139,20,000 /=	0.3
10	145,00,000 /=	0.2
9	154,00,000 /=	0.1

These costs have been obtained from the company.

7 | Analysis

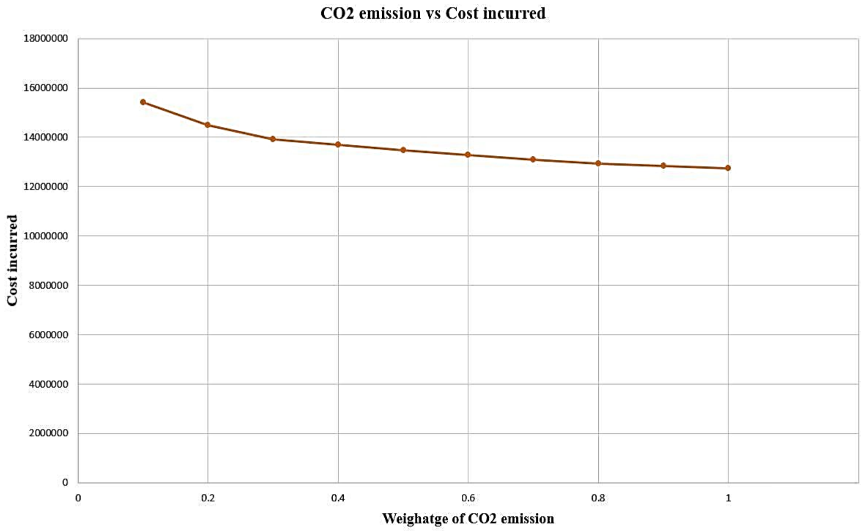

Fig. 4. CO2 emission vs. cost incurred graph.

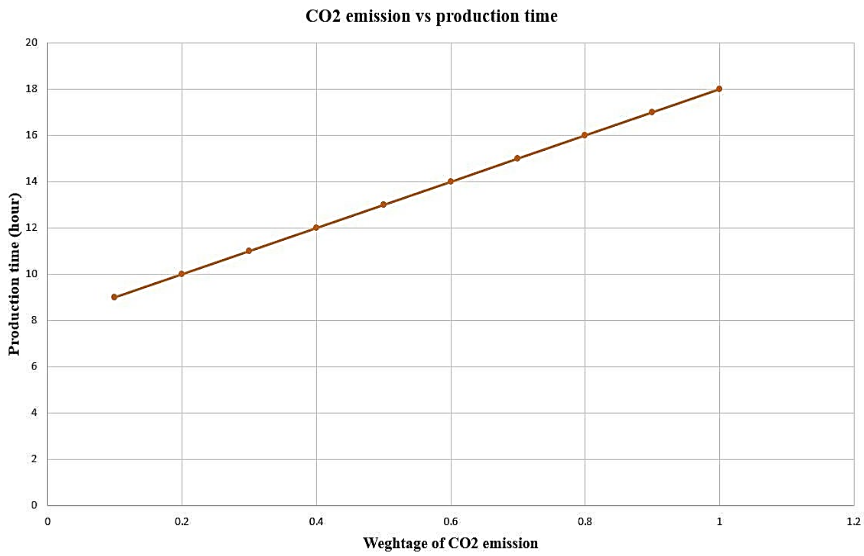

Fig. 5. CO2 emission vs. production time graph.

7.1 | Tradeoff between Total Cost and Production Time

Above the two analyses, two conflicting situations have been arisen between the total supply chain cost and the total production time. For this reason, a tradeoff solution has been generated for determining the optimum value of the cost, production and the weightage of carbon di-oxide emission.

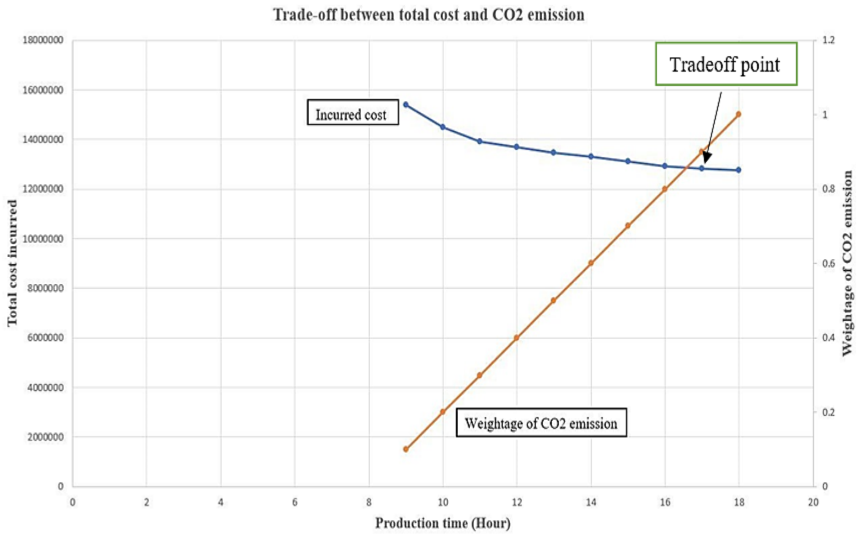

Fig. 6. Tradeoff between total cost and production time.

From this graph, the optimum cost incurred = 128, 00,000, the optimum production time = 16.6 hours. The optimum weightage of carbon di-oxide emission = 0.85.

7 | Discussions

After all the analyses, overall result is generated and decisions can be taken. The fundamental research objective was to minimize the overall supply chain cost with the environmental concerns. Therefore, the cost should be as lower as possible but not sacrificing the environmental issues. Firstly, we have seen the relation of costing with the changing the number of suppliers, retailers and distributors. From that part, we have chosen the minimum value of product types, time periods, suppliers, manufacturers, distributors and retailers. These minimum values will be responsible to minimize the supply chain cost and the carbon di-oxide and other hazardous gas emissions. Finally, we have taken decisions on carbon di-oxide emission purpose. Here, two cases were arisen. Firstly, increase of the total supply chain cost with the reduction of carbon di-oxide. Secondly, increase the carbon di-oxide emission with the increase of the total production time. Then a tradeoff is done between these two aspects and we have got an optimum solution of cost, time and emission.

Besides, Production scheduling using Gantt chart is discussed to introduce all the systems involved with this model. Our whole research calculation is based on the datasets collected from Beximco Pharmaceuticals Limited which is located in Tongi, Gazipur. Here, we have got some ideas from some of their consultants in the firm. We have selected Napa 500 mg for research. Because, it is a Fast-Moving Consumer Good that is called FMCG. So, if we take it as survey product then we can get available data and information.

Again, the emission of carbon di-oxide is measured in two stages. One is the product flow from manufacturer to distributor and other one is the product flow from distributor to retailer. In these two stages, we have considered the total carbon di-oxide emission is high. In these stages, the emission can be done from transportation, production, packaging etc. But we considered here only production

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because its dataset is available to us. But in the context of our Bangladeshi industries, there is no specialized system to measure carbon di-oxide emission specifically. So, we have used weighted emission value to compare with the costing and production time. We have got an idea from their consultancy that if their production time is normal, then the emission occurs normally. But if their production time can be reduced into half of the normal production time, then the carbon di-oxide emission reduced to one-tenth of normal emission. But the overall supply chain cost increases. Additionally, our model can be implemented in the pharmaceutical companies to minimize the total cost and CO_2 emission.

8 | Conclusion

To conclude, we can summarize our whole research work in a few words. We truly acknowledge our limitations. Hence, we will continue our work to obtain a better result. Our goal of the research was to trade-off between cost and carbon di-oxide emission in a pharmaceutical company. To achieve our goal, we visited some pharmaceutical companies and accumulated data which were implemented in our mathematical model to scrutinize that. However, we used Python to solve the model to be more ascertained. This study proposes a mathematical model for optimizing supply chain costs with respect to environmental impact. The aim of the model is to optimize total costs, including production, holding, shipping, and dealer shortages due to out of stock as well as minimizing carbon di-oxide emission in the whole logistics system.

Following recommendations and suggestions for future work are highlighted in this section in order to improve the implementation process of the mathematical model.

I. ERP Software can be used to get precise result. For using the mathematical model, accurate data would be beneficial.

II. More Pharmaceutical Companies can be visited and more people who are involved with the production process should interviewed.

III. Some modifications in Value Stream Mapping can be brought to make it more efficient.

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