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Modeling of Environmental Pollution Due to the Fashion Industry Using the Fractional Programming †

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Abstract: The fashion industry is one of the world's largest and third most polluted industries. It produces a carbon footprint of around 10% annually which is much higher than the footprint produced by flights and shipping. Nowadays, there is an increase in demand for different and new products for all ages of people due to which fast-changing fashion become a trend. But there is a hidden cost in the manufacturing of each material which is ignored by the people and which costs the environment and eventually the health of the people. It not only pollutes the air due to the emission of greenhouse gases but also consumes plenty of water along with the increase in plastic and some other wastes that pollute our environment. The solution to the problem is to avoid and move away from this fast fashion trend and subsequently buy a few clothes that are good in quality and which do not pose a threat to the environment. But this will lower the sale as well as the revenue of the fashion industry which eventually affect our economy. The purpose of this study is to construct a novel fractional mathematical programming model which caters to both the objectives i.e., minimizing environmental pollution and maximizing revenue of the fashion industry with respect to the constraints based on the industry and environment side.

Keywords: Pollution, Fashion Industry, Environment, Green House Gases, Fractional Programming Model

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1. Introduction

With the increase in craze of the fast-moving fashion products as well as the rise in the demand of these products by all ages of people. Fast moving fashion industry inspires a lot of researchers to do research be it optimizing their supply chain or how to maintain the quality of those products. Over the last decades, fashion industry has evolved tremendously with the expansion of the industries [1]. It changes the entire traditional model where mass production of products was done. Instead, the new model eliminates the traditional model and focusses more on the trendy products, seasonal fashion which sometimes changes over night and sometimes seasonally. This will create a pressure among the manufactures to create the product more effectively. To manage the profit in such a demanding and competitive market, it forces the retailers to make the product that would cost them low in price and at the same time compete with the design, quality, and speed of this industry to meet the demands of the customers [2].

In the 1980s, retailers and manufacturers forecast the demand of the customers as well as the fashion trend before consumption to compete in the market [3,4]. In recent years, they are competing with the speed too to provide products that were shown in the fashion shows and desired by the customer [5]. This is basically an unplanned process which reduces the timings between the production and consumption [6]. As this market is highly competitive, retailers need to upgrade their products and schemes to attract more customers [7] and the products in this market have a shorter life span and the margin of profit in these are high [8,9].

Although the fast fashion market is profitable for the business of the retailers but it will also pose a threat to the environment. According to the reports of the Environmental Protection Agency, in 2013 15.1 million tons of textile clothing waste was produced [10,11]. Out of 64.5% of textile waste, nearly 16.2% is recycled in the United States [12]. Chemicals which are applied on the clothes for dye purposes are also harmful to the environment. As the fast fashion market changes frequently, it will also produce a lot of waste due to the changing trend. When these clothes are dumped and burned, they emit a large amount of CO2 into the atmosphere [13,14,15].

Therefore, there is a need to propose a mathematical model which caters to both the objectives i.e., maximizing the revenue as well as minimizing the pollution caused by these fast moving fashion industries. In this paper, we try to formulate a fractional programming model by taking both objectives revenue and pollution with respect to the supply constraint, number of hours constraint, budget constraint as well as distance constraint.

2. Methodology

Table 1. Notations used in the Paper.

Variables	
$\boldsymbol{X_i}$	Quantity of product i produced by manufacturer
D_i	Demand for product i
C_{ik}	Per unit cost of kth material used to make ith product
R_{ik}	Amount of kth material required to make ith product
AQ_k	Quantity available of kth material
CE_i	CO_2 emission per unit of production
HC_m	Hourly cost in operating machine m
H_i	Hours required by machines to make product i
T_i	Traveling cost by vehicle v of importing products i
L_i	Labour cost of product i
TH	Maximum hours a machine can work to make products
LH	Maximum allotted hours for labourers
O_I	Overtime cost of product i
α	If Labour works to make to that particular product i then 1 otherwise 0
W_i	Amount of wastage of product i
TD	Total distance a vehicle v can cover without breakdown
M_i	Maintenance cost of product i (includes warehouse cost)
CTC_i	Carbon tax cost of product i
B	Total budget of the retailer

3. Formulations

Objective Functions

In this paper, we deal with two objective functions i.e., The first objective is related to Maximizing the revenue by considering the cost incurred by the retailers in terms of labor cost, transportation cost, and machinery cost as well as the transportation cost and the second objective is related to Minimizing the pollution that is caused by the burning of clothing wastes and the materials used to make those products by considering the budget of the retailer.

Objective Function 1

Revenue

The revenue of any organization is based on the quantity of products they sell and the unit price of that product by excluding the various costs incurred by the retailers.

The revenue function is represented as follows:

Revenue =

$$\sum_{i=1}^{n} S_i D_i - \sum_{i=1}^{n} \sum_{k=1}^{m} C_{ik} X_i \quad (1)$$

$$- \left[\sum_{i=1}^{n} L_i \alpha X_i + \sum_{i=1}^{n} O_i * h\right] \quad (2)$$

$$- \sum_{i=1}^{n} HC_m H_i X_i \quad (3)$$

$$- \sum_{i}^{n} T_i D_i \quad (4)$$

$$- \sum_{i=1}^{n} M_i X_i \quad (5)$$

$$- \sum_{i=1}^{n} CTC_i \quad (6)$$

Here equation (1) represents the profit function without considering the other charges involved in the business. Equation (2) represents the Labour cost. Equation (3) represents the travelling cost. Equation (4) represents the maintenance cost and Equation (5) represents the Carbon tax cost which is imposed by the government.

Objective Function 2

Pollution

The pollution caused by the fast-fashion industries and due to the wastage of clothes should be minimized. The pollution function is represented as follows: -

$$\sum_{i=1}^{n} W_i X_i + \sum_{i=1}^{n} CB_i X_i \quad (7)$$

Constraints

They are several constraints based on supply of raw material, capacity of machine to do work in a single day, No. of hours a worker can work in a day, Budget constraint.

Constraints are represented as follows: -

1. Constraint related to availability of Raw material

$$\sum_{i=1}^{n} \sum_{k=1}^{m} R_{ik} X_i \leq \sum_{k=1}^{m} AQ_k \quad (8)$$

2. Constraint related to maximum no. of hours a machine can work

$$\sum_{i=1}^{n} H_i X_i \leq TH \quad (9)$$

3. Constraints related to the total travelling distance

$$\sum_{i}^{n} T_i D_i \leq TD \quad (10)$$

4. Constraint related to the Budget of the manufacturer

$$\sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik}X_i + [\sum_{i=1}^{n} L_i\alpha X_i + \sum_{i=1}^{n} O_i * h] + \sum_{i=1}^{n} HC_m H_i X_i + \sum_{i}^{n} T_i D_i + \sum_{i=1}^{n} M_i X_i + \sum_{i=1}^{n} CTC_i \leq B \quad (11)$$

As both the objectives are important so we cater both the objectives using the Fractional Programming method through which we maximize the ratio of revenue to pollution with respect to the constraints described above.

So, we formulate our problem as follows: -

$$Max\ \frac{Revenue}{Pollution}$$

i.e., $$\frac{\sum_{i=1}^{n} S_i D_i - \sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik}X_i + [\sum_{i=1}^{n} L_i\alpha X_i + \sum_{i=1}^{n} O_i * h] + \sum_{i=1}^{n} HC_m H_i X_i + \sum_{i}^{n} T_i D_i + \sum_{i=1}^{n} M_i X_i + \sum_{i=1}^{n} CTC_i}{-\sum_{i=1}^{n} W_i X_i - \sum_{i=1}^{n} CB_i X_i}$$

subject to

$$\sum_{i=1}^{n}\sum_{k=1}^{m} R_{ik}X_i \leq \sum_{k=1}^{m} AQ_k$$

$$\sum_{i=1}^{n} H_i X_i \leq TH$$

$$\sum_{i}^{n} T_i D_i \leq TD$$

$$\sum_{i=1}^{n}\sum_{k=1}^{m} C_{ik}X_i + [\sum_{i=1}^{n} L_i\alpha X_i + \sum_{i=1}^{n} O_i * h] + \sum_{i=1}^{n} HC_m H_i X_i + \sum_{i}^{n} T_i D_i + \sum_{i=1}^{n} M_i X_i + \sum_{i=1}^{n} CTC_i \leq B$$

$$X_i\ belongs\ to\ integer$$

4. Results and Conclusions

In this paper, we formulate a mathematical model which increases the revenue of the fat-moving fashion industry and at the same time decreases the pollution caused by it. We considered mostly all the cost which were bear by the manufacturers i.e., travelling, labour, maintenance and other overhead charges. The pollution causing attributes are also taken with the constraints related to supply, demand, budget for the labour, in travelling and overall budget. One can implement the model once they get the entire data related to this and can reduce the pollution caused by the fast fashion industry.

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Conflicts of Interest: The authors declare no conflict of interest.

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