



Proceeding Paper

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

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[†] Presented at the 6th International Electronic Conference on Atmospheric Sciences, 15–30 October 2023; Available online: <https://ecas2023.sciforum.net/>.

Abstract: The fashion industry is one of the world's largest and third most polluting 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 people of all ages due to which fast-changing fashion is becoming a trend. But there is a hidden cost in the manufacturing of each material, which is ignored by people and which costs the environment and eventually the health of people. It not only pollutes the air due to the emission of greenhouse gases but also consumes plenty of water along with an increase in plastic and some other waste that pollutes our environment. The solution to the problem is to avoid and move away from this fast fashion trend and subsequently buy a few items of clothing that are good in quality and do not pose a threat to the environment. But this will lower the sales as well as the revenue of the fashion industry, which will eventually affect our economy. The purpose of this study is to construct a novel fractional mathematical programming model that caters to both objectives, i.e., minimizing environmental pollution and maximizing the revenue of the fashion industry with respect to the constraints based on the industry and environment.

Keywords: pollution; fashion industry; environment; greenhouse gases; fractional programming model



Citation: Garg, S.; Bhardwaj, R. Modeling of Environmental Pollution Due to the Fashion Industry Using Fractional Programming. *Environ. Sci. Proc.* **2023**, *27*, 22. <https://doi.org/10.3390/ecas2023-15508>

Academic Editor: Anthony Lupo

Published: 31 October 2023



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1. Introduction

With the increasing craze of fast-moving fashion products as well as the rise in the demand for these products by people of all ages, the fast-moving fashion industry inspires a lot of researchers to conduct research, be it optimizing their supply chain or finding how to maintain the quality of those products. Over the last few decades, the fashion industry has evolved tremendously with the expansion of industries [1]. It has changed the entire traditional model where mass production of products occurred. Instead, the new model eliminates the traditional model and focuses more on trendy products and seasonal fashion, which sometimes changes overnight and sometimes seasonally. This will create pressure among manufacturers to create products more effectively. To manage the profit in such a demanding and competitive market, manufacturers are forced to make a product that would cost them a low 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 customers as well as the fashion trend before consumption to compete in the market [3,4]. In recent years, they have competed with speed too to provide products that have been shown in fashion shows and are desired by the customer [5]. This is basically an unplanned process that reduces the time between 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 profit margin of these is high [8,9].

Although the fast fashion market is profitable for the business of the retailers, 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 were produced [10,11]. Out of 64.5% of textile waste, nearly 16.2% is recycled in the United States [12]. Chemicals that are applied on 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 trends. When these clothes are dumped and burned, they emit a large amount of CO₂ into the atmosphere [13–15].

Therefore, there is a need to propose a mathematical model that caters to both objectives, i.e., maximizing the revenue as well as minimizing the pollution caused by the fast-moving fashion industry. 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, and budget constraint, as well as the distance constraint.

2. Methodology

We formulate the problem using Fractional programming model and the variables related to the revenue and pollution objective which are used in this paper are given in Table 1.

Table 1. Notations used in the paper.

Variables	
X_i	Quantity of product i produced by manufacturer
D_i	Demand for product i
C_{ik}	Per unit cost of k^{th} material used to make i^{th} product
R_{ik}	Amount of k^{th} material required to make i^{th} product
AQ_k	Quantity available of k^{th} material
CE_i	CO ₂ emission per unit of production
HC_m	Hourly cost of 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	Labor cost of product i
TH	Maximum hours a machine can work to make products
LH	Maximum allotted hours for laborers
O_I	Overtime cost of product i
α	If labor 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

3.1. 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, and the second objective is related to minimizing the pollution that is caused by the burning of clothing waste and the materials used to make those products by considering the budget of the retailer.

3.2. 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 =

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

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

$$- \sum_{i=1}^n HC_m H_i X_i \tag{3}$$

$$- \sum_i T_i D_i \tag{4}$$

$$- \sum_{i=1}^n M_i X_i \tag{5}$$

$$- \sum_{i=1}^n CTC_i \tag{6}$$

Here, Equation (1) represents the profit function without considering the other charges involved in the business. Equation (2) represents the labor cost. Equation (3) represents the traveling cost. Equation (4) represents the maintenance cost and Equation (5) represents the carbon tax cost that is imposed by the government.

3.3. Objective Function 2

3.3.1. Pollution

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

$$\sum_{i=1}^n W_i X_i + \sum_{i=1}^n CB_i X_i \tag{7}$$

3.3.2. Constraints

There are several constraints based on the supply of raw material, the capacity of a machine to do work in a single day, no. of hours a worker can work in a day, and the budget.

Constraints are represented as follows:

1. Constraint related to the availability of raw material:

$$\sum_{i=1}^n \sum_{k=1}^m R_{ik} X_i \leq \sum_{k=1}^m A Q_k \tag{8}$$

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

$$\sum_{i=1}^n H_i X_i \leq TH \tag{9}$$

3. Constraint related to the total traveling distance:

$$\sum_i T_i D_i \leq TD \tag{10}$$

4. Constraint related to the budget of the manufacturer:

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

As both objectives are important, we cater to 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:

$$\begin{aligned}
 & \text{Max } \frac{\text{Revenue}}{\text{Pollution}} \\
 \text{i.e., } & \frac{\sum_{i=1}^n S_i D_i - \sum_{i=1}^n \sum_{k=1}^m C_{ik} X_i + [\sum_{i=1}^n L_i \alpha X_i + \sum_{i=1}^n O_i * h] + \sum_{i=1}^n HC_m H_i X_i + \sum_{i=1}^n T_i D_i + \sum_{i=1}^n M_i X_i + \sum_{i=1}^n CTC_i}{-\sum_{i=1}^n W_i X_i - \sum_{i=1}^n CB_i X_i} \\
 & \text{subject to } \sum_{i=1}^n \sum_{k=1}^m R_{ik} X_i \leq \sum_{k=1}^m A Q_k \\
 & \sum_{i=1}^n H_i X_i \leq TH \\
 & \sum_i T_i D_i \leq TD \\
 & \sum_{i=1}^n \sum_{k=1}^m C_{ik} X_i + [\sum_{i=1}^n L_i \alpha X_i + \sum_{i=1}^n O_i * h] + \sum_{i=1}^n HC_m H_i X_i + \sum_{i=1}^n T_i D_i + \sum_{i=1}^n M_i X_i + \sum_{i=1}^n CTC_i \leq B \\
 & X_i \text{ belongs to integer}
 \end{aligned}$$

4. Results and Conclusions

In this paper, we formulated a mathematical model that increases the revenue of the fast-moving fashion industry and at the same time decreases the pollution caused by it. We considered mostly all the costs the manufacturers bear, i.e., traveling, labor, maintenance, and other overhead charges. The pollution-causing attributes are also taken into account with the constraints related to supply, demand, budget for labor, traveling, and overall budget. One can implement the model once they obtain complete data related to this and can reduce the pollution caused by the fast fashion industry.

Author Contributions: S.G.: Methodology, Software, Writing—Original Draft; R.B.: Conceptualization, Supervision, Investigation, Writing—Review & Editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

Acknowledgments: We are thankful to Guru Gobind Singh Indraprastha University for undertaking this research.

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

References

- Peters, G.; Li, M.; Lenzen, M. The need to decelerate fast fashion in a hot climate—A global sustainability perspective on the garment industry. *J. Clean. Prod.* **2021**, *295*, 126390. [CrossRef]
- Bick, R.; Halsey, E.; Ekenga, C.C. The global environmental injustice of fast fashion. *Environ. Health* **2018**, *17*, 92. [CrossRef] [PubMed]
- Bhardwaj, V.; Fairhurst, A. Fast-Fashion: Response to Changes in the Fashion Industry. *Int. Rev. Retail. Distrib. Consum. Res.* **2010**, *20*, 165–173. [CrossRef]
- Bong Ko, S.; Jin, B. Predictors of purchase intention toward green apparel products: A cross-cultural investigation in the USA and China. *J. Fashion. Mark. Manag.* **2017**, *21*, 70–87. [CrossRef]
- Fast Fashion. Merriam-Webster.com Dictionary, Merriam-Webster. Available online: <https://www.merriam-webster.com/dictionary/fast%20fashion> (accessed on 30 September 2023).
- Jo, C. *We Buy A Staggering Amount of Clothing, And Most of It Ends Up in Landfills*; HuffPost: New York, NY, USA, 2016.
- “US EPA”. United States Environmental Protection Agency. Available online: <https://www.epa.gov/> (accessed on 30 September 2023).
- What Happens When Fashion Becomes Fast, Disposable and Cheap?* NPR: Washington, DC, USA, 2016.
- Tran, N.P.; Gunasekara, C.; Law, D.W.; Houshyar, S.; Setunge, S.; Cwirzen, A. Comprehensive review on sustainable fiber reinforced concrete incorporating recycled textile waste. *J. Sustain. Cem.-Based Mater.* **2022**, *11*, 28–42. [CrossRef]
- Opinion | Destroying Clothes Is Fashion’s Dirty Secret. And We’re Complicit*; HuffPost: New York, NY, USA, 2018.

11. "Carbon Dioxide". Free Dictionary. Available online: <https://www.thefreedictionary.com/carbon+dioxide> (accessed on 30 September 2023).
12. World Bank Group. *How Much Do Our Wardrobes Cost to the Environment?* The World Bank: Washington, DC, USA, 2019.
13. *Macron Hires Kering CEO to Improve Sustainability of Luxury Fashion*; Euronews: Lyon, France, 2019.
14. *France Clamps down on Fashion Brands that Destroy Unsold Goods so that They Won't Be Found in Discount Bins*; Nationalpost: Toronto, ON, Canada, 2019.
15. Pucker, K.P. *The Myth of Sustainable Fashion*; Harvard Business Review; Harvard Business Publishing: Boston, MA, USA, 2022; ISSN 0017-8012.

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