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RESEARCH ARTICLE

# A Study on Application of Linear Programming on Product Mix for Profit Maximization and Cost Optimization

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## Abstract

**Objectives**: This research aims to sneak into the retailer's perception about that customer segment and plan a product mix accordingly. The focus is on small players in small towns not having deep pockets to synergize the product mix decisions effectively. **Methods**: The data used in this research paper is from Hatchers, a medium-sized enterprise with zero budget for software for product mix decisions. The data was collected through face-to-face interviews with ten representatives and five supervisors in compliance with the existing documents and existing datasheet obtained from the production department, which was slightly updated to make the final output. The data was for one season, i.e., April to March. The data was analyzed to study pre-Linear Programming and post-Linear Programing profits. **Findings**: This examination distinguishes the current asset usage level and the benefit of every period of one of the apparel producing organizations, utilizing a linear programming procedure. Actual consumption of resources (product wise) was calculated to evaluate profit post applying Linear Programing to see the wastage and cost. There was a 54% increase post LP compared to the product-wise resource utilization. Similarly, the profit using Linear programming was more than double as wastage and costing were minimum, and revenue was high. **Novelty**: The article focused on the simple basic principle of linear programming for identifying product mix using Excel(Solver). LINGO. The software solutions become costlier for small firms, whereas Excel is more accessible and cost-efficient. There is a gap in existing literature as previous research has not focused on this aspect for small business houses where adapting software solutions is challenging.

**Keywords:** Linear Programming; Profit maximization; Product Mix; Production; cost optimization

## 1 Introduction

Every organization aims to make a profit for its continuous existence and growth. In present times, the challenge is more critical and prominent for manufacturing industries at all levels of creating goods of the right quality, quantity, and at the right time at the optimum cost for their survival[1]. With the advancement of technology, the latest trends, updated knowledge, and unprecedented problems also surface continuously. To solve these problems, the marketers need to apply the applications of operational research techniques which are over and above their personal experience and market trend[2]. Apparel manufacturers face a similar challenge as the industry is very dynamic and trendier where the customer choice is concerned.

The Indian local textile and apparel market(T&A) is projected at US$ 75 billion in 2020-21. The market dropped 30% from US$ 106 billion in 2019-20. The market is anticipated to recuperate and grow at a 10% CAGR from 2019-20 to reach US$ 190 billion by 2025-26[3]. Apparel constitutes a 73% share of the total T&A market in India[1,4]. Though a substantial percentage of clothing production across the globe occurs in SMEs, the specific issues of this sector require particular attention [3]. In India, 93 percent labor force is involved in unorganized SMEs, of which the clothing sector is a vital part [3]. All the Clothing companies belligerently expurgated costs and reorganized their supply chains. It ensures clothing prices drop compared to the prices of other consumer goods and makes clothing more affordable[5]. Consumers retort to lower prices and a superior assortment of apparel by buying more items. Thus, from 2000 to 2014, the number of garments purchased each year by a typical consumer amplified by 60 percent[6]. Massive upsurges in clothing sales were especially witnessed in emerging economies like India, where more customers joined the middle-class segment[6]. The ever-increasing world population, growing middle class, and rising living standards conclude that this trend will endure[7]. Their demand is mainly the base clothing articles alongside feasible and reasonable pricing, which supports that population of rural Asian nations which doesn't figure it associate in the beguiling nursing marketplace for branded players. Not much research is evident in this area, where the quantitative decision-making tool called linear programming (LP) can be used for the optimization problem of product mix to attract and sustain customers for small or non-branded garment retailers[8].

This research aims to sneak into the retailer's perception of that customer segment and plan a product mix accordingly. The focus is on small players in small towns not having deep pockets to synergize the product mix decisions effectively.

Product Mix, also called Product Assortment, refers to the complete range of products offered by the company. A broad assortment range for providing a choice to the customer is an appropriate strategy from retailers' perspective to ensure the revenue and long-term success of the company by maintaining customer choice as per individual requirements.[9]. However, this large variety for customers benefit for their better choice and satisfaction also creates limitations for the company (cost and complexity for stocking) and the customer (confusion of intention and obligation to purchase).

But generally, this becomes very challenging for the retailer or the marketer to stock such a wide range of apparel a fashion change fast[10]. Also, the trend changes every season. Once the material is stocked, the money is blocked until it is sold, which generally does not happen. Not to mention the fad, which spikes every few months and encourages a new wave every time. These fluctuations are visible even in small towns and rural markets because of the media exposure and the reach. The retailers need to stock efficiently and choose the right mix of products to economize on the cost[9].

### 1.1 Linear Programming

The linear programming model is generally used to achieve optimum solutions under several limitations by studying maximum or minimum objective functions for any given situation. This is not a new concept, developed by Soviet mathematician A. N. Kolmogorov before WWII.[11]

In 1940, George Dantzig created the simplex method to solve linear programming problems. Later in 1945, Stigler developed the application of Linear Programming for Diet Problem Solutions[11]. Eventually, the Linear programming field was further developed, and different researchers used it to calculate the optimum solutions for varied problems. One of the latest research regarding profit maximization using Linear techniques was conducted at the University of Benin Bakery, Benin city Edo State, Nigeria. The aim was to ascertain the daily bread quantity that the firm should produce to keep profits high at optimum cost. The firm used a Linear Programing solver to calculate the amount[12]. Here also, the focus was profit maximization. The application is not limited to a particular industry or domain. Using quantitative methods for decision-making for using available resources like water, fertilizers, labor, feed mix, crop rotation, etc., is also evident. It gives an insight into the practical aspect of Linear Programing methods and their scope.[13] This study also focuses more on increasing farmers' profitability and making decisions accordingly. However, the challenge faced here was addressing the multi goals problems that were difficult to analyze using a Simplex algorithm, besides resource allocation and decision-making. Similarly, we can analyze the usage of Linear Programing for optimal investment in software companies.[14] The research highlighted the benefit of using Linear Programming in small IT firms. The firm cannot acquire high-end software or hire a senior programmer for continuous development at minimum cost. Here, the Simple method was also used to keep costs low while attaining higher profits—one other research[15] regarding poultry feed's high demand and the ever-increasing cost. The linear programming method was used to formulate the optimal feed mix using sixteen feed ingredients to minimize the total feed cost. The challenge was also to keep the total cost of the feed at the minimum level along with maintaining the essential nutrient constraints. The dietary nutritional requirement for broiler was determined by ICAR (Indian Council of Agricultural Research), Indian standard Institutes, and National Research Center. The Microsoft Excel Solver was used here as a Linear Programming tool. The study was critical for small farmers as well as poultry farm owners. One of the latest researches [16] regarding product line allocation has addressed the issue of maintaining the buffer stock. The Buffer allocation program generally deals with the challenge of product line disruption and keeping the optimum buffer minimizing the cost of carrying the inventory. The focus of the study is using an Energy-efficient buffer allocation program through a multi-objective resolution approach. The study leaps forward from the existing literature in addressing multiple objectives, which was a challenge. The method used here was nonlinear, i.e., weighted sum method (WS), epsilon-constraint method (ECM), and non-dominated sorting genetic algorithm NSGA- II. The procedures were a little complicated to be followed as long computation time was involved. Also, cost optimization was not achieved during implementation.

A similar study can be cited [17], which considered the early product development stage for decision-making regarding product specifications. Here also bilevel optimization model was proposed instead of the Linear programming method. The complexity of the process and the cost of executing the model were concerning.

Based on these studies, the researchers felt the need to explore the Linear Programing model for decision-making at various levels for multiple objectives. The inadequacy of research in this area was one of the primary reasons to pursue this research. The aim of small firms to fulfill customers' demand by stocking the variety and economical pricing of the product is a few crucial concerns.

Though some commercial solvers like CPLEX and LINGO, can address Linear programming, the computation for large-scale data becomes a challenge. The calculation takes a lot of time if the product mix exceeds 100 and the solutions are multiples. Also, the cost involved in buying and using these solvers is not feasible for small firms.

#### *1.1.1 Standard form of LP model*

MAXIMIZE / MINIMIZE

Z = C1 X1 + C2 X2 + …….. Cn Xn →objective function

Subject to

a11 x1 + a12 x2 + …... a1n xn <= b1→functional constraint

a21 x1 + a22 x2 + …… a2n xn <= b2→functional constraint

am1 x1 + am2 x2 + ……. amn xn <= bm→functional constraint

x1, x2, ……xn →non negativity constraint

#### *1.1.2 Hatchers Company (whose data is taken for analysis in the case)*

It is an apparel company based out of Indore and owned by Gaurav Anand. It deals with men's clothing. The market comes with a size of (US $19 billion) INR 1,24,423 crore; apparel for men is the largest segment of the apparel industry and is also expected to rise to INR 2,95,795 crore (US $45.5 billion) by 2026 at a CAGR of 9 percent over the next ten years. The different product categories under the men's wear section include tops, pants, coats, winter wear, T-shirts, jeans, everyday wear, activewear, multicultural, innerwear, etc. Shirts in men's wear form the single largest group, followed by trousers and denim.

Denim, activewear, and T-shirts have shown very promising growth in recent years, with square measurements expected to grow at CAGRs by as much as fourteen percent and twelve percent because of factors like the dynamic preference of the customers. Whereas we can say that t-shirts and denim have matured currently as classes and have shown consistent growth over a substantial amount of time, activewear may be a recent development and has massive potential to grow. It is often because of the boom in health care and fitness.

Clothing fabricating firm benefit is profoundly influenced by the expense of assets and asset utilization [18].

The issue addressed in this paper is using the linear programming methodology that the textile manufacturer will adopt for men wearing: v neck t-shirts, polo shirts, simple t-shirts, round-neck t-shirts, and singlet, to evaluate the product mix with available resources for maximum benefit. The purpose was to incorporate LP as a decision method for assessing the optimum combination of products with the available resources in the sector for maximum profit. Interview with retailers also helps to understand the market share of a particular variant of apparel being sold. So, we can propose the following assumptions,

$H_0$ – There is no improvement in profit pre and post-application of LP on product mix problem.

$H_1$ – There is an improvement in profit pre and post-application of LP on product mix problem

## 2 Materials and Methods

The data collection process was objective, and there was a pre-existing secondary database. Also, the additional data was collected through face-to-face performance interviews by (permission of the owner) of representatives (10) and data provided by supervisors(5) in compliance with the existing documents and slightly updated to make the outcome. The principles are applied to the kept resources and consider their consumption and the output quantity of each commodity utilized in the firm. In the apparel manufacturing unit, the ability to use resources (use of resources) was recorded as the major constraint. It defined constraints (threads, fabrics, human resources, overheads, stitching, cutting, and time for finishing) and five customer consignments for uppers (Polo T-shirts, round neck T-shirts, basic T-shirts, singlets, and v neck t-shirts). The data was collected for one season, i.e., April to March. Figures were approximate to maintain the confidentiality of the firm's finances. The linear programing tool was applied to the data, and the result was compared pre LP and Post LP . The objective was tp compare the resource allocation, resource utilization, and profit after applying. Also, as the company was small, the tool used was Excel to minimize the cost and ease of use by the accounts people involved.

**Table 1.** Resource allocation product-wise

| Products (T- shirts and pants) | Fabrics gms | Thread meters | Labor INR | Overhead INR | Cutting (hours) | Sewing (hours) | Finishing Time (hours) |
|---|---|---|---|---|---|---|---|
| Polo T- shirt | 315 | 215 | 11 | 31 | .03 | .35 | .03 |
| Basic T- shirt | 200 | 105 | 5 | 19 | .02 | .15 | .02 |
| Round Neck T- shirt | 195 | 142 | 6 | 20 | .03 | .16 | .03 |
| Singlets | 180 | 105 | 4.5 | 15.5 | .02 | .09 | .02 |
| V neck T- shirt | 50 | 190 | 7 | 37 | .04 | .31 | .04 |

**Table 2.** Resource utilization and maximum value held in stock

| Resource utilized | Maximum held value |
|---|---|
| Fabric(g) | 3,71,25,000 |
| Thread(m) | 2,56,21,830 |
| Labor(INR) | 10,01,000 |
| Overheads(INR) | 50,00,000 |
| Cutting(HOURS) | 5,775 |
| Sewing(HOURS) | 44,500 |
| Finishing(HOURS) | 6,200 |

**Table 3.** Demand and profit table

| | Polo T-shirt | Basic T-shirt | Round neck T-shirt | Singlets | V neck T-shirt |
|---|---|---|---|---|---|
| Demand | 15000 | 24000 | 12000 | 26000 | 11000 |
| Profit | 4.5 | 3.8 | 3.5 | 3 | 6.5 |

## 3 Results and Discussion

Data were analyzed using excel inbuilt mathematical calculation(solver), macros and formulas, and statistical linear programming software/tool, such as LINGO.

Technically, an LPP has five additional requirements:

I. Conditions of certainty are presumed to exist; the numbers in the target and constraints are known with certainty and do not alter during the study period.

II. Proportionality is believed to occur in the goal and the constraints. If four units of a specific rare resource are used for a product's output of one unit, then producing ten units of a product uses 40 units of the resource.

III. Now, the third theoretical principle involves additivity, which means that the average of every activity (sum)is the addition of all the fragmented activities.

IV. The premise of divisibility is that the answers do not need not be a complete number form (integers). Instead, they are divisible, and a value in a fraction can be taken.

V. Finally, all responses or factors are considered to be positive. Negative physical quantity values are not possible; the negative number of textile items cannot simply be produced

**Table 4.** Pre LP-consumption

| **Pre LP-Consumption** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Type** | **Fabric (g)** | **Threads(m)** | **Labour (INR)** | **Overheads (INR)** | **Cutting (Hr)** | **Sewing (Hr)** | **Finishing (Hr)** |
| Polo T-Shirt | 47,25,000.00 | 32,25,000 | 1,65,000 | 4,65,000 | 450.00 | 5,250.00 | 500.00 |
| Basic T- Shirt | 15,60,000.00 | 25,20,000 | 1,20,000 | 4,56,000 | 440.00 | 3,600.00 | 520.00 |
| Round | | | | | | | |
| Neck T- | 23,40,000.00 | 17,04,000 | | 2,40,000 | | | |
| Shirts | | | 72,000 | | 340.00 | 1,920.00 | 380.00 |
| Singlet | 46,80,000.00 | 27,30,000 | 1,17,000 | 4,03,000 | | | |
| | | | | | 476.67 | 2,340.00 | 563.33 |
| V neck T-Shirt | 5,50,000.00 | 20,90,000 | 77,00 | 4,07,000 | 476.67 | 3,410.00 | 476.67 |
| Total | 1,38,55,000.00 | 1,22,69,000 | 5,51,000 | 19,71,000 | 2,183.33 | 16,520.00 | 2,440.00 |
| Available | 3,71,25,000.00 | 2,56,21,830.00 | 10,01,000.00 | 50,00,00. 00 | 5,775.00 | 44,500.00 | 6,200.00 |
| Difference | 2,32,70,00 0.00 | 1,33,52,830 .00 | 4,50,000.0 0 | 30,29,000. 00 | 3,591.67 | 27,980.00 | 3,760.00 |

**Table 5.** Pre LP-profit

| **Pre LP-Profit INR** | |
|---|---|
| **Type** | **Profit** |
| Polo T-Shirt | 67,500 |
| Basic T-Shirt | 91,200 |
| Round Neck T-Shirt | 42,000 |
| Singlet | 78,000 |
| V neck t-shirt | 71,500 |
| Total | 3,50,200 |

## 3.1 Analysis- Steps to Formulate the Model and Results

In addition to other operating data and sales, the data collected from the case firm, Hatchers were analyzed to provide estimates for LPP model parameters.

x1 = number of Polo T-shirts x2 = number of Basic T-shirts
x3 = number of Round Neck T-shirts x4 = number of Singlets
x5 = number of V neck t-shirts
Z = total profit during the month
Now, the linear programming model, maximizing the total
**profit is: Maximize Z (INR Profit) = 4.5 x1 + 3.8x2 + 3.5 x3+ 3x4 + 6.5x5**
**Subject to constraints;**

1. 315x1 + 65x2 + 195x3 + 180x4 + 50x5 $\leq$ 3,71,25,000 (Fabric)
2. 215x1 + 105x2 + 142x3 + 105x4 + 190x5 $\leq$ 2,56,21,830 (Thread)
3. 11x1, +5x2 + 6x3 + 4 5x4 + 7x5 $\leq$ 10,01,000 (Labor
4. 31x1 + 19x2 + 20x3 + 15 5x4 + 37x5 $\leq$ 50,00,000 (Over heads)
5. 03x1 + 0 02x2 + 0 03x3 + 0 02x4 + 0 04x5 $\leq$ 5,775 (Cutting time- hours)
6. 35x1 + 0 15x2 + 0 16x3 + 0 09x4 + 0 31x5 $\leq$ 44,500 (Sewing time-hours)
7. 03x1 + 0 02x2 + 0 03x3 + 0 02x4 + 0 04x5 $\leq$ 6200 (Finishing time-hours)
8. x1$\geq$ 15000; (Customer orders)
9. x2 $\geq$ 24000; (Customer orders)
10. x3 $\geq$ 12000; (Customer orders)

11. x4 $\geq$ 26000; (Customer orders)
12. x5 $\geq$ 11000 (Customer orders)

**Table 6.** Actual consumption of resource product wise (calculated using excel)

| **Actual Consumption (LP)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Type** | **Fabric (g)** | **Threads(m)** | **Labour (INR)** | **Overheads (INR)** | **Cutting (Hr)** | **Sewing (Hr)** | **Finishing (Hr)** |
| Polo T- Shirt | 47,25,000 | 32,25,000 | 1,65,000 | 4,65,000 | 450 | 5,250 | 500 |
| Basic T- Shirt | 15,60,065 | 25,20,105 | 1,20,005 | 4,56,019 | 440 | 3,600 | 520 |
| Round Neck T-Shirts | 23,40,000 | 17,04,000 | 72,000 | 2,40,000 | 340 | 1,920 | 380 |
| Singlet | 46,80,000 | 27,30,000 | 1,17,000 | 4,03,000 | 477 | 2,340 | 563 |
| V neck T-shirts | 37,64,250 | 1,43,04,150 | 5,26,995 | 27,85,545 | 3,262 | 23,338 | 3,262 |
| Total | 1,70,69,315 | 2,44,83,255 | 10,01,000 | 43,49,564 | 4,969 | 36,449 | 5,226 |
| Available | 3,71,25,000 | 2,56,21,830 | 10,01,000 | 50,00,000 | 5,775 | 44,500 | 6,200 |
| Difference | 2,00,55,685 | 11,38,575 | - | 6,50,436 | 806 | 8,052 | 974 |

**Table 7.** Post LP production calculated using solver in MS excel

| **Actual Production (Solution after LP)** | |
|---|---|
| Polo T-Shirt | 15,000 |
| Basic T-Shirt | 24,001 |
| Round Neck T-Shirts | 12,000 |
| Singlet | 26,000 |
| V neck t-shirts | 75,285 |

**Table 8.** Product wise profit post LP

| **Actual Profit INR** | |
|---|---|
| **Type** | **Profit** |
| Polo T-Shirt | 67,500 |
| Basic T-Shirt | 91,204 |
| Round Neck T-Shirts | 42,000 |
| Singlet | 78,000 |
| V neck t-shirts | 4,89,353 |
| Total | 7,68,056 |

## 3.2 Discussion

Since this study is centered on the full utilization of resources to their maximum value held, it is under the assumption that all the units produced of the product mix will be sold to reap the profits. For this to happen, the company must have command over market trends and ongoing trends in the retail apparel sector, and no one better than a retailer can shed light on this topic. This examination distinguishes the current asset usage level and the benefit of one of the attires producing organizations utilizing a linear programming procedure. The all-out use of the organization was being used as a goal work. In attire fabricating firms, effective utilization of materials, for example, textures and sewing strings, and preparing time at various phases of creation just as minimization of work and materials cost are essential to improve their productivity. This can be supported by a recent study undertaken for defining optimum product mix using the theory of constraints [19]. Here, two linear programming models solved the problem of deciding the efficient bird feed by utilizing optimum resources and maximum productivity.

**Table 9.** Comparison of resource utilization

| Pre LP Vs Post LP | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Fabric (g)** | **Threads (m)** | **Labor (INR)** | **Overheads (INR)** | **Cutting (Hr)** | **Sewing (Hr)** | **Finishing (Hr)** | **Profit (INR)** |
| **Pre LP** | 1,38,55,0 00.00 | 1,22,69,00 0.00 | 5,51,000. 00 | 19,71,000 .00 | 2,183.33 | 16,520.00 | 2,440.00 | 3,50,2 00.00 |
| **Post LP** | 1,70,69,3 15.00 | 2,44,83,25 5.00 | 10,01,000 .00 | 43,49,564 .00 | 4,969.04 | 36,448.50 | 5,225.71 | 7,68,0 56.30 |
| **% Increase** | 19% | 50% | 45% | 55% | 56% | 55% | 53% | 54% |

**Table 10.** Comparison of resource utilization in percentage

| Utilization | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Fabric** | **Threads** | **Labor** | **Overheads** | **Cutting** | **Sewing** | **Finishing** |
| **Pre LP** | 37% | 48% | 55% | 39% | 38% | 37% | 39% |
| **Post LP** | 46% | 96% | 100% | 87% | 86% | 82% | 84% |
| **% Increase** | 19% | 50% | 45% | 55% | 56% | 55% | 53% |

This examination indicates a wasteful use of every single authoritative asset. It tends to be inferred that the organization utilizes its assets wastefully with the current framework. Data visualization to ease the decision-making using the dashboard to experience different business scenarios was suggested. As mentioned, the strategies used by developing organizations for optimum resource utilization and waste minimization pave the way for the organization's sustainability[(20)]. The study conducted for Amo Byng Nigeria ltd shows that the Reverse Simplex method for improving the profit by around 9.1% was observed without considering customer orders, i.e., by maintaining optimum product mix.

Therefore, it is conceivable to claim that the organization's global impact can be increased to a critical level by reviewing the current agreement. Referring to the Hatchers' case, the item blend was basic T-shirts, Polo T-shirts, round neck T-shirts, V neck T-shirts, and Singlets with the quantity of 15,000.00, 24000,00, 12000.00, 26000.00, and 11000.00 separately, and with an absolute benefit of INR 3,50,200.00 every month after selling.

## 4 Conclusion

This case study is centered on Hatchers, a medium-sized enterprise. Right now (post LP) the organization produces five kinds of items with the accompanying creation volumes (pieces) every month (Men's Polo shirt, 15000; Men's Basic T-shirt, 24000; Round neck T-shirts, 12000; Singlet, 26000; V-neck T-shirt, 75285). Be that as it may, these generation volumes will give the organization an overall benefit of INR 7,68,056.00 every month.

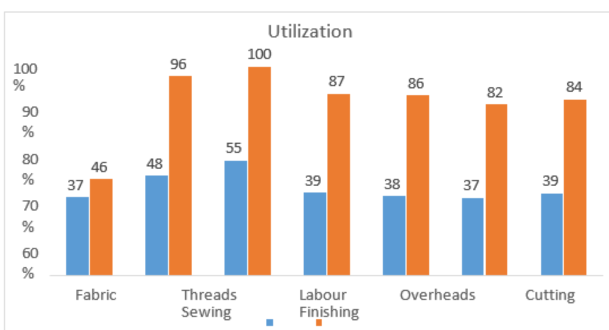


**Fig 1.** Utilization of Resources

Considering the time and money invested for the application, the output is quite high and sustainable as it can be used each quarter or every year. Other than this, the use of solver, an application of MS excel, is convenient and application-oriented. A lot of market information about the apparel industry, especially non-branded garment companies in tier 1 and tier 2 cities, is constantly updated and worked on. A perspective about end-user sales can also be gained, and how assumptions of sales and profits differ from actual sales and profits learned can be visualized.

## References


1) Oladejo NK, Abolarinwa A, Salawu SO, Lukman AF. Optimization Principle And Its'application In Optimizing landmark University Bakery Production Using Linear Programming. *International journal of civil engineering and technology (IJCIET)*. 2019;10(2):183–90. Available from: http://www.iaeme.com/ijciet/issues.asp?JType=IJCIE...
2) Sharma JK. Operations research; theory and applications. India. Macmillan Indian Ltd. 2008.
3) Majumdar A, Sinha S. Modeling the barriers of green supply chain management in small and medium enterprises. *Management of Environmental Quality: An International Journal*. 2018;29(6):1110–1122. Available from: https://doi.org/10.1108/MEQ-12-2017-0176.
4) Annual Report: Indian Textile and Apparel Industry. 2021. Available from: https://aepcindia.com/system/files/Annual%20T%20and%20A%20Industry%20Report-2021.pdf.
5) Remy N, Speelman E, Swartz S. Style that's sustainable: A new fast-fashion formula. McKinsey Global Institute. 2016.
6) Bouton S, Hannon E, Rogers M, Swartz S, Johnson R, Gold A, et al. The circular economy: Moving from theory to practice. *McKinsey center for business and environment Special edition*. 2016.
7) SS M, editor. Handbook of life cycle assessment (LCA) of textiles and clothing. Woodhead publishing. 2015.
8) Woubante GW. The Optimization Problem of Product Mix and Linear Programming Applications: Case Study in the Apparel Industry. *Open Science Journal*. 2017;2(2). Available from: https://osjournal.org/ojs/index.php/OSJ/article/viewFile/853/68.
9) Koschmann A, Sheth J. Brand line extensions: creating new loyalties or internal variety-seeking? *Journal of Product & Brand Management*. 2018;27(4):351–362. Available from: https://doi.org/10.1108/JPBM-08-2017-1535.
10) Childs M, Jin B, Tullar WL. Vertical versus horizontal line extensions: a comparison of dilution effects. *Journal of Product & Brand Management*. 2018;27(6):670–683. Available from: https://doi.org/10.1108/JPBM-01-2017-1386.
11) Render B, Stair RM, Hanna ME. Quantitative Analysis For Management, 11th Edition. .
12) Oluwaseyi KO, Elizabeth A, Olaoluwa OE. Profit Maximization in a Product Mix Bakery Using Linear Programming Technique. *Journal of investment and Management*. 2020;9(1):27–30.
13) Alotaibi A, Nadeem F. A Review of Applications of Linear Programming to Optimize Agricultural Solutions. *International Journal of Information Engineering and Electronic Business*. 2021;13(2):11–21. Available from: https://www.mecs-press.net/ijieeb/ijieeb-v13-n2/IJIEEB-V13-N2-2.pdf.
14) Mustafa AO, Sayegh MAH, Rasheed S. Application of Linear Programming for Optimal Investments in Software Company. *Open Journal of Applied Sciences*. 2021;11(10):1092–1101. doi:10.4236/ojapps.2021.1110081.
15) Mallick P, Muduli K, Biswal JN, Pumwa J. Broiler Poultry Feed Cost Optimization Using Linear Programming Technique. *Journal of Operations and Strategic Planning*. 2020;3(1):31–57. Available from: https://doi.org/10.1177/2516600X19896910.
16) Alaouchiche Y, Ouazene Y, Yalaoui F. Multi-Objective Optimization of Energy-Efficient Buffer Allocation Problem for Non-Homogeneous Unreliable Production Lines. *IEEE Access*. 2022;10:3320–3335. doi:10.1109/ACCESS.2021.3139954.
17) Ji X, Gao Q, Wang H. A bilevel-optimization approach to determine product specifications during the early phases of product development: Increase customer value and reduce design risks. *Expert Systems with Applications*. 2022;188:116012–116012. Available from: https://doi.org/10.1016/j.eswa.2021.116012.
18) Arefayne D, Pal A. Productivity Improvement Through Lean Manufacturing Tools: A Case Study On Ethiopian Garment Industry. *International Journal of Engineering Research & Technology (IJERT)*. 2014;3(9):1037–1045. Available from: https://www.ijert.org/productivity-improvement-through-lean-manufacturing-tools-a-case-study-on-ethiopian-garment-industry.
19) Mohammed AR, Kassem SS. Product Mix Optimization Scenarios: A Case Study for Decision Support Using Linear Programming Approach. *2020 International Conference on Innovative Trends in Communication and Computer Engineering (ITCE)*. 2020;8:50–55. doi:10.1109/ITCE48509.2020.9047758.
20) Hassan U, Haruna A, Lukunti S, Yusuf B. The Optimization Problem of Product Mix and Linear Programing Applications, a Revise Simplex Approach; a Study of Amo Byng Nigeria Limited. 2020. Available from: https://www.africanscholarpublications.com/wp-content/uploads/2021/01/AJASD_Vol18_No2_Sept_2020-29.pdf.