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ENHANCING PROFITABILITY AND PRODUCT MIX OPTIMIZATION THROUGH LINEAR PROGRAMMING PROBLEM: A CASE STUDY ON THE INDIAN GARMENT INDUSTRY

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A B S T R A C T

The present research work investigates the application of Linear Programming Problem (LPP) to generate profits while efficiently managing resources such as raw materials, machinery, labor, transportation, and processing time. The research focuses on Sunshel Textiles India Pvt Ltd., a garment industry situated in Gujarat, India. This company was chosen because of its diversified product range, which requires important management decisions in determining the quantity of products to be produced and sold. The study sampled seven products: suits, blazers, trousers, shirts, half t-shirts, shorts, full-sleeve t-shirts. The data used for the analysis is taken from company records. A LPP model has been formulated to improve the company's operations and the optimal results are being calculated using solver add-in in Microsoft Excel 2019. Analysis of the collected data indicates that Sunshel Textiles Industry has the potential to gain extra 5.5% profit by incorporating the optimized model in their managerial decisions.

1. INTRODUCTION

Garment industries are constantly suffering from a shortage of manufacturing inputs, which leads to lower capacity utilization and thus lower production. However, economic growth depends on management choices that are made at the enterprise level to increase output, either by reducing costs or by maximizing output, thus increasing productivity within the real sector. As a result, business managers are constantly looking for optimal decisions that align with their goals, which primarily focus on maximizing profits.

The expansion of industry puts pressure on management to determine the most effective levels of planning, organizing, leading and controlling production across the various sectors of the economy. This pressure led to the introduction of management theories aimed at dissecting the business landscape and addressing the external challenges presented by the industry's operating environment, as well as the practical problems arising from operations within the industry. To address these challenges, a quantitative approach to modeling and analyzing decision-making problems has been developed. One such quantitative approach is the use of LPP models, using mathematical techniques to ascertain the most advantageous course of action. It was developed by Soviet mathematician A.N.Kolmogorov before WWII (Woubante, 2017).

The objective entails optimizing the linear objective function taking into account the constraints of linear equality and inequality. This process involves

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formulating the problem as a set of linear equations and inequalities, followed by determining optimal values for the decision variables that simultaneously satisfy all imposed constraints. Linear optimization is widely used in many fields, including operations research, economics, engineering, and finance, to name a few. It can be applied to a variety of problems such as resource allocation, production planning, transportation, and network optimization (Aliu et al., 2023; Syifa et al., 2023; Shamsuzzaman et al., 2023).

India's domestic textile and apparel market has seen a significant decline, from US$106 billion in 2019–2020 to an estimated US$75 billion in 2020–21. However, it is projected to recover at a compound annual growth rate (CAGR) of 10% in 2019-20 and reach USD 190 billion by 2025-26. From this market, clothes make up 73% of the total. The apparel sector is an important part of the Indian economy, with a significant proportion (93%) of the workforce employed in unorganized small and medium enterprises (SMEs).

Apparel companies are responding to this challenge by cutting costs and optimizing their supply chains, making apparel more affordable than other consumer goods. This strategy has led to an increase in consumer purchases, with the number of garments purchased per consumer increasing by 60% between 2000 and 2014. This trend has been particularly evident in emerging economies such as India, driven by a growing middle class and rising living standards (Majumdar & Sinha, 2018).

Product mix, the range of products offered by a company, is critical to maintaining customer preferences and revenue. However, offering a wide assortment brings problems in terms of cost and storage complexity, as well as customer confusion. Fashion trends change rapidly, which complicates inventory management, and retailers need to efficiently select the right product mix to reduce costs (Koschmann & Sheth, 2018).

In 1940, Georg Dantzig presented the simple method for solving linear programming problems. This echnique was later applied to food-related problems by Stigler in 1945 (Render et al., 2023; Lin et al., 2020). Another study focused on improving poultry nutrition, aiming to reduce costs while meeting nutritional requirements (Mallick et al., 2020). The complexity of multi-objective problems leads to the exploration of different approaches, such as energy-efficient buffer allocation and binary level optimization (Magnanini et al., 2022). Woubante (2017) used data from a textile manufacturing unit in Ethiopia to estimate the linear programming model parameters. Using LINGO 16.0 software, he showed that improving customer fulfilment can increase company profits by 59.84%. Likewise, Tesfaye et al. (2016) examined data from the Ethiopian garment industry and used a linear programming model to highlight the potential for resource utilization to increase by 46.41% compared to current levels. Their model revealed a potential increase in the company's profits by 145.5%.

In this paper a garment industry, Sunshel Textiles, based in Gujarat, India is being considered. The data has been collected from the company records. A LPP model addressing the effective production planning in order to get maximum profit has been proposed and analysed in this article.

2. MATERIALS AND METHODS

The primary data used in this research paper is from Sunshel Textiles, a large sized enterprise. The data was collected through industrial visits to Sunshel Textiles which is located in Umbergaon, Gujarat.

The visit involved direct observation of the manufacturing process, interviews with the operations manager and various staff. This data was then analyzed using LPP techniques in Microsoft Excel to optimize the production process and minimize costs while meeting production targets.

2.1 Introduction to our dataset

The Table 1 shows details of various products produced by a company and the attributes including fabric used, thread required, labor cost, overhead, average demand, inventory, profit margin, production capacity, monthly capacity. The products include suits, blazers, trousers, shirts, half t-shirts, shorts and full-sleeve t-shirts.

Table 1. Apparel Production Metrics

Product	Fabric Used	Thread Used	Labor Cost	Overh--ead	Average demand	Profit Margin	Production Cap	Monthly Cap	Average current Production
Suit	5	1400	1900	1300	12000	30%	600	14400	13500
Blazer	1.85	550	900	720	12000	30%	600	14400	13000
Trousers	1.3	270	140	120	70000	30%	3200	76800	72000
Shirts	1.55	380	105	90	35000	50%	1800	43200	38000
Half t-shirt	1.15	140	75	65	53000	55%	2600	62400	58000
Shorts	0.8	110	60	55	14000	60%	700	16800	15500
Full-sleeve t-shirt	1.35	200	85	70	27000	45%	1300	31200	28000

The necessary information required for our analysis was provided by the factory. However, certain information which was not given was calculated using the available data for which we have shown the necessary calculations.
Fabric: It is the amount of fabric used in square meters to manufacture one unit of the product.
Example: To make one suit we require 5 square meters of fabric.
Thread: It is the amount of thread used in meters to manufacture one unit of the product.
Example: To make one suit we require 1400 meters of thread.
Labor cost: The cost of labor required to manufacture one unit of product.
Example: The cost of labor for making one suit is Rs.1900.
Overhead: The cost of indirect expenses incurred in the production of one unit of the product.
Example: The overhead cost incurred while making one suit is Rs.1300.
Average demand: It is the average demand for a product in a month.
Example: The average monthly demand of suits is 12000 units.
Profit margin: The percentage of profit earned on the product after deducting all the costs.
Example: The profit percentage earned on one unit of suit is 30%.
Average Current production: It is the average amount of each product being produced in a month.
Example: On an average 13500 suits are being produced in a month.
Production Capacity: The number of units that can be produced per day.
Example: The production capacity for suits is 600 units per day.
Monthly Capacity: The number of units that can be produced in a month.
Example: As the factory operates for 6 days a week and a month comprises 4 weeks, the total number of working days in a month is 24. Hence, the monthly production can be calculated by multiplying the production per day with 24.
For suits the production per day is 600,
Hence the production per month $= 600 \times 4 \times 6 = 14400$
The following table 2 represents the selling price for the products and profit per unit.

Table 2. Selling Price and Profit Per Unit

Product	SP/unit	Profit/unit
Suit	6000	1800
Blazer	3000	900
Trousers	550	165
Shirts	400	200
Half t-shirt	350	192.5
Shorts	300	180
Full-sleeve t-shirt	350	157.5

SP/unit: Selling price of one unit per product.
Profit/unit: Profit earned on one unit of product.
Example: The formula (Selling Price $\times$ Profit Percentage) is used to calculate the profit per unit of a product based on its selling price and profit percentage.
We calculate the profit per unit for suit as:
The selling price of a suit given is 6000, and the profit percentage is 30%.
Using the formula, the calculated profit per unit suit is,
$6000 \times \frac{30}{100} = 1800$.
This means that for each suit sold, the factory earns a profit of 1800. Similarly, the selling price and profit per unit for each product are listed in the Table 2.
The following Table 3, represents the amount of inventory to be kept for the resources and how much of that inventory will be consumed after production.

Table 3. Resource Allocation

Resource Type	Measurement Unit	Inventory	Consumption Value
Fabrics	Meter	378997.5	360950
Threads	Meter	79122750	75355000
Labor	Rupees	62034000	59080000
Overheads	Rupees	47830125	45552500

Consumption value: It is the amount of raw material being consumed in a month.
Here we calculate Consumption value by multiplying amount of fabric used per meter square used by average current production.
Example:

$$\text{Consumption Value} = \sum(\text{Amount of Resources per product} \times \text{Average Current Production})$$

$$\text{Consumption value for fabric} = \sum(\text{Fabric Used per Product} \times \text{Current Production for the Product}) =$$

(5×13500)+(1.85×13000)+(1.3×72000)+
+(1.55×38000)+(1.15×58000)+(0.8×15500)+
+(1.35×28000)

$$= 67500 + 24050 + 93600 + 58900 + +66700 + 12400 + 3780$$

$$= 360950$$

Inventory: Inventory typically refers to the extra resources being held in reserve in addition to the expected consumption value.
We are given that the factory wants to maintain a 5% buffer inventory, which means that they intend to keep an additional 5% of the consumption value as inventory. Maintaining 5% extra inventory helps to mitigate the risks associated with uncertain demand and supply chain disruptions.
To calculate the inventory, we multiply the consumption value by 0.05 (5%) and add it to the consumption value itself. So, we get:
Example:

$$\text{Inventory} = \text{Consumption Value} * 0.05 + \text{Consumption Value}$$

$$\text{Inventory for Fabric} = \text{consumption value of fabric} * 0.05 + + \text{consumption value of fabric} = 360950 * 0.05 + 360950 = 18047.5 + 360950 = 378997.5$$

2.2 Model formulation

Few important terminologies in LPP:

Objective Function: Objective function is a linear function in terms of decision variables. The aim of the study is to optimize it i.e., either maximization or minimization.

Ex : $Max\ Z\ or\ Min(Z) = c_1x_1 + c_2x_2 + c_3x_3 + \cdots + c_nx_n$

Decision Variables: These are used to represent products, services, projects, or other interrelated activities that need to be optimized together to make the best use of resources. These variables are denoted by x_1, x_2, x_3, …, x_n and their values need to be determined to optimize the objective function.

Constraints: The limitation on resources like production capacity, raw-material, labor, man-hours, machines. These resources are expressed as linear inequalities in terms of decision variables known as constraints.

Example: $a_{11}\,x_1 + a_{12}\,x_2 + a_{13}x_3 + \cdots + a_{1n}x_n \leq = \geq b_1$

Non-Negative Constraints: In a real situation the negative values are not possible, thus all decision variables must be non-negative, known as non-negative constraints.

Example: $x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, \ldots, x_n \geq 0$

2.3 Steps for linear programming

Here are the steps to formulate a mathematical LPP:

Step 1: Define the decision variables.

Step 2: Define the objective function.

Step 3: Formulate the constraints.

Generally, LPP can be written as:

$$Max\ Z\ or\ Min(Z) = c_1x_1 + c_2x_2 + c_3x_3 + \cdots + c_nx_n$$

Subject to the conditions,

$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \cdots + a_{1n}x_n \leq = \geq b_1$

$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \cdots + a_{2n}x_n \leq = \geq b_2$

$a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \cdots + a_{3n}x_n \leq = \geq b_3$

..

$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \cdots + a_{mn}x_n \leq = \geq b_m$

$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, \ldots, x_n \geq 0$

2.4 Assumptions

The LPP model has several assumptions that must be met to ensure its accuracy and effectiveness. These assumptions are as follows: (Feng et al. 2022)

1. Certainty: The objective and constraint values are certain and do not change during the period.
2. Proportionality: The value of the decision variable is proportional to the value of the objective function.
3. Additivity: The contribution to the objective function from each decision variable is additive.
4. Divisibility: Solutions can have fractional values rather than being restricted to whole numbers.
5. Non-negativity: All variables and answers are constrained to be nonnegative, as negative values are not feasible in the context of the problem.

3. MATHEMATICAL MODEL

To set up the model, the decision variables were set as:

x_1 = Number of Suits

x_2 = Number of Blazer

x_3 = Number of Trousers

x_4 = Number of Shirts

x_5 = Number of Half T-shirts

x_6 = Number of Shorts

x_7 = Number of Full-Sleeve T Shirts

Then, the LPP model for maximizing the total profit can be expressed as:

Z = Total profit during the month in rupees

In the LPP model,

Maximizing the total profit:

$$Maximizing\ Z = 1800\,x_1 + 900x_2 + 165x_3 + 200x_4 + 192.5\,x_5 + 180x_6 + 157.5x_7$$

Now we will form the constraints,

C1: Fabric Constraint

This constraint ensures that the total fabric used in production cannot exceed the available fabric inventory.

Mathematical Representation:

$$5\,x_1 + 1.85x_2 + 1.3x_3 + 1.55x_4 + 1.15\,x_5 + 0.8x_6 + 1.35x_7 \leq 378997.5$$

C2: Thread Constraint

This ensures that the total thread used in the production of all products does not exceed the thread inventory available.

$$1400\,x_1 + 550x_2 + 270x_3 + 380x_4 + 140\,x_5 + 110x_6 + 200x_7 \leq 79122750$$

C3: Labor Cost Constraint

The labor cost constraint limits the total labor cost to a certain amount based on the available budget.

$$1900\,x_1 + 900x_2 + 140x_3 + 105x_4 + 75\,x_5 + 60x_6 + 85x_7 \leq 62034000$$

C4: Overhead Constraint

This constraint is set to ensure that the total cost of production does not exceed a certain limit based on the available budget

$$1300\,x_1 + 720x_2 + 120x_3 + 90x_4 + 65\,x_5 + 55x_6 + 70\,x_7 \leq 47830125$$

C5 to C11: Monthly Production Capacity for Each Product

This constraint ensures that the total number of products produced in a month does not exceed the maximum capacity of the production unit.

$x_1 \leq 14400$ (suits)

$x_2 \leq 14400$ (blazer)

$x_3 \leq 76800$ (trousers)
$x_4 \leq 43200$ (shirts)
$x_5 \leq 62400$ (half t-shirt)
$x_6 \leq 16800$ (shorts)
$x_7 \leq 31200$ (full-sleeve t-shirt)

C12 to C18: Average demand and Monthly Capacity Constraint

We need to include a constraint that ensures the company produces at least as much as the average demand or more. However, in cases where the average demand exceeds the production capacity, we cannot produce more than the capacity.

Hence, we take the minimum value between the two as the production constraint.

Mathematically, this can be represented as:

$$Production \geq MIN(Average\ Demand, Production\ Capacity)$$

$x_1 \geq MIN(12000, 14400)$
(Suits, In this case we take 12000)
$x_1 \geq 12000$
$x_2 \geq MIN(12000, 14400)$
(Blazer, in this case we take 12000)
$x_2 \geq 12000$
similarly,
$x_3 \geq 70000$ (trousers)
$x_4 \geq 35000$ (shirts)
$x_5 \geq 53000$ (half t-shirt)
$x_6 \geq 14000$ (shorts)
$x_7 \geq 27000$ (full-sleeve t-shirt)

To summarize, the LPP Model is given as:

$$Maximizing\ Z = 1800\,x_1 + 900x_2 + 165x_3 + 200x_4 + 192.5\,x_5 + 180x_6 + 157.5x_7$$

Subject to,

- $5\,x_1 + 1.85x_2 + 1.3x_3 + 1.55x_4 + 1.15\,x_5 + 0.8x_6 + 1.35x_7 \leq 378997.5,$
- $1400\,x_1 + 550x_2 + 270x_3 + 380x_4 + 140\,x_5 + 110x_6 + 200x_7 \leq 79122750,$
- $1900\,x_1 + 900x_2 + 140x_3 + 105x_4 + 75\,x_5 + 60x_6 + 85x_7 \leq 62034000,$
- $1300\,x_1 + 720x_2 + 120x_3 + 90x_4 + 65\,x_5 + 55x_6 + 70\,x_7 \leq 47830125,$

$x_1 \leq 14400,$
$x_2 \leq 14400,$
$x_3 \leq 76800,$
$x_4 \leq 43200,$
$x_5 \leq 62400,$
$x_6 \leq 16800,$
$x_7 \leq 31200,$
$x_1 \geq 12000,$
$x_2 \geq 12000,$
$x_3 \geq 70000,$
$x_4 \geq 35000,$
$x_5 \geq 53000,$
$x_6 \geq 14000,$
$x_7 \geq 27000,$
$x_1, x_2, x_3, x_4, x_5, x_6, x_7 \geq 0$

4. RESULTS

4.1 Model solution

We have used a LPP technique *Simplex Method*. Among the various software packages, we used Solver add-in from Microsoft Excel 2019 to perform the *Simplex Method*.

The optimal solution for an LPP model indicates the optimal number of units of each product that should be produced in order to maximize profit, subject to the given constraints. The optimal solution is given in the Table 4 below.

Table 4. Optimal Solution

Products	Units of each product to be produced	Units of each product to be produced (Rounded-up values)
x_1	14095.966	14096
x_2	14189.77106	14190
x_3	70000	70000
x_4	42471.49282	42472
x_5	62400	62400
x_6	16800	16800
x_7	29804.28124	29805

The solution shows that the company should on an average produce 14,096 suits, 14,190 blazers, 70,000 trousers, 42,472 shirts, 62,400 half T-shirts, 16,800 shorts, and 29,805 full-sleeve T-shirts to maximize their profit. Additionally, the solution provides the maximum profit that can be earned, which is Rs.7,79,18,005.61.

Table 5. Profit After Optimization

Profit After Optimization	
Maximize Z	77918005.61

Table 5 shows us the profit Sunshel Textiles can generate if they were to follow the model presented by this paper.

4.2 Result analysis

We have calculated the current profit earned by Sunshel Textiles on an average in a month by multiplying the profit per unit with the current production of each product.

$$\sum(\text{Average current production} \times \text{profit per unit}) = (13500 * 1800) + (13000 * 900) + (72000 * 165) + (38000 * 200) + (58000 * 192.5) + (15500 * 180) + (28000 * 157.5) = 7{,}38{,}45{,}000`$$

The profit from the current production is calculated to be Rs.7,38,45,000.

Using the optimized model, the maximum profit that the Sunshel Textiles can earn is Rs.7,79,18,005.61. This indicates that there is a difference of Rs.40,73,005.609 between the current profit and the maximum profit that can be earned using the optimized model

On calculating the percentage increase in profit, it is indicated that the Sunshel Textiles has the potential to improve their profit margin by 5.5% by implementing the optimized production plan.
In conclusion, the optimized model provides a production plan that enables the Sunshel Textiles to increase their profit margin significantly.

5. EXTENDING THE MODEL

In order to optimize the production and maximize profits for Sunshel Textiles over the entire year, we have extended our LPP model from a monthly basis to an annual basis. In order to analyze the data extracted from Google Trends and make the predictions for future trends, we have used the following Machine Learning technique.

5.1 GOOGLE trends

Google Trends is a tool provided by Google that allows users to explore the popularity of search queries over a given period of time and in a specific geographic location. It provides insights into what people are searching for and how their interests are changing over time.
It's useful for businesses and researchers to understand demand for products or services in different regions. It provides real-time data and has a large sample size. While it is true that Google Trends does not directly measure actual purchases or sales, it does provide valuable insights into consumer behavior and interests. Google Trends has gained popularity as a prominent source for big data research and applications, owing to several key factors. Its user-friendly interface makes it easy to use, providing valuable insights into consumer interests and behavior for various applications and studies (Jun et al., 2018).
This can be indicative of potential demand, and can help companies like Sunshel Textiles to make informed decisions about their production and marketing strategies.

5.2 Calculation for suits

Table 6 and Table 7 are the trends for suits which help us determine the relative change in interest among the general population with regarding the item, Suits. These datapoints are based on the visits on e-commerce websites via Google for the products in question.
Following are a few snippets of the front 8 rows and the last 5 rows of the table 6 obtained from Google Trends which has been referred for further analysis,
The first 8 rows of the table 6.

Date	Trend	Year	Month
08/04/18	73	2018	April -23
15/04/18	71	2018	April-23
22/04/18	72	2018	April-23
29/04/18	65	2018	April-23
06/05/18	64	2018	May-23
13/05/18	61	2018	May-23
20/05/18	68	2018	May-23
27/05/18	67	2018	May-23

Table 6. Google Trends Suits Data (head)

The last 5 rows of the table 7.

Date	Trend	Year	Month
05/03/23	69	2023	Mar-23
12/03/23	67	2023	Mar-23
19/03/23	70	2023	Mar-23
26/03/23	74	2023	Mar-23
02/04/23	83	2023	Apr-23

Table 7. Google Trends Suits Data (tail)

5.3 Machine learning

Now we use Machine Learning techniques by incorporating Google trend data to train a Random Forest Regressor model. This model then predicts the average trend for the time period May 2023 to April 2024. The implementation was done using Python programming language.
Random Forest Regressor is an ensemble learning algorithm used for regression tasks. It builds multiple decision trees and combines their predictions to predict continuous numerical values. The randomness in building the trees reduces overfitting and improves accuracy. It is used for predicting prices, sales, and other continuous numeric quantities. (Jain and Kumar 2020).

Month	Average demand
May'23	78.53
June'23	68.59
July'23	66.28
August'23	68.16
September'23	66.38
October'23	82.98
November'23	81.9
December'23	74.35
January'24	72.36
February'24	84.01
March'24	70.19
April'24	80.95

Table 8. Average trends for Suits in May 2023 to April 2024

The table 8 shows the average demand for suits over a 12-month period from May 2023 to April 2024 and the corresponding column displays the average demand for suits in each of those months.
Similarly, we calculated the average demands for blazers, trousers, shirts, half t-shirts, shorts and full-sleeve t-shirts. Now we will see the month wise demand for each of the products for the month of May 2023, in Table 9: We use the values from the Table 8 and calculate their deviation from their average. And then use this number to multiply the "Average Demand" we have from the Table 1 to the respective columns. From the above calculation we get the following table with May'23 appropriate values for "Average Demand".
For example, say we need to predict the demand for Suits for the month of May'23. We refer to Table 8 which will give us average trend for suits for the all months. From that we use the value for the month of June'23, which comes out to be 68.59. We have used the value for the month of June and not May, as the goods that are to be ready by June should be manufactured in the month of May. Similar pattern has been used for all further calculations for the following months. Now in order to find the deviation of this trend value from the annual average, we divide 68.59 with 74.04 which is the calculate average for all the months. And the value we get is 0.926. This states that the demand for the month of May'23 will be 0.926 times the average demand or a 7.74% decrease. Hence to calculate the final value, we multiply average demand for suits, which we get from Table 1 as 12000 with 0.926. The final value we get will be 11115.6. We use the exact same logic to predict the demand for all products for the month of May'23, as seen in Table 9 below.

Product	Fabric Used	Thread	Labor Cost	Overheads	Average Demand	Profit Margin	Production Cap	Monthly Cap	Profit Percent	Current Production
Suit	5	1400	1900	1300	11115.6	30%	600	14400	30	13500
Blazer	1.85	550	900	720	8197.2	30%	600	14400	30	13000
Trousers	1.3	270	140	120	73556	30%	3200	76800	30	72000
Shirts	1.55	380	105	90	35941.5	50%	1800	43200	50	38000
Half t-shirt	1.15	140	75	65	59031.4	55%	2600	62400	55	58000
Shorts	0.8	110	60	55	19027.4	60%	700	16800	60	15500
Full-sleeve t-shirt	1.35	200	85	70	30072.6	45%	1300	31200	45	28000

Table 9. Projected Apparel Production Metrics for May'23

Note: Monthly cap and current production are same as in Table 1.
Similar in section 3, we develop a LPP model from Table 9, Table 2 and Table 3. The only difference between them being the "Average Demand" column.

5.4 Model solution

The Table 10 shows us the optimal solution as calculated using model-2. Table 10 is based on the same idea as Table 4, but different in the sense that it is only applicable for the month of May'23.

Products	Units of each product to be produced	Units of each product to be produced (Rounded-up values)
x_1	14146.55684	14147
x_2	13851.64517	13852
x_3	73556	73556
x_4	39495.71756	39496
x_5	62400	62400
x_6	16800	16800
x_7	30072.6	30073

Table 10. Optimal Solution for May'23

The Table 10 shows us the optimal solution for the month of May'23 as predicted by the model 2. It shows the exact number of units that have to be produced to make the maximum profit possible according to the current demand for the products.

Max Z	77738600.98
Profit At Current Production	73845000
Difference In Profit After Optimization	38,93,601

Table 11. Comparing Current and Optimal Profits

The Table 11 shows us the difference in Profit before and after using the model presented by this paper.The profit from the current production is calculated to be Rs.7,38,45,000.
Using the optimized model for the month of May'23, the maximum profit that the Sunshel Textiles can earn is Rs.7,77,38,600.98. This indicates that there is a difference of Rs.38,93,601 between the current profit and the maximum profit that can be earned.
Calculating the percentage increase in profit, we get an increase of 5.27% from the current profit. This indicates that the Sunshel Textiles has the potential to improve their profit margin in the month of May'23 by 5.27% by implementing the optimized production plan.
In conclusion, the optimized model enables Sunshel Textiles to increase their profit margin.

Similarly, the demand for the rest of the months will be:

Product	Jun'23	Jul'23	Aug'23	Sep'23	Oct'23	Nov'23	Dec'23	Jan'24	Feb'24	Mar'24	Apr'24
Suit	10741.2	11046	10758	13448.4	13273.2	12049.2	11726.4	13615.2	11374.8	13119.6	12727.2
Blazer	6927.6	7111.2	7269.6	9648	17996.4	20308.8	16894.8	17440.8	9781.2	10246.8	10393.2
Trousers	72569	72051	72464	74613	73542	71771	68467	73710	70056	77448	75936
Shirts	34601	36491	35693	39434.5	32984	31216.5	30061.5	37250.5	37247	41030.5	39669
Half t-shirt	57075.7	59269.9	59672.7	52496.5	44657.8	43258.6	41832.9	51335.8	62333.3	63865	59715.1
Shorts	18804.8	18508	18006.8	17767.4	17684.8	17785.6	13651.4	14180.6	16595.6	19027.4	19027.4
Full-sleeve t-shirt	29076.3	30194.1	30399.3	26743.5	22750.2	22037.4	21311.1	26152.2	31754.7	32535	30420.9

Table 12. Projected Demand for the Rest of the Months

The Table 12 shows us the projected demand for each product the sell across the next 11 months.
The decision variables for the rest of the months are presented in table 13.

	Jun'23	Jul'23	Aug'23	Sep'23	Oct'23	Nov'23	Dc'23	Jan'24	Feb'24	Mar'24	Apr'24
x_1	14146	14122	14126	14196	13800	13884	14042	13792	14069	13120	13708
x_2	13911	14004	13971	13664	14400	14400	14400	14400	14258	12240	14400
x_3	72569	72051	72464	74613	73542	71771	68467	73710	70056	76800	75936
x_4	41123	40551	40055	40627	41563	42105	43114	41512	40734	41031	39669
x_5	62400	62400	62400	62400	62400	62400	62400	62400	62400	62400	60093
x_6	16800	16800	16800	16800	16800	16800	16800	16800	16800	16800	16800
x_7	29077	30195	30400	27834	28248	29019	30457	28175	31755	31200	30421

Table 13. Optimal Solution for the Rest of the Months

Similarly, we calculate the maximized profit for each month using our mathematical model:

Months	Maximize z	Current profit	Difference
May'23	77738600.98	73845000	3893600.984
Jun'23	77796312.26	73845000	3951312.262
Jul'23	77812511.6	73845000	3967511.6
Aug'23	77790180.74	73845000	3945180.745
Sep'23	77705187.18	73845000	3860187.179
Oct'23	77730729.86	73845000	3885729.861
Nov'23	77820283.53	73845000	3975283.529
Dec'23	77987355.99	73845000	4142355.99
Jan'24	77722234.65	73845000	3877234.65
Feb'24	77898467.99	73845000	4053467.99
Mar'24	75458516.49	73845000	1613516.486
Apr'24	77480376.82	73845000	3635376.817
Total	930940758.1	886140000	44800758.09

Table 14. Profits Comparison for the Rest of the Months

Through this table 14 we can see that by using our optimized mathematical model over the entire year, this company could considerably increase its profit by Rs.4,48,00,758.09.

6. CONCLUSION

This study is centered on Sunshel Textiles Ltd. The profits comparison between the actual production and suggested production using LPP models show considerable differences. It can be concluded that the apparel company should use LPP to determine their optimal product mix.
Thus, it will be possible to obtain the following results:

6.1 Model

Using the optimized model, the maximum profit that the Sunshel Textiles can earn is Rs.7,79,18,005.61. This indicates that there is a difference of Rs.40,73,005.609 between the current profit and the maximum profit that can be earned using the optimized model.
On Calculating the percentage increase in profit, it is indicated that the Sunshel Textiles has the potential to improve their profit margin by 5.5% by implementing the optimized production plan.

6.2 Extended model

By using our optimized mathematical model over the entire year this company could significantly increase its profit by Rs.4,48,00,758.09.

There is a 5.05% increase in the profit by implementing the optimized production plan.

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