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Production Planning and Controlling by Using Mathematical Programming to Maximize Profit: The Case of Ethiopian Textile Industry

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Abstract: Industrial improvement strategy is expressed by the effective product planning and control use resources at every production stage. The whole process should be carried out in a best possible way and at the lowest cost. Production Manager will have to see that the things proceed as per the plans. This is a control function and has to be carried as meticulously as planning. Both planning and control of production are necessary to produce better quality goods at reasonable prices and in a most systematic manner. The analysis and effective utilization of resources are made sustainable by effective management decision making techniques employed in the industry. A quantitative decision making tool called linear programming , Queue model, Critical path and PERT methods can be used for the optimization problem of product planning/mix. Understanding the concept behind the optimization problem of product mix is essential to the success of the industry for meeting customer needs, service quality/rate, determining its image, focusing on its core business, and inventory management. Apparel manufacturing firms profit mainly depends on the proper allocation and usage of available production time, material, and labor resources. This paper considers 49 Textiles and apparel industrial unit in Ethiopia as a case study. The monthly held resources, product volume, and amount of resources used to produce each unit of product and profit per unit for each product have been collected from the company. The data gathered was used to estimate the parameters of the linear programming model and Queue model. The model was solved using LINGO 16.0/Matlab software. The findings of the study show that the profit of the company can be improved by 49.3 percent, that is, the total profit of Birr 4,445,013.33 per month can be increased to Birr 9,334,528 per month by applying linear programming and Queue models if customer orders have to be satisfied. The profit of the company can be improved by 12.35 percent if the linear programming formulation does not need to consider customer orders. Textle and Apparel industries must produce large quantities in shorter lead times in order to stay alive and compete in the current fashion market. Apparel production needs high level of productivity and production lines should be balanced to get shorter lead time in effective way.

Keywords: Linear Programming, Queue Model, profit.

1. Introduction

The deterioration of the environment is a serious threat to social development. The traditional textile industry is one of the world's major sources of industrial pollution, and related environmental issues are becoming an ever greater concern and labor-intensive [1]. Green production is a business strategy that focuses on profitability through environmentally friendly operating processes [1, 3]. The term green manufacturing can be looked at in two ways: the manufacturing of green products, particularly those used in renewable energy systems and clean technology equipment of all kinds, and the greening of manufacturing, reducing pollution and waste by minimizing natural resource use, recycling almost every aspect of modern life involves Mathematical Modeling and benefits from advances in Industrial Mathematical Modeling [2].

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Green production is a business strategy that focuses on profitability through environmentally friendly operating processes [1, 3]. The production planning and control is the "direction and coordination of firms resources towards attaining the prefixed goals" and helps to achieve uninterrupted flow of materials through production line by making available the materials at right time and required quantity,cost and timeliness of delivery. Thus, if there is a deviation between actual production and planned production, the control function comes into action [2]. The essential steps in control activity are:

- Initiating the production,
- Progressing, and
- Corrective action based upon the feedback and reporting back to the production planning.

Ray wild defines "Production planning is the determination, acquisition/gain and arrangement of all facilities necessary for future production of products" [9]. Some of the factors that affect Production Control are:

- Non-availability of materials (due to shortage, etc.);
- Plant, equipment and machine breakdown;
- Changes in demand and rush orders;
- Absenteeism of workers; and
- Lack of coordination and communication between various functional areas of business.

Thus, if there is a deviation between actual production and planned production, the control function comes into action. The essential steps in control activity are:

(1). Initiating the production,

(2). Progressing, and

(3). Corrective action based upon the feedback and reporting back to the production planning.

Objectives of Production Planning and Control

- Systematic planning of production activities to achieve the highest efficiency in production of goods/services.
- To organize the production facilities like machines, men, etc., to achieve stated production objectives with respect to quantity, quality, time and cost.
- Optimum scheduling of resources.
- Coordinate with other departments relating to production to achieve regular balanced and uninterrupted production flow.
- To conform to delivery commitments.
- Materials planning and control.
- To be able to make adjustments due to changes in demand and rush orders.

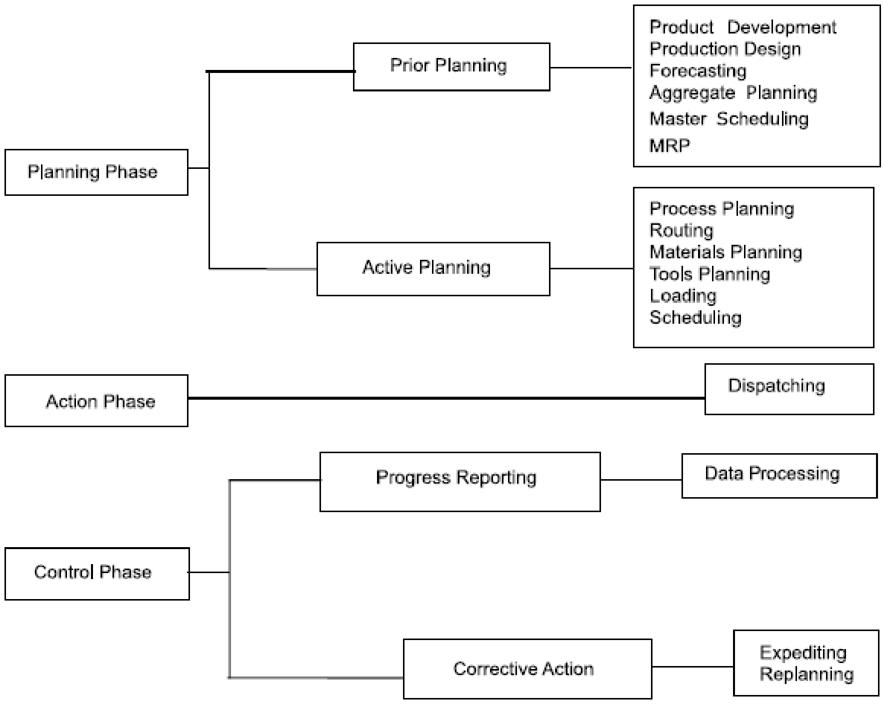

Figure 1. **Phases of production planning and control**

To make a complete Modeling, many Data with different parametric tests have to be done; which means high cost, time taking and more weakness to the person on the work and outcome. Simulation methods can be routinely used across industry to accelerate product development, increase efficiency, and provide fundamental understanding. Used in combination with good analysis and experimentation, Mathematical modeling can drive progress, saving time, cost, effort and resource. Results are tangible, available quickly and project relevant. Operation research can be used to solve real issues and problems and push cutting edge research [3].

Functions of Production Planning and Control

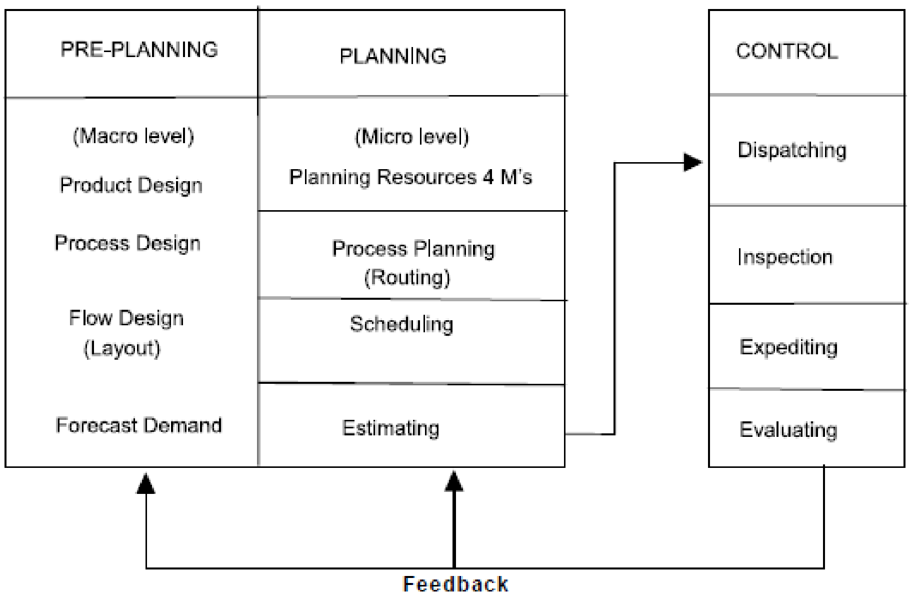

Figure 2. **Functions of production planning and control**

Assessment can be defined as the process of gathering the data and fashioning them into interpretable form for decision-making. It involves collecting data with a view to making value judgment about the quality of a person, object, group or event. Educational assessment is vital in teaching and learning process[8].

2. Methodology

2.1. Data Collection Instruments

Three methods were used to collect the data which were questionnaire, Data on their system and focus group discussion from 13 companies. This research used mathematical programming approach to formulate the decision model with Activity based cost(ABC) data, Theory of constraints(TOC) for the textile companies. This research will clarify the relation between mathematical programming models, TOC and ABC. Managers in the textile companies can applied this decision model to achieve the optimal product-mix under various constraints and to evaluate the effect on profit of input cost, machine hours, labour cost, ovehead cos, other cost, carbon emissions, energy recycling, waste reuse, and material quantity discount. In addition Quantitative and qualitative data will be collected from Ethiopian Textile and Garment Industries. Hence On this research a descriptive survey research design and explanatory research method where both qualitative and quantitative data gathering methods and analysis will be used.

Mathematical Programming Methods

Scheduling is a complex resource allocation problem. Firms process capacity, labour skills, materials and they seek to allocate their use so as to maximize a profit or service objective, or perhaps meet a demand while minimizing costs. The following are some of the models used in scheduling and production control.

- Linear programming model: Here all the constraints and objective functions are formulated as a linear equation and then problem is solved for optimality. Simplex method, transportation methods and assignment method are major methods used here.
- PERT/CPM network model: PERT/CPM network is the network showing the sequence of operations for a project and the precedence relation between the activities to be completed.

  Note: Scheduling is done in all the activities of an organisation i.e., production, maintenance etc. Therefore,all the methods and techniques of scheduling is used for maintenance management [13].

What does critical path signify?

CPM encourages a logical discipline in the planning, scheduling, and control of projects. CPM encourages more long-range and detailed planning of projects. If there is any delay in either starting a critical activity or if the time take for completing a critical activity exceeds the estimated time, the project implementation period will get extended. Thus, the critical activities deserve more attention and control by the project manager [4]. Any delay in critical activity will lead to time-overrun of the project. Since every time overrun invariably results in cost over run, delay in critical activities will also more likely to result in cost-overrun of projects.

- Float is a free time available for an activity
- Total float (TF) = TL(head) − TE (tail) − Duration
- Free float (FF) = TE(head) − TE(tail) − Duration

- Independent float (IF) = TE(head) − TL(tail) − Duration
- Slack of an Event = TL − TE
- The path connecting events with zero slack is the critical path.

The Theory of Constraints (TOC)

The theory of constraints, as proposed by Dr. Eliyahu M. Goldratt in The Goal in 1984, was created as a method of continuous improvement. He believed that each enterprise body is an organic system with its own goals, and there are bound to be constraints in the system that affect the goals. The constraint theory starts from bottleneck management, and moves through the continuous removal of bottlenecks and constraints, thus improving the overall operations and achieving maximum benefits. Since TOC's goal is achieving maximum throughput through short-term optimization procedures for managing resources and eliminating bottlenecks under given overheads and operating expenses [7].

Some researchers have proposed that TOC can be used for product mix decisions in short-term production. Plenert [10] also believed that if TOC is used for multiple resource constraints, the resulting product mix may not be the optimal product-mix, as the determination of the product mix may lead to a bottleneck shiftiness; however, this limitation can be overcome through integer linear programming (ILP) [10]. This study constructs a mathematical programming model that establishes the optimal product mix in the short term through the flexibility of using restricted resources. The use of such restricted resources will affect the results of the ABC costing, which in turn affects the optimal product mix. For example, exceeding the limit of carbon dioxide emissions will increase the carbon tax cost; if it exceeds normal working hours, it will use overtime, which increases the direct labor time with a higher wage rate [11].

TOC: Based on assumption that every system contains at least one constraint at the time that hinders the system from realizing higher profit unless the system accumulate unlimited profit. According to TOC the goals of all companies as economical entities is generate money [7].

- Throughput (T): one unit of product(Xi) in a manufacturing system is = the revenue generated by the system through the production and sales of that product minus the total variable cost (TVC) which is limited to the direct materials that go into that particular product. i.e $T(Xi) = P(Xi) - DM(Xi)$ where P(Xi): selling price and DM (Xi): total cost of the direct materials for product (Xi).
- Throughput the whole system $(TT) = P(Xi) - DM(Xi) * Qi$ where Qi: quantity of product (Xi) sold during the period.
- To maximize the TT, TOC focus on the management of constraints of the system(Having more T and consumes less constraint (S))
- **Objective Function:** The objective function of the production planning model under ABC a is as follows:
  Maximize π = Total Revenue of main product + Revenue of by product − Total material cost − Total direct labor cost − Energy recycling cost saving − Total other fixed cost

$$\pi = TR - TT - F \tag{1}$$

where, $TR = [P_1X_{11} + P_2X_{21} + P_3X_{22} + \beta_1(1-e_1)M + \beta_2(1-e_2)X_{12} + \beta_3 e_3 X_{22}]$; $TT = [L_0 + \eta_1 r_{0t}(Q_1 - G_0)]$; F = fixed cost.

- TOC emphasizes sold product rather than simply output because unsold product does not generate revenue which is the target for maximization [8].
- TOC is equivalent to Conventional and LP in case of a single-constraint(one bottleneck) system and superior to conventional and LP in situations of one bottleneck and one or more local constraints(LC = scarce resource which related to one product only and not subject of competition between all of the products).
- The TOC is built around the contribution margin concept(CM).
- Optimality at product level we have: $CM(Xi) = S(Xi) - DM(Xi) - DL(Xi) - VOH(Xi)$, where
  S(Xi) : selling price for Production i,
  DM(Xi) : direct material needed to produce one unit of product i,
  DL(Xi) : direct labor needed to produce one unit of product i and
  VOH(Xi) : the variable over head cost for one unit of product i.
- Optimality at system level: $TCM = \sum_{i=1}^{n} CM(Xi) * Qi$ where,
  TCM : the sum of the contribution margin for each product multiplied by the number of units sold(tobe sold) of that product.

Activity Based Cost: Activity-based costing provides a more accurate method of product/service costing, leading to more accurate pricing decisions. It increases understanding of overheads and cost drivers; and makes costly and non-value adding activities more visible, allowing managers to reduce or eliminate them [6]. ABC and TOC are used to select optimal production mix. ABC and ABM systen are designed for managers to gather the actual and correct information of price of each sources that is required by each customers, service and product which lead to better cost control and understand the clear view of operations before making any decision [9].

- ABC first collects overhead costs of all the activities of the entire organization and;
- 2^{nd} allocate the cost of those activities to the services,products and customers that are involved in that activity.
- Identifying cost carrier(cost drivers): the reasons behind cost.
- ABC cannot predict profit if the production volume changes.
- ABC views the link b/n resource consumption and activities as absolute, linear and definite.
- Any addition in activities increase the cost and VS, however, in the actual there are discontinuities of costs.
- actually emphasize the requirement to focus and to cut down the cost of complexity of operation(Ronen, B and Geri, N 2005).
- ABC is an accounting method that identifies and assigns costs to overhead activities and then assigns those costs to products. Indirect costs, such as management and office staff salaries, are sometimes difficult to assign to a product.

What are the steps in Activity Based Costing?

- Step 1: Identify the products that are the chosen cost objects.
- Step 2: Identify the direct costs of the products
- Step 3: Select the activities and cost-allocation bases to use for allocating indirect costs to the products for allocating indirect costs to the products.

How to Implement a Simple Activity-Based Costing System

- Look at your overhead costs. Verify that you have enough overhead to be worrying about;
- Identify the big overhead cost.
- Identify the principal activities that use up the overhead costs.Trace the activities to products by using the appropriate measures.

To calculate the per unit overhead costs under ABC, the costs assigned to each product are divided by the number of units produced.

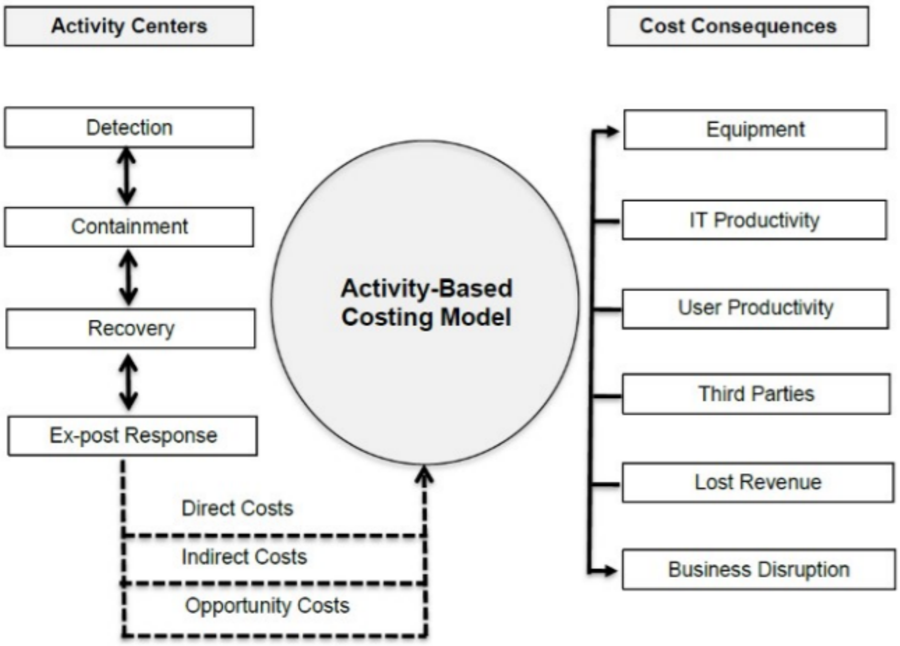

Figure 3.

The Relationships b/n ABC, TOC: ABC can calculate product costs more accurately, while TOC is a step-by-step improvement for bottlenecks to increase profits. In terms of product costing, as TOC is short-term, it uses restricted resources in the production process (for example, total carbon emissions limits, available labor hours and machine hours, restrictions on raw material supply, etc.), which will affect the results of ABC costing, which in turn affects the best product mix. For example, exceeding the limit of carbon dioxide emissions will increase the carbon tax cost. When production takes longer than normal working hours, it is necessary to use overtime, which increases direct labor costs due to the higher wage/income rate [5].

In the case of Industry 4.0, various types of sensors can be installed in a machine, thus, more accurate and reliable Resource and Activity driver data can be collected, which improves the accuracy and immediacy of the ABC cost calculation. On the other hand, the related technologies developed by Industry 4.0 can be applied to the production control of actual production. Under the functional structure of MES, it can respond to the changes in production-related parameters and production resource constraints caused by actual production conditions, and give back information to managers to respond effectively, and adjust the production plan in time. At the same time, it can timely detect the actual situation of production, quality and machine operation, and give back to the manager to take effective improvement measures in time to achieve the planned production target [13].

3. Data Analysis and Interpretation

Unit-Level Direct Labor Cost Function: Assume that overtime work can expand the direct labor resources, and labor is used for handling the material and products. The total cost function of direct labor is the piecewise linear function, as shown in Figure below. The available normal direct labor hours are G_0 and the direct labor hours can be expanded to G_1 with the total direct labor cost respectively being L_0 and $L_0 + m_1 G_1$ at G_0 and G_1. As well as the handling and setup, direct labor is also needed to transfer the products to the next plant. The setup of direct labor hours incudes the time required to replace material or reset programs during each batch start in the dyeing process, like the setup of dyestuff. The total direct labor cost is $L_0 + \eta_1 r_{ot}(Q_1 - G_0)$ in Equation (1), and the associated constraints are shown in Equations (2)-(5):

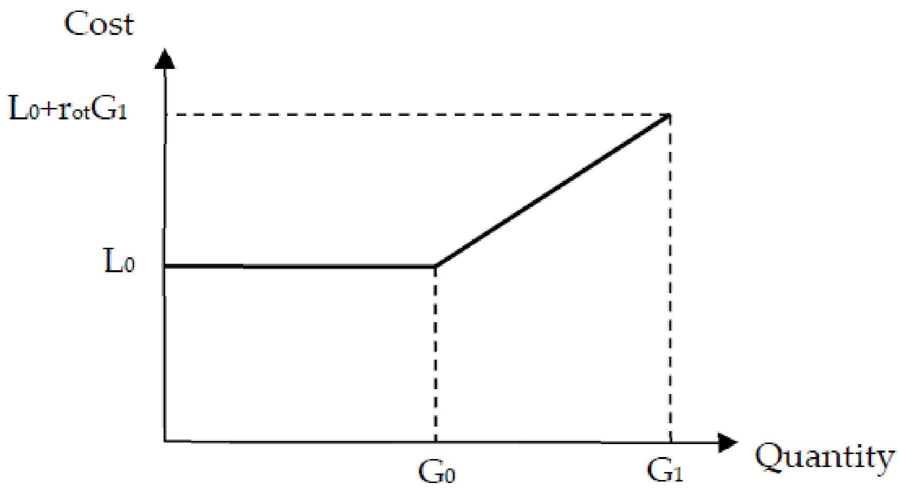

Figure 4. **Direct labor cost function.**

$$Q_0 + Q_1 = l_1 M + l_2 X_{12} + l_3 X_{22} + \mu_i B_i + \mu_j B_j \tag{2}$$

Where $i = 01, 10, 12$ and $j = 20, 23, 30$

$$0 \le Q_0 \le \eta_0 G_0 \tag{3}$$

$$\eta_1 G_0 < Q_1 \le \eta_1 G_1 \tag{4}$$

$$\eta_0 + \eta_1 = 1 \tag{5}$$

Batch-Level Activity Cost Function for Material Handling and Setup Activities:

$$M \le \sigma_{01} B_{01} \tag{6}$$

$$X_{11} \le \sigma_{12} B_{12} \tag{7}$$

$$X_{11} + (1 - e_1) M \le \sigma_{10} B_{10} \tag{8}$$

$$X_{22} \le \sigma_{23} B_{23} \tag{9}$$

$$X_{21} + (1 - e_2) X_{12} \le \sigma_{20} B_{20} \tag{10}$$

$$X_{22} + e_3 X_{22} \le \sigma_{30} B_{30} \tag{11}$$

$$X_{22} \leq \lambda BS \tag{12}$$

Energy Recycl: The textile industry, during the dyeing and finishing processes, needs to generate a lot of heat. It generally uses heat from burning coal, steam boilers, and medium heat boilers and heating furnaces. The use of its high temperature and air heat transfer can enhance the combustion air temperature, and reduce the exhaust temperature to achieve waste heat recovery purposes [14]. However, the textile industry is also a heavy consumer of water [10]. It is therefore evident that water recycling and reuse is also an important wastewater treatment issue [11]. Heat and water are used mainly in the dyeing and finishing process [12]; thus, energy recycling of heat and water will vary quantity of the finished fabric. The energy recycling cost saving for heat and water are C_5RE_h and C_6RE_w, respectively, in Equation (1), and the associated constraints are Equations (13) and (14):

$$RE_h = \rho_1 \times X_{22} \tag{13}$$

$$RE_w = \rho_2 \times X_{22} \tag{14}$$

Where, ρ_1: The relation coefficient between energy recycling of heat and X_{22}; ρ_2: The relation coefficient between energy recycling of water and X_{22}.

Input-Output Relationship: The amount of material input and product output differs because the material suffers loss in the production process, such as in the weaving process. Fabric is made of yarn, and some scrap from the fabric articles will remain that is the input-output coefficient. X_{12} is the quantity of yarn, e_2X_{12} is the quantity of fabric and $(1 - e_2)X_{12}$ is the quantity of scrap fabric, as below:

Production planning model for the data.

$$Max \quad \pi = TR + TT - RE - Q - F \tag{15}$$

Where

$$\begin{aligned} TR &= 97,000X_{11} + 135,000X_{21} + 202,500X_{22} \\ TT &= 570 \times 0.04M + 2100 \times 0.05X_{12} + 2300 \times 0.14X_{22} \\ RE &= (65,000M + 7000m_{22d} + 1800m_{22c} + 1500m_{cem}) \\ Q &= [47,840000 + (170Q_1 - 62560000\eta)] + [60RE_h + 120RE_w] \\ F &= 500,000 \end{aligned}$$

The production planning model for the example data is shown in above Table, which is a mixed integer programming (MIP) model, and the optimal solution is shown in Table, which is obtained by using Lingo 16.0. The optimal solution in the model indicates the optimal product portfolio where the profit is $2,456,100$ from three products and three byproducts. The total revenue is $(3,125,897)$ which is comprised of three products: Draw Textured Yarn $(998,879)$, Greige Fabric $(20,587,745)$ and Finished Fabric $(1,364,000)$. Product quantities are $(3,521.32/ton, 562.47/ton, 17,312.85/ton)m_{22d}(12,854.25)$, $m_{22c}(1564.15)$, and $M(35,547.53)$. Besides,the byproduct revenue of eco-brick is $(2,549,00)(\beta_3e_3X_{22})$ and the energy recycling cost saving for heat and water is $(987,857)(C_5RE_h)$ and $(1,983,489)(C_6RE_w)$, respectively. Three kinds of machine hours relate to false twisting $(35,000)$, weaving $(86,000)$, and dyeing and finishing $(96,645.75)$. Therefore, the mathematical programming in this model combining ABC and TOC can reduce production costs and enhance profit through the efficient distribution of resources.

Sensitivity Analysis of the Quantity Discount of Direct Material: Considering the quantity discount of direct material, this paper divided the material purchase discount pricing into high, medium and low degree levels. This study used three segments of piecewise linear function, as shown in Figure 5. In Equations (15)-(19), this paper replaces the former material cost (C_1M) to become three segments of piecewise discount ($R_1MT_1 + R_2MT_2 + R_3MT_3$). For example, when the amount of material is more than MQ_1, the material cost would become R_1 and the total material cost would be (R_2MT_2). My corporation in this model obtains the highest discount pricing. It indicates that the material cost would be from R_2 to R_3; the quantities that a plant buys and the total cost of materials are shown as (MT_3R_3):

$$\begin{aligned}\pi &= P_1X_{11} + P_2X_{21} + P_3X_{22} + \beta_1(1-e_1)M + \beta_2(1-e_2)X_{12} + \beta_3e_3X_{22} \\ &- [(R_1MT_1 + R_2MT_2 + R_3MT_3) + C_2m_{22d} + C_3m_{22c} + C_4m_{22m}] - [L_0 + \eta_1r_{ot}(Q_1 - G_0)] \\ &- [\delta_1r_{c1}(TC_1 - GC_0) + \delta_2r_{c2}(TC_2 - GC_0)] + C_5Re - F,\end{aligned}$$

$M = MT_1 + MT_2 + MT_3$; $0 \le MT_1 \le \phi_1MQ_1$; $\phi_2MQ_1 < MT_2 \le \phi_2MQ_2$; $\phi_3MQ_2 < MT_3$; $\phi_1 + \phi_2 + phi_3 = 1$.

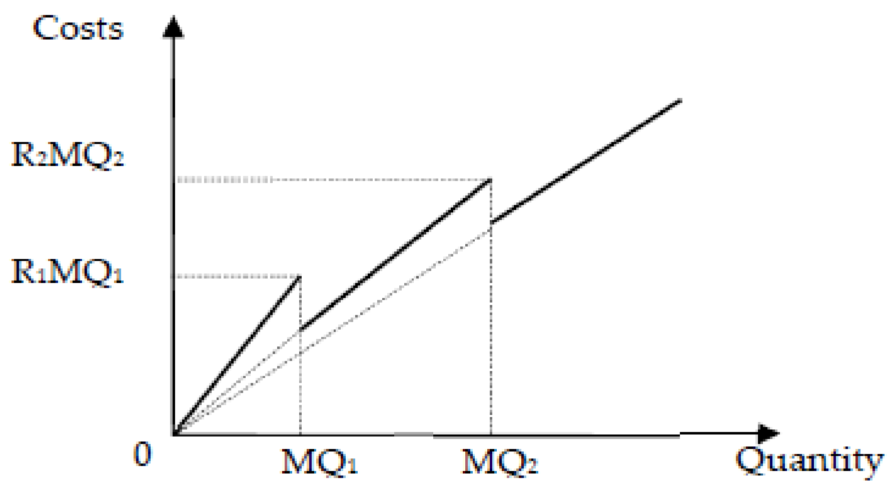

Figure 5. **Direct material cost function**

cost variation Ratio (%)	Normal		Price discount	
	Profit (hundreds)	profit variation Ratio(hundreds)	profit (hundreds)	profit variation Ratio(hundreds)
15	3,235,123	−12.32	3,667,103	−10.14
10	3,730,354	−9.56	3,987,351	−6.79
5	4,001,587	−3.69	4,401,089	−2.01
0	4,321,002	0	4,768,723	0
−5	4,602,178	3.69	4,987,348	2.01
−10	4,874,005	9.56	5,348,679	6.79
−15	5,002,568	12.32	5,355,457	10.14

Table 1. **Table Normal price and price discount**

This research adjusted material cost (M) in the sensitivity analysis to estimate the impact on normal material cost with and without discount pricing. The price is altered by 5 percent from (-15 to 15) percent. If (M)'s cost is raised 5 percent, the profit will be from (4,321,002 to 4,001,587), and if the cost that includes discount pricing is changed, that profit would decrease from (4,768,723) to (4,401,089). However, when price of X_1 is decreased by 12 percent to, the quantities of X_{22} would become zero; when X_2 is raised to (63487) except for continuing decreased volume of X_1 is (52,333) but changed rate to -10 percent, it is not too different from the original price for the product mix. On the other hand, if a corporation needs to increase profit, it only needs to increase the price of X_1 because the increased price would not reduce the quantities of products. However, when prices are down, this not only cuts down the quantities of all of products, but also reduces a firm's profit. Therefore, the changed cost of material in the textile industry would not result in a significant change to a corporation's profit even if costs decrease by 15 percent; however, the profit only increased. When the profit variation ratio (percent) changed to 10.14 percent, this means that when the material cost changes, the corporation's profit would not increase or decrease significantly; even when considering discount pricing, the result is the same as the normal material cost. The data collection procedure was quantitative in nature and relied on face to face interviews with members of the management and line supervisors in accordance with existing records and merely amended to finalize the concepts relevant to the resources held and consumed and the production volume of each product in the case company. The relevant information on the amount of resources used per unit of each product during the month is summarized in Table.

Products (T Shirts and Pants)	Resource used per unit of products						
	Fabrics (Gram)	Threads (Meter)	Labor (Birr)	Overheads (Birr)	Cutting (Min)	Sewing (Min)	Finishing (Min)
Polo T Shirts	3780	2760	11.6	139.2	21.6	271.2	24
Basic T Shirts	2400	1320	60	229.2	13.2	64.8	15.6
Mock Neck T Shirts	2340	1680	75.6	241.2	20.4	124.8	22.8
singlets	2160	1200	49.8	198	13.2	54	15.6
Short Pants	3360	2400	90	450	31.2	241.2	31.2
Total	14040	9360	287	1257.6	99.6	756	109.2

Table 2. **Resources needed per unit of product**

The ability to use resources (resource utilization) was recorded as the major constraints in the case apparel manufacturing unit. Seven constraints (fabrics, thread, labor, overheads, cutting, sewing, and finishing time) and five costumer orders for T-shirt products have been identified. Out of the resources used by the case apparel company, the major items held and consumed are shown in Table 3.

S. No.	Resources			
	Resource Type	Measurement Unit	Held Value	Consumption Value
8.	Fabrics	kg	463980	246322.5
9.	Threads	Meter	319657440	1594644
10.	Labor	Birr	12108096	7089180
11.	Overheads	Birr	59752968	25398300
12.	Cutting	h	69240	27845.04
13.	Sewing	h	534060	200468.4
14.	Finishing	h	74340	30996

Table 3. **Average monthly resources held and consumed in quantity/value terms**

The demand and profit earned from each product during the month for the case apparel company are depicted in Table 4.

No.	Polo T Shirts	Basic T Shirts	Mock Neck T Shirts	Singlets	Short Pants
Demand	190632	286992	159828	308004	154368
Profit per Unit	50.64	43.44	41.16	37.2	81

Table 4. **Demand and profit earned**

Model Formulation: In formulating a given decision problem in mathematical form, one should try to comprehensively understand the problem (i.e., formulate a mental model) by carefully reading and rereading the problem statement. While trying to understand the problem, the decision maker may decide that the model consists of linear relationships representing a firm's objectives and resource constraints. However, the way I approach the problem is the same for a wide variety of decision making problems, and the size and complexity of the problem may differ. An LPP model consists of the following parameters:

An LPP model consists of the following parameters:

- Decision variables that are mathematical symbols representing levels of activity of an operation.
- The objective function that is a linear mathematical relationship describing an objective of the firm, in terms of decision variables, that is to be maximized or minimized.
- Constraints that are restrictions placed on the firm by the operating environment situated in linear relationships with the decision variables.
- Parameters/cost coefficients that are numerical coefficients and constants used in the objective function and constraint equations.

General Form of the Linear Programming Model: In general, if $C = (c_1, c_2, ..., cn)$ is a tuple of real numbers, then the function f of real variables $X = (x_1, x_2, ..., x_n)$ defined by

$$f(X) = c_1x_1 + c_2x_2 + ... + c_nx_n. \tag{16}$$

is known as a linear function. If g is a linear function and $b = (b_1, b_2, ..., b_n)$ is a tuple of real numbers, then $g(x) = b$ is called a linear equation, whereas $g(x)(\leq, \geq)b$ is called a linear inequality. A linear constraint is one that is either a linear equation or a linear inequality. A linear programming problem is one which optimizes a linear function subject to a finite collection of linear constraints. Any LPP having n decision variables can be written in the following form:

$$MaxZ = \sum_{j=1}^{n} C_jX_j \tag{17}$$

Subject to

$$\sum_{i,j=1}^{m,n} a_{ij}X_j(\leq, =, \geq)b_i \tag{18}$$

$$X_j \geq 0 \tag{19}$$

where C_j, a_{ij}, b_i are constants. Common terminology for the aforementioned linear programming model can now be summarized as follows. The function, being optimized (maximized or minimized), is referred to as the objective function. The restrictions normally are referred to as constraints. The information collected from the case company in addition to the sales and other operating data was analyzed to provide estimates for LPP model parameters. To set up the model, the first level decision variables on the volume of products to be produced were set.

- x_1 = number of Polo T Shirts
- x_2 = number of basic T-shirts
- x_3 = number of mock neck T-shirts
- x_4 = number of singlets

- x_5 = number of short pants
- Z = total profit during the month

Now, the linear programming model, maximizing the total profit is:

Model Solution: A powerful linear programming problem solving technique is the simplex method. Among the various software packages, LINGO 16.0 software was used to hold the simplex procedures. The global optimal solution report for this model is as follows.

Objective value:	9,334,528	Variable	
Infeasibilities:	0	Reduced cost	Value
Total solver iterations:	10	2	9,334,528
Elapsed run time seconds:	12.03	X_1	180000
Model class:	LP	X_2	1227453.6
Total variables:	6	X_3	162000
Nonlinear variables:	0	X_4	150000
Integer variables:	0	X_5	193200
Total constraints:	14		
Nonlinear constraints:	0		
Total nonzero:	47		
Nonlinear nonzero:	0		

Table 5.

Row	Slack or Surplus	Dual Price
1	9334527.600000000	1.000000000
2	0.000000000	1.000000000
3	49103232.000000000	0.000000000
4	66917520.000000000	0.000000000
5	0.000000000	0.876363600
6	22774404.000000000	0.000000000
7	1537480.800000000	0.000000000
8	14963484.000000000	0.000000000
9	1499589.600000000	0.000000000
10	0.000000000	5.704545000
11	797853.840000000	0.000000000
12	0.000000000	0.671090900
13	0.000000000	0.524545500
14	0.000000000	0.322727300

Table 6.

Here, there was a difference between the LPP solutions obtained to satisfy customer orders using LINGO 16.0 and actual production in Table 3. In the former case, the product mix was Polo T-shirts, basic T-shirts, Mock neck T-shirts, singlets, and short pants with volumes of 140,000.00, 1,227,453.60, 162,000.00, 150,000.00, and 193,200.00 respectively, and with a total profit of Birr 9,334,527.6 per month upon selling. In the latter case, the product mix was Polo T-shirts, basic T-shirts, mock neck T-shirts, singlets, and short pants with optimal volumes of 180,000.00, 429,600.00, 62,000.00, 150,000.00, and 193,200.00 respectively, and with a total profit of Birr 4,445,013.333 per month. At optimality, resources consumed by the LINGO 16.0 software result were compared with the customer orders during the month. In this case, the profit of the company could be improved by 49.3 percent. From Table, the monthly consumption values of customer orders for each available resource were gathered from the company's records. These consumption values and LPP consumption values are summarized in Table . The ratios of monthly consumption of the resources held were calculated to find the percentage usage by each T-shirt style.

No.	Resources Held per Month			Monthly Resources Consumption		Percentage (%) of Usage	
1.	Type	Unit	Value	Customer order	LPP	Customer order	LPP
2.	Fabrics	Gram	79,330,000	45,053,742	69,146,128	56.8	87.16265
3.	Threads	Meter	55,276,260	26,577,400	42,123,320	48.1	76.20508
4.	Labor	Birr	2,818,416	1,181,530	2,018,016	41.9	71.60107
5.	Overheads	Birr	9,959,188	4,233,050	6,163,094	42.5	61.8835
6.	Cutting	Min	773,004	278,450	436,152	36	56.42305
7.	Sewing	Min	5,742,672	2,004,688	2,846,686	34.9	49.57076
8.	Finishing	Min	759,256	309,964	493,468	40.8	64.99368

Table 7. **Monthly consumption by LPP techniques and customer order production**

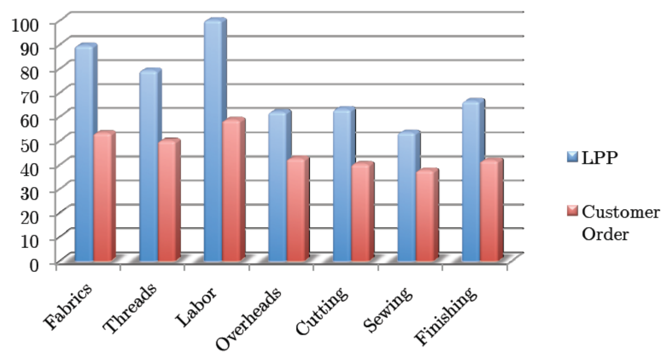

Figure 6. **Comparison of customer order and LPP production resources utilization**

Here, an analysis has been made without considering customer orders to develop an LPP model using monthly consumption of resources. The monthly consumption of each resource values are given under the left-hand side column in Table 5, which can be used as required for the constraints.

Material Type	Quarters				Total
	1st	2nd	3rd	4th	
Spinning					
Cotton	42,652,362	42,652,362	42,652,362	42,652,362	170,609,448
Polyester	11,235,200	11,235,200	11,235,200	11,235,200	44,940,800
Wearing					
Sizing chemicals	4,689,267	4,689,267	4,689,267	4,689,267	18,757,068
Processing					
Chemicals	9,966,840	9,966,840	9,966,840	9,966,840	39,867,360
Dyestuffs	5,888,354	5,888,354	5,888,354	5,888,354	23,553,416
Knit Dyeing					
Chemicals	3,175,786	3,175,786	3,175,786	3,175,786	12,703,144
Dyes	6,328,235	6,328,235	6,328,235	6,328,235	25,312,940
Garment					
Accessories	13,562,773	13,562,773	13,562,773	13,562,773	54,251,092
Chemicals	802,338	802,338	802,338	802,338	3,209,352
Engineering					
Water treatment chemicals	463,123	463,123	463,123	463,123	1,852,492
Total	98,764,278	98,764,278	98,764,278	98,764,278	395,057,112

Table 8. **Quarterly materials requirement plan for 2011 E.C or 2019 G.C (Value in Birr)**

Costs incurred for products under the processes of engineering, selling and distribution, and administrative and general is assumed to be the same for all processes of manufacturing textile and non-textile products. The basis for this assumption is because these processes have same value and application to all processes. From Table, the costs of constraints (material, labor and overheads) were found. Then, the percentages of share of each constraint with respect to the total value of the three constraints of each product were determined exclusively. This is illustrated by Table 6 as shown below. The total material cost is the summation of direct and indirect materials costs. In the same manner, the total labor cost is also the summation of direct and indirect labors costs. The total costs incurred at each process to produce the corresponding products for the last year were calculated. The Table 5 shows the types of products and their costs at the corresponding processes. The costs of processes would be costs of the products under the respective processes if all constraints were consumed at processes to produce the respective products. For example, 181,988,211.03 birr would be cost of yarn as if no further process beyond yarn with the resource already considered.

S.No	Type of Product	The Cost Parameter	Unit Measurement	Annual Value (in Birr)	Percent of Share
1	Yarn	Material	Kilogram	253472816.9	0.7
		Labor	Number	21345956.38	0.06
		Overhead	Number	89157648.82	0.24
2	Fabric	Material	Kilogram	266235053.9	0.66
		Labor	Number	28423109	0.07
		Overhead	Number	110115370.4	0.27
3	CM	Material	Kilogram	306671367.8	0.67
		Labor	Number	30217140.66	0.06
		Overhead	Number	123794542.5	0.27
4	Knit Garment	Material	Kilogram	331720866.5	0.65
		Labor	Number	41064310.62	0.08
		Overhead	Number	139056389.9	0.27
5	Woven Garment	Material	Kilogram	342387691.5	0.52
		Labor	Number	86386624.24	0.13
		Overhead	Number	232108772.6	0.35

Table 9.

S.N	Product Name	Unit Measurement	Annual Sales	Unit cost	Unit profit	Market Location
1	Yarn	Kilogram	83400	72.77	10.92	Local
2	Fabric	Meter	9557912	30.58	4.59	Local & Export
3	CM	Pieces	377912	23.82	3.57	Export
4	Knit Garment	Pieces	12286824	22.99	3.45	Local & Export
5	Woven Garment	Pieces/set	4211400	141.4	21.21	Local & Export

Table 10.

The unit prices are an average unit prices calculated by dividing the total annual sales value in birr of the product to the annual sales quantity or volume. According to the standard of the company, the profit of each product is 15 percent of the overall cost of the product. In this manner, costs as well as profits of each product were determined. Why we were forced to go through this way was due to the absence of required cost data of each product. Simply, the data related to the sales volumes and sales values in terms of birr were available from the company. After determining the costs of products using the above formula as shown in table 8, the unit cost of each constraint were also determined using the percentage of share of each constraint with respect to the others. And, values are provided in Table 8.

4. Conclusion

The model was solved using LINGO 16.0/Matlab software. The findings of the study show that the profit of the company can be improved by 49.67 percent, that is, the total profit of Birr 4,445,013.33 per month can be increased to Birr 9,334,528.3

per month by applying linear programming and Queue models if customer orders have to be satisfied. The profit of the company can be improved by 6.35 percent if the linear programming formulation does not need to consider customer orders. Use of an operational research technique in the production time horizon helps the company to improve its objective. On the other hand, as a result of the model developed, the maximum profit of the company would be 67.356 million ETB with product mix of 0.56 unit of yarn, 0.54 unit of fabric, 0.62 unit of CM, 7.25 units of knit garment, and 1.25 unit of woven garment product. And, the profit according to the new model is highly greater than the current profit level by more than 22.21 million ETB annually. After accomplishing the research, the following recommendations are forwarded towards to the company and researchers. Operation research is tried to find out an optimum value of profit of products. Therefore, this tool should also be applied for the optimization of other products which are going to be produced by the company for better profitability. This research is the corner stone of applying different profit planning techniques for being more profitable. So, other researches should be done on optimization of resources under production of textile and non-textile products.

4.1. Recommendations

Based on the results of this study the following points are recommended.

- The factory loses opportunities in capacity and resource utilizations, improving the resource allocation helps to minimize the overall cost.
- To be able to produce garments in efficient and competitive way factory need to adapt best practices which help to improve productivity.
- In order to improve productivity of the lines, company will be beneficiary by review and implement the proposed productivity improvement scenarios.
- Arranging regular training programs on productivity improvement will help company to improve the productivity of workers.

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