Application of Linear Programming Techniques to Determine the Type and Quantity of Textile Dyed Fabrics

Gera Workie¹, Abebaw Bizuneh ², Senait Asmelash ³
Ethiopian Institute of Textile and Fashion Technology
Bahir Dar University

Abstract
The positive or negative outcome that a firm experiences, depends mostly on the ability of making appropriate decision. The particular area of this research interest is, however, relies on the application of linear programming techniques for textile dyed fabrics to create efficient resource utilization mechanism for textile sector to improve their resource utilization and profitability, taking one of the textile share company as a case study. This share company produces eight textile finished dyed fabrics. The monthly availability of resources utilized to produce all of textile dyed fabrics, and the total cost per meter of fabric of each products have been collected from the case company. The data gathered was mathematically modeled using a linear programming technique which is a practical analysis process and a holistic decision support tool, and solved using Microsoft-Excel solver. Since linear programming offer many advantages to managers in allocating available resources to produce at a minimum cost and pointing out underemployed resources, the computational study of the approaches makes them to provide faster decision on the type and amount of textile dyed fabrics to be produced that yield more income than strategies obtained from trial and error methods to be improved by 72.63% and 65.91%.

Keywords: Cost minimization, Excel Solver, Gross income, Linear Programming, resource utilization, Textile Dyed Fabrics

Introduction
Companies in the world including Ethiopia are continuously faced with wastages of production inputs which result in low capacity utilization. Limited resources must be allocated properly among various products that a firm produces. A company making choices would follow the assumption of purposeful behavior with minimum cost to yield more gross income. Income of the company can only grow if management decisions at the firm level result in boosted output through cost minimization of required resource inputs. Thus, firm managers are always seeking for the right decisions so as to meet their objectives which mainly revolve on how best to increase gross income. However, adopting and using linear programming model in finding solutions to problems in textile industry remain sporadic since production strategy is based on trial and error methods. Most literature in economic development supports the view that linear programming problem, henceforth LPP, is a practical analysis process and a holistic decision support tool that offers many advantages to managers in allocating available resources to produce at a minimum cost and pointing out underemployed resources.

Problem Statement
The case company has dyeing fabrics process flow of work starting from receiving customer orders to packaging through the entire process of roll to batch, half bleaching, wash, dyeing, stentering, calendaring, inspection and packaging. Currently, the case company produces dyed fabrics which are Local sheet 160, Export kid 220, Export kid 160, Local sheet 190, Local sheet 240, Export 160, Local sheet 120 and Export 190. It is a testing task for the manager of the company to identify the type and quantity of products which guarantee more gross income with efficient resource utilization at a minimum cost for the company. The problem addressed here is to determine the type and quantity of dyed fabrics to be produced by the company for efficient resource utilization that can enhance the returns of the company through the application of linear programming technique.
Objective

The objective of this study is to apply linear programming in determining the type and quantity of textile dyed fabrics at minimum costs of resources that yield more gross income.

Review of Literature

Decision making is the study of determining and choosing among options or alternatives based on the preferences and values of the individual. An important factor in decision making is the existence of choices and options \(^{[1]}\). Every manufacturing company employs its resources properly to undertake the manufacturing activities within the organization. Such as, in an allocation problem, when there are a number of activities to be performed, alternative ways of doing them, and handling those limited resources or facilities to the corresponding required outputs. A manufacturing company’s survival in an increasingly competitive market closely depends upon its ability to produce highest quality products at lowest possible cost \(^{[2]}\). In manufacturing ambitious companies, everything is done to ensure smooth production and low costs. Managers must fully understand and continuously try to improve the capabilities and outlook of those gross income providing techniques. A big problem faced by managers during their management is how best to combine these resources and activities in an optimal manner so that the overall efficiency is optimized \(^{[3]}\). Among those classical applications of a linear programming procedure one is the type and quantity of products determination. Commercial applications were begun in 1952 by Charnes, Cooper and Mellon with their optimal blending of petroleum products to make gasoline. According to \(^{[4]}\), this is known as optimization problem, and can be approached using mathematical programming. Different products in a company require distinct amount of resources at their production stages. They also have different production costs and conditions which lead to specific revenues and, therefore, have unlike unit profits. In such condition, the linear programming technique will be used to determine the product mix that will maximize the total profit. It is one of the most widely used operations research tools to determine optimal resource utilization \(^{[5]}\). Linear programming algorithm is a mathematical device started in 1939 by Kantorovich and developed and extended by an American mathematician, \(^{[6]}\) for planning the diversified activities of the U.S. Air Force connected with the problem of supplies to the Force. Afterwards, he suggested this approach for solving business and industrial problems where both the objective and the constraints are linear. Applications quickly spread to other commercial areas and soon eclipsed the military applications which started the field. The simplex technique was introduced by George Dantzig, in 1947. It is the fundamental pillar for solving LPP. Even though, there have been many modifications to the method, especially to take advantage of computer implementations, the essentials features are still the same as they were when the method was invented. Nowadays, Computer programs and spreadsheets are available to handle the simplex calculations (Online Tutorial). The LPP then becomes that of allocating the scarce resources to the products in a manner such that profits are at maximum and/or costs at minimum \(^{[7]}\).

The principal types of application of LPP models are categorized under three headings, namely: blending and mix determination problems, planning and scheduling problems and distribution cost problems \(^{[8]}\). He also notes other types of applications such as plant location decisions, personnel allocation problems, and the analysis of a multi-plant production system to determine whether or not certain plants should be shut down as a result of high cost of production. On the other hand, \(^{[9]}\) assert that although allocating resources to activities is the most common type of application, LPP has numerous other important applications as well.

Linear programming is defined as the problem of optimizing a linear objective function of several decision variables subject to a set of linear equality or inequality circumstances. According to \(^{[10]}\), these and many other optimization decisions can be well handled by modern linear programming modeling procedures via appropriate problem formulation and equation fittings. It refers to a planning, managing and controlling process in rationing scarce resources-labor, direct materials, machines, capital, and indirect materials-in the optimal manner so that to get more gross income. A particular area of this research interest is, however, relies on the application of linear programming techniques in determining the type and quantity of textile dyed fabrics at minimum costs of resources that yield more
gross income. In our case, Bahir Dar textile Share Company is known for producing 100% cotton dyed fabrics based up on the customer specifications and orders by the strategy trial and error method. To expand its market share locally and internationally improved management of production and awareness of resources utilization is needed so as to earn more gross income.

**Linear Programming Model Formulation**

Any linear programming model should have three specifications, namely: objective function, constraints, and non-negativity requirement [3]. As [11] stated, Objective function is simply a mathematical statement expressing the relationship between the items the decision maker wishes to optimize and the level of operation of the decision variables in the problem. It is usually preceded by either maximize or minimize depending on whether the item under consideration is to be maximized or minimized. In addition, LPP must operate within the limits of restrictions placed upon the problem, which the decision maker must always take into consideration. In any linear programming problems, and particularly in the product mix problems, the values of decision variables must be non-negative real numbers.

**Model Directory**

The generalized minimization LPP having \( n \) decision variables can be formulated as follows:

\[
\text{Minimize } W = \sum_{i=1}^{n} C_i X_i \\
\text{Subject to }
\sum_{j=1}^{m} a_{ij} X_j \geq b_i, \quad i=1, \ldots, m \\
X_j \geq 0, \quad j=1, \ldots, n
\]

where \( C_i \), \( a_{ij} \) and \( b_i \) are constants.

Common terminology for the above LPP can now be summarized as follows. The function being minimized, \( W = C_1 X_1 + C_2 X_2 + \cdots + C_n X_n \), is referred to as the objective function. The restrictions normally are referred to as constraints. The first \( m \) constraints (those with a function of all the variables \( a_{ij} X_1 + a_{ij} X_2 + \cdots + a_{ij} X_n \) on the left-hand side) are sometimes called functional constraints (or structural constraints). Similarly, the \( X_j \geq 0 \) restrictions are called non-negativity constraints (or non-negativity conditions).

Any vector \( X_j \) satisfying the constraints of the LPP is called feasible solution of the problem [12, 13, 14]. In this we use the following vocabulary for the solution. A feasible solution is a solution for which all the constraints are satisfied. An infeasible solution is a solution for which at least one constraint is violated. Before attempting to obtain the solution of the LPP, it must be expressed in standard form with the following characteristics.

- All the constraints are expressed in the form of equations except the non-negativity constraints which remain inequalities
- The right-hand-side of each constraint equation is non-negative
- All the decision variables are non-negative
- The Objective function is of maximization or minimization type

In our case, the problem is to find the values of the decision variables \( X_j \) which minimize the objective function \( W \) subject to the \( m = 8 \) constraints and the non-negativity restriction on the \( X_j \) variable. The resulting set of decision variables which minimize the objective function is called the optimal solution. The optimal solutions have been generated by the Microsoft-Excel solver and compared with the on hand company's performance of resource utilization and gross income. At the end, conclusions have been made regarding the findings of the study.

**Data and Sources**

The Sources of data for this research is the personal interview and records of production and operational plan of May, 2015 of Bahir Dar Textile S. Company in Amhara Region. To make it simpler, we select this particular company on the readiness to release significant information for the purpose of this study.
Data Analysis
This segment of the paper analyses the data collected from personal interview and rescored at the company by contacting various operational information and publication of the textile manufacturing company. The following tables try to summarize the labor Hours (which is given in Quantity), Major inputs for production and sales (which is given in value terms Birr Ethiopian currency) of this textile manufacturing industry to provide estimates for Linear Programming model parameter. The product mix that ensures optimum profit was obtained using the mathematical model techniques called Excel Solver, the solution of which included the sensitivity analysis. Bahir Dar Share Company produces dyed fabrics. The cost per meter of fabric for each of the eight types of dyed fabrics and its available resources for the month may, 2015 are given in the accompanying table:

Table 1: The cost per meter of dyed fabrics planned and cost for resources Birr value (month May, 2015)

<table>
<thead>
<tr>
<th>Description</th>
<th>Local Sheet</th>
<th>Export kid</th>
<th>Export kid</th>
<th>Local Sheet 1</th>
<th>Local Sheet 2</th>
<th>Export 160</th>
<th>Local Sheet 120</th>
<th>Export 190</th>
<th>Planned cost Birr value During the Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grey Fabric/linear mtr</td>
<td>16.44</td>
<td>20.64</td>
<td>22.64</td>
<td>18.10</td>
<td>17.64</td>
<td>20.72</td>
<td>17.63</td>
<td>25.27</td>
<td>33269450.52</td>
</tr>
<tr>
<td>(incl. wastage 3%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct labor</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>485186.24</td>
</tr>
<tr>
<td>Indirect labor</td>
<td>0.288</td>
<td>0.288</td>
<td>0.288</td>
<td>0.288</td>
<td>0.288</td>
<td>0.288</td>
<td>0.288</td>
<td>0.288</td>
<td>481929.316</td>
</tr>
<tr>
<td>Stores</td>
<td>0.197</td>
<td>0.197</td>
<td>0.197</td>
<td>0.197</td>
<td>0.197</td>
<td>0.197</td>
<td>0.197</td>
<td>0.197</td>
<td>329859.465</td>
</tr>
<tr>
<td>Chemical Consumption</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>0.83</td>
<td>1388636.48</td>
</tr>
<tr>
<td>Power</td>
<td>1.105</td>
<td>1.105</td>
<td>1.105</td>
<td>1.105</td>
<td>1.105</td>
<td>1.105</td>
<td>1.105</td>
<td>1.105</td>
<td>1848726.88</td>
</tr>
<tr>
<td>Steam Cost</td>
<td>1.315</td>
<td>1.315</td>
<td>1.315</td>
<td>1.315</td>
<td>1.315</td>
<td>1.315</td>
<td>1.315</td>
<td>1.315</td>
<td>2200068.64</td>
</tr>
<tr>
<td>Packing &amp; Inspection</td>
<td>0.126</td>
<td>0.126</td>
<td>0.126</td>
<td>0.126</td>
<td>0.126</td>
<td>0.126</td>
<td>0.126</td>
<td>0.126</td>
<td>210360.9021</td>
</tr>
<tr>
<td>Depreciation(bld+mach)</td>
<td>1.876</td>
<td>1.876</td>
<td>1.876</td>
<td>1.876</td>
<td>1.876</td>
<td>1.876</td>
<td>1.876</td>
<td>1.876</td>
<td>3138653.056</td>
</tr>
<tr>
<td>Total Cost per meter of Fabric</td>
<td>20.08</td>
<td>24.28</td>
<td>26.28</td>
<td>21.74</td>
<td>21.29</td>
<td>24.36</td>
<td>21.27</td>
<td>28.91</td>
<td></td>
</tr>
</tbody>
</table>

Present Model Formulation
The model for use in the present study is formulated by setting the number of decision variables is equal to eight, m = 8. To determine the optimal number of textile dyed fabrics required to be produced at a minimum cost by the textile company is defined as follows:

\[ X_1 = \text{Units of meter fabric Local Sheet 160 to be produced} \]
\[ X_2 = \text{Units of meter fabric Export kid 220 to be produced} \]
\[ X_3 = \text{Units of meter fabric Export kid 160 to be produced} \]
\[ X_4 = \text{Units of meter fabric Local Sheet 190 to be produced} \]
The problem of this study is to minimize total cost which can be expressed as:

\[
W = \text{total cost in Birr to produce these eight products}
\]

Subject to the constraints

\[
X_1 = \text{Units of meter fabric Local Sheet 240 to be produced}
\]
\[
X_2 = \text{Units of meter fabric Export 160 to be produced}
\]
\[
X_3 = \text{Units of meter fabric Local 120 to be produced}
\]

\[
W = 0.08X_1 + 24.28X_2 + 26.28X_3 + 21.74X_4 + 21.29X_5 + 24.36X_6 + 21.27X_7 + 28.91X_8
\]

\[
\begin{align*}
\text{Grey Fabric/linear mtr (incl. wastage 3\%)} & : 16.44X_1 + 20.64X_2 + 22.64X_3 + 18.10X_4 + 17.64X_5 + 20.72X_6 + 17.63X_7 + 25.22X_8 \geq 33269450.52 \\
\text{Direct labor} & : 0.29X_1 + 0.29X_2 + 0.29X_3 + 0.29X_4 + 0.29X_5 + 0.29X_6 + 0.29X_7 + 0.29X_8 \geq 485186.24 \\
\text{Indirect labor} & : 0.2888X_1 + 0.2888X_2 + 0.2888X_3 + 0.2888X_4 + 0.2888X_5 + 0.2888X_6 + 0.2888X_7 + 0.2888X_8 \geq 481929.3176 \\
\text{Stores} & : 0.197X_1 + 0.197X_2 + 0.197X_3 + 0.197X_4 + 0.197X_5 + 0.197X_6 + 0.197X_7 + 0.197X_8 \geq 329859.4645 \\
\text{Chemical Consumption} & : 0.83X_1 + 0.83X_2 + 0.83X_3 + 0.83X_4 + 0.83X_5 + 0.83X_6 + 0.83X_7 + 0.83X_8 \geq 138863.48 \\
\text{Power} & : 1.105X_1 + 1.105X_2 + 1.105X_3 + 1.105X_4 + 1.105X_5 + 1.105X_6 + 1.105X_7 + 1.105X_8 \geq 1848726.88 \\
\text{Steam} & : 1.315X_1 + 1.315X_2 + 1.315X_3 + 1.315X_4 + 1.315X_5 + 1.315X_6 + 1.315X_7 + 1.315X_8 \geq 2200068.64 \\
\text{Packing & Inspection} & : 0.126X_1 + 0.126X_2 + 0.126X_3 + 0.126X_4 + 0.126X_5 + 0.126X_6 + 0.126X_7 + 0.126X_8 \geq 3138653.056 \\
\text{Depreciation (bld+mach)} & : 1.876X_1 + 1.876X_2 + 1.876X_3 + 1.876X_4 + 1.876X_5 + 1.876X_6 + 1.876X_7 + 1.876X_8 \geq 0
\end{align*}
\]

The above LP problem is solved using Microsoft Office Excel (2007) a computer software package. Results obtained for optimal activity pattern and resource allocation in Birr value are displayed.
<table>
<thead>
<tr>
<th>Constrains</th>
<th>Name</th>
<th>Cell Value</th>
<th>Formula</th>
<th>Status</th>
<th>Slack</th>
</tr>
</thead>
<tbody>
<tr>
<td>SL$6</td>
<td>Grey Fabric/linear mtr</td>
<td>33269450.52</td>
<td>$L6=$N6</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$7</td>
<td>Direct labor consumed</td>
<td>485186.24</td>
<td>$L7=$N7</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$8</td>
<td>Indirect labor consumed</td>
<td>481929.3176</td>
<td>$L8=$N8</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$9</td>
<td>Stores consumed</td>
<td>329859.4645</td>
<td>$L9=$N9</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$10</td>
<td>Chemical consumed</td>
<td>138863.48</td>
<td>$L10=$N10</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$11</td>
<td>Power consumed</td>
<td>184872.88</td>
<td>$L11=$N11</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$12</td>
<td>Steam consumed</td>
<td>220006.64</td>
<td>$L12=$N12</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$13</td>
<td>Packing &amp; Inspection consumed</td>
<td>210360.9021</td>
<td>$L13=$N13</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>SL$14</td>
<td>Depreciation(bld+mach) consumed</td>
<td>3138653.056</td>
<td>$L14=$N14</td>
<td>Binding</td>
<td>0</td>
</tr>
<tr>
<td>DS$3</td>
<td>x1</td>
<td>74103.9642</td>
<td>$D3=0</td>
<td>Not Binding</td>
<td>7410 3.96</td>
</tr>
<tr>
<td>ES$3</td>
<td>x2</td>
<td>331256.7069</td>
<td>$E3=0</td>
<td>Not Binding</td>
<td>3312 56.7</td>
</tr>
<tr>
<td>FS$3</td>
<td>x3</td>
<td>301298.4695</td>
<td>$F3=0</td>
<td>Not Binding</td>
<td>3012 98.5</td>
</tr>
<tr>
<td>GS$3</td>
<td>x4</td>
<td>151187.34</td>
<td>$G3=0</td>
<td>Not Binding</td>
<td>1511 87.3</td>
</tr>
<tr>
<td>HS$3</td>
<td>x5</td>
<td>34735.23695</td>
<td>$H3=0</td>
<td>Not Binding</td>
<td>3473 5.24</td>
</tr>
<tr>
<td>IS$3</td>
<td>x6</td>
<td>414572.4925</td>
<td>$I3=0</td>
<td>Not Binding</td>
<td>4145 72.5</td>
</tr>
<tr>
<td>JS$3</td>
<td>x7</td>
<td>365901.7897</td>
<td>$J3=0</td>
<td>Not Binding</td>
<td>3659 01.8</td>
</tr>
</tbody>
</table>
The slack values in our case called surplus values were also very interesting in this research work, since it creates opportunity for the organizations to distinguish those resources which are idle. To this end, organizations, having idea of the expected no idle resources which forces the manager to consider in the production of dyed fabrics at a minimum cost and plan to yield more gross income. If a constraint is exactly satisfied as equality for RHS and LHS, the slack value will be zero. In our case, all resources are binding.

Conclusion

In this paper the problem of how to determine the optimal number of textile dyed fabrics to be produced are Local sheet 160, Export kid 220, Export kid 160, Local sheet 190, Local sheet 240, Export 160, Local sheet 120, and Export 190 is addressed by LPP. From results depicted in Table 2, we compared production as well as gross income obtained by LPP and traditional methods used by the company. The strategies obtained by using LPP yields more dyed fabrics and more gross income than strategies obtained from trial and error methods. The company can make a production quantity and gross income differences of 703923.9654 meters dyed fabrics and Birr 35412071.47 correspondingly if it uses LPP. The production quantity and gross income of the company can be improved by 72.63% and 65.91% respectively. The strategies obtained by LPP, provides the company with an opportunity to make more income from Local sheet 160, Export kid 220, Export kid 160, Local sheet 190, Local sheet 240, Export 160 and Local sheet 120. Had the company used LPP solutions before, more gross income from the same resources could have been realized. The company’s instinct and experience to solve the problem of resource allocation does not guarantee optimal strategies.

Recommendation

The researchers strongly recommend the appropriateness of the linear programming methods to the management of the company that whenever production is taking place to determine the optimal number of products. First, this is evident from the result obtained from the LPP model fitted to the data collected on Bahir Dar Textile S. company, Amhara Region. Interesting findings were deduced. These include the managers of the company make use of modern scientific tools like Excel Solver to plan

<table>
<thead>
<tr>
<th>Gross Income per meter of fabric</th>
<th>Local Sheet 160</th>
<th>Export kid 220</th>
<th>Export kid 160</th>
<th>Local Sheet 190</th>
<th>Local Sheet 240</th>
<th>Export 160</th>
<th>Local 120</th>
<th>Export 190</th>
<th>TP</th>
<th>Total Gross Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional production</td>
<td>1050</td>
<td>3660</td>
<td>37562</td>
<td>2965</td>
<td>2942</td>
<td>32317</td>
<td>1203</td>
<td>525</td>
<td>969132</td>
<td>537315</td>
</tr>
<tr>
<td>LPP Production</td>
<td>7410</td>
<td>3312</td>
<td>30129</td>
<td>1511</td>
<td>3473</td>
<td>41457</td>
<td>3659</td>
<td>0</td>
<td>167305</td>
<td>891435</td>
</tr>
</tbody>
</table>

Table 2: Production Plan Suggested By the company traditional method and using LPP

Results and Interpretation

Analysis carried out from the solution to the LPP model in the previous section using Excel Solver to determine the optimal number of textile dyed fabrics of the case company tells us that the total minimum cost of dyed fabrics in the above model is Birr 39,357,087.18 (Ethiopian Currency). The optimal quantities of each textile dyed fabrics to be produced are Local sheet 160 (X1), Export kid 220 (X2), Export kid 160 (X3), Local sheet 190 (X4), Local sheet 240 (X5), Export 160 (X6), Local sheet 120 (X7), and Export 190 (X8) are 74103.96442; 331256.7069; 301298.4695; 151187.34; 34735.23695; 414572.4925; 365901.7897, and 0 meters respectively. In this result, we observe that only seven out of the eight products can be produced at a minimum cost and Export 190 (X8) is not accountable to yield more gross income.

$K3 \geq 0$ Binding 0
their operations and make use of determining product type and amount of the company. Second considering the challenges of today's world economy and the work complication to make up schedule that is both realistic and economical it is advisable to use analytical method such as linear programming and its techniques for analyzing and manipulating the company operations based on their resources available. Third, once the model is developed it can be reused again and again on an on-going basis and analyze its effect on gross income. Finally, it allows managers to make decisions regarding its employees and resources utilization and ordering every month.

References