Application of Integer Linear Programming Technique in Production Planning: (Case Study of United Nigeria Textiles Plc)

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Abstract
In this research, mathematical model of textile production industry’s problem was developed. The integer linear programming model has been formulated to determine the optimal solutions for two different cases. Case 1: Cotton and polyester selection based on independent production plan. Case 2: Variation in percentage of cotton, polyester and wool in belle production. The integer linear programming model is tested using industrial cases and solved by using standard software package (TORA). The results obtained showed that in both cases, the total profit attained by the application of the developed model stood at N189,695 million. On the other hand, profits made by manual application in both cases were N182,678 million and N181,800 million for case 1 and 2 respectively. In case 1 the net profit amount to N701,717 million and in case the net profit stands at N789,5 million, which represents 3.7% and 4.2% respectively. Due to market competitions, there is a strong need to find a decision tool to manage the textile manufacturing plan in order to maximize profit. This paper describes YFADI, an interactive Decision Support System (DSS) for the management of production in textile production systems.

Keywords: Integer linear programming, model, textile industry, Production plan, YFADI.

1.0 Introduction

The textile industry is one of the major economic activities in Nigeria which do contribute for nation development. Due to market competitions, there is a strong need to find a decision tool to manage the textile manufacturing plan in order to maximize total profit. In textile industry, the planner must manage whole raw material available and find the best production-mix plan. Textile production systems form an interesting area for the study of Production planning problems.

The industry has been developed following both vertical integration, particularly among spinning and weaving firms, and horizontal integration, promoted by the idea that a full line of textile products is necessary for effective marketing, (Olson, 2000). Such production systems comprise various production phases which are illustrated in Figure 1 together with the type of their output. Weaving consists of crossing a yarn, called the weft yarn, with several thousands of yarns composing the warp.

Starching is a procedure that comprises synthesis and special treatment of some warps. Warp making is the arrangement of the warp yarns in parallel on a roll. Each yarn is taken from a bobbin which is put on a bobbin stand.

The textile industry imposes a variety of constraints concerning the integration of an overall scheduling procedure. Typically, a textile production unit is characterized by a multi-phase manufacturing process with multiple production units per phase i.e. parallel machines (Blanco, et al. 2005). The mixed character of a textile production system, which lies between job-shop and flow-shop, makes production management quite complex. In addition, there are sequence dependent operations, and different planning horizons and production characteristics for each phase. Consequently, different production planning algorithms for each phase are required. For example, the weaving process is characterized by long planning horizons and relatively, slow speeds of machines, very long setup times, very large production batches, and mixed order and stock-based production. On the contrary, the warp making process is characterized by short planning horizons and high speed of ma-
machines, short setup times, small production batches and only orders-based production. The above phases pose the most complex production scheduling problems.

Additional special characteristics of the textile industry that have been taken into account in the development of the YFADI production control system are the following:

- Most textile companies are ageing while the technology changes rapidly. These companies own machines of different ages and production characteristics, such as processing speed, changeover possibilities and facilities, etc.
- The changeover (i.e. setup) time of the machines is dependent on the sequence of jobs on the machines. Usually, there are two types of changeover times in the weaving phase, the total and the partial ones, depending on the types of two clothes being processed in sequence. Partial changeover times take place between two successive related jobs and are much smaller than the total ones, which refer to unrelated jobs. Minimization of the total setup times is among the most significant objectives in the scheduling of a textile industrial unit.
- Throughout the set of phases, jobs can be split and processed in parallel. Nevertheless, job splitting has to be weighed up with the advantageous results, mainly in terms of quality of constant processing of a particular job in the same machine.
- Simultaneous setting up of the weaving machines which have been charged with the parallel processing of a particular job should be avoided. It is worth mentioning that the setting-up of a weaving machine usually requires more than two workers, while only one worker can attend to the normal operation of about 10 of them.
- Textile production systems may be treated as a succession of local problems, one per each production phase. The coherence of these local problems should be taken into account by "material requirements planning" or "just-in-time" approaches (Guinnet, 1991).

In recent years, many businesses absolutely compete in quality of goods, price and cost, then the producers who produce high-quality goods at low costs must be the first choice of consumers for selection.

YFADI, meaning well in the Greek language, is a decision support system that has been developed for the production planning and scheduling of a Greek textile industrial plant. In its first release, it covers the operations of warp making, starching and weaving (the shaded area in Figure 1), but a future release will cover all the production phases of the industry, that is, from yarn spinning to the final sewing of clothes. Its main objective is to provide the manager with efficient production management tools, applicable to the multi-phase production of a variety of products. The alternative production plans, provided by the system, help the user to make decisions about the production rates for each product, (Karacapilidis, et al. 2003).

One of the most traditional ways of maximizing profit is to develop mathematical model as a decision support tool for strategic, tactical, and operational analysis. Integer linear programming models have been applied for each decision level in many industries. Gunnarsson, Ronqvist, and Lundgren (2004) presented a model and solution approach that can be used as a decision support tool for strategic analysis as well as tactical planning of the forest fuel industry. The large mixed integer linear programming model developed gives a detailed description of the supply chain problem considered. The model is tested on a real industrial case and produces better and more flexible solutions compar-

![Figure 1: The textile manufacturing process.](image-url)
ed to manual planning. Ioannou (2005) developed appropriate transportation models to derive optimal distribution practices. The optimal planning shows the product flow volumes and the optimized quantities of inter-node shipments by assigning the best source to each demand point. The optimal solution of the linear programming model resulted in savings of approximately one million US dollars and improved demand coverage.

The management science in textile industry problem is really required to support planning production. The textile industry problem is usually concerned with the allocation mixed-product planning with finite capacity constrains in order to meet the customer demand at maximum profit; in textile industry, we focus on the operational planning, then the planner must manage whole raw materials available and find the best production-mix plan.

1.1 Problem statement

The United Nigerian textiles PLC, is one of the latest and biggest textile industries in Nigeria. The United Nigeria textiles PLC, was conceived and located at Ibeshe village, on outskirts of Ikorodu Lagos. Annually textile utilization in Nigeria increases therefore, its production should increase also. The company's annual growth of the textile market demand is the continuous increasing in demand but slightly increasing in profit.

Therefore, this situation urged the sector to look for a different approach to textile production problem. The specific details of the problem environment (i.e. the quantity of textile product for each raw material and the interval time to produce textile). The variable costs of textile production in United Nigeria textiles PLC are the operating cost and labour cost. They produce a variety of five textile products.

Generally, the net profit may increase by increasing sell price or reducing total cost of textile production. In United Nigeria textiles PLC, it is possible however, to increase sell price. Reduction in total cost is also a good way to improve the net profit.

This research is to study the complex problems of textile industry. The problems are concerned with how much of the raw cottons and polyester will be transformed into the valuable textile per day. The decisions include selecting manufacturing between the cotton and the polyester. The mathematical model is formulated to describe the problem of textile product industry in order to support decision making in operational level of production plans that can be solved with the computer software such as TORA.

2.0 Mathematical Model

Notation Index

\( i \) = types of textile product \( i = \{1, 2, 3, \ldots, n\} \)

Decision variables

\( X_i = \) The number of textile product type \( i \) produced (belles per day)

\( Y_i = 1 \) if textile product type \( i \) is produced; 0 otherwise

Parameters

\( C_i = \) Total cost of textile product type \( i \) (N/belle)

\( S_i = \) Sell price of textile product type \( i \) (N/belle)

\( SP = \) The quantity of raw materials supplied

\( D_i = \) The customer's demand of textile product type \( i \) per day (belles)

\( CP_i = \) The capacity of labour involved in producing textile product type \( i \) (belles per day)

\( P_i = \) The quantity of textile product type \( i \) (CC)

Given the above definitions and notation, the model can be formulated as follows:

Maximize

\[ \sum_{i=1}^{n} X_i S_i - \sum_{i=1}^{n} X_i C_i \]  \hspace{1cm} (1)

Subject to:

\[ \sum_{i=1}^{n} P X_i < SP \] \hspace{1cm} (2)

\[ X_i > Y_i D_i \] \hspace{1cm} (3)

\[ X_i < Y_i CP_i \] \hspace{1cm} (4)

\[ X_i > 0 \] \hspace{1cm} and \hspace{1cm} \text{X is Integer} \hspace{1cm} (5)

The objective function (1) seeks to maximize the net profit. Constraint (2) states that the number of products produced is equaled to or less than the quantity of raw material supplied. Constraint (3) states that the quantity of textile produced per day is equaled to or greater than the quantity the customer's demand for each textile product type. Constraint (4) states the capacity of the labour involved in producing textile product type \( i \) (belles per day) and Constraint (5) is specification of the decision variables.
2.1 Model Validation
The integer linear programming models are tested using industrial cases and solved by using standard software package (TORA). TORA is programmed software for problems validation and solutions. The real-case data is given from the United Nigeria Textiles PLC, five textile products consisting of wool, 60%, Polyester, 20% and cotton, 100% are produced. Because of two limitations in manufacturing that United Nigeria Textiles PLC has only one manufacturing line and the cotton and the polyester cannot be produced at the same time, and then we classified the textile manufacturing plan into two cases. The mathematical models developed give a detailed description of each case; two cases are as follows:

**Case 1:** Independent production planning is decided for selecting cotton or polyester (see Figure 2).

- **Case 1.1** three textile product types are operated. Polyester, 20%, Wool, 60% and cotton, 100% in belles are produced.
- **Case 1.2** three textile product types are operated. Polyester, 20%, Cotton, 50%, and Wool, 20%, in belles are produced.

The index \( i \) in the mathematical model for case 1.1 is equal to 1, 2, 3; 1 is Polyester, 20%, in belles, 2 is Wool, 60% in belles and 3 is cotton, 100% belles. Mathematical model for case 1.2 is the same as case 1.1, but index \( i \) for case 1.2 equal to 1, 4, 5; 4 is Cotton, 50% and 5 is Wool, 20% in belles. All constants are shown in Table 1.

| \( \) & \( \) |
| --- | --- |
| **Table 1:** Constants in the model |
| \( C_i \) (₦/belle) & \( D_i \) (belle) |
| 350220 & 90,000 |
| 56160 & 50,000 |
| 60415 & 50,000 |
| 56280 & 50,000 |
| 65460 & 50,000 |

**Mathematical model for case 1.1**

Maximize \( \sum_{i=1}^{3} X_i S_i - \sum_{i=1}^{3} X_i C_i \) \[6\]

Subject to:

- \( P_1 X_1 + P_2 X_2 + P_3 X_3 = SP \) \[7\]
- \( X_1 \leq CP_i \) for \( i = 1, 2, 3 \) \[8\]
- \( X_i \geq D_i \) for \( i = 1, 2, 3 \) \[9\]
- \( X_i \geq 0 \) and \( X_i \) is integer \[10\]

3.0 Results and Discussion

In Case 1.1, the optimal solutions from the model are \( X_1 = 90,000 \) belles, \( X_2 = 50,000 \) belles, \( X_3 = 85,000 \) belles. The net profit is ₦189,695 million. The net profit from manual plan is ₦182,678 million. The results show that the total profit can be increased about 3.7% by using this production plan. All results from case 1.2 are shown in Table 2.

**Case 2:** Variation in percentage of cotton, polyester and wool in belle production (see Figure 3).

- **Case 2.1:** Five textile products are operated. Cotton, 100%, Polyester, 50% and Wool, 60%, in belles are produced.

<p>| ( ) &amp; ( ) |
| --- | --- |
| <strong>Table 2:</strong> Comparing the results from mathematical models and manual plan |</p>
<table>
<thead>
<tr>
<th>Cases</th>
<th>Decision variables ((10^4) belles)</th>
<th>Net profit ((10^8) Naira)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1.1 Model</td>
<td>90</td>
<td>50</td>
</tr>
<tr>
<td>Model</td>
<td>90</td>
<td>65</td>
</tr>
<tr>
<td>Case 1.2 Model</td>
<td>90</td>
<td>-</td>
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<tr>
<td>Model</td>
<td>90</td>
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The planning horizon for this model is daily plan. For further work, the time frame in the model should be considered as a shift including three shifts a day to make the model more realistic case.

References


4.0 Conclusion

The main purpose of this research is to develop a mathematical model and solve the solution that can be used as a decision support tool for operation planning of the textile industry. The integer linear programming models are tested using industrial cases and solved by using standard software packages; TORA, the results from all model show that the total profit can be increased by 3.7% and 4.2% by using this production plan in case 1 and case 2, respectively.