

# Aggregate Production Planning, Case study in a Medium-sized Industry of the Rubber Production Line in Ecuador

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**Abstract.** This research aims to improve the productivity in the rubber line of a medium- sized industry by increasing the production capacities through the use of the Aggregate Production Planning model. For this purpose an analysis of the production processes of the line was made and the aggregate plan was defined evaluating two strategies: Exact Production Plan (Zero Inventory) and Constant Workforce Plan (Vary Inventory) by studying the costs of both inventory maintenance and workforce. It was also determined how the installed capacity was used with the standards of the rubber line and measures for decreasing production costs were proposed. It was proven that only 70% of the plant capacity was being used so it could be possible to produce more units and to obtain a bigger market for the products of this line. +

## 1. Introduction

The Aggregate Production Planning strategy (APP) combines the decision making with respect of the facilities and the planning, defining the production rates for medium-term periods, strategies for the working hours (hiring, firing, subcontracting), inventories level, demand studies, inputs flow, prices and costs among other important variables for its application. [1; 2]

The main objective of the aggregate plan is to determine the optimal combination between the production index and the amount of workforce and inventory. The production index refers to the number of units produced by unit of time. The labor force level is the number of workers needed in the production and the on-hand inventory represents the unused inventory from the previous period. [3]

In general, the production plans of a manufacturing industry are developed through three phases: Production Plan, Master Production Schedule and the Short-term Production Planning. The short-term production plans implement the commercial policy defined in the long-term analysis based on a time horizon of one year for the assignment of resources. [4; 5]

Worldwide, the enterprises of any business area must have the workforce and technology capacity to maintain and manage efficiently the resources. The Aggregate Production Planning makes this possible and allows a higher level of competitiveness.

In Ecuador, new initiatives have been created to industrialize the processes and achieve a higher concurrence in both national and international markets with high-quality products and satisfying the demand. [7]

The enterprise analyzed on this paper is located in Ambato, Ecuador. It is a company that has many production plants such as: leather, plastic, classic canvas, relaxed-style shoe plants and also plants of



thermoplastic mixtures, prefabricated products and various manufacturing industries. In the Various Industries plant many products are made, not only in the rubber line but also in the Eva line for internal and external customers. With the current demand it was found that: works were delayed, the planning was done using wrong production times, the orders couldn't be delivered on time and finally, there was an excess demand among other problems. Therefore, it is not enough to have top-quality products.

This paper proposes a study of the production capacity to improve and/or optimize the planning and production processes in the Various Industries plant of a medium-sized enterprise in Ambato city, Ecuador.

## 2. Methods

Nowadays, there are many techniques to apply the aggregate production planning model. All the strategies of APP involve inventory management, production rates, levels of labor force, capacity and other controllable variables. Among the aggregate planning strategies, the most relevant are the strategies using capacity options and the ones using demand options (trying to level changes in the demand pattern occurred within the planning period). [8; 9]

APP can be established through the following steps:

**Step 1:** Set the demand for each period. The Master Production Schedule is given by the enterprise through the FORECAST program.

**Step 2:** Determine the capacity of the under time, overtime and subcontracted time of each period.

**Step 3:** Establish the workforce costs, hiring and firing, and also the inventory maintenance cost. The cost information was provided by the company management staff.

**Step 4:** Consider the company policy that is applied to the employees or to the inventory levels. In the company, only policies related to bonus payments due to increases in productivity are defined.

**Step 5:** Develop alternative plans and study their total costs. Two types of aggregate planning are determined by means of the mathematical models: Exact Production Plan; (Vary Workforce) and Constant Workforce (Vary Inventory and Stockout).

### 2.1. Exact Production Plan:

For the Exact Production Plan the variable is the number of workers, while the demand remains constant. The constraint of this plan is that the production must be equal to the demand; the equation for this type of plan is shown in equation 1:

$$\text{Units produced} / \text{worker} = \frac{\text{Units produced} / \text{year}}{\text{Days worked} / \text{year}} \quad (1)$$

### 2.2. Constant Workforce Plan:

For the Constant Workforce Plan the variable is the production rate while the number of workers each month is a constant. The formula for the development of this plan is presented in equation 2:

$$\text{Workers needed} = \frac{\text{demand} / \text{mont h}}{(\text{days} / \text{mont h}) \times (\text{units} / \text{worker} / \text{day})} \quad (2)$$

## 3. Results

**Step 1: Determine the demand for each Period.** The Master Production Schedule (MPS) shows what must be produced and when the calculations and the decision making will depend on the demand. This plan included the forecast for sales and orders within the time horizon of the study, as presented in table 1 where the MPS for the next 7 months is shown.

**Table1.**Master Production Schedule.

MATERIAL	JUN	JUL	AGO	SEP	OCT	NOV	DIC
<b>Front Classic carpet</b>	410	404	414	447	466	439	366
<b>Front Dakar carpet</b>	2592	2558	2312	2463	2498	2488	2733
<b>Back Dakar carpet</b>	2329	2345	2546	2403	2360	2358	2246
<b>Circular Flexible Rubber</b>	129	134	123	127	129	109	125
<b>Corrugated Flexible Rubber</b>	1131	1178	1191	1260	1306	1017	1291
<b>Raw Flexible Rubber</b>	601	630	643	687	715	553	737
<b>Mudguard</b>	51	57	86	14	0	0	0
<b>Mudguard layer</b>	1150	1143	1116	1187	1202	1199	1201
<b>Smooth Neolite</b>	448	465	474	469	424	471	481
<b>Diamond- tipped Neolite plus</b>	2019	1932	1972	1992	2040	1894	1936
<b>Total</b>	<b>10860</b>	<b>10846</b>	<b>10877</b>	<b>11049</b>	<b>11140</b>	<b>10528</b>	<b>11116</b>

*Step 2: Determine the capacity of the under time, overtime and subcontracted time for each period.* The enterprise has a costing department, which is charged of studying the times for every activity and to keep them up to date in case of a change of process and/or activity. The production times in the mixing area of every product processed in each of the following lines: line of machine YT01 and line of machine GK30 were determined. The following times were also calculated: the production times in the pressing process separated by the lines of GUIX and JING DAY; production times in the sanding process in the two machines FE01 and EN06. Finally, the most commercialized group of products were determined for the study. With the established times it is possible to determine the production standards for each machine and process.

*Step 3: Estimate the costs of labor force, hiring and firing, and also the costs of inventory maintenance.* Table 2 shows the costs generated by each worker: direct and indirect cost; and benefits given by the company to the workers. With this information the monthly cost is obtained for the analysis.

**Table2.**Labor force costs.

	Monthly Income	Annual Income
Direct costs	484.73	6840.99
Indirect costs	380.72	754.28
Total	865.45	7595.27
Monthly Average	<b>632,94</b>	

*Step 4: Take into consideration the company policy applied to the workers or to the inventory levels.* As stated earlier, the enterprise has policies of bonuses related to the company productivity only for workers; no policy is applied to the inventory.

*Step 5: Develop alternative plans and study their costs.* For the development of aggregate plans, the enterprise supplied all the data. The number of workers in the rubber production line was of 29.

In the aggregate plan of the research the final cost is analyzed within the study time (7 months) considering the labor force costs and the inventory maintenance costs. The hiring and firing costs were not included in the analysis because internal relocation of staff can be done (from one plant to another) which doesn't generate additional costs. The results of each aggregate plan defined in the study are presented next:

### 3.1. Exact production plan:

In this case the capacity depends on the number of workers, for this type of plan the exact demand was determined. [10]

The value of the variable is the number of staff members necessary every month to meet the demand. The constraint is that the produced units cannot exceed the demand, as it is not allowed to produce for keeping an inventory, thus inventory cost is zero.

The monthly labor force cost is \$632.94, considering direct and indirect costs. The number of units produced annually is provided by the company as well as the days worked by year. To determine the units produced by worker, the formula 1 is used and shown below:

$$\begin{aligned} \text{Units produced} / \text{worker} &= (130729 \text{ units/year}) / (7500 \text{ days worker/year}) \\ &= 17.43 \text{ units produced by worker} \end{aligned} \tag{3}$$

With the zero inventory plan the following results were obtained: a total cost of \$123,089.08 in the seven months studied; the amount produced is exactly the demand, so the inventory maintenance cost is zero; concerning the labor force, August and October are the months that need more personnel, 29 persons and July is the month with the lowest number of workers needed, with 26 persons only. The company doesn't have hiring neither firing costs because it implements an internal method of staff relocation, where the workers can be temporarily positioned in other plants, which means no expenses for the enterprise.

### 3.2. Constant workforce plan:

This plan uses the inventory produced in the low demand season to satisfy the demand of the peak demand periods and it is called level production plan because the same number of workers is used in every period. [11]

For this method, the number of workers needed during the study is determined. The demand and the working days per month are set according to the information given by the enterprise, using the formula (4):

$$\text{Workers needed} = (76416) * (18 \text{ units/worker} * 153 \text{ days available}) = 27,74 \text{ Number of workers} \tag{4}$$

By having a constant number of workers, an inventory is generated. To determine the cost of keeping an inventory, it was considered: the use of machinery and electricity, the salaries of the workers and also a reference value of the maintenance of the electric vehicles, which was \$0.28 by month, almost insignificant for calculations.

With this method the results are: the cost is \$125,897.74 in the seven months of the study; the constant number of workers is 28 persons, therefore, in the first month one person would have to be relocated because there were 29 workers at the beginning of the study. At the end of the seven months an inventory of 696 units is generated. Finally, to determine the use of the installed capacity, the values of the demand in the studied period versus the possible production rate are considered according to the standard time, as shown in table 3.

**Table 3.** Use of the installed capacity.

Months	JUN	JUL	AGO	SEP	OCT	NOV	DIC	Total
<b>Total Demand</b>	10860	10846	10877	11149	11140	10528	11116	76416
<b>Production</b>	15120	15120	15120	15120	15120	15120	15120	105840
<b>Machines GUIX 01-02 and JD01-02</b>								
% Use	<b>71.83%</b>	<b>71.73%</b>	<b>71.94%</b>	<b>73.08%</b>	<b>73.68%</b>	<b>69.63%</b>	<b>73.52%</b>	<b>72.20%</b>

It is shown that 72% of the installed capacity is being used in the company. If the decision to sell more products than the ones mentioned in this analysis is considered, the possibility of having more than one work shift could be an alternative.

#### 4. Discussion

According to the previous results, it was found that: with the Exact production plan the total cost is \$123,089.07 which only includes the work force cost as no inventory is generated; and that the maximum variation value of the workforce was of 3 persons in the months of production peak.

On the other hand, with the Constant workforce plan the cost is \$125,897.74, which includes labor force costs and inventory maintenance costs. 29 workers were available initially and the constant labor force is of 28 persons, that's why at the beginning one person had to be relocated. Regarding the inventory maintenance costs, this alternative takes into consideration the Various Industries Logistics area, the wages of the personnel, the electricity and the machinery to estimate an approximate value of the cost to maintain one product in stock.

#### 5. Conclusions

It is concluded that a study was made on the production capacity for the plant of Various Industries in the rubber line, analyzing the production processes of the line and determining the critical processes in the rubber production.

The impact of the Master Production Schedule on the production capacities was analyzed, and this made possible to propose a solution of production volume according to the capacities obtained.

The plant of Various Industries in a medium-sized enterprise in Ambato, Ecuador, has an installed capacity that is large for the present demand of rubber products. Approximately 70% of the capacity is being used to make the current products and satisfy the current demand.

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