An Alternate Model of Aggregate Production Planning for Process Industry: A Case of Cement Plant

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Abstract— This study is about the suggestion of an alternate model of medium range/aggregate production planning (APP) for the process industry. This research is conducted according to the forecasted demand of six months of a leading Cement Industry of Pakistan. A number of methods have developed by researchers to carry out the APP. But all those methods mainly focus on the discrete type of industrial processes. A very little literature addresses the aggregate production planning regarding the process industries. Therefore this study is specifically about the APP of process industry, a case of cement plant. The existing model of aggregate production planning of the selected cement plant is mainly focused on the continuous production and the excess product after meeting the demand is stored in the inventory. Cost analysis has been conducted for the existing model which revealed that nearly half of the total cost is consisted on the inventory holding cost. Different alternatives have been discussed and a proposed model has been developed and analyzed. The results of cost analysis showed that by following the proposed model the company could save approximately 60% of its total cost. Above all, a better preventive maintenance schedule could also be implemented, which might reduce the unplanned break downs and hence the overall efficiency of the plant could also be improved by implementing the proposed model.

Keywords— Aggregate Production Planning, Continuous Production, Inventory Holding Cost, Process Industry

I. INTRODUCTION

Medium range/aggregate production planning (APP) has been an effective tool to control the production, inventory and work force level to reduce the overheads and total cost of production. Usually APP is implemented to discrete parts manufacturing industries; in the meanwhile some researcher have tried to employ APP for continuous production [i]. But these proposed models have limitations and could not be feasible for broader prospect. Therefore this research will provide a basis to apply APP to the process industry such as cement plant. The selected industry is a leading cement plant of Pakistan, which has the capacity of 3700 Tonnes/day. The existing set-up of the industry is to keep plant operational round the clock and after fulfilling the customer demand, remaining excess product is stored in the warehouse as a safety stock for the future demands. The company has invested a large amount to build the warehouse for the storage of excess finish products.

The current strategy of the organization’s management is to produce continuously without considering the customers demand. This study has been conducted by taking the demand forecast of next six months for the company by keeping in view the past records. Being a process industry, the plant is kept operational all the time continuously therefore the unplanned break-downs of the plant caused a heavy investment of the company in the form maintenance. Due to unplanned break-downs a valuable production time is also lost and moreover company has to bear a handsome cost of spare-parts as well. Therefore there is a need to develop an alternate model for the company which could resolve this problem of unplanned break-downs and the customer demands could also be met successfully. Different alternative production plans have been evaluated and a better suited model has been proposed for the industry. The cost analyses for the current and proposed models have been conducted and a detailed discussion has been done and recommendations have been made.

II. LITERATURE REVIEW

Jain et al. [i] introduced a model for a manufacturing scenario where dissimilar machines perform similar operations with different cycle times and production rates, and they proposed configuration-based formulation instead of resource-based formulation to solve aggregate planning problems using several heuristics. Nam and Logendran [ii] defined medium range/aggregate

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production planning (APP) includes accessing the organization’s production, storage capacity and work force level over a limited span of time. The main aims of the APP could be to maximize the utilization of firm’s resources and profit, on time delivery to customers and to minimize the overall cost and inventory. Wang and Fang [iii] discussed the multi-objective problem with fuzzy linear programming (FLP) and concluded that FLP approach is effective than un-fuzzy problem formulation in real scenarios. The researchers [iv] devised heuristics and mathematical relationships based on tabu search method to solve the multi-variable problem of sawmill operations for APP.

Ganesh and Punniyamoorthy [v] revealed that hybrid genetic algorithms-simulated annealing (GA-SA) is more reliable and provide better results than genetic algorithms. Wang and Liang [vi] presented possibilistic linear programming (PLP) model to minimize the overall cost and to help in multi-criterion decision making.

Kumar and Haq [vii] analyzed the effectiveness of ant colony algorithm in combination with genetic algorithm for aggregate production planning. Agrawal [viii] reported a case study of furniture manufacturing for the aggregate planning and accessed various approaches effectiveness. Gomes et al. [ix] developed a multiple criteria mixed integer linear programming model for the construction material manufacturing firm and also proposed a decision support system to find out the better solutions of APP problems. Authors [x] investigated that fuzzy models are more suitable than the stochastic and deterministic approaches for aggregate production-distribution planning (APDP) and they improved their fuzzy model by integrating it with genetic algorithm to make it applicable to the more complex problems. Jamalnia et al. [xi] devised a hybrid fuzzy multi-objective non-linear programming model which attempts to maximize the profit and to minimize the total cost regarding different variables and this model is also synchronized with genetic algorithm.

Researchers [xii] proposed multi-objective linear as well as non-linear programming models of APP for the supply chain management and these multi-objective models had been optimized using genetic algorithm. Ramezanian et al. [xiii] presented the solution for two phase production systems using genetic algorithm and tabu search by developing mixed integer linear programming (MILP) model. The authors [xiv] evaluated a model for the cost of being flexible in a manufacturing environment with respect to existing capacity and the model was used in combination with decision support system for mid-term capacity planning. Wang and Yeh [xv] found that modified particle swarm optimization (MPSO) is more effective than standard particle swarm optimization (SPSO) for complex problems of APP by introducing the idea of sub-particles and coding.

The above discussed literatures generally provide a better solution to the aggregate planning of discrete type of manufacturing firms. But it did not present a satisfactory solution for process industry like cement plant. This study would be helpful to provide a better solution to the cement industry to cope with the fluctuations in aggregate planning at minimum cost and to schedule a better preventive maintenance program to reduce the unplanned failures and break-downs. The mathematical relationships have been developed using well defined terminologies and parameters in section III and numerical values have been computed. The existing model is presented in next section followed by detailed discussion and different scenarios have been evaluated to propose a new model with results and recommendations.

### III. System Model

#### A. Abbreviations and Acronyms

The following abbreviations would be used to develop mathematical relationships:

- \( PC_d \) = Plant Capacity per day
- \( R_{pd} \) = Actual Production per day
- \( R_{pm} \) = Actual Production per month
- \( I_{HC} \) = Inventory Holding Cost
- \( M_{CS} \) = Marginal cost of stock out per ton per month
- \( S_{TCM} \) = Straight time cost per month
- \( O_C \) = Overtime Cost
- \( I_B \) = Beginning Inventory
- \( I_E \) = Ending Inventory
- \( S_S \) = Safety Stock
- \( W_{DM} \) = Working days per month
- \( P_{HM} \) = Production hours available per month
- \( D_{FM} \) = Demand forecast per month
- \( E_U \) = Excess units

#### B. Mathematical Relationships

Actual production per day at 80% plant efficiency:

\[
R_{pd} = PC_d \times 0.80 \quad (1)
\]

Actual production per month will be:

\[
R_{pm} = R_{pd} \times W_{DM} \quad (2)
\]

As the plant are operational 8 hours and 3 shifts round the clock then production hours available per month;
The safety stock must be 10% of demand forecast;
\[ S_S = D_{FM} \times 0.10 \]  
(4)

Ending inventory at the end of each month would be:
\[ I_E = I_B + R_{pm} - S_S \]  
(5)

As the ending inventory of each month would become the beginning inventory of every subsequent month therefore;
\[ I_E = I_B \]  
(6)

The excess units would be the difference of ending inventory and demand forecast;
\[ E_U = I_E - D_{FM} \]  
(7)

The inventory holding cost of per ton per month is Rs. 10, therefore;
\[ I_{HC} = E_U \times 10 \]  
(8)

The straight time cost is Rs. 1200 per operating hour therefore;
\[ S_{TCM} = W_{DM} \times 24 \times 1200 \]  
(9)

IV. RESEARCH METHODOLOGY

The cement plants are generally kept running round the clock without any break. The selected industry is also working on continuous production strategy. The current production strategy of the cement plant has been studied and evaluated in terms of total cost. Different alternatives and strategies have been discussed and an alternate production model has been proposed based on least total cost. The demand forecast for the next six months is given in Table I, keeping in view the past record of the company.

Table I; Demand Forecast of Six Months

<table>
<thead>
<tr>
<th>Month</th>
<th>Demand Forecast (Tonnes)</th>
<th>Demand Forecast (Bags)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>70,500</td>
<td>1,410,000</td>
</tr>
<tr>
<td>August</td>
<td>61,500</td>
<td>1,230,000</td>
</tr>
<tr>
<td>September</td>
<td>66,500</td>
<td>1,330,000</td>
</tr>
<tr>
<td>October</td>
<td>74,500</td>
<td>1,490,000</td>
</tr>
<tr>
<td>November</td>
<td>71,500</td>
<td>1,430,000</td>
</tr>
<tr>
<td>December</td>
<td>79,500</td>
<td>1,590,000</td>
</tr>
<tr>
<td>Grand Total</td>
<td>424,000</td>
<td>8,480,000</td>
</tr>
</tbody>
</table>

The cement plant has the capacity of 3700 Tonnes/day. From the previous record, the capacity utilization of the plant is 80%. Therefore, the actual production will be 2960 Tonnes/day (59,200 bags / day). Existing model is designed to focus on the continuous production, and the excess production is stocked in the inventory.

The beginning inventory at the start of the July is 10,000 Tonnes, which is available in the warehouse. As there are 31 days in the month of July, so the available production hours equal to 744 hours. The total production of July would be 91,760 Tonnes and the ending inventory of July equals to 31,260 Tonnes. The demand forecast for the month of July is 70,500 Tonnes; therefore the safety stock will be 7,050 Tonnes. The excess units of July equal to 24,210 Tonnes and the inventory holding cost of this tonnage is equal to Rs. 242,100 and straight time cost of July will be Rs. 892,800.

In Table III, the calculations of different values have been computed for the six months same as discussed previously the calculations for the month of July. The inventory holding cost for six months comes equal to Rs. 4,843,000 and straight time is equal to Rs. 5,299,200. Therefore the total cost of six months of existing model would be equal to Rs. 10,142,200.

Critique and Discussion on Existing Model:

- The existing model only focuses on the continuous production.
Due to continuous production inventory holding cost is very high.

This means that company has tied up the value added WIP in its stock.

It is the final product, which has fully consumed all the resources and capital.

The values calculated in Table III revealed that 47% of the total cost is consisted on the inventory holding cost.

As it has been analyzed from the above discussed points that existing model is not much economical. Because nearly half of the total cost is consists on the inventory holding cost. This large quantity of inventory is kept only to meet the fluctuations in demand. It might be the possibility that during unplanned break downs, this inventory would be utilized to fulfill the customers demand. But in the current scenario, the plant is assumed to be operating continuously. Due to which, the critical equipment might wear quickly than the normal rate, because there is no rest given in schedule means 24 hour plant operation continuously. Therefore maintenance cost is very high due to the run to failure strategy of the management and consequently the unplanned break-downs occur and company has to bear a high cost of spares as well.

Table III: Calculations of Existing Model for Six Months.

<table>
<thead>
<tr>
<th>Existing Production Model; Very Inventory and Stockout</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Beginning Inventory</strong></td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Working Days per Month</td>
</tr>
<tr>
<td>Production Hours Available (Working Days per Month x 24 Hrs)^*</td>
</tr>
<tr>
<td>Actual Production</td>
</tr>
<tr>
<td>Demand Forecast</td>
</tr>
<tr>
<td>Ending Inventory (Beginning Inventory + Actual Production - Demand Forecast)</td>
</tr>
<tr>
<td>Shortage Cost (Units Short x Rs20)</td>
</tr>
<tr>
<td>Safety Stock</td>
</tr>
<tr>
<td>Units Excess (Ending Inventory - Safety Stock) Only if positive amount</td>
</tr>
<tr>
<td>Inventory Cost (Units Excess x Rs10)</td>
</tr>
<tr>
<td>Straight Time Cost (Production Hours Available x Rs1200)</td>
</tr>
<tr>
<td>Total Cost</td>
</tr>
</tbody>
</table>

Alternate Plans:

**Exact Production and Vary Workforce:**

As the cement is a process industry, so mostly the work force is technically skilled people. Therefore it would not be beneficial for the company to hire and fire the skilled labor. Because it would be very difficult to find the skilled people, if once they left the company. And also it is very expensive procedure of hiring and firing, which is not in the interest of the company in any way. This alternative is not unfeasible.

**Constant Low workforce and Subcontracting:**

A constant low work force and subcontracting is another alternative, but the problem is again the type of process industry. Cement is a complete product; it does not consist on the small components. So the subcontracting is not possible because in the market other cement production companies are the competitors, and nobody gives its finish product to fulfill someone’s demand. So this alternative is also not workable.

**Constant workforce and Overtime:**

In process industry, over time does not have so much impact on the production rate. Plant could not produce more than its capacity. The productivity of the plant could only be increased by optimum utilization of the installed capacity. It does not depend on the extra labor deployment. The plant is already operating round the clock (24 hours) and its productivity could not go beyond...
the designed capacity no matter how much labor is employed. This alternative is again not favorable.

**Constant workforce and Chase Strategy:**
This alternative could be evaluated because it does not apparently conflict any of possible constraints. So this strategy needs to be evaluated.

**Proposed model:**
The existing model requires reformulation of traditional aggregate planning methods to incorporate changes in net production requirements. As the proposed model is “Constant workforce and Chase Strategy”. Therefore, all the calculations would be done again to find out the total cost according to this model.

**Calculations of Proposed Model:**
The Table IV demonstrates that the net production requirement for the month of July is 67,500 tonnes. As it is already known that daily production of the plant is 2,960 Tonnes. So there would be approximately 23 days required to satisfy the demand of this month. There are 31 days available in July; therefore 8 days would be spared after fulfilling the demand.

Production hours required to meet the 67,500 Tonnes demand could be calculated by multiplying 22.80 with operational time (24 hours) of the plant every day which is equal to 547.7 hours. The straight time cost of proposed model for July would be equal to Rs. 657,243.

**Table IV; Calculations for Aggregate Production Planning**

<table>
<thead>
<tr>
<th>Aggregate Production Planning Requirements</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginning Inventory</td>
<td>10,000</td>
<td>7,050</td>
<td>6,150</td>
<td>6,650</td>
<td>7,450</td>
<td>7,150</td>
</tr>
<tr>
<td>Demand Forecast</td>
<td>70,500</td>
<td>61,500</td>
<td>66,500</td>
<td>74,500</td>
<td>71,500</td>
<td>79,500</td>
</tr>
<tr>
<td>Safety Stock (.10 x Demand Forecast)</td>
<td>7,050</td>
<td>6,150</td>
<td>6,650</td>
<td>7,450</td>
<td>7,150</td>
<td>7,950</td>
</tr>
<tr>
<td>Production Requirement (Demand Forecast + Safety Stock - Beginning Inventory)</td>
<td>67,550</td>
<td>60,600</td>
<td>67,000</td>
<td>75,300</td>
<td>71,200</td>
<td>80,300</td>
</tr>
<tr>
<td>Ending Inventory (Beginning Inventory + Production Requirement - Demand Forecast)</td>
<td>7,050</td>
<td>6,150</td>
<td>6,650</td>
<td>7,450</td>
<td>7,150</td>
<td>7,950</td>
</tr>
</tbody>
</table>

*Note: In Table IV, the unit is Tonnes for all values.*

**Table V; Calculations of Proposed Model for Six Months.**

<table>
<thead>
<tr>
<th>Proposed Production Plan: Exact Production (Chase Strategy)</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Requirement</td>
<td>67,550</td>
<td>60,600</td>
<td>67,000</td>
<td>75,300</td>
<td>71,200</td>
<td>80,300</td>
<td></td>
</tr>
<tr>
<td>Production Days Required to meet the Demand</td>
<td>23</td>
<td>20</td>
<td>23</td>
<td>25</td>
<td>24</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Available Working Days per Month</td>
<td>31</td>
<td>31</td>
<td>30</td>
<td>31</td>
<td>30</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Production Hours Required to meet the Demand</td>
<td>548</td>
<td>491</td>
<td>543</td>
<td>611</td>
<td>577</td>
<td>651</td>
<td></td>
</tr>
<tr>
<td>Spare Days to meet the Fluctuations in Demand/Maintenance of the plant</td>
<td>8</td>
<td>11</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Straight Time Cost (Production Hours Required x Rs1200)</td>
<td>Rs657,243</td>
<td>Rs589,622</td>
<td>Rs651,892</td>
<td>Rs732,649</td>
<td>Rs692,757</td>
<td>Rs781,297</td>
<td>Rs4,105,459</td>
</tr>
</tbody>
</table>

**Total Cost** | Rs4,105,459
In Table V production days and production hours required to complete the demand forecast have been computed. Spare days to meet the fluctuations in demand have also been calculated for the new proposed model along with straight time cost which has been assumed to remain same for different number of days in each month in case of proposed model. The total cost of the proposed model is equal to Rs. 4,105,459. This total cost is much more less than the existing model of the cement plant.

Figure 1: Comparison of Straight Time Costs of Existing and Proposed Models.

Figure 1 depicts that the straight time cost of proposed model is lower for all six months than the existing model of the company. Hence as a result the total straight time cost of new proposed model is also much lower than the existing one. It has been identified through the evaluation of proposed model that inventory holding cost is zero for the new model. The chase strategy has been adopted for proposed model therefore there is no need to store items and the fluctuations in demand could be easily dealt in spare days.

V. RESULTS AND DISCUSSION

By comparing the existing and proposed models, the following points have been identified:

- The total cost of the existing model is Rs. 10,142,200 and total cost of proposed model is 4,105,459.
- So, in the proposed model the cost is reduced up to 59.5%.
- The reasons of higher value of total cost for existing model is:
  a. Continuous production and
  b. Carrying excess inventory.
- In proposed model, there is no excess inventory at all, the company is exactly following the demand, and so the cost is much lower as compared to existing model.
- As there is no need to keep safety stock and extra inventory by adopting the proposed model, the company could save a handsome investment to be made in to own a warehouse.
- The fluctuation in demand could be handled in the spare days.
- During spare days, preventive maintenance (overhauling) of the plant could also be done, so that the unplanned break downs could be avoided.
- By implementing a better preventive maintenance schedule through the proposed model overall efficiency of plant could be improved and also the spare parts cost could also be saved by early fault identification during the overhauling.

VI. CONCLUSIONS

From the above results and discussion it has been identified that existing model of the cement plant is no more economical than the new proposed model. The proposed model proves to be more effective and also provides a better preventive maintenance schedule due to which the unplanned break-down could be minimized. By adopting new model there is no need to carry excess inventory and therefore there is no need of warehouse and also the inventory holding cost will be zero. Therefore the proposed model of “Constant workforce and Chase Strategy” is better suited for the selected cement plant as well as for other cements industries for aggregate production planning.

VII. REFERENCES


