Aggregate Production Planning For A Pump Manufacturing Company: Level Strategy

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Abstract - *We discuss a mathematical model to make choices in decision making in the aggregate production planning of the pump manufacturing company. The MILP formulation is based on industrial production. The aim is to help the production managers in selecting the methods used to produce pumps and the final inventory strategy. A case study about a pump manufacturing company is presented here. Under level strategy, the objective is to maintain a stable workforce, avoiding frequent hiring/firing/layoffs. Here production is not synchronized with demand and inventories are built up during low demand periods for use during high demand periods. We use Python program to optimize the problem.*

Key Words: **Aggregate production planning, Mixed integer programming, Level strategy, Python, Pump Manufacturing Company**

1.INTRODUCTION

In the production, APP is a middle term capacity planning that encompasses a time period from 3 to 18 months. The planners make decisions regarding hiring, laying off workers, overtime production, backorder, subcontracting and inventory levels. In the field of production planning it falls between the broad conditions of long-range planning and the highly specific and detailed short-range planning types. APP has attracted the attention of many researchers from several years ago.

Under this level strategy, the objective is to maintain a stable workforce, avoiding frequent hiring/firing/layoffs. Here production is not synchronized with demand and inventories are built up during low demand periods for use during high demand periods. This will be a good strategy to follow when the inventory costs are low or labor unions are strong.

2. LITERATURE REVIEW

R. Ghasemy Yaghin et al (13), proposed a model including both quantative and qualitative constraints and objectives to determine the optimal price markdown policy and APP in a supply chain.

S.M.J. Mirzapour Al-e-hashem et al (15), developed a stochastic model to solve a multi-period multi-product, multisite APP in a green supply chain for a middle-term planning horizon under demand uncertainty.

Aneirson Francisco da Silva and Fernando Augusto Silva Marins (9), proposed a Fuzzy Goal Programming technique (FGP) for a APP problem.

S.M.J. Mirzapour Al-e-hashem et al (16), had considered a supply chain with suppliers, manufacturers and customers, addressing a multi-site, multiperiod, multi-product APP problem with chance.

Carlos Gomes da Silva et al (10), presented an APP model applied to a Portuguese firm that produces construction materials.

Seyed Mohamad Javad Mirzapour Al-e-Hashem et al (17), presented a multi-objective technique to deal with a multiperiod multi-product multi-site APP for a medium-term planning horizon under chance.

R.A. Aliev et al (14), made a fuzzy integrated multi-period and multi-product production and distribution technique in supply chain.

D. C. Aucamp (11), The standard linear programming way to APP is augmented to include advertising and pricing policies.

Krishnaraj C et al (12), have solved a numerical problem for supply chain network design. Anand Jayakumar A et al (8), have solved a supply chain network problem using gravity location method. Anand Jayakumar A et al (7), have solved a SCND problem using LINGO software. Anand Jayakumar A et al (2), have solved a P Median problem using python. Anand Jayakumar A et al (3), have solved a fixed charge problem using python. Anand Jayakumar A et al (6), have solved a revenue maximization problem using aggregate planning. Anand Jayakumar A and Krishnaraj C (1,4), have solved a revenue management problem using LINGO. Anand Jayakumar A and Krishnaraj C (5), have found ways to implement the quality circle in institutions.

3. NUMERICAL PROBLEM

The study being reported here was carried out in a pump manufacturing company situated in Coimbatore city, Tamil Nadu State,India. As the management of this company prefers to maintain anonymity, this company is referred to in this paper as XYZ. The methodology is shown in fig 1.

XYZ has forecasted the demand for the year is shown in table 1 below:

Table 1: Demand Forecast

Month	Demand	Month	Demand
1	21306	7	9828
2	20477	8	10273
3	18203	9	14217
4	11106	10	9520
5	5692	11	18007
6	8616	12	21662

XYZ has 20 workers and 1000 units of pumps on hand now. Each worker can produce 1500 units of pumps per month. The company can recruit from the local labor market, but the recruits have to be trained for 1 month by a worker before they can be used for production. Each worker can train at most 5 recruits during a month. A worker is paid Rs 15000 per month when used in production or training. A worker can be laid off at a cost of Rs 5000 per month. Firing a worker costs Rs 45000. Each recruit is paid Rs 5000 during training.

Production ahead of schedule incurs an inventory holding cost of Rs 10 per unit per month. Each unit of pump not delivered on schedule involves a penalty cost of Rs 5 per month until delivery is completed. However all deliveries must be completed in 12 months. The company requires a final labor force of 20 workers and 1000 units of pumps at the end of 12th month.

The aggregate planning problem is to decide what hiring, firing, producing, storing and shortage policy the company should follow in order to minimize the total costs during the contract period.

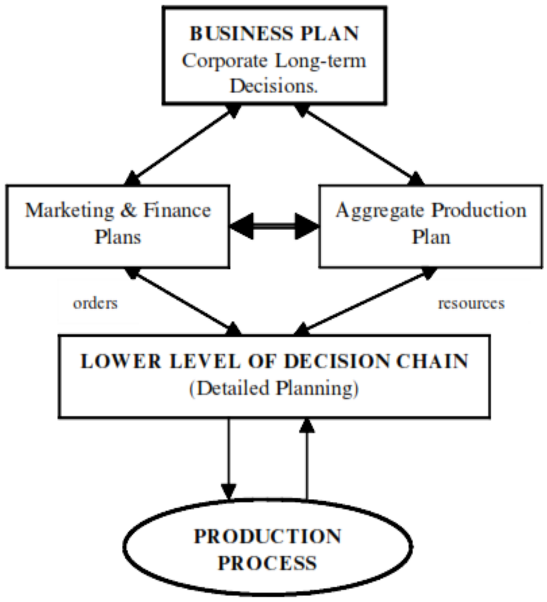

Fig1. The Decision Making Process

4. MATHEMATICAL MODEL

XYZ has 20 workers and 1000 units of pumps on hand now. Each worker can produce 1500 units of pumps per month. The company can recruit from the local labor market, but the recruits have to be trained for 1 month by a worker before they can be used for production. Each worker can train at most 5 recruits during a month. A worker is paid Rs 15000 per month when used in production or training. A worker can be laid off at a cost of Rs 5000 per month. Firing a worker costs Rs 45000. Each recruit is paid Rs 5000 during training.

Decision Variables

W_t = Total workers at the beginning of month t, before firing
P_t = Workers assigned to production in month t
T_t = Workers assigned to training in month t
L_t = Laid off workers in month t
F_t = Workers fired at the beginning of month t
R_t = Total recruits hired at the beginning of month t
I_t = Cumulative inventory at the end of month t
S_t = Cumulative shortages at the end of month t
X_t = Number of units of C produced during month t
Objective Function

The Objective function represents the sum of the following costs:

- Wages of production workers
- Wages of laid off workers
- Cost of fired workers
- Cost of trainees hired
- Wages of workers assigned to training
- Inventory holding cost
- Backorder cost

Minimize $Z = 15000 \sum_{t=1}^{12} Pt + 5000\sum_{t=1}^{12} Lt + 45000\sum_{t=1}^{12} Ft + 5000\sum_{t=1}^{12} Rt + 5000\sum_{t=1}^{12} Tt + 10\sum_{t=1}^{12} It + 5\sum_{t=1}^{12} St$

Constraints

- Size of the workforce
  $Wt = W_{t-1} + R_{t-1} - F_{t-1}$ for t = 2,3,…,12

  The equation guarantees that the total number of workers at the beginning of month t will be equal to the number at the beginning of the month t-1 plus the number trained in month t-1, minus the number fired at the beginning of month t-1.

- Assignment of workforce
  $W_t = P_t + T_t + L_t + F_t$ for t = 1,2,…,12

  The equation guarantees that the total number of workers at the beginning of the month will be assigned to one of the following: Production, Training recruits, Laid off, Fired

- Training
  $R_t < 5T_t$ for t = 1,2,…,12

  The equation guarantees that each worker can train at most five trainees

- Demand/ inventory balance
  $X_t + I_{t-1} = D_t + S_{t-1} + I_t - S_t$ for t = 1,2,…,12

  The left hand side of the above equation is the sum of the current production X_t and the inventory carried over I_{t-1}. Thus, it is the total amount of C available to meet demand in month t. If it exceeds the total requirement, which is the sum of current demand D_t and any backlogs carried over S_{t-1}, then we will have an inventory of I_t at the end of month t. Otherwise, there will be a cumulative backlog of S_t at the end of month t.

- Production capacity
  $X_t < 1500\ P_t$ for t = 1,2,…,12

  The equation gurantees that each worker can produce at the most 1500 units per month.

- Non-negativity constraints
  $P_t, T_t, F_t, R_t, I_t, S_t, X_t, > 0$ for all t = 1,2,…,12

5. PYTHON PROGRAM

The python program is available in the following link www. goo.gl/NG7qte

6. PYTHON PROGRAM

An intel CORE i5 processor 2nd Generation with 4GB RAM was used to process the model.The operating system used was Windows 7. Python 3.5.2 :: Anaconda 4.2.0 was used. PuLP package 1.6.1 was used. The default solver was CBC.The problem was solved in less than 1 second.

7. RESULT AND DISCUSSION

The following result was arrived as shown in table 2 and table 3. Fig 2 shows the fluctuation in the types of workers. Fig 3 shows the status of the workers. Fig 4 shows the inventory and stockout status. Fig 5 shows the production and demand.

Table 2: Worker Details

Month	W	P	T	R	L	F
0	0	0	0	0	0	0
1	20	13	1	0	0	6
2	14	14	0	0	0	0
3	14	12	2	0	0	0
4	14	8	6	0	0	0
5	14	4	10	0	0	0
6	14	5	9	0	0	0
7	14	7	7	0	0	0
8	14	7	7	0	0	0
9	14	9	5	0	0	0
10	14	7	7	0	0	0
11	14	12	2	6	0	0
12	20	15	0	0	5	0

Table 3: Production Details

Month	I	S	X	D
0	1000	0	0	0
1	0	806	19500	21306
2	0	283	21000	20477
3	0	486	18000	18203
4	0	0	11592	1110
5	308	0	6000	5692
6	0	808	7500	8616
7	0	136	10500	9828
8	0	0	10409	10273
9	0	717	13500	14217
10	169	0	10406	9520
11	162	0	18000	18007
12	1000	0	22500	21662

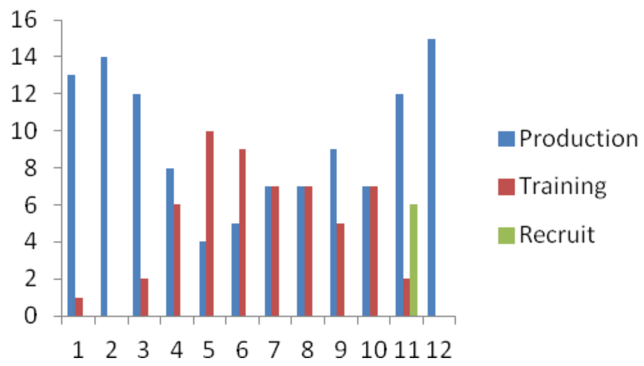

Fig 2. Worker Types

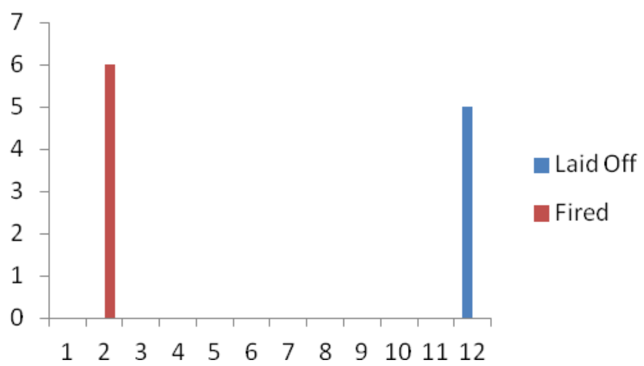

Fig 3. Worker Status

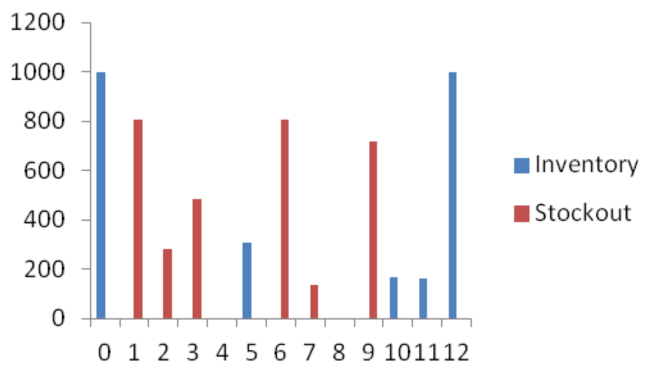

Fig 4. Inventory and Stockout

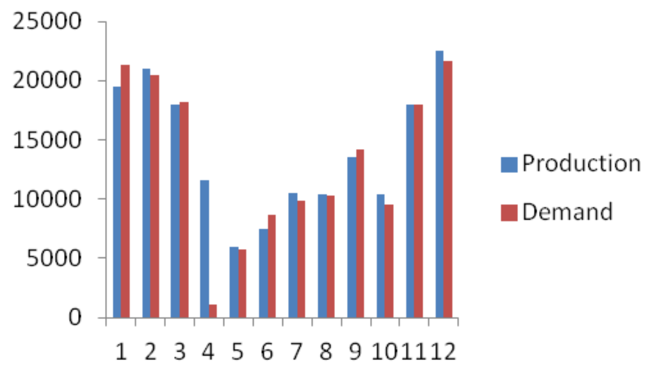

Fig 5. Production and Demand

8. CONCLUSION

Thus we have found the best solution using Python Program.

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