Aggregate Production Planning For A Pump Manufacturing Company: Chase Strategy

Anand Jayakumar A[1], Krishnaraj C[2], Raghunayagan P[3]

[1]*Assistant Professor, Dept of Mech Engg, SVS College of Engineering, Tamil Nadu, India*
[2]*Professor, Dept of Mech Engg, Karpagam College of Engineering, Tamil Nadu, India*
[3] *Assistant Professor, Dept of Mech Engg, Nehru Institute of Engineering and Technology, Tamil Nadu, India*

Abstract - *In this article a mathematical model to make choices in aggregate production planning of a pump manufacturing company. A mixed integer programming suggested is based on industrial production. The idea is to help the production managers in choosing the industrial processes used to make pumps and the inventory strategy. The planning period is one year and decisions are taken based on a discrete time. A case study was done in a pump manufacturing company. Under chase strategy, production rates are changed to match the forecasted demands during the planning horizon. Workforce levels can be changed by hiring or layoff, sub-contracting, use of overtime, use of temporary workers etc. This is basically a "Follow demand" strategy and maintains very low inventory. In this paper we use Python program to optimize the problem.*

Key Words: **aggregate production planning, mixed integer programming, chase strategy, python.**

1.INTRODUCTION

Aggregate production planning is capacity planning from 6 to 18 months ahead. It is concerned to meet requirements and to meet changing demand over the planning period. Aggregate Production Planning (APP) is defined as the same time determination of production, the inventory and the workforce levels of a company on a finite time horizon. The aim is to reduce the total overall expenses to meet a no constant demand assuming fixed sale and production capacity. This problem is particularly complex in production systems producing several types products with demands requiring the maintenance of a large inventory.

Under chase strategy, production rates are changed to match the forecasted demands during the planning horizon. Workforce levels can be changed by hiring or layoff, sub-contracting, use of overtime, use of temporary workers etc. This is basically a "Follow demand" strategy and maintains very low inventory. Hence, this will be a good strategy when the inventory costs are very high. However, such a policy could create labor unrest.

2. LITERATURE REVIEW

Amir Hossein Niknamfar et al (1) developed robust optimization in P-D planning to reduce the total cost of a 3-level supply chain.

Rafael P.O. Paiva and Reinaldo Morabito (17) presented a model to help make decisions in the APP of ethanol and sugar milling companies.

Lorena Pradenas and Fernando Pe˜nailillo (14), introduced a mathematical based model and a heuristic algorithm based on Tabu Search for the problem of APP at a sawmill..

Birger Raa et al (11), discussed the APP–distribution problem for a producer of plastic products that are made using injection moulding.

Reza Ramezanian et al (19), developed MILP model for two-phase APP systems. Because of NP-hard class of APP, they made a genetic algorithm and tabu search for solving this problem.

Mohammadreza Sadeghi et al (15), proposed a multi-objective model for aggregate planning problem in which the parameters of the mathematical model are made in the form of grey numbers.

Randolph F.C. Shen (18), Three control techniques are applied to Holt, Modigliani, Muth and Simon's APP. A statistical analysis is then conducted to study the variability of the sampling distribution of these Monte Carlo runs.

Ankit Singhvi (10), introduced a new technique for APP in supply chains. The technique is based on pinch analysis, which has been mainly used in heat and mass exchanger network analysis.

Leena Steinke and Kathrin Fischer (13), studied the influence of APP on choices regarding facility site location, distribution quantity and part remanufacturing in a closed-loop supply chain network with multiple MTO products.

R. Tadei et al (16), introduced a production scheduling technique in COMPAL S.A., a factory located in Lisbon, Portugal, which produces goods with short life span for the food market.

Tom Vogel et al (20), had showed that production planning model joining the planning tasks usually leads to APP and master production scheduling.

Krishnaraj C et al (12), have solved a numerical problem for supply chain network design. Anand Jayakumar A et al (9), have solved a supply chain network problem using gravity location method. Anand Jayakumar A et al (8), have solved a SCND problem using LINGO software. Anand Jayakumar A et al (3), have solved a P Median problem using python. Anand Jayakumar A et al (4), have solved a fixed charge problem using python. Anand Jayakumar A et al (7), have solved a revenue maximization problem using aggregate planning. Anand Jayakumar A and Krishnaraj C (2,5), have solved a revenue management problem using LINGO. Anand Jayakumar A and Krishnaraj C (6), 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 15000. Each recruit is paid Rs 5000 during training.

Production ahead of schedule incurs an inventory holding cost of Rs 200 per unit per month. Each unit of pump not delivered on schedule involves a penalty cost of Rs 25 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.

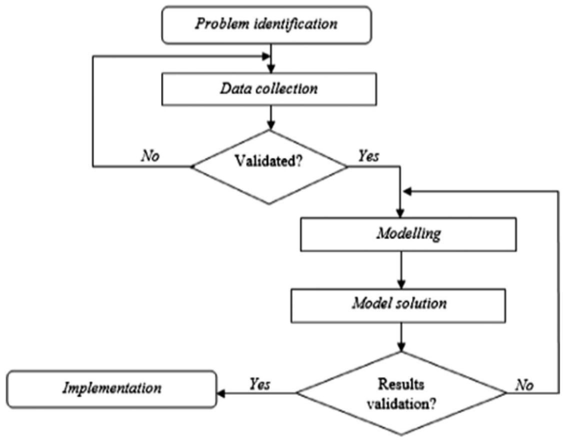

Fig 1. Research Steps

4. MATHEMATICAL MODEL

Decision Variables

Wt = Total workers at the beginning of month t, before firing
Pt = Workers assigned to production in month t
Tt = Workers assigned to training in month t
Lt = Laid off workers in month t
Ft = Workers fired at the beginning of month t
Rt = Total recruits hired at the beginning of month t
It = Cumulative inventory at the end of month t
St = Cumulative shortages at the end of month t
Xt = 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 $Z = 15000\sum_{t=1}^{12} Pt + 5000\sum_{t=1}^{12} Lt + 45000\sum_{t=1}^{12} Ft + 5000\sum_{t=1}^{12} Rt + 5000\sum_{t=1}^{12} Tt + 10\sum_{t=1}^{12} It + 200\sum_{t=1}^{12} St$

Constraints

Size of the workforce

- Wt = Wt-1 + Rt-1 – Ft-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

- Wt = Pt + Tt + Lt + Ft 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

- Rt < 5Tt for t = 1,2,...,12

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

Demand/ inventory balance

- Xt + It-1 = Dt + St-1 + It – St for t = 1,2,...,12

The left hand side of the above equation is the sum of the current production Xt and the inventory carried over It-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 Dt and any backlogs carried over St-1, then we will have an inventory of It at the end of month t. Otherwise, there will be a cumulative backlog of St at the end of month t.

Production capacity

- Xt < 1500 Pt for t = 1,2,...,12

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

Non-negativity constraints

- Pt, Tt, Ft, Rt, It, St, Xt, > 0 for all t = 1,2,...,12

5. PYTHON PROGRAM

The python program is available in the following link www.goo.gl/ZL0BBd

6. COMPUTATIONAL EFFICIENCY

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	L	F	R
0	0	0	0	0	0	0
1	20	14	0	0	6	0
2	14	14	0	0	0	0
3	14	12	0	0	2	0
4	20	16	0	4	0	0
5	8	4	0	4	0	0
6	8	6	0	2	0	0
7	12	8	0	0	4	0
8	8	8	0	0	0	0
9	8	8	0	0	0	0
10	8	7	1	0	0	5
11	13	11	2	0	0	7
12	20	16	0	4	0	0

Table 3: Production Details

Month	I	S	X	D
0	1000	0	0	0
1	0	0	20306	21306
2	203	0	20680	20477
3	0	0	18000	18203
4	0	0	11106	11106
5	0	0	5692	5692
6	345	0	8961	8616
7	1017	0	10500	9828
8	2744	0	12000	10273
9	527	0	12000	14217
10	1507	0	10500	9520
11	0	0	16500	18007
12	1000	0	22662	21662

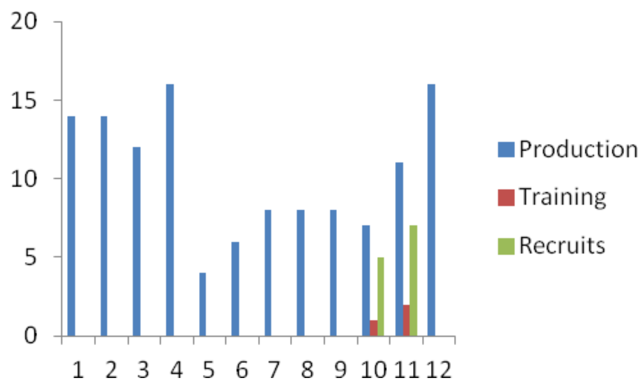

Fig 2. Fluctuations in the types of workers

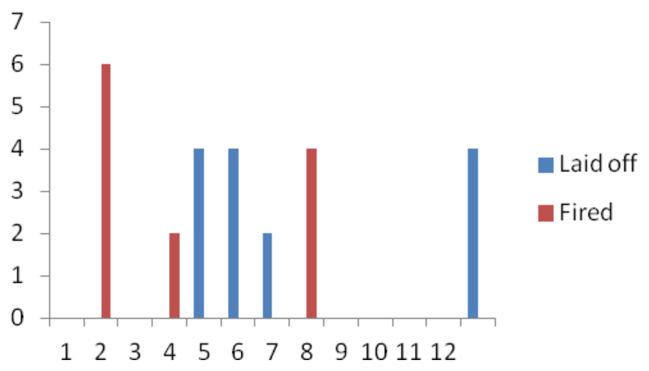

Fig 3. Status of Workers

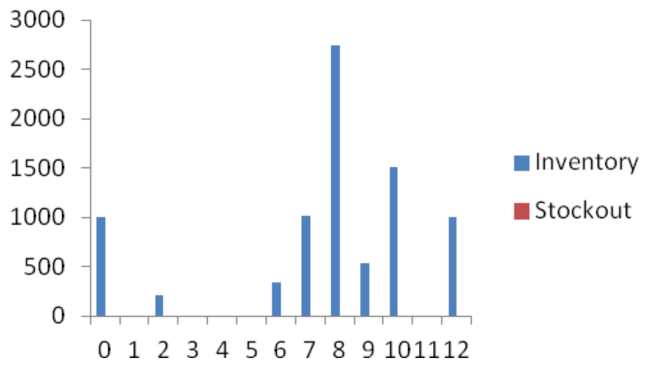

Fig 4. Inventory and Stockout

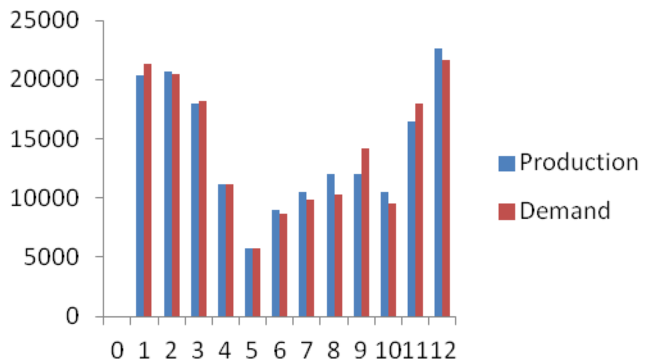

Fig 5. Production and Demand

8. CONCLUSIONS

Thus we have found the best solution using Python Program.

REFERENCES

[1] Amir Hossein Niknamfar,Seyed Taghi Akhavan Niaki and Seyed Hamid Reza Pasandideh, "Robust optimization approach for an aggregate production–distribution planning in a three-level supply chain", International Journal of Advanced Manufacturing and Technology, 2014.

[2] Anand Jayakumar A and Krishnaraj C, "Lingo Based Pricing And Revenue Management For Multiple Customer Segments",ARPN Journal of Engineering and Applied Sciences, Vol 10, NO 14, August 2015, pp 6167-6171.

[3] Anand Jayakumar A, Krishnaraj C and Aravith Kumar A, "Optimization of P Median Problem in PythonUsing PuLP Package", International Journal of Control Theory and Applications, Vol 10, Issue 2, pp. 437-442, 2017

[4] Anand Jayakumar A, Krishnaraj C and Raghunayagan P, "Optimization of Fixed Charge Problem in Python using PuLP Package", International Journal of Control Theory and Applications, Vol 10, Issue 2, pp. 443-447, 2017

[5] Anand Jayakumar A, Krishnaraj C, "Pricing and Revenue Management for Perishable Assets Using LINGO", International Journal of Emerging Researches in Engineering Science and Technology, Vol 2, Issue 3, April 2015, pp 65-68.

[6] Anand Jayakumar A, Krishnaraj C, "Quality Circle – Formation and Implementation", International Journal of Emerging Researches in Engineering Science andTechnology, Vol 2, Issue 2, March 2015.

[7] Anand Jayakumar A, Krishnaraj C, and S. R. Kasthuri Raj, "Lingo Based Revenue Maximization Using Aggregate Planning", ARPN Journal of Engineering and Applied Sciences, Vol. 11, NO. 9, MAY 2016, pp .6075-6081

[8] Anand Jayakumar A, Krishnaraj C, Aravinth Kumar A, "LINGO Based Supply Chain Network Design", Journal of Applied Sciences Research, Vol 11, No 22, pp 19-23, Nov 2015.

[9] Anand Jayakumar, A., C. Krishnaraj, "Solving Supply Chain Network Gravity Location Model Using LINGO", International Journal of Innovative Science Engineering and Technology", Vol 2, No 4, pp 32-35, 2015.

[10] Ankit Singhvi, K. P. Madhavan, Uday V. Shenoy, "Pinch analysis for aggregate production planning in supply chains", Computers and Chemical Engineering, 2004, vol 28, pp 993–999

[11] Birger Raa, Wout Dullaert, El-Houssaine Aghezzaf, "A matheuristic for aggregate production–distribution planning with mould sharing", International Journal of production economics

[12] Krishnaraj, C., A. Anand Jayakumar, S. Deepa Shri, "Solving Supply Chain Network Optimization Models Using LINGO", International Journal of Applied Engineering Research, Vol 10, No 19, pp 14715-14718, 2015

[13] Leena Steinke and Kathrin Fischer, "Extension of multi-commodity closed-loop supply chain network design by aggregate production planning", Logistics Research, 2016, Vol 9, Issue 24

[14] Lorena Pradenas and Fernando Pe˜nailillo, "Aggregate production planning problem.A new algorithm", Electronic Notes in Discrete Mathematics,2004, Vol 18, pp 193–199.

[15] Mohammadreza Sadeghi,Seyed Hossein Razavi Hajiagha and Shide Sadat Hashemi, "A fuzzy grey goal programming approach for aggregate production planning", International Journal of Advanced Manufacturing Technology, 2013, vol 64, pp 1715–1727

[16] R. Tadei, M. Trubian, J.L. Avendafio, E Della Croce and G. Menga, "Aggregate planning and scheduling in the food industry: A case study", European Journal of Operational Research, 1995, Vol 87, pp 564-573

[17] Rafael P.O. Paiva and Reinaldo Morabito, "An optimization model for the aggregate production planning of a Brazilian sugar and ethanol milling company", Annals of Operations Research, Vol 169, pp 117-130

[18] Randolph F.C. Shen, "Aggregate production planning by stochastic control ", European Journal of Operational Research, 1994,Vol 73, pp 346-359

[19] Reza Ramezanian, Donya Rahmani and Farnaz Barzinpour, "An aggregate production planning model for two phase production systems: Solving with genetic algorithm and tabu search", Expert Systems with Applications, 2012, Vol 39, pp 1256–1263

[20] Tom Vogel, Bernardo Almada-Lobo and Christian Almeder, "Integrated versus hierarchical approach to aggregate production planning and master production scheduling", Operations Research Spectrum.