

A Decision Support System to formulate an Aggregate Production Planning Problem

Ravi Yerigeri¹, Manoj N. Kshirsagar², Prof. S.N.Teli³

¹Terna Engineering college, Navi Mumbai, India, rvyerigeri@rediffmail.com

²Terna Engineering college, Navi Mumbai, India, manoj_ksagar@rediffmail.com

³Saraswati College of Engineering, Kharghar, India, shivanandteli@yahoo.com

Abstract: The Aggregate Production Planning (APP) problem is concerned with determining the optimum production, work force and inventory levels for each period of the planning horizon. The

Aggregate Production Planning problem is a multiple objective one that involves many functional areas to create. This paper addresses an implementation of a Decision Support System that supports an aggregate production planning problem.

Conventionally, a revenue function, a cost function and a profit function are selected to be the objective function for Aggregate Production Planning (APP) problems. Though there is a lot of research works on formulations of APP problems, there is no investigation, which formulates the most appropriate for APP problems.

Moreover, the real system had requirements that are not usually considered on APP literature. The model has been designed and calibrated involving theory of constraints (TOC) and profit objective function, which has been optimized to calculate the scenarios with an acceptable computational time within planners expectative. System has been developed using software and its interfaces have been

designed to require the minimum possible interaction from users. The time cost due to the use of non-commercial software has been assessed.

Keywords: Aggregate Production Planning, Decision Support Systems, Objective functions, Theory of Constraints.

INTRODUCTION

Aggregate Production Planning is the process of planning the quality and timing of output over the intermediate time horizon after 3 months to 1 year. Within that frame, the maximum capacity of a production facility is relatively fixed given a forecast, organization labor, materials and capital resources to respond to expected demand which might be either higher or lower than expected.

From the managerial point of view, the decision making process, the production planning process can be to take place in 3 phases: (as shown in fig.1)

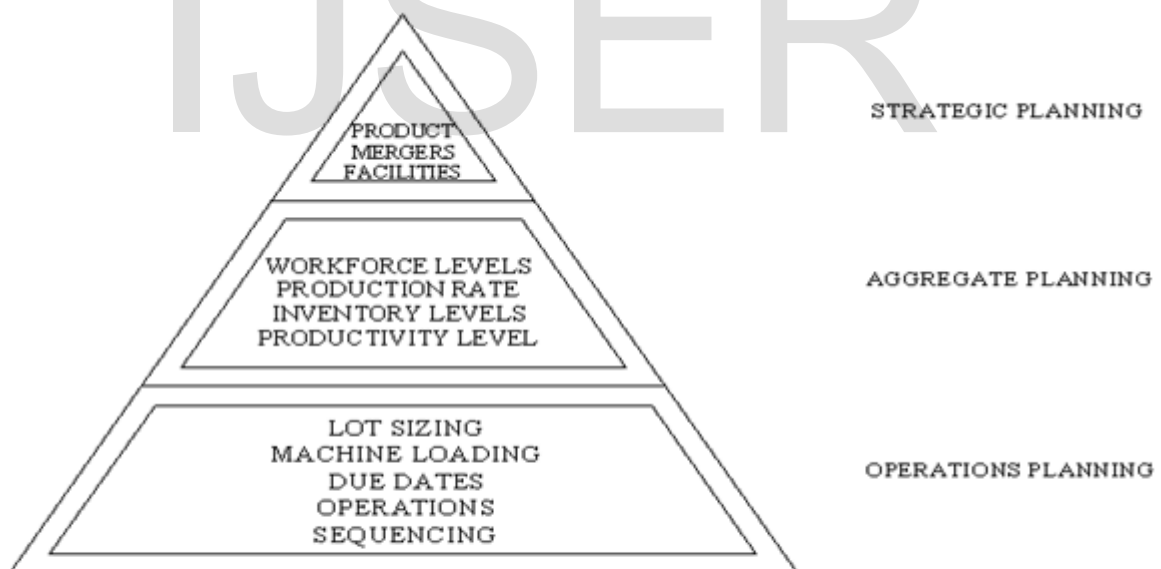


Fig. No. 1 PRODUCTION PLANNING PYRAMID

1. Operation planning,
2. Aggregate planning, and
3. Strategic planning.

Aggregate production planning is a medium range capacity planning. A decision maker must make the

decisions regarding to production quantity, backorder quantity, Subcontracting quantity, inventory level, employment level, hiring and layoff.

Conventionally a revenue function, a cost function and a profit function are chosen to be the objective function for an APP problem. Most of the literatures set the cost function as the main objective function (1-4). Few research works

of the APP problem use a profit function (5). Instead of measuring by cost, factories should evaluate their performance by throughput. This kind of suggestion is called "Theory of constraints (TOC)".

Goldratt has presented TOC for implementation of a system approach to an organization. In order to implement, the gap between day-to-day decision making and the purpose of the organization have to bridge.

Method of measurement than can be agreed upon by all parties must be identified before discussion of improvement. Most would agree that return of investment (ROI) and net profit are sufficient measurements for determining whether an improvement has occurred.

Goldratt has presented the new set of measurements which consists of :

- Throughput (T): The rate at which the system generated money through sales.
- Inventory (I): All the money invested in purchasing the things the system intends to sell.
- Operating Expense (OE): All the money the system spends in turning inventory into throughput (6).

Redefining accounts concepts, Gladratt approach called for a change in emphasis. Managers should aim to raise throughput while simultaneously reducing inventory and operational expense. Traditional accounting focuses on reducing operational which represents the thinking of the "Cost World" (see fig.2).

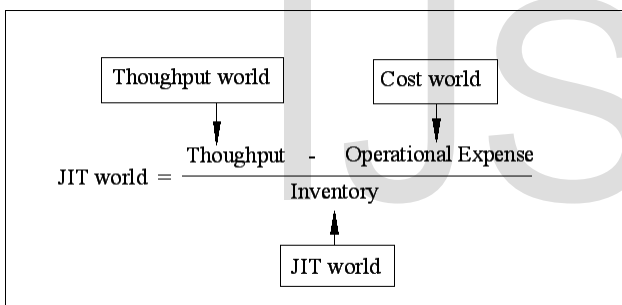


Fig 2: A new paradigm of manufacturing management

Here, the goal of a cost world is to at least breakeven (7). In contrast, the 'JIT World', which concentrates on reducing inventory. This is a welcome relief from the cost mentality and should improve responsiveness of production to change customer demand, since it helps to reduce lead times, and takes much potentially obsolete stock out of the plant. There is danger, however, that JIT thinking will lead to the erosion of the necessary buffer in front of bottlenecks, thus harming throughput.

In this research, a single objective function is used to show the difference of objective setting in production planning problem. Throughput world control both cost and revenue so the main objective of an organization in the sense of TOC is to make more money or to maximize throughput.

THE INVESTIGATION OF AGGREGATE PRODUCTION PLANNING MODEL

In Aggregate Production Planning, a decision maker must make the decisions regarding production quantity, backorder quantity, subcontracting quantity, inventory level, employment level, hiring and layoff as shown in fig. 3

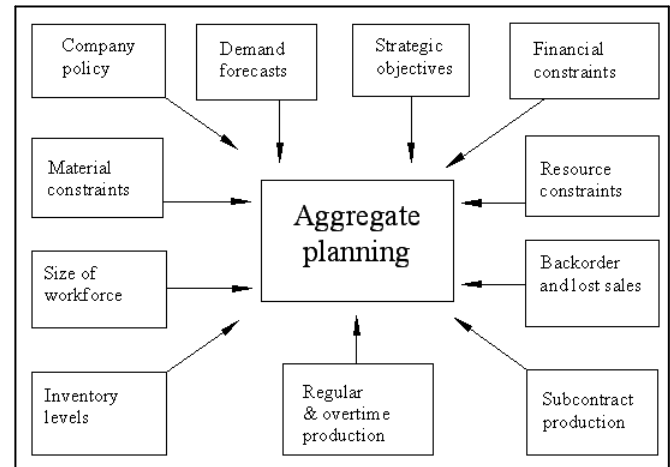


Fig 3: Aggregate production process

In order to take decisions for the APP problem, suitable inputs should be supplied to APP process. Inputs for APP process composes of strategic objectives (objective functions), demand forecasts, company policy (policy constraints), financial constraints, material constraints and resource constraints.

The formulation of APP problems:

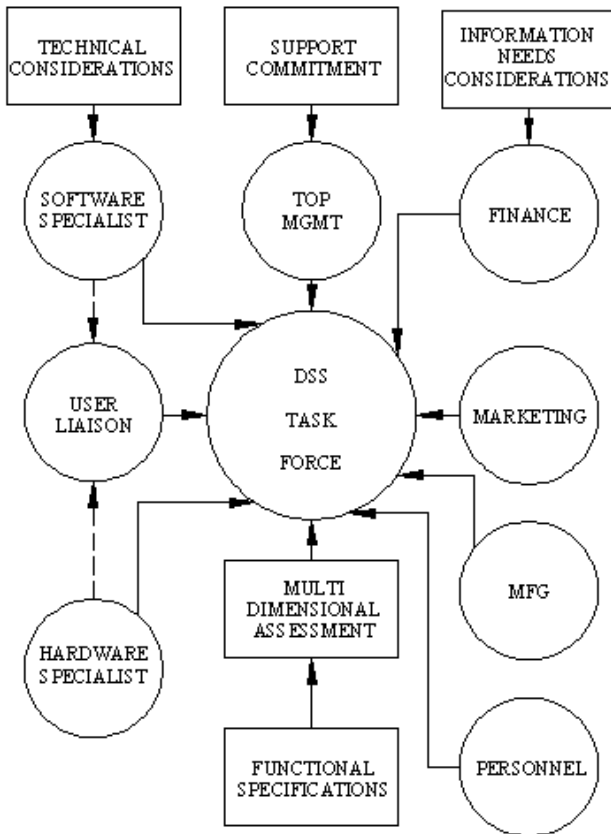
One of essential inputs of APP formulation is the objective function. Most of APP objective functions are:

1. Minimize production costs,
2. Maximize revenue,
3. Maximize profit,
4. Minimize backorder,
5. Minimize total inventory,
6. Minimize a variation of workforce level,
7. Minimize use of overtime, etc.

As it was suggested by Goldratt that instead of measuring cost, factories' should evaluate their performance by throughput (the rate that the cash is generated by the sale of product), inventory (money invested in inventory) and operating expense.

DECISION SUPPORT SYSTEM

This can be defined as a computer based information system consisting of hardware/software and the human element designed to assist any decision maker at any level. However, the emphasis is on semi structured and unstructured tasks. They attempt to combine the use of models or analytical techniques with traditional data access and retrieval functions. They specifically focus on the features which make them easy to sue by non-computer people in an interactive mode, and they emphasize flexibility and adaptability to accommodate changes in the environment and the decision making approach of the user.



No. 4 DSS TASK FORCE

Fig

The aim is to allow the decision maker to employ whatever decision process he chooses and provide him with very rapid feedback of consequences of particular actions. This should enable him to increase his understanding of structure underlying the problem situation so that he can improve his effectiveness in dealing with it.

The benefits of DSS has stated the Peter G. Keen regarding the use of it are as:

1. Increase in the number of alternatives examined,
2. Better understanding of the business,
3. Fast response to unexpected situations,
4. Ability to carry out ad hoc analysis,
5. New insights and learning,
6. Improved communication,
7. Control,
8. Cost savings,
9. Better decisions,
10. More effective team work,
11. Time savings,
12. Making better use of data resources.

The model base component of DSS system as shown in Fig. No. 4

(1) Product	(2) Limiting work center	(3) Processing time per unit (minutes)	(4) Product output rate (per hour)	(5) Selling price	(6) Raw material cost	(7) Profit per unit	(8) Profit per hour
A	Y	10	6	50	20	30	180
B	X	6	10	75	60	15	150
C	Z	5	12	60	40	20	240

TABLE NO. 1

The process includes a series of mathematical and statistical models, which is in conjunction with the data base, enable the DSS to perform any type of modeling analysis. The software system has three sets of capabilities; the database management software (DBMS), model base management software (MBMS) and software for managing the interface between the user and the system, called the dialogue generation and management software (DGMS). This user/system interface is the most important part from the user a point of view since it enables him to access the DSS. It is necessary that his component be as user friendly as possible.

THE APPLICATIONS

In most of APP research works until now, the minimization of production cost is always set as the main objective function (8). Few articles of APP problems use a profit function, therefore use of cost and revenue functions should be investigated and compared with a profit function in order to clarify the goal setting in the APP problem.

The case study considered here will be with 3 kinds of objective functions, namely revenue, cost and profit functions with and without process time constraints are considered. The problem is a multi period model with decisions on, production quantity, backorder quantity, subcontracting quantity, inventory level, employment level, hiring and layoff must be considered.

Different types of methods used for Aggregate Production Planning in different Decision Support Systems, as per the availability are:

1. Linear Decision Rule (LDR),
2. Linear Programming Model (LP),
3. Management Coefficients Model (MCM),
4. Parametric Production Planning Model (PPP),
5. Search Decision Rule (SDR).
6. Productivity Switch Heuristics (PSH),
7. Goal Search Approach (GSA).

In this article, we are using Linear programming to calculate the results of investigation.

To demonstrate, some data are gathered as a case study where it is considered 3 products, A, B and C are sold as shown in the Table No 1 are sold in the market at \$50, \$75 and \$60 per unit respectively.

The market will sale all that can be produced. 3 work centers X, Y and Z process the 3 products in the shown in the above Table No.1. Processing time for each work centre is also shown. Note that each work centre works on all the three products. These can be formulated as resource constraints. Per unit cost of materials shown as RM. In this case, demand is unlimited, no financial, policy and material constraints.

Four different objectives that lead to different performances are considered. They are:

1. Maximize sales revenue:

Without considering process time required, sales personnel will try to sell B at \$75 per unit and none of A and C because it is the highest selling price. Maximize sales revenue is determined by the limiting resource.

Limiting resource for product B is X, which can produce product B at 6 min/part. In an hour product B can be produced for 10 parts so the total sales revenue is \$750. Profit per unit of product B is \$15 and profit for 10 parts or per hour is \$150.

If processing time is considered, the mathematical programming formulation of this objective function for an hour production is

Maximize: $50A + 75B + 60C$
Subject to

$$4A + 6B + 4C \leq 60$$

$$10A + 3B + 3C \leq 60$$

$$5A + 2B + 5C \leq 60$$

Result becomes:

LP optimum found at step 2

Objective function value 859.0909

Variables	Value	Reduced cost
A	0.000000	10.000000
B	2.727273	0.000000
C	10.909091	0.000000

The optimal sale revenue is approximately \$ 859, which is the good objective function for the marketing department but not for the overall organization. Profit per hour from this revenue becomes \$259.09 which is greater than in the case that process time is not considered.

2. Minimizing Cost:

Without considering processing time required, product A, which has the minimum cost at \$20 per unit is selected to produce and none of B and C. Minimize cost is determined by the limiting resource. Limiting resource for product A is Y, which can produce product A at 10 min/part. In an hour product B can be produced for 6 parts so the total cost is 120\$. Profit per unit of product A is \$30 so profit for 6 parts or per hour is \$180.

If processing time is considered, mathematical programming formulation of this objective for an hour production is:

Minimize: $(10+4+6)A + (30+18+12)B + (15+5+20)C$

Subject to

$$4A + 6B + 4C \leq 60$$

$$10A + 3B + 3C \leq 60$$

$$5A + 2B + 5C \leq 60$$

The solution of this model becomes zero because if there is no production, it means that no cost occurs. This is the objective of minimizing cost.

Most of research works solve this problem by including some lower bound constraints. For example, the following constraint may be added:

$$A + B + C \leq 10$$

Then, solution becomes:

Lp Optimum Found At Step 2

Objective function value 314.2857

Variable	Value	Reduced cost
A	4.285714	0.000000
B	0.000000	10.000000
C	5.714286	0.000000

The optimal value is about \$314. This cost comes from the production of A about 4.3 and C about 5.7 which are summed to 10. Profit per hour from this objective becomes \$242.86, which is greater than in the case that processing time is not considered.

3. Maximize profit by TOC

Without considering processing time required, product A which has the maximum profit at \$30 per unit is selected to produce and none of B and C. Maximum total gross profit is determined by the limiting resource. Limiting resource for product A is Y, which can be produce product A at 10min/part. In an hour product B can be produced for 6 parts. Profit per unit of product A is \$30 and profit for 6 parts or per hour is \$180.

The rate of profit per hour is suggested by TOC from chase et al [], which mean processing time is considered . The at which the product is made is base on the bottleneck work center. From the calculation as shown in table I, it is found that product C provides the highest profit of \$240 per hour. In this case, processing time is considered logically by TOC.

4. Maximize profit by Mathematical Mode:

Linear programming formulation to maximize the profit is shown as follows :

Maximise :

$$(50-10-4-6)A + (75-30-18-12)B + (60-15-5-20)C$$

$$\text{Subject to } 4A + 6B + 4C \leq 60$$

$$10A + 3B + 3C \leq 60$$

$$5A + 2B + 5C \leq 60$$

Then solution becomes: Lp Optimum Found At Step3
OBJECTIVE FUNCTION VALUE 286.3636

Variable	Value	Reduced cost
A	2.727273	0.000000
B	2.727273	0.000000
C	8.181818	0.000000

Type of an objective function	Max sales revenue	Max revenue (Math model)	Min Cost	Min Cost (Math model)	Max profit	Max profit by TOC	Max profit (Math model)
Objective function value	750	859.09	120	314.29	120	240	286.36
Profit	150	259.09	180	242.86	180	240	286.36
A	0	0	6	4.29	6	0	2.73
B	10	2.73	0	0	0	0	2.73
C	0	10.91	0	5.71	0	12	8.18

Table No. 2

The optimal profit is approximately \$286, which is the highest profit comparing with the others. Processing time required is considered in constraints. This profit objective function becomes throughput of the system in this case because there are no other operating expenses.

CONCLUSION

The real objective that almost all factories need is how to make more money. Therefore, in this study, the profit is selected as the evaluating performance. From the results in Table No.2, it can be shown that, setting the objective function is very important. The objective that leads to the maximum profit should be set, instead of setting the objective function related to revenue or cost because these objectives direct to the wrong production planning.

Therefore, for future research multi-objective model of the APP problem including maximizing throughput, minimizing operating expenses, and minimizing inventory, which are the three main objectives based on Theory of Constraints, should be developed and evaluated under realistic APP environments.

REFERENCES

1. R.F. Deckro and J.E. Hebert, "Goal programming approaches to solving linear decision rule based aggregate production planning models", IIE transactions, vol.16, no.4, 1984, pp.308-315.
2. F. Hanssmann and S.W. Hess, "A linear programming approach to production and employment scheduling", Management Technology, vol.1, no.2, 1960, pp.46-51.
3. D.A. Goodman: "A New Approach to Scheduling Aggregate Production and Workforce", AIIE T., vol.5, no.2, 1973, pp.135-141.
4. S. Eilon, "Five Approaches to Aggregate Production Planning", AIIE T., vol.7, no.2, 1975, pp.118-131.
5. Abu S.M. Masud and C.L. Hwang, "Aggregate Production Planning Model and Application of three Objective Decision Methods, Ind.J. of Oper. Res., vol.18, no.6, pp. 741-752.
6. Robert E. Stein, Theory of Constraints: Applications in quality and manufacturing, second edition, New York: Marcel Dekker, Inc., 1997.
7. Pieter Pretorius, "Long term decision-making using throughput accounting", IEEE Aficion, vol.2, 2004, pp.861-866
8. F.Hanssmann and S.W. Hess, "A linear programming approach to production and employment scheduling", Management Technology, vol.1, no.1, 1960, pp.46-51.
9. Busaba Phruksapanrat, Ario Ohsato and Pisal Yenradee, "A comment on the formulation of an Aggregate Production Planning Problem", 2006

IJSER