Production Planning in the Inventory Limited Capacity Setting Assuming Permissible Storage Shortage Using Dynamic Programming Model

Firoozeh Attarian, Habibollah Javanmard ,Ali Mardani, Ehsan Kish Hazrate Soltan

Abstract- In the production planning process, two main objectives are satisfying customer demand and achievement of the lowest cost which are sometimes incompatible aims. The increase of inventory level, for example, may result in increase of customer demand; although the holding costs are often at very high level, so the total cost is not estimated at minimum level. Focusing on the minimal cost may cause failing to supply the customer demand and its consequence is loss for the company. In the present research, the situation is named as ''inventory shortage''. The main objective is to develop production planning model of Foulad Azarbayjan Company at Iran assuming inventory limited capacity and permissible storage shortage (backorder). In the line with the main objective, following results are obtained: (1) optimal production rate at the beginning and ending of each period, (2) minimal total cost,(3) inventory optimal level at the beginning of period, and (4) optimal back order rate.

In the present research, data gathering and analysis were undertaken using steel industry's connoisseurs and expert's opinions in the field of production planning and model formulation was according to the dynamic programming method.

Key words: Inventory, Optimum solution, Back order, Production planning.

I. INTRODUCTION

The present intense competition among manufacturing companies causes some challenges in resource allocation and operation timing, so the Production planning is one of the important application branches which have been created through the combination of various industrial engineering techniques with historical methods and mathematical optimization [1]. It is somehow rare that other branches of industrial engineering to have such a high level of capacity to include and accept variety of conceptual and mathematical models. Production planning is defined as a decision making process with respect to some resources which are needed for the future production operations of the organization and also companies are forced to be cautious in their decision makings. The development of market place has highlighted the importance of production efficiency in the manufacturing company's achievement. The aim of effective production planning is optimized usage of needed resources and satisfying customer demands in the given period of time [1]. In general, two limiting factors in production planning are production capacity and inventory capacity with more emphasize and discussion about the former. However, in most of industries including paper production, petrochemical, food, steel, glass, medicine and industrial processing, there are conditions in which the production rate limiting factor is inventory capacity rather than production capacity. For instance, in the steel industry the production capacity is often sufficiently high and customer demands for products are limited by the storage size or in other word by the inventory capacity. Frequently the storage shortages (back orders) and its consequences are not taken into account in the production planning [2]. In the present research it is tried to obtain logical relationship between these two parameters.

Includes resources allocation for considered products quantity demanded and with minimum cost [3].

One can in fact interpret production planning as creating boundary for the organization future production operations. With respect to the above mentioned definition, production planning aims are as follows:

a) Defining production plans based on costs and management policies in financial issues, customer services and work force stability fields; according to these plans it is to decide where extra capacity is needed.

b) Helping the management to understand the impacts of various policies on costs, inventory and production [2].

There are fewer researches about storage shortage strategy in limited inventory setting and its outcomes in the production planning .Two main objectives of production planning are supplying

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customer demands and achievement of lowest costs which are sometimes incompatible aims [4]. The increase of inventory level for example may result in the increase of customer demand although the holding costs are often very high so the final cost is not estimated at minimum level. Focusing on the minimal cost may cause fail to supply the customer demand and loss is its outcome for the company [5]. The situation here is known as inventory shortage .The inventory shortage strategy means that we let to have back orders.

II. RESEARCH QUESTIONS

1. How much is optimum production rate in each period assuming permissible back orders and taking inventory limited capacity into account?
2. How much is optimum production rate at the beginning and end of period?
3. How much is the minimum total cost?
4. How much is the quantity of back orders at the end of each period?

III. MODEL FRAMEWORK

We assume a single resource network with T nodes. The arms connect the resource to each node and it binds node t to node t+1 as t=1,2,…,T-1.The arms direct each T nodes to a well (figure 1) .The needed flow which is directed from node t to well node is known as D_t (assuming that primary inventory and back orders have been allocated such that { D_t } values are net demands which must be supplied through the production). To insure the stable flow, we assume that the system flow in the resource node is equal to $F = \sum_{t=1}^{T} D$. The resulted flow in (o, t) arm is presented by X_t and (t, t+1) arm flow is shown as I_t. The back orders are permissible and so I_t^+ is in-hand stock and I^- represents back order. Assuming some costs incurred in the arm flow, we define $C(X_t)$ and $H(I_t)$ as costs which are functions of flow level, I_t^+ and I_t^- variables are in-hand inventory and back orders at the end of period t respectively. So that the net inventory level is $I_t = I_t^+ + I^-$. In order to determine the possibility of supplying a period demand using the next period production, we add some arms from node t+1 to node t to obtain t=1, 2..,, T-1. The flow in arm (t+1,t) is known as back order level. The resulted network is shown in the figure 1.

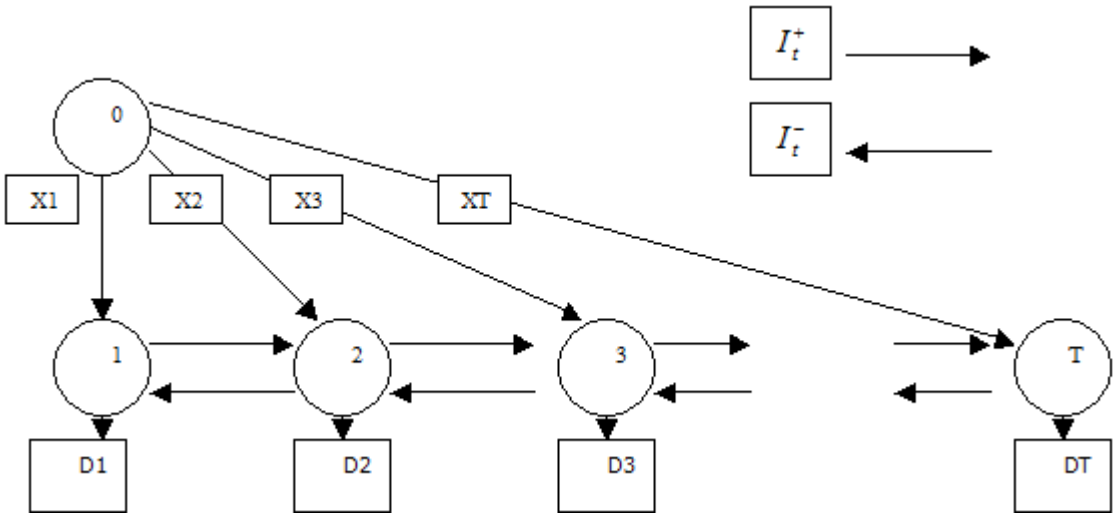

Figure 1.Inventory flow model with *back order quantities*

The following object function is used in the formulation of minimal cost flow:

$$(1)\ Z = \sum_{t=1}^{T} Ct(Xt) + \sum [H_t^+(I_t^+) + H_t^-(I_t^-)]$$

If inventory holding cost and back orders are noted by individual functions, the constraints are:

$$\sum_{t=1}^{T} D_t = \sum_{t=1}^{T} X_t$$

$$X_1 + I_1^- = D_1 + I_1^+$$

$$(2)\ X_t + I_{T-1}^+ + I_t^- = D_t + I_{t-1}^- + I_t^+$$

$$X_T + I_{T-1}^+ = D_T + I_{T-1}^-$$

$$I_t^- \le D_t$$

$$X_t, I_t^+, I_t^- \ge 0$$

Cap_t *is known as inventory capacity of period t.*

Model notations

X_t *=production quantity during period t t=(1,2,…,T)*

I_t *= Net inventory at the end of period t*

I_t^+ *=in-hand inventory at the end of period t*

I_t^- *=back order quantities at the end of period t*

C_t *=production variable cost per unit of product*

H_t^+ *=holding cost of unit from t to t+1 periods*

H_t^- *=back order cost per unit*

D_t *=demand value of period t*

IV. PROCEDURE

In view of objective, the research is known as assessment-applied research. Its assessment nature is due to data collecting and analysis used in decision making, it is also an applied research because applied researches are those ones that develop some assumptions, regulation, principles and techniques for basic researches and are used to solve real administrative problems. With respect to methodology, the research chooses descriptive method because it examines the present situation. Some of the examined subjects in the research include special groups of people which their related information –following analysis- is not generalized to the other groups. Secondly, hypothesis introduced in descriptive research does not explain any reasons to clarify phenomena. It means that in this kind of research, a hypothesis does not indicate the existence of special phenomenon rather it clarifies the relationship between phenomena or concepts. The descriptive statistic is used in the research which applying given and limited statistical techniques, it describes statistical data (inference statistic is used in analytical research method).

The present research is in fact a descriptive research without its research tool i.e. questionnaire and on other hand is not assumed as analytical research because the researcher must provide a hypothesis and using inference statistic, estimating the parameter value through sample feature values and finally , testing the hypothesis statistically.

V. DATA ANALYSIS

The introduced production planning model in the present research is dynamic programming which had been formulated and analyzed using linear programming method. There is not any special algorithm to solve the dynamic programming problem [6]. Dynamic programming is generally one of the effective and efficient methods in problem solving in which decision making is a multistage process. It means that a complex problem is divided into multiple stages such that decision making is undertaken individually in each stage with narrower focus and sub-stages. This property is defined as decomposition in which a complex problem solution is achieved through its decomposition into smaller problems.

The dynamic programming is a mathematical programming specifically designed to complete the calculation efficiency of optimization problems. The basic idea of the technique is decomposition problem. The basic idea of the technique is decomposition of problem into sub-problems with simpler solution.

VI. CASE STUDY AND MODEL NUMERICAL ANALYSIS

The examined problem in the present research is defined as follow. We assume the production designing of the Foulade Azarbayjan Company,the, bar, and 12m length angle are main products ;in various sizes according to the market demand. The production planning unit pursues its decisions based on time and production state beside cost reduction initiatives.

The company production planning has the following features:

1. Production process will not be pending and principal products must be transferred to storages,
2. Production process is limited by the storage capacity ,
3. Production capacity is totally more than holding capacity,

4. The company products demands are more than the existed capabilities and capacities,
5. Products must be held in the company storage at predetermined period and by the end of specified deadline,
6. Establishment costs are high and so it is not possible to establish new production line.

The company identified limitations are:
a) Production capacity limitations which are resulted from production equipment speed for various products,
b) Minimum production limitation: In direction of the company macro scale objectives the top management believes that the company must supply 58000ts products, according to the annual demands , the company should produce 290000ts until August for achieving the goals..
c) Back orders and inventory limitations: This limitation determines the primary parts balance in product inventory,
d) Inventory capacity limitation: The limitation is due to the storage capacity to accept primary parts and products,
e) Limitations due to the product specifications: With respect to the market demand and also considering the company benefits, management determines 40 percent production rate for the first and second products and 60 percent production rate for the third and fourth products.
In the company business process, it may happen that the company do not supply customer demands in which case lost sale will be occurred, but the company will resolve the problem whenever it has in-hand inventory , if not orders will be considered as lost orders.

VII.OPTIMUM APPROACH

We examined the company problem in 6 periods each with one month duration. During these periods, we undertook the production planning of the company four products assuming stable production costs and availability of demand quantities which are shown in Tables 1 and 2. The outcome is as follows: It is necessary to know that although there is sufficient capacity to supply the demands of third and fifth periods for second product, fourth and sixth periods for fourth product and sixth period for the first product, we will not succeed to supply customer demands at the end of specified period. It means that at this point our goods have been depleted.
During the third and second periods customer demands for the first and second products have been supplied through the storage inventory, supplying the demand of other periods is achieved through production process (Table 3.4 and 5).

VIII. RESULT AND CONCLUSION

In the paper, we consider a form of production designing and planning in which good storage capacity is a limiting factor. The problem is more complicated considering the following items:
1- Good storage capacity has stable limitation,
2- Good storage is not permissible,
3- Coming orders will be lost by the good shortage
4- Production costs and good shortage cost are stable.

In the present discussions, above problems were examined but in practice we will see that in processing companies, there are various problems which are out of control .

- With respect to the research findings and in comparison to the past incurred costs, it can be concluded that the company using the policy will be able to implement broader marketing activities to attract more customers if it loses its customers due to failing to satisfy their demands, considering the allocated costs.
- Considering the present inflation rate and with respect to the past financial year, it can be said that total incurred cost is acceptable.
- The most of the company inventory capacity has been utilized such that from the Table 3 it is obvious that only 10000t of inventory from the total 300000t have not been consumed .Through the process of planning , the company will be ready for risk of inventory shortage in the production.

REFRENCES

[1] Riggs, J., Production Systems: Planning, Analysis and Control. Wiley, New York, NY. 1981.
[2] Cohen MA, Lee HL. Strategic analysis of integrated production–distribution systems: models and methods. Operations Research 1988; 36(2): 216–28.
[3] Pohlheim H. Evolutionary algorithms: principles, methods, and algorithms. Online; 2001. Available from _http://www.geatbx.com/ index.html, [accessed on 6 May 2004].
[4] Wee HM, Yu J, Chen MC. "Optimal inventory model for items with imperfect quality and shortage backordering". Omega 2007; 35:7–11.
[5] Park KS, Yun DK." Optimal scheduling of periodic activities" . Operations Research 1985; 33:690–5.
[6] Steinberg E, Parks MS.A preference order dynamic program for a knapsack problem with stochastic rewards. Journal of Operational Research, Society 1979; 30(2):141–7.

APPENDIX-TABLES

Table1. The model cost parameters

Product / Costs	First product	Second product	Third product	Fourth product
Cost price per ton consumed iron bar	538472	538432	538344	538364
Holding costs	30000	30000	30000	30000
Back order costs	53847	53843	53834	53836

Table2. Products demand values

Production / Month	Demand for Bar, size16	Demand for Bar, size18	Demand for Bar, size20	Demand for Bar, size22	Demand Sum
March	9500	10500	15000	15000	15000
April	9000	11000	15000	14000	49000
May	10000	10000	16000	14500	50500
June	11500	11500	17000	13000	53000
July	10000	10500	15000	14000	49500
August	10500	12500	14250	14250	51500

Table3. Production Orders

Production / Month	Bar, size16	Bar, size18	Bar, size20	Bar, size22	Sum
March	9500	10500	15000	15000	50000
April	9000	11000	15000	15000	50000
May	13667	6000	16000	13500	49167
June	7833	11500	17000	12000	48333
July	10000	10000	15000	15000	50000
August	4000	13000	14250	11250	42500
Total	54000	62000	92250	81750	290000

Table4. Product inventories at the beginning and end of period

Back order / Month	Bar, size16	Bar, size18	Bar, size20	Bar, size22
March	0	0	0	0
April	0	1000	0	0
May	3667	0	0	0
June	0	0	0	0
July	0	0	0	0
August	0	0	0	0

Table5. Back orders at the end of period

Back order / Month	Bar, size16	Bar, size18	Bar, size20	Bar, size22
March	0	0	0	0
April	0	0	0	0
May	0	4000	0	0
June	0	0	0	1000
July	0	500	0	0
August	6500	0	0	3000

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