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Integrated Production Planning in Multi-Component Single Product Environment

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Production planning and control has crucial impact on the production and business activities of enterprise. In this paper a modified mathematical model is proposed for planning a single product production where its components are made from different sources. From review of previous research, it is observed that few authors have developed production planning model which is confined to only a single bill of material that is not affiliated with real situation. The major distinct feature of the proposed model is that it plans not only the finished product but also of its component. Finally, this model is applied numerically in production field and its feasibility and compatibility is examined.

Keywords: Production planning and control, multi-component single product, capacity planning, in-time delivery, production equilibrium, inventory control.

1. Introduction

Planning is one of the most powerful tools of managerial function for enterprises. It provides the direction and instruction to co-ordinate and co-operate the enterprise's overall production. Aggregate Production Planning (MRP) is a process that follows medium range forecasting for determining the optimum production, work force and inventory levels for each period of planning horizon for a given set of production resources and constraints. There are different types of capacities which are generally used to manufacture products. Some of these are: regular time capacity, subcontracting capacity, overtime capacity, hiring and firing capacity etc. Sometimes, the regular time production capacity may not be sufficient to cope with the demands of various products. Under such situation, other optional capacities are used in smoothing the impact of demand fluctuations.

From the literature review, it is found that the recent trend of integrated production planning has been shifted to model development keeping an eye of the fulfillment of multiple objectives which resembles the real situation running in various industrial sectors. But in all those studies authors have developed models considering only the completed product. In real world situation, a completed product is a combination of some subassemblies, which are neglected in those reviews. These subassemblies play an important role to the final product. In this paper this problem is taken into

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consideration. Formerly developed model of aggregate production planning have used multi-product or multi-source factors in the model but they have not considered the bill of material in the model. For this reason, various kinds of inconvenience and dissatisfaction occur in allocating production demand and capacity of the plant. So, this inconvenience has motivated us to work with bill of materials of different components of a multi-components product.

Generally, Material Requirement Planning (MRP) is the core function of production planning. As the current practice for production planning is consideration of only finished goods hence it is not suitable for real life situation because every product is made of various types of components. For this reason, various kinds of inconvenience and dissatisfaction occur in allocating production demand and capacity of the plant. Hence it is very important for production planning the consideration of material requirement. For this purpose authors are highly motivated to develop a new approach where materials are considered during production planning. So the objective of this study is to modify the current production planning model so that bill of materials may be considered in the model and minimize total manufacturing cost. The major distinct feature of the proposed model is that it plans not only considering the finished product but also of its components.

After applying this model to production floor, we have found that our proposed model is so much useful in inventory and capacity planning of different production level. In fact, the proposed model is much better to reach our objectives of in time delivery, demand, inventory and capacity planning. The earlier models were only affiliated with final product whereas we aim for integrated planning of components of the final product with the help of multi-echelon stock equation and augmented matrix.

The rest of the paper is organized as follows: literature review is presented in section 2. Mathematical statements are mentioned in section 3.Results and Findings are mentioned in section 4. Section 5 represents the conclusion and References are mentioned at the end of this paper.

2. Literature Review

Integrated production planning is the planning of resource allocation of activities of employees, materials and production capacity in an industry. Countless works have been done in the field of model development for estimating demand, capacity, production and inventory planning in industries for having a good combination between demand and production so that the total costs occurring in industries are minimized. Kanet & Martin (2010) developed a model for production planning for resource capacity of lower level components in 'Integrating production planning and control: towards a simple model for Capacitated ERP'.

Bilgen and Gunther (2010) proposed a mathematical model for better production and distribution activities. The work was on- 'Integrated production planning in the fast moving consumer goods industry: a block planning application'. But the model was confined to for only fast moving consumer goods industry. In the field of capacity demand planning, application of different calculation methods to optimize the operational route carried out by Huang et al. (2009); Liu et al(2010). Huang et al. analyzed the application of various calculation methods in capacity planning but did not pick up the best one for planning.

Process planning optimization based on genetic algorithm and topological sort algorithm for digraph was carried out by Huang et al (2009).Wiers (2002) have done a case study on the integration of APS and ERP in a steel processing plant. The article presents a functional architecture that integrates the two systems, and discusses typical issues that have to be solved when ERP and APS systems have to be integrated. The architecture as presented in this paper may not be applicable to other situations. However, the process and the types of issues that are encountered may be helpful to practitioners that face the problem of how to integrate APS and ERP.

Wang and Liang (2004) presented a novel interactive Possibilistic Linear Programming (PLP) approach for solving the multiproduct aggregate production planning (APP) problem with imprecise forecast demand, related operating costs, and capacity. The proposed approach attempts to minimize total costs with reference to inventory levels, labor levels, overtime, subcontracting and backordering levels, and labor, machine and warehouse capacity. An industrial case demonstrates the feasibility of applying the proposed approach to real APP decision problems. The proposed PLP approach yields an efficient APP compromise solution and overall degree of DM satisfaction with determined goal values. Moreover, the proposed approach provides a systematic framework that facilitates the decision-making process, enabling a DM to interactively modify the imprecise data and related model parameters until a satisfactory solution is obtained. Particularly, several significant management implications and features of the proposed PLP approach that distinguish it from the LP, FGP, FLP, and stochastic linear programming models are presented. Consequently, the proposed approach is the most suitable for making real world APP decisions.

Silva et al. (2004) worked on ‘An interactive decision support system for an aggregate production planning model based on multiple criteria mixed integer linear programming’. This paper presents a multiple criteria mixed integer linear programming model to solve aggregate production planning problems. The model has been developed to optimize three performance criteria for a set of workforce, production, and inventory-related constraints. The performance criteria include: profit, late orders, and the changes in the workforce level. In order to enhance its application in practice, a decision support system based on the model has also been included. They illustrated the use of the decision support system by applying the model to solve an actual aggregate planning problem faced by Portuguese firm that produces construction products.

Aliev et al. (2007) have used Fuzzy-genetic approach to aggregate production–distribution planning in supply chain management. This study develops a fuzzy multi-objective linear programming (FMOLP) model for solving the multi-product aggregate production planning (APP) decision problem in a fuzzy environment. The proposed model attempts to minimize total production costs, carrying and backordering costs and rates of changes in labor levels considering inventory level, labor levels, capacity, warehouse space and the time value of money. The major limitations of the proposed model concern the assumptions made for each of the decision parameters with reference to production costs, forecasted demand, maximum inventory and labor levels, maximum capacity and warehouse space available, and relevant production resources. Hence, the proposed model must be modified make it better suited to the practical application. Furthermore, future researchers may explore the fuzzy properties of decision variable, coefficients,

Jamalnia and Soukhakian (2008) worked on 'A hybrid fuzzy goal programming approach with different goal priorities to aggregate production planning'. In this study a hybrid (including qualitative and quantitative objectives) fuzzy multi objective nonlinear programming (H-FMONLP) model with different goal priorities will be developed for aggregate production planning (APP) problem in a fuzzy environment. Using an interactive decision making process the proposed model tries to minimize total production costs, carrying and back ordering costs and costs of changes in workforce level (quantitative objectives) and maximize total customer satisfaction (qualitative objective) with regarding the inventory level, demand, labor level, machines capacity and warehouse space. The main limitation of this paper is the goals had fuzzy nature and selection of suitable forecasting technique.

To provide solutions to the problems of organizing different resources and making effective allocation so that the usability and practicality of production scheduling can be improved, studies in production scheduling focusing on model formulation (Wang et al. , 2012; Pan et al. , 2010), scheduling calculations (Shu and Wang, 2010) and applications in specific industries (Kopanos et al. , 2010). In these models, authors tried to reveal the scheduling problem occurring in specific industries and to find a way to rectify the problems. As these models are applied to specific industries, so the main disadvantages of them are these models are not practicable for all types of factories.
To increase practicability of production planning, improvements have been done in the choices of multiple objectives, planning model and calculations by Smith et al. (2009). Baykasoglu (2010) proposed a direct solution method that is based on ranking methods of fuzzy numbers and tabu search is proposed to solve fuzzy multi-objective aggregate production planning problem. The major limitation of these multiple objectives of planning model are sometimes authors assume some variables as 'zero' which are not actually 'zero' in normal practice.

Mirzapour et al. (2010) have developed a multi-objective robust optimization model for multi-product multi-site aggregate production planning in a supply chain under uncertainty. In this paper a new robust multi-objective aggregate production planning (RMAPP) model was presented. Some of the features of proposed model are as follows: (i) Considering the majority of supply chain cost parameters such as transportation cost, inventory holding cost, shortage cost, production cost and human related cost; (ii) considering some respects as employment, dismissal and workers' productivity; (iii) considering the working levels and possibility of staff training and upgrading; (iv)considering the lead time between suppliers and sites and between sites and customers' zones; (v) Cost parameters and demand fluctuations are subject to uncertainty. First this problem was formulated as a multi-objective mixed integer nonlinear programming and then transformed into a linear one and reformulated as a robust multi-objective linear programming in which the risk of solution was measured through absolute deviation method instead of sum of square error to remain model linearity. The RMAPP model has not come to an end and the path is still open for researchers to extend some combinations of robust optimization and multi-objective programming approaches to take advantages of them, simultaneously.

Ning et al. (2013) have studied the uncertainty of the market demand, production cost and subcontracting cost based on uncertainty theory. The objective of uncertainty analysis is to maximize the belief degree of obtaining the profit more than the predetermined profit over the whole planning horizon. The main limitation of the uncertainty analysis is the conversion of linear or non-linear variables into crisp equivalents. Sometimes it may be impossible that the model is converted into crisp equivalent. In the situation, uncertain simulation can be used to estimate the values of objective function and constraint functions, and then an intelligent algorithm (such as genetic algorithm) can be employed to solve the model. Vaibhav (2012) worked on MRP-JIT integrated production system. A combined MRP(material requirement planning) and JIT(just in time) system can be more effective manufacturing system which utilizes the best attributes of each manufacturing system need to accommodate the best planning features of MRP and the best execution features of JIT to address the changing needs of industry. When MRP and JIT involve in any production system than its balance the all entire production and also minimize their limitation by work together.

Pochet (2001) have developed Mathematical Programming Models and Formulations for Deterministic Production Planning Problems. They have studied in detail the reformulations for the core or simplest sub problem in production planning; the single-item incapacitated lot-sizing problem, and some of its variants. Such reformulations are either obtained by adding variables – to obtain so called extended reformulations– or by adding constraints to the initial formulation.

Zhong et al. (2015) tried to improve correctness and reasonability of the enterprise production plan and subsequent promote planning and control capability of enterprises by Production Planning Based on Multi-level Process Flow. This paper proposes the space-based multi-level process flow idea and establishes mathematic model and formalized expression of multi-level process flow according to the actual division of the enterprise's production space and manufacturing process of products in space units at different levels. Meanwhile, this paper proposes the concepts of the JOB lead time, POS lead time, ACC lead time and shop lead time, and gives the detailed computing method of different lead times. Based on above work, this paper analyzes mapping of process flow and production plans, expounds specific computing method of flow unit delivery time at different levels.

The paper we have been working on is – 'integrated production planning and control: A multi-objective optimization model'. In the paper of multi-objective optimization model development, Cheng and Xio tried to achieve optimization and control of enter prize manufacturing management by developing a multi-objective production planning optimization model based on integrated production planning. The developers of the model have not considered the bill of material for allocating the components of the product. But now-a-days almost all factories are producing multi-component product. As a result, this kind of limitation motivated us to work on the development of a new model for multi-objective and multi-level components product industry.

3. Mathematical Statements

3.1 Existing Model of Multi-objective Production Planning

Objective Function, Minimize Total Cost (TC) = min (LC+JC+KC+AC)

Here,
TC = Total cost occurring in a plant
LC = the total penalty cost for delayed delivery
JC = total cost of unbalanced production
KC = total inventory cost
AC = total overtime cost

Constraints

ND_t^i = max(GD_t^i- GS_t^i+ SS_t^i, 0)

Here,

GD_t^i=Product demandof item i in period t

ND_t^i = the net demand amount of item i in period t

GS_t^i=Inventory of item i in period t

SS_t^i=Product Safety Stocks of item i in period t

$TQ_t^i = UQ_t^i + NQ_t^i$

Here,

TQ_t^i = available production capacityof item i in period t

UQ_t^i= Product quantity under overtimeproduction of item i in period t

NQ_t^i=Product quantity under regular production of item i in period t

$LQ_t^i = \max\{\sum_{j=1}^{i}(ND_t^j - Q_t^j), 0\}$

Where,

LQ_t^i= the delayed product amount of item i in period t

ND_t^i = the net demand amount of item i in period t = max (GD_t^i- GS_t^i+ SS_t^i, 0)

GD_t^i=Product demandof item i in period t =$F_{\text{offset rules}}$ (FN_t^i ,ON_t^i)

FN_t^i=Product Forecast of item i in period t

ON_t^i= Product Orders of item i in period t

Q_t^i=the production planning quantity of item i in period t

If,

LC = the total penalty cost for delayed delivery

L = the penalty cost per delayed product

Then

LC = $\sum_{t=1}^{n}(LQ_t^i * L)$

$S_t^i = \sqrt{\frac{\sum_{t=1}^{n}(Q_t^i - \bar{Q})2}{n-1}}$

Where,

S_t^i = standard deviation of the product quantity of item i in period t

Q_t^i=the production planning quantity of item i in period t, then

In which $\bar{Q} = \frac{(\sum_{t=1}^{n} Q_t^i)}{n}$

Where,

JC = total cost of unbalanced production

J = the cost coefficient caused by unbalanced production, then

JC = $\sum_{i=1}^{n} S_t^i * J$

$KQ_t^i = \max\{\sum_{j=1}^{i}(Q_t^j - ND_t^j), 0\}$

Where,

KQ_t^i = inventory of item i in period t

Q_t^i=the production planning quantity of item i in period t

ND_t^i = the net demand amount of item i in period t, then

Where,

K = inventory cost per unit time per unit product

KC = total inventory cost, then

KC = $\sum_{t=1}^{n}(KQ_t^i * K)$

$AQ_t^i = \max\{\sum_{i=1}^{n}(Q_t^i - NQ_t^i), 0\}$

Where

AQ_t^i = product quantity of overtime production

Q_t^i=the production planning quantity of item i in period t

NQ_t^i=Product quantity under regular production of item i in period t, Where,

A = extra cost per unit product under overtime production

AC = total overtime cost, then

AC = $\sum_{t=1}^{n}(AQ_t^i * A)$

3.2 Proposed Model

Objective function, Minimize Total Cost (TC) = min (LC+JC+KC+AC)

Here,

TC = Total cost occurring in a plant

LC = the total penalty cost for delayed delivery

JC = total cost of unbalanced production

KC = total inventory cost

AC = total overtime cost

Constraints:

$0 \leq Q_t^i \leq NQ_t^i + UQ_t^i$ for all t, i

The variables of this equation aresame as it is assumed for the existing model.

$E_{t-1}^i + \sum_{t=1}^{n} Q_t^i = \sum_{t=1}^{n} \sum_j k\, ijND_t^j + \sum_{t=1}^{n} E_t^i$ for all i

Here,

s_t^i= the natural inventory of item i, in period t

E_t^i= Echelon stock of item i , in period t

k^{ij}= for echelon stock the amount of item i required to make one unit of item j

r^{ij}= the amount of item i required to make one unit of item j

j=1,2,3,…………………i , to identify items

s(i)= the set of successor items of i , i.e the items consuming directly some amount of item i when they are produced.

For series and assembly structures,

S(i)= singleton for all items i ,and for a finished product i, we always have s(i)=∅

The rest of the constraints remain unchanged as per comparison of existing model

LQ_t^i= max{$\sum_{j=1}^{i}(ND_t^j - Q_t^j)$, 0}

LC = $\sum_{t=1}^{n}(LQ_t^i * L)$

$S_t^i = \sqrt{\frac{\sum_{t=1}^{n}(Q_t^i - \bar{Q})2}{n-1}}$,

$JC = \sum_{i=1}^{n} S_t^i * J$

$KQ_t^i = \max\{\sum_{j=1}^{i}(Q_t^j - ND_t^j), 0\}$

$KC = \sum_{t=1}^{n}(KQ_t^i * K)$

$AQ_t^i = \max\{\sum_{i=1}^{n}(Q_t^i - NQ_t^i), 0\}$

$AC = \sum_{t=1}^{n}(AQ_t^i * A)$

All the terms and equations are discussed below.

3.3 Difference between Existing and Proposed Model

The main difference between the existing model and the proposed model is that an extra constraint is added which is

$E_{t-1}^i + \sum_{t=1}^{n} Q_t^i = \sum_{t=1}^{n} \sum_j k\, ij ND_t^j + \sum_{t=1}^{n} E_t^i$ for all i.

This constraint is used for counting echelon stock of the components of the final product. When the final product is only in consideration no echelon stock will create. But if we consider the components of the final product then at different stage echelon stock will be created.

3.4 Details about Proposed Mathematical Model

3.4.1 Net Product Demand Planning

Net product demand planning is based on the product demand planning, putting the future inventory and safety inventory into considerations and then come to the product net demand planning. Net product demand planning can be derived from the following formula:

$ND_t^i = \max(GD_t^i - GS_t^i + SS_t^i, 0)$

Where,

GD_t^i=Product demand of item i in period t

ND_t^i = the net demand amount of item i in period t

GS_t^i=Inventory of item i in period t

SS_t^i=Product Safety Stocks of item i in period t

The net product planning indicates the future product requirements and is used as a basis of production planning for enterprise.

3.4.2 Available Capacity Planning

Available capacity planning is the planning for the available capacity based on the changes between current capacity and forecast capacity. In this model, the available capacity planning can be indicated by the product quantity, which is the key of this model. Available capacity planning includes the available capacity under both regular production situation and overtime production, and the overtime production can be expressed in the following formula:

$TQ_t^i = UQ_t^i + NQ_t^i$

Where,

TQ_t^i = available production capacity of item i in period t

UQ_t^i= Product quantity under overtime production of item i in period t

NQ_t^i=Product quantity under regular production of item i in period t

When the regular production capacity meets the demand, overtime production is not recommended due to the problems associated with overtime expenses employees' emotion and quality problems etc.

3.5 Multi-Objective Product Production Planning

Product production planning is the product yield planning in certain period in the future and making production planning shall not only consider the net demand planning and available capacity planning, but also all kinds of performance objectives in the production process comprehensively. Four objectives are considered in this model including

i) Maintaining in time delivery
ii) Maintaining production equilibrium
iii) Minimizing inventory and
iv) Minimizing overtime production.

3.5.1 In-time Delivery

In time delivery refers to deliver product to customers, which meet the quantity and quality in the required date and in time delivery will increase the reputation and customer's satisfaction. However, in realistic conditions, the delayed delivery is stationary due to the production capacity, bad equipment, material shortage and other occasional accident or emergency. If the produced product quantity cannot meet the net demand, it must be made up in the subsequent production process. The goal of enterprise is to minimize the delayed delivery and by setting the penalty cost in this model can help achieve this goal.

The delayed product amount can be getting by calculating the net demand and production planning quantity. The formula is:

$LQ_t^i = \max \{\sum_{j=1}^{i} (ND_t^j - Q_t^j), 0\}$

Where,

LQ_t^i= the delayed product amount of item i in period t

ND_t^i = the net demand amount of item i in period t = max (GD_t^i- GS_t^i+ SS_t^i, 0)

GD_t^i=Product demand of item i in period t =$F_{offsetrules}(FN_t^i, ON_t^i)$

FN_t^i=Product Forecast of item i in period t

ON_t^i= Product Orders of item i in period t

Q_t^i=the production planning quantity of item i in period t

If,LC = the total penalty cost for delayed delivery

L = the penalty cost per delayed product

Then

$LC = \sum_{t=1}^{n} (LQ_t^i * L)$

In order to assure the in-time delivery, the smaller LC the better and when LC equals to 0, then it means that all products can be delivered in time during the planning period.

3.5.2 Production Equilibrium

Production equilibrium refers to the stability and balance of the produced products during each production period of enterprises, which can make the production process easier to control and manage, and guarantee the product quantity stability effectively. In this model, the quantity due to production equilibrium is represented by S, which is the standard deviation of the product quantity in each period. The smaller S becomes, the more balanced the production can be. Otherwise represent the more wide fluctuation of the product quantity produced.

Where,

S_t^i = standard deviation of the product quantity of item i in period t

Q_t^i=the production planning quantity of item i in period t, then

$S_t^i = \sqrt{\frac{\sum_{t=1}^{n}(Q_t^i - \bar{Q})2}{n-1}}$,

In which $\bar{Q} = \frac{(\sum_{t=1}^{n} Q_t^i)}{n}$

Where, JC = total cost of unbalanced production

J = the cost coefficient caused by unbalanced production, then

$JC = \sum_{i=1}^{n} S_t^i * J$

3.5.3 Occupied Inventory

When the product demand fluctuates widely or inconstantly, temporary buffer inventory may occur to satisfy the customer's needs. Buffer inventory can be regarded as an up-front investment to satisfy the customer's needs and this inventory will bring certain occupied funds, so for cost reasons, this inventory shall be smaller as possible.

Where,
KQ_t^i = inventory of item i in period t

Q_t^i=the production planning quantity of item i in period t

ND_t^i = the net demand amount of item i in period t, then

$KQ_t^i = \max \{\sum_{j=1}^{i}(Q_t^j - ND_t^j), 0\}$

Where,

K = inventory cost per unit time per unit product

KC = total inventory cost, then

$KC = \sum_{t=1}^{n}(KQ_t^i * K)$

The inventory cost is supposed to be the less the better, when meeting the customers' needs.

3.5.4 Overtime Expenses

When the regular capacity cannot meet the customers' needs effectively, over time work associated with extra overtime cost, will be needed.

Where
AQ_t^i = product quantity of overtime production

Q_t^i=the production planning quantity of item i in period t

NQ_t^i=Product quantity under regular production of item i in period t, then

$AQ_t^i = \max\{\sum_{i=1}^{n}(Q_t^i - NQ_t^i), 0\}$

Where,

A = extra cost per unit product under overtime production

AC = total overtime cost, then

$AC = \sum_{t=1}^{n}(AQ_t^i * A)$

The overtime capacity shall be avoid, when the regular capacity can meet the market demand.

3.6 Echelon Stock Concept for Multi-level BOM structure

The formulation of the general multi-level planning problem does not contain explicitly the single item problem because of the presence of both dependent and independent demand for the items. By using echelon stock concept an interrelation can be established among the items of BOM structure. The formulas are.

$E_t^i = s_t^i + \sum_{j \in s(i)} r^{ij} E_t^j$ for all i , t

$E_t^i - \sum_{j \in s(i)} r^{ij} E_t^j \geq 0$ for all i , t

Above equations refer product structure linking constraint coming from the non-negativity of the natural stock variables.

Here,

s_t^i= the natural inventory of item i, in period t

E_t^i= Echelon stock of item i , in period t

k^{ij}= for echelon stock the amount of item i required to make one unit of item j

r^{ij}= the amount of item i required to make one unit of item j

j=1,2,3,…………………i , to identify items

s(i)= the set of successor items of i , i.e the items consuming directly some amount of item i when they are produced.

For series and assembly structures,

S(i)= singleton for all items i ,and for a finished product i, we always have s(i)=∅

3.7 Formulation of the Model

Based on the above mentioned analysis, performance objectives including in time delivery, production equilibrium, stock inventory and overtime production shall be considered thoroughly, in addition to the net product demand and capacity. All these objectives are interdependent and restrict with each other, which may be hard to reach unify. For example, when the net product demand fluctuates widely, choices between inventory and overtime production shall be made to assure the in time product supply. In order to deal with the fluctuation, there are solutions including increasing the inventory or provide overtime production.

By setting the parameters of the four goals of cost, this model convert the multi-objectives optimization problem into a single objective optimization problem, by adjusting the value of the different cost parameters, managers can make a conscious choice of key targets, in order to achieve optimization of the manufacturing process management and control. The model is described as follows.

3.7.1 Objective Function

Total Cost (TC) =minimize (LC+JC+KC+AC)

Here,

LC= the total penalty cost for delayed delivery;

JC = total cost of unbalanced production

KC = total inventory cost; AC = total overtime cost

Decision Variable: Q_t^i=the production planning quantity of item i in period t

Known Data: FN_t^i, ON_t^i, GS_t^i, SS_t^i, UQ_t^i, NQ_t^i, L, J, K, A

FN_t^i=Product Forecast of item i in period t

ON_t^i= Product Orders of item i in period t

GS_t^i=Inventory of item i in period t

SS_t^i=Product Safety Stocks of item i in period t

UQ_t^i= Product quantity under overtime production of item i in period t

NQ_t^i=Product quantity under regular production of item i in period t

L = the penalty cost per delayed product

J = the cost coefficient caused by unbalanced production

K = inventory cost per unit time per unit product

A = extra cost per unit product under overtime production

3.7.2 Constraints

$0 \leq Q_t^i \leq NQ_t^i + UQ_t^i$ for all t, i

Refer Production Capacity constrint,

$E_{t-1}^i + \sum_{t=1}^{n} Q_t^i = \sum_{t=1}^{n} \quad \sum_j k^{ij} ND_t^j + \sum_{t=1}^{n} E_t^i$ forall i

Refer total product quantity shall equal tothe sum of net product demands of item i in period t

$LQ_t^i = \max \{\sum_{j=1}^{i} (ND_t^j - Q_t^j), 0\}$

$LC = \sum_{t=1}^{n} (LQ_t^i * L)$

Above equiations are constraints due to in-time delivery.

$S_t^i = \sqrt{\frac{\sum_{t=1}^{n} (Q_t^i - \bar{Q})2}{n-1}}$,

$JC = \sum_{i=1}^{n} S_t^i * J$

Above equiations are constraints due to disturbance occurring in production equilibrium.

$KQ_t^i = \max \{\sum_{j=1}^{i}(Q_t^j - ND_t^j), 0\}$

$KC = \sum_{t=1}^{n}(KQ_t^i * K)$

These are constraints for occupied inventory.

$AQ_t^i = \max \{\sum_{i=1}^{n}(Q_t^i - NQ_t^i), 0\}$

$AC = \sum_{t=1}^{n}(AQ_t^i * A)$

The above equations represent constraints due to overtime expenses.

3.8 Applicable Scope and Solution

This model can be applied where the assumption will be met. For any manufacturing enterprise the solution provided by this model can be applied for planning and control to manufacture spare parts and products in the production systems. Application of this model will make the manufacturing enterprise comfort in planning and controlling production system. To get the solution, C programming language is used in this model. Also MATLAB can be applied to get the solution.

4. Results and Findings

To reflect the priority order, expense parameters, including L=400, K=20, J=10, A=50, are set to carry out the optimization model and the results are shown in Table 1.As shown in Table 1 all products can be delivered in time except in time zone 10.Inventory has been produced in different time zones. Also overtime production is necessary in time zone 6 and 10. In this model, besides the planning of the final product, planning for the successor components of the final product can be done.

Table 1: Results

		1	2	3	4	5	6	7	8	9	10	11	12	Total
Demand	Forecast(after average)	36000	36000	36000	36000	36000	36000	36000	36000	36000	36000	36000	36000	432000
	Orders(Reversed cancellation				40000			38000			42000			120000
	Net Demand	36000	36000	32000	40000	36000	34000	38000	36000	30000	42000	36000	36000	432000
Capacity	Regular Capacity	38000	38000	38000	38000	38000	30000	38000	38000	30000	38000	38000	38000	440000
	Over-time Capacity	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	120000
	Total Capacity	48000	48000	48000	48000	48000	40000	48000	48000	40000	48000	48000	48000	560000
Planning	Production Planning	17818	26182	9752	34248	6378	37622	27262	16738	729	43271	12536	31464	
	Inventory Planning	18182	9818	22248	5752	29622	0	10738	19262	29271	0	23464	4536	
	Overtime Planning	0	0	0	0	0	3622	0	0	0	1271	0	0	
	Delayed Delivery Planning	0	0	0	0	0	0	0	0	0	5271	0	0	

5. Conclusion

In the production and business activities and cost control of enterprise production planning and control has important impact. The construction and disadvantages of ERP system has been analyzed in this paper and proposed an optimization model based on multi-objectives production planning. The optimized objectives are in-time delivery, balanced production, inventory, overtime production and through setting cost parameters for all kinds of production objectives in order to maintain the balances among multiple objectives.

A case analysis is given in this paper. The results show that the optimization solution proposed by this model can give decisive supports to the production planning for manufacturing industry and effectiveness of production planning is increased. This model plans for demand and capacity allocation of different production sites and thus inventory and other costs of each and every production floor is minimized. Moreover, by applying this model, we have obtained a better algorithm of production plan using multi-echelon stock of different production sites. Thus, this model can estimate and use various resources more economically than the previous models.

The model built up in this paper is only applied in manufacturing enterprise with multiple occupied resources and multi-level bill of materials. The main limitation of this model is it cannot give solution for service providing organizations which is a big part of our life. Also, we have assumed some fixed data for our model. Complexity in data input may result the simulation of the model to failure. The future studies will be expanded into service enterprises and more production management objectives to enhance the applications of this model.

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