COMPUTER AIDED PRODUCTION PLANNING AND CONTROL SYSTEM FOR A MEDIUM SIZED PHARMACEUTICAL COMPANY

by

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ABSTRACT

Practitioners are very well aware of the problem they are facing in the production planning area . Nowadays , there are extensive information processing equipments and powerful computers . The state of art in the information processing technology enables the practitioners to apply O.R. concepts in their planning activities .

This study proposes a model for production planning and control operations of a medium sized pharmaceutical company . The aim is to minimize the total cost of production and holding inventory . When a resource requirement is different than its normal available time , then an extra cost is also incurred . Items are independent and have external demands to be met . The opening inventory level for each product has an upper bound . The algorithm , at first , disregards capacity requirements of the production and generates an initial solution . Then imposing capacity requirements , the initial solution is smoothed by applying a concept called Next Best Path to generate a better plan .

An experiment is also designed to test the performance of the heuristic . The results reveal that the algorithm generates reasonable plans in very short period of time .

ORTA BÜYÜKLÜKTEKİ BİR İLAÇ FABRİKASI İÇİN BİLGİSAYAR DESTEKLİ ÜRETİM PLANLAMASI VE KONTROL SİSTEMİ

ÖZET

Günümüzde, üretim planlaması sahasında uygulamacılar karşılaştıkları problemlerin farkındalar . Bilgisayar teknolojisinin geldiği düzey sonucu , günümüzün güçlü ve çeşitli bilgi iletişim araçları Yöneylem Araştırması metodlarının üretim planlaması çalışmalarında daha verimli şekilde kullanılmasına imkan tanımaktadır .

Yapılan bu çalışma orta büyüklükteki bir ilaç fabrikasında üretim planlaması ve kontrolü için bir model öngörmektedir . Amaç üretim ve envanter taşıma maliyetinin kapasite artırım maliyeti ile birlikte enazlanmasıdır . Birbirinden bağımsız ürünlerin sadece karşılanmaları gereken piyasa talepleri vardır . Her ürünün aylık açılış envanteri bir üst limite sahiptir . Algoritma , ilk önce sığa gereksinimlerini göz ardı ederek baslangıç çizelgesini oluşturur . Daha sonra olusturulan çizelge sığa gereksinimi açısından daha düşük maliyete sahip yeni bir çizelge haline getirilmek üzere Sonraki En İyi Yol adı verilen bir metod ile yeniden düzenlenir .

Oluşturulan bulgusal metodun performansını ölçmek için bir deney düzenlenmistir . Oluşturulan deneyin sonucu algoritma'nın gerçek veriler ile çok kısa sürede kabul edilebilir çizelgeler ürettigini göstermiştir .

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I. INTRODUCTION

1.1. Problem Definition

This study proposes an integrated computer package for a medium sized pharmaceutical company to plan and control her production activities .

The Company produces almost 100 different products . Demand for each product is determined by the Marketing Department at the beginning of each period and demand must be satisfied in the period it occurs . Backorders are not allowed . Each product has a fixed set-up cost and a unit dependent variable cost . The variable cost has two components :

One is stationary in time and the other non-stationary . Therefore the variable unit production cost can be stated mathematically as follows :

$$C_i(t) = l_i + i_{it}$$

Where

$C_i(t)$:variable unit cost of producing product i in period t

l_i :stationary part of variable unit cost of product i . It is the sum of local material and labour consumption costs .

i_{it} : non-stationary part of variable unit cost of product i . It is the cost of imported materials which depends on the periodical exchange rate .

Each unit held at the beginning of each period incurs a certain percentage of its unit production cost as an inventory holding cost . When a lot is produced it consumes a constant set-up time and each unit produced requires a certain production time . The set-up time and set-up cost are not sequence dependent . If a product is scheduled for two successive periods , one set-up may be eliminated by scheduling that product last in the first period and first in the succeeding period . This possibility is ignored in this thesis , since it can rarely be realized.

A product can only be produced in integer multiple amounts of its standard lot size . These lot sizes are determined during the formula generation of product to yield an optimum result confirming required specifications .

The available normal time for resources is restricted by the number of working days available during each period . In each period , if a resource is used more than its capacity (available normal time) then an overtime cost is incurred . On the contrary , if a resource is used less than its capacity , then an undertime cost is realized.

The inventory level for each product is also restricted. That is , at the beginning of a period a product can not have an inventory level greater than the total sales forecast of a certain number of months' sales .

The objective of the company is to minimize the combined set-up , production , inventory holding , undertime and overtime costs subject to demand and capacity constraints.

The company manages all these problems in a semi-automated manner using both its main frame and PCs . Each month when forecast figures are determined , they are transferred to a Lotus worksheet and for each product a production schedule is prepared by considering its inventory constraint . At that stage , no attention can be paid to the change of the unit production cost during each period . Then these planned production figures are transferred to different worksheets to see their impact on the inventory level and the capacity requirement . After that , modifications are done on the planning worksheet and the effect of it on other worksheets are checked. This iterative procedure continues until a satisfactory production plan is generated .

With the concept introduced in this thesis , the Company will be able to generate her production plan automatically , measure some performance criteria instantaneously , and do sensitivity analysis on production plan very easily . In short this thesis will bring an integration to her production planning system .

1.2. Literature Survey

There are many works in the production planning and scheduling area . In this section , we review some of the relevant previous work .

In the single stage , single item lot sizing area Wagner and Whitin [1958] present a shortest path solution for the single-stage uncapacitated lot sizing problems . Other heuristic algorithms are developed by the practitioners . Florian and Klein [1971] tackle the problem with constant capacity . They present an efficient dynamic programming algorithm using the characterization of the extreme point schedules . Lambrecht and Vander Eecken [1978] consider the variable capacity problem , and they develop an algorithm by fixing the number of periods with zero production . Algorithms which solve Capacitated Lot Sizing Problems without set-up time in a single pass , forward through time , are presented by Eisenhut [1975] , Lambrecht and Vanderveken [1979] , Dixon and Silver [1981] , Dogramaci ,Panayiotopoulos , and Adam [1981] ,and Maes and Van Wassenhove [1986] . Thizy and Van Wassenhove [1985] , Dogramaci , Panayiotopoulos , and Adam [1981] present more elaborate algorithms which require more computational efforts .

In the single-stage lot sizing with shared capacity area Manne [1958] provides a representation of the individual schedules as columns of a linear program . Lasdon and Terjung [1971] improve this approach by employing large scale optimization techniques . Their formulations consists of continuous approximations of zero-one integer structures and a largely integer solution is assured only when the number of products greatly exceeds the number of resource-periods . Newson [1975] develops a heuristic which at first decomposes the problem into separate uncapacitated single-item problems and uses a series of shortest path network problems for each product . He uses a systematic approach to change infeasible production plans on the basis of marginal analysis until the capacity constraints are satisfied . Kleindorfer and Newson [1975] find lower bounds using generalized duality theory with linear programming. Trigeiro , Thomas , and McLain [1989] focus on the effect of set-up time on lot sizing . They work on single-machine lot sizing problems with nonstationary costs, demands ,and set-up times . They decompose the problem into a set of uncapacitated single product lot sizing problems by using the Lagrangean relaxation of capacity constraints . The Lagrangean dual costs are updated by subgradient optimization , and the single item problems are solved by dynamic programming .

The hierarchical approach to production planning is becoming increasingly popular among the researchers . In this approach , the production planning and scheduling problem is partitioned into a hierarchy of subproblems and a coordination between hierarchies is accomplished .
Graves [1982] employs duality and relaxation principles to incorporate feedback between the aggregate planning model , which determines the aggregate capacity and inventory levels , and the detailed scheduling model that determines lot sizes . Bitran , Haas , and Hax [1981] show that the hierarchical approach gives near optimal solutions in some cases .

In the multi-stage lot sizing area Love [1972] shows that in the serial production systems , the optimal solution must have the *nested property* , if the costs are nonincreasing in the time . That is , if there is no demand (external and dependent) , there should be no production in that period . Using this property , he presented a dynamic programming solution .

In the hieararchical multi-stage production planning area Billington et al. [1983] propose the method of product structure compression in order to reduce the problem size and partially aggregate the many items that are linked . Gabbay [1979] devises an aggregation/disaggregation procedure for serial production lines in which items have to pass through the same set of capacitated resources . Bitran et al. [1982] analyze a two-stage production system using hierarchical planning concept .

This study presents a heuristic smoothing approach that uses the shortest path concept of mathematical programming . In this sense , it is a hybrid of the approaches of the works of Newson [1975] , and Trigeiro , Thomas , and McLain [1989] .

II. COMPUTER AIDED PRODUCTION PLANNING AND CONTROL SYSTEM FOR A MEDIUM SIZED PHARMACEUTICAL COMPANY

2.1. A Heuristic Approach to a Multi-Item Multi-Resource Single Stage Production Scheduling Problem

2.1.1. Formulation and Notation

In this section the Production Scheduling problem of the thesis is formulated , and the basic assumptions of our approach are stated .

The production activity of the Company has a dynamic structure represented by a finite number of time periods , $t=1,2,....,T$.

The production facility produces N distinct outputs, $i=1,2,....,N$. All of these items are finished goods with external demands only . Thus we consider problem of scheduling N distinct products over a time span of T periods with given demand levels to be filled during the period they occur .

At time period t , X_{it} units of product i are produced . The amount produced can only be an integer multiple of standard lot size L_i . Together with the starting inventory at the beginning of period t , namely I_{it-1} , X_{it} is distributed among the ending inventory I_{it} and the external demand d_{it} .

It is assumed that $I_{i0} = I_{iT} = 0$ for all $i=1,2,\ldots,N$. This assumption is included in the model for the ease of computations . In real life it is impossible to have zero opening inventory in the first period for all products . In such cases the opening inventory figure is subtracted from demand data beginning from period one and modified demand figures are used in further calculations. In the last period it is wise to produce , if there is a production scheduled , only the demand of that period , since we do not have the data for the coming periods . Another assumption is that demand data are deterministic . At the beginning of each period , the Marketing Department determines the sales forecast figure for each product and these figures constitute a target for the Company to be achieved . These figures can not be changed during the period . At the end of period these figures are compared against actualized values and corrective actions are taken . All planning , financing and other activities during that period are pursued by considering forecasts given at the beginning of the period .Thus , it is reasonable to assume demand data to be deterministic .

There is a fixed set-up cost incurred when a resource is changed over to a different product . The set-up costs are independent of subsequent levels of production and of the prior production configuration of the facility . Also a loss in productive time is incurred during product changeover. Set-ups are represented by binary variables δ_{it} where

$$\delta_{it} = \begin{cases} 1 & \text{if } X_{it} > 0 \\ 0 & \text{Otherwise} \end{cases}$$

The variable unit production cost has two components and changes through time . The stationary part is composed of the local material and the labour overhead cost . The imported material cost changes through time with respect to the exchange rate and represents the non-stationary part of the variable unit production cost . Thus the variable unit production cost may be stated formally as follows ,

$$C_i(t) = l_i + i_{i1} \frac{f(1)}{f(t)}$$

where f(t) represents exchange rate conversion factor for period t . The unit production cost also has a constant term S_i which is incurred once when a lot is scheduled for production .

The set-up and production of one unit of product i requires s_{ik} and b_{ik} units of resource k respectively . Each resource k has a capacity (normal time) , R_{kt} , during period t . At time period t , using resource k less than its capacity R_{kt} incurs an undertime cost with hourly rate u which is constant in time. Moreover if a resource is demanded more than its capacity then an overtime cost is actualized with an hourly rate of o which is constant in time .

Per unit cost of keeping stock of product i at the end of time period t is denoted by h_{it} . It is assumed that the holding cost of one unit of product i is a certain percentage of its unit production cost in that period .

At time period t , product i has a predetermined inventory upper bound , n_{it} , expressed as the number of weeks of sales of that product . So we can not hold more than a few weeks' sales on hand .

Formally the production scheduling problem can be stated as follows :

(P1)

$$\text{Min} \sum_{i=1}^{N} \sum_{t=1}^{T} [S_i \delta_{it} + (l_i + i_{i1} \frac{f(1)}{f(t)}) X_{it} + h_{it} I_{it}] +$$

$$u \sum_{j=1}^{K} \sum_{t=1}^{T} \text{Max}\{P_{jt}, 0\} + o \sum_{j=1}^{K} \sum_{t=1}^{T} \text{Max}\{-P_{jt}, 0\} \qquad (1)$$

s.t.

$$I_{it-1} + X_{it} - I_{it} = d_{it} \qquad i=1,2,...,N \quad t=1,2,...,T \qquad (2)$$

$$R_{jt} - \sum_{i \in M_j} [s_{ij} \delta_{it} + b_{ij} X_{it}] = P_{jt} \qquad j=1,2,...,K \quad t=1,2,...,T \qquad (3)$$

$$0 \le I_{it} \le n_{it} \qquad i=1,2,...,N \quad t=0,1,...,T \qquad (4)$$

$$X_{it} \in \{0, L_i, 2L_i, 3L_i .....\} \qquad i=1,2,...,N \quad t=1,2,...,T \qquad (5)$$

$$\delta_{it} = \begin{cases} 1 & \text{if } X_{it} > 0 \\ 0 & \text{Otherwise} \end{cases} \qquad i=1,2,...,N \quad t=1,2,...,T \qquad (6)$$

By linearizing overtime and undertime cost terms in the objective function of (P1) one can have the following equivalent problem (P2) .

(P2)

$$\text{Min} \sum_{i=1}^{N} \sum_{t=1}^{T} [S_i \delta_{it} + (l_i + i_{i1} \frac{f(1)}{f(t)}) X_{it} + h_{it} I_{it}] +$$

$$u \sum_{j=1}^{K} \sum_{t=1}^{T} U_{jt} + o \sum_{j=1}^{K} \sum_{t=1}^{T} O_{jt} \qquad (7)$$

s.t.

$$I_{it-1} + X_{it} - I_{it} = d_{it} \qquad i=1,2,\ldots,N \quad t=1,2,\ldots,T \qquad (8)$$

$$R_{jt} - \sum_{i \in M_j} [s_{ij} \delta_{it} + b_{ij} X_{it}] = P_{jt} \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (9)$$

$$U_{jt} \geq P_{jt} \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (10)$$

$$U_{jt} \geq 0 \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (11)$$

$$O_{jt} \geq -P_{jt} \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (12)$$

$$O_{jt} \geq 0 \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (13)$$

$$0 \leq I_{it} \leq n_{it} \qquad i=1,2,\ldots,N \quad t=0,1,\ldots,T \qquad (14)$$

$$X_{it} \in \{0, L_i, 2L_i, 3L_i \ldots\ldots\} \qquad i=1,2,\ldots,N \quad t=1,2,\ldots,T \qquad (15)$$

$$\delta_{it} = \begin{cases} 1 & \text{if } X_{it} > 0 \\ 0 & \text{Otherwise} \end{cases} \qquad i=1,2,\ldots,N \quad t=1,2,\ldots,T \qquad (16)$$

The objective of the problem (P2) is to minimize the total production and holding cost of all products , and undertime and overtime cost of all available resources .

Constraint set (8) represents the flow balance equation for each product i in each period t . As we are concerned with single-stage systems , there is no interrelation between products . Equation set (8) ensures that the external demand of product i and its ending inventory during period t is only supplied by the incoming inventory from previous period and current period's production .

Constraint set (9) represents the time varying unused capacity in each period for every resource . Products compete for the set-up and production capacity of the resources . The system has three types of resources : Manufacturing resources , packaging resources ,labour resource (workers) . Therefore the model has more than one resource .

Constraint sets (10) and (11) are added to the model to linearize the undertime terms in the objective function of (P1) . Letting

$$U_{jt} = \mathrm{Max}\{R_{jt} - \sum_{i \in M_j} [s_{ij}\delta_{it} + b_{ij}X_{it}] \text{ , } 0\} \qquad \begin{matrix} j=1,2,\ldots,K \\ t=1,2,\ldots,T \end{matrix}$$

linearizes the undertime terms in the objective function . However this transformation brings in two additional constraint sets because of the fact that if an entity is equal to the maximum of two terms then the entity is greater than or equal to each of these two terms . Therefore constraint sets (10) and (11) must be added to the formulation .

The logic behind constraint set (12) and (13) is the same as in the constraint set (10) and (11) . However they represent overtime level of resource j during period t .

Constraint set (14) represents the inventory upper bound of product i in period t . For each product and in each period , there is an inventory level limitation called the number of weeks. It states that the inventory level of product i in period t can not exceed a predetermined number of weeks of sales of that product .

Constraint set (15) denotes that the production amount of each product can only be an integer multiple of its standard lot size . These standard lot size figures are determined during the formula generation of each product to give the optimum yield and to fulfill certain chemical and physical requirements of the product .

Constraint set (16) is a binary variable set and represents the set-up operation of product i in period t . In period t , if product i has a production scheduled , than the respective binary variable takes value of one . Otherwise it is assigned the value zero .

Table 1 summarizes the notation used in this thesis.

Table 1. Summary of the Basic Notation

b_{ij}	Hours of resource j needed per unit output of product i
C_{jt}	Capacity demanded for resource j during period t
d_{it}	External demand for product i during period t
f(t)	US $ equivalent of one TL
h_{it}	Holding cost rate of keeping one unit of inventory of product i in period t for one unit of time
I_{it}	Number of product i in inventory at the end of period t
i_{it}	Imported material cost of producing one unit of product i in period t
K	Number of resources
l_i	Local material and labour cost of producing one unit of product i
M_j	A set containing products processed by resource j
N	Number of products
n_{it}	Inventory upper bound of product i during period t
O_{jt}	Hours of overtime utilization of resource j in time t
o	Hourly overtime rate
P_{jt}	Level of unused capacity of resource j during period t
R_{jt}	Available normal time of resource j during period t
S_i	Cost of a set-up operation of product i (fixed cost)
s_{ij}	Hours of resource j needed for a set-up operation of product i
T	Number of periods in the planning horizon
U_{jt}	Hours of undertime utilization of resource j in time t
u	Hourly undertime rate
X_{it}	Number of product i produced in time period t
δ_{it}	Binary set-up variable for product i in period t

2.1.2. A Fundamental Insight to the Problem

The problem (P2) can be broken into two sub-problems, and a feasible solution to (P2) subject to constraints (8)-(16) can be generated in stages .

Relaxing the capacity related constraints and capacity utilization cost terms , one has a reduced minimization problem having only inventory balance constraint which can be expressed as follow :

(P3)

$$\text{Min} \sum_{i=1}^{N} \sum_{t=1}^{T} [S_i \delta_{it} + (l_i + i_{i1} \frac{f(1)}{f(t)}) X_{it} + h_{it} I_{it}]$$

s.t. (8),(14),(15),(16)

Applying the Wagner-Whitin conditions ($I_{it}X_{it}=0$) for each product one can optimize the objective function of (P3). The Optimum solution ,$\underline{X}^*$, for (P3) sets a lower bound for the main problem (P2).

Then defining the aggregate capacity required by the production plan during period t for resource j as C_{jt} .

$$C_{jt} = \sum_{i \in M_j} [s_{ij} \delta^*_{it} + b_{ij} X^*_{it}] \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (17)$$

One can state the second problem as follows ;

(P4)

$$\text{Min } u\sum_{j=1}^{K}\sum_{t=1}^{T}U_{jt} + o\sum_{j=1}^{K}\sum_{t=1}^{T}O_{jt} \qquad (18)$$

s.t.

$$\sum_{i\in M_j}[s_{ij}\delta^*_{it} + b_{ij}X^*_{it}] = C_{jt} \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (19)$$

$$R_{jt} - C_{jt} \le U_{jt} \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (20)$$

$$U_{jt} \ge 0 \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (21)$$

$$C_{jt} - R_{jt} \le O_{jt} \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (22)$$

$$O_{jt} \ge 0 \qquad j=1,2,\ldots,K \quad t=1,2,\ldots,T \qquad (23)$$

Because of the fact that we ignored resource capacities the solution of (P3) constitutes a lower bound for the main problem . We assumed that resources had infinite capacity . With (P4) we again restrict resource capacities . Therefore we should either shift production or do nothing if the capacity required by the solution of (P3) is within the capacity bounds . If we have to shift production our new cost should not exceed the value that would have been incurred if we had applied the solution of (P3) including capacity cost . That is our upper bound for main problem is the cost of (P3) increased by the necessary capacity cost .

Formally , z^* ,the cost of (P1) lies in the interval

$$z^*_1(\underline{X}^*) \le z^* \le z^*_1(\underline{X}^*) + z^*_2(\underline{X}^*,\underline{C}^*) \qquad (24)$$

where

$z^*_1(\underline{X}^*)$ is the solution of (P3) and

$z^*_2(\underline{X}^*,\underline{C}^*)$ is the capacity cost of applying plan $\underline{X}^*$ which is the solution of (P3) and requires $\underline{C}^*$ units of capacity .

Therefore the challenge in the solution procedure is to generate successive plans , $\underline{X}^*$, so that the upper bound approaches to the lower bound as much as possible .

There are three considerations :

(a)Selection of an initial solution from which improvements may be easily obtained .

(b)Successive generations of plans so that at each iteration the upper bound decreases .

(c)Criteria for terminating the heuristic procedure.

The initial solution (with no capacity constraints) may be obtained by solving a shortest route problem for each product . The following structure represents the production scheduling of one product .

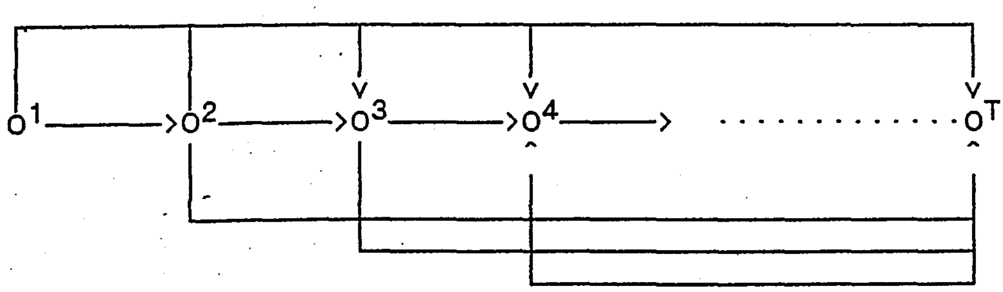


Figure 1. Shortest Route Representation of a Plan

Each node defines a time period and an arc c^{ij} represents the cost of producing at the very end of period i the demands for period i+1 to j inclusive and the cost of holding the respective amount of inventories until it is depleted . In this network there are T(T+1)/2 arcs . Each arc represents a cell in the recursion matrix of figure 2 .

i \ j	1	2	3	. . .	. . .	. . .	. . .	. . .	T
0	c^{01}	c^{02}	c^{03}						c^{0T}
1	c^{11}	c^{12}	c^{13}						c^{1T}
2		c^{22}	c^{23}	c^{24}					c^{2T}
3			c^{33}	c^{34}	c^{35}				c^{3T}
.									
.									
.									
T-1									$c^{T-1,T}$

Figure 2. Recursion Matrix of a Plan

For a T-period problem there are $2^{(T-1)}$ different paths through the network . However by incorporating inventory constraints of (P1) into the network we can reduce the number of paths , thus decreasing processing time of heuristic .

For product i in period t , our production figure can not exceed the value for which the opening inventory constraint in the succeeding period holds . The maximum amount that we can produce is realized if we enter the period t with zero inventory and after supplying the demand for period t we leave with an inventory level equal to the inventory limit for period t+1 .

That is ,

$$X_{it}(max) = I_{it+1}(max) + d_{it} \qquad (25)$$

However

$$I_{it+1}(max) = \sum_{j=1}^{Int(n_{it+1})} d_{it+j} + frac(n_{it+1})*d_{it+int(n_{it+1}+1)}$$

where $Int(n_{it+1})$ is the integer part of n_{it+1} while $frac(n_{it+1})$ shows the fractional part of n_{it+1} .

Therefore equation (25) can be rewritten as :

$$X_{it}(max) = \sum_{j=0}^{Int(n_{it+1})} d_{it+j} + frac(n_{it+1})*d_{it+int(n_{it+1}+1)} \qquad (26)$$

Calculating $X_{it}(max)$ using equation (26) for product i in every period t reduces its recursion matrix considerably.

$X_{it}(max)$ determines the maximum number of period whose demand can be produced during period t . For example if it comes out to be such that we can produce at most j period's demand at the end of period t then every c^{tl} where $j < l \leq T$ would have a cost of infinity preventing these nodes from further consideration . And these nodes will be disregarded during shortest path calculation , causing processing time to decrease .

After determining a shortest route solution for every product , resource requirements for each resource during all periods can be calculated . If shortest route solution demands more than available capacity then we would try to smooth the capacity . At this stage , we should give a definition for the Next Best Path (NBP) concept . NBP is a path which relieves some infeasibility at the least cost by preventing production of a product at the period whose infeasibility is aimed to be removed .

Suppose that in period τ ,some production results are infeasible then all cells in recursion matrix satisfying

$$c^{i\tau-1} \ , \ i \leq \tau-1 \qquad (27)$$

and

$$c^{\tau k} \ , \ k > \tau \qquad (28)$$

are assigned the value infinity . Therefore these nodes will not enter the new plan that NBP will generate .

The effect of NBP to the objective can be calculated as follows :

$$z = z^{new} - z^{old} \qquad (29)$$

where cost terms include both production and capacity utilization costs .

To remove the infeasibility of a resource NBP's for all products processed by that resource are generated and the new plan of the resource with the best performance criteria (one which decreases the upper bound mostly) is replaced by its NBP .

The iterations stop when no more infeasibilities can be removed (announcing overtime/undertime at these points) or improvement in objective function is not considerable after a certain number of iterations .

The algorithm can be summarized as follows :

1. Find an initial solution applying W-W dynamic programs for each product .
2. Compute the resource utilizations in each period for every resource based on the schedules from step 1 .
3. Produce a modified plan applying NBP concept .
4. Apply performance criterion .
5. If any infeasibility remained then move to next infeasibility and go to step 3 . Otherwise stop.

2.1.3. The Algorithm

In this section , a heuristic algorithm to find a reasonably good solution to (P1) is presented . The heuristic generates an initial solution by disregarding the capacity constraints and confirming $X_{it}I_{it}=0$ for every period and every product . Then capacity requirement of the initial solution is calculated and infeasible resource-periods are determined . Beginning from the first period , an infeasible resource is tried to be smoothed by using the NBP concept at each iteration . If an improvement in the upper bound is achieved then the plan is revised by NBP and capacity requirements are modified according to new plan . If no more infeasibilities can be removed in a period then the heuristic proceeds to the next period . When an infeasibility is removed then the algorithm returns to first infeasible period , to check all the infeasibilities with negative results handled apriori to see if an improvement could be done with the new capacity requirements .When all infeasibilities are handled , if there are still some infeasible resource-periods then the algorithm announces overtime/undertime in those periods .

The main body of the algorithm can be summarized as follows :

Step 0 : Using the demand and cost structure for each product generate an initial schedule (apply W-W conditions) by using sub-algorithm INITIAL SOLUTION .

Step 1 : Calculate the capacity requirement of initial solution generated in Step 0 using sub-algorithm CAPACITY CHECK .If there are some infeasibilities for any one of the resources then Goto Step 2 . Otherwise STOP ,current solution is a good solution .

Step 2 : Set t=1;

Step 3 : Find most infeasible resource ,r, during period t by searching percent utilization of resources . If all of resources during period t are feasible then Goto Step 8 . Otherwise Goto Step 4 .

Step 4 : Among all products using resource r find the one with least cost increase using sub-algorithm NEXT BEST PATH by preventing production during period t . If there is a product which decreases the upper bound call this product as product p and Goto Step 5 . Otherwise Goto Step 7 .

Step 5 : Replace production plan of product p with its current plan generated by Next Best Path . Add the change in cost to the Total Cost which is calculated during NBP generation .

Step 6 : Modify capacity requirements of all resources processing product p using sub-algorithm MODIFY CAPACITY .

Step 7 : Apply stopping criterion .

i) if all infeasibilities are removed

ii) if cost improvement is not a noticeable percentage of the already attained cost .

then STOP , current schedule is a good one . Otherwise Goto Step 2 .

Step 8 : If t=T (all periods are considered) then STOP . Infeasibilities are removed as much as possible . All remaining infeasibilities will incur undertime/overtime cost . Otherwise Set t=t+1 and Goto Step 3 .

The main algorithm uses different subalgorithms . A description for each one is in order .

Sub Algorithm : INITIAL SOLUTION

Step 0 : Set k = 1 and TotalCost = 0 .

Step 1 : Deduct the initial inventory of product k from its demand structure until it is depleted . Therefore we would have the initial condition of $I_{k0} = 0$.

Step 2 : For product k construct the recursion matrix by calculating the number of periods whose demand can be produced at once without violating the inventory limit constraint for each period using the formula (30) .

$$X_{kt}(max) = \sum_{j=0}^{Int(n_{kt+1})} d_{kt+j} + frac(n_{kt+1})*d_{kt+int(n_{kt+1}+1)} \qquad (30)$$

Step 3 : Assign cost of infinity to all cells , c^{tj} , in recursion matrix for which the following inequality holds .

$$\sum_{r=0}^{j} d_{kt+r} > X_{kt}(max) \qquad (31)$$

(In the computer program , cost of infinity can be represented by a boolean variable set to false) . With this assignment we guarantee being within the inventory limits .

Step 4 : For each cell in the recursion matrix calculate the cost of production and cost of holding inventory for product k using formula (32) .

$$Cost(c^{tj}) = S_k\delta_{kt} + \sum_{r=t}^{j}[(l_k+i_{k1}\frac{f(1)}{f(t)})\ d_{kr}] + \sum_{r=t+1}^{j} h_{kr}I_{kr} \qquad (32)$$

Step 5 : Generate all possible paths of the recursion matrix . During path generation , save the cheapest path which will show the shortest route (cheapest production plan) for product k at the end of the procedure .

A path can be generated very easily by using a recursive function in computer programming .

Step 6 : Set Total Cost = Total Cost + Cost of Product k .

Step 7 : If all products are scheduled then RETURN to the main algorithm . Otherwise , set k = k+1 and Goto Step 1 .

<u>Sub Algorithm : CAPACITY CHECK</u>

<u>Step 0</u> : Set $j = 1$.

<u>Step 1</u> : Set $t = 1$.

<u>Step 2</u> : Set $C_{jt} = 0$.

<u>Step 3</u> : For all products of resource j , calculate the resource consumption during period t using formula (33) .

$$C_{jt} = C_{jt} + s_{kj}\delta_{kt} + b_{kj}X_{kt} \qquad k \in M_j \qquad (33)$$

<u>Step 4</u> : if $t = T$ then Goto Step 5 . Otherwise , set $t = t+1$ and Goto Step 2 .

<u>Step 5</u> : if $j = K$ (number of resources) then Goto Step 6 . Otherwise , set $j = j+1$ and Goto Step 1 .

<u>Step 6</u> : Set $j = 1$.

<u>Step 7</u> : Set $t = 1$.

<u>Step 8</u> : If $C_{jt} > R_{jt}$ add the overtime cost to the total cost .

$$\text{Total Cost} = \text{Total Cost} + (C_{jt} - R_{jt})*o$$

Otherwise , add the undertime cost to the total cost .

$$\text{Total Cost} = \text{Total Cost} + (R_{jt} - C_{jt})*u$$

<u>Step 9</u> : If $t = T$ Goto Step 10 . Otherwise , set $t = t+1$ and Goto Step 8 .

<u>Step 10</u> : If $j = K$ then RETURN to the main algorithm . Otherwise , set $j = j+1$ and Goto Step 7 .

Sub Algorithm : NEXT BEST PATH

Step 0 : Get infeasible resource r and infeasible period t from the main algorithm .

Step 1 : Let S = { s | s ∈ M_r } (set of the products using resource r) . Set CostTest = Infinity .

Step 2 : Set k = first product in set S .

Step 3 : Set Cost = 0 .

Step 4 : Generate recursion matrix for product k as in the Step 2 and Step 3 of Sub algorithm INITIAL SOLUTION . Furthermore , assign infinity to all cells in the recursion matrix satisfying inequalities (34) and (35) to prevent the production during infeasible period t .

$$c^{it-1} , \quad i \le t-1 \qquad (34)$$

and

$$c^{tl} , \quad l > t \qquad (35)$$

Step 5 : Calculate the cost of production and holding inventory for each cell in the new recursion matrix same as in the Step 4 of Sub algorithm INITIAL SOLUTION .

Step 6 : Generate a new production plan for the product k using new recursion matrix as in the Step 5 of Sub algorithm INITIAL SOLUTION .

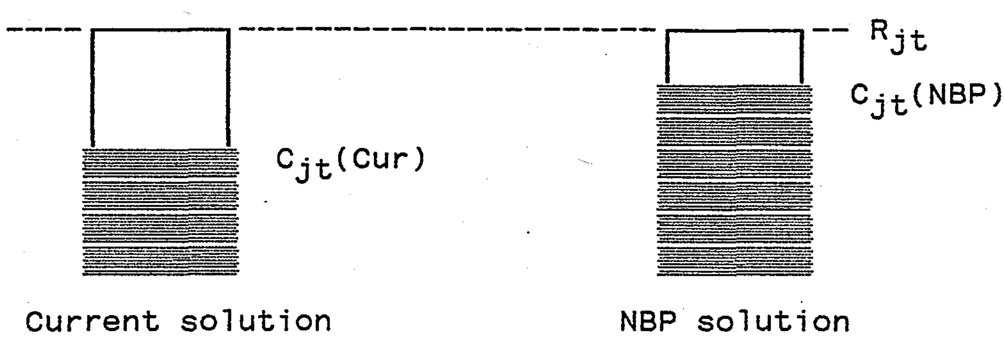
Step 7 : Find the effect of NBP for product k to the production and inventory holding cost .

Cost = Cost - Cost NBP + Cost of Current Plan

Step 8 : Add the change in resource utilization cost of all resources which process product k .

In resource utilization six different situation can occur . Each of them will be analyzed separately .

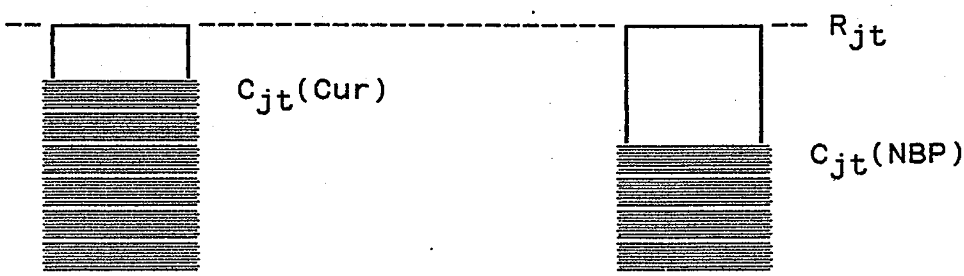
Case 1) Currently , the resource is being under-utilized , and the new solution decreases the degree of under-utilization but it is still less than the capacity .



Then there is a decrease in undertime utilization cost of resource j .

$$\text{Cost} = \text{Cost} + u * [\ C_{jt}(\text{Cur}) - C_{jt}(\text{NBP})\ ]$$

Case 2) Currently , the resource is being under-utilized , and the new solution increases the degree of under-utilization but it is still less than the capacity .

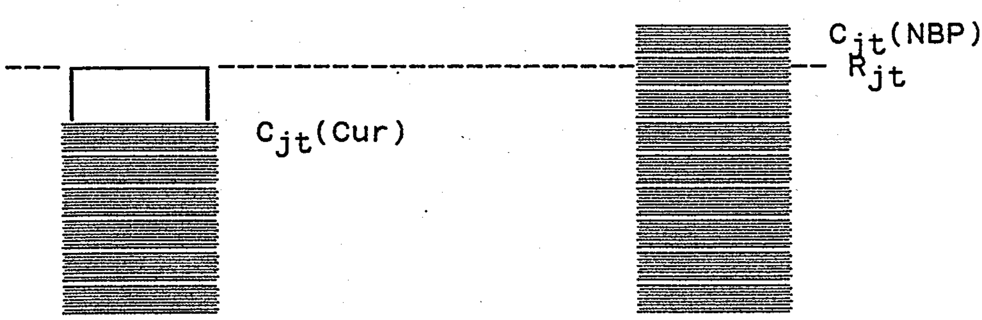


Current solution NBP solution

Then there is an increase in undertime utilization cost of resource j .

$$Cost = Cost + u * [C_{jt}(Cur) - C_{jt}(NBP)]$$

Case 3) Currently , the resource is being under-utilized , and the new solution requires over-utilization of the resource .

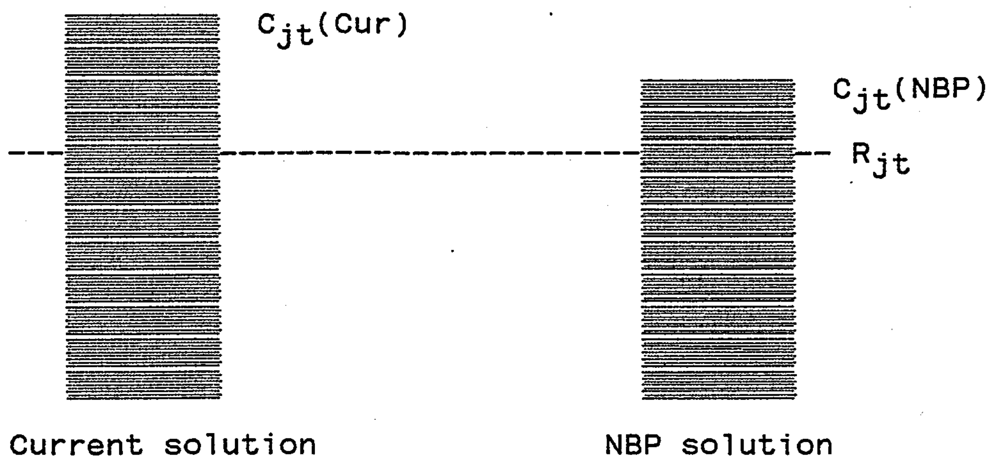


Current solution NBP solution

Then the undertime utilization cost of resource j is removed. However the overtime requirement brings in an additional cost .

$$Cost = Cost - u*[R_{jt}-C_{jt}(Cur)] + o*[C_{jt}(NBP)-R_{jt}]$$

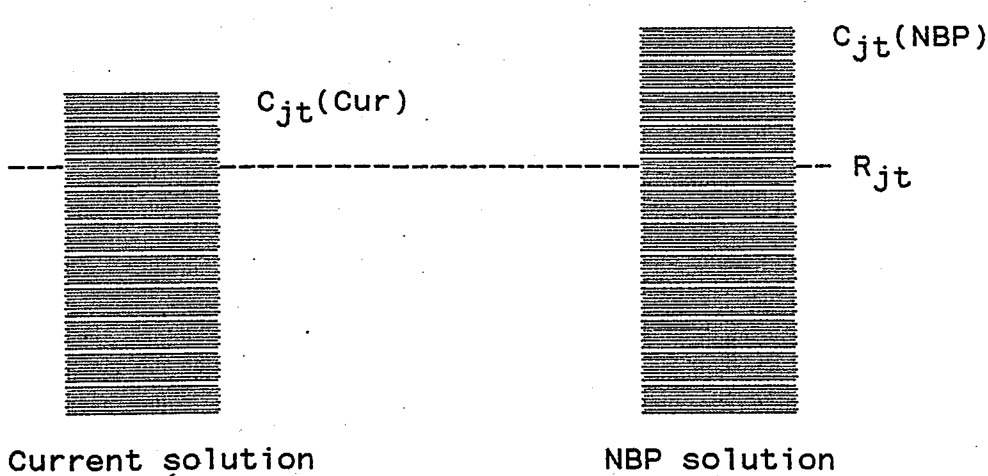
Case 4) Currently , the resource is being over-utilized , and the new solution decreases the degree of over-utilization.



Then there is a decrease in the overtime utilization cost of the resource j .

$$Cost = Cost + o * [C_{jt}(NBP) - C_{jt}(Cur)]$$

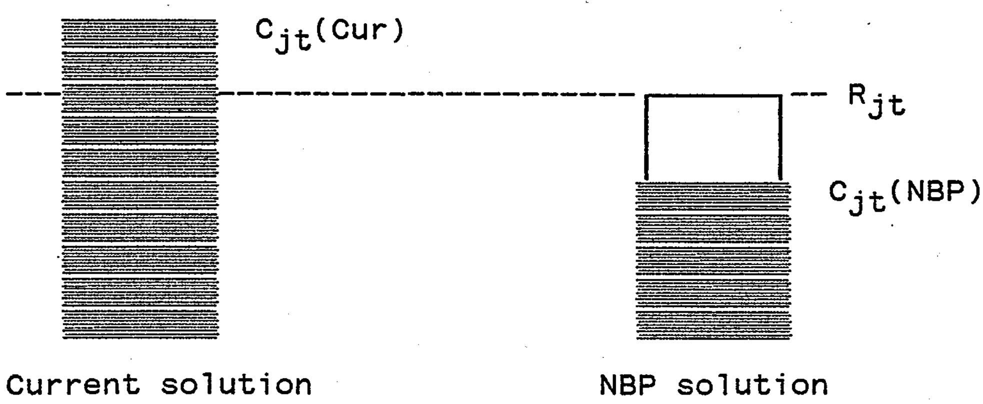
Case 5) Currently , the resource is being over-utilized , and the new solution increases the degree of over-utilization.



Then there is an increase in the overtime utilization cost of the resource j .

$$Cost = Cost + o * [C_{jt}(NBP) - C_{jt}(Cur)]$$

Case 6) Currently , the resource is being over-utilized , and the new solution requires under-utilization of the resource .



Then the overtime cost is removed . However the undertime cost of the new solution brings in an additional cost .

$$Cost = Cost - o*[C_{jt}(Cur) - R_{jt}] + u*[R_{jt} - C_{jt}(NBP)]$$

<u>Step 9</u> : If Cost < CostTest then set CostTest = Cost and save the current product as the best candidate for NBP solution of the resource r .

<u>Step 10</u> : If there are more products in set S then set k = next product in set S and Goto Step 3 . Otherwise , Goto Step 11 .

Step 11 : If Cost < 0 then the upper bound decreases . Replace the production plan of that product with NBP solution and decrease the total cost by the respective amount and RETURN to the main algorithm .

Total Cost = Total Cost + Cost

Otherwise , there is no product which decreases the upper bound.Therefore RETURN to the main algorithm to proceed with the next infeasibility .

Sub Algorithm : MODIFY CAPACITY

Step 0 : Get product k , whose capacity requirement is going to be modified , from the main algorithm .

Step 1 : Let R = { all resources processing product k };

Step 2 : Set j = first resource in the set R .

Step 3 : Set t = 1 .

Step 4 : Add the incremental requirement of NBP solution for product k with respect to the current solution to the total consumption of resource r .

$C_{rt}=C_{rt}-[s_{ij}\delta_{it}(Cur)+b_{ij}X_{it}(Cur)]+[s_{ij}\delta_{it}(NBP)+b_{ij}X_{it}(NBP)]$

Step 5 : If t = T then Goto Step 6 . Otherwise , set t =t+1 and Goto Step 4 .

Step 6 : If all the resources in the set R are processed then RETURN to the main algorithm .

Otherwise , set j = next resource in the set R and Goto Step 3 .

2.2. An Integrated System for Production Planning and Control

2.2.1. System Structure

At the beginning of each year a production plan is generated to cover the budgetted demand . With this production plan , the necessary labour consumption and resource requirements are determined and these figures are recorded as goals to be achieved throughout the year . Each month , the Marketing Department revises its sales forecast considering the current market situation and other related points . The Production Planning Department makes necessary changes in the production plan and modifies the related materials requirement plan . For the current month , the detailed scheduling is done by the Production Planning Department and is distributed to related departments (Production , Quality Control , Warehouses) . At the end of the month , actualized sales and production figures are obtained . These figures are compared against the budget and the deviations from the budget are accounted for . The sources of variances are searched by getting different reports . Actual sales is compared against budgetted sales or actual production is compared against budgetted production . In addition to these , labour consumptions and resource utilizations can be compared against the budget . These comparisons explain the efficiency/inefficiency of production activities . The following flow chart shows the Production Planning and Control System in a systematic manner :

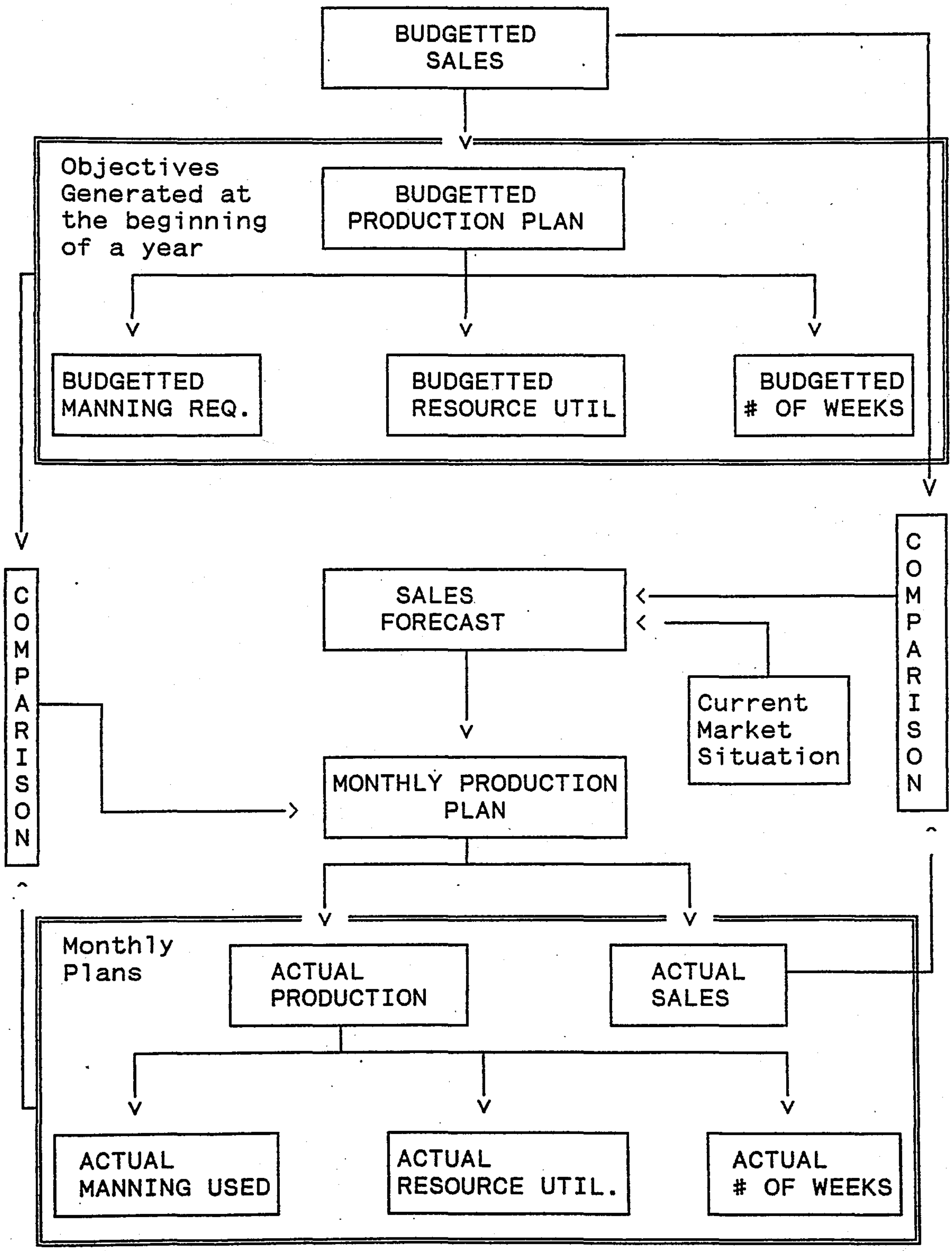


Figure 3. Flow Chart of Production Planning and Control System

Various reports can be generated to control the production activities . The summary of these reports is presented in the next section .

2.2.2. Reports

Various reports can be generated by the package . These are Machine Catalogue , Product Catalogue , Production Plan , Machine Utilization , Volume Variance , Production Plan Cost Breakdown , Number of Weeks Analysis and Manpower Requirement . These reports can be briefly explained as follows :

Machine Catalogue : It shows the products processed by the reported machine with their required set-up and processing times . For Manufacturing resources , the processing time is given as the time required to process a standard lot , for Packaging resources it shows the time required to process one thousand units in hours . Set-up times are in hours per lot . This report is printed for all resources at once .

Product Catalogue : It shows the standard information related to a product (Code , Description , Standard Lot Size , Business Code , ABC Analysis Code , Product Group Name) . It also includes the list of machines and the required times in these machines which process the reported product . The report is printed for all products at once .

Production Plan : When a production plan is generated by using the algorithm presented , the user can directly save it or make any changes and see their effects on the inventory , manpower , resource utilization , and cost. After all changes , the user obtains a good production plan . With this report ,opening inventory , scheduled production units , and forecasted sales units can be observed for each month . The user can define time interval and product groups that will appear on the report .

Machine Utilization : When a production plan is generated , for each resource , the requirement in each period can be calculated with the aid of processing and set-up times . These requirements can be printed as a report . The report shows all the products processed by the resource and their time requirement in hours in each period according to the production plan and shows the percentage that they utilize from the available capacity of the resource . At the end of each resource there are summary lines showing the total requirement and utilization of the resource , and the amount of undertime/overtime required for that resource .

Volume Variance : When the production figures are budgetted at the beginning of the year , the budgetted labour consumption is also calculated for each period , by multiplying the standard unit labour costs with production figures . During the budget year , when actual figures begin to be realized , some deviations from budgetted figures are observed . These variances can be the result of two situations : Actual production figure may deviate from budgetted one because of sales conditions or actual money spent on labour may variate from budget as a result of production conditions (efficient/inefficient working , producing more/less than budgetted units) . This report shows the cause of these variances . For a product , the first four columns show budgetted units , actual units , difference of units , and percentage of difference , respectively . The following four columns show budgetted monetary amount , actual monetary amount , difference of monetary amount and monetary amount of unit difference column (unit difference column multiplied by standard labour unit cost) . The last two columns show the percentage of monetary difference with respect to the total difference by using actual and standard amounts respectively .The report can be printed for a given interval including user defined product groups .

Production Plan Cost Breakdown : The cost incurred by a generated production plan can be printed as a report using the current cost structure . In the report , the production cost and the inventory holding cost appear in separate columns . The cost structure for each product is also printed. The user can determine the period of the report and the product groups that will appear in the report .

Number of Weeks Analysis : The inventory carried by a production plan can be calculated by finding the number of weeks whose demand can be supplied by the opening inventory in a period . This report prints the number of weeks results for the chosen product groups for each period specified by the user . At the end of each group , there are group totals.

Manpower Requirement : The manpower requirement in each period by a certain production plan can be easily calculated by using the man-hours spent for the set-up and production hours of each product . These figures can be printed as a report showing manning requirement in each month and compared against the available manpower to find out the overtime requirement . The report can be printed in a defined period for the specified product groups .

2.2.3. Future extension possibilities

The system presented above is a PC based program and runs on a IBM PS/2 Model 55-SX . However , all the data required is on the main frame . These data should be entered to the PC once each year which might take a lot of time . Therefore a conversion program that obtains all the required data directly from the main frame and convert to a format readable by this program would be of great use. Within the company LOTUS is the mostly used software. Therefore , if attainable , data interchange with LOTUS can be helpful .

A flexible report option can be added to the system so that the user can define the fields to appear on the report . With this reporting option , the user can easily make comparisons of production figures , sales figures .

In business , graphics are more meaningful and powerful than words . Therefore a graphic interface can be added to the system so that the user can define various graphics and analyze the results of planning activities with the aid of graphics .

In the current system , no specialization in manning activities is required . If such a distinction becomes necessary during time , each manpower skill group can be added to the system as a different resource with its setup and processing times .

The current system is designed to run on a single PC and uses the printable character set of Epson printers . In the future , network controls can be added to the system and the program can be used in more than one PC at the same time. This way , different departments can enter the required data from different terminals . For example , the Marketing Department enters sales forecasts for each product. The Cost Accounting Department enters product cost data into the system , etc . Furthermore , with some programming character sets of different printers (especially for the laser printers) can be added to the system . Therefore the reports can be generated on various printers and use their different character fonts .

2.3. Experimental Results

An experiment is designed to see the performance of the heuristic under various circumstances . The experiment is modelled as a 2^k factorial design . The factors that are controlled by various simulation runs are the demand structure , the set-up operation , the variable unit cost , the capacity utilization cost and the inventory upper bounds. During the simulation , each factor is set to one of the two levels denoted as + or - .

The demand structure is identified as the constant demand or the actual demand . The actual demand level shows the real life data for each product including their seasonalities . The constant demand structure is represented by taking the average of the yearly demand for each product.

The set-up operation is modelled as not existing or existing . In the zero set-up case , no set-up operation time or cost is assigned during the simulation runs. The set-up case includes the actual set-up times and the costs for each product .

The variable unit cost is examined under two different levels . In one level , it is assumed to be constant through time . This scenario is achieved by setting the monthly exchange rate constant . In the other case , the variable unit cost is modelled as increasing . This level is attained by decreasing the monthly exchange rate in time . The decreasing unit variable cost case is disregarded , since it is not possible in the current economical context . This case can occur , if the value of TL increases against the US $.

The capacity utilization cost is modeled as either existing or not . That is , for under/over utilization of a capacity we pay a cost , or we can use the capacity as much as required without any additional cost . Not paying any additional cost for the capacity utilization can be applied for the resources which are depreciated to their life time and they do not incur any cost from the accounting point of view .

The inventory upper bounds are modelled as being tight or loose . The inventory bound being loose represents the situation where there is no inventory level limit for any one of the products . This case is achieved in the simulation runs by setting the inventory bound parameters to as high as possible . The tight inventory bounds reflect the current inventory level targets of the company . They show the actual data .

For each factor + level represents the actual data that is applicable to the company and - level shows the counter value for each factor that might take place in any time . Table 2 shows all the factors considered with their level arrangements .

	Factor	−	+
f_1	Demand	Constant	Actual
f_2	Set-Up	None	Exist
f_3	Cost Structure	Constant	Increasing
f_4	Capacity Cost	None	Exist
f_5	Inventory Constraint	Loose	Tight

Table 2. Level Arrangements of the Factors

A design matrix is constructed showing all the combinations of the controlled factors . For each combination a simulation run is executed using an IBM PS-2 Model 55/SX computer with 80386 processor . Each combination is simulated only once , because of the fact that it is impossible to obtain various real life data set for a 70-product and 35-resource system . However this is not a great drawback for the experiment designed if one can realize that each year is almost a replication of the previous one . Therefore , the data sets would be very similar to each other in every year .

The responses examined during simulation runs for each combination are the total cost of the production scheduled by the heuristic and the processing time of the heuristic while generating the schedule . The design matrix of the experiment and the responses of each combination is tabulated in Table 3 .

Combination	f_1	f_2	f_3	f_4	f_5	Solution (1000 TL)	Time (sec)
1	+	+	-	+	+	109,517,074	69
2	+	+	-	+	-	102,734,787	527
3	+	+	-	-	+	104,032,257	113
4	+	+	-	-	-	97,369,629	587
5	+	+	+	+	+	182,392,828	96
6	+	+	+	+	-	136,014,638	490
7	+	+	+	-	+	176,036,721	89
8	+	+	+	-	-	120,940,949	476
9	+	-	-	+	+	109,287,425	108
10	+	-	-	+	-	102,736,762	452
11	+	-	-	-	+	104,154,757	55
12	+	-	-	-	-	97,346,894	471
13	+	-	+	+	+	181,933,090	68
14	+	-	+	+	-	135,716,343	410
15	+	-	+	-	+	176,022,615	57
16	+	-	+	-	-	120,866,983	421
17	-	+	-	+	+	114,021,050	71
18	-	+	-	+	-	104,945,540	659
19	-	+	-	-	+	107,739,202	71
20	-	+	-	-	-	98,695,107	646
21	-	+	+	+	+	190,086,961	67
22	-	+	+	+	-	137,360,475	493
23	-	+	+	-	+	182,920,306	70
24	-	+	+	-	-	124,040,180	492
25	-	-	-	+	+	113,595,474	80
26	-	-	-	+	-	104,535,770	466
27	-	-	-	-	+	107,720,117	75
28	-	-	-	-	-	98,669,982	643
29	-	-	+	+	+	189,398,187	63
30	-	-	+	+	-	135,250,668	408
31	-	-	+	-	+	182,900,422	47
32	-	-	+	-	-	122,189,491	412

Table 3. Design Matrix and the Simulation Results of the Experiment

The main effect and the two-factor interaction effect calculations are done for each factor using equation (36) and (37) respectively .

$$e_j = \frac{1}{16} \sum_{i=1}^{16} G^{ij} R^i \qquad j=1,2,..,5 \quad (36)$$

$$e_{jk} = \frac{1}{16} \sum_{i=1}^{16} G^{ij} G^{ik} R^i \qquad j=1,2,..,5 \quad j < k \leq 5 \quad (37)$$

The notation can be summarized as follows ;

e_j : The main effect of factor j

e_{jk} : The two-factor interaction effect between factors j and k

G^{ij} : The level of factor j in the i^{th} combination . It takes value of -1 or +1 with respect to the level of - or +

R^i : The result of the simulation of the i^{th} combination .

The main effect of factor j is the average change in the response due to moving factor j from its - level to its + level while holding all the other factors fixed . The main effect of factor j does not consider the interaction of different factors . The degree of interaction is measured by the two-factor interaction effect between factors j and k . It is defined to be half the difference between the average effect of factor j when factor k is at its + level (and all factors other than j and k held constant) and the average effect of j when k is at its - level .

Using equation (36) and (37) the main effect and the two-factor interaction effects for each factor is calculated for the experimentation of the heuristic presented . The main effect calculations for each factor are depicted in Table 4 .

	Cost	Time
e_1	(3,560,324)	(17)
e_2	407,670	49
e_3	51,060,564	(58)
e_4	7,992,591	(12)
e_5	30,771,518	(428)

Table 4. The Main Effect Calculations

Table 5 shows the result of the two-factor interaction effect calculations .

	Cost	Time
e_{12}	(285,919)	2
e_{13}	(717,492)	24
e_{14}	(47,324)	6
e_{15}	(2,065,295)	31
e_{23}	281,737	(0.4)
e_{24}	169,784	3
e_{25}	(190,881)	(37)
e_{34}	2,286,849	16
e_{35}	22,892,407	48
e_{45}	(1,904,380)	18

Table 5. The Two-factor Interaction Effect Calculations

Interpreting the main effect calculations reveals that the heuristic generates the lower cost schedules if the demand structure is the actual data since e_1 is negative . The other factors increase the cost when they take the level + . That is , the set-up operation , the increasing cost structure , the capacity utilization costs and the inventory bounds brings in additional costs . From the point of view of the processing time of the heuristic , it is clear that all the factors other than the set-up operation decreases the processing time when they are at level + which denotes the real life application levels for each factor . Therefore the heuristic solves the real life data in a shorter period of time .

The two-factor interaction of the demand factor with the other factors is positive when they are maintained at the same level (both at + or at -) . Such combinations decreases the total cost . However , the processing time decreases only if the demand and the cost structure are at the same level . For other factors , they must have the opposite level with the demand to decrease the processing time .

Having the set-up factor at the same level with the variable unit cost structure and the capacity utilization cost increases the total cost . However these combinations decreases the processing time . Keeping the set-up factor at the same level with the inventory bound decreases the total cost , while the processing time increases .

When the unit variable cost factor and the capacity cost , and the inventory bound factors are at the same level the total cost increases . The processing time , however , increases when the inventory bound is at the same level .

Setting the capacity cost to the same level with the inventory bound decreases the total cost . However it takes longer processing time to find out a solution .

The main effect and the two-factor interaction effect calculations show that the heuristic can generate good solutions to the real life problems (+ level for each factor) in a considerably shorter period of time .

III . CONCLUSION

In the preceding sections the single-stage multi-item production planning problem of a medium sized pharmaceutical company is analyzed and a heuristic algorithm for the solution is introduced . Furthermore for the controlling of the production activities a system is designed and programmed .

The algorithm runs in a very short period of time and generates good solutions . The system gives user the capability of doing sensitivity analysis on the generated solution by altering the production figures and seeing their effects on different performance measures .

The major advantages of the algorithm are its simplicity and implementability on the real life data . Also the system designed brings in an integrity to the production planning and controlling activities of the company .

The algorithm and the system is not company dependent . It can be used by any company which can have similar size of products and resources .

APPENDIX A. Sample Report -MACHINE CATHALOGUE-

P f i z e r I l a ç l a r i A.S. 15 March 1991 Friday Page : 1

MACHINE CATHALOQUE

* BLENDER 1000 KG	Set-Up Time (Hours)	Process Time (Hours/Lot)
0086 DELTACORTRIL 20 TA	2.0	12.0
0095 DIABINESE 100 TABL	2.0	8.0
0110 CORYBAN-D 20 KAPSU	1.0	4.0
0121 BABYPRIN 20 TABLET	2.0	6.0
0270 NEO-TM S/P 20 GR	2.0	3.0
0271 NEO-TM S/P 100 GR	2.0	3.0
0281 VALBAZEN KOYUN 10	4.0	4.0
0098 DUOCID SUSPENSION	2.0	4.0

* BLENDER 400 KG.	Set-Up Time (Hours)	Process Time (Hours/Lot)
0041 TAO 500 MG 16 TABL	2.0	6.0
0050 UNISOM 20 TABLET	2.0	8.0
0159 MINIPRESS 1MG X 30	2.0	4.0
0161 MINIPRESS 5MG X 30	2.0	4.0
0169 MINIPRESS 2MG X 50	2.0	4.0
0167 VISTARYL 25 CAPSUL	1.0	3.0
0189 G.TROSYD 100MG X 3	2.0	1.0
0280 VALBAZEN SIGIR 10	4.0	4.0
0152 GEOPEN 20 TABLET	2.0	4.0
0153 GEOPEN 40 TABLET	2.0	4.0
0154 DUOCID 375 MG 10 T	6.0	4.0
0047 TAO 16 KAPSUL	2.0	6.0
0144 TRIFLUCAN 100 MG 7	1.0	1.0

* BLENDER 2000 KG.	Set-Up Time (Hours)	Process Time (Hours/Lot)
0197 KOMPENSAN 60 TABLE	2.0	6.0
0198 KOMPENSAN 24 TABLE	2.0	6.0

* COLLETTE YAS KARISIM	Set-Up Time (Hours)	Process Time (Hours/Lot)
0095 DIABINESE 100 TABL	2.0	6.0
0197 KOMPENSAN 60 TABLE	2.0	6.0
0198 KOMPENSAN 24 TABLE	2.0	6.0
0041 TAO 500 MG 16 TABL	2.0	6.0
0280 VALBAZEN SIGIR 10	2.0	8.0
0281 VALBAZEN KOYUN 10	2.0	6.0
0189 G.TROSYD 100MG X 3	2.0	3.0
0121 BABYPRIN 20 TABLET	2.0	6.0

* STERILE BLENDER	Set-Up Time (Hours)	Process Time (Hours/Lot)
0059 PRONAPEN 400 SERUM	2.0	10.0
0061 PRONAPEN 800 SERUM	2.0	10.0

APPENDIX B. Sample Report -PRODUCT CATHALOGUE-

Pfizer Ilaçlari A.S. 15 March 1991 Friday Page : 1

PRODUCT CATHALOQUE

* 0010 TERRAMYCIN GOZ MER Pharmaceutical OIN B 226280

Machine Names	Set-Up Time	Process Time
BALL MILL	2.0 Hrs	14.0 Hrs/Lot
PLANETARY MIXER	2.0 Hrs	22.0 Hrs/Lot
IWKA EQUIPMENT	3.0 Hrs	4000.0 Un/Hr

* 0011 TERRAMYCIN DERI ME Pharmaceutical OIN A 83660

Machine Names	Set-Up Time	Process Time
PLANETARY MIXER	2.0 Hrs	22.0 Hrs/Lot
IWKA EQUIPMENT	3.0 Hrs	4000.0 Un/Hr

* 0041 TAO 500 MG 16 TABL Pharmaceutical TAB A 42426

Machine Names	Set-Up Time	Process Time
BLENDER 400 KG.	2.0 Hrs	6.0 Hrs/Lot
COLLETTE YAS KARISIM	2.0 Hrs	6.0 Hrs/Lot
SCT PANS-TABLETS COATING	8.0 Hrs	520.0 Un/Hr
KLIAN EIFFEL	6.0 Hrs	1500.0 Un/Hr
IMA-2 EQUIPMENT	8.0 Hrs	2400.0 Un/Hr

* 0047 TAO 16 KAPSUL Pharmaceutical CAP B 24625

Machine Names	Set-Up Time	Process Time
BLENDER 400 KG.	2.0 Hrs	6.0 Hrs/Lot
ALEXANDER WERCK SLUGGING	3.0 Hrs	6300.0 Un/Hr
MG-2 EQUIPMENT	8.0 Hrs	1600.0 Un/Hr
IMA-2 EQUIPMENT	6.0 Hrs	3600.0 Un/Hr

* 0050 UNISOM 20 TABLET Pharmaceutical TAB C 49000

Machine Names	Set-Up Time	Process Time
BLENDER 400 KG.	2.0 Hrs	8.0 Hrs/Lot
ALEXANDER WERCK SLUGGING	3.0 Hrs	12600.0 Un/Hr
MANESTY-TABLETTING	16.0 Hrs	4900.0 Un/Hr
LACSO TAB/CAP COUNTING	4.0 Hrs	3500.0 Un/Hr

* 0051 STREPTOMYCIN 1 GR Pharmaceutical PWS C 192000

Machine Names	Set-Up Time	Process Time

APPENDIX C. Sample Report -PRODUCTION PLAN-

PRODUCTION PLAN   Pfizer Ilaçlari A.S.   15 March 1991 Friday
(in 000"s of Units)   Initial period of the plan : Dec

Grp	Code	Description	DECEMBER			JANUARY			FEBRUARY			MARCH		
			I(o)	P	S	I(o)	P	S	I(o)	P	S	I(o)	P	S
TAB	0041	TAO 500 MG 16 TABL	23.0	42.4	30.0	35.4	84.9	40.0	80.3	0.0	45.0	35.3	84.9	45.0
	0050	UNISOM 20 TABLET	31.0	0.0	20.0	11.0	49.0	30.0	30.0	0.0	25.0	5.0	98.0	35.0
	0086	DELTACORTRIL 20 TA	10.0	73.9	15.0	68.9	0.0	42.0	26.9	147.8	35.0	139.7	0.0	50.0
	0095	DIABINESE 100 TABL	18.0	0.0	16.0	2.0	47.3	20.0	29.3	0.0	25.0	4.3	31.5	24.0
	0121	BABYPRIN 20 TABLET	81.0	197.0	93.5	184.5	0.0	171.0	13.5	197.0	126.0	84.5	197.0	160.0
	0152	GEOPEN 20 TABLET	12.0	0.0	7.2	4.8	14.7	10.0	9.5	29.4	15.0	23.9	29.4	17.0
	0153	GEOPEN 40 TABLET	3.0	0.0	1.8	1.2	7.3	2.7	5.8	0.0	2.8	3.0	7.3	3.6
	0154	DUOCID 375 MG 10 T	28.0	33.0	35.0	26.0	66.0	66.0	26.0	165.0	69.0	122.0	0.0	78.5
	0159	MINIPRESS 1MG X 30	49.0	0.0	18.0	31.0	0.0	29.0	2.0	64.0	29.0	37.0	0.0	33.0
	0161	MINIPRESS 5MG X 30	0.0	2.0	0.5	1.5	0.0	1.1	0.4	2.0	1.2	1.2	2.0	1.0
	0169	MINIPRESS 2MG X 50	13.0	0.0	2.6	10.4	0.0	3.8	6.6	0.0	4.3	2.3	6.7	4.6
	0189	G.TROSYD 100MG X 3	38.0	0.0	11.0	27.0	0.0	16.0	11.0	19.7	15.0	15.7	19.7	18.0
	0197	KOMPENSAN 60 TABLE	90.0	0.0	26.4	63.6	0.0	51.7	11.9	52.8	60.5	4.2	79.2	71.5
	0198	KOMPENSAN 24 TABLE	67.0	0.0	44.0	23.0	132.0	66.0	89.0	0.0	82.5	6.5	198.0	99.0
	0280	VALBAZEN SIGIR 10	0.0	3.9	0.9	3.0	0.0	1.7	1.3	3.9	2.3	2.9	0.0	1.2
	0281	VALBAZEN KOYUN 10	7.0	63.4	17.3	53.1	0.0	11.5	41.6	63.4	51.8	53.2	63.4	63.3
CAP	0047	TAO 16 KAPSUL	1.0	24.6	5.0	20.6	0.0	8.0	12.6	0.0	8.0	4.6	24.6	9.0
	0110	CORYBAN-D 20 KAPSU	70.0	0.0	66.0	4.0	78.8	82.5	0.3	157.6	49.5	108.4	0.0	38.5
	0144	TRIFLUCAN 100 MG 7	0.0	0.0	0.0	0.0	6.6	2.7	3.9	0.0	0.7	3.2	0.0	1.3
	0167	VISTARYL 25 CAPSUL	20.0	0.0	11.0	9.0	39.8	18.0	30.8	0.0	16.0	14.8	79.6	22.0

APPENDIX D. Sample Report -MACHINE UTILIZATION-

RESOURCE UTILIZATION (in hours) Pfizer Ilaçlari A.S. 24 March 1991 Sunday
Initial period of the plan : Dec Daily Working Hours : 7.45

Resource	Code	Description	DECEMBER Avail: 149 Req.	% Ut	JANUARY Avail: 142 Req.	% Ut	FEBRUARY Avail: 149 Req.	% Ut	MARCH Avail: 186 Req.	% Ut
BLENDER 1000 KG	0086	DELTACORTRIL 20 TA	14.0	9.40			14.0	9.40	26.0	13.9
	0095	DIABINESE 100 TABL			26.0	18.3			18.0	9.66
	0110	CORYBAN-D 20 KAPSU			5.0	3.53	9.0	6.04		
	0121	BABYPRIN 20 TABLET	8.0	5.37			8.0	5.37	8.0	4.30
	0270	NEO-TM S/P 20 GR			8.0	5.65				
	0271	NEO-TM S/P 100 GR			8.0	5.65				
	0281	VALBAZEN KOYUN 10	8.0	5.37			8.0	5.37	8.0	4.30
	0098	DUOCID SUSPENSION	26.0	17.4					42.0	22.5
	RESOURCE TOTAL		56	37.5	47	33.2	39	26.1	102	54.7
BLENDER 400 KG.	0041	TAO 500 MG 16 TABL	8.0	5.37	14.0	9.89			14.0	7.52
	0050	UNISOM 20 TABLET			10.0	7.06			18.0	9.66
	0159	MINIPRESS 1MG X 30					10.0	6.71		
	0161	MINIPRESS 5MG X 30	6.1	4.08			6.0	4.03	6.0	3.22
	0169	MINIPRESS 2MG X 50							6.0	3.22
	0167	VISTARYL 25 CAPSUL			4.0	2.83			7.0	3.76
	0189	G.TROSYD 100MG X 3					3.0	2.01	3.0	1.61
	0280	VALBAZEN SIGIR 10	8.0	5.36			8.0	5.37		
	0152	GEOPEN 20 TABLET			6.0	4.24	10.0	6.71	10.0	5.37
	0153	GEOPEN 40 TABLET			6.0	4.24			6.0	3.22
	0154	DUOCID 375 MG 10 T	10.0	6.71	14.0	9.89	26.0	17.4		
	0047	TAO 16 KAPSUL	8.0	5.37					8.0	4.30
	0144	TRIFLUCAN 100 MG 7			2.0	1.41				
	RESOURCE TOTAL		40	26.8	56	39.5	63	42.2	78	41.8
BLENDER 2000 KG.	0197	KOMPENSAN 60 TABLE					14.0	9.40	20.0	10.7
	0198	KOMPENSAN 24 TABLE			14.0	9.89			20.0	10.7
	RESOURCE TOTAL		0	0.00	14	9.89	14	9.40	40	21.4
COLLETTE YAS KARISIM	0095	DIABINESE 100 TABL			20.0	14.1			14.0	7.52
	0197	KOMPENSAN 60 TABLE					14.0	9.40	20.0	10.7
	0198	KOMPENSAN 24 TABLE			14.0	9.89			20.0	10.7
	0041	TAO 500 MG 16 TABL	8.0	5.37	14.0	9.89			14.0	7.52
	0280	VALBAZEN SIGIR 10	10.0	6.68			10.0	6.71		
	0281	VALBAZEN KOYUN 10	8.0	5.37			8.0	5.37	8.0	4.30
	0189	G.TROSYD 100MG X 3					5.0	3.36	5.0	2.68
	0121	BABYPRIN 20 TABLET	8.0	5.37			8.0	5.37	8.0	4.30
	RESOURCE TOTAL		34	22.7	48	33.9	45	30.2	89	47.7

APPENDIX E. Sample Report -VOLUME VARIANCE-

DETAILED VOLUME VARIANCE — Pfizer Ilaçlari A.S. — 24 March 1991 Sunday

From : Dec
To : Feb

Grp	Code	Description	UNITS (*1000) Budget	Actual	Diff	% Diff	AMOUNT (*1,000,000 TL) Budget	Actual	Diff	Diff @Std	DIFF/T.DIFF Act	Std
TAB	0041	TAO 500 MG 16 TABL	127.3	127.3	0.0	0.0	56.6	56.6	-0.0	0.0	-0.0	0.0
	0050	UNISOM 20 TABLET	49.0	49.0	0.0	0.0	17.2	0.0	17.2	0.0	1.5	0.0
	0086	DELTACORTRIL 20 TA	147.8	147.8	0.0	0.0	33.3	33.3	0.0	0.0	0.0	0.0
	0095	DIABINESE 100 TABL	47.3	47.3	0.0	0.0	51.6	0.0	51.6	0.0	4.4	0.0
	0121	BABYPRIN 20 TABLET	394.0	394.0	0.0	0.0	46.3	23.1	23.1	0.0	2.0	0.0
	0152	GEOPEN 20 TABLET	44.1	44.1	0.0	0.0	53.6	35.7	17.9	0.0	1.5	0.0
	0153	GEOPEN 40 TABLET	7.3	7.3	0.0	0.0	16.7	0.0	16.7	0.0	1.4	0.0
	0154	DUOCID 375 MG 10 T	264.0	264.0	0.0	0.0	129.1	113.0	16.1	0.0	1.4	0.0
	0159	MINIPRESS 1MG X 30	64.0	64.0	0.0	0.0	23.4	0.0	23.4	0.0	2.0	0.0
	0161	MINIPRESS 5MG X 30	4.0	4.0	0.0	0.0	8.7	4.4	4.3	0.0	0.4	0.0
	0169	MINIPRESS 2MG X 50	0.0	0.0	0.0	Inf.	0.0	0.0	0.0	0.0	0.0	0.0
	0189	G.TROSYD 100MG X 3	19.7	19.7	0.0	0.0	12.0	12.0	0.0	0.0	0.0	0.0
	0197	KOMPENSAN 60 TABLE	52.8	52.8	0.0	0.0	49.0	49.0	0.0	0.0	0.0	0.0
	0198	KOMPENSAN 24 TABLE	132.0	132.0	0.0	0.0	50.4	0.0	50.4	0.0	4.3	0.0
		PHARMA TAB	1353.2	1353.2	0.0	0.0	547.8	327.1	220.7	0.0	18.7	0.0
	0280	VALBAZEN SIGIR 10	7.8	7.8	0.0	0.0	15.0	7.5	7.5	0.0	0.6	0.0
	0281	VALBAZEN KOYUN 10	126.8	126.8	0.0	0.0	19.1	19.1	0.0	0.0	0.0	0.0
		ANIMAL HEALTH TAB	134.6	134.6	0.0	0.0	34.2	26.7	7.5	0.0	0.6	0.0
		TOTAL TAB	1487.8	1487.8	0.0	0.0	582.0	353.8	228.2	0.0	19.3	0.0
		TOTAL PHARMA	1353.2	1353.2	0.0	0.0	547.8	327.1	220.7	0.0	18.7	0.0
		TOTAL ANIMAL HEALTH	134.6	134.6	0.0	0.0	34.2	26.7	7.5	0.0	0.6	0.0
		TOTAL PRODUCTS	1487.8	1487.8	0.0	0.0	582.0	353.8	228.2	0.0	19.3	0.0

APPENDIX F. Sample Report -PRODUCTION PLAN COST BREAKDOWN-

PRODUCTION PLAN COST BREAKDOWN Pfizer Ilaçlari A.S. 24 March 1991 Sunday
(in 000's of Units and in 000,000's of TL) Initial period of the plan : Dec Holding Cost Rate = 6.00 %

Grp	Code	Description	Unit Cost	DECEMBER SER : 1.00000000 Prod	Inv	Total	JANUARY SER : 1.00000000 Prod	Inv	Total	FEBRUARY SER : 1.00000000 Prod	Inv	Total	MARCH SER : 1.00000000 Prod	Inv	Total
TAB	0041	TAO 500 MG 16 TABL	14139.0	599	20	619	1200	30	1230	0	68	68	1200	30	1230
	0050	UNISOM 20 TABLET	1106.0	0	2	2	54	1	55	0	2	2	108	0	109
	0086	DELTACORTRIL 20 TA	745.6	55	0	56	0	3	3	55	1	56	110	3	113
	0095	DIABINESE 100 TABL	3241.8	0	4	4	153	0	154	0	6	6	102	1	103
	0121	BABYPRIN 20 TABLET	218.6	43	1	44	0	2	2	43	0	43	43	1	44
	0152	GEOPEN 20 TABLET	18026.8	0	13	13	265	5	270	530	10	540	530	26	556
	0153	GEOPEN 40 TABLET	35401.4	0	6	6	260	3	263	0	12	12	260	6	267
	0154	DUOCID 375 MG 10 T	16433.2	542	28	570	1085	26	1110	2711	26	2737	0	120	120
	0159	MINIPRESS 1MG X 30	2433.0	0	7	7	0	5	5	156	0	156	0	5	5
	0161	MINIPRESS 5MG X 30	12275.0	25	0	25	0	1	1	24	0	24	24	1	25
	0169	MINIPRESS 2MG X 50	7980.6	0	6	6	0	5	5	0	3	3	54	1	55
	0189	G.TROSYD 100MG X 3	4837.5	0	11	11	0	8	8	95	3	98	95	5	100
	0197	KOMPENSAN 60 TABLE	1548.7	0	8	8	0	6	6	82	1	83	123	0	123
	0198	KOMPENSAN 24 TABLE	667.0	0	3	3	88	1	89	0	4	4	132	0	132
		PHARMA TAB		1265	109	1373	3105	95	3200	3696	137	3834	2781	200	2982
	0280	VALBAZEN SIGIR 10	14779.8	58	0	58	0	3	3	58	1	59	0	3	3
	0281	VALBAZEN KOYUN 10	1998.8	127	1	128	0	6	6	127	5	132	127	6	133
		ANIMAL HEALTH TAB		184	1	185	0	9	9	185	6	191	127	9	136
		TOTAL TAB		1449	110	1559	3105	104	3209	3881	143	4024	2908	209	3117
CAP	0047	TAO 16 KAPSUL	7287.0	179	0	180	0	9	9	0	6	6	179	2	181
	0110	CORYBAN-D 20 KAPSU	895.0	0	4	4	71	0	71	141	0	141	0	6	6
	0144	TRIFLUCAN 100 MG 7	93016.5	0	0	0	611	0	611	0	22	22	0	18	18
	0167	VISTARYL 25 CAPSUL	1462.6	0	2	2	58	1	59	0	3	3	116	1	118
		PHARMA CAP		179	6	185	740	10	750	141	30	171	296	27	323
		ANIMAL HEALTH CAP		0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL CAP		179	6	185	740	10	750	141	30	171	296	27	323
		TOTAL PHARMA PRODUCTS		1444	115	1559	3845	105	3950	3837	167	4004	3077	227	3304
		TOTAL ANIMAL HEALTH PRODUCTS		184	1	185	0	9	9	185	6	191	127	9	136
		TOTAL PRODUCTS REPORTED		1628	116	1744	3845	114	3959	4022	173	4195	3204	236	3440

APPENDIX G. Sample Report -NUMBER OF WEEKS ANALYSIS-

DETAILED NUMBER OF WEEKS (in 1,000,000's of Tl)

P f i z e r I l a ç l a r i A.S.

Initial period of the plan : Dec

24 March 1991 Sunday

Grp	Code	Description	Unit Cost	DECEMBER I(o)	DECEMBER Week	DECEMBER S	JANUARY I(o)	JANUARY Week	JANUARY S	FEBRUARY I(o)	FEBRUARY Week	FEBRUARY S	MARCH I(o)	MARCH Week	MARCH S
TAB	0041	TAO 500 MG 16 TABL	14139.0	325.2	0.8	424.2	500.5	0.9	565.6	1134.7	1.8	636.3	498.4	0.8	636.3
	0050	UNISOM 20 TABLET	1106.0	34.3	1.4	22.1	12.2	0.4	33.2	33.2	1.1	27.7	5.5	0.1	38.7
	0086	DELTACORTRIL 20 TA	745.6	7.5	0.7	11.2	51.4	1.8	31.3	20.1	0.8	26.1	49.0	1.3	37.3
	0095	DIABINESE 100 TABL	3241.8	58.4	1.1	51.9	6.5	0.1	64.8	94.9	1.2	81.0	13.9	0.2	77.8
	0121	BABYPRIN 20 TABLET	218.6	17.7	0.9	20.4	40.3	1.1	37.4	3.0	0.1	27.5	18.5	0.5	35.0
	0152	GEOPEN 20 TABLET	18026.8	216.3	1.5	129.8	86.5	0.5	180.3	171.3	0.6	270.4	430.8	1.6	306.5
	0153	GEOPEN 40 TABLET	35401.4	106.2	1.4	63.7	42.5	0.4	95.6	207.1	1.8	99.1	108.0	0.8	127.4
	0154	DUOCID 375 MG 10 T	16433.2	460.1	0.8	575.2	427.3	0.4	1084.6	427.3	0.4	1133.9	2004.3	1.7	1290.0
	0159	MINIPRESS 1MG X 30	2433.0	119.2	2.1	43.8	75.4	1.1	70.6	4.9	0.1	70.6	90.0	1.1	80.3
	0161	MINIPRESS 5MG X 30	12275.0	0.0	0.0	6.1	18.4	1.3	13.5	4.9	0.3	14.7	14.2	1.2	12.3
	0169	MINIPRESS 2MG X 50	7980.6	103.7	3.5	20.7	83.0	2.5	30.3	52.7	1.5	34.3	18.4	0.5	36.7
	0189	G.TROSYD 100MG X 3	4837.5	183.8	2.7	53.2	130.6	1.7	77.4	53.2	0.7	72.6	75.9	0.9	87.1
	0197	KOMPENSAN 60 TABLE	1548.7	139.4	2.2	40.9	98.5	1.2	80.1	18.4	0.2	93.7	6.5	0.1	110.7
	0198	KOMPENSAN 24 TABLE	667.0	44.7	1.3	29.3	15.3	0.3	44.0	59.4	1.1	55.0	4.3	0.1	66.0
		PHARMA TAB		1817	1.1	1493	1588	0.7	2409	2285	0.9	2643	3338	1.2	2942
	0280	VALBAZEN SIGIR 10	14779.8	0.0	0.0	13.3	44.3	1.6	25.1	19.2	0.6	34.0	43.2	2.2	17.7
	0281	VALBAZEN KOYUN 10	1998.8	14.0	0.4	34.6	106.1	1.8	23.3	83.1	0.8	103.5	106.3	0.8	126.5
		ANIMAL HEALTH TAB		14	0.3	48	150	1.7	48	102	0.7	138	149	1.0	144
		TOTAL TAB		1830	1.1	1540	1739	0.7	2457	2387	0.9	2780	3488	1.2	3086
CAP	0047	TAO 16 KAPSUL	7287.0	7.3	0.2	36.4	150.3	2.5	58.3	92.0	1.5	58.3	33.7	0.5	65.6
	0110	CORYBAN-D 20 KAPSU	895.0	62.6	1.0	59.1	3.6	0.0	73.8	0.3	0.0	44.3	97.0	3.7	34.5
	0144	TRIFLUCAN 100 MG 7	93016.5	0.0	0.0	0.0	0.0	0.0	251.1	360.0	4.2	65.1	294.9	3.2	120.9
	0167	VISTARYL 25 CAPSUL	1462.6	29.3	1.5	16.1	13.2	0.5	26.3	45.0	1.7	23.4	21.6	0.7	32.2
		PHARMA CAP		99	0.9	112	167	0.4	410	497	2.3	191	447	2.0	253
		ANIMAL HEALTH CAP		0	0.0	0	0	0.0	0	0	0.0	0	0	0.0	0
		TOTAL CAP		99	0.9	112	167	0.4	410	497	2.3	191	447	2.0	253
		TOTAL PHARMA PRODUCTS		1916	1.1	1604	1755	0.6	2818	2782	1.0	2834	3786	1.2	3195
		TOTAL ANIMAL HEALTH PRODUCTS		14	0.3	48	150	1.7	48	102	0.7	138	149	1.0	144
		TOTAL PRODUCTS REPORTED		1930	1.1	1652	1906	0.7	2866	2885	1.0	2972	3935	1.2	3339

APPENDIX H. Sample Report -MANPOWER REQUIREMENT-

MANNING REQUIREMENT (in man-hours) P f i z e r I l a ç l a r i A.S. 24 March 1991 Sunday
Initial period of the plan : Dec Number of Man Available : 79

Grp	Code	Description	DECEMBER Available : 11771			JANUARY Available : 11182			FEBRUARY Available : 11771			MARCH Available : 14714		
			Hrs	Man(#)	% Ut	Hrs	Man(#)	% Ut	Hrs	Man(#)	% Ut	Hrs	Man(#)	% Ut
TAB	0041	TAO 500 MG 16 TABL	235	1.6	2.00	430	3.0	3.85				430	2.3	2.92
	0050	UNISOM 20 TABLET				194	1.4	1.73				365	2.0	2.48
	0086	DELTACORTRIL 20 TA	171	1.1	1.45				171	1.1	1.45	311	1.7	2.11
	0095	DIABINESE 100 TABL				514	3.6	4.60				352	1.9	2.39
	0121	BABYPRIN 20 TABLET	284	1.9	2.41				284	1.9	2.41	284	1.5	1.93
	0152	GEOPEN 20 TABLET				211	1.5	1.89	379	2.5	3.22	379	2.0	2.58
	0153	GEOPEN 40 TABLET				189	1.3	1.69				189	1.0	1.28
	0154	DUOCID 375 MG 10 T	199	1.3	1.69	367	2.6	3.28	871	5.8	7.40			
	0159	MINIPRESS 1MG X 30							236	1.6	2.00			
	0161	MINIPRESS 5MG X 30	40	0.3	0.34				39	0.3	0.33	39	0.2	0.27
	0169	MINIPRESS 2MG X 50										70	0.4	0.48
	0189	G.TROSYD 100MG X 3							153	1.0	1.30	153	0.8	1.04
	0197	KOMPENSAN 60 TABLE							272	1.8	2.31	395	2.1	2.68
	0198	KOMPENSAN 24 TABLE				292	2.1	2.61				425	2.3	2.89
		PHARMA TAB	928	6.2	7.89	2197	15.5	19.65	2405	16.1	20.43	3392	18.2	23.05
	0280	VALBAZEN SIGIR 10	88	0.6	0.75				89	0.6	0.75			
	0281	VALBAZEN KOYUN 10	113	0.8	0.96				113	0.8	0.96	113	0.6	0.77
		ANIMAL HEALTH TAB	201	1.4	1.71	0	0.0	0.00	202	1.4	1.71	113	0.6	0.77
		TOTAL TAB	1130	7.6	9.60	2197	15.5	19.65	2607	17.5	22.14	3505	18.8	23.82
CAP	0047	TAO 16 KAPSUL	124	0.8	1.05							124	0.7	0.84
	0110	CORYBAN-D 20 KAPSU				198	1.4	1.77	368	2.5	3.13			
	0144	TRIFLUCAN 100 MG 7				123	0.9	1.10						
	0167	VISTARYL 25 CAPSUL				171	1.2	1.53				310	1.7	2.11
		PHARMA CAP	124	0.8	1.05	492	3.5	4.40	368	2.5	3.13	434	2.3	2.95
		ANIMAL HEALTH CAP	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00	0	0.0	0.00
		TOTAL CAP	124	0.8	1.05	492	3.5	4.40	368	2.5	3.13	434	2.3	2.95
		TOTAL PHARMA	1052	7.1	8.94	2689	19.0	24.04	2773	18.6	23.56	3825	20.5	26.00
		TOTAL ANIMAL HEALTH	201	1.4	1.71	0	0.0	0.00	202	1.4	1.71	113	0.6	0.77
		TOTAL PRODUCTS	1254	8.4	10.65	2689	19.0	24.04	2975	20.0	25.27	3939	21.1	26.77

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