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Using Multiple Objective Techniques To Model Hierarchical Production Planning (HPP) Problems (Part II : Computional Study)

مدخل البرمجة الهدفية لبناء نموذج لتخطيط الإنتاج الهرمى (الجزء الثانى - دراسة تطبيقية)

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خلاصة : فى هذا البحث تم عمليا اختبار اداء وفعالية النموذج الرياضى الذى تم تطويره و عرضه فى مقالة سابقة باختيار سبع من مسائل التجارب تم استيفاء معطياتها من مصنع لإنتاج الإطارات الكاوتشوك. و تم تنفيذ هذه المسائل على الحاسب بغرض الفحص الكامل للتأثيرات التى تحدث عند اجراء تغيير فى أوزان الأهمية النسبية لمتغيرات الانحراف المتعلقة بكل هدف من أهداف الخطه الإجمالية كذلك التأثيرات الناتجة عند اجراء تغييرات فى الطاقه الإنتاجية و عند افتراض درجات مختلفة للخطأ فى التنبؤ بالطلب . و قد أظهرت نتائج التطبيقات السبع قدرة البرمجة الهدفية على توليد خطط بديلة و امكانية التنبؤ حتى مستوى خطأ فى التنبؤ قدره ٣٠٪ و أخيرا حساسية البرمجة الهدفية للمتغيرات فى الطاقة الإنتاجية .

ABSTRACT - This paper includes the application and computational study of the two models which had been proposed in part I of this work by Rasmy et al [16] . In such models the production planning and scheduling problem -in a single stage system - is partitioned into a hierarchy of two sub-problems , the aggregate planning sub-problem (for product types) , and the detailed scheduling sub problem (for families or group of items that are contained in a given product type).A multiple objective model was proposed for solving each sub - problem . The muitiple objective programming models permit the decision makers to consider explicity the relative values of different objectives at each decision making level . Multiple objective methods can be used to generate more than one solution (alternative , non - dominated or satisfactory solutions) and to provide information on the trade -offs - among objectives .

The computation:l study consists of solving seven test problems. The data used for these test problems are adapted from the rubber types factory reported by Bitran , Haas and Hax [1] . The results show that the proposed models are very efficient in dealing with such problems .

1. INTRODUCTION

In the literature on production planning ,significant attention has been given to single stage manufacturing systems , in which their multi-products processed in batches through a single stage (or one machine) . The importance of the single stage production system is two - fold . On the theoretical side , it is the elementary cell in investigating multi-stage situations . On the practical side, many complex situations such as the assembly lines can be viewed for planning and scheduling purposes as just one big machinery (or stage).

Two basic approaches to the single - stage production planning problem have been offered in the literature . The first approach is the monolithic approach which formulates the production planning and scheduling problem as a large mixed-integer linear programming model (e.g. Manne [15] , Dzielinski and Gomory [3] and Lasdon and Terjung [11] . A rolling horizon procedure is commonly used for solving the monolithic programme . This procedure requires solving a finite horizon multi-period problem and implementing only the first period's decisions . One period later , the multi-period problem is updated as better forecasts become available ,and the procedure is repeated.

The second approach is the hierarchical approach which is suggested to deal with the various levels of production decisions in a decisions in a hierarchical framework . In this apprach , the production planning and scheduling problem is partitioned into a hierarchy of subproblems (e.g. Hax and Meal [8] , Bitran and Hax [2], Bitran , Haas and Hax [1] , and Graves [6]) . Each hierarchical subproblem has its own characteristics including length of planning horizon , level of detail of the required information and forcasts . A separate mathematical programming model is used for each subproblem to make the decision at each hierarchical level .The solution of the higher level model creates some of the constraints for the model below it . Again the system is performed on a rolling horizon basis by solving each hierarchical subproblem each period and implementing the immediate period's decisions .

Three reasons have led operations researchers to favour the hierarchical approach more than the monolithic approach . The first reason is that , the hierarchical approach reduces the complexity of the solution process by breaking the overall production planning problem into a number of simpler subproblems , each of which is much easier to solve than the original problem.In contrast, the monolithic approach will result in a large detailed integrated model which is very hard to solve in a direct way .

The second reason is that , the hierarchical approach may cope with uncertainty , since it needs only aggregate product demand data over the planning horizon , with detailed product demand data over a much shorter scheduling horizon. This is important in light of the fact that much data at the detailed level are uncertain at the time time aggregated decisions are made . If detailed and aggregated decisions were combined in a single large model as proposed in the monolithic approach , the detailed decisions would be made earlier .

The third reason is that the hierarchical approach recognizes the distinct characteristics of the type of management participation, the scope of the decision , the level of the aggregation of the required information and the time framework in which the decision is to be made. In Hax's opinion [7] , it would be a serious mistake to attempt to deal with all these decisions simulataneously,via a monolithic system or model . Even if computer and methodological capabilities would permit the solution of a large detailed integrated model , which is clearly not the case today , this approach is inappropriate because it is not responsive to the management needs and would prevent the interaction between models managers at each organization echelon .

Past work on hierarchical systems has concentrated on building mathematical programming models for each hierarchical subproblem.All these models are of the classical forms , that is , they can treat explicitly only one objective .This objective is expressed as optimisation of a function that must be homogeneous, this means that all relevant decision variables have to be converted such as to become measurable by a common unit , (most often , the function that must be minimized is the cost function or any other function related to the control of cost at each hierarchical level) . In In other words , past hierarchical systems have considered that the plan which has the minimum costs is the best of all choices . However , in many industrial systems it is clear that the minimization of the total production costs in all levels is not the sole objective of management .
In fact , the real production planning problem involves multiple objectives , which cannot be optimised simultaneously due to the inherent conflict between them . Multiple objective problems involve making trade-off decisions to get the " best compromise" solution . Several approaches have been proposed in the literature for solving the multiple objective decision making problem . Hwang and Masud [9] have provided an excellent survey of these approaches .

One of the more attractive approaches for solving the multiple objective decision making problems is the goal programming approach. Although several goal programming models have been reported in the literature for solving the production planning problem (e.g. Lee [13],Lawrence and Burbridge [12] and Gonzaleg and Reeves [5] , they did not recognize the hierarchical framework as a system philosophy for designing and solving the multilevel decision problem .In part I of this work by Rasmy et al [16], we proposed a new approach for solving the production planning and scheduling problem called " Goal programming Approach to Hierarchical Production Planning ".This approach combines the attractive features of both goal programming as a powerful tool for multi - objective analysis and the hierarchical system as an effective framework for decision making in a single - stage batch processing environment .

For our proposed research we assume that there are two levels of the product aggregation in the product structure from the Hax and Meal framework [8] . Production items may be aggregated into families aggregated into types . Type is a collection of items that have the same demand pattern , the same unit costs , direct costs (excluding labour costs) , holding costs per unit per period, and the production time required per unit . A family is a set of items within a type such that the items share a common setup . This form of aggregation may result in partitioning the production planning and scheduling problem into two subproblems in a hierarchy. The two subproblems are the aggregated production planning subproblem and the family disaggregation subproblem .

The aggregated production planning subproblem,the highest level of planning in the hierarchical system , is concerned with the effective allocation of production resources amongst product types to satisfy demand over a specified planning horizon . Typical decisions to be made at this level are the determination of production and inventory levels for each product type and regular and overtime workforce levels in each time period . The family disaggregation subproblem , the second level of planning , is concerned with the disaggregation of aggregated production plan for each type into production schedules for families belonging to that type over a short scheduling horizon . Typical decisions to be made at this level are the determination of production and inventory levels for each family within a type in each time period in the scheduling horizon .

In " Goal Programming Approach to Hierarchical Production Planning ", both the aggregated planning subproblem for product types and the family disaggregation subproblem are modelled in a goal programming format . The aggregated planning model for types is a simple planning model . It considers only one constrained production resource , that is , the regular production time available in each time period which must be used to the full extent . The model incorporates a single option for varying the resource level , that is , the overtime available in each time period which must not exceed certain maximum limits . The planning horizon of this model consists of six periods (i.e. 6 months) . This model involves two goals . The first goal is to satisfy demand for all product types in each period by production in the same period of demand . This goal reflects the desire of the firm to co - ordinate the production schedule of types with their demand schedule so as to minimize the inventory holding costs , the material handling costs and the transportation costs . The second goal is to realize the desired ending inventory levels for each product type in the last period of the planning horizon . This goal reflects the management's view of controlling the inventory levels of all product types while providing a reasonable level of safety stock . The two goals are of the same priority , that is the model is a weighted linear programming model . This model can be solved using a normal linear programming method . The resulting production quantities of each type in only the next three periods are transmitted to the family disaggregation model of this type to determine the corresponding production quantities of famil-ilies belonging to it . Thus , the planning system has a number of disaggregation models equal to the number of the types in the product structure . Each model is designed on the same basis .

The family disaggregation model involves two goals . The first goal is to co-ordinate production schedules of families belonging to a type with production schedule of that type . This goal is implemented by setting the amounts determined by the aggregate plan for a type in the next three periods as the aspired levels for the sum of the production of the families in this type in these periods. The second goal is to control families inventory levels in each period in the triple period scheduling horizon to ensure that no overstocks will occure . This goal reflects the desire to produce famil-ilies in the correct quantities such that the storage requirements for each family in each period not to be violated . The two goals are of the same priority .

The structure of the family disaggregation model is based uppon using the dominant production schedules for each family as suggested by Manne [15] . That is the production of each family at any given period in the scheduling horizon is either zero or the sum of consecutive net demands for some periods into the future .We mean by net demand in a given period , the demand which cannot be satisfied from the initial inventory in this period . When dealing with a time horizon of T periods the total number of dominant production schedules to be considered for each family , is 2 . Thus , for a scheduling horizon of three periods length , as the case of the horizon of the family disaggregation model , the total number of dominant production schedules for each family equals 4 . These schedules are determined for all families in a type outside the model and used as inputs .The decision variables included in this model are of the integer zero - one type . Each family has four of these binary variables , one for each production schedule . A specific decision variable is used to decide whether a specific production schedule is used for producing a specific family or not .This specific variable would have the value one if its specific production schedule is used for producing this specific family and the value zero if it is not used . The optimal production schedule for a family may be among the pure strategies ,that is , only one of all the decision variables of the different production schedules of this family would have the value one .

The linear , zero - one goal programming model for the family disaggregation , can be solved using the linear , zero - one programming method , or by relaxing the integral restrictions of the zero-one variables and using continuous variables if the problem is of the large size , or by generating all the possible effective combinations for the solutions of the zero-one variables.if the problem is of the small size . The solution of the family disaggregation model may result in a production schedule for families that would not achieve the first goal which relates to the co- ordination of the production schedules of the families in a type, with the production schedule of that type. The achievement of this goal is necessary for assuring consistency between the aggregate plan for a type and production schedules of families in that type .
The disagreement between the plan of a type and the schedules of families in that type , happens whenever the total amount allocated amongest all these families is either below or above the amount amount to be produced of this type , as was determined by the aggregate planning model at any time period .

Since the new approach would implement the output of the family disaggregation model only for the first period of the scheduling horizon ,it is necessary to adjust only the decisions of this period so as to make the sum of the production quantities of all the families in a type , to equal the production of this type in the immediate period . The required adjustment is made according to three decision rules . This set of decision rules is considered as a basic element in the disaggregation process .

2- PROBLEM DEFINITION & DATA

The Proposed models will be applied on seven test problems adapted from the rubber types factory reported by Bitran , Haas and Hax [1] . For the sake of this study , we consider the product structure contains five families aggregated into two types . The product structure characteristics and other information are given in figure (1) .

P1

P1F1 P1F2

Family setup costs = $ 90
Holding cost=$.31/unit a period
Overtime cost =$9.5/hour
Productivity Factor = .1 hr/unit
Production lead time = 1 month
Regular workforce costs and unit costs .

P2

P2F1 P2F2 P3F3

Family setup costs = $120
Holding cost=$.4/unit a period
Overtime cost = $9.5/hour
Productivity Factor = .2hr/unit
Production lead time = 1 month
production costs are considered fixed .

Total regular work force = 2000 hrs / period
Total overtime work force = 1200 hrs/period
One Period = 4 weeks

Figure(1) : Product Structure and Relevant Information .

Product type P1 is composed by two families P1F1 and P1F2 . The second product type is partitioned into three families P2F1,P2F2 and P2F3 . Table (1) exhibits the demand pattern for both product types. Product type P1 has a terminal demand season (corresponding to the requirements of snow tyres) . Demand for product type P2 is highly fluctuating throughout the year . Families are a group of items sharing the same moulds in the curing presses and ,therefore , sharing a common setup cost . The items are , for instance , White wall and regular wall tyres of agiven class . Families have the same cost same cost characteristics and the same productivity rates as their corresponding types .

Table (1) Demand PATTERNS OF PRODUCT TYPES

Time Period	Product Type 1 P1	Product Type 2 P2
1	12736	6174
2	7813	2855
3	0	4023
4	0	4860
5	0	7131
6	0	9665
7	1545	17603
8	7895	14276
9	10982	11706
10	15782	15056
11	16870	8232
12	15870	7880
13	9878	10762
TOTAL	99371	120223

Each test problem consisted of applying the goal programming approach to a full year of simulated plan operations.First,aggregated plan for types is generated using a 6 period planning hirizon .Second,for each type , the production quantities of a type are allocated among it's families for the next three periods . The allocation of production quantities among families is carried out by the family disaggregation model using a 3 period scheduling horizon . The results of the disaggregation model , only for the first period ,are implemented after making the necessary adjustments . Adjustments are made by means of a set of decision rules to realize the consistency between the aggregate production plan and the family disaggregation procedure in the first period . One period later , the hierarchical production planning problem is updated as new information becomes available , and the process is repeated . This means that in one simulation run , this process is repeated thirteen times . At the end of each simulation run , the following information is obtained:-

(1) Finalised production schedules for types and families .
(2) Deviations of actual attainment from desired attainment for the hierarchical production planning system's goals I , II, and III
(3) Total number of setups for each family in a year .
(4) Cimulative inventories for types (measured as the number of units times the number of periods a type stays in inventory).
(5) Total overtime used in a year .

The seven runs are executed to examine throughly the effects of changing the weights of the deviational variables associated with each goal , the production capacity , and the forecast errors . The data used in the computational experiments for the purpose of making these sensitivity analysis is given below : -

Capacity (3 Cases)

(1) Normal Capacity : 2000 hours / period regular time .
(2) Loose Capacity : 2500 hours / period regular time .
(3) Tight Capacity : 1600 hours / period regular time .

Overtime is 60% of the regular hours in all three cases.

Forecast Errors (3 Cases)

(1) Zero forecast error
(2) 10%
(3) 30%

Forecast errors are uniformly distributed in intervals of the type [a , a] are introduced in both two levels , type level and family level .

Weights of Deviational Variables of Aggregated Planning Model for

Types (3 Cases)

(1) Equal weights for all deviational variables .
(2) Bigger weights only for positive deviational variables .
(3) Bigger weights only for positive and negative deviational. variables associated with product type 2 (except in the third , fourth , fifth and sixth times of the application of the hierarchical planning process . In each of these times . the first period demand for type 1 is zero and consequently there is no meaning for making a bias towards the production of type 1).

In all three cases of weights of deviational variables of aggregate planning models , the family disaggregation model is solved solved using equal weights on all its deviational variables .

3 - COMPUTATION ANALYSIS

The aggregated planning model for types is solved by using a normal linear programming code . Due to the small size of the family disaggregation subproblem (12 zero - one variables for the model of product type 2) the family disaggregation is solved by considering the set of all possible effective combinations of the values of the 0 - 1 variables . A special computer code is designed for two purposes, the solution method of the family disaggregation model, and the application of the decision rules.The seven test problems are solved on personal computer BBC / B (32 k bytes). The average running time for each simulation run is within 9 hours. These 9 hours represent the time needed for solving the HPP problem on a rolling horizon basis , i.e. solving the aggregated planning model for types 13 times , the family disaggregation model for type 1 13 times , and the family disaggregation model for type 2 - 13 times . More than 90% of the running time is consumed in solving the aggregate planning model .

The results of the runs are summarized in table 2 .Table 3 to 6 show the computer output of run number 7 as an example for the different runs . For any additional details , you are advised to go ISMAIL [10] .

In the tables of the finalised production schedule (*) of each run, letter 'N' is only appeared beside the actual level of a goal in a period to show that this goal is not attained in that period.

The disappearence of letter ' N ' means that the corresponding goal is attained . The desired and the actual levels of goals I for type 1 in each time period are arranged in columns 2 and 3 respecrespectively . Similarly , the desired attainment , and the actual attainment levels of goals I for type 2 are provided in columns 6 and 7 . The actual attainment of goal II , the inventory levels of both types in last period are found in the last element of columns 4 and 7 . The desire ending inventory level in last period for each type is zero , except only in Run 6 'Tight Capacity ' , in which the desired levels for types 1 and 2 are 15288 and 18496 respect_vely. The actual levels of goal III , the ending inventory levels for families P1F1 , P1F2, P2F1 , P2F2 and P2F3 in each time period are shown in columns 10,13,16,19, and 22 respectively . Goal III for a family in a period is attained whenever its inventory level in this period is below its overstock level . The overstock level for each family in each time period equals to approximately four period 's demand of this family .

(*) Each run in a finalised production schedule represents the first period's decision in each repitition time for the hierarchical plnning process in each simulation run .

4 - SENSITIVITY COST ANALYSIS

(A) Sensitivity to Relative Importance of Aggregate Planning Goals

Runs 1,2 and 3 show the effect of changing the weight of the deviational variables of the aggregate planning model , for solving the problem with normal capacity and zero forecast errors . In all three cases the family disaggregation model for each product type is solved using equal weights on all deviational variables . The developed alternative plans are plan 1,plan 2 and plan 3 .

Total overtime used by all three plans is the same , and represents the minimum hours needed over the total regular production hours for satisfying all demands in all periods . Although the sum of the deviations of actual levels from desired levels of all goals in all periods ,is the same in all the three plans as shown in Table (2) , it can be noticed that the cumulative inventory levels are not the same in the three plans . Moreover , a minor change in the total number of setups is noticed in Plan 3 . Carrying inventory for product type P2 in most periods , in each plan is imperative , because demand of this product type is highly fluctuating throughout the year . A cost analysis is presented in Section D to show the difference between the three plans from the total operational costs point of view .

(B) Sensitivity to Forecost Errors

Runs 1 , 4 and 5 shows the impact of forecast errors in production planning decisions . 1 unit of demand of type 2 is only unfilled in case of 10 % forecast errors (Run 4) . 664 unit of demand of type 2 is unfillled in case of 30 % forecast error (Run 5) . These unfilled units represent a 99.47 % service level . These results show that the GP approach performs well under forecast errors of up to 30 % .

(C Sensitivity to Capacity Availability

Runs 6 and 7 evaluate the performance of the GP approach under different capacity conditions. Run 6 uses only 1600 hours of regular capacity per period . Run 7 expands the regular capacity to 2500 hours. Run 6 is executed using an aspiration level for the inventory in the last period , equal to approximately two period's demand for each type , to force the aggregate planning model to use the available overtime hours in all periods ,for the purpose of providing a reasonable serv.ce level under tight capacity . Run 7 is carried out considering some changes in the weights of the deviational deviational variables of the aggregate planning model especially in the times 8 through to 13 of the application of the hierarchical process . This is done to minimise the growth of inventories in succeding periods . Results of Run 6 and Run 7 show that the purposed approach is sensitive to capacity changes. Under tight capacity , there is a significant increase in both total overtime used , and the amount of unfilled demand , the opposite is true under loose capacity . These reults support the use of the GP apporach in evaluating proposals for production capacity .

Table (2) A Summary of Computational Results With Proposed GP Approach To MPP

	Run 1 Normal Capacity No forecast Error Plan 1	Run 2 Normal Capacity No forecast error Plan 2	Run 3 Normal Capacity No forecast error Plan 3	Run 4 Normal Capacity 10% forecast error	Run 5 Normal Capacity 30% forecast error	Run 6 Tight Capacity No forecast error	Run 7 Loose Capacity No forecast error
(1) Total deviations of actual levels from desired levels of all goals in all periods	35118	35118	35119	36405	43247	124977	60118
(2) Total number of setups of all families in all periods	51	51	50	52	59	46	50
(3) Total cumulative inventories of both types P1 and P2	102310	89719	136579	91601	108535	213481	189047
(4) Total overtime hours used in all periods	7981.7	7981.7	7981.7	7921.3	9293	12420.4	1481.7
(5) Total unfilled demands of both types P1 and P2 in all periods	—	—	—	1	664	3757	—

Run 7

Case : Loose Capacity

Capacity: 2500 hrs/period regular time, 1550 hrs/period overtime Forecast Errors: Zero
Goals : I : Production level for each type P1 , P2 in each period : corresponding demands for each type
II : Inventory levels for types P1,P2: in last period: 0,0
III : Overstock levels for families P1F1,P1F2,P2F1,P2F2,P2F3: Average of four period's demand for each family .

Aggregate Production Plan for Types P1,P2						Detailed Production Plan Resulting form Disaggregation of Types P1,P2 into Families													
						Families Belonging to Type P1						Families Belonging to Type P1							
Type 1			Type 2			P1F1			P1F2			P2F1			P2F2			P2F3	
Dem.	Prod.	Inv.	Dem.	Pro.	Inv.	Dem.	Prod.	Inv.	Dem.	Pro.	Inv.	Dem.	Pro.	Inv.	Dem.	Prod.	Inv.	Dem.	Pro.
12736	12736	0	6174	6174	0	8236	8236	0	4500	4500	0	2555	2555	0	2143	2143	0	1476	1476
7813	7813	0	2855	8593 N	5738	4711	4711	0	3102	3102	0	1167	5391	4224	986	2500	1514	702	702
0	0	0	4023	12500 N	14215	0	0	0	0	0	0	1650	2177	4751	1514	6755	6755	359	3568
0	0	0	4860	12500 N	21855	0	0	0	0	0	0	1946	9113	11918	1865	1193	6083	1049	2194
0	0	0	7131	12500 N	27224	0	0	0	0	0	0	2805	6144	15257	2666	6356	9773	1660	0
0	0	0	9665	12500 N	30059	0	0	0	0	0	0	4054	1900	13103	3417	6461	12817	2194	4139
1545	1545	0	17603	17603 N	30059	927	927	0	618	618	0	7108	9061	15056	6356	2500	8961	4139	6042
7895	7895	0	14276	8552 N	24335	4701	4701	0	3194	3194	0	5995	2322	11409	4918	6230	10273	3363	0
10982	10982	0	11708	7009 N	19638	6670	6670	0	4312	4312	0	4984	5230	11629	4043	1779	8009	2679	0
15782	15782	0	15056	4609 N	9191	9894	9894	0	5888	5888	0	6399	0	5230	5134	0	2875	3523	4609
16870	16870	0	8232	4065 N	5024	10001	10001	0	6869	6859	0	3422	0	1808	2875	3216	3216	1935	849
15870	15870	0	7880	4565 N	1709	9598	9598	0	6272	6272	0	3129	1321	0	3009	0	207	1742	3244
9878	9878	0	10762	9053 N	0	5973	5973	0	3905	3905	0	4448	4448	0	3864	3657	0	2450	948

N : Goal not achieved .

Table (3) A-Finalised Production Schedule For Types And Families.

Continue Run 7

Table (4) B- Deviations of Actual Attainments From Desired Attainments For Goals I, II and III

I - Sum of deviations of actual production levels for the two types P1,P2 from desired levels (i.e. the corresponding demands) in all periods.	60018
II - Sum of deviations of actual inventory levels for the two types P1,P2 from desired levels .	0
III - Sum of deviations of actual inventory levels for all families from desired overstock levels in all periods.	0
Total deviations of I , II and III	60018

Table (5) C- Number of Setups of Families in All Periods

Number of setups of families belonging to type P1		Number of setups of families belonging to type P2		Total
P1F1	9	P2F1	11	
P1F2	9	P2F2	11	
		P2F3	10	
Total	18		32*	50

* There is a saving of 7 setups in manufacturing families belonging to product type P2 during all periods,because scheduling each periods need 39 setups.

Table (6) D- Cumulative Inventories And Total Overtime

Cumulative inventory of type P1	0
Cumulative inventory of type P2	159047 units
Total Overtime	1481.7 hours

(D) Cost Analysis

Although the minimization of the total operational costs is not explicitly considered as a goal within the set of goals of the proposed approach , this approach can generate several alternative solutions with different levels of inventory holding costs , and overtime costs , and different number of setups .

Total operational costs can be considered as one of the significant indicators for measuring the effectiveness of the alternative plans . Table (7) presents a comparison of the total operational costs resulting from the three alternative plans(plan 1, plan 2 and plan 3). The comparison is made assuming different values of the setup costs .

Table (7) COMPARISON OF TOTAL COSTS OF ALTERNATIVE PLANS

Case of set up costs of each family	Cost	Plan 1	Plan 2	Plan3
a)Low Setup Costs:				
P1F1,P1F2: 90,90 P2F1,P2F2,P2F3: 110,110,110	Total costs $	122000	116963	130391
	setup/total cost	4.3%	4.49%	3.97%
b) Medium Set Costs:				
P1F1,P1F2:300,90 P2F1,P2F2,P2F3: 300,100,400	Total costs $	128960	124023	137531
	setup/total cost	9.47%	9.92%	8.96%
c) High Setup Costs:				
P1F1,P1F2: 5000,50 S1) P2F1,P2F2,P2F3: 400,400,1000	Total costs $	181400	176963	186411
	setup/total cost	35.64%	36.87%	32.83%
S2) High Setup Costs:				
P1F1,P1F2:800,800 P2F1,P2F2,P2F3: 800,800,8000	Total costs $	229550	231713	251611
	setup/total cost	49.13%	51.78%	50.23%
S3) High Setup Costs:				
P1F1,P1F2:8500,8500 P2F1,P2F2,P2F3: 1100,1100,1100	Total costs $	306050	301013	298611
	setup/total cost	61.85%	62.89%	58.07%

In viewing the three plans with respect to the total costs of each,we observe that plan 2 is more efficient than the other two plans in case of medium and low setup costs. However, in cases of high setup costs we find that plan 2 is more efficient in case (S1). Plan 1 is more efficient in case (S2) and Plan 3 is more efficient in case (S3).

The final management choice between these quite different can be made by its assessments of solution results from both the attainment level of quantitative goals and upon other significant quanti-iative indicators not found with the two decision models of the system, such as total operational costs .Thus, this approach allows mangement a significant degree of flexibility to judge which plans of operation they will choose to implement from a group of logically and rationally chosen alternative plans .

5 - SUMMARY

The GP approach is efficient for generating quite different alternative plans from which the final management choice can be made on the basis of evaluating the results of each plan , from both the attainment levels of quantitative goals and on other quantitative criteria not found in the hierarchical decision model , such as the total production costs of each plan .

The GP approach performs well under forecast errors of up to 30% .

The approach is sensititive to production capacity changes ; therefore , it can be used in evaluating different proposals for production capacity .

REFERENCES

(1) Bitran,G.R.,Haas, E.A. and Hax ,A.C. " Hierarchical Production Planning : A Single Stage System ", Operations Research ,Vol.29 No.4 PP 717 - 743 (July-August 1981).

(2) Bitran , G.R., and Hax, A.C.,"On the Design of Hierarchical Production Planning Systems ", Decision Science 8 , PP 28 - 55 (1975).

(3) Dzielinski ,B.P., and Gomory ,R.E., "Optimal Programming of Lot Sizes,Inventory and Labour Allocations " ,Management Science , Vol.11,No. 9 PP 874 -890 (July 1965) .

(4) Elsayed ,A.E.et al "Analysis and Control of Production Systems" Prentice Hall Int , (1985) .

(5) Gonzalez , J.J., and Reeves,G.R.," Master Production Scheduling a Multiple -Objective Linear Programming Approach " , International Journal of Production Research , Vol.21 . No. 4 , PP 553-562 ,(1983) .

(6) Graves, S.C.,"Using Lagrangean Techniques to Solve Hierarchical Production Planning Problems ", Management Science , Vol. 28 , No. 3, PP 260-275 , (March 1982) .

(7) Hax, A.C.,"Production and Inventory Mangement " ,Prentice-Hall Inc.,Englewood Cliffs , New Jersy ,(1984) .

(8) Hax. A.C. ,and Meal ,H.C., " Hierarchical Integration of Production Planning and Scheduling " in Studies in Management Science , Vol. 1 , Logistics , M.A. Geisler (ed) , North Holland -American Elsevier, New york , (1975) .

(9) Hwang ,C.L., and Masud , A.S.M. , " Multiple Objective Decision Making :Methods and Application - A State of the Art Survey", Spriger-Verlag ; New York ,(1979).

(10) Ismail , S.E.,"Goal Programming Approach To Hirarchical Production Planning " Master thesis ,ISSR , Cairo Univ.,(1987).

(11) Lasdon , L.S. , and Terjung , R.C.,"An Efficient Algorithm for Multi-item Scheduling" ,Operations Research , Vol. 19 , No. 4 PP. 946 -989 (July-August 1971).

(12) Lawrence, K.D., and Burbridge ,J.J.,"A multiple Goal Linear Programming Mode. for Co -ordinated Production and Logistics Planning ",International Journal of Production Research, Vol. 14 ,PP 215 (1976).

(13) Lee , S.M.," Goal Programming for Decision Analysis", Auerbach Publishing Co., Philadelphia, (1972) .

(14) Magee, J.F.,and Boodman, D.N. "Production Planning and Inventory Control", McGraw Hill , New York ,(1967) .

(15) Manne , A.S.,"Programming of Economic Lot Sizes", Management Science Vol 4 , No. 2. PP 115-135 (January 1958) .

(16) Rasmy ,M.H. ,Ismail,S. " Using Multiple Objective Techniques TO Model Hierarchical Production Planning Problems .(Part I : Theorytical Study)", Under publication , (1991).