Aggregate Planning Technique at a Mixed Seasonal Beverages Production Plant, A Case Study

Mahmoud A. Hinnawi*

ABSTRACT

Sizable proportion of production organizations are interested in adopting advanced production planning methods. Planners use aggregate planning to achieve a production plan that will effectively utilize the organization's resources to satisfy expected demands. The production planning of mixed seasonal products is usually a complex assignment. A beverages plant is producing three kinds of beverages with variable demand month-wise according to seasons change. As a result, over-time is needed through some months, while, under-time is happening through others. In this paper, cost analysis is conducted for the present production plan, then operations research approaches were used to create three models to generate a better production plan for that company with respect to cost. These models include transportation model, linear program model, and a dynamic model. A comparison is made between the three models to investigate the suitability in terms of cost reduction and adoptability.

The LP model seems more adequate for this plant with an encouraging cost reduction rate. The study takes into account, among others, the costs of overtime/under-time, hiring /firing, inventory holding cost, etc. Finally, this study suggests to adopt production plan that resulted from the linear production model in this study with 6.23% cost reduction among current production plan. All basic financial data used in calculations were provided by the manufacturer without any interfere from the researcher.

Keywords: Aggregate Production Planning, Mixed Seasonal Products, Operations Research.

* **Department of Production and Design Engineering, Faculty of Mechanical and Electrical Engineering, Damascus University.**

التخطيط الكلي في مصنع إنتاج مشروبات موسمية مختلطة، دراسة حالة

د. محمود الحناوي*

الملخص

تهتم نسبة كبيرة من المنظمات الإنتاجية في اعتماد أساليب تخطيط الإنتاج المتقدمة. يستخدم المخططون منهج التخطيط الكلي لتحقيق خطة الإنتاج التي سوف تستخدم على نحو فعال موارد المنظمة لتلبية الطلب المتوقع. عادة تكون عملية تخطيط الإنتاج في المنظمات ذات المنتجات الموسمية المختلطة مهمة معقدة. يُنتج مصنع مشروبات غازية ثلاثة أنواع من المشروبات لها معدلات طلب شهري متغير وفقاً لتغير الفصول. ونتيجة لذلك، هناك حاجة إلى ساعات عمل إضافية خلال بضعة أشهر، بينما، يحدث فائض في ساعات العمل خلال أشهر أخرى. في هذه الورقة، جرى تحليل لتكاليف الخطة الإنتاجية الحالية ثم تم استخدام مفاهيم بحوث العمليات لتوليد ثلاثة اقتراحات من أجل خطة إنتاج أفضل لتلك الشركة فيما يتعلق بالتكاليف. تشمل هذه النماذج: نموذج النقل، نموذج البرمجة الخطي، ونموذج ديناميكي. ثم أجريت مقارنة بين النماذج الثلاثة للتحقق من مدى الملاءمة من حيث خفض التكاليف وقابلية التطبيق العملي. تبين أن الخطة المقترحة وفق نموذج البرنامج الخطي أكثر ملاءمة لهذا المصنع مع نسبة خفض تكاليف مشجعة قدرها 6.32% مقارنة مع خطة الإنتاج الحالية. وقد تم الحصول على كل البيانات المالية المستخدمة في الحسابات من الشركة المصنعة دون أي تدخل من الباحث.

الكلمات المفتاحية: تخطيط الإنتاج الكلي، المنتجات الموسمية المختلطة، بحوث العمليات.

* مدرس، كلية الهندسة الميكانيكية والكهربائية، جامعة دمشق.

1. Introduction:

When sales vary significantly according to season, the manufacturer makes special provisions to integrate the acquisition of raw materials and labor with an effective production schedule which satisfies customers' requirements. The recommended procedure is called aggregate planning, and many algorithms produce a good definitive solution.

Aggregate planning involves planning 6 months and more in the future, whereas detailed planning is concerned with the shorter term (weeks or months)[1]. Many authors have suggested different solutions to use aggregate planning in manufacturing organizations in order to improve systems utilization. To achieve this, some authors used transportation models [2], others suggested a nonlinear programming model for a multi-product multi-site aggregate production planning [3], others suggested genetic algorithms to solve a model for two phase production systems [4], also linear programming and fuzzy logic were used to propose to solve aggregate planning problems [5] [6].

There are numbers of important informational needs for effective aggregate planning. First, the available resources over the planning horizon must be known, including facilities. Also, a forecast of expected demand must be available. Finally, planners must take into account any policies regarding changes in employment levels; figure (1) and table (1) list the major resources and costs that must be taken into account.

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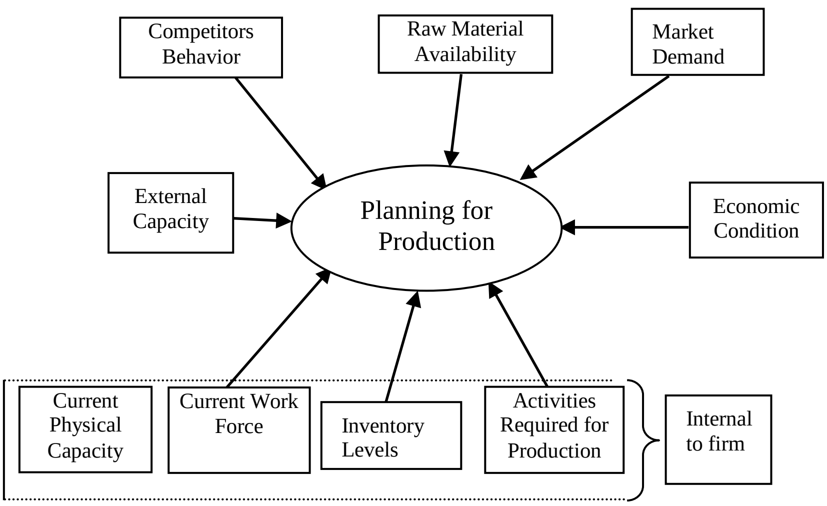


Fig. 1 Required Inputs to the Production Planning System.

Table 1. Major resources and costs.

RESOURCES	**COSTS**
Work force production rates	Inventory carrying cost
Facilities and equipment	Backorders
Demand forecast	Hiring/firing
Policy statements on work force changes	Overtime
Subcontracting	Inventory changes
Inventory levels changes	Quality costs
Backorders	

2. Importance Of Aggregate Planning :

Beverages industries are engaged in the production of 'Mixed Seasonal' products, which means big fluctuations in utilizing resources and that lead to considerable drops in returns and profits. In order to reduce the production costs and increase profit, it is mandatory to utilize existing plant capacity and resources efficiently.

Such targets compel to improve production planning technique or in other words to implement optimal (mathematical) Aggregate Production Technique which consider decision variables as: production rate, inventory levels, back logs, capacity change, hiring and lay off, over-time, under time, change over/month. Significant savings can be realized by correctly modeling and solving the aggregate production-planning problem [8].

3. Describtion Of The Current Production Plan And Costs:

The company is engaged in the production of three mixed seasonal products which are: Cola, Lemon, and Orange tastes.

The regular working hours in general shift are eight hours per day (8 hr/day).

Available regular plant hours per year = 2064 hr/yr

Available overtime plant hours per year = 2564 hr/yr

Demand data at the company is maintained brand wise for twelve months as shown in table (2).

Table 2. Aggregation of Beverages Demand

#	*Month*	Demand of Cola	Demand of Orange	Demand of Lemon	Aggregate Demand
		(LTR)	(LTR)	(LTR)	(LTR)
1.	Feb.	14000	8750	12250	35000
2.	March	16000	10000	14000	40000
3.	April	28000	17700	24675	70375
4.	May	34000	21450	29950	85400
5.	June	46000	28950	40675	115625
6.	July	46000	29025	40675	115700
7.	Aug.	32840	20721	29039	82600
8.	Sept.	25990	16458	23054	65500
9.	Oct.	23982	15207	21311	60500
10.	Nov.	16792	10705	14903	42400
11.	Dec.	12500	7912	11038	31450
12.	Jan.	9610	3660	8955	22225
	Total	305714	190538	270525	766775

In figure (2) the demand data depicts seasonal trends, the peak period starts from May to August and the slack period from December to February.

The month-wise production plan currently adopted at the plant along with related costs is presented in table (3). From which we can calculate the total costs per year:

Total costs for the current plan = 6433230.032 SL/yr

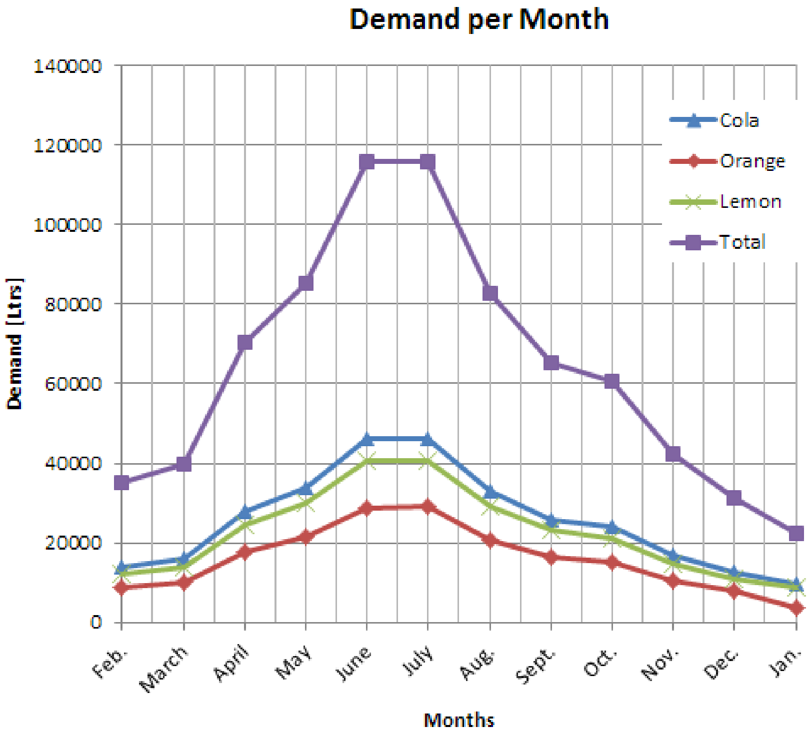


Fig. 2. Month- wise Demand on Products.

4. Optimizing Methods

Three commonly used optimizing techniques in aggregate planning are adopted in this paper, which are [ix]:

1. Transportation Model.
2. Linear Programming
3. Dynamic Programming.

4.1 Transportation Model.

Assuming cost and variable relationships are linear and demand can be treated as deterministic; then more easily formulated transportation method is applied. It can be also termed as period model since it relates production demand to production capacity by periods. Let:

C_t = Unit production cost in regular working hours.
P_t = Production (in hours) in regular time.
C_t' = Unit production cost in over time.
P_t' = Production (in hours) in over time.
h_t = Inventory carrying cost per unit held from period ‘t’ to ‘t+1’
I_t = On-hand inventory at the end of period ‘t’
B_t = Production capacity of period ‘t’
D_t = Forecasted demand (in Bottles) in period ‘t’
NI_t = Net inventory at the end of any period.
(I^+) = Inventory.
(I^-) = Back orders.

Table 3. The month-wise production plan currently adopted at the plant along with related costs.

#	Month	Agg. Demand [LTR]	Agg. Prod. [LTR]	Cost to Produce [SL/LTR]	Invt. Carrying Cost [SL/LTR]	On Hand Invt. [LTR]	Cost of REG. Labor Hours [SL/hr]	Reg. Labor Hours (Hr)	Cost of Labor In.O.T [SL/hr]	Over Time [Hr]	Cost to Inc. one Lab. Hour [SL/hr]	Working Hours incr. [Hr.]	Cost to Dec. one hour [SL]	Working Hr. Dec.. (Hr)	Cost per month [SL]
		D_t	(P_t)	C_t	h_t	I_t	C_{RT}	L_{RT}	C_{OT}	L_{OT}	C^+	Lt^+	C^-	L_t^-	(Z)
1	Feb	35000	35000	4.7	0.77	-	504.4	192	538	26.3					275494.2
2	Mar	40000	40000	4.7	0.77	-	504.4	208	538	41.4	5.76	31.1			315367.536
3	Apr	70375	105000	4.7	0.77	34625	504.4	208	538	416	5.76	374.6			851042.146
4	May	85400	105000	4.7	0.77	54225	504.4	208	538	416	5.76	-			863976.45
5	Jun	115625	105000	4.7	0.77	43600	504.4	208	538	416	5.76	-			855795.2
6	Jul	115700	105000	4.7	0.77	32900	504.4	208	538	416	5.76	-			847556.2
7	Aug	82600	105000	4.7	0.77	55300	504.4	208	538	416	5.76	-			864804.2
8	Sep	65500	105000	4.7	0.77	94800	504.4	208	538	416	5.76	-			895219.2
9	Oct	60500	35000	4.7	0.77	69300	504.4	208	-	-	5.76	-	25	416	323217.2
10	Nov	42400	35000	4.7	0.77	61900	504.4	208	-	-	5.76	-	-	-	317078.2
11	Dec	31450	-	4.7	0.77	30450	504.4	-	-	-	-		25	208	23679.5
12	Jan	22225.6	-	4.7	0.77	-	504.4	-	-	-	-				0
														Total	**6433230**

Then the objective function will be "minimize total cost":

$$Z = Min\left[\sum_{t=1}^{T} C_tP_t + h_tI_t + C'_tP'_t\right]$$

Subjected to:

Demand Constraint: The number of units produced by source 'i' in period 'j' cannot be less than the demand during that period;

$$\sum_{i=1}^{n}\sum_{j=1}^{n} P_{ij} \geq \sum_{t=1}^{n} D_t$$

Capacity Constraint: The number of units produced by source 'i' in period 'j' cannot exceed the capacity of sources during that period;

$$\sum_{i=1}^{n}\sum_{j=1}^{n} P_{ij} \leq \sum_{t=1}^{n} B_t$$

Inventory constraint: Net inventory (NIt) at the end of any period is related to the ending inventory level of the prior period (t-1) and the production (Pt) and demand rate (Dt) of the current period.

$$\begin{cases} NI_t = NI_{t-1} + P_t - D_t \\ NI_t = I^+ - I^- \end{cases}$$

Variable constraints: Any of these variables should not have values less than zero.

$$P_t,\ P'_t,\ I^+,\ I^- \geq 0$$

The solution of the transportation model is illustrated in table 4, at which rows present engaged production hours' month wise with production option in regular time and over time, and columns present demand periods. Last column contain information about production capacity in each production period. While the top right corner of each cell presents the unit production cost in SL per hour per month (including operational and inventory carrying cost). The solution of the transportation model is also presented in (figure 3). The total cost for the transportation model is calculated and found equal for (6782511.3 SL). The network diagram in (figure 3) reflects production in regular and over time month-wise with the inventory status. We can notice that:

- For regular production the engaged plant hours (208 hours) are almost constant from February to December. No production is carried out in January.

- Constant over time is engaged from April to September with minor over time in February and March.
- Demand of peak periods is met by carrying inventory, from April to January.
- The network diagram clearly represents how the demand is met, rather by current month's production or by inventory.

4.2 LINEAR PROGRAMMING MODEL

Among the numerous methods capable of developing mathematical models include aggregate production planning. A literature survey reveals that linear programming (LP) is a conventionally used technique [5].

The objective is to determine the optimal work force level, inventory level and amount to be produced during any production period, such that the cost of the production plan is minimized. We now describe a typical formulation of this variety of production planning problems:

Table 4. Solution by Transportation Technique (hours-wise).

Month	Prod. Time	Feb.	March	April	May	June	July
Feb.	Reg. Time	1294.5 192	1424	1553.5	1683	1812.5	1942
	Over Time	1328.1 26.3	1457.6	1587.1	1716.6	1846.1	1975.6
March	Reg. Time		1294.5 208	1424	1553.5	1683	1812.5
	Over Time		1328.1 41.4	1457.6	1587.1	1716.1	1846.1
April	Reg. Time			1294.5 208	1424	1553.5	1683
	Over Time			1328.1 230.7	1457.6 185.3	1587.1	1716.1
May	Reg. Time				1294.5 208	1424	1553.5
	Over Time				1328.1 139.5	1457.6 276.5	1587.1
June	Reg. Time					1294.5 208	1924
	Over Time					1328.1 237.1	1457.6 178.9
July	Reg. Time						1294.5 208
	Over Time						1328.1 334.7
Aug.							
Sep.							
Oct.							
Nov.							
Dec.							
Jan.							
	Demand (Hrs.)	218.3	249.4	438.7	532.8	721.2	721.6

Table 4. Solution by Transportation Technique (hours-wise) (continued).

Month	Prod. Time	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Cap Hrs
Feb.	Reg. Time	2071.5	2201	2330.5	2460	2589.5	2719	192
	Over time	2105.1	2234.6	2334.1	2493.6	2623.1	2752.6	26.3
March	Reg. Time	1942	2071.5	2201	2330.5	2460	2589.5	208
	Over time	1975.6	2105.1	2234.6	2334.1	2493.6	2623.1	41.4
April	Reg. Time	1812.5	1942	2071.5	2201	2330.5	2460	208
	Over time	1846.1	1975.6	2105.1	2234.6	2334.1	2493.6	416
May	Reg. Time	1683	1812.5	1942	2071.5	2201	2330.5	208
	Over time	1716.1	1846.1	1975.6	2105.6	2234.6	2334.1	416
June	Reg. Time	1553.5	1683	1812.5	1942	2071.5	2201	208
	Over time	1587.1	1716.1	1846.1	1975.6	2105.6	2234.6	416
July	Reg. Time	1924	1553.5	1683	1812.5	1942	2071.5	208
	Over time	1457.6 81.3	1587.1	1716.1	1846.1	1975.6	2105.6	416
Aug.	Reg. Time	1294.5 208	1924	1553.5	1683	1812.5	1942	208
	Over time	1328.1 225.9	1457.6 190.1	1587.1	1761.1	1846.1	1975.6	416
Sep.	Reg. Time		1294.5 208	1924	1553.5	1683	1812.5	208
	Over time		1328.1 9.9	1457.6 169.5	1587.1 106.4	1761.1 130.2	1846.1	416
Oct.	Reg. Time			1294.5 208	1942	1553.5	1683	208
	Over time			1328.1	1457.6	1587.1	1761.1	
Nov.	Reg. Time				1294.5 208	1942	1553.5	208
	Over time				1328.1	1457.6	1587.1	
Dec.	Reg. Time					1294.5 65.91	1942 142.1	208
	Over time					1328.1	1475.6	
Jan.	Reg. Time						1294.5	
	Over time						1328.1	
	Demand (Hrs.)	515.2	408	377.5	314.4	196.1	142.1	

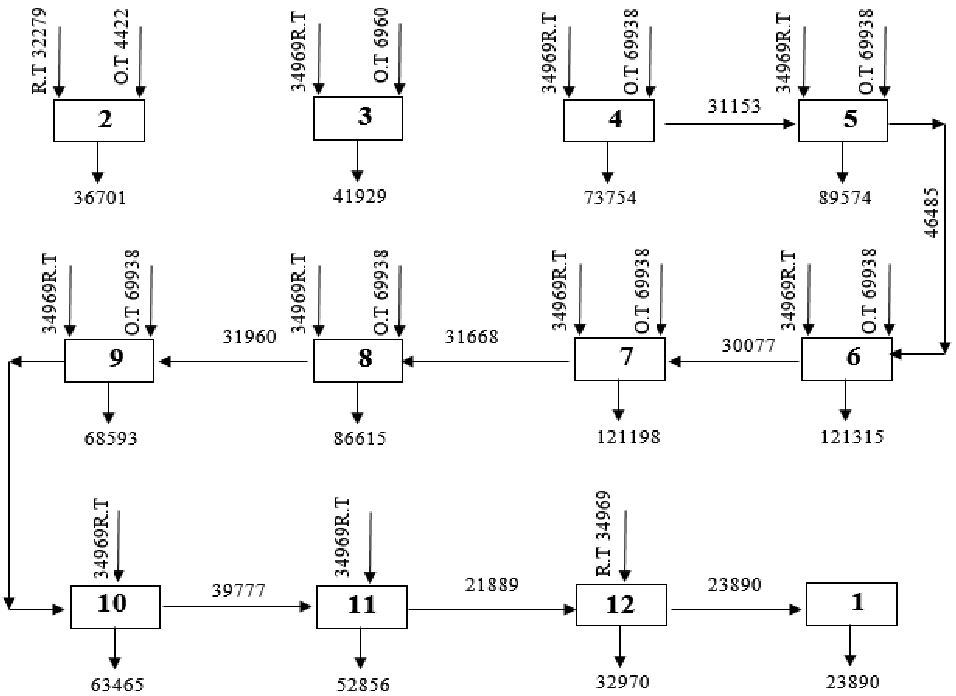


Fig. 3. Transportation Model Solution Network.

$$Z = Min\left[\sum_{t=1}^{T} C_t P_t + C_{RT} L_{RT} + C_{OT} L_{OT} + h_t I_t + C_{lt} l_t + C'_{lt} l'_t\right]$$

Where:

D_t = Forecasted demand in period 't'.

P_t = Quantity to be produced in period 't'.

C_t=Unit production cost in period 't' (excluding labor).

I_t = On hand inventory at the end of period 't'.

h_t= Inventory carrying cost per unit held from period 't' to 't+1'.

L_{Rt}= Regular time (Plant-hours) with fixed work-force level in period 't'.

C_{Rt} = Cost of a unit plant hour of regular time during period 't'.

ℓ_{ot}= Over time (Plant-hours) scheduled during period 't'.

C_{ot}= Cost of a unit Plant hour (with fixed workforce level).

ℓ_t= Increase in work-force level in Plant-hours from period (t-1) to 't'.

C_{lt}= Cost to increase the one plant hour in period 't'.

ℓ'_t = Decrease in work-force level in work-hours from period (t-1) to 't'.

C'_{lt}= Cost to decrease the one plant hour in period 't'

T= Time horizon for production planning.

Constrained to:

- Net inventory (NI_t) at the end of any period is related to the ending inventory level of the prior period (t-1) and the production (P_t) and demand rate (D_t) of the current period.

$$NI_t = NI_{t-1} + P_t - D_t$$

$$NI_t = I^+ - I^-$$

- The current period's regular time plant-hours (LRt) is related to the prior period's plant-hours (LR, t-1) and the rates of increasing (Lt) and decreasing (Lt') the work-force level during the current period.

$$L_{RT} = L_{R,t-1} + l_t - l'_t$$

$$L_{Rt} \leq L_{R\,\max}$$

- Over time (Lot) in any period is related to the period's scheduled production level 'LRt' and work force level.

$$L_{Ot} - L_{ut} = mP_t - L_{Rt}$$

$$L_{ot} \leq L_{o\,\max}$$

L_{ut} is the planned under utilization of the work force (i.e. against planned reduction in productivity). This occurs when the cost of such under utilization is less than the alternative costs of carrying additional inventory or temporary changing the work force level.
m =Number of Plant- hours required per unit of 'Pt' (Ltr.)

- Finally the non-negativity constraint is added.

$$P_t,\ I_t,\ L_{RT},\ I_t^+,\ I_t^-,\ \ell_{ot},\ \ell_{ut} \geq 0$$

LINGO™ computer software package is used to solve the LP model optimally.

The output of the model was (see appendix A):

Global optimal solution found at iteration: 62

Objective value (Total Cost): 6032497

The results obtained from the model solution are presented in a network diagram figure 4.

The main features of production plan of this solution are as below:

- Regular production level is almost constant (34969 Ltr) from period February to period December with slight change in January (22225.6 Ltr).
- Constant overtime is engaged only from period May to July. The duration of over time is under decline from August to November, and there is no overtime in December and January.
- Inventory is carried from 'April to June' only with maximum level 23325 Ltr.
- The situation of under time has not occurred.

4.3 Dynamic Programming Model

4.3.1 Mathematical Model

Dynamic Programming (DP) determines the optimum solution to an n-variable problem by decomposing it into n stages with each stage constituting a single-variable sub-problem. The computational advantage is that DP optimizes single-variable sub-problems [8]. This model is applicable for situations when a single production system is used to produce mixed products with common denomination.

The product may be stored from one period to the next at a known cost per unit. This model also provides an opportunity to take into account the 'Setup Costs' from product to product, while neither LP model nor transportation model provide this option.

The problem is to decide the production level month wise to minimize the total relevant cost during planning horizon. The total cost incurred to produce the units in 't^{th}' period, including setup and production cost.

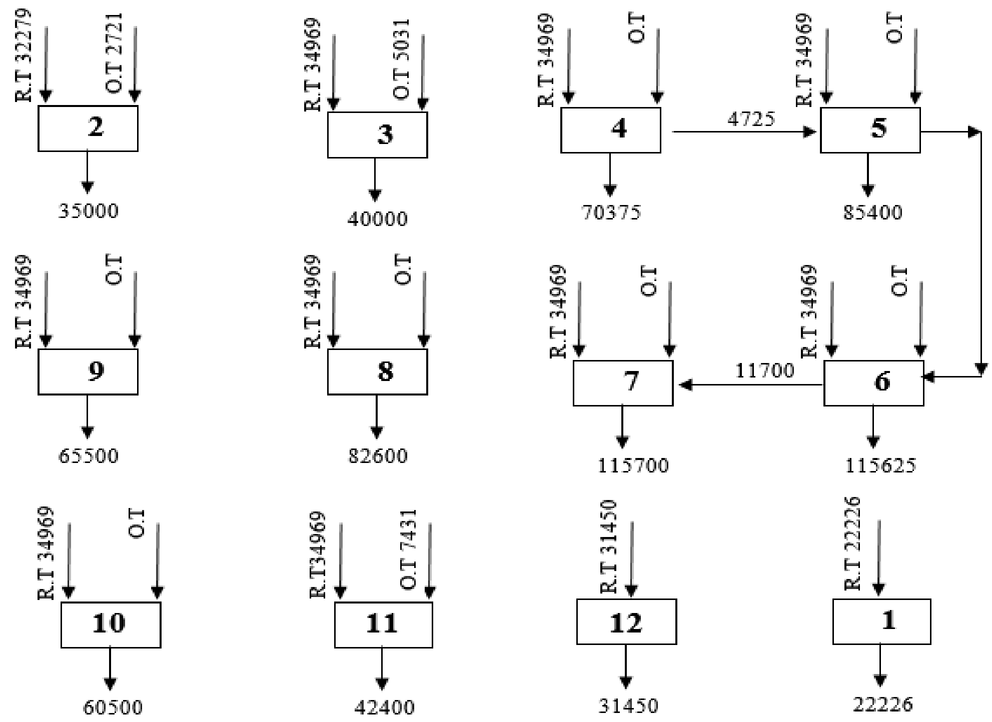


Fig. 4. Linear Program Model solution network

$K_t = A_t + C_t P_t$

A_t = The setup cost in the 't th' period.

C_t = The unit production cost in the 't th' period.

P_t = Production in 't th' period.

B_t = Capacity in terms of production.

Cn-l = Cost to produce Dj units in the last productive period.

I_t =Inventory level in period 't'.

h_t =Inventory holding cost from period t to (t+1).

n =Total number of periods.

ℓ =Nonproductive periods.

m =Dependent variable on 'l''.

$$Z = Min\left[\sum_{t=1}^{n-m} K_t + C_{n-l}\sum_{t=n}^{n-(m-1)} D_t + \sum_{t=n-m}^{n-1} I_t h_t\right]$$

$$Where, n-\ell \geq n-m$$

Subject to $P_t \leq Bt$.

$$I_t = I_{t-1} + P_t - D_t$$

$$B_t \geq 0, \quad I_t > 0$$

The pertinent data including set up costs is presented in table 5.

4.3.2. SOLUTION BY DYNAMIC PROGRAMMING

After setting the problem inputs and the governing formula to minimize the cost, we consider 12 options for solving:

4.3.2.1. OPTION –1

We consider the situation when there are zero inventories, it means that for every period we have to produce as per requirement (figure 5), and then the production cost will be:

$$Z_1 = Min\left[\sum_{t=1}^{12} K_t + C_{12}\sum_{12}^{13} D_t + \sum_{t=12}^{11} I_t h_t\right]$$

$$\sum_{t=1}^{13} D_t \ \& \ \sum_{12}^{11} I_t h_t = 0$$

$$\Rightarrow Z_1 = Min\left[\sum_{T=1}^{12} K_t\right] = Min\left[\sum_{t=1}^{12}(A_t + C_t X_t)\right]$$

$$X_t = D_t$$

$$\Rightarrow Z1 = 6917698.89SL$$

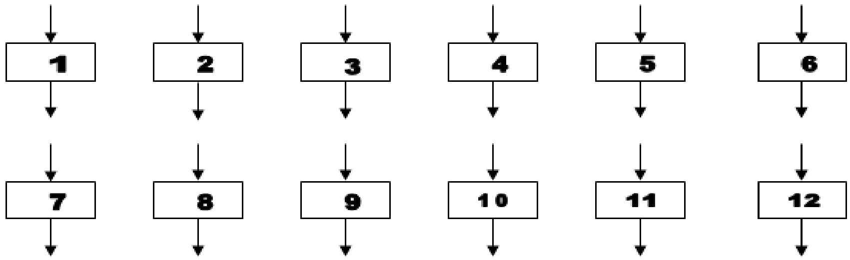


Figure 5. Graphical presentation of option No. 1.

4.3.2.2. OPTION –2

When the last period (12th) is non-productive, so in (11th) period it has to produce so much quantity that it could meet the requirement of last period also (figure 6). Then the production cost will be:

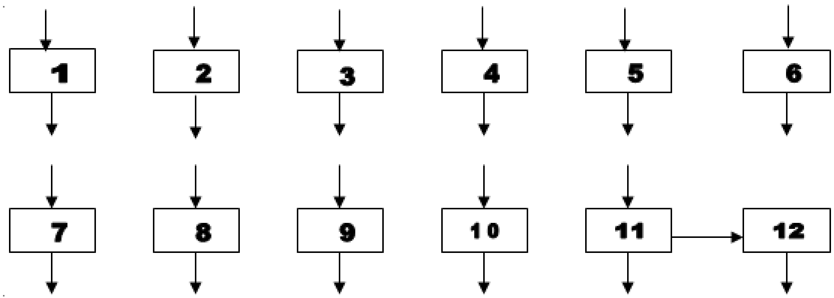


Figure 6. Graphical presentation of option No. 2.

$$Z_2 = \min[\sum_{t=1}^{11}(A_t + C_t D_t) + C_{11} D_{12} + I_{11} h_{11}]$$

$$= \min[11A + C_{11}\sum_{t=1}^{11} D_t + C_{11} D_{12} + h_{11} D_{12}]$$

$$= \min[11(48090) + 1311.3(4693.2) + (1311.3)(142.1) + 131.13(142.1)]$$

$$= 528990 + 6154193.16 + 186335.73 + 16833.57$$

$$= 6888152.46 SL$$

4.3.2.3. OPTION-3

When we keep the last two periods (11^{th} & 12^{th}) non-productive (figure 7), then in the (10^{th}) period it has to produce so much quantity that it can meet the requirements of remaining periods also, then the production cost will be: This procedure will continue in the same manner and we get the following results (table 6).

The option ‘3’ is found economically best. This option suggests to meet the demand of periods from February to November by producing in each month according to demand without carrying inventories and keep the plant shutdown in December and January (see Figure 7). Although the option is economically best, but practically not visible.

We can now collect the proposed solutions’ costs in a table (table 7) and make comparison to choose the solution with minimum cost, noting that the objective of this research is to minimize costs with a practically feasible solution.

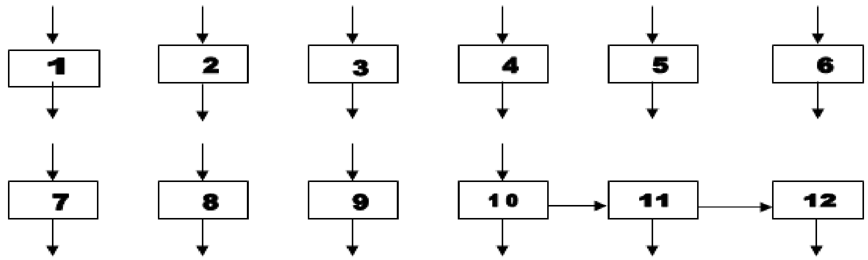


Figure 7. Graphical presentation of option No. 3.

Table 5. Data Transformation for Dynamic Programming

S.No	Months	Demand **(D_t)** (hr)	Cumulative Demand **($\sum D_t$)** (hr)	Reverse Cumulative Demand **($\sum D_t'$)** (hr)	Setup Cost **(A)** (SL/m)	Production Cost **(C)** (SL/hr)	Inventory Holding Cost **(h)** (SL/hr)	**.hx D_t'** (SL)	Reverse Commutation **$\sum$.hx D_t'** (SL)
01	Feb.	218.3	218.3	4835.3	48090	1311.3	131.13	634052.9	3851838.8
02	March.	249.4	467.7	4617	48090	1311.3	131.13	605427.2	3217785.9
03	April.	438.7	906.4	4367.6	48090	1311.3	131.13	572723.4	2612358.7
04	May	532.8	1439.2	3928.9	48090	1311.3	131.13	515196.6	2039635.2
05	June	721.2	2160.4	3396.1	48090	1311.3	131.13	445330.6	1524438.7
06	July	721.6	2882	2674.9	48090	1311.3	131.13	350759.6	1079108.1
07	August	515.2	3397.2	1953.3	48090	1311.3	131.13	256136.3	728348.5
08	Sept.	408	3805.2	1438.1	48090	1311.3	131.13	188578	472212.19
09	Oct.	377.5	4182.7	1030.1	48090	1311.3	131.13	135077	283634.19
10	Nov.	314.4	4497.1	652.6	48090	1311.3	131.13	85575.42	148557.19
11	Dec.	196.1	4693.2	338.2	48090	1311.3	131.13	44348.2	62981.77
12	Jan.	142.1	4835.3	142.1	48090	1311.3	131.13	18633.57	18633.57
	$\sum$	4835.3							

Table 6. Cost comparison for options from Dynamic Programming Model.

Option No.	**Cost Incurred (SL)**	**Option No.**	**Cost Incurred (SL)**
1	**6917608**	**7**	**7357421**
2	**6888152**	**8**	**7660086**
3	**6884410**	**9**	**8057196**
4	**6921896**	**10**	**8524434**
5	**7008883**	**11**	**9049067**
6	**7149375**	**12**	**9826610**

Table 7. Cost Comparison of Different Techniques of Aggregate Planning.

Classical Production Planning (SL /Yr)	Transportation Model (SL /Yr)	Linear Programming (SL /Yr)	Dynamic Programming (SL /Yr)
6581613	6782511	**6032497**	6884410

5. CONCLUSION

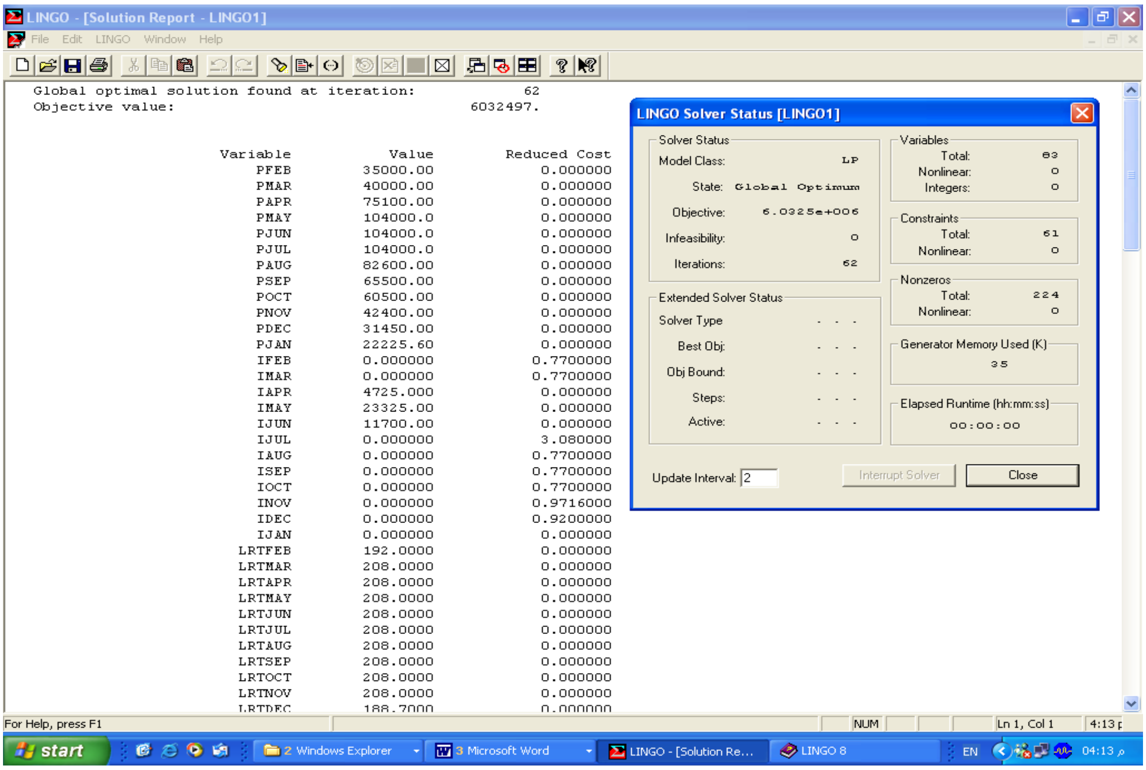
It is concluded that for the production planning on aggregate basis, linear production model technique (solved by using LINGO™ Program) is more appropriate for this company with 6.23% cost reduction among Classical Production Planning, where different seasonal products can be aggregated using Liter as a common denominator (table 7). The objective function involves in minimizing direct pay roll, over time, hiring/ firing and inventory holding costs. A workable Master Production Schedule (MPS) can be prepared using aggregate production planning technique.

Appendix A
The Solution of Linear Program by LINGO software.

Global optimal solution found at iteration: 62

Objective value: 6032497.

Row	Slack or Surplus	Dual Price
1	6032497.	-1.000000
2	0.000000	-0.4184005
3	0.000000	-7.928000
4	0.000000	-7.928000
5	0.000000	-7.928000
6	0.000000	-8.698000
7	0.000000	-9.468000
8	0.000000	-10.23800
9	0.000000	-7.928000
10	0.000000	-7.928000
11	0.000000	-7.928000
12	0.000000	-7.928000
13	0.000000	-7.726400
14	0.000000	-7.576400
15	0.000000	5.760000
16	0.000000	5.760000
17	0.000000	-25.00000
18	0.000000	5.760000
19	0.000000	-25.00000
20	0.000000	-25.00000
21	0.000000	-25.00000
22	0.000000	5.760000
23	0.000000	5.760000
24	0.000000	5.76000
25	0.000000	-25.00000
26	0.000000	-25.00000
27	0.000000	-538.0000
28	0.000000	-538.0000
29	0.000000	-538.0000
30	0.000000	-666.3333
31	0.000000	-794.6667
32	0.000000	-923.0000
33	0.000000	-538.0000
34	0.000000	-538.0000
35	0.000000	-538.0000
36	0.000000	-538.0000
37	0.000000	-504.4000
38	0.000000	-479.4000
39	0.000000	33.60000
40	0.000000	2.840000
41	0.000000	64.36000
42	0.000000	131.1733
43	0.000000	290.2667
44	0.000000	418.6000
45	0.000000	64.36000
46	0.000000	33.60000
47	0.000000	33.60000
48	0.000000	2.840000
49	19.30000	0.000000
50	74.64640	0.000000
51	366.0000	0.000000
52	384.0000	0.000000
53	173.4000	0.000000
54	0.000000	128.3333
55	0.000000	256.6667
56	0.000000	385.0000
57	128.4000	0.000000
58	231.0000	0.000000
59	261.0000	0.000000
60	369.6000	0.000000
61	416.0000	0.000000
62	416.0000	0.000000


LINGO - [Solution Report - LINGO1]
File Edit LINGO Window Help
Global optimal solution found at iteration: 62
Objective value: 6032497.
Variable Value Reduced Cost
PFEB 35000.00 0.000000
PMAR 40000.00 0.000000
PAPR 75100.00 0.000000
PMAY 104000.0 0.000000
PJUN 104000.0 0.000000
PJUL 104000.0 0.000000
PAUG 82600.00 0.000000
PSEP 65500.00 0.000000
POCT 60500.00 0.000000
PNOV 42400.00 0.000000
PDEC 31450.00 0.000000
PJAN 22225.60 0.000000
IFEB 0.000000 0.7700000
IMAR 0.000000 0.7700000
IAPR 4725.000 0.000000
IMAY 23325.00 0.000000
IJUN 11700.00 0.000000
IJUL 0.000000 3.080000
IAUG 0.000000 0.7700000
ISEP 0.000000 0.7700000
IOCT 0.000000 0.7700000
INOV 0.000000 0.9716000
IDEC 0.000000 0.9200000
IJAN 0.000000 0.000000
LRTFEB 192.0000 0.000000
LRTMAR 208.0000 0.000000
LRTAPR 208.0000 0.000000
LRTMAY 208.0000 0.000000
LRTJUN 208.0000 0.000000
LRTJUL 208.0000 0.000000
LRTAUG 208.0000 0.000000
LRTSEP 208.0000 0.000000
LRTOCT 208.0000 0.000000
LRTNOV 208.0000 0.000000
LRTDEC 188.7000 0.000000
LINGO Solver Status [LINGO1]
Solver Status
Model Class: LP
State: Global Optimum
Objective: 6.03225e+006
Infeasibility: 0
Iterations: 62
Variables
Total: 62
Nonlinear: 0
Integers: 0
Constraints
Total: 61
Nonlinear: 0
Nonzeros
Total: 224
Nonlinear: 0
Extended Solver Status
Solver Type
Best Obj:
Obj Bound:
Steps:
Active:
Generator Memory Used (K)
35
Elapsed Runtime (hh:mm:ss)
00:00:00
Update Interval: 2
Interrupt Solver
Close
For Help, press F1
NUM
Ln 1, Col 1
start
2 Windows Explorer
3 Microsoft Word
LINGO - [Solution Re...
LINGO 8
EN
04:13

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Received	**2016/03/02**	**إيداع البحث**
Accepted for Publ.	**2016/10/03**	**قبول البحث للنشر**