# Aggregate planning problem solving using linear programming method

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Abstract. Aggregate production planning is concerned with the determination of production, inventory, and work force levels to meet fluctuating demand requirements over a planning horizon that ranges from six months to one year. An aggregate planning model based on linear programming is developed here. In our paper we mainly focus on experimenting with workforce. We mainly follow changing three criteria of workforce such as fixed workforce, changing workforce and the combination of fixed and changing workforce. Using these three criteria the total cost of production of a cable industry is reduced. The percentage of cost reduction is different in these criteria's. TORA software has been used to evaluate the optimized value.

Keywords: Aggregate Planning, Linear Programming, TORA.

## **1 INTRODUCTION**

Aggregate planning is the process of developing, analyzing, and maintaining a preliminary, approximate schedule of the overall operations of an organization. It plays an important role for planning any kind of production work. Aggregate planning is an intermediate range capacity planning. It covers a time horizon of two to twelve months, in some cases the time extends to 18 months. The goal of aggregate planning is to achieve a production plan that will effectively utilize the organization resources to satisfy expected demand. Organizations take three kinds of capacity decisions. They are: long term, intermediate term and short term. Many organizations make business plan that covers both long term and intermediate term planning. These decisions depend

On companies policies, strategies, forecast for different products, services, competitive and political condition and so on. In our paper we have discussed about a specific problem of production work interrelated with demand, capacity, production, inventory and cost of all these sectors. We have solved that problem with linear programming.

## 2 INPUTS TO AGGREGATE PLANNING

Aggregate planning begins with a forecast of aggregate demand for the intermediate range. This is followed by a general plan to meet demand requirements for setting output, employment and finished-goods inventory levels or service capacities.

Aggregate planners are concerned with the quality and the timing of expected demand. If total expected demand for the planning period is much different from available capacity over the same period, the major approach of planners will be to try to achieve a balance by altering

capacity, demand or both. On the other hand, even if capacity and demand are approximately equal for the planning horizon as a whole, planning may still be faced with problem of dealing with uneven demand within the planning interval. In some periods, expected demand may exceed projected capacity, in others expected demand may be less than projected capacity, and in some periods the two may be equal. The task of aggregate planners is to achieve rough equality of demand and capacity over the entire planning horizon. Moreover, planners are usually concerned with minimizing the cost of the aggregate plan, although plan, although cost is not the only consideration.

Effective aggregate planning requires good information. First, the available resources over the planning period must be known. Then, a forecast of expected demand must be available. Finally, planners must take into account any policies regarding changes in employment levels. Companies in the travel industry and some other industries often experience duplicate orders from customers who make multiple reservations but only intend to keep at most one of them. This makes capacity planning all the more difficult.

## **3 AGGREGATE PLANNING VARIABLES**

Aggregate planning or the development of a month by month intermediate range schedule of product service bundles, is based on an intermediate demand forecast. By observing the flow of demand, future demand can be predictable. However, the precision with which future demand can be predicted decreases the farther into the future one attempts to look. Depending on the planning system a business uses, this characteristic of forecasting may be more or less significant like the following systems:

- A) Make-to-stock system
- B) Make-to-order system
- C) Assemble-to-order system

In a Make-to-stock system, the entire schedule is based on forecasted demand. In a Make-toorder system, manager have purchase orders in hand when they are planning, so they know the demand for products and services at least as forward as their processing lead times. Assemble-to-order systems are a combination of the make-to-stock and make-to-order approaches. Production of customer orders are scheduled using components and subassemblies that have been made to stock.

Aggregate planners have limited set of variables: it indicates only the inventory account, the monthly production rate, the size of the work force, and the extent of subcontracting.

## **4 METHODOLOGY**

The Procedure of the aggregate planning problem solve is:

1. We collect the data of beginning inventory, demand, regular time days, over time days.

2. We have calculated the total cost at fixed workforce, at changing workforce & the combination of fixed and changing workforce.

3. Then we have formulated the equations with the help of above data and then solve it in TORA.

4. We have used the optimum value from TORA to get the optimum total cost.

5. We have done the cost calculation in Microsoft Excel.

## **5 BASIC ASSUMPTION AND NOTATIONS**

For the development of Aggregate Planning we have assumed:

Dt = Demand

Rt = Regular time production used in period t (rt)

 $\begin{array}{l} Ot = Over time \ production \ used \ in \ period \ t \ ( \ ot \ ) \\ It = Inventory \ (ending) \ used \ in \ period \ t \ ( \ it \ ) \\ St = Shortage \ in \ period \ t \ ( \ st \ ) \\ OUTt = No. \ of \ unit \ outsourced \ ( \ outt \ ) \\ Ut = Under \ utilization \ in \ period \ t \ ( \ ut \ ) \\ Ht = No. \ of \ people \ hired \ in \ period \ t \ ( \ ht \ ) \\ Wt = No. \ of \ people \ working \ in \ period \ t \ ( \ wt \ ) \\ Lt = People \ laid \ off \ in \ period \ t \ ( \ lt \ ) \end{array}$ 

## **6 DEVELOPMENT OF AGGREGATION METHOD**

## 6.1 At fixed workforce

Regular time cost (R.T.) = $1000$ (rt)
Over time Cost $(O.T.) = 1500$ ( ot )
Inventory $cost = 20$ (it)
Shortage $cost = 5000$ (st)
Hours/ day = $16$
No. of people $= 200$
Hour to produce one unit $= 1.28$

RT capacity = 200\*12.5\*17=42500OT capacity = 200\*12.5\*9=22500RT Production = 42500OT Production = 22500Total capacity = 42500+22500=65000End inv. = 1000+65000-65500=500RT cost = 42500\*1000 = 42500000OT cost = 22500\*1500 = 33750000Inv. Cost = 500\*20 = 10000Total cost = 4250000+33750000+10000 = 76260000Total cost for 12 months = 845436000

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Fig 1 Aggregate plan for fixed workforce

## 6.2 Optimum Table (At fixed workforce)

Problem Formulation: Min z= 1000Rt + 1500Ot + 20It + 5000St Rt + Ot - It = 65500 - 1000= 64500 Rt <= 42500 Ot <= 22500 Rt, Ot, It, St >= 0 Putting these equations in TORA we have got our RT pro and OT pro value. Those are:

- RT Pro. 42500, 37500, 45000, 40000, 42500, 45000, 47500, 37500, 42500, 45000, 42500, 40000
- OT Pro. 22000, 14000, 22500, 18500, 17000, 14500, 19000, 17300, 19300, 18300, 20800, 0

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Fig 2 Optimum Solution, RT Pro. and OT Pro. value in TORA Using RT Pro. and OT Pro. value in Microsoft Excel we have got our optimum cost.

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10	March	3500	71000	45000	45000	25000	22500	45000000	33750000	(	78750000	
11	April	2500	61000	40000	40000	20000	18500	40000000	27750000		67750000	
12	May	1500	61000	42500	42500	17500	17000	42500000	25500000		68000000	
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Fig 3 Optimum Table for Fixed Workforce

The total cost for 12 months= 812300000

The total cost for 12 months in previous table= 845436000

So, the reduced cost= 845436000 - 812300000 = 33136000

The percentage of the reduced cost= 3.92%

## 6.3 At Changing Workforce

Regular time cost (R.T.) = 1000 (rt )Over time Cost (O.T.) = 1500 (ot )Inventory cost = 20 (it )Shortage cost = 5000 (st )Hours/ day = 16No. of people = 200Hour to produce one unit = 1.28Hiring cost= 5000 (ht)Layoff cost= 4000 (lt)Out sourcing cost= 2000 (outt)Underutilization cost= 20 (ut) RT capacity = 213\*17\*12.5= 45262.5 OT capacity = 213\*9\*12.5 = 23962.5RT Production = 45262.5OT Production = 23962.5Total capacity = 45262.5+23962.5+0= 69225 Total Production = 45262.5+23962.5= 69225 End inv. = 1000+69225-65500= 3725 RT cost = 45262.5\*1000= 45262500 OT cost = 23962.5\*1500= 35943750 Inv. Cost = 3725\*20= 74500 Hiring cost= 13\*5000= 65000 Total cost =45262500+35943750+74500+65000+0+0= 81345750 Total cost for 12 months = 843516000

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Fig 4 Aggregate plan for Changing Workforce

## 6.4 Optimum Table (At Changing Workforce)

Problem Formulation:

$$\label{eq:min_z} \begin{split} & \text{Min } z = 1000\text{Rt} + 1500\text{Ot} + 20\text{It} + 5000\text{Ht} + 4000\text{Lt} + 2000\text{outt} \\ & \text{Rt} + \text{Ot} - \text{It} + \text{OUTt} = 65500 - 1000 = 64500 \\ & \text{Rt} <= 45262.5 \\ & \text{Ot} <= 23962.5 \\ & \text{Rt}, \text{Ot}, \text{It}, \text{Ht}, \text{Lt}, \text{OUTt} >= 0 \end{split}$$

Putting these equations in TORA we have got our RT pro and OT pro value.

- RT Pro. 45262.5, 31875, 55125, 34200, 39525, 45000, 53200, 35812.5, 48237.5, 49437.5, 51425, 40000
- OT Pro. 19237.5, 16400, 15875, 12050, 16425, 15000, 13800, 11087.5, 8137.5, 0, 9912.5, 1700

Using RT Pro. and OT Pro. value in Microsoft Excel we have got our optimum cost.

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0	March	0	71000	55125	55125	30625	15875	55125000	23812500	0	78937500	
1	April	14750	61000	34200	34200	17100	12050	34200000	18075000	0	52275000	
2	May	5050	61000	39525	39525	16275	16425	39525000	24637500	0	64162500	
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5	August	11400	58300	35812.5	35812.5	16712.5	11087.5	35812500	16631250	0	52443750	
6	Septembe	5625	62000	48237.5	48237.5	22700	8137.5	48237500	12206250	0	60443750	
7	October	14562.5	64000	53100	49437.5	23600	0	49437500	0	0	49437500	
8	Novembe	3662.5	65000	51425	51425	27225	9912.5	51425000	14868750	0	66293750	
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1	Total		733500								738537500	
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Fig 5 Optimum Table for Changing Workforce

The total cost for 12 months= 738537500The total cost for 12 months in previous table= 843516000So, the reduced cost= 843516000 - 738537500 = 104978500The percentage of the reduced cost= 12.45%

### 6.5 The combination of Fixed and Changing workforce

Regular time cost (R.T.) = 1000 (rt)Over time Cost (O.T.) = 1500 (ot)Inventory cost = 20 (it)Shortage cost = 5000 (st)Hours/ day = 16No. of people = 200Hour to produce one unit = 1.28Hiring cost= 5000 (ht)Layoff cost= 4000 (lt)Out sourcing cost= 2000 (outt)Underutilization cost= 20 (ut)

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Fig 6 Aggregate plan for Combination of Fixed & Changing Workforce The calculation procedures are same as shown before in 6.1 & 6.3. The total cost of 12 months= 853079250

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10	March	.0	71000	55125	55125	30625	15875	0	55125000	23812500	0	789375	00
11	April	14750	61000	34200	34200	17100	12050	0	34200000	18075000	0	522750	00
17	May	5050	61000	39525	39525	16275	16425	0	39525000	24637500	0	641625	00
13	June	0	60000	45000	45000	20000	15000	0	45000000	22500000	0	675000	00
14 15	At Fix	ed Workfo	rces										
10	-	A REAL PROPERTY AND A REAL PROPERTY A REAL PROPERTY A REAL PROPERTY AND A REAL PROPERT											
17	July	5000	72000	47500	47500	22500	19500	0	47500000	29250000	0	767500	00
18	August	3000	58300	37500	37500	17500	17500	500	37500000	26250000	2500000	662500	00
19	Septembe	0	62000	42500	42500	20000	19500	0	42500000	29250000	0	717500	00
20	October	200	64000	45000	45000	20000	18800	0	45000000	28200000	0	732000	00
21	Novembe	1200	65000	42500	42500	22500	21300	0	42500000	31950000	0	744500	00
22	December	1200	41700	40000	40000	25000	500	0	40000000	750000	0	407500	00
23													
24	Total		733500									7966187	50
35													

## 6.6 Optimum Table (At the combination of Fixed and Changing workforce)

Fig 7 Optimum Table for Combination of Fixed & Changing workforce

The total cost for 12 months= 796618750The total cost for 12 months in previous table= 853079250So, the reduced cost= 853079250 - 796618750 = 56460500The percentage of the reduced cost= 6.62%

## **7 RESULT AND DISCUSSION**

In this paper, we studied the aggregate planning of a cable industry using linear programming. We optimized the total cost in three criteria's. We targeted the workforce. At first we calculated the cost keeping the workforce fixed, then calculated the cost changing the workforce & at last calculated the total cost at the combination of fixed & changing the workforce. We calculated the optimum cost by forming equations and solving it in TORA. After getting the optimum result from TORA, we used that results to calculate the optimum cost. After that we compared both results and found the percentage of the reduced cost. The linear programming result we have used that showed us the most optimum result.

+ <b>‡</b> +				
	Types	Contents	The Total Cost	% of Cost
			(12 months)	Reduction
		Estimated Cost	845436000	
	At fixed workforce	Optimum Cost	812300000	3.92
		Reduced Cost	33136000	
	At changing	Estimated Cost	843516000	
	workforce	Optimum Cost	738537500	12.45
		Reduced Cost	104978500	
	The combination of	Estimated Cost	853079250	
	fixed & changing	Optimum Cost	796618750	6.62
	workforce	Reduced Cost	56460500	

Table 1 List of all estimated, optimum & reduced cost in three conditions

## **8 CONCLUSIONS**

In this paper we studied about aggregate planning of a cable industry using linear programming model. In the first sector of problem formulation we have calculated the total cost in old manner. After that we have calculated the total cost using linear programming method. We have done all the calculations focusing on workforce. Our main target was to optimize the total cost and we have done it successfully. We have used TORA software to find the optimum result.

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