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-to-order 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)

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)

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

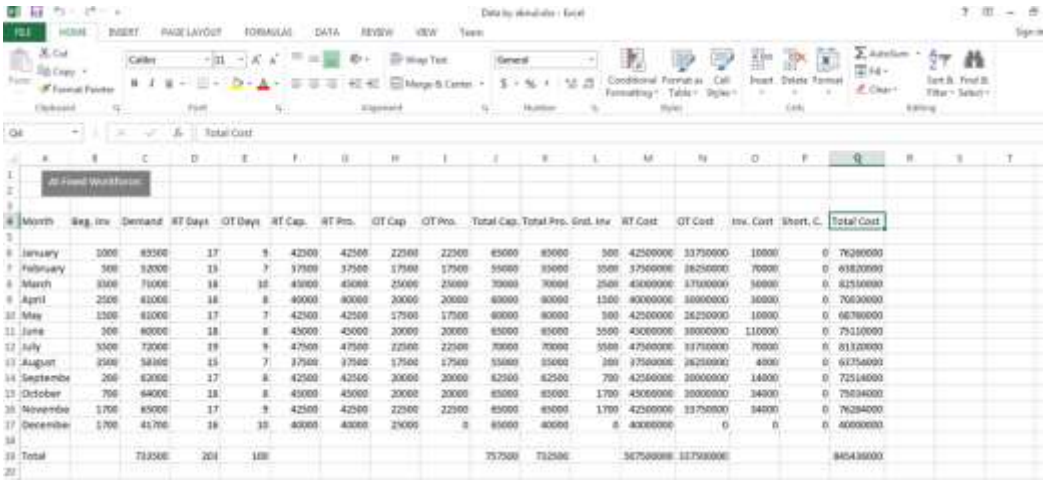


Fig 1 Aggregate plan for fixed workforce

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

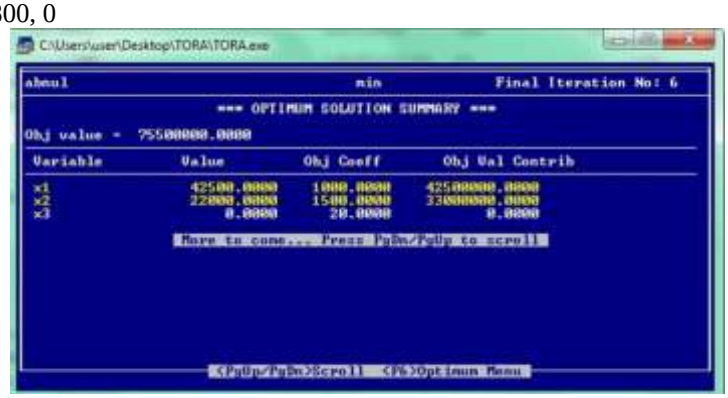
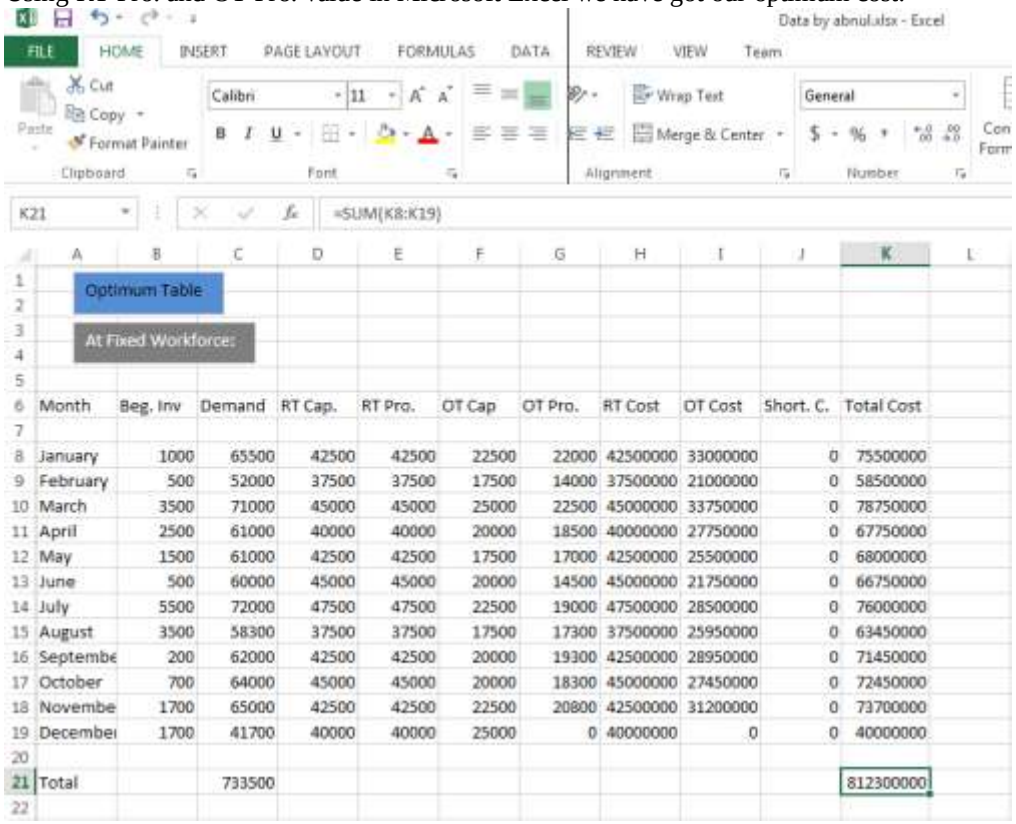


Fig 2 Optimum Solution, RT Pro. and OT Pro. value in TORA

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



Month	Beg. Inv	Demand	RT Cap.	RT Pro.	OT Cap	OT Pro.	RT Cost	OT Cost	Short. C.	Total Cost
January	1000	65500	42500	42500	22500	22000	42500000	33000000	0	75500000
February	500	52000	37500	37500	17500	14000	37500000	21000000	0	58500000
March	3500	71000	45000	45000	25000	22500	45000000	33750000	0	78750000
April	2500	61000	40000	40000	20000	18500	40000000	27750000	0	67750000
May	1500	61000	42500	42500	17500	17000	42500000	25500000	0	68000000
June	500	60000	45000	45000	20000	14500	45000000	21750000	0	66750000
July	5500	72000	47500	47500	22500	19000	47500000	28500000	0	76000000
August	3500	58300	37500	37500	17500	17300	37500000	25950000	0	63450000
Septembe	200	62000	42500	42500	20000	19300	42500000	28950000	0	71450000
October	700	64000	45000	45000	20000	18300	45000000	27450000	0	72450000
Novembe	1700	65000	42500	42500	22500	20800	42500000	31200000	0	73700000
Decembe	1700	41700	40000	40000	25000	0	40000000	0	0	40000000
Total		733500								812300000

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 = 16
No. of people = 200
Hour to produce one unit = 1.28
Hiring 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= 23962.5
RT Production = 45262.5
OT Production = 23962.5
Total 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

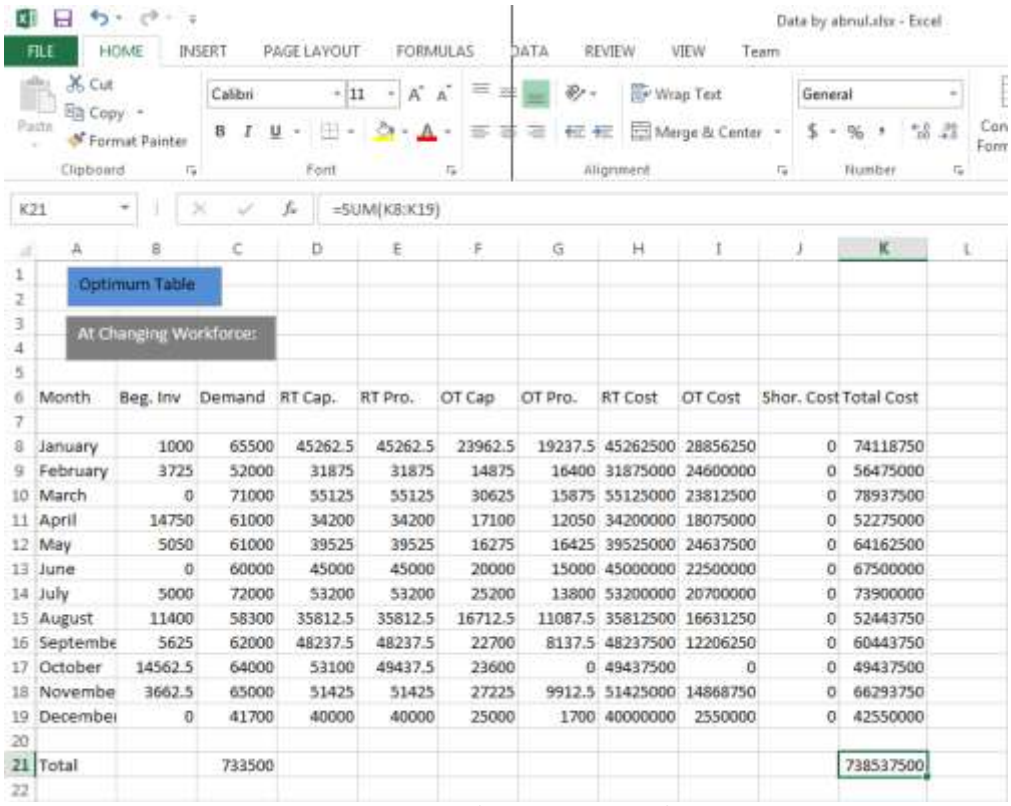
Fig 4 Aggregate plan for Changing Workforce

6.4 Optimum Table (At Changing Workforce)

Problem Formulation:

Min z= 1000Rt + 1500Ot + 20It + 5000Ht + 4000Lt +2000outt
Rt +Ot – It + OUTt = 65500 – 1000= 64500
Rt <= 45262.5
Ot <= 23962.5
Rt, Ot, It, Ht, Lt, OUTt >= 0

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.



Month	Beg. Inv	Demand	RT Cap.	RT Pro.	OT Cap	OT Pro.	RT Cost	OT Cost	Shor. Cost	Total Cost
January	1000	65500	45262.5	45262.5	23962.5	19237.5	45262500	28856250	0	74118750
February	3725	52000	31875	31875	14875	16400	31875000	24600000	0	56475000
March	0	71000	55125	55125	30625	15875	55125000	23812500	0	78937500
April	14750	61000	34200	34200	17100	12050	34200000	18075000	0	52275000
May	5050	61000	39525	39525	16275	16425	39525000	24637500	0	64162500
June	0	60000	45000	45000	20000	15000	45000000	22500000	0	67500000
July	5000	72000	53200	53200	25200	13800	53200000	20700000	0	73900000
August	11400	58300	35812.5	35812.5	16712.5	11087.5	35812500	16631250	0	52443750
Septembe	5625	62000	48237.5	48237.5	22700	8137.5	48237500	12206250	0	60443750
October	14562.5	64000	53100	49437.5	23600	0	49437500	0	0	49437500
Novembe	3662.5	65000	51425	51425	27225	9912.5	51425000	14868750	0	66293750
Decembe	0	41700	40000	40000	25000	1700	40000000	2550000	0	42550000
Total		733500								738537500

Fig 5 Optimum Table for Changing Workforce

The total cost for 12 months= 738537500
The total cost for 12 months in previous table= 843516000
So, the reduced cost= 843516000 - 738537500= 104978500
The 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 = 16
No. of people = 200
Hour to produce one unit = 1.28
Hiring cost= 5000 (ht)
Layoff cost= 4000 (lt)
Out sourcing cost= 2000 (outt)
Underutilization cost= 20 (ut)

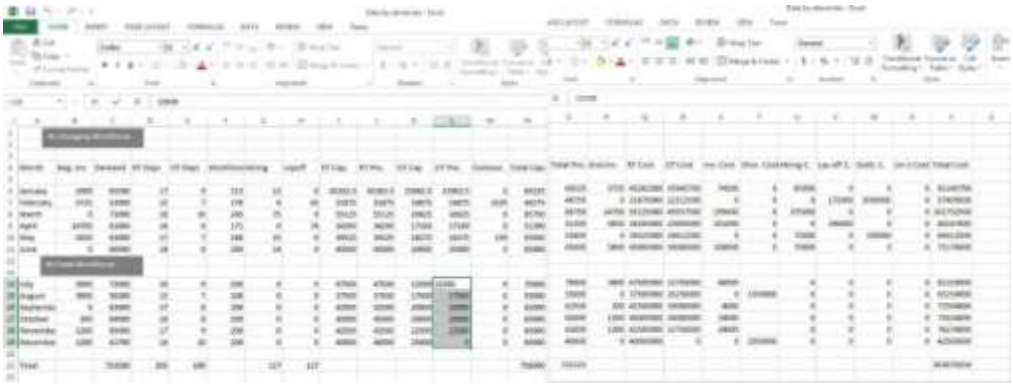
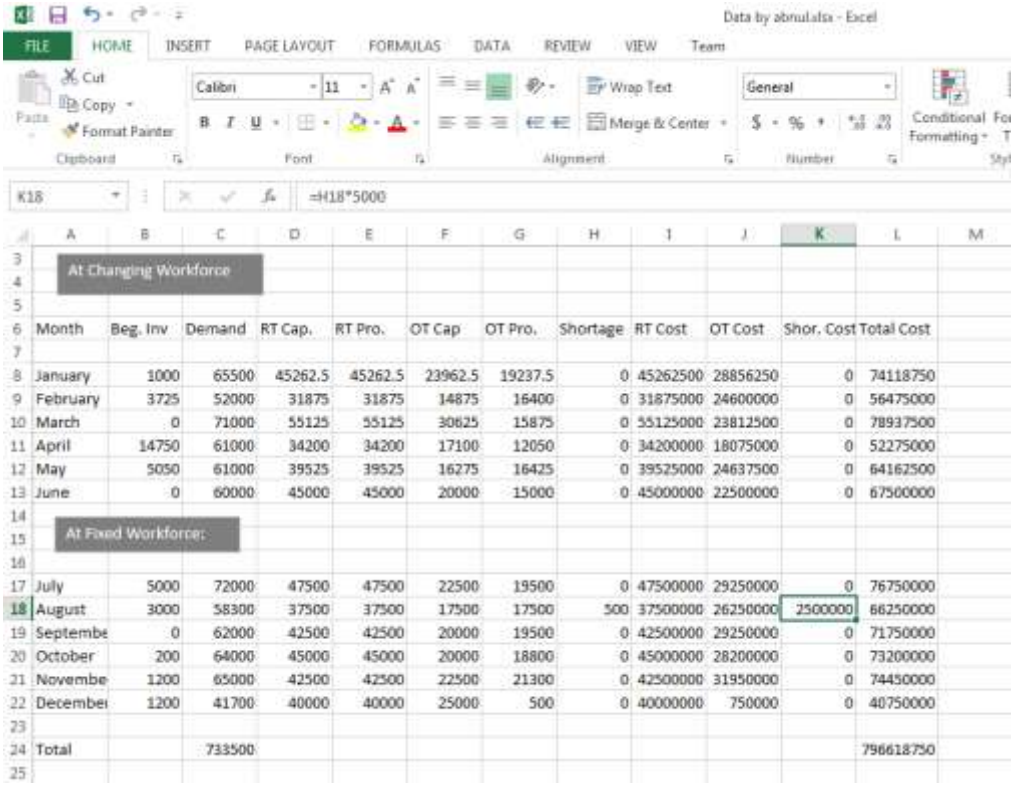


Fig 6 Aggregate plan for Combination of Fixed & Changing Workforce

The calculation procedures are same as shown before in 6.1 & 6.3.
The total cost of 12 months= 853079250

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



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At Changing Workforce

Month	Beg. Inv	Demand	RT Cap.	RT Pro.	OT Cap	OT Pro.	Shortage	RT Cost	OT Cost	Shor. Cost	Total Cost
January	1000	65500	45262.5	45262.5	23962.5	19237.5	0	45262500	28856250	0	74118750
February	3725	52000	31875	31875	14875	16400	0	31875000	24600000	0	56475000
March	0	71000	55125	55125	30625	15875	0	55125000	23812500	0	78937500
April	14750	61000	34200	34200	17100	12050	0	34200000	18075000	0	52275000
May	5050	61000	39525	39525	16275	16425	0	39525000	24637500	0	64162500
June	0	60000	45000	45000	20000	15000	0	45000000	22500000	0	67500000
At Fixed Workforce:											
July	5000	72000	47500	47500	22500	19500	0	47500000	29250000	0	76750000
August	3000	58300	37500	37500	17500	17500	500	37500000	26250000	2500000	66250000
Septembe	0	62000	42500	42500	20000	19500	0	42500000	29250000	0	71750000
October	200	64000	45000	45000	20000	18800	0	45000000	28200000	0	73200000
Novembe	1200	65000	42500	42500	22500	21300	0	42500000	31950000	0	74450000
Decembe	1200	41700	40000	40000	25000	500	0	40000000	750000	0	40750000
Total		733500									796618750

Fig 7 Optimum Table for Combination of Fixed & Changing workforce

The total cost for 12 months= 796618750
The total cost for 12 months in previous table= 853079250
So, the reduced cost= 853079250 – 796618750 = 56460500
The 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.

Types	Contents	The Total Cost (12 months)	% of Cost Reduction
At fixed workforce	Estimated Cost	845436000	**3.92**
	Optimum Cost	812300000	
	Reduced Cost	33136000	
At changing workforce	Estimated Cost	843516000	**12.45**
	Optimum Cost	738537500	
	Reduced Cost	104978500	
The combination of fixed & changing workforce	Estimated Cost	853079250	**6.62**
	Optimum Cost	796618750	
	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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BIOGRAPHES

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