Application of Quantitative Methods on problem solving

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Abstract: *Within scope of this paper there are presented quantitative methods – linear programming applied on problems defined by case study of Calgary Desk Company. In this paper is presented situation of CALDESCO Company in different scenarios of optimization of resources. Results vary from very satisfied and inspiring to very devastating. Three scenarios were developed in order to find best solution and create further recommendations. Linear equations were created and Lingo software was used for calculations. According to those three scenarios, we strongly recommend usage of Scenario 3 in order to have maximized capacities and maximized profit. Scenario 3 is not final solution and we can recommend some future adaptation of this scenario. This paper is significant for educational purposes, management institutions and industry.*

Keywords: *linear programming, quantitative methods, management, industrial logistics, optimization of resources*

1. INTRODUCTION

It is September and the Calgary Desk Company (CALDESCO) of Calgary, Alberta, is about to plan the production schedule for its entire line of desks for October. CALDESCO is a well-established manufacturer. Due to internal policy of production quotas (which will be detailed later), it has been able to sell all desks manufactured in a particular month. This, in turn, has given the company reliable estimates of the unit profit contributed by each desk model and style.

1.1. The Desks

CALDESCO manufactures a student size desk (24 × 42 in.), a standard size desk (30 × 60), and an executive size desk (42 × 72), in each of the three lines: (1) economy, (2) basic pine, and (3) hand-crafted pine.

The economy line uses aluminum for the drawers and base and a simulated pine-laminated 1-inch particle board top. Although the basic pine desk use 3/2 inch pine sheets instead of particle board, they are manufactured on the same production line as the tops of the economy line models. Because its drawers and base are mode of wood, however, a different production line is required for this process.

Hand-crafted desks have solid pine tops that are constructed by craftsmen independent of any production line. This desk line uses the same drawers and base (and hence the same production line for this process) as the basic pine desk line. Hand-crafted desks are assembled and finished by hand.

1.2. Production

Production Line 1 is used to manufacture the aluminum drawers and base for the economy models; production line 2 is used to manufacture the tops for the economy and basic models. There are two production lines 3, which are used to manufacture drawers and bases for the basic and hand-crafted lines. (Two lines are necessary to meet production targets.)

The production times available on the three production lines are summarized on the Excel spreadsheet below. The time requirements (in minutes) per desk for the three different types of production lines, the finishing and assembly times, and the time required to hand-craft certain models are also summarized on the spreadsheet.

1.3. Labor

CALDESCO currently employs a workforce of 30 craftsmen, but due to vacations, illnesses, etc. CALDESCO expects to have only an average of 80% of its craftsmen available throughout the month. Each available craftsman works 160 hours per month. The expected total labor availability, which is also given on the spreadsheet, is:

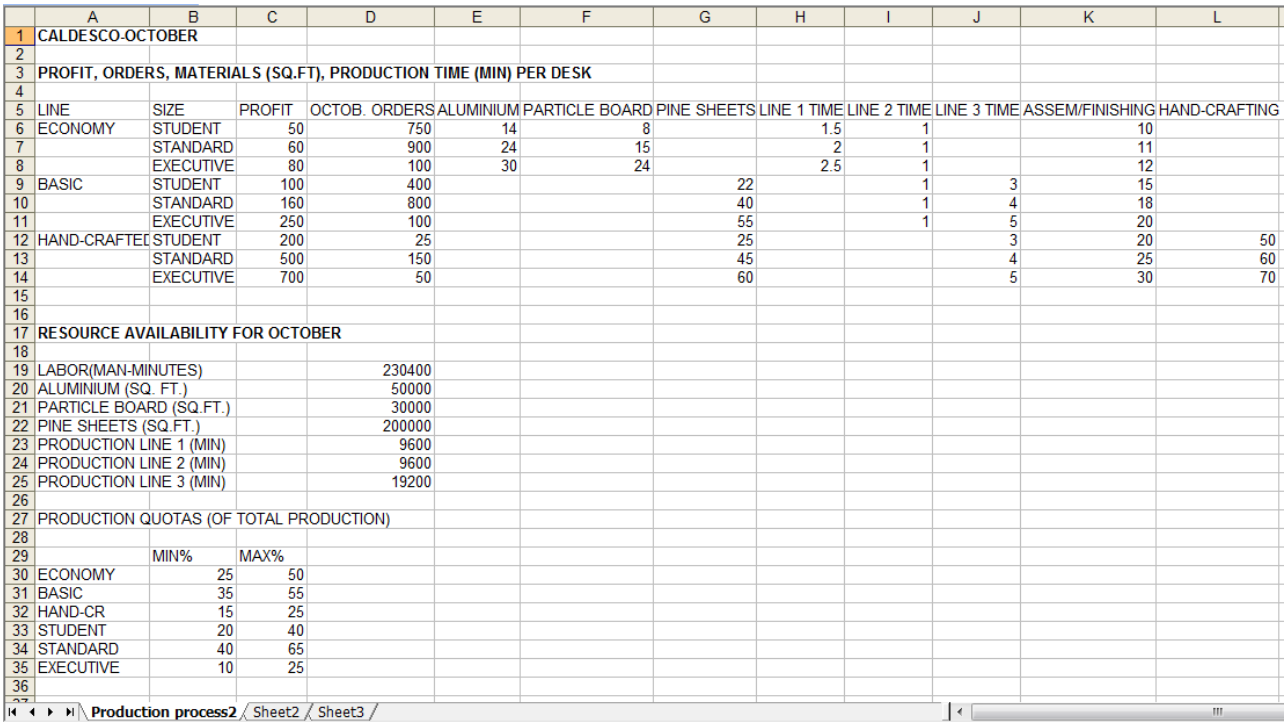
(0.80) * (30 craftsmen) * (160 hours/craftsmen) * (60 minutes/hour) = 230,400 worker-minutes.

Each craftsman in CALDESCO's shop is capable of doing all the tasks required to make any model desk; including running of the manufacturing lines, assembling the product, or performing the detailed operations necessary to produce the hand-crafted models.

Two craftsmen are required for each production line, but only a single craftsman is needed for hand crafting and a single craftsman is needed for assembly and finishing. Thus, the total amount of man-minutes required to produce a desk = 2* (the total production line time) + (hand-crafting time) + (assembly/finishing time).

1.4. Materials Requirements

As detailed earlier, the economy desks use aluminum and laminated particle board, whereas the basic and hand-crafted models use real pine. The amounts of aluminum, particle board, and 3/2 inch thick pine sheets (in square feet) required to produce each style of desk are summarized on the spreadsheet along with the September availability of aluminum, particle board, and pine sheets.



	A	B	C	D	E	F	G	H	I	J	K	L
1	CALDESCO-OCTOBER											
2												
3	PROFIT, ORDERS, MATERIALS (SQ.FT), PRODUCTION TIME (MIN) PER DESK											
4												
5	LINE	SIZE	PROFIT	OCTOB. ORDERS	ALUMINIUM	PARTICLE BOARD	PINE SHEETS	LINE 1 TIME	LINE 2 TIME	LINE 3 TIME	ASSEM/FINISHING	HAND-CRAFTING
6	ECONOMY	STUDENT	50	750	14	8		1.5	1		10	
7		STANDARD	60	900	24	15		2	1		11	
8		EXECUTIVE	80	100	30	24		2.5	1		12	
9	BASIC	STUDENT	100	400			22		1	3	15	
10		STANDARD	160	800			40		1	4	18	
11		EXECUTIVE	250	100			55		1	5	20	
12	HAND-CRAFTED	STUDENT	200	25			25			3	20	50
13		STANDARD	500	150			45			4	25	60
14		EXECUTIVE	700	50			60			5	30	70
15												
16												
17	RESOURCE AVAILABILITY FOR OCTOBER											
18												
19	LABOR(MAN-MINUTES)			230400								
20	ALUMINIUM (SQ. FT.)			50000								
21	PARTICLE BOARD (SQ.FT.)			30000								
22	PINE SHEETS (SQ.FT.)			200000								
23	PRODUCTION LINE 1 (MIN)			9600								
24	PRODUCTION LINE 2 (MIN)			9600								
25	PRODUCTION LINE 3 (MIN)			19200								
26												
27	PRODUCTION QUOTAS (OF TOTAL PRODUCTION)											
28												
29		MIN%	MAX%									
30	ECONOMY	25	50									
31	BASIC	35	55									
32	HAND-CR	15	25									
33	STUDENT	20	40									
34	STANDARD	40	65									
35	EXECUTIVE	10	25									
36												

Production process2 | Sheet2 | Sheet3

1.5. Company Policy/Quotas

CALDESCO has been able to sell all the desks it produces and to maintain its profit margins in part by adhering to a set of in-house quotas. These maximum and minimum quotas for desk production are given on the spreadsheet. CALDESCO will meet all outstanding orders for September. These are also summarized on the spreadsheet.

1.6. Profit Contribution

The unit profits, which have been determined for each style of desk, are also summarized on the spreadsheet.

1.7. The report

Prepare a report recommending a production schedule to CALDESCO for October. In your report, analyze your results, detail the amount of each resource needed if your recommendation is implemented, and discuss any real-life factors that might be considered that have not been addressed in this problem summary nor listed on the spreadsheet.

Discuss some appropriate "what-if" analyses including:

1. An analysis of the viability of instituting a bonus plan costing about $70,000 per month that is anticipated to reduce absenteeism from 20% to 15%.

2. An analysis of the possibility of purchasing a new production line 2 for $800,000 and hiring 10 new workers at $60,000 each per year (assume the 20% absentee rate). Assume that October is a typical month and that the resulting increased production per month would be matched each month.

Specifically determine:

- How long it would be before these changes became profitable (i.e. until these fixed costs were paid off)

- After the purchase of the line was paid off, how much additional profit you would expect to earn each month. (Don't forget the added cost of new workers.)

3. Other observations and scenarios you feel might be reasonable.

Your report should give a complete description/analysis of your final recommendation complete with tables, charts, graphs, and so on. The complete model and the computer printouts are to be included in appendices.

2. INTRODUCTION TO PROBLEM SOLUTION

2.1. Problem statement

Calgary Desk Company (CALDESCO) is company from Alberta, Calgary and their main activities are in producing different kinds of tables and furniture. In this case we have situation in which CALDESCO is producing 9 different types of desks i.e. student, standard and executive in three different categories i.e. economy, basic and hand-crafted. CALDESCO is able to sell all those products that are produced but they need to respect in-house quotas. From other side, material, labor and production are most important variables for further optimization of resources. Future months are main CALDESCO managers target for anticipating level of costs, materials, labor and other resources as well as anticipating future revenues. Main problems are related to clarifying current situation in terms of resources and also analysis of the viability of instituting a bonus plan that should reduce absenteeism. Second problem is related to potential purchasing of new production line and hiring new workers. According to mathematical models and software usage as well as in accordance with resources data, report is done and represents potential solution that should be considered by management of Calgary Desk Company.

2.2. Assumption / approximations made

We assume that all mentioned resources that are displayed in TABLE 1 of Calgary Desk Company are verified values and we assume that there will be no changes of those values. Each change of any of those values of resources will lead to further changes in mathematical model and in final result of analysis. There is highly possibility for changes of those values in real life situation, and those changes will implicate more complex mathematic model. Changes of values of resources could appear because of problems with supplier, problems with buyers and internal problems within company. Reasons for problems with suppliers and buyers could be numerous and therefore, we assume that all of those potential problems will not actually happened and that only changes that need to be done are related to reorganization within the company – which is our basic assumption. According to orders that are displayed in table bellow, current profit (unit price* number of orders) is $339,500.

Table 1, Calgary Desk Company resources

	A	B	C	D	E	F	G
1	CALDESCO-OCTOBER						
2							
3	PROFIT, ORDERS, MATERIALS (SQ.FT), PRODUCTION TIME (MIN) PER DESK						
4							
5	LINE	SIZE	PROFIT	OCTOB. ORDERS	ALUMINIUM	PARTICLE BOARD	PINE SHEETS
6	ECONOMY	STUDENT	50	750	14	8	
7		STANDARD	60	900	24	15	
8		EXECUTIVE	80	100	30	24	
9	BASIC	STUDENT	100	400			22
10		STANDARD	160	800			40
11		EXECUTIVE	250	100			55
12	HAND-CRAFTED	STUDENT	200	25			25
13		STANDARD	500	150			45
14		EXECUTIVE	700	50			60
15							
16							
17	RESOURCE AVAILABILITY FOR OCTOBER						
18							
19	LABOR(MAN-MINUTES)			230400			
20	ALUMINIUM (SQ. FT.)			50000			
21	PARTICLE BOARD (SQ.FT.)			30000			
22	PINE SHEETS (SQ.FT.)			200000			
23	PRODUCTION LINE 1 (MIN)			9600			
24	PRODUCTION LINE 2 (MIN)			9600			
25	PRODUCTION LINE 3 (MIN)			19200			
26							
27	PRODUCTION QUOTAS (OF TOTAL PRODUCTION)						
28							
29		MIN%	MAX%				
30	ECONOMY	25	50				
31	BASIC	35	55				
32	HAND-CR	15	25				
33	STUDENT	20	40				
34	STANDARD	40	65				
35	EXECUTIVE	10	25				

2.3. Solution approach / computer program used

In this paper we use LINGO software which represents comprehensive tool designed for Nonlinear, Linear, Quadraticaly, Second order cone, Stochastic and other models. We will use LINGO software for linear optimization. LINGO has excellent performances in terms of diversity of problem solving, with present set of fast built-in solvers and also LINGO is very user friendly. Mathematic model is entered into software with appropriate syntaxes and result that is received will further influence on future management decisions. Entered model and results received are displayed in Appendices section.

3. RESULTS

As mention in paper above, current profit is $339,500. Potential maximum profit of CALDECO Company is $397,916 which is grater for 17,2% from current profit. According to those results we can say that difference between current situation and potential maximization of profit is not drastic and there is high level of optimization present. However, 17.2% is not eider a small percentage of distinction therefore CALDESCO Company need to carefully analyses current situation and to continue with good work and good results in future. From side of considering computer output results, optimization is firstly related in this presentation to specific desk capacity and ration between quantities of produced and sold items and its maximization values. If CALDESCO Company wants to

achieve maximization of profit, they need to consider mentioned ratio. In table bellow is displayed this ratio.

Table 1. Products quantity as computer output result and current situation

Nr.	Products	Ideal Produced/sold nr. of products in order to maximize profit (A)	Current situation (B)	Difference of A and B value in %
1.	Quantity of Economy Student desks	750	750	0%
2.	Quantity of Economy Standard desks	1440	900	60%
3.	Quantity of Economy Executive desks	100	100	0%
4.	Quantity of Basic Student desks	400	400	0%
5.	Quantity of Basic Standard desks	921	800	15.12%
6.	Quantity of Basic Executive desks	1100	100	1000%
7.	Quantity of Hand-crafted Student desks	1357	25	5328%
8.	Quantity of Hand-crafted Standard desks	150	150	0%
9.	Quantity of Hand-crafted Executive desks	50	50	0%

From the above Table 1 and displayed data, we can say that in 5 cases with products : Economy Student desks, Economy executive desks, Basic student desks, Hand crafted standard desks and Hand crafted executive desks, optimization of resources i.e. ratio of produced and sold products is excellent and there is no possibility to be on higher level of optimization. In case of product Basic Standard desks, we have difference in 15.12% between ideal produced/sold number of products and current situation, we can say that difference does not have extreme value and that with some additional optimization this product could achieve better days.

In case of product economy standard desk, we have highly differentiated ratio between ideal situation and current situation. Difference in 60% shows that resources for this product are not optimized well and there is growing need to create some actions in order to create better results for this product on market.

In case of Basic executive desk and handcrafted student desk, we have extremely high differentiation between ratio of ideal scenario and current situation. We strongly recommend that this products production and selling options need to be optimized because results are more than 1000% higher in case of ideal situation for both products.

In table 2, bellow is displayed values for resources such as: Aluminum, Particle board, Pine sheets, Production line 1, 2 and 3 and also Labor resource.

Table 2, Unused resource in ideal scenario referring to current situation

Nr.	Resource	Unused resource in ideal scenario	Current value of resources (C)	Unused resource in % of C
1.	Aluminum	1.940	50.000	3.88%
2.	Particle board	0	30.000	0%
3.	Pine sheets	50.185	200.000	25.01%
4.	Production line 1	5345	9600	55.67%
5.	Production line 2	4889	9600	50.92%
6.	Production line 3	3895	19200	20.28%
7.	Labor	0	230.400	0%

According to computer output and data described in table above, we can say that results of optimization of resources for CALDESCO Company are very good for some resources and form the other hand very bad for some others. In case of resources such as Particle boards and Labor Caldesco Company have full optimization which results in 0% of unused resource. In case of Aluminum, we have very good optimization with just 3.88% if unused material. Situation is different with Pine sheets where 25% are unused and optimization need to be better performed with this resource. Problem definitely persists in Production lines, where percentage of unused resources goes from 20.28% in production line 3 to extreme maximum of 55.67%. In this field company CALDESCO need to create better results and to perform serious actions.

4. WHAT IF ANALYSIS

4.1 Scenario 1

According to case information, CALDESCO currently employs a workforce of 30 craftsmen, but due to vacations, illnesses, etc. CALDESCO expects to have only an average of 80% of its craftsmen available throughout the month. Each available craftsman works 160 hours per month. Total worker minutes are *230,400 worker-minutes*.

Within scenario 1, we need to consider an analysis of the viability of instituting a bonus plan costing about $70,000 per month that is anticipated to reduce absenteeism from 20% to 15%.

Therefore after using of formula and calculating of working-minutes we receive result of *244.800 working-minutes.*

Maximum profit that is reachable for CALDESCO Company is $423.297 which is for 6.37% higher than in initial case.

After receiving results of computing operation with introduced new value of working-minutes, we have received data related to changes in quantity of ideal produced/sold number of products in order to maximize profit. These data are displayed in Table 3 bellow.

Table 3, Products quantity as computer output result and current situation

Nr.	Products	Ideal Produced/sold nr. of products in order to maximize profit (A)	Current situation (B)	Difference of A and B value in %
1.	Quantity of Economy Student desks	751	750	0.01%
2.	Quantity of Economy Standard desks	1439	900	59.8%
3.	Quantity of Economy Executive desks	100	100	0%
4.	Quantity of Basic Student desks	442	400	10.5%
5.	Quantity of Basic Standard desks	1058	800	32.25%
6.	Quantity of Basic Executive desks	1172	100	1072%
7.	Quantity of Hand-crafted Student desks	1453	25	5712%
8.	Quantity of Hand-crafted Standard desks	150	150	0%
9.	Quantity of Hand-crafted Executive desks	50	50	0%

Results are devastating in some cases. Main problems are in optimization of produced and sells products of Basic Executive Desk and Hand crafted student desk. In case of Hand crafted executive Desks, Hand crafted standard desks, Economy executive desks and Economy student desks, situation remain same and results are extremely positive in terms of optimization. Products such as Economy standard desks, Basic standard and Basic Student desks need to be involved into following actions in order to become more profitable products.

Here in Table 4 bellow are displayed results related to resources optimization.

Table 4, Unused resource in ideal scenario referring to current situation

Nr.	Resource	Unused resource in ideal scenario	Current value of resources (C)	Unused resource in % of (C)
91.	Aluminum	1.950	50.000	4.9%
2.	Particle board	7	30.000	0.03%
3.	Pine sheets	37.421	200.000	18.72%
4.	Production line 1	5345	9600	55.67%
5.	Production line 2	4638	9600	48.31%
6.	Production line 3	2573	19200	13.4%
7.	Labor	0	230.400	0%

In results we can see that there are slight changes in optimization level in almost all resource categories. Production Line 1 is only resource that remains same.

After increasing of working time for 5% there are significantly better results noticed and we think that further increasing of this category will have more benefit for CALDESCO Company.

4.2 Scenario 2

Within this scenario we have perform an analysis of the possibility of purchasing a new production line 2 for $800,000 and hiring 10 new workers at $60,000 each per year with assumption that the absentee rate is 20%. Also we need to make assumption that October is a typical month and that the resulting increased production per month would be matched each month.
In Table 5 bellow are displayed results of product optimization.

Table 5, Products quantity as computer output result and current situation

Nr.	Products	Ideal Produced/sold nr. of products in order to maximize profit (A)	Current situation (B)	Difference of A and B value in %
1.	Quantity of Economy Student desks	930	750	12.4%
2.	Quantity of Economy Standard desks	1344	900	149.3%
3.	Quantity of Economy Executive desks	100	100	0%
4.	Quantity of Basic Student desks	400	400	0%
5.	Quantity of Basic Standard desks	2271	800	283.25%
6.	Quantity of Basic Executive desks	604	100	604%
7.	Quantity of Hand-crafted Student desks	682	25	2728%
8.	Quantity of Hand-crafted Standard desks	150	150	0%
9.	Quantity of Hand-crafted Executive desks	50	50	0%

This change influences on results in positive way. Increase of quantity of produced/sold Economy student desk, Basic Standard desk, Economy Standard Desk is beneficial for CALDESCO Company. From the other hand, there is present decrease of Hand Crafted desks. Profit in this case on monthly basis is $875.500.

Here bellow in Table 6 is displayed results of resources optimization for Scenario 2 according to computer output.

Table 6, Unused resource in ideal scenario referring to current situation

Nr.	Resource	Unused resource in ideal scenario	Current value of resources (C)	Unused resource in % of C
1.	Aluminum	1.724	50.000	3.4%
2.	Particle board	0	30.000	0%
3.	Pine sheets	15.340	200.000	7.67%
4.	Production line 1	5267	9600	54.86%
5.	Production line 2	13.552	9600	141.16%
6.	Production line 3	0	19200	0%
7.	Labor	29.104	230.400	0%

According to presented results we can say that optimization of resources was successful in terms of better optimized resource of Particle boards, Pine sheets and product line 3. However, problems occurs with labor and working time as result is 29.104 unused resource of labor could lead to further actions related to optimization of resources. Also, production lines are not used equally in order to optimize number of produced items in timely manner. Hence, profit on monthly basis is $875.500 therefore we can recommend such company settings.

If company purchases a new production line, then the profit will increase for monthly profit of CALDESCO Company on monthly basis for $339.500. If expenses are related to new production line purchasing in total $800.000 and also introducing of 10 new workers with annual salary of $60.000 each. Before introduction of new product line, company will earn $339.500, and after introduction of new product line $875.500 therefore investment for production line will be paid off in one month and additionally $50.000 should be paid on monthly basis for new workers.

4.3 Scenario 3

As we have in computer output extreme non-optimized situation with two products Basic Executive Desk and Hand Crafted Student Desk we propose optimization of those two products production. As other products and resources are well optimized, we need to consider of creation of new network of buyers for those two products. If we have extreme situation of produced 1100 of Basic executive desks when current situation is 100 and 1350 Hand crafted student desks when current situation is 25 units, then we need to consider introduction of more labor force from one hand and full capacity usage of all production lines in order to increase production for several times. At current situation, we have 54.3% of usage of product line 1, production line 2 is used approximately 50% and production line 3 is used 80%. One of the first actions that we recommend is optimization of current resources of production lines and labor. Also, investments in new production lines and labor force are something that is very attractive in this specific situation of extreme values.

Table 7. Products quantity as computer output result and current situation

Nr.	Products	Ideal Produced/sold nr. of products in order to maximize profit (A)	Current situation (B)	Difference of A and B value in %
1.	Quantity of Economy Student desks	750	750	0%
2.	Quantity of Economy Standard desks	1440	900	60%
3.	Quantity of Economy Executive desks	100	100	0%
4.	Quantity of Basic Student desks	400	400	0%
5.	Quantity of Basic Standard desks	921	800	15.12%
6.	Quantity of Basic Executive desks	1100	100	1000%
7.	Quantity of Hand-crafted Student desks	1357	25	5328%
8.	Quantity of Hand-crafted Standard desks	150	150	0%
9.	Quantity of Hand-crafted Executive desks	50	50	0%

Production line 1	5345	9600	55.67%
Production line 2	4889	9600	50.92%
Production line 3	3895	19200	20.28%

Table 8, Unused resource in ideal scenario referring to current situation

Overall profit made after introduction of new product line 2 and increasing labor force to 90% is $1.160.180 on monthly basis.

5. OVERALL RECOMMENDATION

In this paper is presented situation of CALDESCO Company in different scenarios of optimization of resources. Results vary from very satisfied and inspiring to very devastating. In initial scenario In case of Basic executive desk and handcrafted student desk, we have extremely high differentiation between ratio of ideal scenario and current situation. We strongly recommend that this products production and selling options need to be optimized because results are more than 1000% higher in case of ideal situation for both products. Also in Scenario 3, this opportunity is further analyzed and conclusion is related to further optimization of resources and creation of new product lines and introduction of new labor force. Monthly profit in with this scenario is $339,500.

In Scenario 2. Investment in new production line as well as introduction of new labor force influences on results in positive way. Increase of quantity of produced/sold Economy student desk, Basic Standard desk, Economy Standard Desk is beneficial for CALDESCO Company. From the other hand, there is present decrease of Hand Crafted desks. Profit in this case on monthly basis is $875.500.

In Scenario 3, we need to consider introduction of more labor force from one hand and full capacity usage of all production lines in order to increase production for several times.

Overall profit made after introduction of new product line 2 and increasing labor force to 90% is $1.160.180 on monthly basis.

According to those three scenarios, we strongly recommend usage of Scenario 3 in order to have maximized capacities and maximized profit. Scenario 3 is not final solution and we can recommend some future adaptation of this scenario. At first glance we need to maximize usage of production lines, and then afterwards to invest in one more production line and to try to minimize absenteeism on 10%. With implementation of those changes, we will have increasing in profit for 3.41 times than current monthly profit is.

6. LITERATURE

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