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An approach towards optimization of production technique- A case study on small scale industry

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Abstract

This research paper provides an idea about the present manufacturing scenario and future changes possible in this direction in small scale industries (here tiffin manufacturing firm). Firstly the current situation is analyzed using linear programming model and sensitivity analysis is done to track the changes. Then for future two techniques are discussed to improve manufacturing process. Owing to intense global competition advanced manufacturing technology (AMT) is considered as a means of improving competitiveness. Another means of overcoming present problem is the use of flexible manufacturing system (FMS) design. This paper describes a methodology of analysis and evaluation of FMS design. This research paper presents an overview and guidance for manufacturing companies which can invest in advanced manufacturing techniques and flexible manufacturing system designs. It discusses the advantages and disadvantages associated with the use of these methods of manufacturing. It also offers suggestions on each step to improve and analyze the whole procedure adopted.

Introduction

Today is the era of global competition; the world has turned out to be a global village. Competition among manufacturers in developing countries is remarkably vigorous due to trade liberalization. Manufacturing firms in developing countries have traditionally been relatively protected. They have also been subject to heavy regulation. Small scale industries are from that bunch which is hardly hit as the owners of these firms believe in traditional methods of manufacturing. Another reason which can be cited is the lack of resources mainly financial resources. The example taken here is about a tiffin manufacturing firm XYZ Steels which is involved in manufacturing three types of tiffins each having three variants. They are using traditional methods of manufacturing and their main motto is to grab more market share with minimal investment.

Linear programming model is best means to get optimum level of production under present available resources. And sensitivity analysis is the study of sensitivity of the optimal solution of an LP problem due to discrete variation in resources one at a time. For keeping pace with changing market scenario and to withstand competition AMT i.e. advanced manufacturing technology and flexible manufacturing system (FMS) design are rays of light FMSs have been introduced in several European countries, North America, and South East Asia as a means for increasing productivity and quality as well as a means for maintaining and/or improving competitiveness. A

survey of related literature in AMT indicates that excessive attention has been paid to technical development, but not enough to the adjustments needed in the organizations to accommodate the technology.

Literature Review

Linear programming model is used in management of any organization as it helps in taking critical decision about allocation of resources available to various activities. These activities can include various production activities (producing different products), marketing activities (advertising in different media), financial activities (making capital investments), or some other activities. Some of its application goes beyond the allocation of resources. Various researchers have applied this technique in different circumstances.

Kazan et al.(2000) formulated a mixed integer linear programming model to identify less nervous production schedules in a rolling horizon basis. Chang and Chang (2001) developed a mixed integer optimization model for solving the inventory problem with variable lead time, crashing cost and price-quantity discount In previous researches of inventory problem, storage space and batch size were not often considered even though they are important issues that should not be ignored. Kanyalkar and Adil (2005) and Mandal et al. (2006) constructed inventory models with the consideration of constrained storage space. Jeph Abara applied Integer Linear Programming to the Fleet Assignment Problem Christian H. Timpe, Josef Kallrath applied a mixed integer-programming model that was successfully implemented in BASF.

.Problem identification

The firm XYZ Steels is a small scale firm involved in the manufacturing of three types of tiffins, each having three variants. On a whole the firm manufactures nine types of tiffins. One of the major problems identified is that the firm manufactures tiffins according to the orders placed by the distributors and not on the basis of optimal production technique through which they can push there excess products into the new markets and finally grow bigger and in case of deficiency can invest more to grow. Therefore they are not able to compete with other brands available. Also as these products are not purchased on every day basis so it could be concluded that tiffin industry has reached to a level which comprise mainly of replacement sale and few new sales mainly seasonal which act as another hurdle in their way. The main aim of the company is to grab maximum market share with little investment.

Methodology adopted

- **Data collection**-The method adopted for data collection was personal interviewing. The collected data is shown in appendix as table no1 and table no 2.
- **Data analysis**-For the purpose of analysis of data linear programming model was the best suited to the current situation. Linear programming is a powerful problem solving tool that aids management in making decisions about how to allocate its resources to various activities to best meet organizational objectives. It uses a mathematical model to represent the problem being studied. LP is mathematical technique for optimum allocation of scarce or limited resources such as labour,

material, etc, to several competing activities like products, services, etc. Once the problem is identified then next step is to formulate the problem. Formulation of problem involves many steps which are:

○ **Determining decision variables:** The activity value represents the extent to which each activity is performed. These activities are also known as decision variables. Here the firm manufactures three types of tiffins –full tiffin, baby tiffin and box tiffin. Each type of tiffin has three variants so there are nine decision variables. They are represented as x_1, x_2, \dots, x_n . All decision variables are continuous, controllable and non-negative.

○ **Framing of objective function:** The objective function of each LP problem is a mathematical representation of the objective in terms of measurable quantity such as profit, cost, revenue, etc. it can be in two forms either profit maximization or cost minimization. Here the firm's objective is to maximize profit. So the objective function is

$$\text{Optimize (maximize) } Z = c_1x_1 + c_2x_2 + \dots + c_nx_n$$

Here c_j 's are coefficients of decision variable x_j representing the per unit contribution to the value of objective function.

○ **Framing of constraints pertaining to objective function:** There are always certain limitations on the use of limited resources, eg. Labour, machine, raw material, money, etc. Such constraints are expressed as linear equalities or inequalities in terms of decision variables. The solution of LP must satisfy these constraints.

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n (\leq, =, \geq) b_1$$

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n (\leq, =, \geq) b_m$$

Here x_{ij} represents the amount of resources consumed per unit of variable x_j and b_i represent the total availability of the i th resource.

○ **Non-negativity condition:** All decision variables must be greater than zero so they should satisfy non-negativity condition.

Decision Variables

X_i is the the no of tiffins manufactured of each type

X_1 = no of full tiffin having 2 boxes

X_2 = no of full tiffin having 3 boxes

X_3 = no of full tiffin having 4 boxes

X_4 = no of box tiffin of 3 inch

X_5 = no of box tiffin of 4 inch

X_6 = no of box tiffin of 5 inch

X_7 = no of baby tiffin having 2 boxes

X_8 = no of baby tiffin having 3 boxes

X_9 = no of baby tiffin having 4 boxes

- (1) Represents the objective function of Maximizing Profit
- (2) Represents Total available quantity of frames (in kg) per week
- (3) Represents Total available quantity of boxes (in kg) per week
- (4) Represents Total available quantity of accessories (in kg) per week
- (5) Represents Total available labour hours per week
- (6) ,(7)...(13),(14) Represents Maximum Production capacity of each tiffin per week (15), (16)...(22),(23) Represents Minimum Production of each tiffin per week

Mathematical Model

$$\text{Maximize } Z = 5x_1 + 5.56x_2 + 7x_3 + 0.5x_4 + 0.7x_5 + 0.75x_6 + 0.8x_7 + x_8 + 1.33x_9$$

(1)

Subject to constraints

$$0.17x_1 + 0.2x_2 + 0.23x_3 \leq 450$$

(2)

$$0.3x_1 + 0.42x_2 + 0.55x_3 + 0.04x_4 + 0.055x_5 + 0.065x_6 + 0.06x_7 + 0.09x_8 + 0.12x_9 \leq 2910$$

(3)

$$0.03x_1 + 0.03x_2 + 0.03x_3 + 0.01x_7 + 0.012x_8 + 0.014x_9 \leq 210$$

(4)

$$0.18x_1 + 0.18x_2 + 0.18x_3 + 0.027x_4 + 0.027x_5 + 0.027x_6 + 0.038x_7 + 0.038x_8 + 0.038x_9 \leq 1340$$

(5)

$$x_1 \leq 900$$

(6)

$$x_2 \leq 900$$

(7)

$$X_3 \leq 700$$

(8)

$$X_4 \leq 8500$$

(9)

$$X_5 \leq 6500$$

(10)

$$X_6 \leq 5500$$

(11)

$$X_7 \leq 5000$$

(12)

$$X_8 \leq 4500$$

(13)

$$X_9 \leq 3800$$

(14)

$$X_1 \geq 750$$

(15)

$$X_2 \geq 750$$

(16)

$$X_3 \geq 600$$

(17)

$$X_4 \geq 7200$$

(18)

$$X_5 \geq 5700$$

(19)

$$X_6 \geq 4200$$

(20)

$$X_7 \geq 4200$$

(21)

$$X_8 \geq 3800$$

(22)

$$X_9 \geq 2900$$

(23)

Non-negativity condition

All X_i 's ≥ 0

Now whole problem is solved using QM for Windows software. Then Sensitivity analysis is done. Sensitivity analysis is a technique that evaluates the relationship between the optimal solution and changes in LP model parameters. It provides the sensitive ranges within which the LP model parameters can vary without changing the optimality of the current optimal solution. The process of studying the sensitivity of optimal solution of an LP problem is also called post optimality analysis as it is done after an optimal solution.

Result

Using Linear programming model problem is framed and it is solved using QM for Windows. The solution obtained is depicted in table no 3. It represents the no. of tiffins of each type manufactured per week with current resource restrictions and the maximum profit earned per week with available resources. Sensitivity analysis is also done to record the change in profit level. Table no 4 shows the change in profit level with change in labour hours all with other resources constant. And it is graphically depicted in Fig 1. Increase in labour hours increases profit. Table no 5 shows the change in profit level with change in quantity of frames with all other resources kept constant and it is graphically depicted in Fig 2. Increase in quantity of frames increases profit. Table no 6 shows the change in profit level with change in quantity of boxes with all other resources kept constant and it is graphically depicted in Fig 3. Increase in quantity of boxes increases profit. Table no 7 shows the change in profit level with change in quantity of accessories and it is graphically depicted in Fig 4. Increase in quantity of accessories does not effect profit level.

Table no 3: Optimal solution with available resources

Decision Variable(Types of Tiffens) X_i	Values of Variables(No. of Tiffens)
X_1	837
X_2	750
X_3	685
X_4	7200
X_5	6469
X_6	4200
X_7	4200
X_8	3800
X_9	3800
Optimum Profit (Z)	Rs. 36647

Table no 4: Total profit level with different labour hours

Labour Hours	Profit
1320	36192.0
1330	36470.0
1340	36647.0
1350	36746.0
1360	36817.0

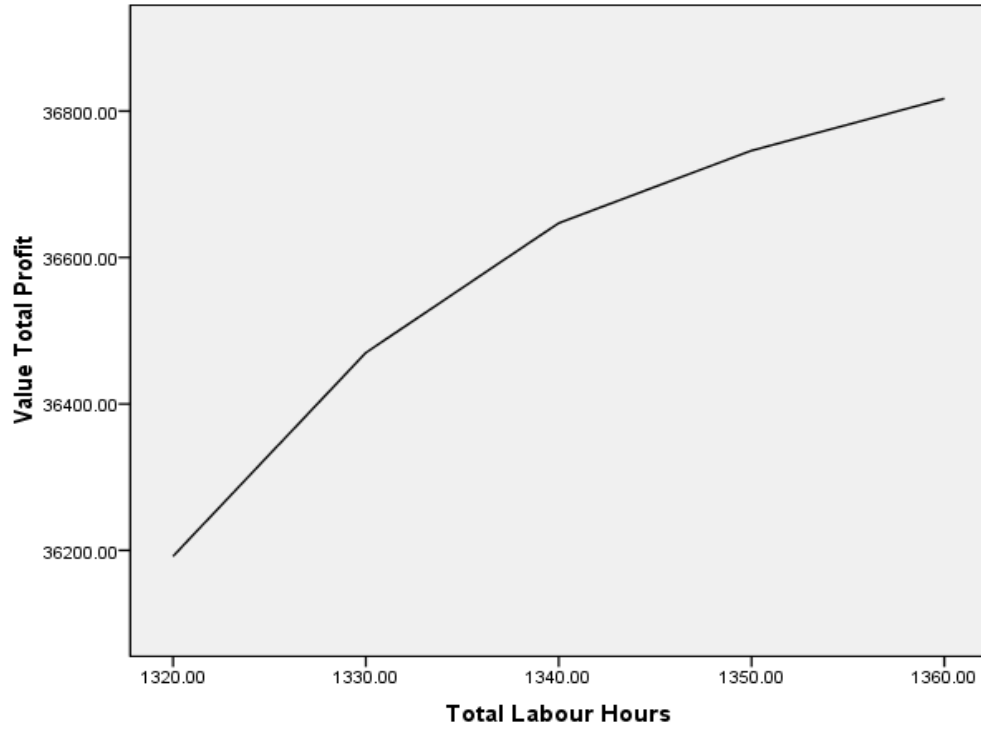


Fig 1: Depicting sensitivity analysis of Labour Hours and its effect on total profit.

Table no 5: Total profit level with different quantity of frames

Quantity of Frames(in Kg)	Profit
430	36542.0
440	36595.0
450	36647.0
460	36694.0
470	36728.0

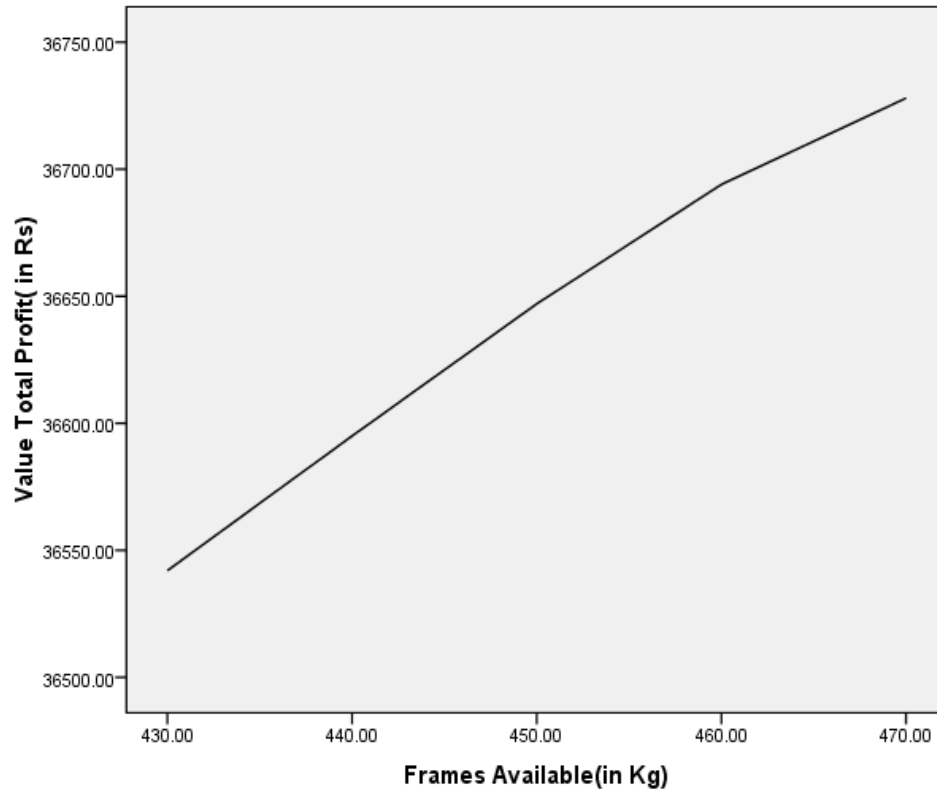


Fig 2: Depicting sensitivity analysis of quantity of frames available and its effect on total profit

Table no 6: Total profit with different quantity of boxes

Quantity of boxes(in kg)	Profit
2890	36498.0
2900	36578.0
2910	36647.0
2920	36705.0
2930	36746.0

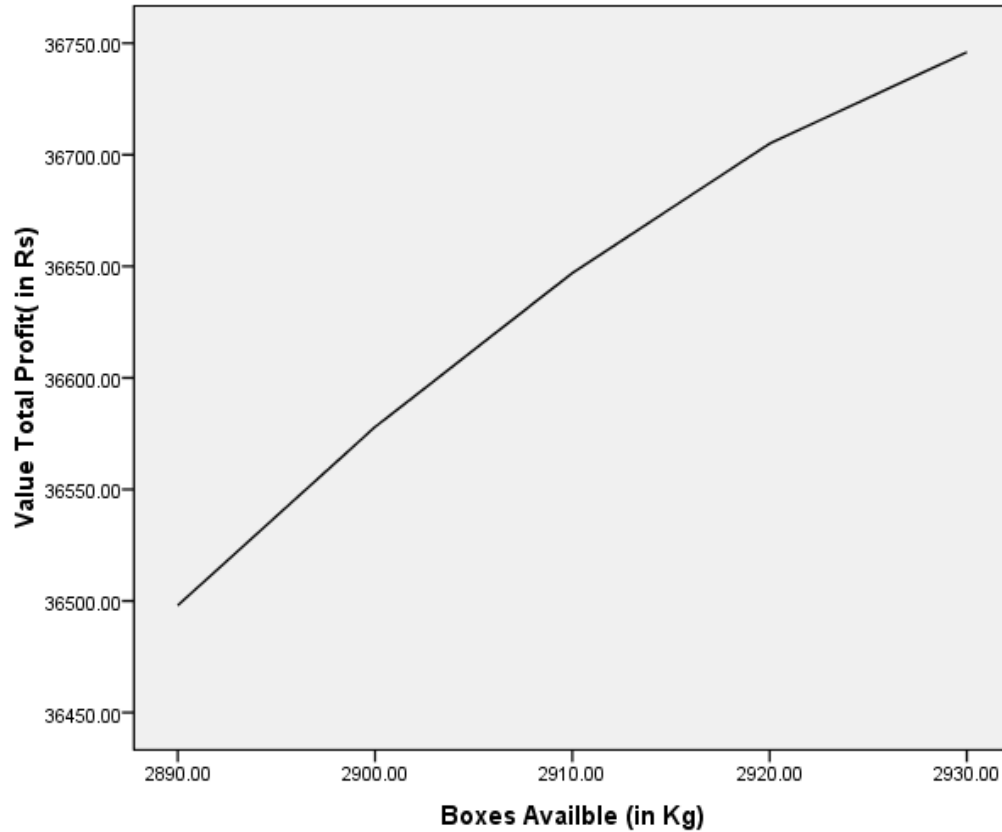


Fig 3: Depicting sensitivity analysis of quantity of boxes available and its effect on total profit.

Table no 7: Total profit with different quantity of accessories

Quantity of Accessories(in Kg)	Profit
190	36647.0
200	36647.0
210	36647.0
220	36647.0
230	36647.0

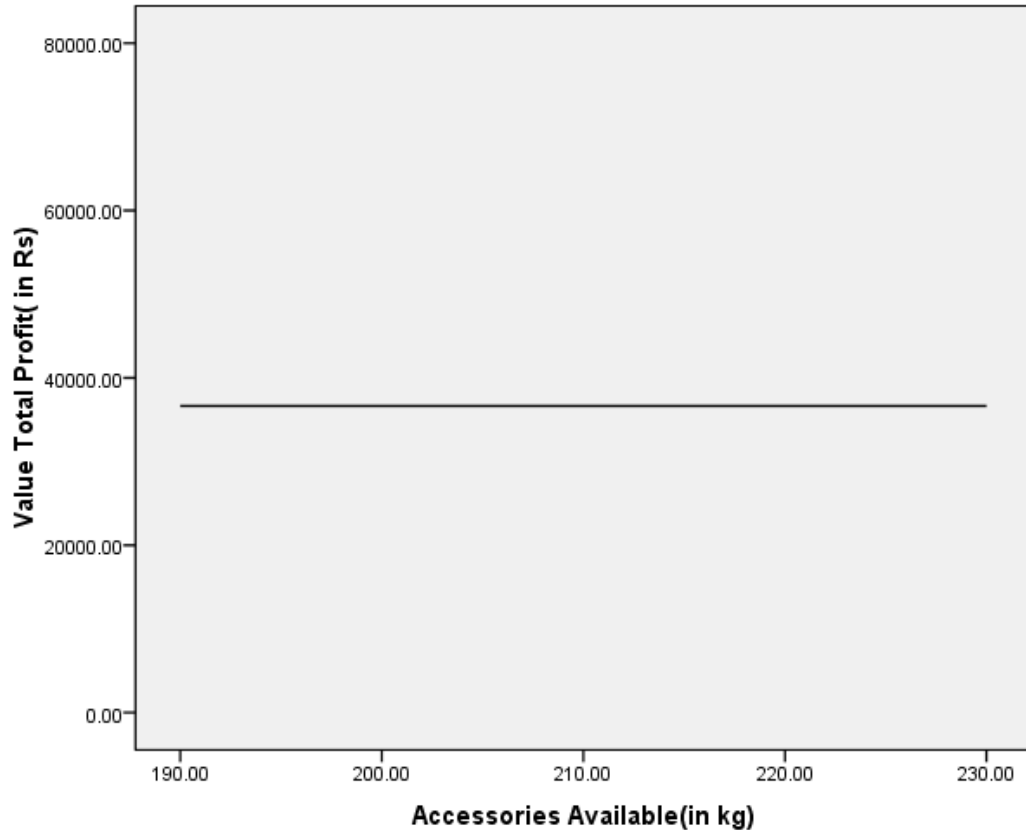


Fig 4: Depicting sensitivity analysis of quantity of accessories available and its effect on total profit

Proposed solutions

By using LP model and sensitivity analysis we have obtained the optimum profit value under the current available resources. But to use the firms full capacity some changes in the labour hours and raw material are proposed as under.

- Quantity of frames available per week should be increased from 450 kg to 494 kg.
- Quantity of boxes available per week should be increased from 2910 kg to 3250 kg.
- Quantity of accessories available per week should be increased from 210 kg to 232 kg.
- Amount of labour hours available per week should be increased from 1340 hrs to 1510 hrs.

The above changes if incorporated would increase total profit by Rs 2032 per week.

Table no 8: Comparison of current and proposed solution

Resources	Current values	Proposed valued
Frames (in kg)	450	494
Boxes (in kg)	2910	3250
Accessories(in kg)	210	232
Labour hours(in hrs)	1340	1510
Profit(in Rs)	36647	38679

Looking at the present situation of the firm and its future investment plans AMT and FMS designs are suggested to the management of the firm. AMT refers to computer aided technologies in design, manufacturing, transportation and testing. Some industrialists and economists (Stainer et al,1996) believe that AMT has great potential to offer manufacturing companies, with many tangible and intangible benefits. In the survey of current research and the applications of existing investment appraisal techniques, this paper attempts to provide an overview and guidance for manufacturing companies which are planning to invest AMT.

Some advantages of using AMT

- Reduced number of labor
- Improved product quality
- Increased product/ process flexibility
- Enhanced time efficiency
- Shortened time to market
- Some weak-points of using AMT
- High level of investments
- Payback period is long
- Lack of experience with AMT implementation
- Investment may result in increased cost of manufacturing

Flexible manufacturing systems (FMS) are automated, integrated systems of equipment and information flow, arranged for the economic production of small batches of complex components Flexible manufacturing systems(FMS) design is a complex problem which is concerned with the selection from a wide variety of available system configurations and control strategy alternatives in the light of several criteria (costs, production, flexibility etc.), many of which are difficult to quantify . The FMS concept has the following advantages:

- Reduced lead-time and increased throughput;
- Indirect labour reduction
- Increases in machine utilization
- Work in process inventory reduction
- Good balance of production and flexibility

Conclusion

Linear programming helps in attaining the optimum use of productive resources. It also indicates how a decision maker can employ his productive factors effectively by selecting and distributing (allocating) these resources. It also improves the quality of decisions as depicted in the above case of tiffin manufacturing firm. With the use of LP model we got the number of tiffins of each variant which the firm should manufacture in order to have maximum profit with the available resource restrictions. Sensitivity analysis is a tool to identify the effect of variation of resources on the overall objective of the firm whether it is profit maximization or cost minimization.

By doing sensitivity analysis of above problem we came to a conclusion that by increasing labour hours, quantity of frames, quantity of boxes we can increase the profit but increase in quantity of accessories does not effect the profit level.

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Appendix

Table no 1: Data collected via personal interviewing

	X1		X2		X3		X4		X5		X6	
	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit
Frames	0.17	17	0.2	20	0.23	23						
Boxes	0.3	33.6	0.42	47.04	0.55	61.6	0.04	4	0.055	5.5	0.065	6.5
Accessories	0.03	3.9	0.03	3.9	0.03	3.9						
Labour hrs	0.18	4.5	0.18	4.5	0.18	4.5	0.027	0.67	0.027	0.67	0.027	0.67
Overhead		10		10		10		2.33		2.33		2.33
Total cost per unit		69		85.44		105		7		9		10.5
Selli Selling Price		74		91		112		7.5		9.7		11.25
ProfiProfit		5		5.56		7		0.5		0.7		0.75
	X7		X8		X9							
	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit	Quantity per unit	Cost per unit						
	0.06	6	0.09	9	0.12	12						
	0.01	1.3	0.012	1.56	.014	1.82						
	0.038	1.3	0.038	1.3	0.038	1.3						
		2.75		2.75		2.75						
		11		15		19						
		11.8		16		20.33						

Table no 2: Current resources available with respective unit costs

Resources	Total available	Cost
Labour hours	1340 hrs	Rs 25 per hr
Quantity of Frames (in kg)	450 kg	Rs 100 per kg
Quantity of Boxes (in kg)	2910 kg	Rs 112 per kg
Quantity of accessories(in kg)	210 kg	Rs 130 per kg