Leverage of Advanced Manufacturing Effectiveness: A Case of Apparel Industry

G. Asghar[1], M. Jahanzaib[2], M. Noman[3]

[1,2,3]*Industrial Engineering Department, University of Engineering and Technology Taxila, Pakistan*
[2]jahan.zaib@uettaxila.edu.pk

Abstract-This study is about the effectiveness of latest technology flexible machines in apparel manufacturing. Techniques to justify the advanced manufacturing systems, break-even and sensitivity analysis have been developed to analyze the significance between the conventional as well as the latest flexible machines. Payback Period (PP) and Return on Investment (ROI) are renowned methods to validate the investments. These terms are calculated for both conventional model machines and for latest model. The comparison is made between them. The production rate and annual profit of each model has been calculated and compared. The break-even analysis showed that the profit margin is increased by using the latest flexible machines while producing the same quantity as with the conventional machines. It is analyzed that the break-even is achieved earlier by using latest flexible machines as compared to the conventional ones. The sensitivity analysis verified the outcomes of break-even analysis. It has been learned that the advanced manufacturing improves the performance of the system and is justified in the manufacturing environment.

Keywords-Advanced Manufacturing, Break-Even, Payback Period, Return on Investment, Sensitivity Analysis.

I. INTRODUCTION

This work is a specific study of apparel manufacturing which has been taken for the analysis of advanced manufacturing effectiveness of latest technology. It consists of comparison of conventional machines versus the latest flexible machines in terms of productivity and the financial benefits gained by companies. This comparison is only in terms of financial benefits; it does not cover the strategic & other benefits gained by the firms adopting the latest technology flexible machines/equipments. A leading apparel manufacturing company was having a unit of 220 conventional machines of model GL714 previously. It has recently established a new unit of 220 machines of latest model GL546. This case study would evaluate the benefits gained by the company in monetary terms. First, the conventional financial figures are calculated for each of the models separately, and then the comparison is made between these figures of two models. It is also analyzed with the help of break-even analysis that how much profit could be earned by the company against the specified production quantities. The sensitivity analysis has been carried out to verify the recommendations of break-even analysis.

II. LITERATURE REVIEW

Methods have been developed for justifying investment in advanced manufacturing systems. It is discussed [i] that the adoption of advanced manufacturing technology (AMT) involves major investment and a high degree of uncertainty and, hence, warrants considerable attention within a manufacturing firm at the strategic level. Researchers [i-iii] reported that justification of investments in advanced manufacturing systems can be grouped into three categories; (i) The economic approach involving the classical financial justification techniques of Payback Period (PP), Return on Investment (ROI), Internal Rate of Return (IRR), and Net Present Value (NPV); (ii) The strategic approach involving analysis of competitive advantage, business objectives, research and development objectives and technical importance; (iii) The analytic approach involving value analysis, portfolio analysis and Risk Analysis (RA).

These methods vary significantly from each other due to non-monetary factors [iv]. Economic justification methods of manufacturing investments are discussed [v]. The authors [vi] stated that the economic justification of advanced technology has been a very popular approach and they also reported that the cost/benefit analysis is also utilized for AMT project appraisals. These attempts aim to improve a firm's ability to account for costs and benefits. It is reported [vii] that the Payback period (PP) technique was the most popular method of AMT appraisal in his study of the machine tool industry. He also investigated that Return on Investment (ROI) was the second most popular technique being used for AMT appraisal.

They [viii] found that PP techniques continue to be popular in the USA, the UK and the Czech Republic. As the payback methods are generally effective for short-term perspective on investments, which can be dangerous for AMT projects. It would be quite interesting to note that the Japanese [ix] also use the payback method most frequently; it serves more as a performance measurement tool than as a rigid financial criterion. However, it is suggested [x] that this method has more disadvantages than the payback method because it does not measure the economic value of the project.

It is analyzed [x-xi] that the firms where the level of risk and uncertainty make up the most critical elements of the justification process, it is observed that risk sensitivity analysis is the most appropriate evaluation technique. They [xii] investigated that in comparing conventional projects for installation of robots, the flexibility and reprogram ability of the robot merits a lower hurdle rate. Works cited by the authors [xiii-xiv] have identified several barriers that may encounter manufacturing companies to adopt AMT successfully. Researchers [xv] investigated machine rates and prioritized different process parameters for developing technology driven manufacturing strategy. Authors [xvi] discussed the financial and accounting methods used by the managers for decision making as well as for the justification of AMT. Studies conducted by researchers [xvii] in Czech Republic revealed the problems associated with adoption of AMT from the management point of view. It is reported [xviii] that Analytical Hierarchical Process (AHP) is very effective in multi-criterion decision making for the selection and evaluation of AMT. The steady conducted by [xix] assessed the critical factors which influence the adoption of AMT in small and medium-sized enterprises (SMEs). Researchers [xx] found that Flexible Manufacturing System (FMS) has the greatest impact on producer's value due to its high effects on quality and cost while Just-in-Time is found to be the most successfully employed AMT. A number of studies also advocated by the authors [xxi] that a collaborative approach of Concurrent Engineering (CE) product delivery approach is better suited than the conventional Product Delivery Process (PDP) and this approach is valid and successfully implemented in manufacturing organizations for the delivery of products at lower cost. A significant work has been carried out by the researchers [xxii] in prioritizing the different activities of a business environment according to the manufacturing strategy adopted by the manufacturing firm.

The mathematical relationships have been developed using well established techniques and the parameters of interested are defined in section III and numerical values have been calculated. Model is presented in next section followed by methodology and coherently scenarios with results and recommendations.

III. System Model

A. Abbreviations and Acronyms

The following abbreviations have been used;

T_a = Available Time or Number of machine hours available per day at 85% efficiency
T_o = Time required for making one piece
N = Number of units (pieces)produced per day
N_p = Number of pairs produced per day
$N_{d/d}$ = Number of dozens produced per day
R_p = Hourly Production rate of complete unit
TM = Total number of machines (220 machines)
NM = No. of machines operated by one operator(8 m/c)
M = Number of operators needed
M_t = No. of operators needed for three shifts
$R_{p/m}$ = Production rate of each Machine
$R_{p/mnth}$ = Monthly production rate
$R_{p/annl}$ = Annual production rate
S_p = Unit Sale Price
S_{mnth} = Monthly sales (revenue)
S_{annl} = Annual sales (revenue)
LC_m = Total salary paid per month
LC_d = Labor cost per dozen
VC = Variable Cost per Unit
VC_d = Variable cost per dozen
VC_{annl} = Annual variable cost
FC = Fixed Cost
TC_{annl} = Total Annual Cost
P_{annl} = Annual Profit
ROI_{annl} = Annual Return on Investment

B. Mathematical Relationships

Number of dozens produced per day would be;

$$N_{d/d} = \frac{T_a}{24T_o} \qquad (1)$$

And the hourly production rate of the complete unit of 220 machines would be;

$$R_p = \frac{T_a}{576T_o} \qquad (2)$$

Number of operators needed for three shifts are;

$$M_t = \frac{TM}{NM} \times 3 \times 1.30 \qquad (3)$$

In the above equation 1.30 is multiplied because 30% extra work force is needed to compensate the leaves and absenteeism.

Production Rate of each Machine could be;

$$R_{p/m} = \frac{T_a}{576 \times 220T_o} \qquad (4)$$

Monthly production rate of the complete unit (220 m/c) would be;

$$R_{p/mnth} = \frac{T_a}{576T_o} \times 24 \times 30 \qquad (5)$$

It is to be noted here that 24 and 30 denote the 24 hours per day and 30 days in a month.

Annual production rate of the complete unit (220 m/c) would be;

$$R_{p/annl} = \frac{T_a}{576T_o} \times 24 \times 30 \times 12 \quad (6)$$

In the above equation 12 shows the number of months in a year.

Monthly sales (revenue) generated would be;

$$S_{mnth} = \frac{T_a}{576T_o} \times 24 \times 30 \times S_p \quad (7)$$

Annual sales (revenue) generated would be;

$$S_{annl} = \frac{T_a}{576T_o} \times 24 \times 30 \times 12 \times S_p \quad (8)$$

The labor cost in terms of salary paid to the worker would be;

$$LC_d = \frac{LC_m}{\frac{T_a}{576T_o} \times 24 \times 30} \quad (9)$$

The variable cost of one dozen would be;

$$VC_d = VC + LC_d \quad (10)$$

Annual variable cost will be;

$$VC_{annl} = VC + 12LC_m \quad (11)$$

Total annual Cost will be;

$$TC_{annl} = FC + VC + 12LC_m \quad (12)$$

Annual profit will be;

$$P_{annl} = S_{annl} - (FC + VC + 12LC_m) \quad (13)$$

Annual return on investment (ROI) will be;

$$ROI_{annl} = \frac{P_{annl}}{TC_{annl}} \quad (14)$$

Payback period (PBP) could be;

$$PBP = \frac{\text{Break even Quantity}}{N_{d/d}} \quad (15)$$

IV. Research Methodology

This study focuses on the determination of break-even point and sensitivity analysis, for the specified units of conventional and latest flexible knitting machines of apparel manufacturing. Leading apparel manufacturing company has installed a new unit of 220 knitting machines of latest model GL546. Previously, it had also another unit of 220 knitting machines of model GL714. The management has taken this step due to the increasing orders /demand of fashion articles by the customers. Conduct the financial analysis and benefits gained by the company. Scrap rate is 5% and the production efficiency is 85%. There are three main types of socks (i) Crew Socks, (ii) Quarter Socks and (iii) No Show/Low Cut/Ankle Socks. The conventional knitting machines are of Model GL714. The word G stands for Goal and L for Lonati, 7 means 3.5 inch cylinder diameter, 1 means single feed machine and 4 means four colors feeds. Therefore the maximum possible variation of colors is up to five colors. The latest knitting machines are of model GL546. The digit 5 means 4 inch cylinder diameter, 4 means four main feeds and 6 means six colors feeds. So, the possible variation of colors is up to ten colors in the product. There are two scenarios under study which have been discussed.

Scenario I for Model GL714

The price of single feed knitting machine of Model GL714 equals \$ 20,370, with total price of 220 machines equals \$4.4814million and the fixed by adding the installation and basic infrastructure cost like building, land etc. would be equals \$5.0 million. The variable cost (including materials means yarn, energy consumption, processing materials, finishing and packing costs & all other miscellaneous) equals \$ 8/dzn. The average sales price of one dozen socks of plain/ non fashion article equals \$ 20/dzn. The cycle time for crew, quarter and low cut socks are 166 sec/piece, 156 sec/piece, and 148 sec/piece respectively. The average cycle time is 156.67 sec/piece or 2.61 minutes/piece. There are 3 shifts and 8 hours per shift and machines are operated round the clock means 24 hours. Therefore number of machine hours equals 5,280 hours and at 85% efficiency 4488 hours.

The production rate of 220 machines is 178.67 dozens/hour. But as we know that the scrap rate is 5%, so the good quality production rate is 170.16 dozens/hour. One operator operates 8 machines so 28 operators would be required for one shift. As 30% extra work force is maintained to manage the rests and absenteeism of the operators. So to operate one shift the operators needed would be 37 operators and for three shifts 110 operators would be enough. These 110 operators also include the helpers, which feed the yarn to the machines and change the cones when required. These helpers which feed the yarn to the machines are called bobbin keepers. In-spite of the above mentioned workforce, there would be 21 technicians required to keep up the maintenance of the machines and also to rectify the malfunctioning of the machines and to minimize the break-downs. These 21 technical members team consists of 5 line in-charges and 15 shifts mechanics and one head of this technical staff. Production rate of each machine equals 0.7735 dzns/hr/m/c. Monthly production rate of the complete unit (220 m/c) is equals 122,517.30 dzns/month. Annual production rate equals 1,470,207.6 dzns / yr.

Monthly and yearly sales (revenue) generated are \$2.45 million and \$29.404 million respectively. The total salary paid to the workers of a complete unit equals \$14,445/month. Therefore the labor cost per dozen would be \$0.1179 and the variable cost per dozen would become \$8.1179. The annual variable cost is \$11.935 million/year and the total annual cost (by adding the fixed and variable) equals \$16.934998 million/year. The annual profit (which is the difference of annual sales and total annual cost) is equals \$12.469153 million/year. Annual return on investment (ROI) would be 73.63%.

TABLE I
CALCULATION OF COSTS AND SALES AGAINST DIFFERENT QUANTITIES FOR MODEL GL714

Quantity (Q) (1000)	Fixed Cost ($)	Variable Cost ($)	Total Cost ($)	Sales ($)
50	5,000,000	405,895	5,405,895	1,000,000
100	5,000,000	811,790	5,811,790	2,000,000
150	5,000,000	1,217,685	6,217,685	3,000,000
200	5,000,000	1,623,580	6,623,580	4,000,000
250	5,000,000	2,029,475	7,029,475	5,000,000
300	5,000,000	2,435,370	7,435,370	6,000,000
350	5,000,000	2,841,265	7,841,265	7,000,000
400	5,000,000	3,247,160	8,247,160	8,000,000
450	5,000,000	3,653,055	8,653,055	9,000,000
500	5,000,000	4,058,950	9,058,950	10,000,000
550	5,000,000	4,464,845	9,464,845	11,000,000
600	5,000,000	4,870,740	9,870,740	12,000,000

In Table I different quantities in thousands have been taken and the variable cost, total cost and the sales against these quantities are calculated. It is noted that the fixed cost would be same for all the quantities.

Break Even Analysis Model GL714

According to the values calculated in Table I, the break-even point is plotted below as;

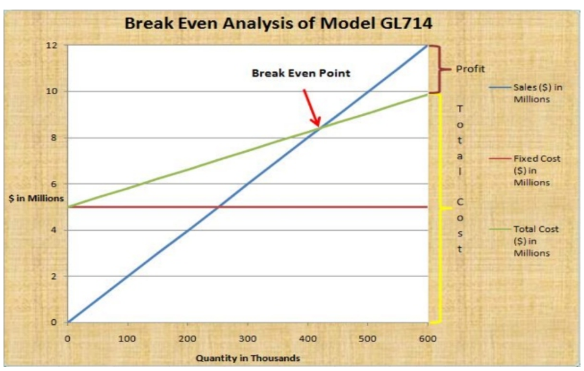

Fig. 1. Break Even Analysis of Model GL714

As the above given Fig.1 shows that the break-even point is achieved at 420,000 dozen in terms of manufacturing quantity or 8.40 million dollars in monetary terms. Using either of these above figures, the payback period is calculated according to equation (18), which is 103 days for the conventional model machines of GL714.

Scenario II for Model GL546

The price of four feed knitting machine of Model GL546 equals $ 23,150, with total price of 220 machines equals $5.093 million and the fixed by adding the installation and basic infrastructure cost like building, land etc. would be equals $5.6116 million. The variable cost (including materials means yarn, energy consumption, processing materials, finishing and packing costs and all other miscellaneous) equals $10/dzn. The average sales price of one dozen socks of fashion socks (Article) equals $28/dzn. The cycle time for crew, quarter and low cut socks are 90 sec/piece, 82 sec/piece, and 76 sec/piece respectively. So the average cycle time is 82.67 sec/piece or 1.38 minutes/piece. There are three shifts and 8 hours per shift and machines are operated round the clock means 24 hours. Therefore number of machine hours equals 5,280 hours and at 85% efficiency 4488 hours. The production rate of 220 machines is 337.89 dozens/hour. But as we know that the scrap rate is 5%, so the good quality production rate is 321.8 dozens/hour. One operator operates 8 machines so 28 operators would be required for one shift. As 30% extra work force is maintained to manage the rests and absenteeism of the operators. To operate one shift the operators needed would be 37 operators and for three shifts 110 operators would be enough. These 110 operators also include the helpers, which feed the yarn to the machines and change the cones when required. These helpers which feed the yarn to the machines are called bobbin keepers. In-spite of the above mentioned workforce, there would be 21 technicians required to keep up the maintenance of the machines and also to rectify the malfunctioning of the machines and to minimize the break-downs. These 21 technical members team consists of five line in-charges and 15 shifts mechanics and one head of this technical staff. Production rate of each machine equals 1.463 dzns/hr/m/c. Monthly production rate of the complete unit (220 m/c) equals 231,717.30 dzns/month. Annual production rate equals 2,780,607.6 dzns / yr.

Monthly and yearly sales (revenue) generated are $6.4880844 million and $77.857012 million respectively. The total salary paid to the workers of a complete unit equals $14,445/month. Therefore the labor cost per dozen would be $0.06234 and the variable cost per dozen would become $10.06234. The annual variable cost is $27.980 million/year and the total annual cost (by adding the fixed and variable) equals $33.591019 million/year. The annual profit (which is the difference of annual sales and total annual cost) equals $44.265993 million/year. Annual return on investment (ROI) would be 131.78%.

TABLE II
CALCULATION OF COSTS & SALES AGAINST DIFFERENT QUANTITIES FOR MODEL GL546

Quantity (Q) (1000)	Fixed Cost ($)	Variable Cost ($)	Total Cost ($)	Sales ($)
50	5,611,600	503,117	6,114,717	1,400,000
100	5,611,600	1,006,234	6,617,834	2,800,000
150	5,611,600	1,509,351	7,120,951	4,200,000
200	5,611,600	2,012,468	7,624,068	5,600,000
250	5,611,600	2,515,585	8,127,185	7,000,000
300	5,611,600	3,018,702	8,630,302	8,400,000
350	5,611,600	3,521,819	9,133,419	9,800,000
400	5,611,600	4,024,936	9,636,536	11,200,000
450	5,611,600	4,528,053	10,139,653	12,600,000
500	5,611,600	5,031,170	10,642,770	14,000,000
550	5,611,600	5,534,287	11,145,887	15,400,000
600	5,611,600	6,037,404	11,649,004	16,800,000

The above Table II shows the calculations of fixed, variable and total costs and sales against different Quantities for the latest flexible knitting machines of Model GL546.

Break Even Analysis of Model GL546

According to the values calculated in Table II, the breakeven point for latest model machines is plotted below as;

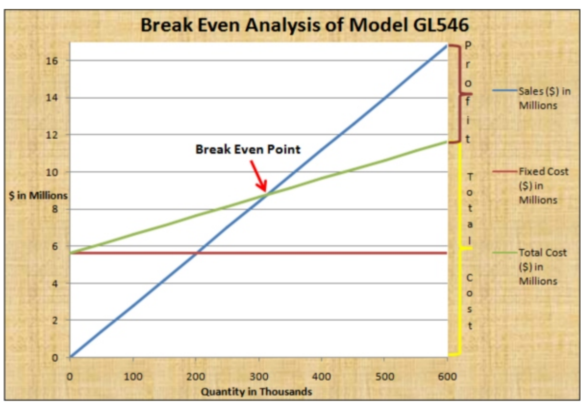

Fig. 2. Break-even Analysis of Model GL546

As the above given Fig. 2 shows that the break-even point is achieved at 313,000 dozen in terms of manufacturing quantity or 8.80 million dollars in monetary terms. Using either of these above figures, the payback period is calculated according to equation (18), which is 41 days for the latest model machines of GL546.

Comparison of Models

TABLE III
COMPARISON DIFFERENT VALUES OF BOTH MODELS

Comparison		
Value	**Model GL714**	**Model GL546**
Fixed Cost	$ 5.0 Millions	$ 5.6116 Millions
Variable Cost/year	$ 11.935 Millions	$ 27.980 Millions
Sales/year	$ 29.404 Millions	$ 77.857 Millions
Profit/year	$ 12.469 Millions	$ 44.266 Millions
Production Rate/hr	170.16 dzn/hr	321.80 dzn/hr
Production Rate/operator	6.07 dzn/hr	11.49 dzn/hr
Production Rate/machine	0.7735 dzn/hr	1.463 dzn/hr
Annual Rate of Return	73.63%	131.78%
Payback Period	103 days	41 days

In the above Table III, the comparison of both models is made, which shows that the fixed and variable is high for the latest model machines. At the same time the annual sales and profit is also very high for the latest machines. The production rate of latest model is better than the conventional machines.

Comparison of Break-evens of Models

As the comparison is made between different values of both models of conventional and latest model machines in Table III, in the same way, comparison would be made between breakeven points of both models as given below in Fig.3.

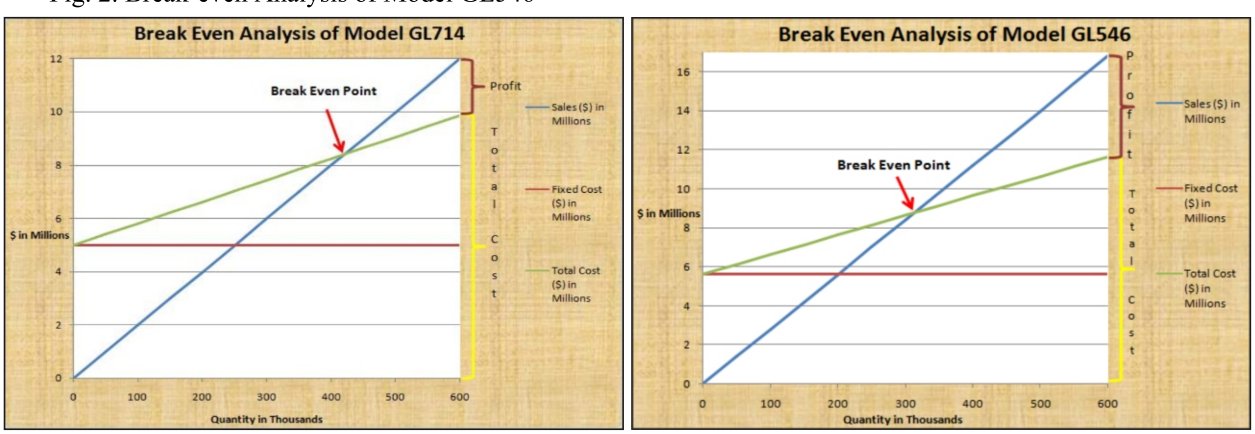

Fig. 3. Comparison of Break-evens

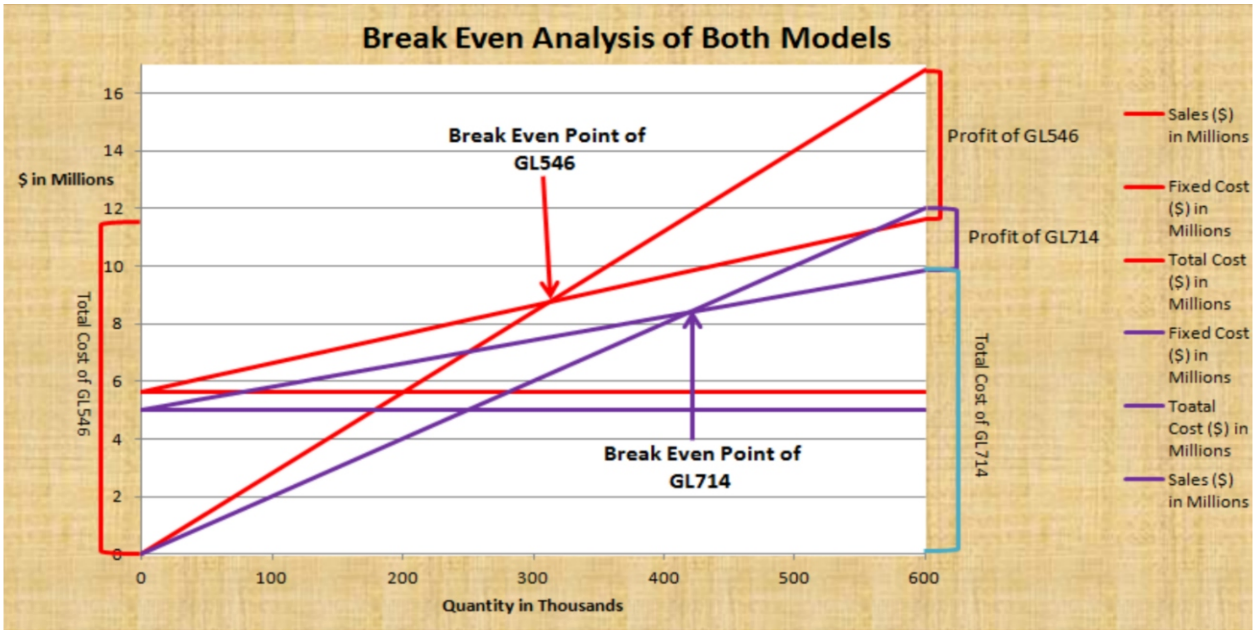

Fig. 4. Overlapped view of the Break-evens

The comparison of break-evens in Fig.3 demonstrates that for model GL714 machines, 420,000 dzns should be produced to reach at no profit and no loss situation and for model GL546 machines, only 313,000 dzns should be produced to reach at break-even point.

In Fig. 4, the red colored lines are used for the values of Model GL546 and purple colored lines are used for Model GL714. This graph shows that the break-even for Model GL546 is achieved earlier as compared to the Model GL714. It is also depicted by this graph that the profit area is much wider for Model GL546 than for the Model GL714 for the same production Quantity for both the models.

Sensitivity Analysis

The objective of sensitivity analysis is to select the better suited machine's model between two alternatives (Model GL714 and Model GL546). There are six important variables, which have direct effect on the selection of model's machines. These variables are Fixed Cost, Variable Cost, Sales/Revenue, Production Quantity, Quality and Profit. All the mentioned terms have been selected as variables because the values of these terms have been computed previously in two scenarios. The comparison has also been made between these terms. An analysis has been carried out in AHP™ to prioritize the selected variables.

Fig. 5. Prioritization of Variables w.r.t. Machine's Model Selection

There are three options in Expert Choice™ (AHP) to prioritize the selected variables. These options are pairwise numerical comparisons, pairwise verbal comparisons and pairwise graphical comparisons. The pairwise graphical comparisons method is used to prioritize the selected variables. The above Fig.5 shows the priorities with respect to the goal, which is selection of better machine's model. The top priority has been given to the profit maximization which is obviously the core objective of organization. In the same way all other variables have been prioritized.

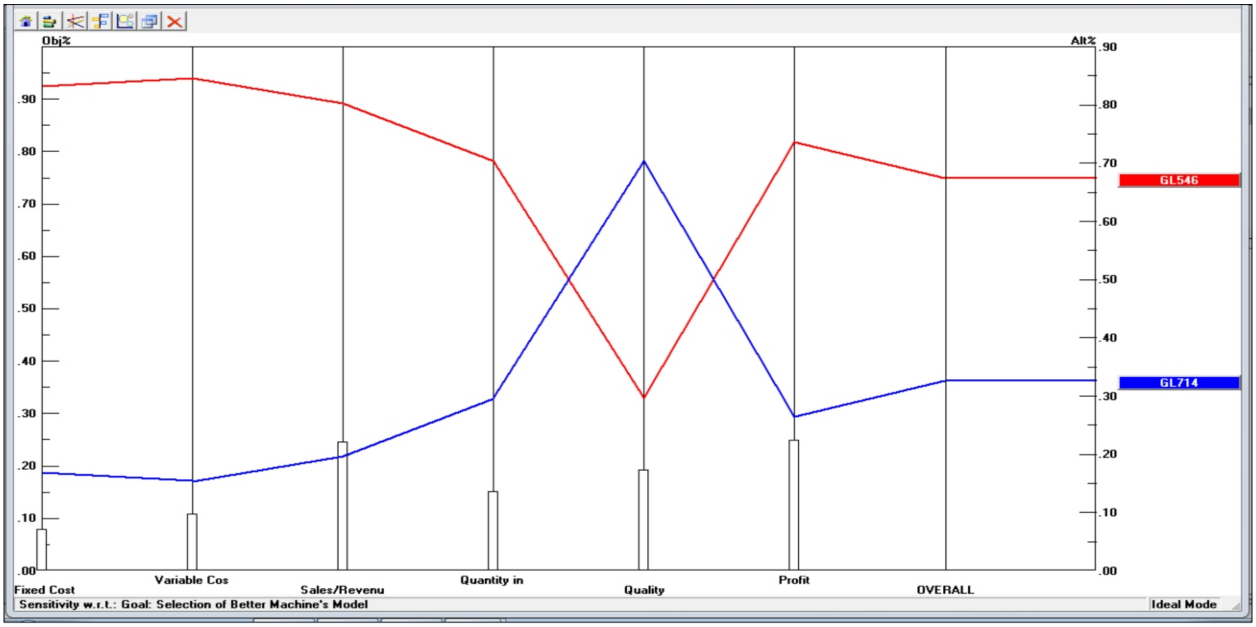

Fig. 6. Performance Sensitivity for Nodes

The above Fig. 6 of performance sensitivity for nodes shows that the model GL546 is 67% prioritized and model GL714 is given 33% priority. The weighted sensitivity analysis in Fig. 7 illustrates that all the variable will favor the selection of model GL546 machines except the quality. As demonstrated by the trends in Fig. 7, the quality has negative trend, which means that the selection of model GL546 will have inverse impact on the quality of the product.

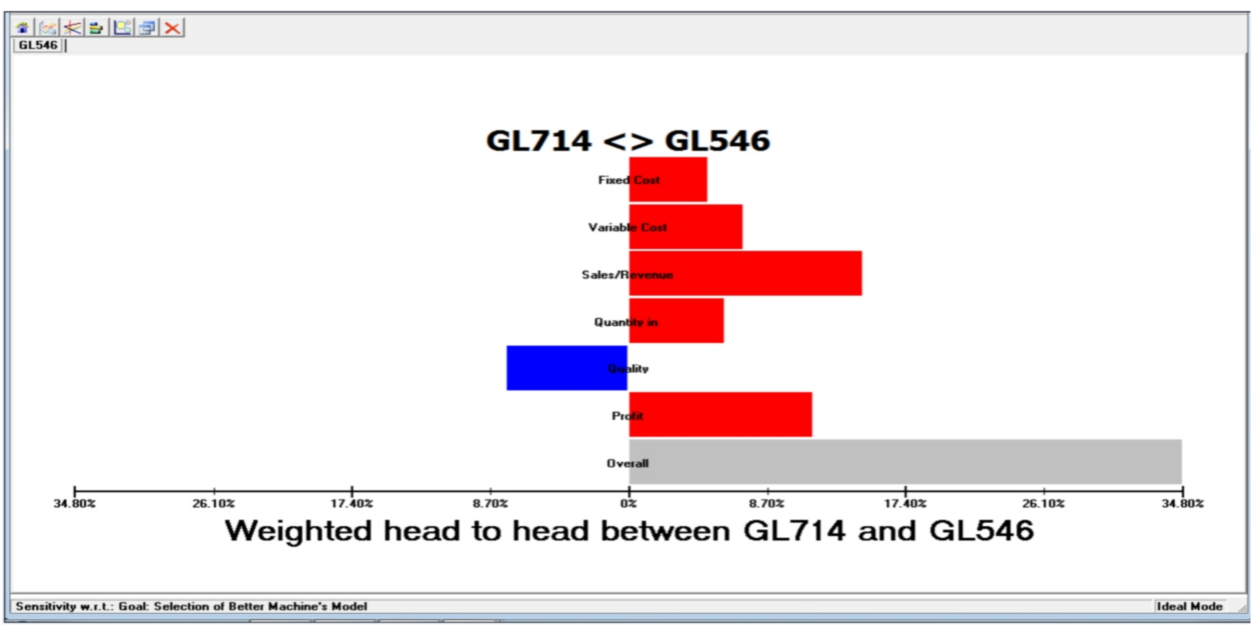

Fig. 7. Weighted Head to Head Sensitivity Analysis of Models

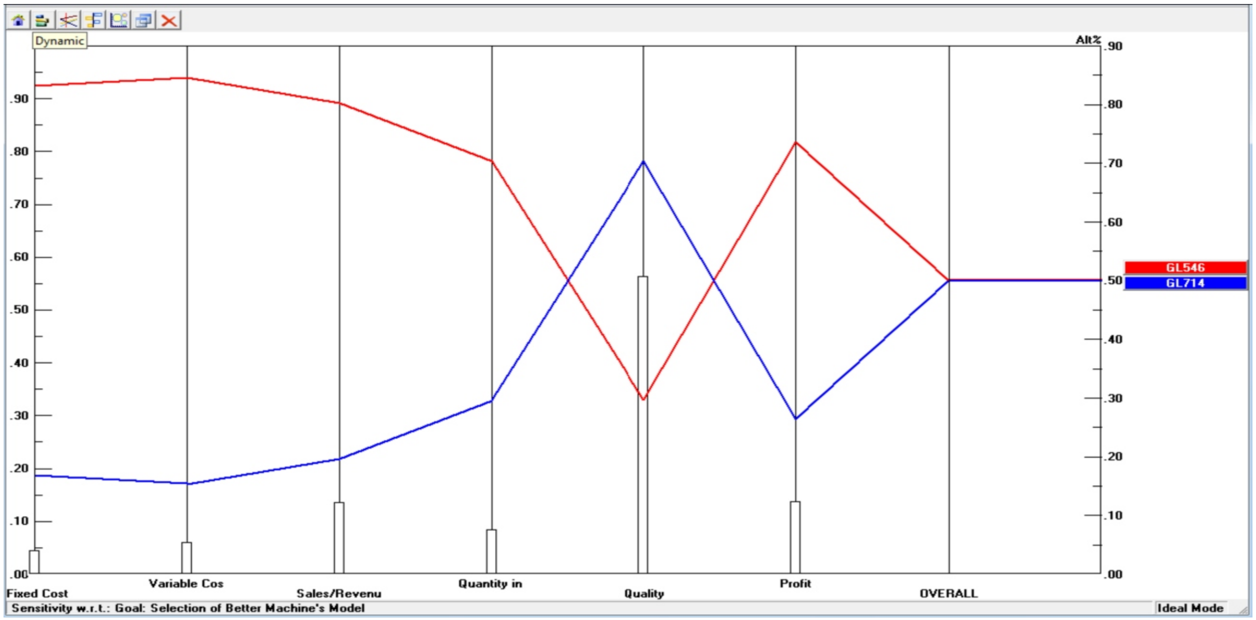

Fig. 8. Sensitivity Analysis for Quality at 58% Rating

The above Fig. 8 shows that if the quality is given 58% rating then both the models has equal chances of selection. But at 58% rating of quality the value of profit has been decreased from 24.5% to 12%. This describes that the profit margin squeezed up by rating the higher value of quality than the default value. In the same way the quality rating also has impact on the quantity and sales, which have been decreased from 14.7% and 24.2% to 8% and 14% respectively.

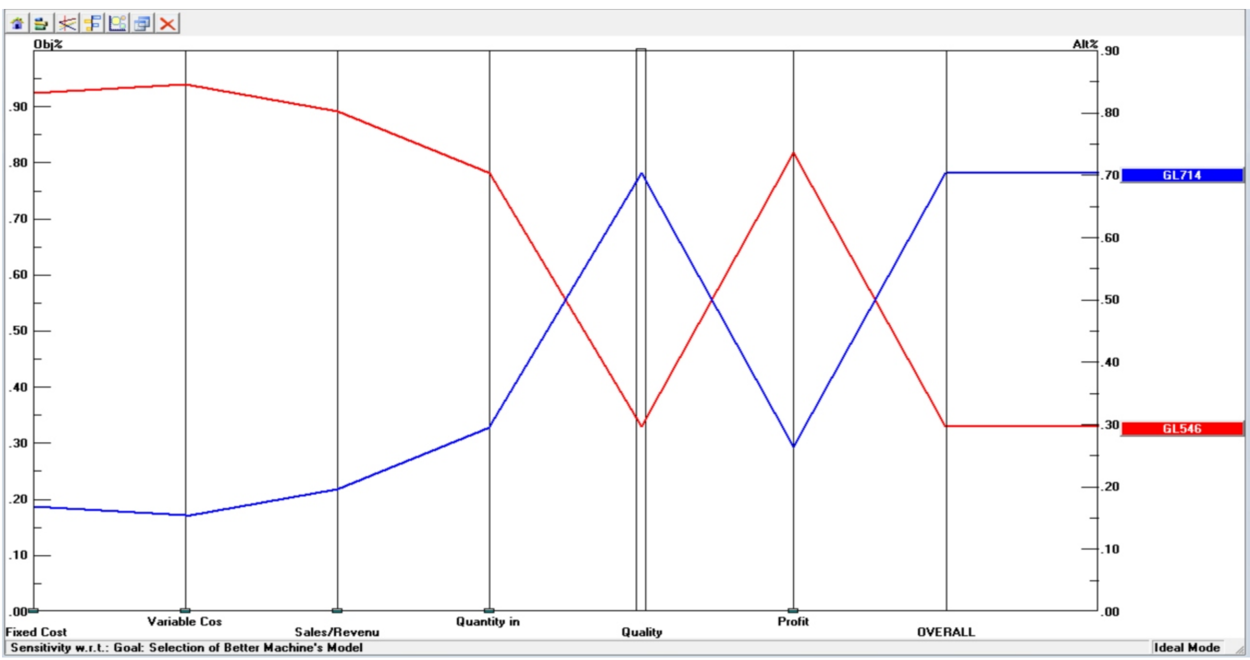

Fig. 9. Sensitivity Analysis for Quality at 100% Rating

The above Fig. 9 describes that if hundred percent rating will be given to the quality, then the suggested alternative would be totally opposite to the original decision. Then the most suitable alternative would be model GL714 machines with 71% rating and the rating of model GL546 would be only 30%. The reason for the quality to be sensitive is that as the production rate of model GL546 is very high therefore the rejection quantity would also be very high.

The quality of the product is checked and controlled by the quality control (QC) department which is a separate dedicated department to control the quality of the product at every stage and all the quality standards are followed (like ISO-9001, ISO-14001, ISO-17025, WARP, OKEOTEX-100, Fair Trade etc.). Means that the quality is not only managed through the machines but also it is managed through proper quality control department, which maintains the product quality from knitting to the packing stages. At the end, the quality assurance (QA) department again verifies the product quality before shipping to the customer. Therefore the quality would not be an issue.

V. RESULTS AND DISCUSSION

Break even for GL714 shows that the quantity of 420,000 dzn should be produced to reach at no profit and no loss situation.

Break even for GL546 shows that we have produce 313,000 dzn to reach at no profit and no loss situation.

The break even analysis also shows that if we produce 600,000 dzn by using machines of GL714, then the profit will be $ 2.130 Millions.

But if the machines of Model GL546 are used for the same quantity, then profit will be $ 5.151 Millions.

The annual profit of GL714 machines is $ 12.469 Millions and annual profit for GL546 is $ 44.266 Millions.

The payback period for Model GL714 is 103 days and the payback period for Model GL546 is 41 days.

The annual rate of return for GL714 is 73.63% and annual rate of return for GL546 is 131.71%.

There is not a significant difference in terms of fixed cost for both the models but the there is a considerable difference in variable costs between two models. Variable cost for GL714 is $ 11.935 Millions and for GL546 is $ 27.980 Millions.

There is also a lot of difference in production rates, as the production rate for GL714 is 170.16dzn/hr. and the production rate for GL546 is 321.80dzn/hr.

The sensitivity analysis of both the models also suggests that the most suited model would be GL546 of flexible machines.

VI. CONCLUSIONS

Leverage of AM has been carried out and established that it is the most beneficial for the company to use latest flexible machines for coping with the new design changes and an analysis based of financial terms recommended use of flexible machines of model GL546. Sensitivity analysis using AHP also recommended use of AM for fulfilling the demands of the customers. It is concluded that the latest/flexible machines have greater productivity; therefore this will automatically decrease the lead time to a significant extent.

REFERENCES

[i] J. R. MEREDITH and N. C. SURESH, "Justification techniques for advanced manufacturing technologies," *International Journal of Production Research,* vol. 24, pp. 1043-1057, 1986.

[ii] F. Raafat, "A comprehensive bibliography on justification of advanced manufacturing systems," *International Journal of Production Economics,* vol. 79, pp. 197-208, 2002.

[iii] M. H. Small, "Justifying investment in advanced manufacturing technology: a portfolio analysis," *Industrial Management & Data Systems,* vol. 106, pp. 485-508, 2006.

[iv] Z. Banakar and F. Tahriri, "Justification and Classification of Issues for the Selection and Implementation of Advanced Manufacturing Technologies," *World Academy of Science, Engineering and Technology,* vol. 65, pp. 341-349, 2010.

[v] M. D. PROCTOR and J. R. CANADA, "Past and present methods of manufacturing investment evaluation: a review of the empirical and theoretical literature," *The Engineering Economist,* vol. 38, pp. 45-58, 1992.

[vi] M. H. Small and I. J. Chen, "Economic and strategic justification of AMT inferences from industrial practices," *International Journal of Production Economics,* vol. 49, pp. 65-75, 1997.

[vii] R. J. Fotsch, "Machine tool justification policies: their effect on productivity and profitability," *Journal of Manufacturing Systems,* vol. 3, pp. 169-195, 1984.

[viii] F. Lefley, F. Wharton, L. Hajek, J. Hynek, and V. Janecek, "Manufacturing investments in the Czech Republic:: An international comparison," *International Journal of Production Economics,* vol. 88, pp. 1-14, 2004.

[ix] P. Y. Huang and M. Sakurai, "Factor automation: the Japanese experience," *Engineering Management, IEEE Transactions on,* vol. 37, pp. 102-108, 1990.

[x] P. L. Primrose, *Investment in manufacturing technology*: Chapman & Hall, 1991.

[xi] P. M. Swamidass and M. A. Waller, "A classification of approaches to planning and justifying new manufacturing technologies," *Journal of Manufacturing Systems,* vol. 9, pp. 181-193, 1990.

[xii] K. Jenkins, P. Smith, and A. Raedels, "The financial evaluation of robotics installations," *Robotics,* vol. 3, pp. 213-219, 1987.

[xiii] F. Chan, M. Chan, H. Lau, and R. Ip, "Investment appraisal techniques for advanced manufacturing technology (AMT): a literature review," Integrated Manufacturing Systems, vol. 12, pp. 35-47, 2001.

[xiv] A. S. Sohal, R. Schroder, E. O. Uliana, and W. Maguire, "Adoption of AMT by South African manufacturers," Integrated Manufacturing Systems, vol. 12, pp. 15-34, 2001.

[xv] M. Jahanzaib and K. Akhtar, "Technology driven strategy (TDS) using machine automation cost in discrete parts manufacturing," KUWAIT JOURNAL OF SCIENCE AND ENGINEERING, vol. 34, p. 207, 2007.

[xvi] J. Hynek and V. Janeček, "Economic Justification of Advanced Manufacturing Technology," in Proceedings of the 2nd WSEAS Int. Conf. on Management, Marketing and Finances (MMF'08), 2008, pp. 103-108.

[xvii] J. Hynek, V. Janeček, and L. Svobodová, "Problems associated with investment in advanced manufacturing technology from the management point of view," WSEAS Transactions on Systems, vol. 8, pp. 753-762, 2009.

[xviii] Z. Taha, Z. Banakar, and F. Tahriri, "Analytical hierarchy process for the selection of advanced manufacturing technology in an aircraft industry," International Journal of Applied Decision Sciences, vol. 4, pp. 148-170, 2011.

[xix] M. Darbanhosseiniamirkhiz and W. K. Wan Ismail, "Advanced Manufacturing Technology Adoption in SMEs: an Integrative Model," Journal of technology management & innovation, vol. 7, pp. 112-120, 2012.

[xx] R. Abdullah and M. G. Hassan, "Advanced Manufacturing Technology: The Perceived Impact on Producer's Value," The Asian Journal of Technology Management (AJTM), vol. 5, 2012.

[xxi] S. A. M. Mirza Jahanzaib, K. Akhtar, and T. Aslam, "Improvement in Subsisted Product Delivery Process of Manufacturing Organization using Concurrent Engineering," Life Science Journal, vol. 10, 2013.

[xxii] S. A. Masood, M. Jahanzaib, and K. Akhtar, "Key Performance Indicators Prioritization in Whole Business Process: A Case of Manufacturing Industry," Life Science Journal, vol. 10, 2012.