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Justification of Advanced Manufacturing Technologies (AMT)

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Increasingly, discounted cash flow (DCF) techniques have been questioned when used for evaluating technology intensive long-term investment proposals. This is mainly because DCF techniques ignore the intangible benefits accruing from these systems. This paper attempts to justify an investment in a new technique – the advanced manufacturing technology (AMT) using the extended Brown–Gibson model. It can be seen that investment in AMT is attractive if we consider the benefits accruing from the subjective factors. This is an attempt to help practising managers to convince their top management of the investment worthiness of AMT.

Keywords: AMT; Flexibility; Intangible benefits

1. Introduction

The development of science and technology has led to many new concepts and products, which are replacing the old ones. Similarly, in the field of financial management, many new concepts have emerged relating to revenues and costs. While evaluating capital intensive technological projects, such as flexible manufacturing systems (FMSs), conventional financial management techniques such as capital budgeting undervalue the strategic benefits arising from advanced manufacturing technology (AMT). Flexibility, improvement in productivity and quality, faster response to market shifts, shorter throughput and lead time and savings in inventory and labour costs, etc. enable customer demands to be met in a shorter time [1–6] The objective of this paper is to develop a new model, which justifies the investment in AMT.

Changing customer preferences and tastes oblige the manufacturer to change his products frequently. Increased consumer awareness has led to the manufacture of high-quality goods. The manufacturing process has to be faster to meet market demands at the appropriate time and to overcome competition. All these factors have led to changes in manufacturing processes, which have prompted many manufacturers to adopt computer-integrated manufacturing, namely AMT. AMT has operational, technical superiority and other intangible benefits, compared to traditional systems.

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2. Problems in Using Conventional Techniques

The logic behind the use of the discounted cash flow (DCF) technique is that the value of the money received in future is less compared to the value of money today. DCF does not recommend any specific time period as a reference point for evaluating the investment proposal. However, it is a common practice in industry to expect the investment in AMT to pay back in a relatively short period of 4–5 years [4]. The purpose of investing in AMT is for long-term benefits, and evaluating the proposal for a short time horizon is certainly wrong.

The decision to fix a time period of 4–5 years arbitrarily is taken by management and is not a prerequisite for using the DCF technique. The second error occurs in the use of very high discount rates, which adversely affect the cash flow 5 or more years in the future. Opportunity cost of the capital is a better estimator than the highest prevailing market rate, which gives a distorted figure [4,7].

The assumption of steady cash flow in the future using traditional technologies will not be of much advantage if a competitor acquires a competitive advantage by using advanced technology such as an FMS, and thereby attains a higher market share. In such an event, the company cash flow is bound to deteriorate along with its market share in advanced manufacturing technology products, in the light of declining cash flows from the conventional system. In other words the assumption of the status quo in terms of market share and margins using traditional systems is erroneous. In addition, conventional accounting techniques do not take account of the intangible benefits accruing from AMT during project evaluation.

3. Brown–Gibson Model

The Brown–Gibson model [8] was developed for evaluating alternative plant locations using certain objective and subjective factors. It is a quantitative model, which helps in selecting the best location from a given set of alternatives. The model is very useful in the sense that it is able to quantify the subjective factors. In this model, both the subjective and objective factors are converted into consistent and dimensionless indices.

3.1 Extended Brown–Gibson Model (EBG)

The present analysis is an attempt to use the Brown–Gibson model to evaluate traditional manufacturing systems, compared to AMT to choose the better one. The extended Brown–Gibson model (EBG) takes into account the cost and time dimensions of the factors considered for evaluation in the objective factor aspects of the Brown–Gibson model. A new objective factor model has been developed to measure the manufacturing system preference measure (MSPM).

3.2 The General Brown–Gibson Model

If the decision under consideration consists of m alternatives, then the preference measure of particular alternatives i is measured as follows:

$MSPM_i = \alpha \{(CTE_i)\ 1/\Sigma\ CTE_i\} + (1 - \alpha)\ SFM_i$

$MSPM_i$ = manufacturing system preference measure for alternative i

CTE_i = cost and time effectiveness for alternative i

SFM_i = subjective factor measure for alternative i

$CTE_i\ (1/\Sigma CTE_i)$ = objective factor measure for alternative i

α = objective factor weightage

The best alternative will be chosen based on the best manufacturing system preference measure.

3.3 Extended Brown–Gibson Model for Quantitative Factors

An organisation's measure of effectiveness, which is tangible, could be measurable in terms of the cost and time dimensions. Some of the measures are:

The speed with which the product reaches the customer.

The time taken to render services to the customer.

The time taken to bring the machines into working conditions.

The total costs, total revenues, and the total profits of the organisation.

The costs concerned with any manufacturing organisation can be classified into effective costs and ineffective costs. Effective costs would include those costs which the organisation would like to maximise, such as profits and revenues. Ineffective costs would involve those costs which are to be minimised, such as production costs and the overall total costs of the organisation. The time factor can also be classified into effective and ineffective time. Here, all productive time would be effective, and all non-productive time would be ineffective. Any organisation would like to maximise the effectiveness of cost and time and minimise the ineffective cost and time.

The extended Brown–Gibson model is used to evaluate a traditional manufacturing system, and an AMT system such as an FMS for the justification of the best system for the operation. In the process of justification of AMT, the cost and benefits can be treated as effective and ineffective costs, and effective and ineffective times, as shown in Fig. 1.

Model Explanation

$$CTE_i = EC_i\ 1/\Sigma\ EC_i + (IEC_i\ \Sigma\ 1/IEC_i)^{-1} + ET_i\ 1/\Sigma\ ET_i + (IET_i\ \Sigma\ 1/IET_i)^{-1} \quad (1)$$

EC_i = effective cost of alternative

ET_i = effective time of alternative

IEC_i = ineffective cost of alternative

IET_i = ineffective time of alternative

In Eq. (1), the expressions $EC_i\ (1/\Sigma\ EC_i)$ and $ET_i\ (1/\Sigma\ ET_i)$ are the terms related to the positive aspects of time and cost. Here, an attempt has been made to make the cost and time dimensions into dimensionless indices.

The sum of the cost expression for all the alternatives is equal to 1 and the sum of the time expression for all the alternatives is also equal to 1. The other two expressions, namely $(IEC_i\ \Sigma\ 1/IEC_i)^{-1}$ and $(IET_i\ \Sigma\ 1/IET_i)^{-1}$, are related to ineffective cost and time.

An example is taken from [9] to explain the usefulness of the model. The data are shown in Table 1 for three states of the economy, namely, downturn economy, normal economy, and economic upturn. In the table, the annual cost represents the annual overhead cost. The purchase cost and the installation cost etc. are capitalised as the initial cost, and the initial cost is depreciated assuming a depreciable life of 5 years and

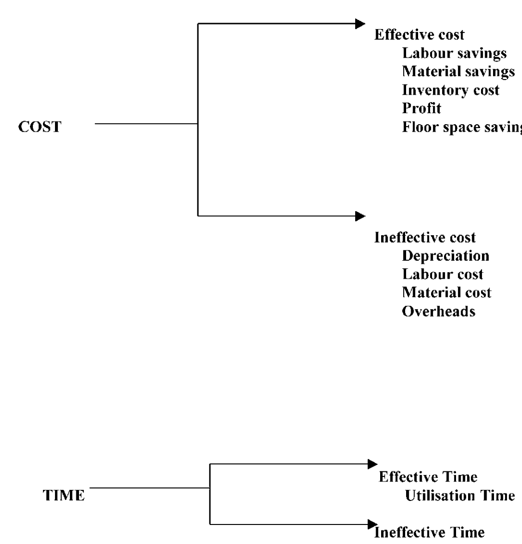

Fig. 1. Effective and ineffective costs and times.

Table 1. Production example.

Project	@TS			@AMT		
State of economy	1	2	3	1	2	3
Initial cost ($1000s)	100	100	100	400	400	400
Annual cost ($1000s)	100	100	100	40	40	40
Product cost ($/unit)	11	10	9	9	8	7
Product selling price ($)	18	20	22	18	20	22
Demand (1000s of units)	20	30	40	20	30	40

@TS, traditional systems; AMT, advanced manufacturing technologies. 1, economic downturn; 2, normal economy; 3, economic upturn.

Table 2. State of economy 1 (economic downturn) AMT.

Years	1	2	3	4	5	Present value
Annual cost (IEC)	40	40	40	40	40	134.09
Profit (EC)	180	180	180	180	180	603.40
Depreciation (IEC)	80	80	80	80	80	268.17

Table 3. State of economy 1 (economic downturn) TS.

Years	1	2	3	4	5	Present value
Annual cost (IEC)	100	100	100	100	100	335.20
Profit (EC)	140	140	140	140	140	469.30
Depreciation (IEC)	20	20	20	20	20	67.04

Table 4. State of economy 2 (normal economy) AMT.

Years	1	2	3	4	5	Present value
Annual cost (IEC)	40	40	40	40	40	134.09
Profit (EC)	360	360	360	360	360	1206.7
Depreciation (IEC)	80	80	80	80	80	268.17

Table 5. State of economy 2 (normal economy) TS.

Years	1	2	3	4	5	Present value
Annual cost (IEC)	100	100	100	100	100	335.20
Profit (EC)	300	300	300	300	300	1005.64
Depreciation (IEC)	20	20	20	20	20	67.04

depreciation is considered as an ineffective cost in the model. No tax is assumed, and the model is used after finding the present value for all the costs for the period of 5 years at a cost of capital of 15% for various states of the economy for both traditional and advanced manufacturing technologies and are shown in Tables 2 to 7. The values are substituted in the EBG model and the objective factor rating for the alternatives

Table 6. State of economy 3 (economic upturn) AMT.

Years	1	2	3	4	5	Present value
Annual cost (IEC)	40	40	40	40	40	134.09
Profit (EC)	600	600	600	600	600	2011.30
Depreciation (IEC)	80	80	80	80	80	268.17

Table 7. State of economy 1 (economic upturn) TS.

Years	1	2	3	4	5	Present value
Annual cost (IEC)	100	100	100	100	100	335.2
Profit (EC)	520	520	520	520	520	1743.12
Depreciation (IEC)	20	20	20	20	20	67.04

Table 8. Objective factor rating.

	State of economy		
	1	2	3
AMT	0.492	0.486	0.483
TS	0.517	0.514	0.508

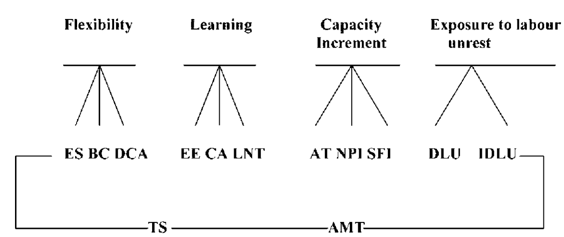

Fig. 2. Subjective factors. ES, economy of scope; BC, back-up capability; DCA, design change accommodation; EE, experience and expertise; CA, competitive advantage; LNT, leader in new technology; AT, additional tool; NPI, new product introduction; SFI, saving in future investment; DLU, direct union labour; IDLU, indirect labour union.

are calculated for different states of the economy, as shown in Table 8.

Table 8 shows that the AMT scores less than the TS. At this point, it is very tempting to adopt traditional systems. However, a closer look at the subjective factors of the intangible benefits reveals a different picture. The subjective factors are considered and classified into two levels based on their dependency [10], as shown in Fig. 2. The subjective factors in each level are compared pairwise. Management must decide the relative importance of the subjective factors based on objectivity and reality.

Example: The relative importance of the level 1 factors:

Flexibility is more important than learning, capacity increment and exposure to labour unrest.

Capacity increment is more important than learning.

Table 9. Subjective factors relative importance (level 1).

Subjective factors	Pairwise comparisons						Sum	Relative importance index
	1	2	3	4	5	6		
Flexibility	1	1	1	–	–	–	3	3/6 = 0.500
Learning	0		–	0	1	–	1	1/6 = 0.167
Capacity Increment	–	0	–	1	–	1	2	2/6 = 0.333
Exposure to labour unrest	–		0	–	0	0	0	0/6 = 0
Total							6	1

Table 10. Flexibility (second level factors).

Subfactors	Pairwise comparisons			Sum	Relative importance
	1	2	3		
ES	1	0	–	1	1/4 = 0.25
BC	0	–	1	1	1/4 = 0.25
DCA	–	1	1	2	2/4 = 0.50
Total				4	1

Learning is more important than exposure to labour unrest.

As there are 4 subjective factors, $6(4c_2)$ pairwise comparison is as shown in Table 9.

Subjective Factor Rating. In the pairwise comparison, flexibility scores 1 whereas the others score zero, as flexibility has been assigned a higher priority by the management.

Similarly the capacity increment scores 1 when it is compared with learning and exposure to labour unrest, and learning scores 1 when it is compared with exposure to labour unrest. The relative importance of the factors is calculated and is shown in Table 9.

Similarly, for the calculation of the relative importance of the second level factors, the pairwise comparisons are repeated with different second level factors. This is shown in Tables 10–13.

In the next phase of the calculation for each lower level subjective factor, the pairwise comparisons are repeated with different manufacturing systems to determine relative ranking. This is shown in Table 14.

Table 11. Learning (second level factors).

Subfactors	Pairwise comparisons			Sum	Relative importance
	1	2	3		
EE	0	1	0	1	13 = 0.333
DCA	1	–	1	2	2/3 = 0.667
LNT	–	0	0	0	0
Total				3	1

Table 12. Capacity increment (second level factors).

Subfactors	Pairwise comparisons			Sum	Relative importance
	1	2	3		
AT	0	0	–	0	0
SFI	1	–	0	1	1/3 = 0.3333
NPI	–	1	1	2	2/3 = 0.667
Total				3	1

Table 13. Exposure to labour unrest (second level factors).

Subfactors	Pairwise comparison	Sum	Relative importance
DLU	1	1	1
IDLU	0	0	0
Total		1	1

Table 14. Economy of scope (second level factors).

	Pairwise comparison	Sum	Manufacturing system rating
AMT	1	1	1
TS	0	0	0

Table 15.

Subfactors	Subfactor relative importance	First level factors relative importance	AMT	TS
ES	0.25	(Flex) 0.5	1	0
BC	0.25	(Flex) 0.5	1	0
DCA	0.50	(Flex) 0.5	1	0
EE	0.333	(Lea) 0.167	1	0
CA	0.667	(Lea) 0.167	1	0
LNT	0	(Lea) 0.167	1	0
AT	0	(Cap) 0.333	1	0
SFI	0.333	(Cap) 0.333	1	0
NPI	0.667	(Cap) 0.333	1	0
DLU	1	(Exp) 0	1	0
IDLU	0	(Exp) 0	1	0

Likewise, with respect to all other second level factors, the two manufacturing systems are compared with each other and the manufacturing system ratings are calculated.

To determine the subjective factor measure for a manufacturing system, multiply the manufacturing system rating for each lower level factor by their relative importance index and the related higher level factor rating and sum the products. This is shown in Table 15.

$$\text{Subjective factor for AMT} = (0.5 \times 0.25 \times 1 + 0.5 \times 0.25 \times 1$$
$$+ 0.5 \times 0.5 \times 1 + 0.167 \times 0.333 \times 1 + 0.167 \times 0.667 \times 0$$

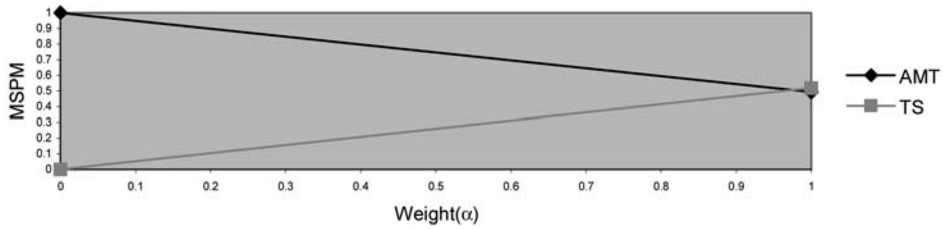

Fig. 3. Sensitivity of MSPM for each manufacturing system with respect to weighting (α) for economic downturn.

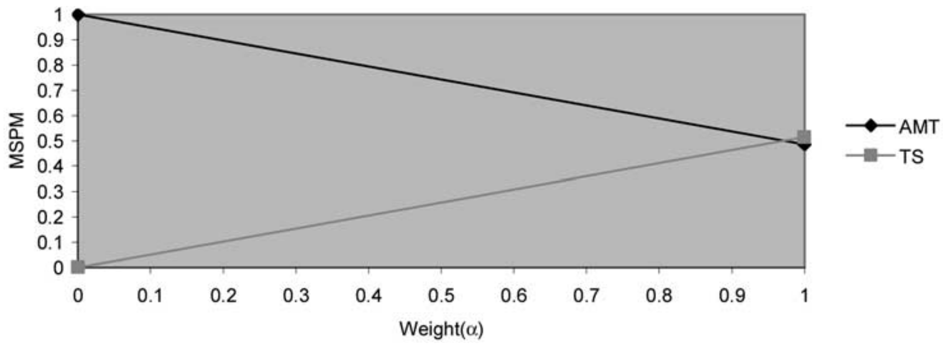

Fig. 4. Sensitivity of MSPM for each manufacturing system with respect to weighting (α) for normal economy.

$+ 0.333 \times 0 \times 1 + 0.333 \times 0.333 \times 1 + 0.333 \times 0.667 \times 1$

$+ 0 \times 1 + 0 \times 0)$

$= 1$

Subjective factor for TS =0

Sensitivity Analysis. The above analysis assisted in arriving at scores related to objective factors as well as to subjective factors. These scores are substituted in the General Brown–Gibson model to develop two decision models as shown below.

$$\text{MSPM(AMT)} = \alpha(0.492) + (1 - \alpha)\ 1$$
$$= -0.508\ \alpha + 1 \quad (2)$$
$$\text{MSPM(TS)} = \alpha(0.517) + (1 - \alpha)\ 0$$
$$= 0.517\alpha \quad (3)$$

Using the decision models, the firm can choose a particular manufacturing system based on different objective factor weightings (α), corresponding to the decision situation. Figures 3 to 5 show the vulnerability of the decision to weighting of factors for different states of the economy.

For states of the economy 1 and 2, the critical weighting that changes the decision from AMT to TS is 0.97. The critical weighting for state of economy 3 is 0.98.

4. Conclusion

In the decision problem, the expression related to the time dimension is not taken into consideration. If it is incorporated, it may change the decision model equations (2) and (3). To achieve the benefits arising out of the use of AMT necessitates taking a holistic approach before making a decision on its viability. It has been found that the major stumbling block in the introduction of AMT has been its high costs and top management's desire to justify the system from a purely quantifiable financial angle. This management stand is understandable, when we consider the very high initial investment required; however, the intangible benefits arising out of the subjective factors, as shown in the model, are many and important.

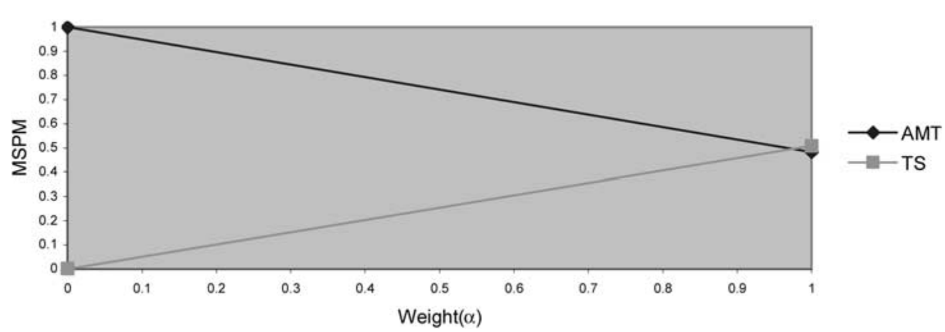

Fig. 5. Sensitivity of MSPM for each manufacturing system with respect to weighting (α) for economic upturn.

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