Factors for evaluating factory automation projects – inferences from an Indian survey

Article *in* Work Study · August 1995

DOI: 10.1108/00438029510091486

3 authors:

K.V. Sambasivarao
Indian Institute of Technology Delhi
4 PUBLICATIONS **199** CITATIONS
SEE PROFILE

S G Deshmukh
Indian Institute of Technology Delhi
388 PUBLICATIONS **13,600** CITATIONS
SEE PROFILE

R. P. Mohanty
Siksha O Anusandhan University Bhubaneswar Odisha India
147 PUBLICATIONS **2,866** CITATIONS
SEE PROFILE

Factors for evaluating factory automation projects – inferences from an Indian survey

K.V. Sambasivarao, S.G. Deshmukh and R.P. Mohanty

Introduction

Globally, manufacturing facilities are constantly being upgraded in order to provide competitive advantages. Parunndekar[1] observes that Indian manufacturing firms have recognized the importance of automating their production systems to meet the challenges posed by the pluralistic market. However, adoption of such automation projects involves large investments and a strategic management style. Meredith and Suresh[2] state that any financial investment in economic activities requires a justification for the purpose of committing capital. The introduction of automation projects (AP) can, and many would say should, include changes in the prevailing management style and in the organizational culture of a firm. Thus, the decision-making process with regard to the selection of AP is quite complex, because the commercial success of the firm is highly dependent on the mechanics of such a process. In addition to the obvious quantitative benefits accruing from the introduction of AP, they can offer a large number of qualitative (intangible) benefits. Datta *et al.*[3] observed that these are generally difficult to quantify. Researchers have attempted to convert the relative importance of qualitative benefits into priority weights (PW) for procedures involving the selection and evaluation of AP. Mohanty[4] states that project selection and evaluation involve decisions that are critical to the profitability, growth and survival of the manufacturing firm in the increasingly competitive global scenario. Such decisions are complex and require analysis of tangible and intangible attributes.

A major problem in the adoption of advanced manufacturing systems is the identification of automation factors (AF) that are mandatory for selection and evaluation of AP. Today most major corporations in India are making attempts to select and implement AP. Mohanty[4]observed that the real-life decision-making process in the project selection is compounded by a variety of multidimensional issues which are:

- Huge investments require financial analysis to assess long-term profitability.
- The long-term strategic benefits such as flexibility, improved quality etc. and intangible benefits have to be quantified for the evaluation purposes.
- Irreversibility of the decision making.
- Greater financial risks in terms of future unforeseen costs.
- Organizational risks in terms of unanticipated changes in the system.
- Lack of information for making accurate estimates of future returns.
- Cost patterns of new technologies are rarely understood, and the knowledge and expertise to make critical evaluations lies with only a few individuals within the organization.

Selection and evaluation of AP is thus a complex process and requires analysis of a large number of issues. In this context, an attempt has been made to formulate a framework for converting the relative importance of such attributes into priority weights. A brief discussion on the literature, the formulation of framework and the application of the methodology are dealt with in the following sections.

Literature review

Datta *et al.*[3] and Demmel and Askin[5] have reported in the literature that selection and evaluation processes are highly dependent on a large number of attributes. Naik and Chakravarthy[6] reviewed selection and justification procedures and suggested a four-stage framework for the strategic acquisition of new manufacturing technologies.

Park *et al.*[7] stated that the implementation of automation technologies entails a large initial investment under a long-term, uncertain environment. They also observed that the decision to implement AP must be determined by expectations concerning factors of demand such as the breadth and the variety of products, the quality of demand, and also the quality of products. Bessant and Hayward[8] and Boer and During[9] argued that the full benefits of AP are not realized for economic, technical, and organizational reasons.

It is observed from the literature that researchers have identified a large number of attributes and made varying attempts to classify them. For example, Tayyari and Kroll[10] have separated attributes into two categories: direct cost benefits, and intangible (hidden) benefits. Demmel and Askin[5] have identified a considerable number of implementation issues and placed these under three categories: strategic, tactical, and pecuniary (economic) issues. Wabalickis[11] has classified AP attributes into three categories: direct cost factors, strategic and tactical attributes.

Young and Murray[12] discussed procedures for acquiring FMS. They have identified seven factors for the purpose: system quality; productivity; system reliability; system diagnostics; flexibility; material management; and economics. Mohanty[13] has considered six types of attributes: strategic; technological; human; social; pre-production costs; and direct production cost factors. He has considered economic issues both in pre-production and production cost categories. Wabalickis[11] has considered four attributes such as: inventory costs; sales; operating costs; and start-up costs and seven sub-attributes: lead-time; minimize inventory; product mix response; profitability; product change response; tooling; and scrap for evaluating three manufacturing systems using the analytic hierarchy process. Mohanty and Venkatraman[14] have adopted 12 attributes for selecting an automated manufacturing system. Datta *et al.*[3] have used 12 attributes for the justification of FMS. Demmel and Askin[5] have adopted 15 attributes for evaluating advanced manufacturing technologies. Sambasivarao and Deshmukh[15] have adopted numerous attributes for the design and implementation of AP. They have also classified attributes into five categories: economic; human; social; strategic; and technological attributes.

There is certainly no shortage of identification and classification of the attributes and issues affecting decisions about AP. Researchers have perceived the attributes with different names but the spirit behind the expression is the same. For example, Mohanty[13] has considered hardware as plant and equipment, Troxler and Blank[16] have perceived market position as growth, and Datta *et al.*[3] have considered the financial position as investment and management information as the information system.

A large number of attributes are identified from the literature and classified into five categories. The majority of authors have referred to these same attributes but with different expressions. These attributes are identified and listed in Table I.

The attributes identified from the literature were reviewed by professionals from both academia and industry in the present study. A framework is designed for converting the relative importance of attributes into priority weights. The implications of the framework are explained and are demonstrated in Indian industry, to derive the list of prioritized attributes; this is explained in the following section.

Factor	Sub-factor (attribute)	References
Economic	Consumables	14, 19, 21
	Design	5, 6, 14, 19, 21, 24
	Inspection and control	6, 14, 19, 21, 27
	Inventory	1, 4, 6, 8, 10, 11, 14, 19, 21, 22, 24
	Labour	5, 6, 8, 9, 11, 14,17, 19, 21
	Maintenance	5, 11, 17, 19, 21
	Material	5, 17, 19, 21, 27
	Material handling	5, 14, 19, 21, 27
	Modification	5, 6, 9, 14, 19, 21,22
	Quality	4, 6, 10, 11, 14, 19, 20, 21, 22, 24, 27
	Throughput	5, 6, 10, 14, 19, 20, 21, 24, 25
	Training	5, 9, 10, 11, 14, 21, 22
Human	Employee co-operation	9, 21, 24
	Employee relations	4, 5, 9, 21, 22, 24, 26
	Employee morale/motivation	4, 5, 6, 14, 19, 21, 22, 24, 26
	Manpower planning	10, 14, 19, 21, 22
Social	Community development	14, 19, 21, 26
	Customer satisfaction	6, 9, 14, 17,19, 21, 24, 26
	Ecology	14, 19, 21
	Working environment	7, 9, 14, 19, 21
Strategic	Finance position	4, 11, 13, 14, 19, 21, 22, 24, 26
	Government advantage	6, 11, 22
	Management development	5, 11, 14, 19, 21, 22
	Market position	4, 5, 6, 11, 13, 14, 20, 22, 24, 25, 26
	Research and development	14, 19, 21, 22
	Technology position	4, 5, 13, 14, 19, 20, 21, 22, 24, 26
Technological	Availability	5, 7, 8, 14, 19, 21, 24, 26
	Capacity utilization	1, 4, 8, 9, 11, 14, 19, 21, 22, 24
	Compatibility	5, 6, 9, 14, 19, 21
	Flexibility	5, 6, 7, 8, 11, 14, 19, 20, 21, 24, 26, 27
	Hardware	5, 6, 10, 11, 13, 14, 19, 21
	Management information	14, 19, 21, 26
	Manufacturing engineering	4, 5, 9, 10, 14, 19, 20, 21, 27
	Productivity	6, 11, 14, 19, 21, 24, 26, 27
	Reliability	4, 14, 19, 21, 26
	Software	5, 10, 11, 14, 17, 19, 21
	Technical feasibility	4, 5, 14, 19, 21, 22, 24

Table I. List of attributes identified for SI from literature

Framework for converting attribute priorities into priority weights

When a change in the existing manufacturing system is proposed, a consensus idea may be sought. People in an organization may hold conflicting views about the best method of reaching any goal, and an understanding of these different perspectives is useful. Also, for successful implementation, it is useful to maintain a degree of participation from those who will be affected by the eventual decision. If a new manufacturing system is imposed from higher up, without the full knowledge and participation of all, it is almost sure to be unworkable. Huang and Sakurai[17] observe that, in Japan, the automation systems are designed and selected by their own technical staff. For successful adoption, a company needs the support of their appropriately trained employees to operate as well as design and select automated equipment. Employees are given due preference to participate in the automation process and the employees recognize the specific needs of the factory more than most outside consultants.

The present study incorporates a four-stage framework which is devised to help obtain a consensus means of reaching a desired goal. The framework is devised for deriving corporate goals and evolving a list of prioritized objectives.

(1) A group of people who participate in the decision making must be identified and called for a consensus confrontation.

(2) The group will (again) meet and identify the goals or objectives of the proposal. The objectives or attributes may be identified from reading expert views, practical experience, individual opinions, and consultation with practitioners. A list of consensus attributes are generated in the meeting.

(3) The group is asked to rate the attributes on an appropriate (n-point) scale. Generally, the automation factors are difficult to quantify. However, their relative importance is converted into priority weights using an appropriate scale.

(4) Responses for each attribute are tested using t-test for acceptable data. If the input sample (respons-

es) of an individual attribute is unacceptable, then the theoretical mean and priority weight (PW) is put to the group and they are asked to modify it until they agree on a value. Step 3 is repeated for acceptable data. Finally, acceptable data for all attributes are obtained.

The framework is illustrated in Figure 1. The application of the framework in Indian industry is explained in the following sections.

An Indian survey

The context of the survey was a plan to identify the potential attributes relating to Indian manufacturing industry and to use the framework to obtain a list of prioritized attributes. Thirty-seven attributes were identified for the purpose. First, an open-ended list of attributes was identified from the literature. Then, the list of attributes was categorized into five sections: economic; human; social; strategic; and technological factors – in consultation and discussion with professionals. The purpose of the survey was to:

- identify potential attributes for selection and evaluation of AP;
- develop a methodology for convening attribute priorities into priority weights;
- examine the relative importance of attributes;
- list and rank the prioritized attributes; and
- draw the attention of industry to the importance of AF.

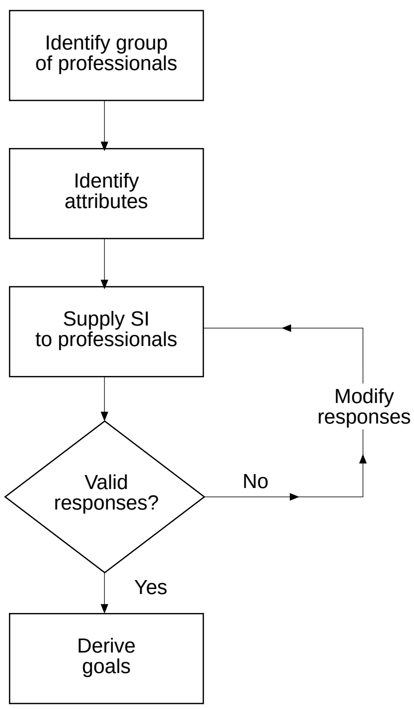

Figure 1. Framework for prioritizing attributes

Details of the survey

Primary data for the study were collected from various industry professionals and academics through a self-addressed mail questionnaire. Prior to administering the questionnaire, the survey instrument was reviewed by members of the target audience – three academics and two industry professionals. The results of their inputs were used to ensure clarity and completeness, and to eliminate any ambiguities.

A copy of the final version of the questionnaire was mailed to 125 professionals. The professionals were from across the country and all are currently involved in automation projects. The sample included automobile and auto parts, CNC machine tools and allied manufacturers, electrical and electronics equipment, R&D, academics, turnkey and developmental projects. Thirty-two respondents replied, representing a 25 per cent response rate. Apart from collecting responses to the basic questions, a few open-ended responses were also obtained.

Table II summarizes the characteristics and profile of the respondents and their organizations. A simple, seven-point scale was devised to rate each attribute. The scale is given in Table III. Professionals were requested to indicate the priorities for the attributes listed. The responses were gathered and analysed. The suitability of the responses was tested using *t*-test. If the *t* value did not fall in the critical region, the respondent was informed and asked to modify the priority (if he/she was willing and able to do so). Finally, all valid responses were analysed as follows.

Analysis of data

The sample of inputs consisted of the responses from five types of industry. Responses were processed on an individual sector basis as well as at an aggregate level. The priorities of each attribute were gathered on an indivi-

	Values in %
Title of the respondent	
President or director of firm	9.4
General manager (manufacturing)	18.7
Head of the department	21.9
Assistant engineer	18.8
Academician	31.2
Title of department	
Research and development	21.9
Business	15.6
Production	31.2
Strategic management	21.9
Others	9.3
Turnover of the organization[a]	
Below $5m (millions)	40.0
$6m to $25m	13.3
$26m to $50m	20.0
$51m to $100m	13.3
Above $101m	13.3
Manpower of the organization	
Below 100	5.8
101 to 500	58.8
501 to 1,500	17.6
Above 1,501	17.6
Business category	
Automobile and auto parts	12.5
CNC machine tools and allied products	37.6
Electrical and electronics equipment	12.5
Research and development, academics	31.2
Turnkey and developmental projects	6.2

Note:
N = 32
[a] Excluding academicians

Table II. A profile of the respondents

Priority score	Explanation
7	Very important
6	Important
5	Essential
4	Necessary
3	Considered
2	Less considered
1	Least advised

Table III. Relative importance rating scale

dual basis and the mean calculated. This is treated as the priority weight (PW). The average of the highest and lowest priorities of an attribute is treated as the theoretical mean. The validity of the samples was tested using *t*-test. The standard deviation for each attribute was also calculated. To test the responses, the sample mean and standard deviation were calculated. The mean and standard deviation of various attributes are listed in Table IV (for all responses). The calculation procedure for the attribute "Finance position" is illustrated in Figure 2.

Attribute: finance position

Number of responses (sample size) : 32

Priority scores:

6 7 4 6 5 6 5 4 5 6 4 6 5 6 5 5 6
5 3 5 5 6 5 4 5 6 4 6 7 6 5 6

Highest priority : 7

Lowest priority : 3

Theoretical mean : 5

Priority weight : 5.312

Standard deviation : 1.184

Figure 2. Calculation procedure for the attribute "Finance position"

Hypothesis testing

The hypothesis for a given attribute is tested for acceptable responses. The sample is tested at a specified level of confidence using *t*-test. For example, the ongoing responses are tested at a 95 per cent confidence level. The relation is expressed as:

$$t = (M - \mu)^* \sqrt{n}/\sigma \text{(for } v \text{ d.o.f.)} \quad (1)$$

where

μ = sample mean

M = theoretical mean

n = sample size (number of responses)

σ = standard deviation

v = $(n - 1)$ d.o.f.

α = significance level.

Based on the *t* values, the significance of mean difference (theoretical mean and PW) was tested. Figure 3 gives the procedure adopted for one such attribute. Following the adoption of a similar procedure for the other attributes, the *t* values and PW shown in Table IV were obtained. In the current study acceptable data for all attributes were obtained.

For example, the input sample for the attribute "Finance position" at the 95 per cent confidence level was acceptable. Hence, we could accept the PW. This indicates that corporate goals are often set to improve the finance

Automation factor	Mean	Std	*t*-dist	PW
Quality	6.000	0.696	–1.016	6.125
Management development	5.000	0.909	–1.749	5.312
Finance position	5.000	1.184	–1.493	5.281
Flexibility	4.500	1.560	–1.586	4.938
Technology position	4.500	1.321	–1.873	4.938
Throughput	4.500	1.749	–1.415	4.938
Technical feasibility	4.500	1.352	–0.915	4.719
Design	4.000	1.619	–1.965	4.562
Manufacturing engineering	4.000	1.619	–1.965	4.562
Customer satisfaction	4.000	1.694	–1.461	4.438
Productivity	4.000	1.731	–1.430	4.438
Reliability	4.500	1.499	0.236	4.438
Compatibility	4.000	1.269	–1.672	4.375
Inventory	4.000	1.240	–1.568	4.344
Market position	4.000	2.053	–0.861	4.312
Hardware	3.500	1.798	–1.966	4.125
Labour	3.500	1.676	–1.899	4.062
Material	4.500	1.560	1.586	4.062
Research and development	4.000	1.919	–0.184	4.062
Training	3.500	2.038	–0.868	3.812
Employee co-operation	3.000	1.029	0.344	3.719
Employee relations	3.500	1.446	–0.734	3.688
Availability	3.500	1.452	0.487	3.375
Manpower planning	3.500	1.576	0.449	3.375
Capacity utilization	3.500	1.397	0.886	3.312
Management information	3.500	1.446	0.734	3.312
Maintenance	3.500	1.436	0.985	3.281
Employee morale/motivation	3.500	1.250	1.131	3.250
Software	3.500	1.436	0.985	3.250
Inspection and control	3.500	1.424	1.242	3.188
Working environment	3.500	1.325	1.467	3.156
Workforce composition	3.000	1.029	0.344	2.938
Material handling	3.000	1.166	0.606	2.875
Consumables	3.000	1.321	1.873	2.562
Government advantage	3.500	2.038	–0.868	2.156
Community development	2.000	0.808	1.313	1.812
Ecology	2.000	0.695	1.780	1.781

Table IV. Priority weights of attributes of sampled composite industry

Hypothesis:

$H_0 = \mu$
Assumption = The input sample is reliable and acceptable at 95% of confidence level

$H_1 \neq \mu$
Assumption = The input sample is not reliable and not acceptable

Critical region: $-t_\alpha/2 < t < t_\alpha/2$ for $v = 31$, $\alpha = 0.05$, $-1.749 < t < 1.749$

Procedure: Calculate the value of t

$t = (M - \mu) * \sqrt{n}\, \sigma$ (for v degrees of freedom) = –1.493

Conclusion: Accept the null hypothesis which assumes that sample is acceptable at 95% level of confidence

Figure 3. Hypothesis testing

position. Similar observations can be made regarding the other attributes.

Implications of the study: some observations

The responses were processed sector-wise. Table V shows the listing of priority weights of attributes on a sector basis. The ranking of each attribute is shown based on the highest PW. Table IV shows the composite results of all responses.

From the study, it was observed that quality, finance position, management development, throughput, technology position, flexibility, technical feasibility, etc. were given the greatest prominence (and achieved the highest PW). Human factors, community development, and ecology achieved the lowest PW and are obviously of low priority to most decision makers. From Table V, it can be seen that all types of industry give the highest priority to quality and the lowest to ecology but also that different industries have different priorities.

Using the above study, AP can be appraised for their investment justification, for which many analytical justification approaches are adopted. Naik and Chakravarthy[6] and Meredith and Suresh[2] have reviewed and explained various justification approaches. These include: scoring models, multi-attribute decision models such as the analytic hierarchy process (AHP), the linear additive model, and the technique for order preference by similarity to ideal solution (TOPSIS).

Apart from the SI, a few open-ended responses were obtained. Respondents made observations on common difficulties in adapting to automated manufacturing systems such as:

- lack of technical skills;
- managerial problems;
- lack of confidence to implement automated systems;
- absence of clear-cut policy direction towards automation;
- poorly understood evaluation methods; and
- strong resistance to adopting automation.

Concluding remarks

Technological change is dynamic. In a competitive environment, manufacturing firms are struggling to implement AP successfully. In this context, an attempt has been made to evolve a framework which converts attribute priorities into priority weights. A survey has been conducted to study the relative importance of various attributes. The study was intended to suggest some potential attributes for judging the implementation of AP. This framework may be used for identification of corporate goals, the selection of automation criteria and for deriving goal priorities. The usefulness of this methodology can be summarized as follows.

Economy

In the national economy, the automated manufacturing sector occupies a very significant position. The government of India has liberalized its economy and is aiming to achieve success in

Attribute	Auto	CNC	Electr	R&D	Turnkey
Availability	4.000	3.167	4.000	3.300	2.500
Capacity utilization	2.250	3.667	2.250	4.100	1.500
Community development	2.000	1.750	2.000	1.700	2.000
Compatibility	5.000	4.167	5.000	4.500	2.500
Consumables	2.250	2.667	2.500	2.600	2.500
Customer satisfaction	4.250	4.500	4.250	4.700	3.500
Design	5.750	4.167	5.750	4.100	4.500
Ecology	1.500	1.833	1.500	2.000	1.500
Employee co-operation	3.000	4.000	3.000	3.800	4.500
Employee morale/motivation	2.500	3.500	2.500	3.400	4.000
Employee relations	3.250	3.833	3.250	3.600	5.000
Finance position	5.750	5.167	4.750	5.400	5.500
Flexibility	5.750	4.667	5.750	4.500	5.500
Government advantage	2.000	2.417	2.000	2.000	2.000
Hardware	5.500	3.667	5.500	3.800	3.000
Inspection and control	2.250	3.500	2.250	3.400	4.000
Inventory	3.500	4.500	3.000	4.900	5.000
Labour	3.750	4.167	3.750	4.200	4.000
Maintenance	3.000	3.333	3.000	3.500	3.000
Management development	6.000	4.917	6.500	5.000	5.500
Management information	3.250	3.333	3.250	3.500	2.500
Manpower planning	3.750	3.250	3.750	3.300	3.000
Manufacturing engineering	4.000	4.750	4.000	4.400	6.500
Market position	3.750	4.500	3.750	4.300	5.500
Material	4.250	4.000	4.250	3.800	5.000
Material handling	2.500	3.000	2.500	3.300	1.500
Productivity	4.250	4.500	4.250	4.400	5.000
Quality	6.250	6.083	6.250	5.900	7.000
Reliability	5.500	4.083	5.500	4.100	4.000
Research and development	5.000	3.750	5.000	4.000	2.500
Software	4.000	3.000	4.000	3.000	3.000
Technical feasibility	5.250	4.500	5.250	4.700	4.000
Technology position	5.250	4.750	5.500	4.700	5.500
Throughput	4.500	5.083	4.500	5.300	4.000
Training	4.500	3.583	4.500	3.500	4.000
Workforce composition	2.250	3.167	2.250	3.000	4.000
Working environment	2.500	3.417	2.500	3.000	5.000

Table V. Priority weights of attributes sector-wise global markets. Manufacturing industries are faced with heavy market pressures both from home and abroad. Responding to these pressures needs flexible manufacturing technologies which can quickly respond to market changes and attack niche markets where they can be identified. The need for automation in a growing economy like India is well acknowledged. The present study is meant to help in promoting and addressing automation issues and implications.

Industry

The study provides a basic framework within which various attributes can be evaluated to assess the degree to which they meet objectives for successful implementation at an individual industry level and at a micro level. A list of prioritized attributes was obtained from the survey. This may draw the attention of manufacturers to those factors which are generally considered important when evaluating automation projects – and which they should themselves evaluate.

Academics

Industry, perhaps not surprisingly, values "hard" economic and quality-related factors and not "softer" people-related factors. There is perhaps a need for further education and promotion of the relationships between these two sets of factors.

References

1. Parundekar, S., "Justification for automated manufacturing systems: design of a decision support system (DSS)", unpublished master's thesis, National Institute of Industrial Engineering, Bombay, 1990.
2. Meredith, J.R. and Suresh, N.C., "Justification techniques for advanced manufacturing technologies", *International Journal of Production Research*, 1986, pp. 1043-57.
3. Datta, V., Sambasivarao, K.V., Kodali, R. and Deshmukh, S.G., "Multi-attribute decision model using the analytic hierarchy process for the justification of manufacturing systems", *International Journal of Production Economics*, Vol. 28 No. 2, 1992, pp. 227-34.
4. Mohanty, R.P., "Project selection by a multiple-criteria decision-making method: an example from a developing country", *International Journal of Project Management*, Vol. 10 No. 1, 1992, pp. 31-8.
5. Demmel, J.G. and Askin R.G., "A multiple-objective decision model for the evaluation of advanced manufacturing system technologies", *Journal of Manufacturing Systems*, Vol. 11 No. 3, 1992, pp. 179-94.
6. Naik, B. and Chakravarthy, A. K., "Strategic acquisition of new manufacturing technology: a review and research framework", *International Journal of Production Research*, Vol. 30 No. 7, 1992, pp. 1575-601.
7. Park, Y.H, Park., E.H. and Ntuen, C.A., "An economic model for cellular manufacturing systems", in Parsaei, H., Ward, T. and Karwoski, W. (Eds), *Justification Methods for Integrated Manufacturing Systems*, Elsevier, New York, NY, 1990, pp. 176-92.
8. Bessant, J. and Hayward, B., "Flexibility in manufacturing systems", *Omega*, Vol. 14, 1986, pp. 465-73.
9. Boer, H. and During, W.E., "Management of process innovation – the case of FMS: a systems approach", *International Journal of Production Research*, Vol. 25, 1987, pp. 1671-82.
10. Tayyari, F. and Kroll, D.E., "Total cost analysis of modern automated systems", in Parsaei. H., Ward, T. and Karwoski, W. (Eds), *Justification Methods for Computer Integrated Manufacturing Systems*, Elsevier, New York, NY, 1990, pp. 234-41.
11. Wabalickis, R.N., "Justification of FMS with analytic hierarchy process", *Journal of Manufacturing Systems*, Vol. 7 No. 3, 1988, pp. 175-82.
12. Young, A.R. and Murray, J., "Performance evaluation of FMS", *International Journal of Operations & Production Management*, Vol. 6 No. 5, 1986, pp. 57-62.
13. Mohanty, R.P., "Analysis of justification problems in CIMS: review and projections", *International Journal of Production Planning and Control*, Vol. 4 No. 3, 1993, pp. 260-71.
14. Mohanty, R.P. and Venkatraman, S., "Use of analytic hierarchy process for selecting automated manufacturing systems", *International Journal of Management*, Vol. 13 No. 8, 1993, pp. 45-57.
15. Sambasivarao, K.V. and Deshmukh, S.G., "Understanding the implementation process of advanced manufacturing systems: emerging trends in mechanical engineering", in Agarwal, S. *et al.* (Eds), *Proceedings of 8th ISME Conference on Mechanical Engineering*, Tata-McGraw-Hill, Delhi, 1993, pp. 653-58.
16. Troxler, J.W. and Blank, L., "Decision support system for value analysis of integrated manufacturing technology", in Parsaei, H., Ward, T. and Karwoski, W. (Eds), *Justification Methods for Computer Integrated Manufacturing Systems*, Elsevier, New York, NY, 1990, pp. 193-202.
17. Huang, P.Y. and Sakurai, M., "Factory automation: the Japanese experience", *IEEE Transactions on Engineering Management*, Vol. 37 No. 2, 1990, pp. 102-8.

Further reading

Afzulpurkar, S., Huq, F. and Kurpad, M., "An alternative framework for design and implementation of cellular manufacturing", *International Journal of Operations & Production Management*, Vol. 13 No. 9, 1993, pp. 4-17.

Ferdows, K., Miller, J.G., Nakane, J. and Vollmann, T., "Evolving global manufacturing strategies: projections the 1990s", *International Journal of Operations & Production Management*, Vol. 6, 1986, pp. 6-16.

Frazelle, E., "Suggested techniques enable multi-criteria evaluation of material handling alternatives", *Industrial Engineering*, Vol. 17 No. 2, 1985, pp. 42-9.

Fry, T.D. and Smith, A.E., "FMS implementation procedure: a case study", *IIE Transactions on Industrial Engineering*, Vol. 21 No. 3, 1989, pp. 288-93.

Ghosh, B.K. and Wabalickis, R.N., "A comparative analysis for the justification of future manufacturing systems", *International Journal of Operations & Production Management*, Vol. 11 No. 9, 1991, pp. 4-23.

Hin, L.K., Leong, A.C. and Gay, R.K.L., "Selection and justification of advanced manufacturing technologies", in Sen, A., Winsor, J. and Gay, R. (Eds), *Proceedings of the 2nd International Conference on Computer Integrated Manufacturing*, World Scientific and Global Publications Services, Singapore, 1993, pp. 136-43.

Park, C. and Son, Y., "An economic evaluation model for advanced manufacturing systems", *The Engineering Economist*, Vol. 34 No. 1, 1988, pp. 1-26.

Primrose, P.L., *Investment in Manufacturing Technology*, Chapman & Hall, London, 1991.

Sambasivarao, K.V. and Deshmukh, S.G., "Strategic framework for implementing the flexible manufacturing systems in India", *International Journal of Operations & Production Management*, Vol. 14 No. 4, 1994, pp. 52-65.

Weatherall, A., *Computer Integrated Manufacturing*, Affiliated East-West Press Pvt Ltd, New Delhi, 1988.