EVA-Based Decision Model for Manufacturing Investment and Its Application

Hiroshi Katayama

EVA-BASED DECISION MODEL FOR MANUFACTURING INVESTMENT AND ITS APPLICATION

Hiroshi KATAYAMA

Department of Industrial and Management Systems Engineering,
School of Science and Engineering, Waseda University
Ohkubo 3-4-1, Shinjuku Ward, Tokyo, Japan. (post code 169-0072)
Tel. & Fax. +81-3-5286-3297
EMAIL: kata@kata.mgmt.waseda.ac.jp
HTTP://www.kata.mgmt.waseda.ac.jp/

***Keywords*:** decision support systems, economic value added (EVA), cash-flow, capital cost, stakeholder, strategic decision-making, manufacturing investment, advanced manufacturing systems (AMS), activity based cost, opportunity loss, simulation

ABSTRACT

In this paper, in order to evaluate manufacturing investment alternatives, two effective performance measures, i.e. manufacturing economic value added (M-EVA) and manufacturing market value added (M-MVA) are proposed and discussed. Their effectiveness is examined through their application to a case study, which tackles a large-scale investment problem of advanced manufacturing system (AMS), and obtained result clarified that proposed measures together with simulative evaluation method provide quantitative instrument for rational decision-making for advanced manufacturing system investment in the era of IT-oriented business environment, where the right timely decisions are critical.

INTRODUCTION

These years, many Japanese enterprises tend to implement western style of management [16], [17] such as cash flow based financial evaluation, shareholder oriented activity deployment, which become more critical due to recent electronic business environment [3], [5], [9], [15], [18]. In accordance with this trend, economic value added (EVA) is given attention as a relevant measure to evaluate management decision alternatives [8], [10]. EVA is an objective criterion of business units indicating how much amount does the annual reward exceeds the capital cost. Therefore, company can embody stakeholder-oriented decision-making by maximising this value.

On the other hand, regarding to the world emerging environmental issue, life cycle performance of manufacturing business unit such as maintainability, reparability and disposability of facility is another big issue giving positive impact to stakeholders. These performance criteria are considered as the key factors of life cycle costing (LCC) [1]. In this sense, consolidation of LCC approach to the concept of EVA -based cost evaluation is a natural extension of EVA for manufacturing activity.

Meanwhile, Katayama et al [4] proposed an evaluation model of facility investment based on net present value (NPV) method, in which opportunity cost regarding with facility idle [See expression (1)] [11], [12].

$$NPV = \sum_{n=1}^{N}(1-t_n)\{REV_n - EXP_n + DEP_n - OPP_n\}(1+r)^{-n} - INV \quad (1)$$

Notation

NPV	:Net present value	REV_n	:Revenue
DEP_n	:Depreciation cost	OPP_n	:Opportunity cost
t_n	:Tax rate	EXP_n	:Expenditure
r	:Capital cost rate	INV	:Initial investment

However, this model has following problems to overcome. Proposed EVA-based investment decision-making is for tackling these.

1) As a consequence relying on free cash flow measure, performance of the first year will be quite low, because initial investment gives strong influence on initial year.
2) Considered measure does not always compensate the capital cost of each year, as it is not intended.
3) Although investment problem of advanced manufacturing system (AMS) is kept in mind, advantage of product-mix capability is not considered.

Based on this background and focusing on economic performance evaluation of manufacturing system, this paper proposes two effective performance measures, i.e. manufacturing economic value added (M-EVA) and manufacturing market value added (M-MVA) which indicates net current EVA value of manufacturing system. Then, their effectiveness is examined through their application to a case study, which tackles a large-scale investment problem of advanced manufacturing system.

AN INVESTMENT EVALUATION MODEL

Proposed M-MVA considers, in addition to the conventional manufacturing cost issues, various opportunity costs generated by inefficient utilisation of resources such as man, machine and material related manufacturing resources [7], [14], and facility life cycle costs such as maintenance, restoration and replacement cost together [2]. The definitions of M-EVA and M-MVA are given in expressions (2) and (3) respectively.

$$M\text{-}EVA_t = NOPAT_t - COC_t \quad (2)$$

$$M\text{-}MVA_T = \sum_{t=1}^{T} M\text{-}EVA_t / (1+r)^{t-1} \quad (3)$$

$$NOPAT_t = I_t - DP_{2.t} + C^I{}_t - C^{OP}{}_t + INV_t \quad (4)$$

$$COC_t = r \cdot D_t \quad (5)$$

$$D_t = D_{t-1} - I_{t-1} \quad (6)$$

$$I_t = R_t(1 - T^C) + DP_{1.t} + L^B{}_t - INV_t \quad (7)$$

$$R_t = \sum_k P_{tk} Q_{tk} - C^{GM}{}_t - DP_{1.t} - L^B{}_t - C^I{}_t \quad (8)$$

$$C^{GM}{}_t = C^{MF}{}_t + C^{LC}{}_t \quad (9)$$

$$C^{MF}{}_t = \sum_{n=1}^{6} C_{nt} \quad (10)$$

$$C^{OP}{}_t = \sum_{n=7}^{9} C_{nt} \quad (11)$$

$$C^{LC}{}_t = \sum_{n=10}^{12} C_{nt} \quad (12)$$

Notation

$M\text{-}EVA_t$: M-EVA value at t-th term
$M\text{-}MVA_T$: M-MVA value during T-th term
$NOPAT_t$: net operational profit after tax
COC_t : capital cost
r : capital cost rate
I_t : free cash flow
$DP_{2.t}$: actual depreciation cost
$C^I{}_t$: paid interest
$C^{OP}{}_t$: opportunity cost
INV_t : new investment
D_t : indebtedness
R_t : pre-tax return for taxation
T^C : corporate tax rate
$L^B{}_t$: booked loss value
$DP_{1.t}$: planned depreciation cost based on accounting scheme
$P_{t,k}$: sales price of product k
Q_{tk} : sales quantity of product k
$C^{GM}{}_t$: total operation cost
$C^{MF}{}_t$: manufacturing cost
$C^{LC}{}_t$: facility life cycle cost
$C_{n,t}(n=1,..,6)$: manufacturing cost Items (6 types of cost: direct material cost, machine operation cost, set-up cost, transportation cost, testing cost, processing cost for defective products)
$C_{n,t}(n=7,..,9)$: opportunity cost items (3 types of cost: facility idle cost, materials/parts waiting cost, worker waiting cost)
$C_{n,t}(n=10,..,12)$: facility life cycle cost items (3 types of cost: maintenance cost, restoration cost, replacement cost)

In the following section, expected contribution of two manufacturing systems is evaluated by using these definitions.

CASE STUDY

In this section, an example of performance evaluation, that illustrates the effectiveness of the proposed procedure, is described. The purpose of this example is to show how to incorporate intangible factors in the economic evaluation process of advanced manufacturing systems by using a hidden cost estimation model proposed above. Case study, which is a typical investment decision-making of advanced manufacturing system offered by collaborated machinery company H in Japan, in which decision-maker is asked to choose more preferable system among alternatives, i.e. new candidate manufacturing system B and current system A, is carried out in terms of simulation analysis [13].

Suppose that manufacturing company is currently producing three different kinds of products, i.e. product 1, 2 and 3, each of which has different operation sequences. This manufacturing system [See Figure 1] has problem of inflexibility, which contains capability to react fluctuation of product-mix and demand quantities. Essential factor of this problem is that facility M_2 and M_3 are dedicated ones for processing product 2 and 3 respectively. To improve this inflexibility, the case company is speculating about investing more flexible manufacturing system.

The new system [See Figure 2] has two flexible machining cells FMC_1 and FMC_2 by which the operations performed by facility M_2 and M_3 separately in the current system can be performed by either one of these cells. Moreover, this new system can produce 3 more products, i.e. product 4, 5 and 6, of which demands are currently rejected due to poor capability. Thus it is anticipated that the company could preserve a certain mixture flexibility of 6 products and their volume change. This capability provides an effective hedge against demand uncertainty. However, in spite of this expected benefits, it is difficult to make a discretionary decision of whether to invest in new system or not unless the company can convert these merits into tangible terms. Thus the company should investigate the economic justification of these alternatives.

The outline of each system configuration is summarised as follows.

<Feature of system A (current system)>

1) Three products, i.e. product 1, 2 and 3, can be manufactured.
2) Facility M_2 and M_3 can process only product 2 and 3 respectively whereas facility M_1 and M_4 can process both. Therefore, job routing has some complexity.
3) Transportation of work in this system is performed by a traditional conveyer system.
4) Direct labour cost is relatively high due to some manual work.
5) Utility cost such as electricity is high level.
6) Facility breakdown occurs frequently and product yield rate is low.
7) Tool set-up time is relatively long due to manual changeover.
8) Depreciation cost is now almost negligible.
9) Maintenance related cost is relatively low.

<Feature of system B (new system)>

1) Six products, i.e. product 1, 2, 3, 4, 5 and 6, can be manufactured. Therefore, this system has product-mix superiority.
2) Facility FMC_1 and FMC_2, equivalent flexible machining cells, as well as M_1 and M_4 can process all of the

considered products with simple job routing, i.e. flow type logistics [6].
3) Transportation of work in this system is performed by automated guided vehicle (AGV) system.
4) Direct labour cost stay low level because of highly automated system.
5) Utility cost such as electricity is low level.
6) Facility breakdown rarely occurs and product yield rate is relatively high.
7) Tool set-up time is relatively short by the grace of automatic tool changer.
8) Depreciation cost is very high due to new investment.
9) Maintenance related cost is relatively high because of advanced structure.

CONDITION OF SIMULATION EXPERIMENT

Some relevant variables and parameters supposed for simulation analysis are summarised in the following description.

1) Planning horizon
The planning horizon is five-year period, and the company operates eight hours a day, five days a week and fifty-two weeks a year. Therefore, the simulation time horizon is 624,000 minutes.
2) Annual demand quantity of each product: Supposed to follow normal distribution $N(1300,100^2)$
3) Input rate of each product to manufacturing system: Suppose materials are input every average processing time of M_1, the first process, and dispatching rule in the system is first come first service scheme. Each product is processed individually, i.e. lot size is always single.
4) Processing time and set-up time of each product and facility
Machining operation time of each product by each facility and set-up time of each facility are given in Table 1 and 2 respectively.
5) Maintenance concerned data
Parameters of stochastically fluctuated data are summarised in (a)-(c) and other constants are given in Table 3.
   (a) Time between facility breakdown: Exponential distribution with mean time μ.
   M_1, M_2, M_3, M_4: μ =7,000 minutes, FMC_1, FMC_2: μ =14,000 minutes
   (b) Time duration of facility breakdown: Supposed to follow normal distribution $N(180,10^2)$
   (c) Life span of facility parts: Supposed to follow normal distribution $N(1440,150^2)$
6) Product yield rate:
   Current system (manufacturing system A): 7%
   New system (manufacturing system B): 5%
7) Initial debt: 30,000,000 Yen
8) Necessary investment for manufacturing system B: 15,000,000 Yen
9) Value of the current manufacturing system: 4,000,000 Yen
10) Capital cost rate: 4%, Corporate tax rate: 40%
11) Planned depreciation rate of facility: 10 years fixed sum.
12) Actual depreciation rate of facility: 60% annual fixed rate
13) Cost data
Cost data supposed for simulation are summarised in Table 4 to Table 11.

RESULTS AND CONSIDERATION

Simulation experiments were performed for above two manufacturing systems by using an effective object-oriented simulation package called WITNESS™. After some tedious manipulation of the developed simulator and two cases of five-year term simulation, result of each cost evaluation were obtained and these are summarised in the following tables, where Table 12 gives the result of manufacturing system A (current system) and Table 13 is of manufacturing system B (new system).
From these tables, it is revealed that manufacturing system A is unable to cover its capital cost in some years although certain level of annual reward is expected. On the contrary, through investing new advanced manufacturing system (manufacturing system B), the case manufacturing division can transform itself from negative M-MVA organisation to value creating organisation in the future five-year scope, i.e. from -1,661,000 Yen M-MVA to +2,568,000 Yen M-MVA organisation. From this outcome, considered investment alternative, i.e. system B, can be regarded as an effective choice.

CONCLUDING REMARKS

This paper proposed two effective performance measures for investment decision-making, i.e. manufacturing economic value added (M-EVA) and manufacturing market value added (M-MVA) and examined their effectiveness through case study offered by collaborated machinery company in Japan, which is tackling a large-scale investment problem of advanced manufacturing system. Obtained result clarified that proposed measures together with simulative evaluation method described in this paper provide quantitative instrument for rational decision-making for advanced manufacturing system investment in the era of IT-oriented business environment, where the right timely decisions are critical.

ACKNOWLEDGEMENTS

This research has been accomplished with the support of Waseda University Grants for Special Research Projects 2001-2002 and Grant-in-Aid for Scientific Research of Japan Society for the Promotion of Science [JSPS] and Ministry of Education, Culture, Sports, Science and Technology for 2000-2001. The author sincerely expresses deep acknowledgement to these organisations.

REFERENCES

[1] Emblemsvag, J. and Bras, B., “Method for life-cycle design cost assessments using activity-based costing and uncertainty,” *Engineering Design & Automation*, 1997, Vol. 3, No. 4, pp. 339-354.
[2] Gu, P. and Singh, D., “Product life-cycle serviceability analysis for supporting engineering design 1: activity based cost analysis of life-cycle services”, *Engineering Design &*

Automation, 1997, Vol. 3, No.3, pp. 255-274.
[3] Katayama H. and Bennett D. J., "Lean production in a changing competitive world: a Japanese perspective", *International Journal of Operations and Production Management*, 1996, 16(2), 8-23.
[4] Katayama, H., Lee, D. J., Hiraki, S. and Nakane, J., "Activity-based evaluation for manufacturing system investment -in consideration of opportunity losses-", *Proceedings of the 2nd Asia Pacific decision Science Institute Meeting*, 1998, pp. 93-95: Summary Paper Version (10 pages Full Paper Version in CD-ROM), Taipei.
[5] Katayama, H., "On selection of cost drivers for effective Activity Based Costing -An empirical approach-", *Proceedings of the 4th Asia-Pacific Decision Sciences Institute*, 1999, pp. 374-376, Shanghai.
[6] Muramatsu, R., *Foundations of Production Management- New Edition- (Shinpan – Seisan Kanri no Kiso: in Japanese)*, 1989, P. 169-191, Kunimoto Publishing Co. Ltd., Tokyo.
[7] Nakajima, S., *Introduction to TPM –Total Productive Maintenance-*, Productivity Press, Portland, OR., 1988.
[8] Park, C. S. and Kim, G. T., "An Economic Evaluation Model for Advanced Manufacturing Systems Using Activity-Based Costing", *Journal of Manufacturing Systems*, 1995, 14(6).
[9] Sakurai, M., *Management of indirect cost (Kansetsu-hi no Kanri: in Japanese)*, Chuo Keizai Sha, Tokyo., 1995.
[10] Son, Y. K. and Park, C. S., "Economic Measure of Productivity, Quality and Flexibility in Advanced Manufacturing Systems", *Journal of Manufacturing Systems* , 1987, 6(3), 193-206.
[11] Son, Y. K. and Park, C. S., "Quantifying opportunity costs associated with adding manufacturing flexibility", *International Journal of Production Research*, 1990, 28(6), 1183-1194.
[12] Son, Y. K., "A cost estimation model for advanced manufacturing system", *International Journal of Production Research*, 1991, 29(3), 441-452.
[13] Son, Y. K., "Simulation-Based Manufacturing Accounting for Modern Management", *Journal of Manufacturing Systems*, 1993, 12(5), 417-427.
[14] Suzuki, T., *New directions for TPM*, Japanese Institute of Plant Maintenance, Tokyo., 1992.
[15] Takakuwa, S., *Economic analysis of FA/CIM (FA/CIM no Keizaisei Bunseki: in Japanese)*, Chuo Keizai Sha, Tokyo., 1995.
[16] Van Breukelen, Q. H., Koolhaas, C. B. and Kumpe, T., *The Improvement Machine*, Addison Wesley/Longman, Amsterdam, 1998.
[17] Womack, J. P., Jones, D. T. and Roos, D., *The Machine that Changed the World*, Rawson Associates, New York, 1990, pp. 48-137.
[18] Yoshikawa, T., "ABC/ABM: The state of the arts (ABC/ABM no Subete: in Japanese)," *IE Review*, 1998, Vol. 39, No. 2-5, pp. 57-62, pp. 44-49, pp. 72-76, pp. 62-66.

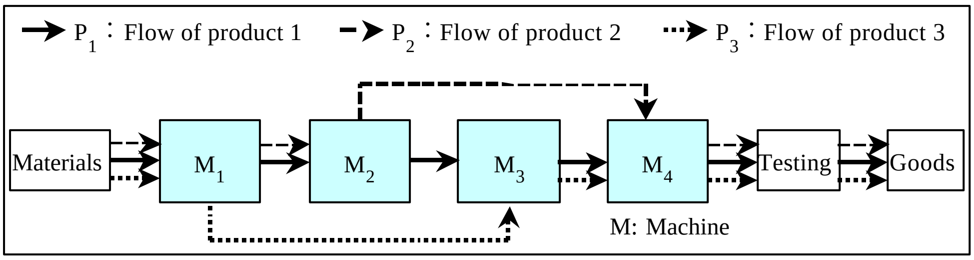

Figure 1. Routing of each product in the manufacturing system A (current system)

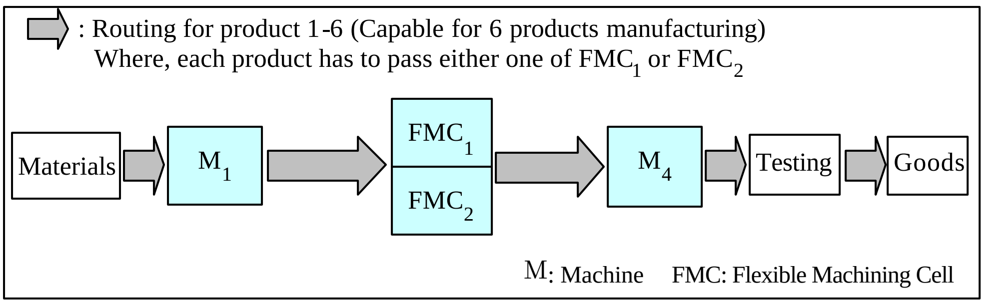

Figure 2. Routing of each product in the manufacturing system B (new system)

Table 1. Processing time matrix [min./unit]

Product \ Facility	M_1	M_2	M_3	M_4	FMC_1 FMC_2
P_1	20	25	15	10	35
P_2	15	35	-	15	30
P_3	15	-	35	20	35
P_4	15	-	-	15	35
P_5	20	-	-	15	35
P_6	20	-	-	17	35

Table 2. Processing time matrix [min./unit]

Facility	M_1	M_2	M_3	M_4	FMC_1 FMC_2
Set-up time [min./time]	1.0	2.0	2.0	1.0	0.5

Table 3. Maintenance concerned data [min./time]

Facility	M_1	M_2	M_3	M_4	FMC_1 FMC_2
Time between breakdown	7000	7000	7000	7000	14000
Time duration of breakdown	180	180	180	180	180
Time between planned maintenance	3360	3360	3360	3360	3360
Time duration of maintenance	120	120	120	120	150
Time between parts change	1440	1440	1440	1440	1440
Transportation time to	20	20	20	20	25
Parts change time	15	15	15	15	20
Facility disassemble time	3	3	3	3	5
Facility assemble time	4	4	4	4	6

Table 4. Processing cost of each facility

Facility	M_1	M_2	M_3	M_4	FMC_1 FMC_2
Machining cost [\/min.]	20	25	25	20	18
Direct labour cost [\/year]	1,000,000	1,000,000	1,000,000	1,000,000	800,000

Table 5. Direct material cost and sales price of each product

Product	P_1	P_2	P_3	P_4	P_5	P_6
Direct material cost [\/unit]	2,500	2,200	2,000	2,200	2,200	2,400
Sales price [\/unit]	10,000	9,000	9,000	90,000	10,000	9,000

Table 6. Transportation cost

Product	Forklift	AGV
Facility cost [\/m]	3	15
Labour wage [\/m]	20	0

Table 7. Set-up cost of each facility

Facility	M_1	M_2	M_3	$\mathbf{M_4}$	FMC_1 FMC_2
Jig/tool cost [\/min.]	60	60	60	60	100
Operation cost [\/min.]	40	40	40	40	50

Table 8. Set-up cost of each facility

Facility	M_1	M_2	M_3	$\mathbf{M_4}$	FMC_1 FMC_2
Labour wage [\/time]	70	70	70	70	100
Operation cost [\/time]	30	30	30	30	50

Table 9. Maintenance cost of each facility

Facility	M_1	M_2	M_3	$\mathbf{M_4}$	FMC_1 FMC_2
Jig/tool cost [\/min.]	70	70	70	70	100
Operation cost [\/min.]	30	30	30	30	50

Table 10. Repair cost of each facility

Facility	M_1	M_2	M_3	M_4	FMC_1 FMC_2
Jig/tool cost [\/min.]	100	100	100	100	120
Operation cost [\/min.]	50	50	50	50	70

Table 11. Replacement cost of each facility

Facility	M_1	M_2	M_3	M_4	FMC_1 FMC_2
Jig/tool cost [\/min.]	100	100	100	100	120
Operation cost [\/min.]	50	50	50	50	70
Parts transportation cost [\/min.]	120	120	120	120	150
Parts cost [\/time]	2000	2000	2000	2000	3000

Table 12. Result of analysis (manufacturing system A: current system) [10^3 Yen]

Term / Item	1	2	3	4	5
Sales revenue	29,653	31,891	27,485	28,226	28,244
Manufacturing cost	22,169	22,715	20,687	21,054	21,042
Facility life cycle cost	1,654	2,203	2,097	1,743	2,128
Total opportunity cost	1,775	847	955	3,104	1,584
Free cash flow	3,258	3,854	2,685	3,281	3,176
NOPAT	1,124	2,840	1,663	205	1,649
Capital cost	2,400	2,139	1,831	1,616	1,354
M-EVA	-1,276	701	-168	-1,412	295
M-MVA	-1,661				

Table 13. Result of analysis (manufacturing system B: new system) [10^3 Yen]

Item \ Term	1	2	3	4	5
Sales revenue	30,877	29,616	32,091	28,604	28,395
Manufacturing cost	21,294	19,713	21,546	21,288	20,707
Facility life cycle cost	2,412	2,349	2,402	2,159	2,374
Total opportunity cost	317	242	308	172	200
Free cash flow	-7,900	4,463	4,924	3,250	3,422
NOPAT	4,113	2,665	3,513	2,281	2,695
Capital cost	2,400	3,032	2,675	2,281	2,021
M-EVA	1,713	-367	838	0	674
M-MVA	2,568				