

# EVA-BASED DECISION MODEL FOR MANUFACTURING INVESTMENT AND ITS APPLICATION

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## 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.

$$M\text{EVA}_i = NOPAT_i - COC_i \quad (2)$$

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

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

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

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

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

$$R_t = \sum_k P_{tk} Q_{tk} - C_t^{GM} - DP_{1,t} - L_t^B - C_t^I \quad (8)$$

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

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

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

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

### Notation

$M-EVA_t$	: M-EVA value at $t$ -th term
$M-MVA_T$	: 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
$C_t^I$	: paid interest
$C_t^{OP}$	: opportunity cost
$INV_t$	: new investment
$D_t$	: indebtedness
$R_t$	: pre-tax return for taxation
$T^C$	: corporate tax rate
$L_t^B$	: 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 $k$
$C_t^{GM}$	: total operation cost
$C_t^{MF}$	: manufacturing cost
$C_t^{LC}$	: facility life cycle cost
$C_{n,t}(n=1, \dots, 6)$	: 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)
$C_{n,t}(n=7, \dots, 9)$	: opportunity cost items (3 types of cost: facility idle cost, materials/parts waiting cost, worker waiting cost)
$C_{n,t}(n=10, \dots, 12)$	: 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 conveyor 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  $\mu$ .  
 $M_1, M_2, M_3, M_4: \mu = 7,000$  minutes,  $FMC_1, FMC_2: \mu = 14,000$  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<sup>TM</sup>. 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.

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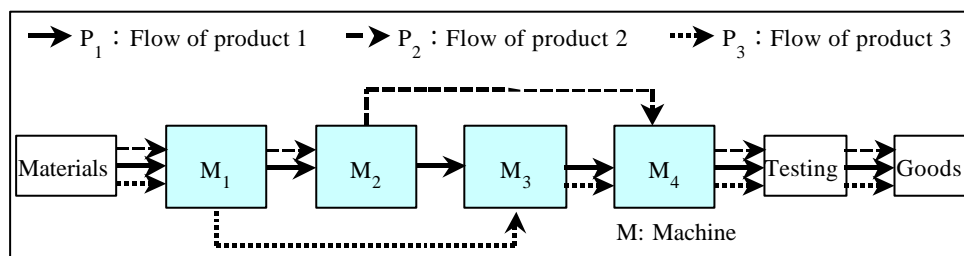


Figure 1. Routing of each product in the manufacturing system A (current system)

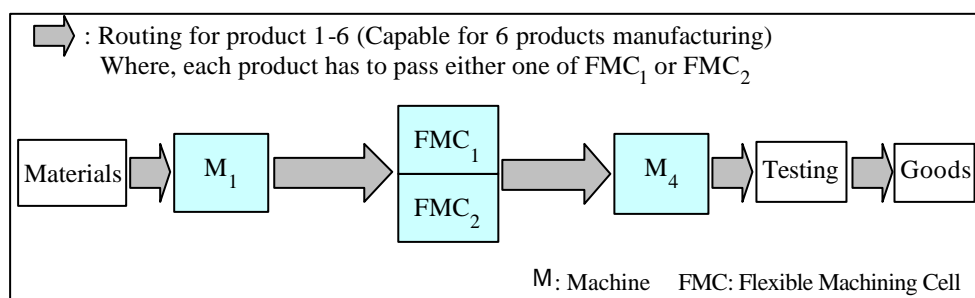


Figure 2. Routing of each product in the manufacturing system B (new system)

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

Product \ Facility	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
P <sub>1</sub>	20	25	15	10	35
P <sub>2</sub>	15	35	-	15	30
P <sub>3</sub>	15	-	35	20	35
P <sub>4</sub>	15	-	-	15	35
P <sub>5</sub>	20	-	-	15	35
P <sub>6</sub>	20	-	-	17	35

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

Facility	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
Set-up time [min./time]	1.0	2.0	2.0	1.0	0.5

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

Facility	M <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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 <sub>1</sub>	P <sub>2</sub>	P <sub>3</sub>	P <sub>4</sub>	P <sub>5</sub>	P <sub>6</sub>
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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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 <sub>1</sub>	M <sub>2</sub>	M <sub>3</sub>	M <sub>4</sub>	FMC <sub>1</sub> FMC <sub>2</sub>
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]

Item	Term	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				