The Real Options for Adaptability to Environmental Change in Enterprise Resource Planning Systems

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Abstract— This paper discusses the options for adaptability to environmental change inherent in enterprise resource planning (ERP) systems, the value of these options, and methods to asses the ERP value.

The first point of discussion is the issue of ascertaining the effectiveness of ERP, an underlying asset. We divide the effectiveness into two types—effectiveness in actually generating cash and effectiveness confined to opportunity cost reduction—and propose a method for calculating the ERP value effective in generating cash. In this paper, we provide as Case Study 1 a specific proposal for ascertaining effectiveness through the valuation of ERP introduction and of the Electronic Data Interchange (EDI) function realizable as a result of ERP introduction.

The second point of discussion is the valuation of information systems in the context of business acquisition and divestiture. Although business acquisition and divestiture is another unavoidable topic for corporate management, information system valuation has not been discussed in that context. We present a valuation method for the purpose of including information systems in divestment value, something not considered heretofore, to reveal the potential value of information systems in corporate management. In Case Study 2, we take up the divestiture of a certain business site. Calculation of the market price of an information system in such circumstances indicates the practicality and effectiveness of applying option valuation to information systems.

Keywords— ERP system development, investment valuation, opportunity cost, real options

I. INTRODUCTION

A. Economic Efficiency

PREVIOUSLY, evaluation of the economic efficiency of information system investments was often performed using the payback period method. In a management environment that requires the effective utilization of capital, however, evaluation using the Net Present Value (NPV) method is becoming increasingly prevalent. However, in cases of investment in software platforms that become the infrastructure for systems such as ERP, there are times when approval for project commencement cannot be obtained when the evaluation is performed using the NPV method. This is because only effectiveness as a solution to immediate problems is assessed, and adaptability to future changes in the information systems environment is excluded from evaluation. We believe that to fairly assess the value of a software platform, evaluation must take into account the value of applications that may be implemented on the platform in the future, the flexibility to cope with application expansion, contraction, and splitting, and the effects on operation.

Table 1 shows the possible options and their descriptions and the conditions in which the adaptability to environmental change inherent in information systems is considered an option.

Table 1   options in information system investments

Options	Description / Conditions
Defer	The right to make an investment provided the environment is in place.
	Investment opportunities will exist in the future. Even if the organization waits, it will not incur a competitive disadvantage.
Expand Contract	The right to expand investment after the initial investment. The right to contract project scale by means of the initial investment.
	Splitting of the development project is possible. The time of recovery of the initial investment is delayed. A payoff increase (loss decrease) or operating expense contraction is expected due to expansion (contraction) of the project scope or scale.
Split	The right to minimize damage in the event development fails.
	Splitting or parallel operation at the development stage is possible. Work on highly risky portions can begin first.
Explore	The right to invest provided the results are favorable.
	Operation limited in scope is possible. Development using a portion of the assets required for full-scale investment is possible. Risk can be ascertained. There is no impact on operations even if development is discontinued.
Abandon	The right to obtain liquidation value through discontinuation of the project.
	An alternate proposal exists. Discontinuation will result in no major damage to competitive position or external reputation.
Compound	Two or more of the above options are combined and affect each other.

B. Previous Research on Option Valuation

Since the 1990s, a number of studies have been published that consider the adaptability to environmental change inherent in

information systems as an option and assess its value.

The first such study was by Dos Santos, who discussed the experimental adoption of an advanced technology. Dos Santos proposed adding the value of subsequent projects that adopt the technology as an option value to the original experimental adoption [1].

Panayi and Trigeorgis applied growth (expansion) options to IT investments at a telecommunications company and performed analyses [2].Kambil, Henderson and Mohsenzadeh, taking as an example the introduction of handheld computers at a municipal hospital, asserted that the value of subsequent full-scale implementation is an option included in the experimental introduction project [3].

Amram and Kulatilaka discussed Internet sales of mortgage-backed securities and analyzed the expansion option value included in the introduction of an image processing system as a first-stage infrastructure [4].

Benaroch and Kauffman elucidated the defer option problems [Is "problems" adequate? Isn't "issues" better?] in connection with the timing of deployment of a POS debit card service by a VAN operator in New England [5].

Billington, Johnson and Triantis analyzed the supply chain strategy of Hewlett-Packard from a real options perspective [6].

Taudes et al. formulated the value of software platforms such as ERP as follows [7].

$$
\left.
\begin{array}{l}
\text{Value of a software platform} \\
= \text{NPV of fixed application portfolio} \\
+ \text{Option value of implementation opportunities}
\end{array}
\right\} \quad (1)
$$

In this study, Taudes et al. took the payroll reduction resulting from user productivity enhancement as the principal factor of the first term on the right-hand side of (1), took EDI (Electronic Data Interchange) with customers or parts suppliers that have ERP systems as the second term on the right-hand side of (1), and performed valuation as the option to cope with expansion. They formulated the effect of EDI, the underlying asset of the option, as follows:

$$ Pt = Nt \cdot b \qquad (2) $$

where, Pt is the application effect in period t, Nt is the number of transactions processed by the application in question during period t, and b is the cost reduction amount per transaction. That is, in previous research, the underlying asset value of the option to cope with expansion was regarded as simply the accumulation of cost reduction effects resulting from EDI transactions.

II. ISSUES IN ECONOMIC EFFICIENCY EVALUATION

A. Avoidance of the Mixture of Two Effects

As shown in the study by Taudes [7] in effects calculation for software platforms such as ERP, ordinarily the cost reduction amount resulting from user productivity improvement is calculated. In the case of Taudes [7], the value for user productivity improvement is estimated at 2%, and the annual effect is calculated at $240,000 on the basis of an average worker salary of $80,000. Also, Taudes [7] describe that empirical support for (2) is provided by Mukhopadhyay [8] who study the benefits obtained by Chrysler through introducing EDI-based purchasing. In each case, the mixing of cash generation effects and opportunity cost reduction effects can be considered a problem. We believe that to solve this problem, it is necessary in information system valuation to eliminate the effects confined to opportunity cost reduction and propose a more objective valuation method.

In this paper, in Case Study 1 we attempt to solve the issue through valuation of ERP introduction and of the EDI function realizable as a result of ERP introduction. This analysis is similar to Taudes [7] .

B. Valuation of Information Systems in the Buying and Selling of Businesses

While the acquisition and divestiture of businesses is not an everyday occurrence, it is by no means unusual in today's corporate management environment. Nevertheless, information system valuation has not been discussed in previous research. This is because the value of information systems has not been a subject for discussion in negotiations. To reveal the potential value of information systems in corporate management, it is necessary to propose a valuation method for including information systems in the divestment value.
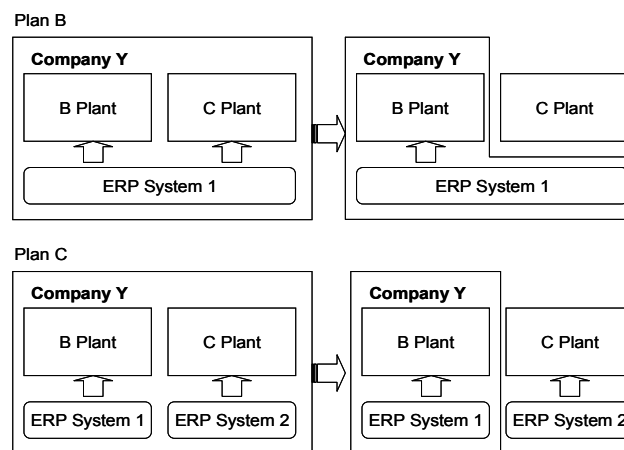

Fig. 1 structures of the systems

In Case Study 2, we discuss the divestiture of a certain business site. As shown in Plan B of Fig. 1, when one set of information systems covers multiple business sites, tasks associated with systems separation arise at the time of business site divestiture. In contrast, as shown in Plan C of Fig. 1, if the business site to be divested has an independent system, it becomes possible to recover the systems construction cost, which increases by alternatives available in negotiations. In

addition, calculation of the market price in this type of situation shows the feasibility and effectiveness of applying option valuation to information systems.

III. CASE STUDY 1 (ELIMINATION OF OPPORTUNITY COST REDUCTION EFFECTS IN ASSESSMENT OF UNDERLYING ASSET VALUE)

We discuss in this paper a method for eliminating the effects confined to opportunity cost reduction and actually ascertaining the cash generation effects in information system valuation. We extract quantifiable factors from the improvement effects on routine work, which include many qualitative factors, and summarize those factors in the inventory reduction amount, and ascertain the cash flow improvement amount. We use ¥1,000,000 as the monetary unit in Sections 3 and 4, including the amounts shown in the tables.

A. ERP Introduction in Response to Manufacturing Line Expansion

Company X, a manufacturer of machine parts, considered introduction of an ERP system on the occasion of manufacturing line expansion at its A Plant. Although the direct impetus for consideration was the existing computer's incapacity to accommodate an increase in the number of terminals used for the issuance of work instructions to the plant floor or data collection, the context was the desire for lead time reduction for the plant overall. Tables 2- 3 show the estimated introduction costs and development costs.

We verify the value of this project. Increased costs occurring if the company continues use of the existing system are costs associated with a personnel increase (1 person) related to data handling on the additional line and a decrease in productivity resulting from manual processing. Using a work analysis technique applied heretofore, we estimate the decrease in productivity (x percent), calculate the resulting increase in work hours (y hours), and calculate the increase in payroll (z yen) by multiplying the work hours by the average salary. We calculate the amount of payroll reduction to be obtained from the avoidance of increased costs to result from ERP introduction and, furthermore, from a productivity increase to be achieved by the application of ERP to existing manufacturing lines. We consider those figures as the effects of ERP introduction. With this calculation method, opportunity cost reduction factors are included in the effects. These factors include employment costs that cannot be cut, the avoidance of cost increases from factors such as response deterioration attributable to an increase in transactions, and increased productivity due to lower error

frequency resulting from the simplification of data processing.

Table 2   installation expenses for the A Plant

Item	Amount
Server & OS	18.6
Design & Development	19.0
Vendor's Support	36.0
ERP Licenses	28.0
Training	24.0
Data Migration	5.6
Total	**131.2**

Table 3   annual ongoing expenses for the A Plant

Items	ERP	Present
Maintenance/Server & OS	0.3	0.3
Maintenance/Terminals	0.3	0.2
Maintenance/ERP	5.6	0.0
Operations	3.0	3.0
Total	**9.2**	**3.5**

Taking a different approach, we eliminate the effects confined to opportunity cost reduction in the information system valuation and attempt a more objective valuation method (refer to Fig. 2). We first perform a work analysis that includes the additional manufacturing line and then prepare a post-system introduction workflow. We extract the quantitative effects by comparing the two workflows, identifying improvements, and performing a numerical evaluation. At this stage, we calculate personnel cost reduction and logistics cost reduction which will be realized by improving working processes.   (Fig. 2 (1) and (2)). We also analyze and break down items confined to qualitative effects and identify quantifiable components (quantification of qualitative effects). In this case, first, manufacturing lead time is reduced due to automation of data receipt and delivery. We further break this result down into lead time reduction in planning, parts procurement, manufacturing, and delivery. We narrow down ascertainment of the resulting effects to the amount of decrease in parts on the shop floor and finished goods and calculate it as the monetary value of improvement in the capital turnover ratio (Fig. 2 (3)). We further identify additional logistics cost reductions (Fig. 2 (4)) and payroll reductions (Fig. 2 (5)) as the results of indirect work improvement.
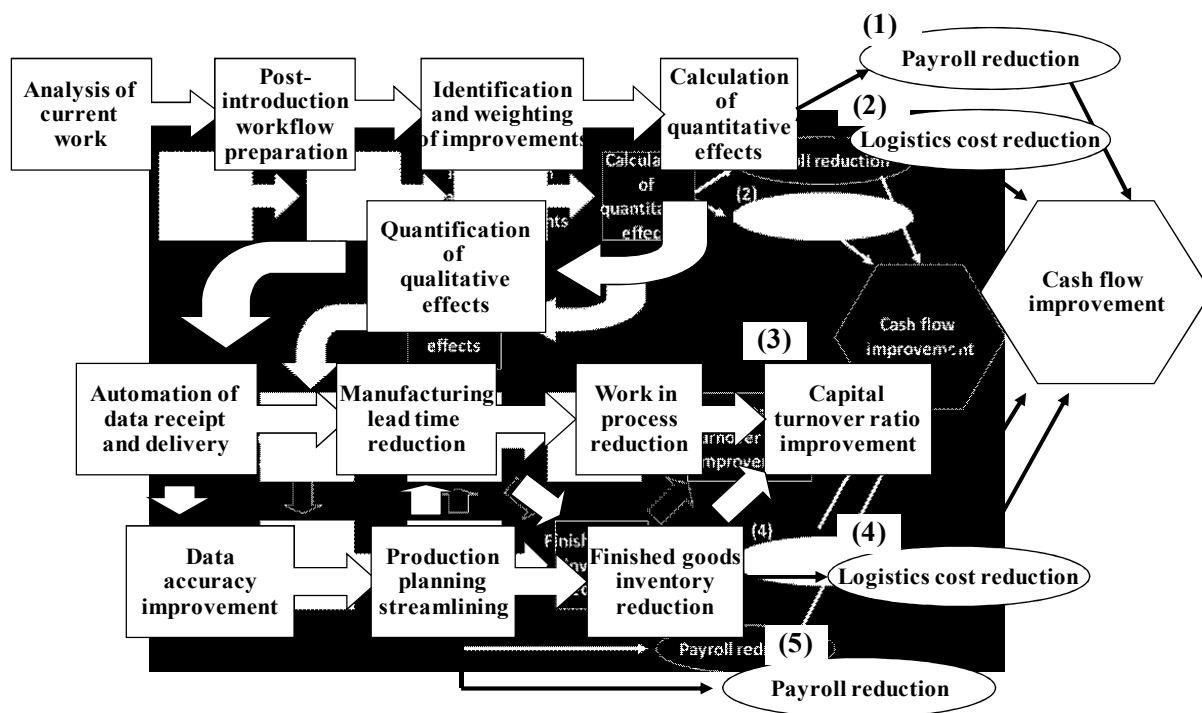
Fig. 2   evaluating value of ERP system processes

Through the above analysis, the increase in inventory (the total of component parts, work in process, finished goods) caused by a manual processing attendant on manufacturing line expansion, due to a decrease in logistics speed, was estimated at 15%. It is assumed that this cost increase can be avoided by ERP introduction, and the effect of this is shown in (3). Table 4 shows the figures for sales and inventory values based on this calculation.

Annual Effect
  = Inventory amount × Rate of decrease × Interest rate
    + Employment cost × Number of redundancies

$$\text{(3)}$$

Substitution into this equation of the figures for VIII and IX in Table 4, a 15% rate of increase, and an interest rate of 4% results in:

$$1377 \times 0.15 \times 0.04 + 7.5 \times 1 = 15.8 \ . \tag{4}$$

Furthermore, since the ERP system will also cover all indirect work on the current lines, effects on those lines can also be expected. Reductions of two employees and 5% of the total finished goods inventory resulting from streamlining of production control and shipping processing were estimated. These effects, too, were calculated using (3). Substitution into (3) with the figures in IV and IX in Table 4, a 5% rate of decrease, a reduction of two employees, and an interest rate of 4% results in:

Table 4   items for the evaluation

	Item	Amount	Remarks
I	Annual sales	36,000	Actual + Planned value of the additional line portion
II	Cost of sales	30,600	Cost ratio of 0.85
III	Inventory	5,508	Actual + Planned value of the additional line portion 18% of cost of sales (actual value)
IV	Finished goods	1,267	23% of inventory
V	Component parts inventory	165	3% of inventory
VI	Work in process	4,076	74% of inventory
VII	Sales from the additional line	9,000	Planned value
VIII	Inventory from the additional line	1,377	Application of 18% of the actual value of the proportion of cost of sales
IX	employment cost	7.5	Actual value Per person

$$1267 \times 0.05 \times 0.04 + 7.5 \times 2 = 17.5 \tag{5}$$

The value of this ERP introduction project calculated according to the NPV method is shown using

$$\sum_{n=1}^{n} \frac{\text{annual effect} - \text{increase of annual operation}}{(1 + \text{interest rate})^n}$$
$$- \text{Initial investment} \tag{6}$$

Insertion into (6) of the values from (4) and (5) (annual effect), the difference in the total amount in Table 3 (annual operational cost increase), the total initial investment amount in Table 2, n= 5, and an interest rate of 0.04 results in an NPV for the ERP introduction of

$$\sum_{n=1}^{5} \frac{((15.8 + 17.5) - (9.2 - 3.5))}{(1 + 0.04)^{n}} - 131.2 = -8.3 \qquad (7)$$

When the target investment recovery according to Company X internal regulations is n= 5, the initial investment and increased costs cannot be recovered. This result is attributable to the fact that "Option value of implementation opportunities," the second term on the right-hand side of Formula (1), is not assessed. We next verify how valuation of this project changes if a corporate strategy involving utilization of the EDI function of ERP is adopted.

B. Effects of EDI

We calculate the effects of EDI. Here we once again use the process applied to calculate the value of ERP introduction. Through this calculation, the following effects were confirmed.
(a) Reduction in payroll due to a decrease in labor hours for data input, etc.
(b) Reduction in logistics costs, including warehouse costs and emergency transportation costs, due to shortening of manufacturing lead time
(c) Reduction in inventory (finished goods, component parts, and work in process) of related products due to factors including shortening of lead time from data input to product shipment

There are two types of EDI systems: systems for which the other parties to data exchange are customers and systems for which they are suppliers. Table 5 shows the amounts of effects for each type of the system.

Table 5   effects of the EDI system

	Item	Customer EDI	Supplier EDI
(a)	Payroll	7.5	3.7
(b)	Logistics	3.0	0
(c)	Finished Goods	126.7	0
	Component Parts	16.5	16.5
	Work in Process	407.6	203.8

The five year cumulative effect on cash flow, Ve, is calculated using the formula:

$$Ve = \sum_{n=1+t}^{5+t} \frac{(I \times \alpha \cdot r + P + L)}{(1 + r)^{n}} \qquad (8)$$

where t is the period from ERP operation to the start of EDI, α is the ratio of products covered by EDI, r is the interest rate (0.04), I is the inventory reduction amount, P is the payroll reduction amount, and L is the logistics cost reduction amount.

We insert the figures from Table 5 4 into (8) and calculate

Vc, the current value of the effects of a customer EDI system. Taking t= 1 and α= 0.6, the result is

$$Vc = \sum_{n=1+1}^{5+1} \frac{(550.8 \times 0.6 \times 0.04 + 7.5 + 3)}{(1 + 0.04)^{n}} = 101.5 \qquad (9)$$

Similarly, we calculate Vc, the current value of the effects of a supplier EDI system. Taking t = 2 and α = 0.7, the result is

$$Vs = \sum_{n=1+2}^{5+2} \frac{((16.5 + 203.8) \times 0.7 \times 0.04 + 3.7)}{(1 + 0.04)^{n}} = 40.6 \qquad (10)$$

The introduction cost is estimated as 10.1 for a customer EDI system and 3.7 for a supplier EDI system, and the NPV of EDI introduction is as follows:

$$\text{NPV of EDI} = (Vc - 10.1) + (Vs - 3.7) = 128.3 \qquad (11)$$

C. Valuation of the EDI Option

In this case study, we calculated that an EDI introduction realizes (a) payroll reduction and (b) logistics cost reduction, and also promotes improvement in routine work, which leads to (c) inventory reduction. We ultimately calculated the effect on cash flow. Through this process, the effects confined to qualitative effects are eliminated and the value of systems is ascertained as an objective amount. In other words, the mixing of the actual cost reduction and opportunity cost reduction is avoided. Also, the values derived in that calculation are the commitments of each department and can be used in after-the-fact verification.

Previous research assumed that EDI introduction projects were securitized and subject to market transactions and assessed a project value including that premium. However, equation (11) shows that this is unnecessary and that it is meaningful to actualize and utilize the EDI function. It is important that management establish a corporate strategy that enables the exercise of the EDI option and that involved departments act accordingly.

IV. CASE STUDY 2   (A VALUATION METHOD TO INCLUDE INFORMATION SYSTEM DIVESTMENT VALUE)

In this section, we propose a valuation method to include information systems in the divestment value, something not considered previously.

A. System Construction Options

Company X, discussed in the previous section, has acquired Company Y. It's information system uses independently developed software run on a mainframe and covers the headquarters plant (B Plant) and one other plant (C Plant).

The following three options for the design of an information system to serve as an implementation tool in a project to incorporate Company Y into Company X's global structure can be considered. (See Fig. 3.)

Plan A: Make improvements based on Company Y's existing

system.

Plan B: Scrap Company Y's existing system and develop a new system to cover both the B Plant and C Plant.

Plan C: Scrap Company Y's system as well, but introduce separate systems at the two plants.
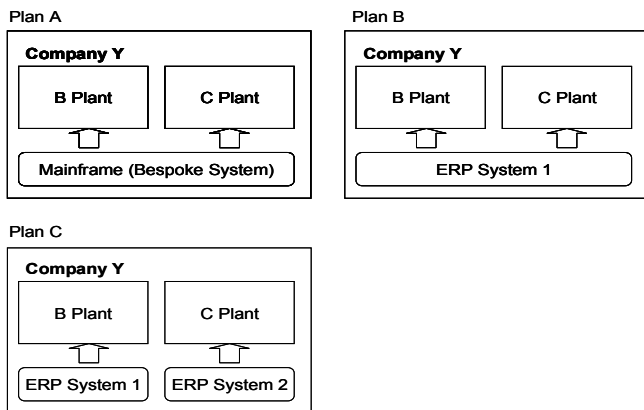

Fig. 3 plans for restructuring the information system

Table 6 shows the initial investment amounts, annual operational costs, and effects amount for the five-year period from the start of operation for each of the three plans. Plans A is advantageous from a cost perspective, however it was abandoned because it doesn't conform to Company X's policy of global unification of production management systems.

The management of Company X's European operation was unable to eradicate a sense of uncertainty concerning the future of the acquired C Plant and began to consider divesting C Plant under certain circumstances. Plan C was prepared as a result of that consideration.

Table 6 development estimations

Plan	A	B	C
Initial Investment	569	1212	1496
Annual Expenses	161	105	162
Effects	2772	2772	2772

.

B. Valuation of the Contraction Option

Equation (12) shows the value of Plans B and C.

$$V = E + \sum_{⊞=1}^{5} \frac{(⊞ - ⊞)}{(1 + ⊞)^{⊞}} - I \qquad (12)$$

Here, E is the cumulative effects amount, A is the annual operational cost of Plan A, O is the annual operational cost of the plan under evaluation, r is the interest rate, and I is the initial investment for the plan under evaluation.

Substitution figures of Plan B in Table 6 into (11) results in

$$3208 - 436 + \sum_{⊞=1}^{5} \frac{(161 - 105)}{(1 + 0.04)^{⊞}} - 1212 = 1808 \qquad (13)$$

Substitution figures of Plan C in Table 4 into (11) results in

$$3208 - 436 + \sum_{⊞=1}^{5} \frac{(161 - 162)}{(1 + 0.04)^{⊞}} - 1496 = 1271 \qquad (14)$$

The value is only approximately 70% of that of Plan B in (13). However, Plan C entails the benefit that the development cost of the C Plant information system could be recovered in the event the plant is divested. The development cost of the C Plant system was estimated at 496 .

We perform valuation of the options inherent in Plan C. If a bond for Plan C were issued, it would be a bond with a principal of 1496 , maturity of five years, and the possibility of a return of 496 at a certain period in time. We use the Black-Scholes method in Formula (15) in the calculation of financial options to calculate the valuation of such a bond if it were traded on the market.

$$P = -SN(-d_1) + X e^{-rT} N(-d_2)$$
$$d_1 = (⊞⊞\left(\frac{⊞}{⊞}\right) + \left(⊞ + \frac{⊞^2}{2}\right)⊞) / ⊞\sqrt{⊞} \qquad (15)$$
$$d_2 = d_1 - ⊞\sqrt{⊞}$$

where P is the option premium, S is the underlying asset (system development cost), X is the recovery amount, T is the option period, r is the safe interest rate, σ is volatility, and $N(-d_1)$) and $N(-d_2)$ are the cumulative probability.

Volatility (σ) in this case is the uncertainty with respect to the conclusion of negotiations to divest the plant. Calculation taking σ as 50%, 70%, and 90%, T as 3, 4, and 5 years, and r as 4% results in the premium values shown in Table 7.

Table 7 evaluation of contract options

T	50%	70%	90%
3	23.5	71.6	131.0
4	35.8	95.8	162.8
5	47.2	115.4	186.5

.

At the same time, in the event of development of a system according to Plan B and the divestiture of C Plant, the task of extracting data for the C Plant from the system and transferring it to the acquiring party would occur. We estimate the cost of this as 50 and compare the change in the values of the two plans. The value of Plan B, V_B, and the value of Plan C, V_C, are shown in the following equations:

$$V_B = V_{Bg} - \frac{⊞}{(1 + ⊞)^{⊞}} \qquad (16)$$

$$V_C = V_{Cg} + P + \frac{X}{(1 + ⊞)^{⊞}} + \sum_{⊞=⊞+1}^{5} \frac{(16.1 - 10.5)}{(1 + ⊞)^{⊞}} \qquad (17)$$

where V_{Bg} is the value in (13), D is the data transfer cost, V_{Cg}

is the value in (14), P is the option premium, X is the recovery amount, T is the period from system development to divestiture, and r is the safe interest rate. Also, the fourth term on the right-hand side of (17) is a term that factors in the post-transfer operating cost reduction.

Table 8 shows a comparison of the two plans when the volatility is set at 0.7 in view of the prospects for the successful conclusion of negotiations.

In the event that C Plant is transferred, it is confirmed that Plan C is more advantageous when $\sigma = 0.7$. It is also clear that quickly realizing the plan would be advantageous from the standpoint of operating cost reduction.

Table 8   values of the contract options

T	3	4	5
V_B	1763.7	1765.3	1766.9
V_C	1877.4	1836.8	1794.1

In this case study, we performed valuation of the options inherent in an information system in the circumstances of divestiture of a business. Previously, in negotiations for the buying and selling of businesses in the manufacturing industry, the major subjects of discussion have been people (the number and quality of employees), assets (buildings and facilities), money (financial circumstances), and technological capabilities. The subject of information systems has not been addressed.

As we have mentioned, the previous research has not covered information systems in such situation. This is attributable to the fact that participation in negotiations by people who understand the value of information systems has been uncommon due to the restrictions applying to people involved in negotiations that are not publicly disclosed until an agreement is concluded. Looking at the situation from the opposite direction, this shows that few ordinary business managers are aware of information systems.

Issues raised in negotiations heretofore are human assets, fixed assets, financial assets, and technological assets. The inclusion of information systems among the matters for consideration will contribute to informing managers of the impact on the corporate value of the value of information systems and changes in that value over time. Furthermore, information systems have the potential of becoming a new source of information for use in reaching acquisition and investment decisions. (See Fig. 4) The inclusion of information systems among matters for consideration will also contribute to recognition of the value of information systems among managers and users in ordinary circumstances.
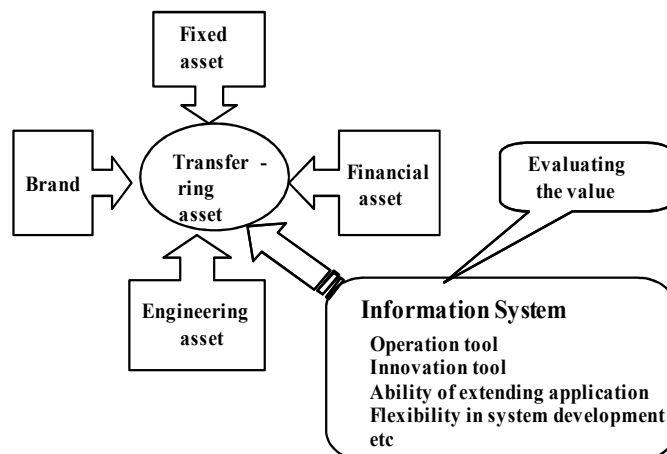

Fig. 4   a new perspective of asset evaluation

V．CONCLUSIONS

We discussed the need to ascertain the adaptability to environmental change inherent in information systems as investment options in order to fairly value information system investments.

In the first point of discussion (Case 1), we divided the effectiveness into two types—effectiveness in actually generating cash and effectiveness confined to opportunity cost reduction—and proposed a method for calculating the ERP value effective in generating cash.

In the second point of discussion (Case 2) is the valuation of information systems in the context of business acquisition and divestiture. We presented a valuation method for the purpose of including information systems in divestment value, something not considered heretofore, to reveal the potential value of information systems in corporate management.

In Case 1, it is difficult to verify the validity of ERP system introduction because of the broad scope of application of the ERP system introduction discussed. However, we think that if all effects are concentrated into inventory reduction and limited to the cash flow improvement effect, the direction for system development becomes clear. With regard to option valuation of the EDI function inherent in the ERP system, the mixing of actual cost reduction and opportunity cost reduction can be avoided using a similar approach.

In Case 2, we calculated the value of an information system as a disposal option, taking into account the uncertainty surrounding the business divestiture. In information system option valuation, ordinarily securitization of the investment option and trading on the market is assumed and valuation is performed using a binominal model or the Black-Scholes method. In situations such as this, including information systems among the assets for divestment in the securitization assumption is realistic and indicative of the effectiveness of option valuation.

Examination of previous research including Taudes [7] shows that the great majority of studies evaluate software platform expandability as the "option value of implementation

opportunities." Considering the current corporate management environment, this approach alone is insufficient; it is necessary to develop an information system valuation method focused on the potential for personnel reduction.

We will try in new case study, assessing the information system value by focusing on potential personnel reductions will be achievable through the development of a new information system.

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