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# Renovation of an IT Infrastructure and its POC Analysis

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## ABSTRACT

*In recent years the evolution of highly developed and complicated computerization has boosted the importance to business of IT infrastructure. Enhancement of business agility is not possible unless greater flexibility is built into IT infrastructure. More often than not, MIS's today are not flexible enough in this sense to agilely accommodate demands for system change incessantly confronting them.*

*We have been concentrating our research on MIS flexibility, its evaluation and the development of methodology for its enhancement. This paper aims to present a comparative evaluation via* POC *(penalty of change) analysis of system alternatives involving a case of renovation of IT infrastructure. To start with, we will define the concept of MIS flexibility. We will then describe an actual case of renovation of IT infrastructure and define the problem it involved and go on to illustrate the evaluation of MIS flexibility via* POC *analysis.*

## INTRODUCTION

In recent years the evolution of highly developed and complicated computerization has boosted the importance to business of IT infrastructure. Enhancement of business agility is not possible unless greater flexibility is built into IT infrastructure. More often than not, MIS's today are not flexible enough in this sense to agilely accommodate demands for system change incessantly confronting them.

We have been concentrating our research on MIS flexibility, its evaluation and the development of methodology for its enhancement. This paper aims to present a comparative evaluation via *POC* (penalty of change) analysis of system alternatives involving a case of renovation of IT infrastructure. To start with, we will define the concept of MIS flexibility. We will then describe an actual technology implementation and define the problem it involved and go on to illustrate the evaluation of MIS flexibility via *POC* analysis, enumerating project risks accompanying the technology implementation.

## OVERVIEW OF THE POC ANALYSIS

### POC as a Substitute Index of MIS Flexibility

For the present purpose, let us draw on the definition of MIS flexibility and the scheme for its evaluation that we proposed in Furukawa (2001a, 2001b) as the following.

Agile management cannot be realized unless well-renovated IT infrastructure guarantees maximally efficient implementation of MIS change at a minimal cost and in a minimal time. The business value of an MIS (hereafter to be referred to as MIS value for short) is generated by the use process of an application function working on IT infrastructure (Hamillton, 1981). Then MIS value (V) might be represented by the following formula:

$$V = \frac{f(F,U)}{g(C,T)} ‰ \quad (1)$$

where *C*, *T*, *F* and *U* stand for cost, time, function and use, respectively. Incidentally, Johanson et al (1993) defines MIS value in terms of quality, service, cost and cycle- time.

As regards the evaluation of MIS effectiveness, methods traditionally utilized have been, in the classification of cost/benefit methodology, "Total Quantification with Qualitative analysis (JIPDC, 1981)", "Information Economics" and "Contribution to Corporate Performance" (Utunomiya, 1993; Myer, 1989). But perception and use of a particular information system can be heavily conditioned by personal and situational variables (Lucas, 1974). This fact in particular makes it difficult to evaluate MIS effectiveness quantitatively. Deemed relatively reliable for this purpose, however, are the following five measures: "High levels of system use", "User satisfaction with the system", "Favorable attitudes about MIS function", "Achievement of objectives", "Financial payoff" (Laudon, 2000). In fact, many MIS researchers have shifted their focus to the human and organizational measures of system success such as information quality, system quality, and the impact of systems on organizational performance (DeLone, 1992).

These evaluation methods or criteria focus on the numerator of formula (1), which in effect represents the MIS use process, *i.e.* how easily adaptable an MIS is for the user. Quick use of an adapted MIS enables a) quick recognition of an environment change, and b) quick decision-making on countermeasures against the change. However, for all the research efforts on this adaptability, we know of no established methods that an organization could use to maximize above-mentioned six kinds of MIS value.

On the other hand, c) quick implementation of countermeasures chosen to cope with environmental changes involves change of an MIS itself. These days MISs are growing increasingly large in scale, as are the demands for modification of existing ones to cope with incessant changes inside and outside organizations. Unfortunately, however, we have no systematized methods we can turn to for minimizing the cost and time required to meet change demands, *i.e.* the denominator of formula (1). We hear of many cases of MIS implementation that have met with troubles such as failure to deliver by the due date, excess over an estimate, productivity deterioration (increases in backlogs), malfunctioning (activity inability, operational inability, increases in bugs), system failure (failure of a system to be used as intended). All this shows that no reliable methods have been established to estimate or predict the denominator of formula (1), *i.e.* the cost and time required for MIS implementation and in the use process.

Therefore, let us postulate MIS flexibility as an ability to absorb future change demands on an MIS, and let us express it formulaically with (1):

$$Flex = \frac{Const}{g(C,T)} = \frac{1}{POC} \quad (2)$$

where C and T stand for cost and time, respectively.

Formula (1) suggests that *POC* can serve as a substitute index for quantitative evaluation of the flexibility of an MIS. It also obviously shows the following relationship between MIS flexibility and *POC*:

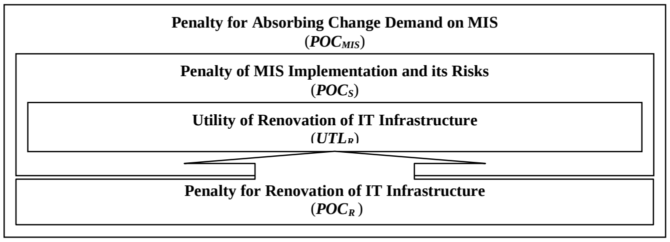
- If *POC* is high, MIS flexibility is low.
- If *POC* is low, MIS flexibility is high.

*POC* can serve as an index for measurement of the ability to absorb future demands for MIS change and can be accounted for in terms of cost and time.

### Structure of MIS Flexibility

As detailed in a relevant section in Furukawa 2001b, a moderate renova-

*Figure 1: Structure of MIS Flexibility*




tion of IT infrastructure can contribute to greater ease and efficiency of MIS modification [**utility of renovation**].

We know from experience that modification of an MIS is liable to expose it to system risks of some sorts or other, and that these risks are most to blame for impairment of MIS efficiency. However, if we moderately renovate IT infrastructure by building into it some preemptive risk-evasion strategies by anticipation, these strategies can be expected to reduce system risks that future MIS modification would almost inevitably entail. But implementation of such a renovation incurs a *POC* of its own [***POC* of renovation**]. Therefore let us represent MIS flexibility in terms of the substitute index of *POC* as in Figure 1. This figure suggests that the *POC* [$POC_R$] paid for a moderate renovation of IT infrastructure can generate the benefit [$UTL_R$] [**utility of renovation**] of reducing the *POC* ($POC_S$) that processing of demands for system change would incur in future (Hereafter let us use the term "*renovation of IT infrastructure*" to refer to the application of IT to an existing MIS for enhancement of its flexibility).

The above observation allows us to represent the *POC* of a whole MIS change ($POC_{MIS}$) with formula (2):

$$POC_{MIS} = POC_S + \left(POC_R - UTL_R\right) \qquad (3)$$

**Future-Oriented POC Analysis**

The *POC* analysis we proposed in Furukawa (2001a) has been expanded and generalized as summarized below (Furukawa, 2002):

Enhancement of MIS flexibility cannot be realized unless the possibility of system risks is reduced by means of moderate strategic renovation of IT infrastructure. This infrastructure renovation actually means providing preemptive risk-evasion strategies in anticipation of future MIS modification. What we should consider in this connection is how to evaluate what combination of system alternatives would incur the least *POC* (cost and time). For this purpose, it is necessary to enumerate a possible set of risk-evasion strategies we should provide for application to the combination of system alternatives, and evaluate both the penalty of change the very provision of these strategies would incur and the utility that their application would also generate (*i.e.* their utility in reducing penalty that we would otherwise have to pay when addressing change demands in future).

Since anticipatory provision of evasion strategies for possible future system changes, by its very nature, involves predictive uncertainty, it should be dealt with as a probabilistic event. Therefore, before going on into our detailed discussion, let us refer to a related idea involving a probabilistic event in the form of formula (3), an idea proposed by Chryssolouris, G. et al (1996) in the context of the evaluation of flexibility of manufacturing systems:

$$POC = \sum_{s=1}^{n} Pe(X_s)\Pr(X_s) \qquad (4)$$

where
$X_s$ = the state after change *s (1, 2,…, S)*
$Pe(X_s)$ = the penalty for change *s*,
$\Pr(X_s)$ = the occurrence probability of change *s*.

The calculation of *POC* can be viewed as an application of single-attribute decision-making under conditions of uncertainty (*i.e.*, the decision problem of selecting a combination of system alternatives for the enhancement of MIS flexibility); $X_s$ is a possible future scenario (*i.e.*, the state brought about by the implementation of the *s*th system change); $Pe(X_s)$ is the attribute value for the future scenario (*i.e.*, required management resources for the *s*th change); and $\Pr(X_s)$ is the probability of the possible occurrence of the future scenario; the numerical value of *POC* is the expected value of the penalty payable for the system change leading to the possible future scenario.

*Table 1: Factors for POC Calculation*

| Change Demand *k* (*l*=3) | | | | Set of Risk Evasion Strategies | | Occurrence Probability of Change *X* |
|---|---|---|---|---|---|---|
| *p* (*q*=8) | Combination of Alternatives ($Al_{jp}$) | | | | | |
| | *k*=1, *j*= 2 | *k*=2, *j*=2 | *k*=3, *j*= 2 | $St_{ip}$ *i*=*n*(*p*) | | $\Pr(X_{ip})$ |
| 1 | $Al_{11}$ | $Al_{12}$ | $Al_{13}$ | *i*=5 | $St_{11}$ | $\Pr_{11}$ |
| | | | | | $St_{21}$ | $\Pr_{21}$ |
| | | | | | $St_{31}$ | $\Pr_{31}$ |
| | | | | | $St_{41}$ | $\Pr_{41}$ |
| | | | | | $St_{51}$ | $\Pr_{51}$ |
| 2 | $Al_{11}$ | $Al_{12}$ | $Al_{23}$ | =2 | $St_{12}$ | $\Pr_{12}$ |
| | | | | | $St_{22}$ | $\Pr_{22}$ |
| 3 | $Al_{11}$ | $Al_{22}$ | $Al_{13}$ | =2 | $St_{13}$ | $\Pr_{13}$ |
| | | | | | $St_{23}$ | $\Pr_{23}$ |
| 4 | $Al_{11}$ | $Al_{22}$ | $Al_{23}$ | =3 | $St_{14}$ | $\Pr_{14}$ |
| | | | | | $St_{24}$ | $\Pr_{24}$ |
| | | | | | $St_{34}$ | $\Pr_{34}$ |
| 5 | $Al_{21}$ | $Al_{12}$ | $Al_{13}$ | =2 | $St_{15}$ | $\Pr_{15}$ |
| | | | | | $St_{25}$ | $\Pr_{25}$ |
| 6 | $Al_{21}$ | $Al_{12}$ | $Al_{23}$ | =2 | $St_{16}$ | $\Pr_{16}$ |
| | | | | | $St_{26}$ | $\Pr_{26}$ |
| 7 | $Al_{21}$ | $Al_{22}$ | $Al_{13}$ | =3 | $St_{17}$ | $\Pr_{17}$ |
| | | | | | $St_{27}$ | $\Pr_{27}$ |
| | | | | | $St_{37}$ | $\Pr_{37}$ |
| 8 | $Al_{21}$ | $Al_{22}$ | $Al_{23}$ | =3 | $St_{18}$ | $\Pr_{18}$ |
| | | | | | $St_{28}$ | $\Pr_{28}$ |
| | | | | | $St_{38}$ | $\Pr_{38}$ |

Here, let us represent a change demand as *k*( $1 \le k \le l$ ), a system alternative for a change demand *k* as *j*( $1 \le j \le m(k)$ ) and a combination of system alternatives for a change demand as *p*( $1 \le p \le q$ ). Where the number of change demands is *l*, the number (represented as *q*) of combinations of system alternatives for processing all change demands can be represented as *q*= $n(1) \times n(2) \times \ldots \times n(l)$ (*q*=8 in Table 1). On the other hand, let us represent a set of risk-evasion strategies for *p* as *i*( $1 \le i \le n(p)$ ) and enumerate a set of risk-evasion strategies(*i*) to be provided for each *p* of *q* combinations of system alternatives and let us give the notation of $\Pr(X_{ip})$ to the probability of the occurrence of the state of affairs where a set of risk-evasion strategies (*i*) will be applied. Then, the expected value of $POC_p$ (*POC* payable for execution of each *p* of the *q* combinations of system alternatives) can be represented with formula (4) after the fashion of Chryssolouris, G. et al (1996).

$$POC_p = \sum_{i=1}^{n(p)} Pe(X_{ip})\Pr(X_{ip}) \qquad (4)$$

In order to process all (=*l*) change demands, we need to implement *q* combinations of system alternatives for them. And each of these combinations of system alternatives is supposed to have been provided with a set of risk-evasion strategies in advance. An aim of this paper is to establish the methodology for selecting a system plan comprised of combinations of system alternatives and sets of risk-evasion strategies, which will best serve the purpose of MIS flexibility enhancement. A combination of system alternatives that will show the lowest value of *POC* ($POC_{min}$) can be represented with formula (5) (Furukawa, 2002):

$$POC_{\min} = \sum_{p=1}^{q} \min POC_p \qquad (5)$$

As the structure of MIS flexibility in Figure 1 visually shows, enhancement of MIS flexibility can only be realized by reduction of system risks via renovation of IT infrastructure. In order to evaluate a system plan, therefore, we must enumerate all sets of risk-evasion strategies to be applied to combinations of system alternatives, and then we must estimate both the penalty for the provision of the strategies ($POC_R$), and the penalty for the implementation of the system alternatives ($POC_S$) and the utility ($UTL_R$) that the application of the strategies will generate in the enhancement of MIS flexibility.

The following formula (6) represents the effect of the application of a set of risk-evasion strategies to a combination of system alternatives in future. This formula means that a combination of system alternatives that will incur the lowest penalty ($POC_{min}$) can be identified through close scrutiny of what set of risk-evasion strategies will be the best one to be applied to a combination of system alternatives to be implemented to process all change demands. There can be no doubt about the validity of this idea, insofar as it closely reflects the fact that one and the same IT infrastructure is shared by all possible application systems.

$$Pe(X_{ip}) = POC_S(p) + POC_R(ip) - UTL_R(ip) \qquad (6)$$

where

$POC_S(p)$ = the penalty for applying a combination of system alternatives $p$ to all change demands (without a set of risk-evasion strategies provided),

$POC_R(ip)$ = the penalty for providing a set of risk-evasion strategies $i$ for a combination of system alternatives $p$,

$UTL_R(ip)$ = the utility of applying a set of risk-evasion strategies $i$ to a combination of system alternatives $p$.

## CASE STUDY OF AN IT INFRASTRUCTURE RENOVATION

### A Case of Preparation for the New Millennium

System designers ought to have been able to foresee the occurrence of the year 2000(Y2K) problem at the stage when the data were being designed. This even implies that they virtually programmed the Y2K problem, which they could have averted, as was the case with Company X.

Company X was one of the first corporations in Japan that have introduced computers. In the late 1960s, they also undertook a change in their application system from batch to on-line real time processing. The change was executed by adding DAM files (direct access method) and programs written in Assembler for real-time processing to the existing batch processing system. The new system was only used during the daytime. The old batch system took over data from the new system after regular office hours for processing during the night. A scrap-and-build approach to the system development had been dismissed in order to meet the demand of the executives, who were anxious to start using the new system as soon as possible.

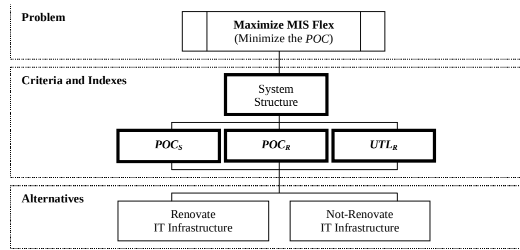
In the late 1980s, with rapid business and environmental changes pressing upon them and with an increasingly large-scale and complicated system to attend to, the MIS Division of the firm had inevitably been swamped with a huge backlog and they had been incessantly making desperate efforts for sheer maintenance of the system they had built 20 years before. After racking their brains about how to overcome their predicament, they decided to adopt a scrap-and-build approach after all and replace old DAM files and others with a relational database (RDB). The procedure that they worked out for the change consisted of:

- building a new RDB normalized with a data dictionary (DD), with all data from the existing MIS integrated into it,
- creating an interface between the existing MIS and the new RDB,
- and finally switching over from the existing MIS to the new system, which would access the new RDB directly.

This renovation cost far more than expected and required serious efforts of the engineers. But both the running cost and the backlog decreased as the changeover progressed. In the fall of 1999, most IT personnel in the world were in great fear of the arrival of the Y2K. At this time, the changeover of the firm's MIS had already been completed. Because of the superior flexibility of the IT infrastructure (system structure), the expansion of the date-fields to accommodate the change of millennia was completed by the next day by a mere modification of the definition of the date-fields in the DD.

To build a DB with a DD, it is indispensable to carry out the definition of key fields and their relationship, which incurs a *POC* of its own. But properly created, a DD will bring us utilities such as the ease of data use, which enhances the agility of decision-making on selection of strategy alternatives for coping with environment changes and the ease of MIS renovation, which enhances the agility of the execution of the selected action.

*Figure 2: Description of the Problem via AHP*




## DEFINITION AND ANALYSIS OF THE PROBLEM VIA AHP

Let us imagine Company X being currently involved in a predicament described above, and in order to define the problem it is faced with, let us represent it by means of Analytic Hierarchy Process (AHP) as in Figure 2. The decision Company X is required to make is whether to execute a renovation of IT infrastructure or not. Since the decision, needless to say, is going to be made in the expectation that a renovation will generate utility, the goal of the problem is "maximization of MIS flexibility (*i.e.* minimization of the *POC*)". The criteria and indexes for flexibility evaluation are described in Table 2 with regard to general categories of factors underlying MIS flexibility. In this case, however, estimations of $POC_S$, $POC_R$ and $UTL_R$ need to be conducted with a particular focus on the flexibility factor of "System Structure."

Table 3 and Table 4 show the result of the evaluation of a renovation after the fact, and the Total Score of Table 4 indicates that "Renovate IT infrastructure" had an advantage after all. But as we proposed in the formulation of formula (6), a renovation of IT infrastructure (*i.e.* provision of risk-evasion strategies) needs to be executed in advance against the possibility of system changes that may be demanded in future. Then, unless we predict all change demands that may be made on the existing MIS in future, we cannot estimate $POC_S$, $POC_R$ and $UTL_R$ before the fact.

*Table 2: MIS Flexibility and Indexes for its Evaluation*

| Category | | Meaning | Risk-prone change | Risk | Evasion Strategy | Index for Evaluation | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Viewpoint | Cost | Time | Utility |
| Hardware | Exchangeability | Easiness of exchange and change of hardware | Machine replacement | System unusable | Enhancement of Connection interchangeability, Enhancement of Upper compatibility (open protocol, open system) | Enhancement of Connection interchangeability, Enhancement of Upper compatibility (open protocol, open system) | Human resources (Man-month) | Time distance (exchange speed) | Shortening of exchange time, reduction of cost |
| | | | Upgrading basic software | System unusable | Enhancement of Connection interchangeability, Enhancement of Upper compatibility Multiplexing, back up & recovery, insurance & maintenance contract, out-sourcing (external equipment) | | | | |
| | Fault tolerance | Ability to continue to provide service on given application functions | Trouble outbreak from bugs in basic software | System uncontrollable, System breakdown | Back up & recovery, preventive maintenance | Availability | Opportunity loss, Recovery cost | MTBT, MTTR | Reduction of opportunity loss and recovery cost |
| | | | Trouble outbreak from bugs in application programs | System unusable, System failure | Thoroughness of testing, standardization, educational training, back up & recovery | | | | |
| | | | Trouble outbreak from operational error | System failure | Educational training, job enrichment, out-sourcing (skilled engineer) | | | | |
| Application system | System structure | Ability to add new application function (degree of structuring) | External environmental changes, Enterprise-internal changes in managerial function and /or in business process | Delay in due date delivery, excess over the estimates, productivity deterioration, malfunction, system failure | Technological strategies: Standardization of protocol (open system)? Structured analysis / design / programming, and Data-Oriented Approach (Structuring, Normalization) | Structuring of Systems and programs | Cost for change demands, Cost for structuring | Time for change demands, Time for structuring | Reduction of *POC* for design |
| | | | | | Organizational strategies: Accumulation of engineers' experience and enhancement of skills, educational training of users, Workload (reduction of engineers' overload), Job enrichment, Practical use of external consultants | Quality of database (Number of access paths from application program to data, Number of programs and data requiring change, ratio of management-target entities included in database), Tendency of backlog volume on the time axis | Cost for change demands, Cost for database development | Time for change demands, Time for database development | Reduction of *POC* for design |
| | Service area | Ability to provide unexperienced service for the first time | Request for unexperienced business field | Delay in due date delivery, excess over the estimates, productivity deterioration, malfunction, system failure | Rearranging management-target entities and Building database | Ratio of BPs and management-target entities given a service | Cost for change demands, Cost for new service | Cost for change demands, Cost for new service | Reduction of *POC* for design |
| | IT adoption | Ability to provide a service with unexperienced technology and/or method | IT innovation, Implementation of new technology | Delay in due date delivery, excess over the estimates, productivity deterioration, malfunction, system failure | Accumulation of engineers' experience, R&D, Standardization of system development, Educational training (dissolution of skill deficiency) | Technological continuity and degree of experience | Cost for change demands, Cost for expertise enhancement depending on proficiency levels | Time for change demands, Time for expertise enhancement depending on proficiency levels | Reduction of *POC* by learning |

*Table 3: Evaluation of the Problem*

| View Point for Evaluation | Accomplished Modification |
|---|---|
| **Ratio of Programs Structured** | Standardized database accessing statements for all programs |
| **Ratio of Subsystems Structured** | Secured the mutual independency of subsystems in existing MIS via database |
| **Ratio of Data compiled into Database** | Built up Data Dictionary by normalizing whole data in existing MIS |

| Criteria | | Method for Evaluation | Result of Evaluation |
|---|---|---|---|
| *POC* | Cost | Cost for renovation of existing MIS infrastructure | $1 million? 120 man-month |
| | Time | Time for renovation of existing MIS infrastructure | 12months |
| Utility | Indexes | The number of programs required to access necessary data | Reduced to 30 percent |
| | | The number of programs requiring modification to accommodate future change demands | Reduced to 65 percent |
| | | The number of data-items that need to be added and/or changed to accommodate future change demands | Reduced to 35 percent |
| | | Ratio of management-target entities included in Database | 65% of all the management-target entities of the Enterprise |
| | Cost | Reduction of cost required to accommodate future change demands in comparison with the alternative of Not-Renovate | Reduced to 70 percent |
| | Time | Reduction of time required to accommodate future change demands in comparison with the alternative of Not-Renovate | Reduced to 60 percent |

*Table 4: AHP Calculation*

**Weight via Paired Comparison**

| | Cost | Time | Utility | Weight |
|---|---|---|---|---|
| Cost | 1 | 3 | 1/5 | 0.188 |
| Time | 1/3 | 1 | 1/7 | 0.081 |
| Utility | 5 | 7 | 1 | 0.731 |

Calculated via Paired-Comparison

**Total Score of Each Alternative via AHP**

| Alternatives | Cost | Time | Utility | Total Score |
|---|---|---|---|---|
| Renovate | 1/3 | 1/5 | 9 | 0.718 |
| Not -renovate | 3 | 5 | 1/9 | 0.228 |

## CONCLUSION

In this paper, we have defined the concept of MIS flexibility in terms of *POC* and in relation to IT infrastructure renovation and proposed a Future-Oriented *POC* analysis. We have also given an account of an actual case of renovation of IT infrastructure and defined the problem it involved. We have then wound up our discussion by illustrating the evaluation of MIS flexibility via our proposed *POC* analysis. The Future-Oriented *POC* Analysis, which we have presented in this paper, has revealed that the *POC* analysis can serve as an effective and useful tool for the evaluation of IT infrastructure, and ultimately for the development of methodology for enhancement of MIS flexibility.

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