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Integrating Security Indifference Curve to Formal Decision Evaluation

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Abstract**—** Decisions are regularly made during a project or daily life. Some decisions are critical and have a direct impact on project or human success. Formal evaluation is thus required, especially for crucial decisions, to arrive at the optimal solution among alternatives to address issues. According to microeconomic theory, all people's decisions can be modeled as indifference curves. The proposed approach supports formal analysis and decision by constructing indifference curve model from the previous experts' decision criteria. These knowledge embedded in the system can be reused or help naïve users select alternative solution of the similar problem. Moreover, the method is flexible to cope with unlimited number of factors influencing the decision-making. The preliminary experimental results of the alternative selection are accurately matched with the expert's decisions.

Keywords**—**Decision Analysis and Resolution, Indifference Curve, Multi-criteria Decision Making.

I. Introduction

Decisions are regularly made during a project or daily life. Some decisions are critical. All significant factors have to be considered and evaluated accurately. However, decisions are often subject to individuals, and they tend to deviate from the proper choice.

Each alternative solution has its own some inferiority and superiority. Based on the general principle, if an alternative is better than the other compared by some factors, and it is not defeated in any aspects, then that alternative is considered the winner. However, in most decision problems, it is hardly found the solution that dominates all the others. Decisions in one area almost always impact others. For examples, making key trade-off decision of the amount of testing time (schedule) may effect the number of defects detected and removed from the software product (quality). Making the decision to grant credit lines to applicant firms needs to justify the risk of a borrower's failure to make loan payments to the loan interest rate earned.

As decision-making is subject to constraints, it is challenging to tradeoff these different factors. A formal evaluation process can be applied to reduce subjectivity.

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CMMI [1] is a well-known organizational process improvement model invented by Software Engineering Institute (SEI) of Carnegie Mellon University. The model contains best practices of several essential areas of activities in a project. One of the areas of activities called Decision Analysis and Resolution (DAR) is a cluster of recommended practices of which the purpose is to analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria. The organizations are expected to establish guidelines to determine which issues should be subjected to a formal evaluation process. Typically, issues that have multiple alternative solutions and evaluation criteria lend themselves to a formal evaluation process. For instances, in a software project, typical issues include selection among architectural or design alternatives, make-or-buy decision, supplier selection, and selection of risk mitigation strategy.

Formal evaluation is a structured approach. The process involves: 1) establishing the criteria for evaluating alternatives; 2) identifying alternative solutions; 3) selecting methods for evaluating alternatives; 4) evaluating the alternatives using the established criteria and methods; 5) selecting recommended solutions from the alternatives based on the evaluation criteria.

According to Thompson [2], process activities can be classified into two types: algorithmic or creative. Algorithmic activities may be carried out without significant human intervention. While creative activities are unpredictable and subject to individuals' creativity. This research used result of the creative activities for alternatives compilation which done algorithmically reducing decision process unpredictability.[2]

This research presents a method for evaluating alternatives as stated in step 3 activity of the formal evaluation process described earlier. Steps 1 and 2 can be considered as creative process activities according to Thomson's work [2]. The implementation of the proposed method automates the activity of step 4 and provides the recommended solutions in step 5. The indifference curve technique used in security markets is applied in this work. The approach to automating the formal evaluation process starts with collecting expertise's decisions in the past together with the criteria data of the identified alternative solutions. Alternative factors are analyzed based on the decider. Decisions of former issues or problems are

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learned and modeled as a proxy of experts for a new problem with a set of alternative solutions as input. The identification of the best alternative solution is mostly based on the indifference curve principle.

Boness et al. [5] proposed an approach similar to this research. Their approach accredits the awareness of risks when evaluating a project. The decision outcome can be "Do not proceed", "Proceed with criteria", or "Proceed" based on three major factors: cost, goal and risk information. However, only the three factors are individually concerned, and it highly relies on experts' appraisal. The trade-off decisions, such as the "high risk high return" investment strategy are ignored in their research work. Consequently, some high risk projects with extreme returns are not reported as alternative solutions. Compared to the decision evaluation approach presented in this work, the trade-off decisions will be automatically learned and signaled from the proposed model.

The contents in this paper are organized as follows: section 2 briefly reviews the indifference curve model. The details of the proposed method applying indifference curve for alternative evaluation are then described in Section 3, followed by the architectural design of the implementation of our approach in section 4. The experiments and results are reported in Section 5. Section 6 summarizes the work and findings of this paper.

II. Indifference Curve

In microeconomic theory, indifference curve is a term that is used to describe investors' behaviors. The indifference curve can be considered as a curve on which every point representing each decision equivalently satisfies a decision-maker. A decision is justified by the combinatorial factor values of each alternative. Nevertheless, an indifference curve represents trade-off decisions particular to an individual's behavior. None of the functions can accurately model everyone's behavior because it is highly subjective.

The indifference curve principle is often used for modeling security investors' behaviors. In general, the principle of "high risk high return" is one of the decision criteria applied for the stock investment. The investors usually justify the average return against the standard deviation of return, which is considered as risk, when selecting portfolio of security [3], [4]. Fig. 1 shows a series of factor values of security portfolio selected by a particular security investor that reflects the high risk high return selection criteria. The curve in Fig. 1 is similar to the indifference curve which could be applied to model decision behaviors in other domains.

In this work, the indifference curve is adapted to model the equivalent ranked alternatives in general decisions. Due to the limitation of decomposing the constituent factor values of an alternative in general decision domains, the arc connecting between the coordinates of a couple of alternatives does not exist as shown in the indifference curve of Fig. 2. The link between a pair of coordinates can be calculated by averaging the values of the two coordinates that could always exist in security investment as shown in Fig. 3 of which the indifference curve is smoother than that of Fig. 2. Therefore, the virtual connecting arc is presented in the indifference curve model used in this work.

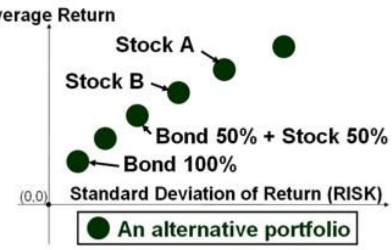

Fig. 1 A series of factor values of security portfolio selection

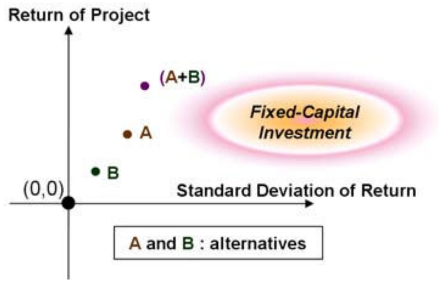

Fig. 2 Indifference curve in general decision domains

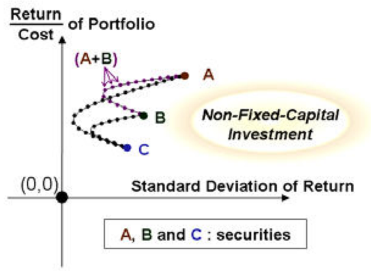

Fig. 3 Indifference curve in security investment domain

III. Decision Model

This section describes the derivative of major factors for an alternative and the Indifference Curve Model for depicting human decision behaviors. Only major factors are considered in the model presented in this paper.

A. Derivative of Major Factor

Each alternative solution can contain several factors. There are two levels of factors defined in this work: – major factor and minor factor. Only the major factors are considered during the alternative evaluation. The value of a major factor can be derived from its constituent minor factors. In order to identify a set of minor factors comprising a particular major factor, Ishikawa's fishbone diagram [7] can be used to analyze the cause-and-effect relationships. An example of the fishbone diagram is illustrated in Fig. 4.

Considering the major factor – Return of project shown in Fig. 4, the analysis shows that the return of project is a function of three minor factors: earned income, company reputation, and gained experience. In turns, each minor factor may contain a set of its attributes. Each attribute may further own a set of its sub-attributes, and so on. A particular attribute or sub-attribute can belong to more than one minor factors as appear in Fig. 4.

The formula f to compute the value of a particular major factor from its constituent minor factors is depicted in Fig. 5. Weighted sum formula is often applicable in causal analysis. Otherwise, other techniques such as neural networks from machine learning community, statistical techniques, or experts' estimation can be applied to obtain the proper weight values.

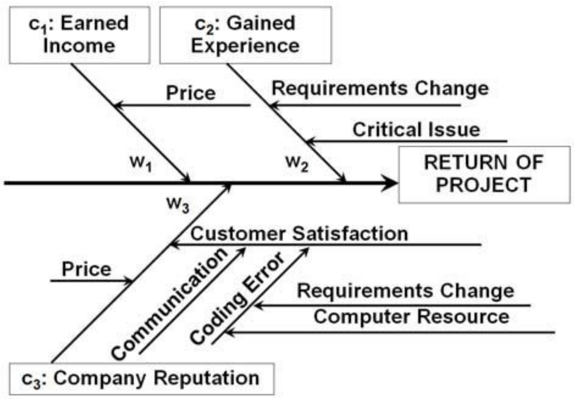

Fig. 4 Fishbone diagram to analyze minor factors of a major factor

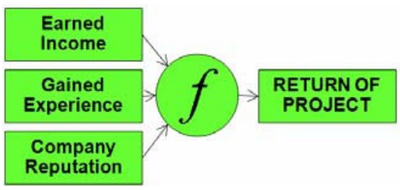

Fig. 5 Derivative of major factor value from constituent minor factors

Cost and effort are two distinct examples of major factors typically evaluated in most projects. They can be formulated using weighted sum formula. In general, cost is usually defined in terms of any expenses one has to pay for when adopting an alternative. Another typical major factor, effort, can be defined as time spent by workers in each level, including the owner. Example of the derivative of total effort using weighted sum formula would be:-

$$C = \sum_{i=1}^{N} c_i \times w_i \qquad (1)$$

C : Total Effort

c_i : a real number of expected cost value of the i[th] minor factor

w_i : a positive real number of weight of the i[th] minor factor

N : a positive integer number of minor factors

The value of weight can be computed by least Mean Square Error method. TABLE I shows example of possible input for calculating the value of major factor using weighted sum formula (1). The major factor – total effort, depends on three minor factors: Wage of low level labor, Manager's time spent, and Owner's time spent. Note that the input need not be the same unit because the weight will be normalized automatically.

The total effort can then be computed using weighted sum formula as shown below.

$$\begin{aligned} \text{Total Effort} = {} & (\text{Wage of Low Level Labor}) * 0.001 \\ & + (\text{Manager'Time Spent}) * 183 \\ & + (\text{Owner's Time Spent}) * 521 \end{aligned} \qquad (2)$$

TABLE I
EXAMPLE OF INPUT FOR CALCULATING WEIGHTS OF MINOR FACTORS IN A MAJOR FACTOR FORMULA

Minor Factors			Major Factor
Wage (Baht)	Manager's Time (Month)	Owner's Time (Month)	**Evaluated Total Effort (Point)**
15000	0.008333	0.001852	**19**
300	0.000694	0.000926	**1**
9000	0.001042	0.000185	**10**
108000	0.0125	0.066667	**160**
18000	0.008333	0.022222	**36**
1200	0.001042	0.000185	**2**
54000	3	4	**1600**
2100	0	0.233333	**110**
0	0.25	0.5	**200**
375	0.0125	0.033333	**16**
31.25	0.0625	0.005556	**4**
1125	0.0125	0.008333	**6**

It is possible that each particular alternative may have different set of attributes. For example, in risk management, a particular alternative can represent different risk handling strategies applied. Suppose the first alternative represents the risk acceptance strategy, while the strategy underlying the second alternative is risk avoidance. Applying the risk acceptance strategy means the project is simply aware of the existence of the risk without any cost expense. Whereas selecting the risk avoidance strategy means destroying the risk absolutely and accepting the increased handling cost. Fig. 6 illustrates the possible different fishbone diagrams of the two alternatives described earlier. In this situation, when calculating the value of associated major factor, the value of the missing attribute is simply assigned to zero.

The merit of each alternative containing n major factors can be scored as a point in n-dimensional space, of which the coordinate on each axis represents the associated major factor value.

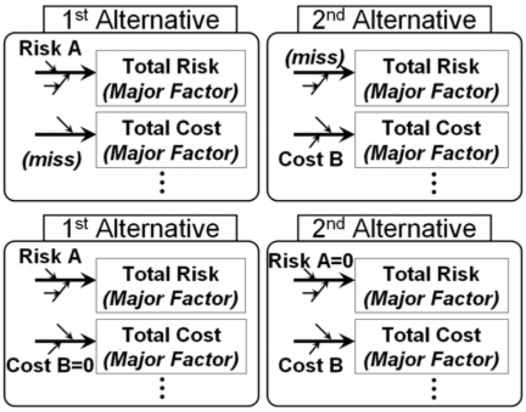

Fig. 6 Possible different fishbone diagrams of two alternatives

B. Alternative Evaluation Approach

Despite the fact that indifference curve is subject to an individual's decision favors, the technique can be applied to select the solution of similar issues or problems based on the past evaluation model of a particular decision-maker. This is because most of the indifference curves still have the same appearance, i.e. similar steep in the proximity region called Similar Area. The concept of Similar Area is comparable to *k*NN (*k*-nearest neighbor) classifier [6] in Machine Learning area of study. *k*-NN is a type of instance-based learning where the target function is locally approximated from *k* closest training examples in the feature space. It is also regarded as a lazy learner which defers all computation until the query instance arises. The contour of Similar Area is determined by the model user. Using the rule of thumb, the Similar Area covers about 50% of the winner-loser alternative pairs, which is analogous to the value assigned to parameter *k* in the *k*-NN classification. A set of winner-loser pair relations is identified by an expert, and used as input when constructing the indifference curve model. A set of winner-loser alternative pairs and Similar Area are shown in Fig. 7.

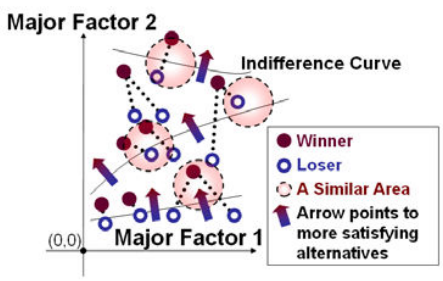

Fig. 7 Similar Areas

When a new problem arises, and a pair of candidate solutions need be evaluated, the approach of majority vote is used here to justify the winner of the two candidates. Using the existing indifference curve model similar to the new problem, those winner-loser pairs within the Similar Area are considered as authorized voters. The result of each voter is obtained by applying the following rules:

$$(\mathbf{C1}-\mathbf{C2})\bullet(\mathbf{W}-\mathbf{L})>0 \rightarrow \mathit{C1\ win\ C2}$$
$$(\mathbf{C1}-\mathbf{C2})\bullet(\mathbf{W}-\mathbf{L})<0 \rightarrow \mathit{C2\ win\ C1}$$
$$(\mathbf{C1}-\mathbf{C2})\bullet(\mathbf{W}-\mathbf{L})=0 \rightarrow \mathit{C2 \sim C1}$$

where $\mathbf{C1}$ and $\mathbf{C2}$ are tuples of major factors of the two candidates;
$\mathbf{W}$ and $\mathbf{L}$ are tuples of the winner and loser respectively

In Fig. 8, those small circles represent the alternatives identified in the past experienced problem, and they have been already evaluated as the winner or loser by an expert. The opaque circle represents the winner paired with the loser transparency circle. The two cross marks – a black and a white – are candidate solutions of the current encountering problem. The proximity of any pair of alternatives implies similarity between both alternatives. It also implies similarity between the corresponding problems. The big dashed-line circle outlines the area of similarity between the past and the current problem. Fig. 9 illustrates some results obtained from the voting rules. Example outcomes from applying all possible 3 rule conditions are reported geometrically in the figure.

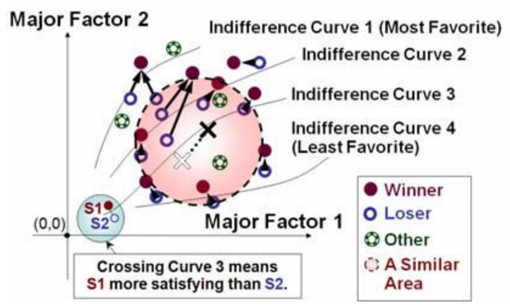

Fig. 8 Geometry analysis of alternatives with 2 major factors

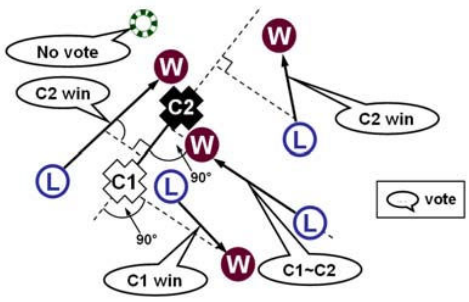

Fig. 9 Some results from the voting rule condition

C. Approach's Capability

The proposed approach is flexible to be adapted to the cases when the decision depends on more than 2 major factors, or when the inquiry contains more than 2 alternative solutions.

For learning purpose, the comparative satisfaction is assigned to each pair of alternatives in a set of expert's judgment. However, users can classify the alternatives into absolute ranking value, such as "most satisfying", "neutral", or "unacceptable" (Note that the ranking can be quantified into a number such as 3, 2, 1 respectively), rather than justifying comparative satisfaction between an alternatives pair, e.g. choiceA wins choiceB. The indifference curve principle can create the satisfaction boundaries from the markers specified by experts as shown in Fig. 10. As more historical data has been accumulated, this capability can evolve to process control mechanism that could signal trade-off decisions. For example, in case of supplier selection, suppose there are 3 vendors, A, B, C with the satisfaction scores: 4, 4.5, 4.2 respectively. Therefore, vendor B was selected in the first year. In the second year, among 3 vendors, D, E, F with the satisfaction scores: 3.9, 4.1, 4.3 respectively, then vendor F was selected. For the consecutive years later, it has been observed that the winner vendor always scored around 4. But in the 5th year, the satisfaction scores of the alternatives W, X, Y, Z dropped to 1.1, 2.5, 0.1, 2.0 respectively. The causal analysis revealed that the satisfaction scores sharply decreased because the productivity of coding in C++ is not high enough to trade-off the violent price drop of C++ software product in the markets as most companies turn to coding in Java currently. The independent justification from a single major factor could not signal the situation as the proposed approach could report.

Additionally, the approach allows a user to configure some attributes in order to increase the satisfaction level with the most worth investment as shown in TABLE II. Merging Ki-zen or PDCA (Plan-Do-Check-Act) [7] improvement cycle into the proposed framework is conveniently implemented.

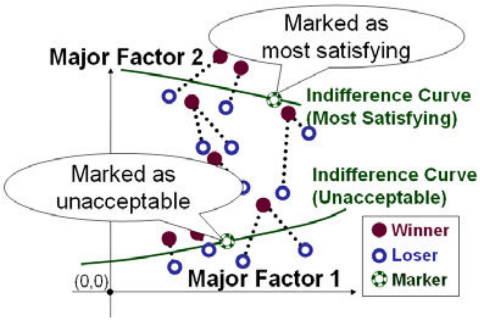

Fig. 10 Adaptation in process control

TABLE II
ALTERNATIVES FOR IMPROVEMENT OPTIMIZATION.

Change	Unit	Satisfaction Level up
Increase officer salary ($)	30	1
Reduce size of room (m^2)	10	50
Plant (amount of tree)	1000	25
Install pure wood furniture (amount of room)	5	7

IV. DESIGN

The structural design of the decision learning and evaluation system contains three subsystems:– Model Provider, Model User and Core as illustrated in Fig. 11. The Model Provider receives the input information from an expert and then stores it in associated repository residing at the Core layer. When a user enters the system to request for alternatives evaluation of the new problem, all the required information of the encountering problem need be input through the Model User interfaces. The input information will be then executed at the Core layer, which will analyze and report the result of the relative satisfaction among the inquiry alternatives to the user. The following subsections describe more details of each system component.

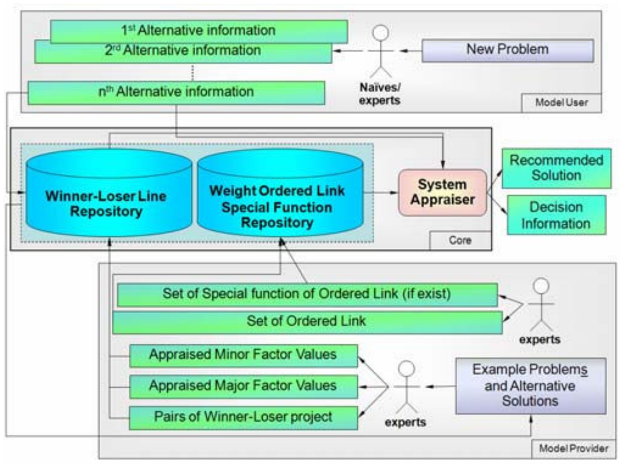

Fig. 11 Architectural design of the decision system

A. Model Provider

This subsystem communicates with the person who is an archetype for the behavior model. Some of the inputs to the subsystem include:

- Model name e.g. "Business Satisfaction"
- Learned alternative name (optional) e.g. "Project01"
- Major Factor Name e.g. "Reputation", Minor Factor Name e.g. "Customer Satisfaction", Attribute Name e.g. "Salary" and Ordered Link of Consecutive Levels e.g. "Cost - Labor", "Business Satisfaction – Reputation")
- Functions of the Ordered Links using total weighted sum formula as default or a specified function e.g. Complexity = (Line of Code)^2
- Numerical values of major factors, minor factors, attributes associated with each learned alternative as appear in TABLE I.
- Set of expert's judgment e.g. Project01 win Project02, Project06 win Project01.

Example of input screen is shown in Fig. 12.

The advantage of using the weighted sum formula as shown in Equation (1) is the automation of weight computing in case the model user is unable to reasonably justify the values of minor factor's weights. The least Mean Square Error technique can resolve this issue and the system will automatically compute the major factor value for its constituent minor factors.

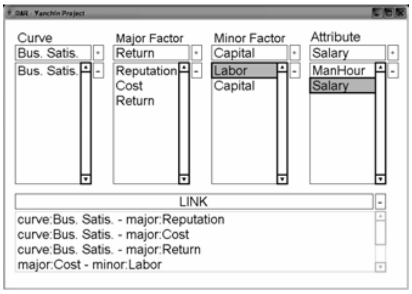

Fig. 12 Example of input screen

B. Model User

When a user requests for the alternative evaluation to support the decision-making, a set of required inputs include:

- Model Name of new problem, that is selected from the item list provided by the database. Beware that the chosen model name reflects the valid goals corresponding to the user. For example, the goals of a customer are different from that of an entrepreneur using the same model.
- Numerical values of major factors, minor factors and attributes associated with each query alternative. For the best result, it is suggested to minimize the "not available" values.

C. Core

The Core agent analyzes and returns the best alternative based on the similarity of the query data and the indifference curve model existing in the system. The weights of required functions will be calculated by the subsystem using total weighted sum formula as default or specified functions.

Once all the major factor values of all candidates have been calculated, the indifference curve principle is adapted to support the decision activity.

V. Experiment

The experiment was conducted on the Land Development Domain. Yanchin Partnership Limited has run the business on apartment construction. The subject who provided the information for constructing the decision learning and evaluation model is one of the company's administrators. He has the experience in land-improvement business for more than 35 years. The information of 18 medium-sized projects of which the cost in the first three years is less than 10 million Baht (approximately 34 Baht = 1 USD). Three project characteristics: expected cost, expected return on investment (ROI) and expected customer satisfaction (here customer satisfaction is considered exclusively from ROI) are used as the major decision factors. The logarithmic values of these three major factors were used when constructing the model. The additional input is a set of expert's judgment pair containing 31 winner-loser lines. Red cubes win more than lose. Blue hollow pentagon prisms lose more than win. Green pyramids achieve an equality in win-lose. One of the visualization perspectives of the model constructed is illustrated in Fig. 13.

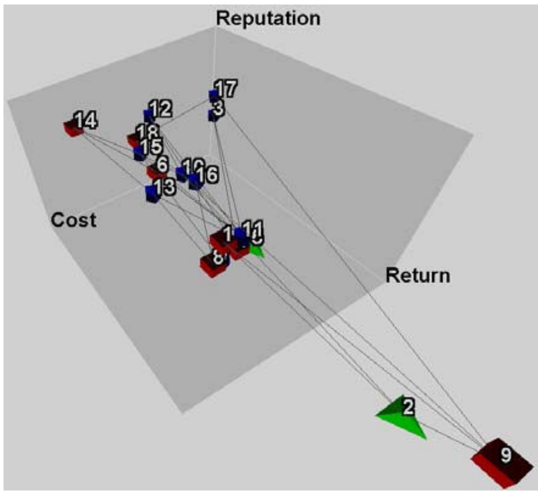

Fig. 13 Decision Model created from 18 projects with the decision criteria of Cost, ROI and Customer Satisfaction

Afterwards, a current part-time clerk experimented on the evaluation of alternative solution of three problems. The seventh and the fourteenth are candidate solutions of the revenue-objective problem. The ninth and the eleventh are candidate solutions of the second problem of which the objective is to increase the feature of service for apartments. The tenth and the seventeenth are candidate solutions of the third problem of which the objective is to satisfy minor group of customers. Using 50% of the whole winner-loser lines as the similar area, the results of the three cases as reported in TABLE III are correct compared to the solutions provided by the administrator.

TABLE III
EXPERIMENTAL RESULTS

Problem No.	Expert's Decision	**System's** Decision (Vote as winner 1st : 2nd)
1	1st win	**9:6**
2	1st win	**9:6**
3	2nd win	**6:9**

VI. Conclusion

The Decision and Analysis (DAR) process area in the well-known CMMI process improvement model provides recommended practices of formal evaluation process applied to critical decisions. This paper proposed a flexible and extensible approach to evaluating the alternative solutions using the security indifference curve model. The implemented decision system has learned the decision criteria input by experts. The input knowledge is integrated with the indifference curve principle to construct the intelligent alternative evaluation system. The majority voting from the surrounding winner-loser pairs nearby the inquiry alternatives is used to identify the solution. Each alternative contains a number of major factors, which in turns, consist of a set of minor factors. A minor factor may further contain a set of attributes, which may further contain sub-attributes. These relationships can be visualized and analyzed by the cause-and-effect or fishbone diagram. The combination of major factors effects the decision based on those selection criteria embedded in the system.

The preliminary experiments were conducted. The results of alternative selection are correct compared with the decisions from the expert.

The implemented decision system would be reused for the alternative evaluation of the similar problems. It is also useful for the naïve users to select the alternative solution based on the experts' decision criteria on the similar problem domain.

REFERENCES

[1] M. B. Chrissis, M. Konrad, and S. Shrum, CMMI® Second Edition Guidelines for Process Integration and Product Improvement, Addison-Wesley, Boston, 2007.
[2] S. Thompson, T. Torabi, and P. Joshi, "A Framework to Detect Deviations During Process Enactment", *Computer and Information Science, 2007. ICIS 2007. 6th IEEE/ACIS International Conference*, IEEE Computer Society, July 11-13, 2007, pp 1066 – 1073.
[3] H. Markowitz, "Portfolio Selection", The Journal of Finance, Vol. 7, No. 1, Blackwell Publishing, UK, Mar, 1952, pp. 77-91.
[4] M. H. Partovi and M. Caputo, "Principal Portfolios: Recasting the Efficient Frontier", Economics Bulletin, Vol. 7 no. 3, 2004, pp. 1-10.
[5] K. Boness, A. Finkelstein, and R. Harrison, "A lightweight technique for assessing risks in requirements analysis", *IET Periodicals, Volume: 2, Issue: 1*, Institution of Engineering and Technology, UK, February 2008, pp 46-57.
[6] M. Tom, Machine Learning, McGraw Hill, New York, 1997.
[7] S. Donna, Quality, fourth edition, Pearson Prentice Hall, New Jersey, 2006.