A Case Study of Source Selection and Evaluation by Using the Analytic Hierarchy Process

Nam Yong Lee
Department of Computing, Soongsil. University,
Email: nylee@computing.soongsil.ac.kr

Abstract: *Over the last several decades, the topic of the source selection and evaluation has gained a great attention in the information systems community as an effective tool to acquire information systems in an organization. The source selection and evaluation process is a multiple-criteria decision-making problem associated with several evaluation issues. In this case study, evaluation issues include management, technologies, logistics, and cost. This case study was conducted to compare a new source selection and evaluation process by using the analytic hierarchy process with the traditional approach. This study provides useful insight about how to apply the analytic hierarchy process technique to the traditional approach.*

Keywords: *Source Selection and Evaluation, Software Development Project Management, Analytic Hierarchy Process*

1. Introduction

Over the last several decades, the source selection and evaluation (SSE) process has been emphasized to acquire effectively information systems (IS) in an organization under an increasingly complex environment of acquisition of IS. In order to improve the traditional SSE process, a multiple-criteria decision-making (MCDM) technique needs to be incorporated in the traditional SSE process [4] [6]. Therefore, a case study of SSE at the initial phase of system development life cycle (SDLC) is discussed. The SSE process is based on the analytic hierarchy process (AHP) technique to improve the traditional SSE process.

In this study, a literature survey was limited to ABI/INFORM. According to the results of the literature review, there have been numerous studies on the selection of single software package [4] [6] [8] [10]. Based on the types of applications, these studies can be classified into the four categories: decision support systems, expert systems, executive information systems, and others. One of interesting findings is that there has been no study on the SSE for the acquisition of an integrated, large-scale IS.

A SSE is a process to examine and evaluate the facts leading up to the award decision in the competitive acquisition of IS [9]. At the initial phase of the SDLC, the SSE is much more difficult because the user's requirements are not specifically defined and the package of request for proposal is not clearly defined. However, a SSE team must find out the best one of several proposals of competing offerors. In order to overcome the ambiguity of the decision-making, a MCDM technique is required. The success of a SSE also requires an adequate source selection plan to include monitoring and an established time frame if a SSE process is to run smoothly. The source selection plan is a guide for the SSE process. It follows an acquisition strategy, a work breakdown structure, and an acquisition plan in an organization [7]. This case study utilized a large-scale IS, which provides an automated message handling, data base management, automatic machine translation, and distributed networking capability [2] [3] [5].

Although a SSE depends on a specific situation of the acquisition of IS in an organization, a well defined criteria and process is essential to effectively acquire IS. Without the well-defined SSE criteria and process, it is likely to select a beautiful proposal but there is no good product. Based on the AHP, this study provides a more effective SSE process. This study also shows how to apply the AHP technique to the traditional SSE.

2. Structure of Evaluation Criteria

Especially, a source selection process is considered formal when a specific evaluation group structure such as a SSE board is established to evaluate proposals and select the best source for contract award. The chairperson of a SSE board coordinates all activities necessary to conduct and to document the SSE process [1] [2]. The deputy chairperson serves as the primary advisor to the SSE board.

1. Technical criteria
  1.1. Engineering
    1.1.1. Integration of customer furnished equipment of hardware under operating system
      1.1.1.1. Previous commercial application
      1.1.1.2. Extent of modification
      1.1.1.3. Risks associated with software development
      1.1.1.4. The degree of prior operational experience
      1.1.1.5. Ability of the system to transition
    1.1.2. Ability of the machine translation support system
      1.1.2.1. Ability to accommodate future growth and enhancement
    1.1.3. Ability of the system to accommodate future system interface
      1.1.3.1. Interface to external systems
      1.1.3.2. Intelligence Support System
      1.1.3.3. The other information systems
    1.1.4. Ability of mapping system
      1.1.4.1. Generation of graphics
      1.1.4.2. Incorporation of the furnished equipment associated with Mapping
      1.1.4.3. Life-cycle and maintainability of projection system
  1.2. Ability to furnish
    1.2.1. Hardware
      1.2.1.1. Availability of the commercial-off-the-shelf hardware on a schedule
      1.2.1.2. Degree of complexity of customer furnished equipment
      1.2.1.3. Ability of supporting documentation
    1.2.2. Commercial firmware and software
      1.2.2.1. Minimizing modifications while meeting requirements
      1.2.2.2. Degree of user friendliness
      1.2.2.3. Operator proficiency with minimal prior experience
    1.2.3. Functions and features
      1.2.3.1. Operational ease of function
      1.2.3.2. Utilization of functions to minimize time.
  1.3. Installation
    1.3.1. Installation practice of commercial equipment
      1.3.1.1. Degree of understanding of installation requirement
    1.3.2. Site engineering with adequate resource
      1.3.2.1. Engineering to minimize risk in meeting schedule
      1.3.2.2. Engineering to integrate all system components
    1.3.3. Transition and cutover plan
  1.4. Quality assurance
    1.4.1. Quality assurance methodology used to minimize on-site failures
    1.4.2. Resources - the number and quality of personnel
    1.4.3. Testing program

2. Logistic criteria
  2.1. Training
    2.1.1. Understanding of the preparation of training material
    2.1.2. Quality and ease of use of the embedded training package
    2.1.3. Availability of qualified and skilled personnel
    2.1.4. Past experience in developing embedded training package
    2.1.5. Approach to conduct the on-the-job training prior to the system test
  2.2. Maintenance support
    2.2.1. Methods for determining and acquiring the range and quantity of spare parts
    2.2.2. Maintenance plan for repair, replenishment, and storage of spare parts
    2.2.3. Location of maintenance personnel and repair parts
    2.2.4. Consideration and utilization of the local industry
    2.2.5. Past experience in the preparation of technical manuals
  2.3. Logistic management
    2.3.1. Experience and past performance of related personnel
    2.3.2. Overall management techniques and control

3. Management criteria
  3.1. Consortium
    3.1.1. Relationship between the members of the consortium
    3.1.2. Involvement of each member
    3.1.3. Involvement of Korean industry in the area of logistics
  3.2. Contract management
    3.2.1. Past performance on similar systems as overall integrator
    3.2.2. Degree of project control to assure schedule and cost
    3.2.3. Ability to operate the present prototype system.

4. Cost criteria
  4.1. Cost proposal
    4.1.1. Compliance with instructions
      4.1.1.1. Completeness,
      4.1.1.2. Correctness, and
      4.1.1.3. Traceability of the labor, material, and other d irect cost data
    4.1.2. Appropriateness of the methodology used to determine thos rate
  4.2. Cost realism
    4.2.1. Rationale
    4.2.2. Compatibility between man-hours in the cost proposal and
      those in the technical, management, and logistic proposals

Table 1. Evaluation Criteria

In absence of the chairperson, the deputy chairperson assumes all duties and responsibilities of the chairperson. Team leaders assigned specific areas of evaluation responsibility maintain workbooks containing deficiencies sheets for each proposal evaluated. Also, they submit an evaluation summary documentation to the chairperson within established schedule dates. Furthermore, they recommend issues and positions for negotiations with offerors to the contracting manager as required and participate in negotiations as requested. All members will conduct a qualitative and quantitative assessment of offeror proposals. They also submit the completed rating sheets and supplement documentation to the team leader within schedule dates [5].

Evaluation criteria are those aspects of a proposal that will be evaluated quantitatively and qualitatively to arrive at an integrated assessment as to which proposal can be best meet the organization's requirement and need as described in the request for proposal [9]. The criteria define the organizational objectives and their relative importance, so that the potential offerors may judge the basis upon which their proposals are evaluated and how they can devote their efforts in preparing their proposals.

A selection criterion is a guide for evaluating how well an offeror's approach meets the need. For example, performance, accuracy, schedule, cost, and facilities can be criteria in some cases. Especially, the criteria should be measured by quantitative scales or by specific qualitative terms that are readily understandable by the evaluator [5]. In order to reach to a level of detail to identify the advantages and disadvantages as well as deficiencies of proposal regarding the required items or the required services based on the work breakdown structure [7]. In general, the evaluation criteria and their importance should be consistent with those in the statement of work.

As shown in Table 1, this case study utilized the four major criteria: 1) technical, 2) logistic, 3) management, and cost criteria. The technical criterion is more important than the logistic criterion. The logistic criterion is more important than the management criterion. The management criterion is more important than the cost criterion. Offerors are cautioned that award will be made to an offeror submitting other than the lowest cost based upon the technical, logistic, and management merits of the proposal. No advantage accrues to an offeror who submits an unrealistically low cost proposal. A proposal must be comprehensive and in detail. A proposal also meets all requirements with the minimum risk.

2.1 Technical Criterion

The technical criteria consist of the four factors: engineering, ability to furnish, installation, and quality assurance. First, the engineering factor can be divided into several subfactors. The integration of customer furnished equipment of hardware and software to provide user operating systems friendly is important. The software is reviewed for the previous commercial application, the extent of modification to commercial software packages and the risks associated with software developments. Second, the factor of the ability to furnish consisted of three subfactors. Equipment (hardware)- availability of commercial off-the-shelf hardware is important. The degree of complexity of customer furnished equipment relative to operation is important. Ability of supporting documentation supplied with the commercial certification is important. Commercial firmware and software- minimizing modifications while meeting requirements is important. Third, the installation factor consisted of three subfactors. Installation practice for the commercial equipment - degree of understanding of the installation requirement as detailed in the proposal is important. In the site engineering, adequate resources are dedicated to the engineering to minimize the risk in meeting schedules and to integrate all components. Transition and cutover plan is to identify the details and constraints to accomplish successful cutover from the present prototype system. Fourth, the quality assurance consisted of four subfactors. Quality assurance method is used to minimize on-site failures. Resources are required to conduct a quality assurance. The well-designed testing program is essential.

2.2 Logistic Criterion

The logistics criteria consist of three factors such as training, maintenance support, and logistics management. First, the training subfactor includes the offeror's understanding of the preparation of training material, the quality of embedded operator training packages, and availability of qualified and skilled personnel to prepare the required training documentation in important, the offeror's past experience, and an approach to the on-the-job training. Second, maintenance support subfactor consists of the methods for determining and acquiring the range and quantity of spare parts necessary to operate and maintain the equipment, maintenance plan, location of maintenance personnel and repair parts, etc. Third, logistic management subfactor consists of experience and past performance, and overall management techniques and control.

2.3 Management Criterion

The management criteria consist of two factors: consortium relationship and contract management. First, the consortium subfactor includes the relationship established between the members of the consortium and the demonstrated involvement of each member will be evaluated. The involvement of industry particularly in the area of logistics and long-term support is relevant. Second, the contractor management subfactor includes the past performance on relevant field, the degree of project control to assure schedule and cost compliance while fulfilling all requirements, and the ability to operate the present prototype system during the implementation of the information systems.

2.4 Cost Criterion

The cost criterion consists of two factors: cost proposal and cost realism. First, the first subfactor is composed of the offeror's cost proposal in terms of compliance with the Government standard instructions, i.e., the completeness, correctness, and traceability of the labor, material, and other direct cost data provided. Also, an audit agency conduct an audit to evaluate the correctness of the rates involved and the appropriateness of the methodology used to determine those rates. Second, the second subfactor is the cost realism. The offeror's cost proposal will be evaluated in terms of the magnitude of the effort proposed to the task involved. Where the offeror has, for specific reasons, proposed fewer hours than required, the rationale must be fully explained. Compatibility will also be evaluated between man-hours in the cost proposal and those in the management, technical, and logistics proposals.

3. Traditional Source Selection Process

In this section, the traditional SSE process is discussed. The seven proposals submitted by the offerors are evaluated in a sequence as determined by the SSE board. In order to ensure maximum objectivity, equity, and fairness, the evaluators record all deficiencies and items that need to be clarified. Review of each proposal included the use of an request for proposal checklist to insure that all requirements have been addressed satisfactorily. In general, the traditional SSE process consisted of the four phases: 1) check and record all deficiencies, 2) evaluate the mandatory and technical requirements, 3) value evaluation, and 4) cost evaluation.

In this study, the value evaluation is emphasized. To perform the value evaluation, a value rating was formulated for each criterion, factor, and subfactor identified as the evaluation criteria for solicitation of the project. Rating value assessments for a given subfactor was made through the team discussion of value expressed in a given proposal. There are various scoring systems such as three, four, five, and n-descriptor scoring systems. The selection of a rating scale depends on the situation of a project. In this case, the four scoring system to establish and to assign a rating value for each subfactor.

When completing an evaluation-rating sheet, each team provides the narrative rationale for each rating value assignment. This narrative is especially important because it can be used as the basis for the negotiation and the debriefings. The factor rating was based on the subfactor ratings. The factor rating was used to make the criterion rating. The value rating is to assess the quality of each item because the offerors' responsiveness to the minimum requirements has been evaluated previously. If an evaluator encounters any area with an unresolved deficiency, the evaluator must assess the impact of the deficiency. This concept is critical because the cumulative results of the evaluation rating will be major consideration in determining whether a competitive range is established and in the negotiations.

The evaluators rely on their professional judgement and the findings of discussion within the team. The SSE board rating for a given criterion or factor is the arithmetic mean of the ratings of all evaluators assigned. Traditionally, the criterion ratings recorded in four scoring system will be used by the chairperson of SSE board to calculate the technical, logistic, and management ranking value. The criterion ranking value can be calculated by the formula: CRV = PR/HPR, where CRV = criterion ranking value, PR = panel rating for a criteria of offer, and HPR = highest panel rating scored for the criteria across all offerors. Table 2 shows the calculated rating for seven offerors.

Criteria (Weight)	Evaluation Factors	A	B	C	D	E	F	G
Technical Criteria (45%)	Integration of customer furnished equipment	4	3	2	2	2	2	4
	Ability of the machine translation support system	4	2	2	3	2	3	3
	Ability of the system to accommodate future systems interface	4	3	3	3	2	3	4
	Ability of mapping system	4	3	4	4	3	2	2
	Ability of the commercial-off-the-shelf hardware	3	2	3	3	4	4	3
	Commercial firmware and software	4	4	2	4	3	3	3
	Software	3	3	2	3	2	3	3
	Functions and features	4	3	4	4	4	4	4
	Installation practice for commercial equipment	3	4	3	3	3	2	3
	Site engineering with adequate resource	3	3	3	3	3	3	3
	Quality assurance methodology used to minimize on-site failures	3	3	3	3	3	2	3
	Resources - the number and quality of personnel	4	4	3	3	3	3	4
	Testing program	3	4	2	3	3	3	4
Logistic Criteria (25%)	Training	3	3	2	2	2	3	4
	Maintenance support	4	2	3	2	2	2	4
	Logistic management	2	3	3	2	3	3	2
Management Criteria (20%)	Consortium	4	2	2	2	2	2	3
	Contract management	4	3	2	1	2	1	4
Cost Criteria (10%)	Cost proposal	3	3	2	2	2	4	4
	Cost realism	3	3	2	2	3	3	3
Total Scores		69	60	52	52	54	55	67
Ranking		1	3	6.5	6.5	5	4	2

※ Note: A, B, C, D, E, F, and G indicate the offeror, respectively.

Table 2. Traditional Evaluation Scoring

Cost team members review all offerors' cost proposals to find out obvious cost submission errors or omissions, which are required to be submitted. They also examine all offerors in terms of cost realism and calculate the total cost for each acceptable cost plan. A cost ranking value can be computed by the formula: CRV = 1 - ETSLC/LTSLC, where CRV = cost ranking value, ETSLC = evaluated total systems life cost of the offer, and LTSLC = lowest total systems life cost of the lowest evaluated offer. The high SSE board applied weight assignment for the total system life cycle cost subfactor. The cost points formula (Cost points = Cost ranking value * Cost weight) for this evaluation was used. On the other hand, the higher level of authority than the evaluation group establishes the evaluation criteria and their relative importance. In order to minimize bias and realize an optimum measure of objectivity, the scoring and weighing functions are separated. In order to calculate weighted criteria scores, the formula (Criteria points = Criteria ranking value * Weighing) was used.

4. Source Selection Process by the AHP

The complexity of SSE calls for a formal decision analysis technique. Over the last several decades, numerous researchers have done in the field of MCDM. Among these, Saaty and Shim pointed out that the AHP technique has been applied to a wide range of decision problems. The AHP is a method for modeling ill-structured problems such as a SSE. The AHP is one of the most important decision analysis techniques for MCDM. The AHP has received considerable attention as a decision support system generator. For the reason, the AHP can be used effectively on microcomputers. For example, the Expert Choice is a DSS generator based on the AHP for microcomputers or personal computers.

The AHP's scoring technique was used to determine the relative weights of evaluation criteria [7]. The qualitative programming approach was used to synthesize the offeror's proposal scores to arrive at one score per proposal. The AHP technique leads to the selection of the best offer in terms of the maximization of the underlying utility function of the evaluators [10]. This study utilized the Expert Choice, which is a decision support tool based on the AHP [8].

In order to determine the relative weight of the proposal evaluation criteria at each level, the pairwise comparison of the AHP was conducted on the basis of the group discussion of panel as a peer group. The results of each panel leader's judgement were aggregated. In this case, there are the four criteria at the first level, eleven factors at the second level, and thirty-five subfactors at the lowest level. In order to improve the consistency for all input matrices, the sizes of the input matrices are relatively small, ranging from 2*2 to 5*5. The maximum eigenvalue was used to check the consistency of the judgements. This maximum eigenvalue (max) is transformed into the consistency index (CI) by using the formula (CI =(max-n)/(n-1)). As a rule of thumb, if CI is less than 0.10 the judgement is acceptable. As shown in Table 3, the global and local weights are identical at the first level. At the second level, the consistency indexes are much less than 0.1. In order to combine criteria and factors, the formula (C [l,k] = C¬i, where C[l,k] is the global relative weight of components at level k, with respect to the element on l, C¬i, i-1 is the matrix with rows consisting of estimated local relative weights, and i represents the number of elements at level i) was used.

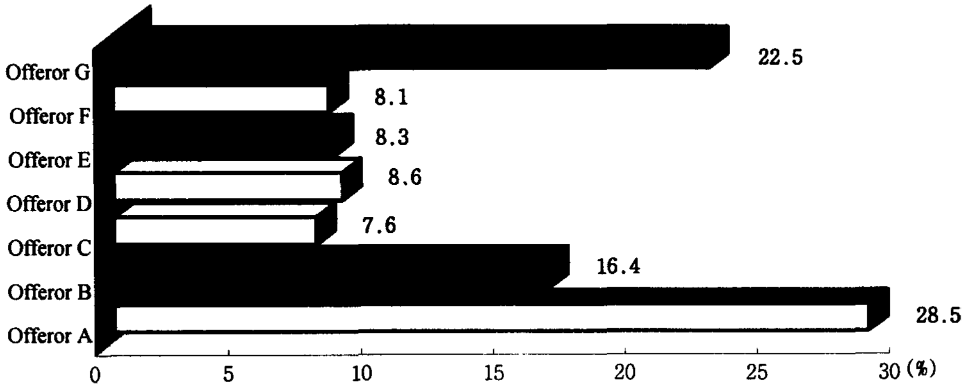
Criteria (Weight)	Evaluation Factors	Local Weight	Global Weight
Technical Criteria (0.564)	Engineering factor	0.431	0.243
	Ability to furnish	0.246	0.139
	Installation	0.189	0.107
	Quality assurance	0.135	0.076
Logistic Criteria (0.238)	Training	0.163	0.039
	Maintenance support	0.540	0.128
	Logistic management	0.297	0.071
Management Criteria (0.130)	Consortium	0.750	0.098
	Contract management	0.250	0.033
Cost Criteria (0.068)	Cost proposal	0.333	0.023
	Cost realism	0.667	0.045

Table3. Global and Local Relative Weights

The Expert Choice provides the evaluators various options in order to meet evaluator's need and convenience in a situation. In this research, the type of "preference for" is used to compare offeror's proposals at each level of criteria. The qualitative programming supports a theoretical background for such as synthesis. More details of this kind of information can be showed in many researches on the AHP [4] [6] [8] [10]. However, the detailed process and mathematical explanation of the AHP are beyond this case study.

The seven offeror's proposals were evaluated through pairwise comparisons. The final result of the comparison of seven proposals is a relative score for each offeror's proposal. These scores were used to synthesize into a single score for each offeror's proposal as shown in Figure 1. The overall inconsistency index is 0.04, which is acceptable. The authors have evaluated seven proposals by using the hypothetical data. The findings indicated that the final result of this research is very similar to the true result of the project.

Figure1. Leaf Nodes



(Note: Overall inconsistency index=0.04)

5. Conclusion and Discussion

As mentioned earlier, the goal of the SSE process is to select one of several offerers that can best meet the organization's requirements. However, the SSE is very complex and difficult because of the high uncertainty under current IS technologies. Organizations cannot be met by using the traditional SSE process. Thus, the traditional SSE process should be enhanced by using the MCDM technique.

There are several advantages of the MCDM technique. First, the AHP allows the decision maker to focus on the comparison of just two alternatives at a time. Second, the AHP supports one to examine the evaluators' consistency in judgement. Third, sensitivity analysis can be performed to assess the effect of changes in the attribute weights on overall rating of each alternative. Therefore, the AHP is able: 1) to deal with human inconsistency and error, 2) to provide an explanation of choice, and 3) to foster insight for the decision maker. Although there are some disadvantages of the AHP, the advantages outweigh the disadvantages of the AHP as a DSS generator.

The SSE based on the AHP can be apply to more effectively select and evaluate the best offeror because the AHP can overcome the limitations of the traditional approaches. Under uncertainty, the AHP offers a flexible approach to assist the evaluators in the SSE process. As a MCDM methodology, the AHP provides both subjective and objective factors. It has been applied to evaluate the various software packages. It helps an evaluator identify the criteria and evaluate the offeror's proposals. It allows factors to be specified in a multicriteria setting, provides the ability to express the relative importance of the multiple criteria being considered, and uses pairwise comparisons in extracting information. Therefore, it can be concluded that the best approach is a way to combine the traditional approach and the AHP technique in order to reduce the uncertainty of a complex SSE.

6. REFERENCES

[1] U.S. Information Systems Engineering Command, Project Manager, AWIS/CCS, Draft Acquisition Strategy Paper for TACCIMS, 1986.

[2] Joint TACCIMS PMO between the U.S, DoD and Korea MND, Source Selection Evaluation Plan (Draft), 1986.

[3] MITRE Corporation, The Theater Automated Command and Control Information Management System (TACCIMS) Acquisition Plan (Draft), 1986.

[4] Mustafa, M.A. and Murphree, E.L., "A Multicriteria Decision Support Approach for Project Compression", Project Management Journal, Vol.20, No.2, 1989, pp.29-34.

[5] Program Executive Office-Networks, Project Manager TACCIMS, Theater Automation Command and Control Information System Proposal Evaluation and Source Selection: Standing Operating Procedures, 1988.

[6] Schoner, B. and Wedley, W.C., "Ambiguous Criteria Weights in AHP: Consequences and Solutions", Decision Sciences, Vol.20, No.3, 1989, pp. 462-475.

[7] Shim, J.P. and Lee, N.Y., "A Conceptual Model for

Developing WBS of a Large-Scale Information Systems Project by Using DoD-STD-2167A", DSI Annual Meeting, 1991.
[8] Taylor, G. Stephen and Shim, J.P., "Microcomputer Based Decision Support Systems Applied to Human Resource Management", Collegiate Microcomputer, Vol.8, No.3, 1990.
[9] U.S. Army Material Command, Procurement: The Source Selection, AMC-P 715-3, Vol.1, 1987.
[10] Zahedi, F., "A Method for Quantitative Evaluation of Expert Systems", European Journal of Operational Research, Vol.48, No.1, 1990, pp.136-147.
[11] S. Cem Karacal, "Evaluating embedded decision processes of manufacturing systems through simulation", Proceedings of the 1997 conference on Winter simulation conference, 1997, pp.781-785.
[12] Jalal Nikoukaran, Vlatka Hlupic and Ray J. Paul, "Criteria for simulation software evaluation", Proceedings of the 1998 conference on Winter simulation conference, 1998, pp.399-406.
[13] J-M Yeh, "A modified procedure for synthesizing ratio judgments in the analytic hierarchy process", The Journal of the Operational Research Society, Oxford, Vol.50, Iss.8, 1999, pp.867.
[14] Dean S Hartley III, "Military Operations Research : Quantitative Decision Making", Norcross, Vol.31, Iss.3, 1999, pp.280-282.
[15] Andrew Colin, "The analytic hierarchy process", Dr. Dobb's Journal, San Mateo, Vol.24, Iss.2, 1999, pp.123-127.
[16] Vlatka Hlupic, "Guidelines for selection of manufacturing simulation software, IIE Transactions, Norcross, Vol.31, Iss.1, 1999, pp.21-29.
[17] H Wang, "A comparative study of the prioritization matrix method and the analytic hierarchy process technique in quality function deployment", Total Quality Management, Abingdon, Vol.9, Iss.6, 1998, pp.421-431.
[18] Goh, T N, "Prioritizing processes in initial implementation of statistical process control", IEEE Transactions on Engineering Management", New York, Vol.45, Iss.1, 1998, pp.66-72.