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Research on using ANP to establish a performance assessment model for business intelligence systems

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ABSTRACT

In order to compete in the rigorous environment, the electronization has enabled business to deploy business intelligence (BI) systems for the purpose of decision-making. However, to avoid the ineffective experiences during the deployment, it is important to clarify the impact factors of a BI system and find out a suitable assessment method to evaluate the performance of BI systems. In this paper, an analytic network process (ANP) based assessment model was constructed to assess the effectiveness of BI systems. Furthermore, an expert questionnaire was used to filter out useful performance matrices, used as the subcriteria of the ANP model. Finally, a real case was analyzed using the constructed ANP-based effectiveness assessment model for Business Intelligence systems. The results indicate that the most critical factors that impact the effectiveness of a BI system are: output information accuracy, conformity to the requirements, and support of organizational efficiency. Utilizing this model to assess the BI performance of the studied case, it reveals that 24% improvement in effectiveness has been reached, which consists with the perception of the management level. Therefore, this effectiveness assessment model can be used to evaluate the performances of a BI system. It can also provide performance indices and improvement directions for BI users and vendors, respectively, for the total succession in system effectiveness and satisfaction.

1. Introduction

Traditional enterprises may normally face issues such as the overflow of data, the lack of information, the lack of knowledge and insufficiency of reports. Therefore, in order to make prompt decision within the shortest period of time possible to keep pace with the situation, high levels of management commonly make decisions based on their experiences, leading to the ever-increasing risk of decision failure while lowering the value of the decision itself. As worldwide competition is maturating, past decision-making modes can no longer satisfy the requirements of enterprises for decision efficiency and benefits; enterprises must make good use of electronic tools to quickly extract useful information from huge volume of data by providing the skills of fast decision-making (Rakar & Jovan, 2004). The way to promote the electronization solutions from the operational level to the decision making level is a topic enterprises cannot avoid in the face of the next wave of electronization. The information system applied within the enterprises should be able to demonstrate the data or information with accuracy and in real-time, in order to expedite the speed of processing and decision-making. Existing electronization software package can provide a set of complete solutions for the operation and management processes of enterprises. However, the effects of the implementation of electronization tools vary that the probability of failure is higher than that of the success (Ward, Hemingway, & Daniel, 2005). Therefore, defining the performance of information tool and laying down related assessment criteria is an important issue that has to be tackled for the deployment of electronization.

Business intelligence (BI) is the tool used by enterprises to collect, manage and analyze structural and non-structural data and information by taking advantage of modern information technology (IT). It utilizes a substantial amount of collected data during the daily operational processes, and transforms the data into information and knowledge to avoid the supposition and ignorance of the enterprises (Wang, 2005). Under the speed-oriented operation mode, in order to improve management effects and performance, BI will surely become the tool enterprises would like to actively deploy as well as the solution that can bring enterprises competitive edge. However, current BI application is still at its fledging stage and most of the enterprises fall short of sufficient understanding

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towards BI (Wang, 2005); currently, research on conducting performance evaluation for the implementation of BI system is scarce, not to mention the analysis of on-line performance. Beside that, managers usually have to measure all the pros and cons to achieve a balance in assessing the performances of BI/IT systems. Different end users and IT people adopt different performance measurement criteria. Therefore, it is a significant issue to implement across-the-board considerations to incorporate different viewpoints and perspectives from manifold experts in BI development and usage into the choice for assessing BI performance effectiveness.

In order to lower the failure risk after implementation, it is necessary to conduct in-depth discussion for the aforementioned issue. Therefore, this research starts by analyzing BI benefits, takes advantage of analytic network process (ANP) to discuss BI effectiveness and related performance assessment indications. The results thus provide enterprises that are interested in deploying BI systems with a consistent and effective assessment model for future BI implementation while serving as a direction of future improvement and enhancement for BI software suppliers and consulting companies.

The remainder of this paper is organized as follows. Section 2 presents the related studies regarding to this research. Then, the research theory and method is presented in Section 3. Section 4 demonstrates the proposed architecture for assessing the performance of BI systems. An empirical research and related analysis is illustrated in Section 5. Then a case study on a global supplier of computer peripherals is described in Section 6, and the summary and conclusions are drawn finally.

2. Information systems

With the demands for information technology, application software and enterprise information tactics constantly are enhanced and expanded. The deployment of SCM, ERP, CRM systems, etc. has become mature, and the growth of business intelligence information system will become a new direction for enterprises' electronization construction (Chung, Lee, & Pearn, 2005).

2.1. Business intelligence

Starting from the use of initial data storage devices, enterprises have continued innovating and creating new system modes, in a pursuit of higher operation efficiency. After the development of relational database, the development of business intelligence is then underway. Currently, there are multiple software suppliers and specialty consulting companies conducting even more logic planning and enhancement for the function and applicability of BI systems, e.g. tools assisting enterprises in decision-making such as data warehouse and real-time analysis. Hence, commercial logic thinking is still being innovated and developed and through such processes, systematic enterprise operation mode is expected to be created to enhance the competitive edge of enterprises.

The application of business intelligence is the process through which enterprises take advantages of modern information technology to collect, manage and analyze structural or non-structural data. In order words, through the extraction, integration and analysis of data, technology and commercial processing procedures in the decision-making are supported (Wang, 2005). Problems and a huge amount of data of enterprises are input into data mining systems for data analysis so that decision makers can obtain useful information promptly for making correct judgment; that is, in regard to enterprise operating contents, abilities of fast understanding and deducing are provided, and thus enhancing the quality of decision-making and improving performance and expediting processing speed (Back, 2002). Business intelligence is an analysis mechanism by which automated decision-making regarding business status, sales analysis, customer demand, product preference, etc. is provided for enterprises through large database system analysis as well as mathematical, statistical, artificial intelligence, data mining and on-line analysis processing (OLAP) (Berson & Smith, 1997; Thomsen, 2002). Eckerson Wayne (2005) held that BI must be able to provide the following tools: production reporting tools, end-user query and reporting tools, on-line analysis processing, dashboard/scorecard tools, data mining tools, planning and modeling tools.

BI is not only a tool reflecting issues, but also the management of transferring internal messages in the enterprise environment (Eckerson Wayne, 2005). Therefore, apart from substantial IT support, sound and proper planning abilities are needed when constructing BI working environment, for example, ensuring the delivery and implementation of BI projects; ability of acquiring standardized data elements and changing process to ensure the quality of data acquired, integrating all strategic objectives within the organization, and designing strategic map and transmitting important corporate value. Therefore, BI covers a wide range of tools and broad scope, and among the commonly mentioned important applications are data warehouse, data mining, OLAP, decision support system (DSS), balance scorecard (BSC), etc. All in all, the purpose of BI is to provide users with the best possible assistance in the process of decision-making. Apart from delivering the right information to right person during the right time (Back, 2002; Eckerson Wayne, 2005), at the BI planning, implementing and go-live stages, enterprise operation contents and business objectives must be understood in order to properly plan related performance measurement indices and ensure the correctness and validity of the information provided by BI.

2.2. Performance measurement indices of information system

Effectively assessing the efficiency of an information system is the key element in the successful implementation of the system. Assessing the performances of an information system means if the information system can be accepted by users, and if users' work-related needs can be met and the objective at the initial implementation can be achieved. As to how to assess the efficiency of information system, roughly it can be classified into the assessment of system satisfaction and the assessment of effectiveness. Among the assessments of system satisfaction are contents correctness (Doll & Torzadeh, 1988; Ives, Olson, & Baroudi, 1983), resilience of the format (Doll & Torzadeh, 1988), easiness of the operation (Doll & Torzadeh, 1988; Tan & Lo, 1990), real-time nature (Doll & Torzadeh, 1988), integrity of the output (Doll & Torzadeh, 1988), credibility of the output (Ives et al., 1983), integration and safety of the system (Tan & Lo, 1990). Wildemann (1987) indicated that the success of the information system should be considered from both aspects of the success of project management and the efficiency of software execution at the time of system implementation. If a business intelligence system can be successfully implemented, it can play its due role in four aspects, namely, assisting in understanding business status, measuring organization performance, improving stakeholder relationship, and creating profitable opportunities (Wang, 2005).

To prevent inefficiency of an information system after the introduction from appearing again, assessing the effectiveness of a BI system is an important issue and must be carefully planned. It can serve as the criteria for BI system selection and implementation. However, current research has not yet pointed out the effectiveness and its assessment methods after BI system actually goes online. Therefore, through literature discussion, this research summed up 40 criteria of evaluating information system performances. Proper key criteria are then picked out through experts' questionnaires as the major basis for constructing BI system performance assessment model. This paper proposes to apply ANP method to construct an integrated performance evaluation model for BI systems. ANP method was proposed by Saaty and Takizawa (1986), and it is an extension of analytic hierarchy process (AHP). In reality, the elements within the hierarchy of various criteria are often interdependent, but low-level elements may dominate high-level ones. A feedback relationship also exists in the process, thus, this structure resembles a network system.

The network relationship of ANP method does not only present the dependencies between criteria, but also calculate the relative weights (eigenvectors) of each criterion. The result of these computations forms a super matrix. After computation of the relationship between the super matrix and the comprehensive evaluations, it is possible to derive the weight values between criteria and alternatives. The higher the weights, the more priority will be placed. In this manner, it is possible to select the most appropriate alternative (Saaty, 1996). Jharkharia and Shankar (2007) used ANP method to select distribution service providers. They indicated that ANP method does not only establish a better understanding of the complex relationship between criteria in decision making, but also improves the reliability of decision-making. Chung et al. (2005) adopted the matrix method proposed by Saaty and suggested a simplified ANP structure to analyze the inputs and outputs of many kinds of production processes. The best product mix can be derived by integrating experts' opinions. ANP method is mostly applied in the selection of multiple feasible alternatives, such as resource allocations and sequencing, to improve the reliability of decisions in the evaluation process (Jharkharia & Shankar, 2007; Lee, Chen, & Chang, 2006; Lin, Chiu, & Tsai, 2008). In this paper, details of the ANP technique will not be discussed. However, Section 3 will present an application of the ANP technique to the assessment of business intelligence systems.

3. Research theory and method

This research method is consisted of three parts. The first part chooses the factors that influence the BI system's effects as the foundation of the ANP analysis method. In this section, we sort out the key elements that influence the effects of information systems after gathering kinds of documents, and resort to the experiences and opinions acquired from questionnaire for experts. The second part adopts the selected elements to build up the ANP model. The third part is for case study. Based on the analysis result of the ANP model, the contents of interview are designed, the experiences of the studied company implementing the BI system and the effects after the implementation are presented, and subsequently, we verify that the effectiveness of the ANP structure built up in this research in the appraisal of a BI system.

3.1. ANP theory overview

ANP method was proposed by Saaty (1996) in 1975. It is an extension of analytic hierarchy process (AHP). In reality, the elements within the hierarchy of various rules are often interdependent. Low-level elements also dominate high-level elements. There is a feedback relationship. In such instances, the structure of a system resembles that of a network. ANP method is stemmed from this type of network system structure (Wang, 2005). Fig. 1 illustrates the structural relationship of ANP method (Wang, 2005). This system can be divided into two parts. The first part is the control hierarchy, consisting of network relationships between the goal, criteria and sub-criteria. The control hierarchy affects the internal relationships of the system. The second part is the network hierarchy, consisting of network relationships between elements and clusters.

The network relationship of ANP method does not only present the relationship between rules, but also calculate the relative weightings (characteristic vectors) of each rule. The result of these computations forms a super matrix. Finally, after the computation of the relationship of the super matrix and the comprehensive evaluations, it is possible to derive the interdependence of each valuation criteria and options and the weighting of priorities. The higher the priority weightings, the more priority will be placed. In this manner, it is possible to select the most appropriate option (Saaty, 2003). In the previous literature regarding the application of ANP method, Saaty and Takizawa (1986) uses the matrix applications to solve the network structure of ANP method, in a similar way to AHP method. However, their approach considers the interdependence between rules and options. Meade and Sarkis (1999) proposed the use of ANP method to conduct policy analysis in order to evaluate projects so that organizations become more swifter and better in improving procedures and achieving specific targets. Lee and Kim (2000) applied Saaty's ANP method in the selection of IT systems in order to respond to the interdependency of the valuation rules and feasible projects.

Jharkharia and Shankar (2007) used ANP method to select distribution services providers. They indicated that ANP method does not only establish a better understanding of the complex relationship between valuation criteria in decision-making, but also improves the reliability of decision-making. Chung et al. (2005) adopted the matrix method proposed by Saaty and suggested a simplified ANP structure to analyze the inputs and outputs of many kinds of production processes. The best product mix can be derived by integrating experts' opinions. From the previous literature, we know that ANP method is mostly applied in the selection of multiple feasible options, such as resource allocations and sequencing, in order to improve the reliability of decisions in the evaluation process (Jharkharia & Shankar, 2007). Therefore, this study applies ANP method to construct an assessment model to effectively evaluate the performances of BI systems.

3.2. ANP decision-making flowchart

Step 1: *Definition of policy issues and establishment of policy-making members*
All the factors that may affect policy issues should be incorporated based on the nature of the policy issues, in order to define the domain of discussions. A body of decision makers should be established in order to collate the opinions of the experts in the relevant fields, based on the level of complexity, and the fields of domain issues involved. Generally, the number of surveyed expert should not be too much, 5–50 is a suitable number (Reza & Vassilis, 1988).

Step 2: *Construction of the network hierarchy layer structure of the problems*
After consolidating and categorizing relevant information, key issues that affect the decisions are identified. The network hierarchy layer valuation model is illustrated in Fig. 2. In the structure, there exists interdependency within each layer and loop arcs are used to indicate feedback relationships.

Step 3: *Questionnaire surveys and expert preference integration*
According to the network hierarchy layer valuation model structured for the decision issues, weightings are given to each element according to their corresponding upper elements via questionnaires issued to experts to gather

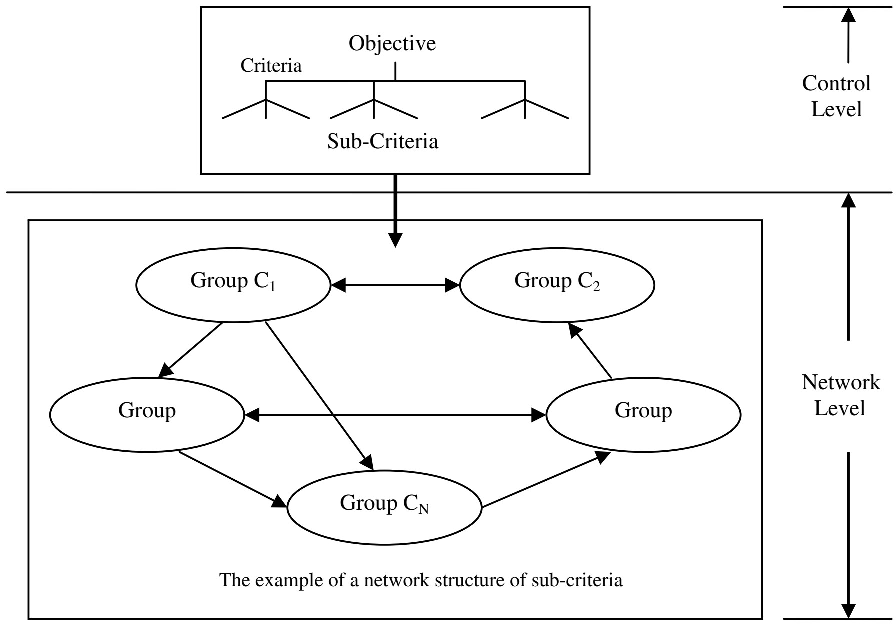

Fig. 1. Structural relationship of ANP method.

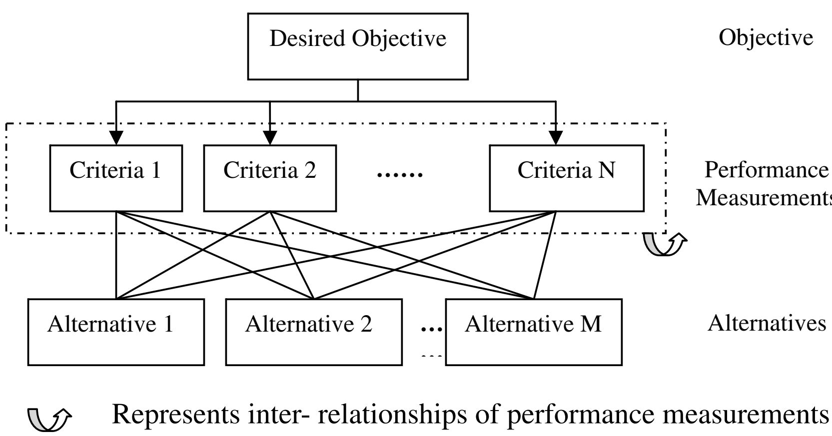

Fig. 2. ANP network hierarchy layer valuation model architecture (Saaty, 1996).

opinions regarding the relative importance of different elements. If there are a number of experts involved in the evaluation, averages can be used to compute the collective weightings. When it comes to the integration of expert preferences, Saaty (1980) thinks that geometrical averages yield better results.

Step 4: *Establishment of pairwise comparison matrixes*
After the consolidation of judgments and preferences from various experts, it is possible to construct a comparison matrix of multiple valuation criteria and options. ANP method applies a measurement of 1–9 and derives relative weightings based on this measurement. These weightings then are entered as values of the super matrix structure so as to reflect the interdependency and relative importance of each valuation criteria and option.

Step 5: *Consistency test*
In the ANP method, decision makers or experts who make judgments or preferences must go through the consistency test, which are conducted based on the consistency ratios (C.R.) of the comparison matrixes. The C.R. of a pairwise comparison matrix is the ratio of its consistency index to the corresponding random value. The details can be found in Saaty's (Saaty, 2005).

Step 6: *Computations of super matrixes*
A super matrix lists down all the sub-matrixes consisting of all the clusters and necessary elements in the order on the left and upper sides of the matrix. If the aggregate of the column vectors of a super matrix is not equal to 1, it is called an un-weighted super matrix, which may be converted with specific procedures to make it a weighted super matrix. Afterwards, the matrix will be limited, and gradually the consolidation of the interdependency and relative weightings will be derived (Saaty, 1996).

Step 7: *Selection of most optimal options*
Desirability index (DI) is used to determine the most optimal options. The formula is as follows:

$$\mathrm{DI}_i = \sum_{j=1}^{r} S_{ij} = \sum_{j=1}^{r} R_j W_{ij}, \quad \forall i,\ j = 1, 2, \ldots, r, \tag{1}$$

where DI_i is denotes expected indicator of the number *i* option; S_{ij} is denotes the weighting of number *i* option under the criteria of number *j*; R_j is denotes the relative weighting of number *j* sub-criteria; W_{ij} is denotes the relative weighting of number *i* option under number *j* sub-criteria.

The option with the highest value of expected indicators is the most optimal option A^*:

$$A^* = \{A_i|DI_i = \text{maximum}_{k=1,2,\ldots,n}(DI_k)\}. \quad (2)$$

4. Business intelligence ANP performance assessment model

4.1. Selection of impact factors

The ANP assessment model is aimed to assist enterprises to evaluate the effectiveness of a BI system. It provides the effective check and the effective analysis to those enterprises that have implemented or are going to implement a BI system, and improves the usability and satisfaction of BI system. In this research, the key elements that influence the performances of an information system are constructed after interviewing those seniors in the information department of industrial sectors and listening to the visions and opinions of experts. The ambiguous and unsuitable factors in the questionnaire are modified or deleted. Finally, the questionnaire consists of four categories of criteria, i.e. function of a BI system, service and integration ability, meeting user's needs, and meeting enterprises requirements, and includes a total of 26 questions, designed with the Likert-type scale. Twelve copies are released, and nine valid copies are recovered. The return rate is 75%.

By following the opinions from experts, we choose nine performance indicators. Of the nice indicators, system response time, system security, and output information accuracy belong to the criteria of functions of a BI system, while implementing experiences of consultant, comprehension degree of implementer's business are for the criteria of service and integration ability. The indicators of the criteria of meeting user's needs include support degree of user and high management level and conformity to the requirements. Finally, support of organizational efficiency and support in decision-making in organization are the indicators of the criteria of meeting enterprise requirements. After discussion with BI experts and managers in the information department, the interdependency among those nine performance indicators as the sub-criteria can be obtained, as shown in Table 1.

4.2. ANP performance assessment model

In this paper, the goal of the ANP performance assessment model (Fig. 3) is defined as 'assessing the performance of a BI system'.

Table 1
The interdependency between selected indicators

Criteria	Criteria								
	1	2	3	4	5	6	7	8	9
1. System response time				√	√		√	√	
2. System security				√	√		√	√	
3. Output information accuracy				√	√		√	√	√
4. Implementing experiences of consultant	√	√	√		√		√		
5. Comprehension degree of implementer's business	√	√	√	√			√		
6. Support degree of user and high management level							√	√	√
7. Conformity to the requirements	√	√	√	√	√	√		√	√
8. Support of organizational efficiency	√	√	√			√	√		√
9. Support in decision-making in organization			√			√	√	√	

Note: √ means that the interaction exists among criteria.

The major criteria which influence the goal include functions of a BI system (FBIS), service and integration ability (SIA), meeting user's needs (MUN) and meeting enterprises requirements (MER), and they are interacted and interdependent. The sub-criteria refer to those performance indicators, i.e. system response time (SRT), system security (SS), output information accuracy (OIA), implementing experiences of consultant (IEC), comprehension degree to implementer's business (CDIB), support degree of users and high management level (SDUH), conformity to the requirement (CR), support of organizational efficiency (SOE) and support in decision-making in organization (SDM).

5. Empirical research and analysis

5.1. Expert questionnaire

This paper utilizes ANP model to design expert questionnaire, and appraises the relative importance of criteria as numbers using the fundamental scale of the AHP, shown in Table 2 (Saaty, 2005).

In the questionnaire distribution phase, to avoid any ambiguity or hard readability that may affect the external nature of answers given by the interviewees, and to facilitate the understanding about this ANP model, our researchers physically visited the interviewees to make an on-site survey. The projection presentation and comparison of criteria was utilized to expedite the understanding of the meaning and contents in the questionnaire by those interviewees. Reza and Vassilis (1988) pointed out that the number of experts as interviewee should not be too much, and in general, 5–15 persons are best suited. Therefore, our estimated distribution number of questionnaires was allocated as three copies for implementation consultants and 12 for the user-side that have implemented the BI system. Among the latter targets, nine copies were distributed to the IT personnel and three to end users. The final participates of survey were 12, among them, three were consultants, seven were IT persons and two were end users. The return rate was 80%.

The sub-criteria in the ANP model are subject to discussion and conclusion through relevant documents and finally are screened by experts. In addition, the design of the questionnaire has been audited and discussed by BI experts with rich experiences for modification or correction. Thus, we believe the questionnaire in this research is somewhat in expert's consideration. The Cronbach'α value of the questionnaires is 0.8225, which means the ANP expert questionnaire exhibits high reliability (Saaty, 2005).

5.2. The results of BI performance evaluation model

Through real examples, this research verifies the ANP-based business intelligence performance assessment model. As criteria have made the pair comparison a great deal, we can only choose several comparison matrixes as samples. In this research, the super decision software is used to define the BI performance assessment model.

5.2.1. Pair-wise comparisons of major criteria

Under the key factors that influence the effects of a BI system, the experts appraise the relative importance among the four performance indicators (major criteria). The appraisal results are shown in Table 3. The matrix showing pair-wise comparisons of major criteria along with the eigenvector (e-vector) of these indicators is shown in Table 3.

In order to ensure the consistency of experts' judgments, the consistency checks must be conducted. Table 3 lists the result of the pair comparison matrixes. The C.R. = 0.0134, which is less than 0.1, is an indication of the consistency of experts' evaluations

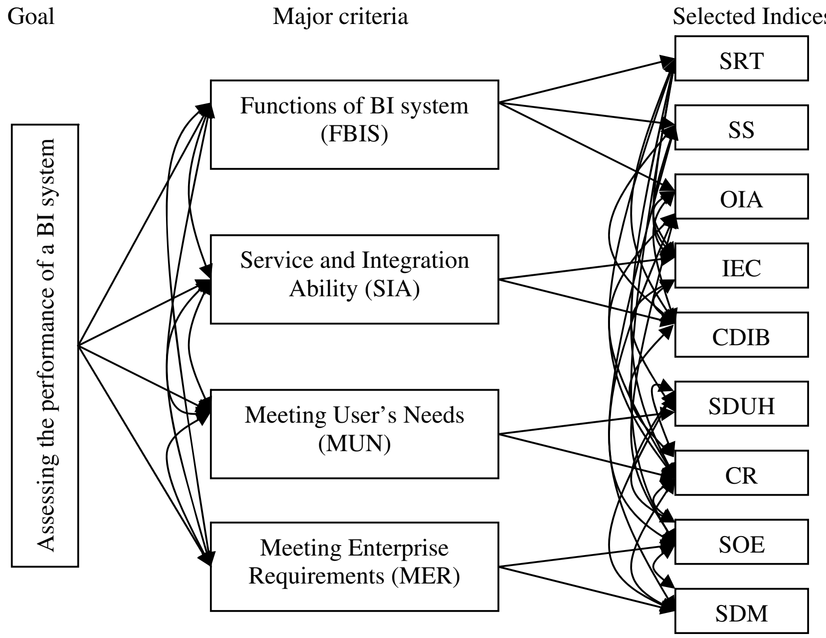

Fig. 3. Business intelligence ANP performance assessment model.

Table 2
Definition and description of the nine grades appraisal scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experiences and judgement slightly favor one factor over another
4	Moderate plus	
5	Strong importance	Experiences and judgement strongly favor on factor over another
6	Strong plus	
7	Very strong or demonstrated importance	An factor is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring on factor over another is of the highest possible order of affirmation
Reciprocals of above	If factor *i* has one of the above none zero numbers assigned to it when compared with factor *j*, then *j* has the reciprocal value when compared with *i*	A rational assumption

(Saaty, 1980). The result also demonstrates that the enterprise has implemented the BI system to meet enterprises' requirements.

With the weight value (the eigenvector), we can have the weight of each criterion in the target, as is shown in matrix *A* below.

$$A = \begin{bmatrix} 0.095 \\ 0.247 \\ 0.288 \\ 0.370 \end{bmatrix}. \tag{3}$$

5.2.2. Pair-wise comparisons of interdependencies of major criteria

To understand the interdependencies of the major criteria, the pair-wise comparison must be made among the major criteria to obtain the weights of all the criteria of the goal. From Table 4, it

Table 4
Pair-wise comparison among major criteria for enhancing functionalities of BI Systems

	Service and integration ability	Meeting user's needs	Meeting enterprises requirements	Eigenvector
Service and integration ability	1	0.929	0.540	0.254
Meeting user's needs	1.077	1	0.562	0.270
Meeting enterprises requirements	1.854	1.781	1	0.476

Note: C.R. = 0.0001.

Table 3
Pair-wise comparisons among performance indicators under assessing the performance of BI system

	Functions of a BI system	Service and integration ability	Meeting user's needs	Meeting enterprises requirements	Eigenvector
Functions of a BI system	1	0.418	0.262	0.300	0.095
Service and integration ability	2.393	1	0.874	0.730	0.247
Meeting user's needs	3.823	1.1436	1	0.618	0.288
Meeting enterprises requirements	3.377	1.370	1.617	1	0.370

Note: C.R. = 0.0134.

shows that the importance level of meeting enterprises requirements on the functionality enhancement of BI system is 1.781 times higher than that of meeting users' needs. Other figures can be interpreted in same way. Thus, we can have the comparative weight values after comparison of primary criteria. Therefore, under the criterion of FBIS, the relative weight values for ESIP, MUN, and MER are (0.254, 0.270, 0. 476), respectively.

The figures show that the performance indicators of MER have the greatest impact on the FBIS while the ESIP influences less. In addition, the C.R. value is 0.0001 and is less than 0.1, which means the appraisal result of experts is consistent. By resorting to the same method, we can have the importance level and the comparison figures. The results are shown in matrix B of formula 4, in which the values in matrix represent the weights value of those criteria

$$B = \begin{bmatrix} 0 & 0.328 & 0.135 & 0.122 \\ 0.254 & 0 & 0.334 & 0.403 \\ 0.270 & 0.331 & 0 & 0.475 \\ 0.476 & 0.431 & 0.531 & 0 \end{bmatrix}. \quad (4)$$

From the matrix we can see that the weight is sequenced in this way: 1 MER, 2 MUN, 3 ESIP. Thus we know the main targets of survey (BI consultants, IT persons and users) care MER the most. If it is aimed to improve the effects after implementing BI systems, MER should have the highest priority.

$$D = \begin{array}{c} \\ 2.1 \\ 2.2 \\ 2.3 \\ 2.4 \\ 2.5 \\ 2.6 \\ 2.7 \\ 2.8 \\ 2.9 \end{array} \begin{array}{c} \begin{array}{ccccccccc} 2.1 & 2.2 & 2.3 & 2.4 & 2.5 & 2.6 & 2.7 & 2.8 & 2.9 \end{array} \\ \begin{bmatrix} 0 & & & 0.093 & 0.081 & & 0.062 & 0.065 & \\ & 0 & & 0.132 & 0.121 & & 0.078 & 0.088 & \\ & & 0 & 0.360 & 0.374 & & 0.204 & 0.280 & 0.347 \\ 0.348 & 0.331 & 0.243 & 0 & 0.183 & & 0.092 & & \\ 0.119 & 0.138 & 0.177 & 0.150 & 0 & & 0.056 & & \\ & & & & & 0 & 0.210 & 0.230 & 0.329 \\ 0.241 & 0.350 & 0.205 & 0.265 & 0.241 & 0.201 & 0 & 0.146 & 0.145 \\ 0.292 & 0.181 & 0.158 & & & 0.249 & 0.135 & 0 & 0.179 \\ & & 0.217 & & & 0.550 & 0.163 & 0.191 & 0 \end{bmatrix} \end{array}. \quad (6)$$

5.2.3. Pair-wise comparison of the selected indicators under major criteria

The three detailed indicators, SRT, SS, and OIA, affect the enhancement of the BI functions. The comparison result between the importance of SRT, SS and OIA and the importance of FBIS (major criterion) in the expert's assessment is shown in Table 5.

In Table 5, it shows that OIA is 6.601 times more important than SRT for the enhancement of BI functionality. Under the criterion of enhancing the functions of a BI system, the relative weightings of SRT, SS, and OIA are 0.114, 0.242, and 0.644, respectively. The comparison of importance levels of others can be obtained in the same manner. The result is shown in the matrix of formula 5, where the values represent the relative weighting of each selected indicators compared to that of the major criterion. We can discover from the matrix C that it is suitable to design evaluation indicators for the OIA, IEC, UECC and MR criteria if the effects of a BI system is to be evaluated

$$C = \begin{bmatrix} 0.114 & & & \\ 0.242 & & & \\ 0.644 & & & \\ & 0.623 & & \\ & 0.377 & & \\ & & 0.722 & \\ & & 0.278 & \\ & & & 0.214 \\ & & & 0.789 \end{bmatrix}. \quad (5)$$

5.2.4. Pair-wise comparison among selected indicators

In Table 6, the figure in the block of second column and third row means the importance of IEC is 2.44 times that of the CDIB. With same manner, we know the importance comparison pairs. The result is shown in the matrix D of formula 6, in which the figures represent the weight values of selected indicators.

5.3. Calculation of matrix M

The aggregation of all the relative weightings of the pair-wise comparison matrices (formula 3–6) derives the un-weighted super matrix M (shown in Table 7) of the BI system assessment model. However, the super matrix M does not meet with "column stochastic" limitation, i.e. the sum of each of the column must be 1. It is necessary to compute appropriate weightings so that the aggregation of all the column values will be equal to 1. After performing necessary operations for the limitation of the weighted super matrix, the converged super matrix M' is derived. As the sum of rows less than 1 is called the un-weighted matrix, we add some certain weights to make the sum equal to 1 and obtain a weighted matrix M', Table 8. After the limitations of the weighted super matrix, the converged super matrix M'' is derived, as shown in Table 9.

Table 5
Pair-wise comparison of performance indicators under FBIS criterion

	SRT	SS	OIA	Eigenvector
SRT	1	0.553	0.152	0.114
SS	1.811	1	0.440	0.242
OIA	6.601	2.274	1	0.644

Note: C.R. = 0.0239.

Table 6
Pair-wise comparison of performance indicators under SRT

	IEC	CDIB	CR	SOE	Eigenvector
IEC	1	2.44	1.70	1.23	0.348
CDIB	0.409	1	0.373	0.444	0.119
CR	0.587	2.678	1	0.715	0.241
SOE	0.813	2.253	1.398	1	0.292

Note: C.R. = 0.0157.

Table 7
The un-weighted super matrix M

		Goal	Major criteria				Selected indicators								
		0.0 Assessing the performance of BI system	1.1 FBIS	1.2 SIA	1.3 MUN	1.4 MER	2.1 SRT	2.2 SS	2.3 OIA	2.4 IEC	2.5 CDIB	2.6 SDUH	2.7 CR	2.8 SOE	2.9 SDM
Goal	0.0 Assessing the performance of a BI system	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Major criteria	1.1 FBIS	0.095	0	0.238	0.135	0.122	0	0	0	0	0	0	0	0	0
	1.2 SIA	0.247	0.254	0	0.334	0.403	0	0	0	0	0	0	0	0	0
	1.3 MUN	0.288	0.270	0.331	0	0.475	0	0	0	0	0	0	0	0	0
	1.4 MER	0.370	0.476	0.431	0.531	0	0	0	0	0	0	0	0	0	0
Selected indicators	2.1 SRT	0	0.114	0	0	0	0	0	0	0.093	0.081	0	0.062	0.065	0
	2.2 SS	0	0.242	0	0	0	0	0	0	0.132	0.121	0	0.078	0.088	0
	2.3 OIA	0	0.644	0	0	0	0	0	0	0.360	0.374	0	0.204	0.280	0.347
	2.4 IEC	0	0	0.623	0	0	0.348	0.331	0.243	0	0.183	0	0.092	0	0
	2.5 CDIB	0	0	0.377	0	0	0.119	0.138	0.177	0.150	0	0	0.056	0	0
	2.6 SDUH	0	0	0	0.722	0	0	0	0	0	0	0	0.210	0.230	0.329
	2.7 CR	0	0	0	0.278	0	0.241	0.350	0.205	0.265	0.241	0.201	0	0.146	0.145
	2.8 SOE	0	0	0	0	0.214	0.292	0.181	0.158	0	0	0.249	0.135	0	0.179
	2.9 SDM	0	0	0	0	0.786	0	0	0.217	0	0	0.550	0.163	0.191	0

Table 8
The weighted super matrix M'

		Goal	Major criteria				Selected indicators								
		0.0 Assessing the performance of BI system	1.1 FBIS	1.2 SIA	1.3 MUN	1.4 MER	2.1 SRT	2.2 SS	2.3 OIA	2.4 IEC	2.5 CDIB	2.6 SDUH	2.7 CR	2.8 SOE	2.9 SDM
Goal	0.0 Assessing the performance of a BI system	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Major criteria	1.1 FBIS	0.095	0	0.119	0.068	0.061	0	0	0	0	0	0	0	0	0
	1.2 SIA	0.247	0.127	0	0.167	0.201	0	0	0	0	0	0	0	0	0
	1.3 MUN	0.288	0.135	0.165	0	0.238	0	0	0	0	0	0	0	0	0
	1.4 MER	0.370	0.238	0.216	0.265	0	0	0	0	0	0	0	0	0	0
Selected indicators	2.1 SRT	0	0.057	0	0	0	0	0	0	0.093	0.081	0	0.062	0.065	0
	2.2 SS	0	0.121	0	0	0	0	0	0	0.132	0.121	0	0.078	0.088	0
	2.3 OIA	0	0.322	0	0	0	0	0	0	0.360	0.374	0	0.204	0.280	0.347
	2.4 IEC	0	0	0.311	0	0	0.348	0.331	0.243	0	0.183	0	0.092	0	0
	2.5 CDIB	0	0	0.189	0	0	0.119	0.138	0.177	0.150	0	0	0.056	0	0
	2.6 SDUH	0	0	0	0.361	0	0	0	0	0	0	0	0.210	0.230	0.329
	2.7 CR	0	0	0	0.139	0	0.241	0.350	0.205	0.265	0.241	0.200	0	0.146	0.145
	2.8 SOE	0	0	0	0	0.107	0.292	0.181	0.158	0	0	0.249	0.135	0	0.179
	2.9 SDM	0	0	0	0	0.393	0	0	0.217	0	0	0.551	0.163	0.191	0

5.4. Selection of the best evaluation indicator

The selection of the best alternative depends on the outcome of the desirability index (DI), shown in Table 10. According to the DIs shown in Table 10, the larger the priority weighting, the higher the priority of being adopted is. From Table 10, most experts think the 'Output information accuracy' (OIA) can best evaluate the benefits of BI. The OIA indicator is also the most concerned one for users and consultants to improve the total benefits of BI systems. The 'conformity to the requirements' (CR) ranks the second, and 'support in decision-making in organization' (SDM) the third. 'system response time' (SRT) is believed to be hardest factor to appraise the benefits resulted from BI systems.

5.5. Analysis of criteria weightings

To make effective judgment on the results of the ANP model analysis, those experts in survey are divided into two groups. One is those with technical background (including consultants and IT personnel) and the other is end users. We have made an analysis to see if there is any difference on the priority sequence between the two groups of experts. The result is shown in Tables 11 and 12.

In Tables 11 and 12, the results show that the average weight priority sequences are identical between the technical experts and the end users. Among the indicators, the most addressed is number 2.3-OIA (0.1853, 0.1794), which is followed by number 2.7-CR (0.1691, 0.1687) and number 2.9-SDM (0.1559, 0.1628). The SRT is the least important item. Thus, we can see that both the technical experts and the end users have identical opinions on the conclusion of performance evaluation indicators from this research. Those assessment indicators can be utilized as the basics for the companied intending to implement or implemented.

5.6. Summary

The above analysis shows that there is little difference on the importance of the nine performance indicators between experts with different backgrounds. For the effects of the BI system, they regard OIA as the first priority indicator, followed by CR and SDM, and etc. It demonstrates that both IT personnel and end users expect accurate information from the BI system. Thus, to improve

Table 9
The converged super matrix M''

		Goal	Major criteria				Selected indicators								
		0.0 Assessing the performance of BI system	1.1 FBIS	1.2 SIA	1.3 MUN	1.4 MER	2.1 SRT	2.2 SS	2.3 OIA	2.4 IEC	2.5 CDIB	2.6 SDUH	2.7 CR	2.8 SOE	2.9 SDM
Goal	0.0 Assessing the performance of a BI system	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Major criteria	1.1 FBIS	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.2 SIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.3 MUN	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.4 MER	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Selected indicators	2.1 SRT	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2.2 SS	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
	2.3 OIA	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
	2.4 IEC	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185
	2.5 CDIB	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100	0.100
	2.6 SDUH	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067	0.067
	2.7 CR	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
	2.8 SOE	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169
	2.9 SDM	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127	0.127

Table 10
The desirability index (DI) and sequence of assessing criteria for BI systems

Performance criteria	DI	Sequence
2.3 OIA	0.1853	1
2.7 CR	0.1691	2
2.9 SDM	0.1559	3
2.8 SOE	0.1270	4
2.6 SDUH	0.1161	5
2.4 IEC	0.0998	6
2.5 CDIB	0.0675	7
2.2 SS	0.0457	8
2.1 SRT	0.0336	9

the effectiveness of the BI system, the accuracy of results should always be addresses. After all, mistaken information does nothing for the operations of enterprise, and even worse, it could bring fatality to the enterprise.

6. Case study

To verify the effectiveness of the ANP model, we studied a company that has implemented the BI system as an example. Through the interview, the process of implementing the BI system and using information can be presented.

6.1. Case brief

The company in the case was founded in the US in 1981, and is the largest supplier of computer peripherals. The company has set up its operation centers in Switzerland, Hong Kong and Taiwan. Listed in NASDAQ, with 7200 employees, the company has products like internet cams, input devices, multi-media systems, computer microphones, mobile phone earphones, bluetooth earphone, recreation devices and other items with human interface devices. In this research, the survey targets are the managers in charge of products manufactured in the Hsinchu Science-based Industrial Park.

6.2. Analysis

This research adopts the manner of interview to know the various situations the company meets when it promotes the BI system. The interviewees are the senior managers in the information department of the company.

Questions in the interview:

1. System aspect
   The company has adopted ERP as the tool of data analysis before the BI system is implemented. Therefore, global MRP is executed and material plan is generated. It is a challenge for the planning job. To improve the planning efficiency, the

Table 11
Weightings analysis of selected indicators for all experts

Expert	Performance indicators that influence on effect of BI system								
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
E1	0.0336	0.0457	0.1853	0.0998	0.0675	0.1161	0.1691	0.127	0.1559
E2	0.0460	0.0774	0.1604	0.1074	0.0602	0.0548	0.1742	0.2190	0.1006
E3	0.0446	0.0253	0.1587	0.0373	0.0362	0.2070	0.1589	0.1142	0.2178
E4	0.0229	0.0155	0.0757	0.1358	0.1071	0.1490	0.1691	0.121	0.2039
E5	0.0504	0.0230	0.1890	0.1070	0.0213	0.1656	0.1416	0.0956	0.2065
E6	0.0271	0.0507	0.2242	0.0521	0.0921	0.0593	0.1890	0.1770	0.1285
E7	0.0414	0.0725	0.1074	0.0903	0.0631	0.1297	0.2361	0.1309	0.1286
E8	0.0216	0.0363	0.1056	0.1153	0.0344	0.1578	0.1954	0.1507	0.1829
E9	0.0266	0.0696	0.2100	0.1023	0.0958	0.1201	0.0778	0.1037	0.1941
E10	0.0250	0.0368	0.3327	0.1240	0.0368	0.0280	0.1758	0.1315	0.1094
E11	0.0312	0.0521	0.2233	0.1007	0.0931	0.0765	0.2042	0.1017	0.1172
E12	0.0332	0.0430	0.2510	0.1260	0.1028	0.1292	0.1382	0.0514	0.1252
Average	0.0336	0.0457	0.1853	0.0998	0.0675	0.1161	0.1691	0.1270	0.1559

Note: E1–E3 are the consultants, E4–E10 are the IT personnel, and E11–E12 are the end users.

Table 12
Weightings analysis of selected indicators for 10 experts

Expert	Performance indicators that influence on effect of BI system								
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
E1	0.0336	0.0457	0.1853	0.0998	0.0675	0.1161	0.1691	0.1270	0.1559
E2	0.0460	0.0774	0.1604	0.1074	0.0602	0.0548	0.1742	0.2190	0.1006
E3	0.0446	0.0253	0.1587	0.0373	0.0362	0.2070	0.1589	0.1142	0.2178
E4	0.0229	0.0155	0.0757	0.1358	0.1071	0.1490	0.1691	0.121	0.2039
E5	0.0504	0.0230	0.1890	0.1070	0.0213	0.1656	0.1416	0.0956	0.2065
E6	0.0271	0.0507	0.2242	0.0521	0.0921	0.0593	0.1890	0.1770	0.1285
E7	0.0414	0.0725	0.1074	0.0903	0.0631	0.1297	0.2361	0.1309	0.1286
E8	0.0216	0.0363	0.1056	0.1153	0.0344	0.1578	0.1954	0.1507	0.1829
E9	0.0266	0.0696	0.2100	0.1023	0.0958	0.1201	0.0778	0.1037	0.1941
E10	0.0250	0.0368	0.3327	0.1240	0.0368	0.0280	0.1758	0.1315	0.1094
Average	0.0339	0.0453	0.1749	0.0971	0.0615	0.1187	0.1687	0.1371	0.1628

Note: E1–E3 are the consultants and E4–E10 are the IT personnel.

company bought Oracle Data Warehouse and saved the transaction data, customer orders and cost information into the database. Then, the company bought Business Objects 5.0, which is used to assist managers and users in generating dynamic reports. The BI system is expected to shorten the duration of data processing, to improve the integration and completeness of information, and to catch the data required by the analysis for the submittal to the superior. To improve the effects of the system, the company implemented Oracle 11i at the end of 2004. Now, the IT personnel are active to try to present the information from the BI system in the manner of showing on the war room dashboard, and to enhance the conformity and resistance of the output information for efficiency improvement of decision-making.

2. Implementation aspect
The company utilizes the BI implementation team in the US and India to implement and integrate the BI systems in the branches in the globally. Thus, the leader of each branch must physically visit the US headquarters and the India Branch to exchange the demands with local teams. The KPIs (key performance indices) are generated after the discussion and coordination among managers and IT department personnel in each branch company and thus they have high reference value. The participants and use of BI system are shown in Fig. 4. From Fig. 4, the design center of BI system is set in the US and India and it is responsible for the coordination and communication with suppliers of BI system. The IT personnel in the Worldwide Service Provider are responsible for learning and describing the special skills for interface design, KPI, formulation of cube data and statement format development. Also, they need to understand the current situations of users, promote the functions of BI systems, and enable the users to be interested in the use of the system and willing to query or analyze with the means of BI tools. The Worldwide Service User includes operations and finance departments, and the managers, who ought to raise their opinions for the KPIs and the interfaces, are offered with a set of suitable analysis tool after communicating with IT personnel.

3. Effect aspect
By utilizing the indicators and weightings of the ANP model, the effectiveness can be computed with the scores of the interviewees through formula 7. The overall effectiveness analysis is shown in Table 13.

$$\sum_{j=1}^{9} W_j \times G_i = \mathrm{PV}_i \quad \text{for all } i \tag{7}$$

W_j is the weighting of No. j assessment indicator ($j = 1,2,\ldots,9$). G_i is the score from the No. i interviewee. PV_i is the effectiveness recognized by No. i interviewee for the BI system.

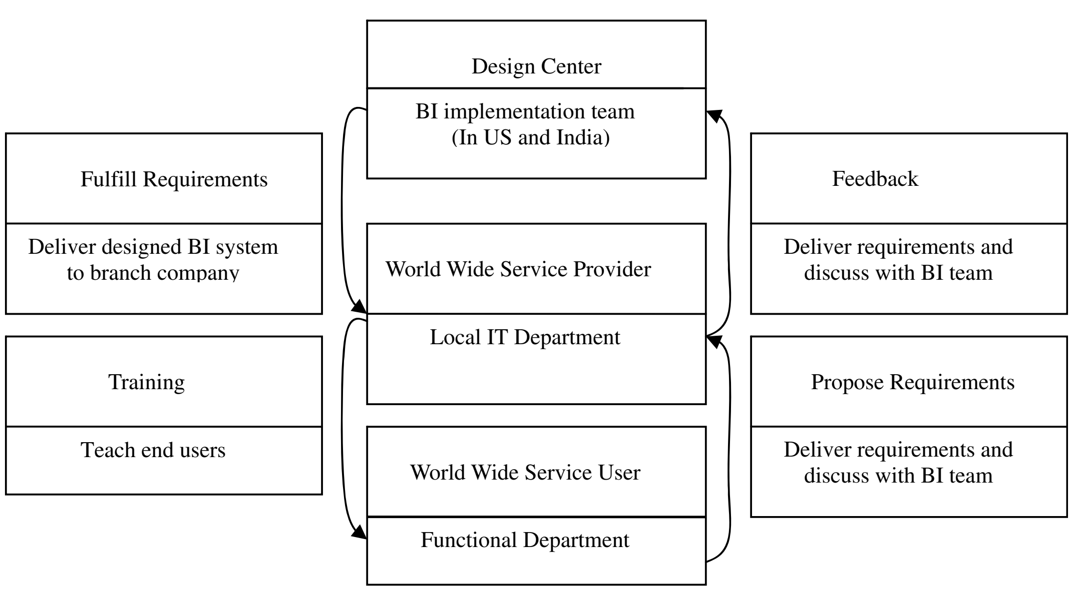

Fig. 4. Participants and use of BI system.

Table 13
Effectiveness analysis of the studied company

	Weightings	Score before implementation	Score after implementation	Situation before implementation	Effect after implementation
SRT	0.0336	0.5	0.3	0.0168	0.0101
SS	0.0457	0.5	0.3	0.0229	0.0137
OIA	0.1853	0.5	0.4	0.0927	0.0741
IEC	0.0998	0.5	0.9	0.0499	0.0898
CDIB	0.0675	0.5	0.9	0.0338	0.0608
SDUH	0.1161	0.5	0.6	0.0581	0.0697
CR	0.1691	0.5	0.6	0.0846	0.1015
SOE	0.1270	0.5	0.7	0.0635	0.0889
SDM	0.1559	0.5	0.7	0.0780	0.1091
Total effect				50%	61.76%

From Table 13, we can see that the effect after implementing the SRT, SS and OIA is lower than the effect before implementation. The interviewees said that SRT does not meet with the expected standard of a complete report being generated every five seconds. Besides, the data warehouse function of the BI system is implemented only with the Excel to perform the integration and analysis of data, so the possibility of data leakage or file loss is quite high and SS is not ideal. The reason why the effect of OIA is poor is that the senior managers have different views on the same collected data, which often leads to misunderstanding or self-contradiction. It is advisable to adjust the performance evaluation system for consistent and meaningful performance indicators before the BI system is implemented. This will deteriorate the performance figures since they do not represent the real performance. Other performance indicators are higher than these before implementation. In whole, the effect has increased by 24% after the implementation of the BI system.

To verify the consistency between the result of the evaluation model and the real assessment result, this research uses the questionnaires and surveys five participants and users for their real feeling (with 20 increment, from satisfactory to not satisfactory level). The survey is aimed for the real satisfaction after the implementation of the BI system, and the survey targets include five persons, namely, financial department managers, operation department managers and IT personnel. The five persons give out the satisfaction degree of 40, 20, 20, 40, and 40, respectively. The integrated satisfaction level is 32%. From this, the total satisfaction means that those persons are satisfied with the BI system and have positive view on the system. The result from the model in this research gives similar satisfaction level.

In the verification of the case study, experienced IT seniors determine the result of assessment, and we can see the efforts given by them in the implementation of the BI system. Although the SRT, SS and OIA do not render distinctive effects, the interviewees have expressed they are seeking for the improvement and promotion of Dashboard project for further growth. Other performance indicators in the evaluation of the BI system do bring benefits to the company. Therefore, the participants should learn the interface function in a more willing way, discover the questions and make discussion and communication with IT personnel. For IT personnel, they should enrich their special skills and understand more of the user's requirements. In this way, through achieving both improved efficiency and right decision-making, differential competitive advantage can be generated for total success.

7. Conclusions

In recent years, all enterprises look for an efficient and effective information system as the tool to obtain competitive advantage. To lower operational costs and retain competitiveness, many enterprises expect to implement the BI system, integrate the internal and external data of the enterprises, interpret the data, and transfer them into useful information. However, the implementation of information system can not make distinctive effectiveness without suitable evaluation indicators. Thus, defining suitable indicators for evaluating the performances of a BI system is necessary.

In this research, the ANP structure for the evaluation of a BI system is used as the assessment model. The key factors that impact on the effect of BI system are discussed, and the interview cases are used to explain the feasibility of the model. The structure can be not only used by the enterprises that have implemented the system, but also can be referenced by the prospective enterprises for lowering risk and reducing future failure possibility.

Suggestions and conclusions are given as follows:

1. The ANP assessment model for BI systems built up in this research has been subjected to the judgment of 12 experts for the comparison among the performance indicators and criteria. In the process of creating the ANP decision model, the discussion with experts and end users was made before the relationships among levels and aspects are given. Therefore, the ANP structure in this research is reliable and valid.
2. The appraisal result has shown that 'meeting enterprises requirements' (MER) is the most concerned criteria that senior experts evaluate, followed by 'meeting user's needs' (MUN).
3. To build the assessment model of a BI system, this paper chooses nine indicators, which are system response time (SRT), system security (SS), output information accuracy (OIA), implementing experience of consultant (IEC), comprehension degree to implementer's business (CDIB), support degree of users and high-level (SDUH), conformity to the requirements (CR), support of organizational efficiency (SOE) and support in decision-making in organization (SDM).
4. The comprehensive assessment result has shown that the critical factors used to evaluate the effect of a BI system include, in their priority sequence, output information accuracy (OIA), conformity to the requirement (CR), support of organizational efficiency (SOE), and system response time (SRT). This is to say that in the process of implement ting a BI system, the users do not care about the advanced functions that the system has, but emphasize on the accuracy of information they have. Excessive pursuit of the system response time (SRT) may give adverse results. To software suppliers and IT personnel, they should focus on the fast and correct information acquisition when they develop or sell the software. In addition, most enterprises will check the enterprise service and integration ability (ESIA) according to the experiences and expertises of consultants, so the supplier should stress the training and cultivation of consultants. To most enterprises, the key for the success of implementing a BI project lies in the right choice of consultants and the full-time participation of consultants during the whole process.
5. To boost the effectiveness and representation of this research, we adopt case interviews to discuss and understand the current

situations of an enterprise that implements a BI system. By studying the difference between the results from model and the result from the case, we found that the effect has improved by 24% after the implementation of the BI system. The employees in the company give similar view. Thus, the BI system actually promotes the total performance of the company.

6. The assessment model for the BI system given in this research still lacks the detailed performance measurement indicators. Future research can start from the design of performance indicators and provide more detailed and practical formulas to show the effectiveness of a BI system.

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