Fuzzy DEMATEL Model for Evaluation Criteria of Business Intelligence

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Abstract: In response to an ever increasing competitive environment, today's organizations intend to utilize business intelligence (BI) in order to promote their decision support. In other words, BI capabilities for enterprise systems would be essential to evaluate the enterprise systems. Hence, the key factors for evaluating intelligence-level of enterprise systems have been determined in past studies. More in this research, the causal relationships between criteria of each factor have been obtained to construct impact-relation map. To this aim, this study presents a new hybrid approach containing fuzzy set theory, and the decision making trial and evaluation laboratory (DEMATEL) method. This study considered six main factors for evaluation of BI for enterprise system include: analytical and intelligent decision-support, providing related experiment and integration with environmental information, optimization and recommended model, reasoning, enhanced decision-making tools, and stakeholders' satisfaction; and have determined the root or cause criteria in each factor. In general, the outcomes of this study can be used as a basis for roadmap of differentiation of BI capabilities in the form of evaluation criteria. Also, it can provide an effective and useful model by separating criteria into cause group and effect group in an uncertainty environment.

1 INTRODUCTION

Traditional enterprises are often involved issues such as overflow of data, shortage of information/knowledge and inadequacy of reports (Lin et al., 2009, Mikroyannidis and Theodoulidis, 2010, Yigitbasioglu and Velcu, 2012), naturally makes disorder in organizational decision making process. Thus, with regard to the importance of information in business environment and managerial decision making process (Bucher et al., 2009) as well as to achieve the main objective of any corporation that is "right access to information quickly" (Sahay and Ranjan, 2008), utilizing the decision support is considered as one of the organizational requirements of current and future, to support management decision making and planning (Power and Sharda, 2007).

In the past studies, decision support systems are considered as an island system besides the other information systems in organization (Kristianto et al., 2012, Gunasekaran and Ngai, 2012, Xu et al., 2007, Sancho et al., 2008, Doumpos and Zopounidis, 2010). However, as (Alter, 2004) states today's approach to decision support creates an integrated decision support environment, and takes the intelligence requirements of enterprise systems into consideration. It means that business intelligence (BI) are capabilities of enterprise systems which enable organization in decision support process and tools (Ranjan, 2008).

In most evaluation model, BI has been considered as tools or independent systems. In our previous research (Ghazanfari et al., 2011, Rouhani et al., 2011), we have found 34 criteria and 6 core categories about BI of enterprise systems by considering BI as an umbrella concept to create a comprehensive decision support environment. However, due to this fact that there is no evident study to evaluate BI of an enterprise system from an overall perspective, determining the importance level and effect of the given criteria on the overall system performance is so important. Hence, this study proposes a novel model combining the fuzzy set theory to deal with the vagueness of human thought, and the Decision Making Trial and Evaluation Laboratory (DEMATEL) method to construct impact-relation map and determine cause group and effect group. In general, the main

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objectives of this study can be grouped into 3 as follows: (1) determine the cause and effect criteria of BI for enterprise systems; (2) build impact-relation diagram between the evaluation criteria in each factor; (3) determine the key criterion of each factor. The summary view of this research can be seen in Fig. 1.

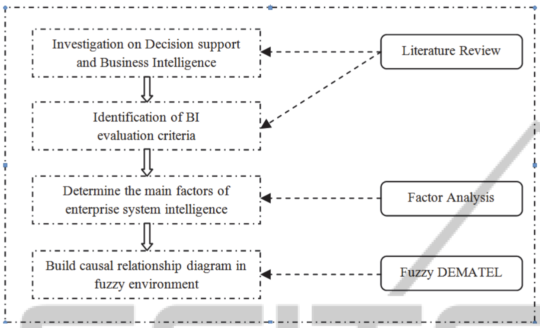

Figure 1: The main steps of the evaluation procedure.

Indeed, this research was carried out to find answers to the above research objectives. Therefore, the remainder of this study is structured as follows. In section 2, a wide-range of review from prior studies both in context of BI are presented. In section 3, research methods are discussed in detail. The findings of this research and comprehensive discussion about the empirical study are described in section 4. Finally, section 5 contains the conclusion and future direction of the research.

2 BUSINESS INTELLIGENCE

Managers know that traditional analysis tools and methods could not be afforded to meet the decision-making requirements in terms of timely and accurately response (Bucher et al., 2009, Mikroyannidis and Theodoulidis, 2010, Duan et al., 2011). Hence, many organizations are seeking to adopt BI applications as a Data-driven DSS to efficiently manage corporate operations and improve organizational decision making (Isik et al., 2011, Petrini and Pozzebon, 2009, Cheng et al., 2009).

The term BI was introduced by (Luhn, 1958) as a set of techniques based on statistical procedures with proper communication facilities and input-output equipment in order to accommodate all information problems of an organization. In other words, BI integrates the analysis of data with decision support system to provide information to people throughout the organization in order to improve strategic and tactical decisions (Li et al., 2008).

In this regard, BI has been proposed as a generic term to describe leveraging the organizations internal and external information assets for adopting better business decisions (Kimball and Ross, 2002).

In here, we label BI among system-enabler approach comprised of broad capabilities and functions to support the strategic decision-making process by preparing an appropriate decision support environment.

In this paper, according to previous studies, factors and related criteria of each factor in context of business intelligence of enterprise systems has determined .A brief description in relation to each factor is presented as follows (Ghazanfari et al., 2011):

Analytical and Intelligent Decision-support (F1). This factor includes capabilities and competencies of an enterprise system to support decision makers by visual reports and to inform them by alarms and warnings utilizing agents and through channels. The base of these information, knowledge's and reports is data warehouse of enterprise.

Providing Related Experiment and Integration with Environmental Information (F2). In this factor, decision makers get support and assist via importing data from business environment and providing them with groupware to decide by collective intelligence.

Optimization and Recommended Model (F3). This factor covers criteria and specifications which attempt to optimize decision making results using optimization methods and simulation techniques. In this factor interactive optimizing via dynamic and evolutionary prototyping are considered and base on them, recommendations to decision maker would be offered.

Reasoning (F4). In each organizational deciding, reason presenting is important for giving rationality to decision makers, in this factor capability of knowledge reasoning and forward and backward reasoning are spotted as business intelligence evaluation criteria in enterprise systems and software.

Enhanced Decision-making Tools (F5). Decision makers are often more interested in verbal and conceptual judgments rather than crisp and certain values. Regarding this advantage, in this factor, the capability of enterprise systems in analyzing fuzzy values and multi criteria decision making are considered as BI evaluation criteria.

Stakeholders' Satisfaction (F6). This factor includes the points of view of organizational stakeholders about consequences of decisions which made by supporting of BI. Accusation and precision of the decision are considered as satisfaction criteria of organizational stakeholders in this factor.

3 METHODOLOGY

This study proposed an integrated approach to evaluate BI criteria for enterprise systems based on hybrid model combined fuzzy set theory, and DEMATEL method. The DEMATEL method is a comprehensive method in order to build a structural model based on digraphs, which can separate involved factors into cause and effect groups (Wu and Lee, 2007). Then, due to the fuzzy nature of this study, the fuzzy logic is applied to deal with the vagueness of human thought in such fuzzy environment.

3.1 Fuzzy Set Theory

In today's environment of uncertainty with different daily decision making problems of diverse intensity, the results can be misleading if the fuzziness of human decision-making is not taken into account (Tsaur et al., 2002). Furthermore, the crisp values are insufficient and unrealistic for a subjective judgment, especially when the information is vague or imprecise (Chang and Wang, 2009). Thus, fuzzy logic can be employed to measure ambiguous concepts related with human beings subjective judgments (Zhou et al., 2011). Indeed, fuzzy set theory is designed to deal with the vagueness of human thought. According to (Zadeh, 1965), "a fuzzy set is a class of objects with a continuum of grades of membership".

3.2 Decision Making Trial and Evaluation Laboratory

The Decision Making Trial and Evaluation Laboratory (DEMATEL) technique emerged at Battelle Memorial Institute through its Geneva Research Center (Fontela and Gabus, 1976), is especially pragmatic way for constructing a causal relationship with matrices or digraphs (Büyüközkan and Çifçi, 2012). As a result, alternatives having more effect on another are considered cause and those receiving more influence from another are embedded in effect group (Seyed-Hosseini et al., 2006). Furthermore, the DEMATEL method displays which factors have more fundamental importance on the whole system and which have not (Zhou et al., 2011). According to (Lee et al., 2010), DEMATEL is employed to find all causal relationships includes (direct and indirect) and strength of influence between all variables of a complicated system through matrix calculation.

In general, due to demonstration capabilities of directed relationships of sub-systems, they are more valuable than directionless graphs. Also, digraph portrays a contextual relation between the elements of the system, in which the numeral indicates the strength of influence. Hence, the DEMATEL method can convert the relationship among the causes and effects of factors into an intelligible structural model of the system (Wu and Lee, 2007). Currently, DEMATEL method has been adopted in various fields (Liou et al., 2008, Tseng, 2009, Hu et al., 2011, Wu, 2012, Wu, 2008, Tzeng et al., 2007, Vujanović et al., 2012, Chou et al., 2011, Tseng et al., 2012, Rouhani et al., 2013). In this study, the DEMATEL method takes complex systems and directly compares the relative relationship among different BI characteristic, using a matrix to calculate all direct and indirect cause and effect relationships and level of influence between BI characteristics, especially through the use of impact-relation map to simplify the decision making. Essential definitions of DEMATEL method are described as follows:

Definition 1: (Construct the initial direct relation matrix). The initial relation matrix A is a $n \times n$ matrix can be obtained through pairwise comparison in which A_{ij} is denoted as the degree to which the criterion i affects the criterionj, i.e. $A = [a_{ij}]$.

Definition 2: (Normalize the direct relation matrix). The normalized direct relation matrix D can be acquired by using the formula (1), in which all elements of the matrix D are between $[0,1]$ and all elements on the principal diagonal elements are equal to zero.

$$D = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} A \qquad (1)$$

Definition 3: (Build total relation matrix). The total relation matrix T is calculated by using formula (2).

$$T = D(I - D)^{-1} \qquad (2)$$

Where I is denoted as the identity matrix.

Furthermore, the sum of rows and sum of columns of matrix T can be acquired through the formulas (3) and (4), in which R denote the sum of rows and C denote the sum of columns.

$$R_i = \sum_{j=1}^{n} t_{ij} \qquad (3)$$

$$C_i = \sum_{i=1}^{n} t_{ij} \quad (4)$$

Definition 4: (Set a threshold value to establish impact-relation map (IRM)). Threshold value must be set in order to explain the structural relation between factors. Also, it is necessary for removing insignificant effects in matrix T. Here, the threshold value has been obtained by expert opinion.

3.3 The Proposed Method

In the following, the complete procedure of the hybrid model in uncertainty environment is explained.

Step 1: goal setting and forming a committee. At first, in the decision making process a goal should be identified. Also, Advantages and disadvantages are evaluated and optimal alternative are selected. So, it is essential to form a committee in order to collect group knowledge and solve the problem.

Step 2: aggregate decision-makers assessments by interpreting the linguistic information into fuzzy scale. To obtain the relationship between evaluation criteria's a group of experts were invited to make assessments in context of influences and directions. Furthermore, in order to deal with the imprecise assessments by experts the linguistic variables is applied

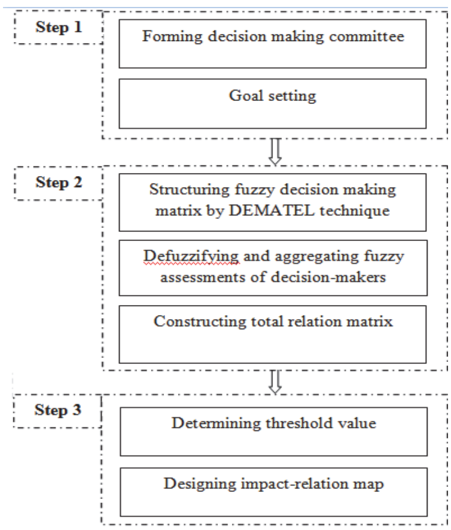

Figure 2: The main steps of the proposed method.

Step 3: designing and analyzing the impact-relation map. Evaluation in DEMATEL methods is based on expert opinions and builds causal relationship diagram. Indeed, the DEMATEL is used to separate criteria into cause and effect group. The normalized direct-relation matrix D is calculated based on Eq. (1). Then, Eq. (2) is used to obtain the total relation matrix T. Next, by using Eqs (3) - (4), the causal relationship diagram can be acquired. At this stage, if the value of $R - C$ is positive, it means that the criteria has more impact on other criteria. Finally, to find suitable effects, the threshold value of each factors were defined by expert's decisions. The complete procedure of the proposed method is shown in Fig 2.

4 EMPIRICAL RESULTS

In this section, the empirical study shows how organizations applied the proposed method to determine the BI criteria of enterprise systems for to enhance the competitive advantage. Sub-section 4.1 contains description about the problem, questionnaire and the expert interview. Applications of the proposed method are described in sub-section 4.2. Finally, the results of total relation matrix and impact-relation maps are discussed in sub-section 4.3.

4.1 Materials

In recent decades enterprise systems have been used to help managers in decision making process. But due to the lack of BI in enterprise systems, organizations need to evaluate these systems in terms of intelligence-level before buying and deploying them. Therefore, in this study, we develop an overall perspective using hybrid model combining fuzzy logic and causal and effect decision making model based on 34 criteria and 6 core factors had been identified in our previous research (Ghazanfari et al., 2011).

Table 1: The correspondence of linguistic terms and values.

Linguistic terms	Triangular fuzzy numbers
Very high influence (VH)	(0.75,1,1)
High influence (H)	(0.5,0.75,1)
Low influence (L)	(0.25,0.5,0.75)
Very low influence (VL)	(0,0.25,0.5)
No influence (No)	(0,0,0.25)

Hence, the questionnaire for DEMATEL analysis is used based on factor analysis results to specify interrelationships between criteria of each factor using 5 point linguistic scale includes "Very high, High, Low, Very low, and No" which is expressed in positive triangular fuzzy numbers as shown in Table 1. The prepared questionnaire were distributed between expert committee includes IT Managers, System Analysts, and BI experts.

4.2 Applications of the Proposed Method

The proposed method is divided into three steps. In first step, the committee defined the goal to gain structural model, and specify the importance-level and impact-level of each criteria in order to evaluate enterprise systems in viewpoint of BI. In step 2, based on factor analysis results 6 main categories includes analytical and intelligent decision-support (F1), providing related experiment and integration with environmental information (F2), optimization and recommended model (F3), reasoning (F4), enhanced decision-making tools (F5), stakeholders' satisfaction (F6) had been explored.

More, the inter-relationships between criteria of each factor for each decision-maker were obtained by using fuzzy linguistic scale. Then, the CFCS method was used to defuzzify aggregate all assessments data. Finally, the total relation matrix was acquired in this step.

In step 3, the threshold value was obtained based on expert's opinion to construct impact relation diagram. Therefore, the threshold value for analytical and intelligent decision-support (F1), providing related experiment and integration with environmental information (F2), optimization and recommended model (F3), reasoning (F4), enhanced decision-making tools (F5), stakeholders' satisfaction (F6) were 0.137, 0.574, 0.414, 1.481, 3.332, and 0.488. These threshold means that only value over them were considered and the others were insignificant. Finally, the impact-relation map for each factor could be obtained based on those threshold values. The values of (R+C) and (R-C) were obtained to construct impact-relation map in Tables (2-7).

Table 2: The values of (R+C) and (R-C) for (F1).

Criteria	R	C	R+C	R-C
Visual graphs (X1)	1.489	2.118	3.607	-0.629
Alarms and warnings (X2)	1.369	2.401	3.770	-1.032
Online analytical processing (X3)	1.809	1.566	3.375	0.243
Data mining techniques (X4)	2.196	1.261	3.457	0.935
Data warehouses (X5)	2.531	0.544	3.075	1.987
Web channel (X6)	1.326	0.903	2.229	0.423
Mobile channel (X7)	0.687	1.265	1.952	-0.578
Intelligent agent (X8)	1.850	1.782	3.632	0.068
Multi agent (X9)	1.517	1.285	2.802	0.232
Summarization (X10)	1.278	2.170	3.448	-0.892
E-mail channel (X11)	0.482	1.239	1.721	-0.757

Table 3: The values of (R+C) and (R-C) for (F2).

	R	C	R+C	R-C
Groupware (X12)	6.863	5.711	12.574	1.152
Flexible models (X13)	3.935	5.931	9.866	-1.996
Problem clustering (X14)	3.613	5.469	9.082	-1.856
Import data from other systems (X15)	5.323	3.794	9.117	1.529
Export reports to other systems (X16)	4.740	3.433	8.173	1.307
Combination of experiments (X17)	6.345	5.633	11.978	0.712
Situation awareness modeling (X18)	4.896	5.282	10.178	-0.386
Group decision-making (X19)	4.756	6.180	10.936	-1.424
Environment awareness (X20)	5.992	5.030	11.022	0.962

Table 4: The values of (R+C) and (R-C) for (F3).

	R	C	R+C	R-C
Optimization technique (X21)	4.740	1.921	6.661	2.819
Learning technique (X22)	3.031	2.991	6.022	0.040
Simulation models (X23)	4.798	2.584	7.382	2.214
Risk simulation (X24)	1.795	3.010	4.805	-1.215
Evolutionary prototyping model (X25)	2.406	3.649	6.055	-1.243
Dynamic model prototyping (X26)	2.684	3.417	6.101	-0.733
Dashboard/recommender (X27)	0.798	2.680	3.478	-1.882

Table 5: The values of (R+C) and (R-C) for (F4).

	R	C	R+C	R-C
Financial analysis tools (X28)	4.955	3.234	8.189	1.721
Backward and forward reasoning (X29)	4.653	4.956	9.609	-0.303
Knowledge reasoning (X30)	3.715	5.133	8.848	-1.418

Table 6: The values of (R+C) and (R-C) for (F5).

	R	C	R+C	R-C
Fuzzy decision-making (X31)	7.163	6.162	13.325	1.001
MCDM tools (X32)	6.163	7.164	13.327	-1.001

4.3 Discussion

The aim behind the DEMATEL method is to find the relation between the identified criteria and construct impact-relation map. Hence, in this study the DEMATEL method was adopted to define the weighted significance of each criterion in related to each factor and map out the impact-level of each of them as shown in impact-relation map (Fig. 3).

In respect to Tables (2-7) the criteria of each factor were classified into positively affected and negatively affected group. Positively affected group are those with have positive (R-C) value. In the simplest sense, the criteria in this group influence the other criteria most and are influenced the other criteria least. In here, we show these criteria as shadowed object. Liekwise, negatively-affected group are those with have negative (R-C) value between the other criteria. In here, we show these criteria as non-shadowed object.

Whit respect to the above arguments, in factor F1, online analytical processing (X3), data mining techniques (X4), data warehouses (X5), web channel (X6), intelligent agent (X8), and multi agent (X9) were considered as the positively affected criteria and the other factors include visual graphs (X1), alarms and warnings (X2), mobile channel (X7), summarization (X10), and finally e-mail channel (X11) were considered as the negatively affected criteria. The key criterion of factor F1 was found to be "data warehouses (X5)". In a similar vein, the criteria of providing related experiment and integration with environmental information (F2) include groupware (X12), import data from other systems (X15), export reports to other systems (X16), combination of experiments (X17), environment awareness (X20) were the positively affected criteria and flexible models (X13), problem clustering (X14), situation awareness modelling (X18), group decision-making (X19) were the negatively affected criteria. The key criterion of factor F2 was found to be "import data from other systems (X15)".

In terms of optimization and recommended model factor (F3), the criteria optimization technique (X21), learning technique (X22), simulation models (X23) were grouped into the positively affected criteria and risk simulation (X24), evolutionary prototyping model (X25), dynamic model prototyping (X26), dashboard/recommender (X27) were grouped into the negatively affected criteria. The key criterion of factor F3 was found to be "optimization techniques (X21)".

Table 7: The values of (R+C) and (R-C) for (F6).

	R	C	R+C	R-C
Stakeholders' satisfaction (X33)	0.476	1.476	1.952	-1
Reliability and accuracy of analysis (X34)	1.476	0.476	1.952	1

In reasoning factor (F4), financial analysis tool (X28) was a positively affected criterion. Also, backward and forward reasoning (X29), and knowledge reasoning (X30) were the negatively affected criteria. The key criterion of factor F4 was found to be "financial analysis tools (X28)". Also, in regard to factor F5, fuzzy decision-making (X31) was considered as positively affected criteria and MCDM tools (X32) was considered as negatively affected criteria. The key criterion of factor F5 was found to be "fuzzy decision-making (X31)".

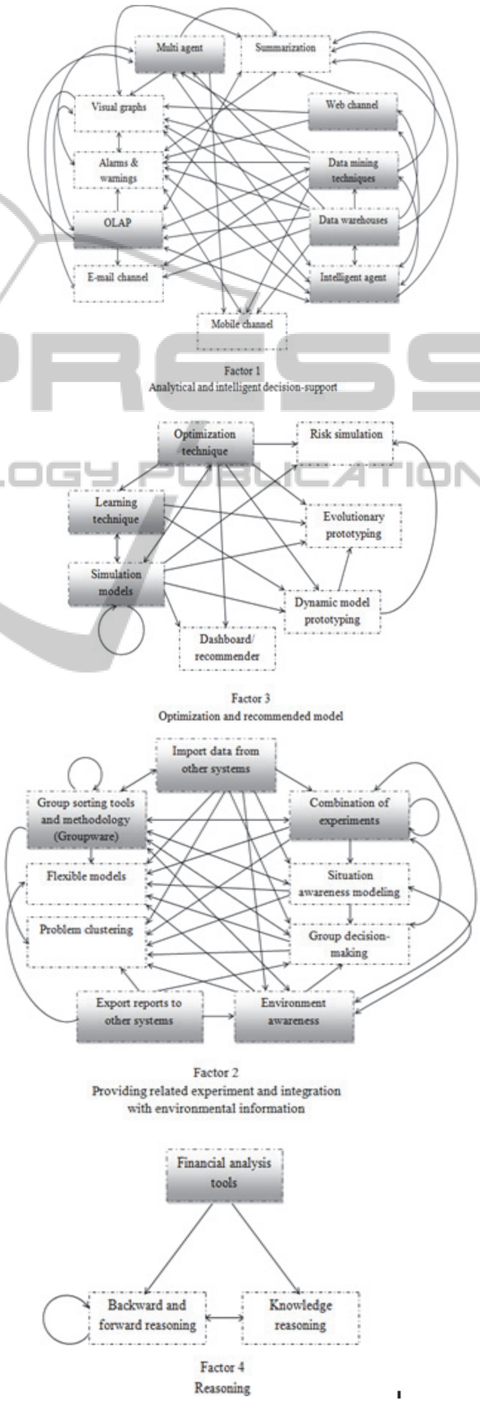

Figure 3: The impact-relation maps of six factors derived by fuzzy DEMATEL method.

Finally, reliability and accuracy of analysis (X34) was a positively affected criteria and stakeholders' satisfaction (X33) was a negatively affected criterion in factor F6. The key criterion of factor F6 was found to be "reliability and accuracy of analysis (X34)".

5 CONCLUSIONS

Nowadays, various types of enterprise systems (ES) have been used by organizations to enhance competitive advantage through data integration and analysis in real environment. Due to this fact that these systems are presented as one of the integral part of organizational decision making process, evaluating BI for enterprise systems and determining the importance-level of each intelligent tools is so important to create decision support environment for managers in decision-making process. In this study, after reviewing on prior BI evaluation model, by considering BI in viewpoint of system-enabler, an evaluation model based on hybrid model containing fuzzy logic and DEMATEL technique was developed. In here, fuzzy DEMATEL method was fully described. Based on proposed method, the factors and criteria were assessed through expert committee, all responses were aggregated and finally, the total relation matrix of each factor was acquired. Then, with considering expert opinions, the threshold values for each factor were determined in order to identifying significant relationship between criteria of each factor and removing insignificant relationships. Here, a new evaluation model was developed using hybrid concept to assess importance-level and influence level of each criteria. Furthermore, the key criterions of each factor were determined in terms of intelligence for enterprise system. So, further researches are needed to rich cause and effects model by gathering universal data. Applying other MCDM methods in a fuzzy environment to arranging BI evaluation criteria, and comparing the results of these methods is also recommended for future research.

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