Data Warehouse System Selection Decisions: a Comparative Study of Two Multi-Criteria Decision-Making Methods

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Abstract

As data warehouse system evaluation and selection are often costly and time consuming, the need for a decision-aid approach to software selection is obvious. The aim of this study is to establish the important criteria including technical and managerial factors to be considered in selecting a data warehouse system. In this paper, both analytic hierarchy process (AHP) and fuzzy multi-criteria decision-making (FMCDM) method are used to improve the decision-making processes and reduce the time in evaluating and selecting a data warehouse system. The AHP is used to examine the relative importance of data warehouse system selection criteria, sub-criteria and alternatives. Owing to vague concept frequently represented in decision environment, a fuzzy multi-criteria decision-making method is also proposed to solve data warehouse system selection problem. To verify the feasibility of the two methods, a case study was performed in the context of a project aiming to build an agricultural products tracking and monitoring system. The result indicates that the two methods determine the same alternative as the most suitable data warehouse system for the case study.

1. Introduction

With the implementation of business processes automation software in enterprises, data are piled up quickly enterprise-wide. To organize the data and help companies make sensible business decision, data warehousing implementation is expected to grow quickly [31][43][54]. When correctly implemented, a data warehouse (DW) system enables companies to enjoy benefits and obtain timely information for decision-making [13]. However, because of the complicated and variety of functionality of data warehouse systems, the evaluating and ultimate selecting data warehouse products that fit needs are daunting tasks for many companies.

Software selection is not a technical task, but rather a subjective and uncertain decision process [44]. Selecting a suitable software system among many products depends on the assessment of their objective, measurable criteria (e.g., acquisition cost and training cost) and subjective criteria (e.g., compatibility, vendor selection and technical factors). The software selection decisions involve simultaneously considering multiple criteria including tangible and intangible factors, and making priorities among those factors can be difficult. When evaluating data warehouse software, Kimball et al. [22] suggested the evaluation should encompass business and technical requirements. However, he did not propose a systematic approach to help companies make decisions.

The selection of a most suitable data warehouse system from a set of alternatives on the basis of many criteria is a multi-criteria decision-making problem. The values of selection criteria are often qualitatively described or imprecisely measured. The importances of criteria are also varying under different requirements and situations. In this paper, both analytic hierarchy process (AHP) and fuzzy multi-criteria decision-making (FMCDM) method are used to improve the decision-making processes and reduce the time in evaluating and selecting a data warehouse system. The reasons for choosing AHP and FMCDM methods include: (1) both are multi-criteria decision-making methods; (2) a great diversity of applications; (3) decision-makers used different instruments to assess criteria and alternatives. AHP uses scale of relative importance measurement by using numerical judgments. However, the evaluation is made by using linguistic terms directly in FMCDM method. (4) to obtain strong confidence of final result, if the two methods can determine the same alternative as the best selection.

2. Literature Review

2.1 Analytic Hierarchy Process

AHP first developed by Saaty [40] to resolve decision-making problems by structuring each problem into a hierarchy of criteria. Pairwise comparisons are performed among the criteria under the same node with a scale of measurement. The scale of relative importance measurement consists of judgments ranging from equal importance to extreme importance (equal, moderate, essential or strong, demonstrated, extreme) corresponding to the numerical judgments (1, 3, 5, 7, 9) and compromises (2, 4, 6, 8) between these values [41]. The decision makers need to judge the relative importance of each criterion and then specify a preference on each criterion for decision alternatives.

In short, the AHP method involves four steps to solve a decision making problem [28] [47] [57]:

Step 1: Structuring the decision problem

The first step involves developing a hierarchical structure of the problem. The number of levels in the hierarchy depends on the complexity of the decision problem. The typical hierarchy of the AHP model consists of focus, criteria, sub-criteria and alternatives [42]. The highest level of the hierarchy is the overall goal or focus. The intermediate levels consist of the criteria and sub-criteria for judging the alternatives.

Step 2: Creating pairwise comparison matrix

Creating a pairwise comparison matrix is an attempt to find the relative importance among the criteria. The nine-point scale is used to obtain a concise pairwise comparison of all criteria at each level of the hierarchy [41]. The pairwise comparison judgments are made with respect to elements of one level of hierarchy given the element of the next higher level of hierarchy, starting from the top level down to the bottom level. For a group decision setting, every team member assigns his or her own pairwise comparison. Four methods can combine the individual pairwise comparison matrix to obtain a consensus pairwise comparison matrix for the entire team, namely, consensus; vote or compromise; geometric mean approach, and separate models or players [12].

Step 3: Determining normalized weights

The eigenvector derived from the matrix created in Step 2 contains the measures of relative importance among the criteria and is used to determine the normalized and unique priority weight of each criterion in the decision making hierarchy.

Step 4: Synthesize the priorities

The final step is to synthesize the solution for the decision problem, namely, to obtain the set of overall priorities for all alternatives. The normalized local priority weights of criteria and sub-criteria obtained from Step 3 are aggregated to produce global composite weights which used to evaluate decision alternatives.

2.2 Fuzzy Multi-criteria Decision-making Method

Fuzzy set theory, involving the fuzziness of data, was introduced by Zadeh [56]. It was developed to solve problems, in which descriptions of activities and observations were imprecise, vague and uncertain. A fuzzy set is a class of objects, with a continuum of membership grades, where the membership grade can be taken as an intermediate value between 0 and 1. A fuzzy subset A of a universal set X is defined by a membership function $f_A(x)$ which maps each element x in X to a real number [0, 1]. When the grade of membership for an element is 1, it means that the element is absolutely in that set. When the grade of membership is 0, it means that the element is absolutely not in that set. Ambiguous cases are assigned values between 0 and 1.

In this study, triangular fuzzy numbers are used as membership functions, corresponding to the elements in a set, as shown in Figure 1. The reason for using a triangular fuzzy number is that it is intuitively easy for the decision makers to use and calculate. A fuzzy number is a triangular fuzzy number if its membership function can be denoted as follows:

$$f_A(x) = \begin{cases} \dfrac{x-c}{a-c} \ , & c \le x \le a \\ \dfrac{b-x}{b-a} \ , & a \le x \le b \\ 0 \ , & \text{otherwise} \end{cases}$$

where a, b, and c are real numbers and $c \le a \le b$.

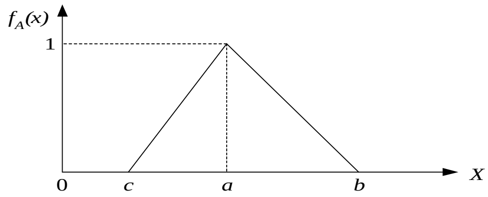

Figure 1: Membership function of a triangular fuzzy number

Fuzzy set theory is primarily concerned with quantifying the vagueness in human thoughts and perceptions, where linguistic terms can be properly represented by the approximate reasoning of fuzzy set theory. The importance weights of various criteria and the rating values of DW alternatives are considered as linguistic terms throughout this paper. A linguistic term can be defined as a variable whose values are not numbers, but words or sentences in natural language. The importance weight can be evaluated by linguistic terms such as very low, low, medium, high and very high. These linguistic terms can be expressed via triangular fuzzy numbers as shown in Figure 2.

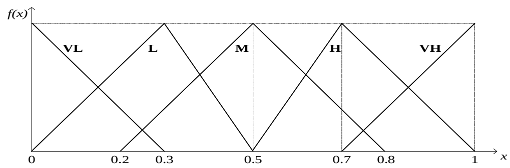

Figure 2: Membership functions

A systematic approach to the data warehouse system selection problem, based on fuzzy set theory and multi-criteria decision analysis, is described in this section. For a data warehouse system selection decision-making problem, there are a group of n decision-makers ($D_1, D_2,..., D_n$), who evaluate the importance weights of k criteria ($C_1, C_2,\dots, C_k$) and the appropriateness of m DW alternatives ($P_1, P_2,\dots, P_m$), under each of these k criteria. Let W_{td} (t=1, 2,…, k; d=1,2,…, n) be the weight given to C_t by decision maker D_n. Let R_{itd} (i=1, 2,…, m; t=1, 2,…, k; d=1,2,…, n) be the rating assigned to alternative P_i by decision maker D_n under criterion C_t. Wt and R_{it} are defined as follows:

$$W_t = (\frac{1}{n}) \otimes (W_{t1} \oplus W_{t2} \oplus \cdots \oplus W_{tn}) = \frac{1}{n} \sum_{d=1}^{n} W_{td} \quad (1)$$

and

$$R_{it} = (\frac{1}{n}) \otimes (R_{it1} \oplus R_{it2} \oplus \cdots \oplus R_{itn}) = \frac{1}{n} \sum_{d=1}^{n} R_{itd} \quad (2)$$

where W_t is the average importance weight of criterion C_t and R_{it} is the aggregated rating of alternative P_i under criterion C_t. After the weights and ratings have been aggregated, each aggregated rating of alternative P_i and criterion C_t (R_{it}) can further be weighed by the aggregated weight (W_t) to obtain the final rating F_i, i.e. the fuzzy appropriateness index of each alternative P_i. The F_i can be obtained by aggregating R_{it} and W_t, denoted as

$$F_i = (\frac{1}{k}) \otimes [(R_{i1} \otimes W_1) \oplus (R_{i2} \otimes W_2) \oplus \cdots \oplus (R_{ik} \otimes W_k)] = (\frac{1}{k}) \sum_{j=1}^{k} (R_{ij} \otimes W_j) \quad (3)$$

The prioritization of the aggregated assessments must be ranked among alternatives. Since the aggregated assessments are represented as triangular fuzzy numbers, a method of ranking these fuzzy triangular numbers is required. There are several methods of ranking fuzzy numbers [6] [9] [20] [27]. In this paper, the maximizing set and minimizing set methods [9] were applied, because of ease of use and application in previous studies [11] [19] [53] [55].

Let Fi (i=1, 2,…, m) be the fuzzy appropriateness index values of m alternatives. Chen [9] defined the maximizing set $M = \{ (x, f_M(x)) \mid x \in \Re \}$ with

$$f_M(x) = \begin{cases} \dfrac{(x - x_{\min})}{(x_{\max} - x_{\min})}, & x_{\min} \le x \le x_{\max} \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

and minimizing set $G = \{ (x, f_G(x)) \mid x \in \Re \}$ with

$$f_G(x) = \begin{cases} \dfrac{(x - x_{\max})}{(x_{\min} - x_{\max})}, & x_{\min} \le x \le x_{\max} \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

where

$x_{\min} = \inf S, \quad x_{\max} = \sup S, \quad S = \bigcup_{i=1}^{m} F_i, \quad F_i = \{ x \mid f_{Fi}(x) > 0 \}, \quad i = 1, 2, ..., m.$

Further, the right utility value $U_M(F_i)$ and left utility value $U_G(F_i)$ for alternative i are defined as

$$U_M(F_i) = \sup(f_{Fi}(x) \cap f_M(x)), \; i = 1, 2, ..., m \quad (6)$$

$$U_G(F_i) = \sup(f_{Fi}(x) \cap f_G(x)), \; i = 1, 2, ..., m \quad (7)$$

and the total utility or ordering value for alterative i is

$$U_T(F_i) = \frac{U_M(F_i) + 1 - U_G(F_i)}{2} \quad (8)$$

The alternative with maximum $U_T(F_i)$ value is the optimal choice in the decision-making problem.

3. Criteria for Selecting DW System

3.1 Technical Features

The technical features determined how well the software system could satisfy the company's requirements and how effectively it fitted in with the existing information systems and infrastructure. The technical aspects for data warehouse system selection included both front-end utilities and back-end utilities [7] [22].

(1) Front-end utilities

Front-end utilities present and provide access to data for the user community. These front-end services must fulfill the diverse needs of users, commonly required during browsing, querying and reporting warehouse data; they include display interface [5] [14] [50], analysis tools [51] and query functionality [32] [38] [51].

(2) Back-end utilities

Back-end utilities are responsible for gathering, preparing, and storing the data, and also for managing the data warehouse system, stressing the compatibility and integration capability of software systems. Therefore, back-end utilities consist of compatibility [3] [30], integration [5] [14] [16] [34] [37], the database [5] [7] [37], ETL functionality [5] [8] [23] [36], data quality checks [2] [49] [52], metadata management [8] [18] [51] and DW administration [7] [51].

3.2 Managerial criteria

The managerial criteria are concerned with the administration features of software systems, which satisfy the goals of decision makers. Within these administrative factors, cost and vendor characteristics are two important elements [25] [26] [45].

Data warehouse systems have different expenditure levels, some being considered more expensive than others. The concept of total cost of ownership (TCO) not only includes the price of purchase but also many other purchase-related costs [4].

One important IT management function of the supply side is the procurement of IT products to satisfy the requirements of a company [46]. Vendors play a key role in the acquisition of IT products and the computerization of an organization [1] [15]. Hence, the selection of a suitable vendor must be undertaken, when implementing a data warehouse system. Vendors should be able to provide related products, have technological capabilities and the knowledge and experience to implement a data warehouse system [21].

(1) Total cost of ownership

From the TCO viewpoint, the software system costs should include expenses associated with software acquisition, maintenance and use, including both direct and indirect costs [35]. Love and Irani [29] also identified IT costs as being both direct and indirect, with direct costs consisting of the software purchase, including the licensing fee, the cost of the hardware, including installation and getting the system up and running, as well as the external consulting fee to implement the system. The indirect costs include the necessary components to allow the users to become familiar with the system, such as training costs, maintenance costs, system upgrade costs, and the labor costs of support personnel.

(2) Vendor characteristics

It is important for a vendor to provide ongoing support for system installation and maintenance after the software has been purchased. Therefore, enterprises will tend to purchase software packages from more credible and stable vendors. Issues to be addressed when evaluating software vendors include vendor reputation [24] [30] [47] [48], vendor stability [30] [48], vendor support [3] [25] [26] [47] [48] and vendor experience [17] [39] [47].

4. The DW System Selection Procedure

In this section, we have developed an AHP-based and a fuzzy multi-criteria decision-making method for the selection of a data warehouse system. The two approaches comprise a nine-step procedure, shown in Figure 3. An example, using the two selection procedures, is presented in the next section.

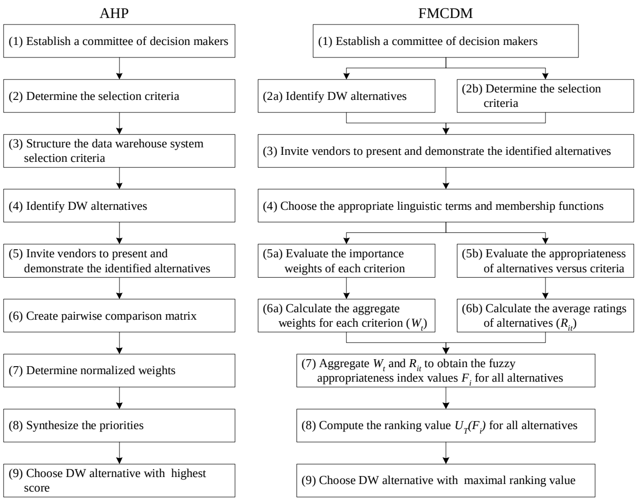

Figure 3: The data warehouse system selection procedure

5. A Case Study

To increase the efficiency of Agricultural Products Logistics, one County Farmers' Association located in the middle part of Taiwan and Taiwan's Government have planned to set up a nationwide product tracking system to monitor quality, quantity, and price of various vegetables and fruits. The project will result in systems that will generate more than one terabytes of data each year. These data will need to be kept for ten years to support the evaluations and decisions of quality control, efficiency improvement and policy changes. To store large volume of historical data for the access of various subject areas, a data warehouse system is in order.

5.1 Applying the AHP method

The following steps illustrate the data warehouse system selection using analytic hierarchy process.

Step 1: Establish a committee of decision makers

In order to select the most suitable DW system for the project, six experts with IT and business backgrounds, including one acting as collaborating principal director of the project, formed a committee to make the selection decision.

Step 2: Determine the selection criteria

This study established the selection criteria mainly from literature survey, then the criteria was verified through pre-tested with four consultants from four data warehousing vendors to ensure that all the criteria were well formulated and properly understood.

Step 3: Structure the DW system selection criteria

This step involves formulating an appropriate hierarchy of the AHP model consisting of the goal, criteria and sub-criteria according to the results of pre-test. Figure 4 shows the structuring of the data warehouse system selection decision into a hierarchy of five levels. The top-level of hierarchy presents the overall goal or focus of the problem. The general criteria are usually considered important in determining the appropriateness of data warehouse software which forms the second level of the hierarchy. The two criteria are technical features and managerial factors. At the third and fourth levels, these criteria are decomposed into more detailed elements that may affect the system selection. The third level of the hierarchy places the sub-criteria defining the four sub-criteria for the second level criteria. The technical capabilities can be divided into two major areas: front-end and back-end utilities. For the managerial factors, total cost of ownership and vendor characteristics are two important elements. There are three fourth level sub-criteria related to front-end utilities, namely, display interface, analysis tools and query functionality. The back-end utilities include seven sub-criteria: compatibility, integration, ETL functionality, database, data quality checks, metadata management, and DW administration. The sub-criteria associated with total cost of ownership remained as direct cost and indirect cost. The vendor characteristics consist of vendor reputation, vendor stability, vendor support and vendor experience. The bottom level consists of three alternatives.

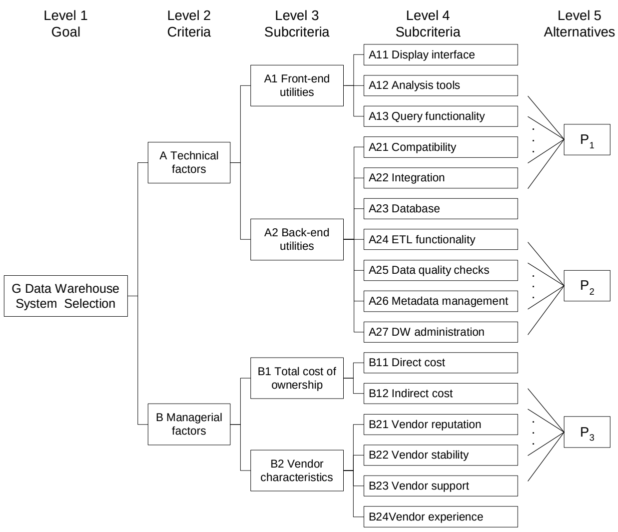

Figure 4: AHP model for data warehouse system selection

Step 4: Identify DW alternatives

The committee identified three prospective DW alternatives according to the marketing research report. These alternatives are the leading DW products in the global market.

Step 5: Invite vendors to present and demonstrate the identified alternatives

Before evaluated the ratings of alternatives, the committee invited three vendors to present and demonstrate their DW products. All the three DW vendors have branch office in Taiwan. The selection criteria and detail explanation were sent to three vendors by e-mail. Then, after two weeks, each vendor was given about three hours to reply the selection criteria and demonstrate its DW system formally.

Step 6: Create pairwise comparison matrix

A questionnaire including all criteria, sub-criteria and alternatives of the five levels AHP hierarchy was designed to collect the pairwise comparison matrices. The questionnaire is composed of two sections. The first section includes seven pairwise AHP comparison matrices to identify the importance of criteria. The second section includes sixteen AHP comparison matrices to evaluate the three alternatives versus sixteen sub-criteria at level 4. A supplement which described the hierarchy, detail explanation of each criterion and a sample questionnaire was also provided. Before filling out the matrix, all experts were briefed about how to create pairwise comparison matrices. The collected data were then analyzed and normalized.

Step 7: Determine normalized weights

The pairwise comparison matrices obtained from six experts are combined using the geometric mean approach.

Step 8: Synthesize the priorities

After calculating the normalized priority weights for each pairwise comparison matrix of the AHP hierarchy, the next step is to synthesize the local priority weights of criteria and sub-criteria for obtaining the set of global composite priorities.

Step 9: Choose DW alternative with highest score

Based on the global priority weights of the three alternatives, we find that alternative P_3 had the highest weight. Therefore, it is obvious that the best choice of data warehouse system is P_3. The committee can recommend that the alternative P_3 is the most suitable data warehouse system for the project.

5.3 Applying the FMCDM method

The following steps illustrate the data warehouse system selection using fuzzy multi-criteria decision-making method.

Step 1: Establish a committee of decision makers

In order to select the most suitable DW system for the project, six experts with IT and business backgrounds, including one acting as collaborating principal director of the project, formed a committee to make the selection decision.

Step 2: Identify DW alternatives and determine the selection criteria

The committee identified three prospective DW alternatives, according to the marketing research report. These alternatives were included among the leading DW products in the global market. The selection criteria in this study were established mainly from the literature survey. These criteria were verified via pre-testing with four consultants from four data warehousing vendors, to ensure all were well formulated and properly understood. Table 1 lists the major criteria for data warehouse system selection in FMCDM method.

Table 1: Data warehouse system selection criteria

Selection criteria
C_1: Display interface
C_2: Analysis tools
C_3: Query functionality
C_4: Compatibility
C_5: Integration
C_6: Database
C_7: ETL functionality
C_8: Data quality checks
C_9: Metadata management
C_{10}: DW administration
C_{11}: Direct cost
C_{12}: Indirect cost
C_{13}: Vendor reputation
C_{14}: Vendor stability
C_{15}: Vendor support
C_{16}: Vendor experience

Step 3: Invite vendors to present and demonstrate the identified alternatives

Before evaluating the ratings of alternatives, the committee invited three vendors to present and demonstrate their DW products. All three DW vendors had branch offices in Taiwan. The selection criteria and a detailed explanation were sent to the three vendors via e-mail. Then, after two weeks, each vendor was given about three hours to address the selection criteria and formally demonstrate the DW system.

Step 4: Choose the appropriate linguistic terms and membership functions

The decision makers then used the importance weighting set W and appropriateness rating set R, described in Section 2.2, i.e. W={Very low, Low, Medium, High, Very high}, R={Very poor, Poor, Fair, Good, Very good}, to evaluate the importance weight of the selection criteria and the preference rating of the alternatives versus the criteria.

Step 5: Evaluate importance weights of each criterion and suitability of alternatives versus criteria

From Steps 1, 2 and 3, we know that the six decision makers ($D_1, D_2, \ldots, D_6$) based their decisions on the sixteen selection criteria ($C_1, C_2, \ldots, C_{16}$), when choosing the most suitable DW system among the three alternatives (P_1, P_2, P_3).

Step 6: Calculate the aggregate weights for each criterion and average ratings of alternatives

Through triangular fuzzy number aggregation by Eq. (1), the aggregated weights (W_t), of the sixteen criteria, determined by the six decision makers, were obtained; this is shown in Table 11. By using Eq. (2), the average fuzzy appropriateness rating (R_{it}) of alternatives P_i under each criterion C_t could be obtained.

Step 7: Aggregate W_t and R_{it} to obtain the fuzzy appropriateness index values F_i for all alternatives

By using Eq. (3), the aggregation can be achieved by averaging the alternatives over all the criteria; the results of the fuzzy appropriateness index (F_i) values could be obtained.

Step 8: Compute the ranking value $U_T(F_i)$ for all alternatives

By using the maximizing set and minimizing set method, the ranking values of the three alternatives' fuzzy appropriateness indices can be obtained

Step 9: Choose DW alternative with maximal ranking value

The ranking order of fuzzy appropriateness indices for the three alternatives is $U_T(F_3)$, $U_T(F_1)$, and $U_T(F_2)$. Hence, it is obvious that the most appropriate data warehouse system is P_3. Thus, the committee can be comfortable in recommending alternative P_3 as the most suitable data warehouse system for the project.

6. Discussion

The final results show that two methods obtained the same outcome. Both methods determined P_3 is the most suitable data warehouse system of case study. Hence, the committee had strong confidence to determine that P_3 is the final selection for the project. The case study revealed some strengths and weaknesses of using the AHP and FMCDM as shown in Table 2.

Table 2: The pro and con of AHP and FMCDM methods

AHP	FMCDM
Advantages:	*Advantages:*
■ Structuring a decision problem into a hierarchy can help to understand and simplify the problem. ■ The AHP method combines both qualitative (tangible) and quantitative (intangible) criteria. ■ The priority weights of criteria and sub-criteria show the concerns and preferences of decision makers. ■ Several AHP software packages can help to calculate the relative weights of decision criteria and alternatives automatically. In this study, Expert Choice was used to perform the calculation. ■ The consistency ratio can be used to check whether decision makers' opinions are consistent.	■ The use of fuzzy set theory improves decision-making procedure by considering the vagueness and ambiguity in the real-world system. ■ The FMCDM method combines both qualitative (tangible) and quantitative (intangible) criteria. ■ The decision makers can use linguistic terms to evaluate criteria and alternatives easily and intuitively. ■ The decision makers do not need to re-evaluate all criteria or alternatives when increasing in number of criteria or alternatives.
Disadvantages:	*Disadvantages:*
■ The scale of relative importance for judgments is not easy for comparing among criteria. ■ Oversimplifying the hierarchy may lose some important interdependencies among criteria. Overextending the hierarchy may increase time and complexity for creating pairwise comparison matrices. ■ Sometimes, it is difficult to interpret the global composite weights which used to evaluate decision alternatives.	■ It lacks ready-made software packages to computerize decision processes. In this study, Microsoft Excel was used to execute the computation step by step. ■ The membership functions and ranking fuzzy numbers method are subjectively determined in this study. ■ The method only considers the bottom criteria as compared with AHP.

7. Conclusions

Although the evidence show that the information systems are beneficial to enterprises, it is not easy to make decision about which software system to procure. The choice of a suitable software system can lead to productivity improved and costs reduced; the selection of an unsatisfactory software product can incur the loss of acquisition cost and time waste in short-term. Hence, the evaluation and selection of such software systems play an important role before real implementation. The increasing demand for timely business information and the need to improve the quality of decision making are motivating companies to consider implementing data warehouse system. The proliferation of data warehouse software packages has created a difficult, complex decision problem of evaluation and selection.

In this paper, two simple, easy to use and systematic methods based on AHP and fuzzy sets have been proposed to aid the selection among alternatives with several decision criteria. The applicability of two methods was illustrated through the case study of data warehouse system selection for the agricultural products tracking and monitoring system in Taiwan. With the survey of various software selection articles and the pre-test of several professions from DW vendors, we were able to develop complete selection criteria, which can be used to help the project selected a data warehouse system. The decision took into consideration of both technical and managerial issues. The final results show that two methods obtained the same outcome. Both methods determined the same alternative as the most suitable data warehouse system of case study.

The AHP method structured the technical and managerial factors into a hierarchy of five levels. The scale of relative importance measurement is used to examine the relative importance of data warehouse system selection criteria, sub-criteria, and alternatives. By synthesizing the normalized matrices values of criteria, sub-criteria, and alternatives, the global priority weights of alternatives can be determined. The FMCDM method used fuzzy set theory, fuzzy algebraic operations and ranking fuzzy numbers with maximizing and minimizing sets, to solve the decision-making problem of choosing among alternatives, using ranking based on linguistic assessment. The use of fuzzy set theory improves the decision-making procedure by considering the vagueness and ambiguity prevalent in real-world systems. We also found that using triangular fuzzy numbers made data collection, calculation and interpretation of the results easier for decision makers. Although the case study was related to a specific software system and industry, the same concept can be applied to other software products and industrial sectors.

The research can be further extended in two directions. For AHP method, sensitivity analysis can be used to check the impact of change in the input data of the proposed model. Since, some changes in the hierarchy or judgment may lead to a different outcome [33]. For FMCDM method, the proposed model can be computerized. By implementing fuzzy linguistic assessments on a computer, decision makers can automatically obtain the ranking order of alternatives.

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