AN INTEGRATED AHP-TOPSIS METHODOLOGY TO EVALUATE FOR ADOPTION COTS DATABASE COMPONENTS BASED ON EFFICIENCY

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ABSTRACT: *Adopting commercial off-the-shelf (COTS) components in development projects of large systems provide benefits of software reuse; these include, accelerated development, increased dependability, and reduced process risk. However choosing the right component among multiple alternatives is considered a hard process and may involve risk. Throughout the system development life cycle, many stakeholders contribute from their own perspectives, and interests. For example, business owner would primarily be concerned with meeting the requirements within the assigned cost and schedule. End users would want the product easy to use. Thus, usability is a user-focused quality attribute. Under such circumstances, there should be a mechanism that helps stackeholders to make decisions accordingly. Multiple-Criteria Decision-Making (MCDM) or Multiple-Criteria Decision Analysis (MCDA) is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision-making. In this research work, an application of decision-making methodology has been introduced. It employs two well-known MCDM techniques, namely Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The new model, as a hybrid approach from AHP and TOPSIS, has been designed to facilitate the decision-making process, featuring the ability to analyze and select the best alternative from a number of COTS components. In this respect, the aim of using AHP is to analyze the structure of the database software selection problem and to obtain weights of the selected criteria. Then, TOPSIS technique is used to calculate the alternatives' ratings COTS or Database Software component.*

Key word: Commercial of the shelf (COTS), Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS), Analytical Hierarchy Process (AHP), Efficiency, Time Behavior, Multiple Criteria Decision Making (MCDM)

I. INTRODUCTION

Using commercial off-the-shelf (COTS) software products in large systems provides many benefits, including the potential of rapid delivery to end users, lower risk, and the opportunity to reuse software components that are already tested and validated. During the system development life cycle, many stakeholders contribute from their own objectives, perspectives, and interests. For example, a business owner would primarily be concerned with meeting system requirements within an allotted budget and schedule. Analysts would want the product built per requirements. Quality assurance would focus on the quality of products and services as provided to the customers. End users would desire a product that is easy to use, difficult to misuse, and performs as intended. A project manager would want to construct and manage the development process. Consequently, for systems that depend on COTS products, the evaluation and selection of appropriate products is essential to the success of the entire system.

Numerous systems are being built using COTSs worldwide under different circumstances and different operational environment conditions. In the case of re-using COTS products, the benefits can be outlined easily. However, the process of choosing a particular COTS package among several existing ones is a hard one for organizations. The choice of adopting the best COTS has to be completely investigated and carefully understood.

This contribution suggests an evaluation process that serves the purpose of choosing the appropriate COTS in an organization by a group of developers. The evaluation process provides the knowledge that is necessary to be certain about choosing a particular method, and without such knowledge the uncertainty will compromise the benefits. Thus, choosing the appropriate COTS achieves a high degree of reusability and the desired benefits. Although in the literature several methodologies can be found to assess decision makers to evaluate COTS alternatives for adoption, none of them used three levels of critera, and there was no attempt to integrate AHP with other techniques used in such circumstances. The importance of our methodology herein is the fact that it overcomes previous shortfalls through applying the three levels of criteria, characteristics, and sub-characteristics, along with the concept of integrating AHP with TOPSIS.

The starting point for our research work, herein, is the Rawashdeh and Matalkah [12], simply because it includes the common software quality characteristics. The following is the evaluation discussion of the high-level of characteristic 'Efficiency', along with its associated sub-characteristics.

Efficiency is the capability of the software product to provide appropriate performance, relative to the amount of resources used, under stated conditions. Efficiency is the degree to which something effectively uses (i.e., minimizes its consumption of) its resources. These may types of resources such as computing (hardware, software, and network), machinery, facilities, and personnel [8]. The sub-characteristics of Efficiency are Time-behavior, Resource-behavior [2]. Attributes associated to "Time Behavior" Which can be described as the capability of the software product to provide appropriate response and processing time and throughput rates when performing its function [6]. Time Behavior attributes can be decomposed into: (i) Response Time: is the time between the arrival of an event and the generation of response to it [4], (ii) Scalability: is the ease with which an application or component can be modified to expand its existing capacities [4]. Scalability: is the ability of a system to continue to meet it performance as the demand for the software functions increases [10]. (iii) Capacity: is the minimum number of things (e.g. transactions, storage) that can be successfully handled [4]. Attributes associated to "Resource Behavior": Which can be described as the capability of the software product to use appropriate amounts and types of resources when the software performs its function under stated condition [6]. Resource Behavior attributes can be decomposed into: (i) Memory Utilization: the amount of memory needed by a component to operate the minimum, maximum or estimated memory size may be indicated (or recommended size for optimum performance). (ii) Disk Utilization: this attribute specifies the disk space used by a software component, including both space used for storing its code and the space used during the execution. An evaluation is made, for each of the attributes, by comparing the corresponding feature among Oracle 9i and SQL Server 2005. The objective of this step is to obtain pairwise comparison judgment matrices; which will be used to determine the normalized weights. The Analytic Hierarchy Process (AHP) methodology developed by Thomas L. Saaty [13], is probably the best-known and most widely-used model in decision-making. It is a powerful traditional decision-making tool in determining the priorities among different criteria, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method is used to solve problems using multi-criteria decision-making process. On the other hand, the new developed model, herein, features the ability to analyze and select the best alternative from a number of COTS components using AHP and TOPSIS techniques as a hybrid approach.

The remainder of this paper is organized as follows: Section II presents the Literature Review. Section III describes the AHP methodology. Section IV describes the TOPSIS method. Section V. Proposed integrated multi-criteria decision methodology. Section VI. Defining the Attributes and Assigning their Appropriate Metrics. Section VII. Weights Generation Methods with TOPSIS Approach in the AHP, section VIII. Reasoning the choice of the best alternative, Finally, Section IX draws out the Conclusions and Future work.

II. Literature review

In [14], it is suggested that in order to solve the group decision making problems with ordinal interval preference information, a new decision method is proposed based on VIKOR method. The VIKOR method of compromise ranking determines a compromise solution, providing a maximum "group utility" for the "majority" and a minimum of an "individual regret" for the "opponent". The shortfall of the proposed method is the fact that there is no integration between AHP and VIKOR. In addition, the proposed method only used one level of criteria with alternatives, whereas our methodology applies three levels, these include: criteria, characteristics and sub-characteristics, and that is why we chose to integrate AHP with VIKOR**.**

The research work by [11] focused on the evaluation of wastewater treatment alternatives. Fuzzy VIKOR method is proposed for identifying the most suitable wastewater treatment alternative. The computational procedure is illustrated through a case study conducted in Istanbul. The limitation of the proposed FUZZY-VIKOR is the one level of criteria for alternatives and there is no integration with AHP, whereas our research work utilizes three levels and facilitates integration of AHP and VIKOR**.**

COTS-Aware Requirements Engineering and Software Architecting (CARE/SA) proposed by Chung, L [3] for evaluating, matching, and selecting of COTS components. CARE/SA method uses the architectural aspects, functional aspects and non-functional aspects of COTS components. It indicates that each component is represented by the unique attributes which consists of its architectural, functional and non-functional aspects. However, Chung's research work did not use numbers to represent the weight. Consequently, the outcome of the evaluation process is not a specific numeric value; which can be considered as a constraint.

In [7], Jadhav and Sonar suggested that Multi Criteria Decision Making Methods helps the decision makers to solve the problem of selection and evaluation of software components in which problem is defined as a collection of multiple criteria that needs to be taken into account. It gives the overview of Multi Criteria Decision Making Methods like: AHP, Weighted Scoring Method (WSM) and Hybrid Knowledge Based System (HKBS). They compared the three approaches and concluded that HKBS is a better technique than AHP and WSM. Unfortunately, each comparison was carried out independently, and there was no attempt to perform integration between the three techniques AHP, WSM, and HKBS in order to facilitate observation of different possible outcomes.

Arvinder Kaur *et al*, in [9] provide a brief overview of the evolutionary techniques. It also derives a hierarchical decomposition method to draw goals from that impact factors. It introduces off-the-shelf-option (OSTO) method for the selection of software components which compares the scores and cost associated with each alternative and their relative comparison. It introduces various factors in the selection of reusable software components. It also presents the evaluation criteria based on various classifications as functional requirements, product quality attributes, strategic concerns and architecture and domain compatibility. It gives the result of two case studies using OSTO method. The component which has a good quality assurance score is selected for consideration. The limitation of this approach is that it can be very sensitive to bias or the experience of the personnel. The OTSO method does not address which method or model is used to determine reuse cost estimated for COTS software components. Whichever approach is used, the OTSO method extends the final COTS software evaluation by allowing the consideration of other factors that may influence the decision.

Wei et al, in [15] used the AHP method to identify priority in selecting ERP System. Similarly, Yigit *et al*, in [16] developed an interactive model using AHP to facilitate the selection of Web-based learning object software. In addition, [2] applied ANP method to appraise and select the best operating system with regard to organizational factors and strategic performance metrics. The limitation on the afore-mentioned contributions is that they used a traditional Multiple Criteria Decision-Making, namely AHP.

III. The Analytical Hierarchy Process (AHP) methodology

The AHP is developed by Thomas L. Saaty [13], probably the best-known and most widely-used model in decision-making. It is a powerful decision-making tool in determining the priorities among different criteria. The AHP encompasses six basic steps

Step 1. AHP decomposes a complex decision problem into several sub-problems forming a hierarchy. The goal of the problem is placed at the top level, representing the root, and the characteristics are decomposed into several nested sub-levels representing the process of breaking down the criteria into sub-criteria.

Step 2. A decision matrix, based on Saaty's nine-point scale, is constructed. The decision maker uses the fundamental 1-9 scale to assess the priority score. In this context, the assessment of 1 indicates equal importance, 3 moderately importance, 5 strongly importance, 7 very strongly importance, and 9 indicate the extreme importance (Table 1). The values of 2, 4, 6, and 8 are intermediate values of importance. The decision matrix involves the assessments of each alternative in respect to the decision criteria. If the decision making problem consists of n criteria and m alternatives; the decision matrix takes the form:

$$D = \begin{bmatrix} d_{11} & d_{12} & \dots & d_{1n} \\ d_{21} & d_{22} & \dots & d_{2n} \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ d_{m1} & d_{m2} & \dots & d_{mn} \end{bmatrix}$$

Step 3. The third step involves the comparison in pairs of the elements that make up the hierarchy. The aim is to set their relative priorities with respect to each of the elements at the next level up. The Pairwise comparison matrix, based on the Saaty's one-to-nine scale, has the following format, where w_i represents the weight value of the criteria:

Decision-Matrix *Pair-Comparison-Matrix*

$$\begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \dots & w_2/w_n \\ \cdot & & & \\ \cdot & & & \\ \cdot & & & \\ w_n/w_1 & w_n/w_2 & \dots & w_n/w_n \end{bmatrix}$$

Assuming *n* is the number of criteria, then the number of pairwise comparisons between them is equal to $n(n-1)/2$. Each value (a_{ij}) in the left-hand matrix is matched with the corresponding (w_i / w_j) value in the right hand matrix. Each pairwise, $a_{ij} \leftrightarrow w_i / w_j$, is computed as follows:

$w_i / w_j = 1 / a_{ji}$ in all cases except when $i = j$ then $w_i / w_j = 1$. In the comparison matrix, a_{ij} can be interpreted as the degree of preference of *i*th criteria over *j*th criteria. It appears that the weight determination of criteria is more reliable when using pairwise comparisons compared to the method of obtaining them directly, because it is easier to make a comparison between two attributes than to make an overall weight assignment.

Step 4: Verify the consistency of judgments across the Consistency Index (CI) and the Consistency Ratio (CR) : $CI = (\lambda_{max} - N) / (N - 1)$

where λmax is the Eigen value corresponding to the matrix of pair-wise comparisons and n is the number of elements being compared, Consistency ratio (CR) is defined by: $CR = CI / RCI$

where, (RCI) is a random consistency index defined in Table 2. A value of CR less than 0.1 is generally acceptable; otherwise the pair-wise comparisons should be revised to reduce incoherence.

Step 5. The comparison matrix has to be normalized. Therefore, each element has to be divided by the sum of the entries of the corresponding column. In that way, a normalized matrix is obtained in which the sum of all elements vector is 1.

Step 6. The eigenvalues of this matrix need to be calculated, which would give the relative weights of criteria. The relative weights obtained in the third step should satisfy the formula: $A * W = \lambda_{max}$ Where *A* represents the Pairwise comparison matrix, *W* represents the weight and λ_{max} represents the highest eigenvalues. If there are elements upward in the hierarchy, the weight vector is calculated by multiplying each element (weight coefficient) by its parent at the higher level, this process continues until the top of the hierarchy is reached. The alternative with the highest weight coefficient value should be taken as the best alternative.

IV. Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS)

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method was first developed in 1981 by Hwang and Yoon [5]. Its basic concept is that the chosen alternative should have the shortest distance from the ideal solution and the farthest from the negative-ideal solution. TOPSIS assumes that we have m alternatives (options) and n attributes/criteria and we have the score of each option with respect to each criterion. The steps of TOPSIS model are as follows:-

Table 1 : Scale of relative importance according to [13]

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is favored very strongly over another; it dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Intermediate values of importance
Reciprocal	If variable *i* has one of the above numbers assigned to it when compared with variable *j*, then *j* has the value 1/ number assigned to it when compared with *i*. More formally if n_{ij} = x then n_{ji} = 1 / x	

Table 2 Average RCI values

Number of criteria	Consistency ratio index
1	0
2	0
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Step 1: Construct normalized decision matrix. This step transforms various attribute dimensions into non-dimensional attributes, which allows comparisons across criteria. Normalize scores or data as follows

$r_{ij} = x_{ij} / (\Sigma x^2_{ij})$ for i = 1, …, m; j = 1, …, n

Step 2**:** Construct the weighted normalized decision matrix. Assume we have a set of weights for each criteria w_j for j = 1,…n, Multiply each column of the normalized decision matrix by its associated weight, An element of the new matrix is: $v_{ij} = w_j r_{ij}$

Step 3: Determine the ideal and negative ideal solutions. Using the following equations

For ideal solution:-

$A^* = \{ v_1^*, …, v_n^*\}$, where $v_j^* = \{ \max (v_{ij})$ if $j \in J$; $\min (v_{ij})$ if $j \in J' \}$

For negative solution:-

$A' = \{ v_1', …, v_n' \}$, where $v' = \{ \min (v_{ij})$ if $j \in J$; $\max (v_{ij})$ if $j \in J' \}$

Step 4: Calculate the separation measures for each alternative. Using the following equations : $S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{½}$ i = 1, …, m for the ideal alternatives

$S'_i = [\Sigma (v_j' - v_{ij})^2]^{½}$ i= 1,……,m for the negative alternatives

Step 5**:** Calculate the relative closeness to the ideal solution C_i^*

$C_i^* = S'_i / (S_i^* + S'_i)$, $0 < C_i^* < 1$

Step 6 : Select the option with C_i^* closest to 1.

V. Proposed integrated multi-criteria decision methodology

The proposed methodology is designed in such a way that makes the use of Multiple Criteria Decision Making (MCDM) techniques as efficient as possible. Two different techniques, namely AHP and TOPSIS, are combined in order to rank alternative software according to criteria. The reason for using the well-known AHP technique is to structure the decision hierarchy of the problem. Finally, to rank the alternatives, one of the most efficient MCDM techniques such as TOPSIS is used. The main steps of the proposed integrated methodology to be elaborated by decisions-makers for the database software selection problem are as follows:

Step 1: Define criteria and sub-criteria that are most affecting in the Database software selection problem

Step 2: Construct a hierarchy decision model for the Database software.

Step 3: Determine the comparison matrix for each level (level of criteria and sub (criteria) by using AHP technique

Step 4: Determine the global weight by normalizing the local weight

Step 5: Use the TOPSIS technique to assess the alternatives

Step 6: Select the best Database software alternative

Figure 1 illustrates the process of the proposed integrated methodology to evaluate and select the Database software.

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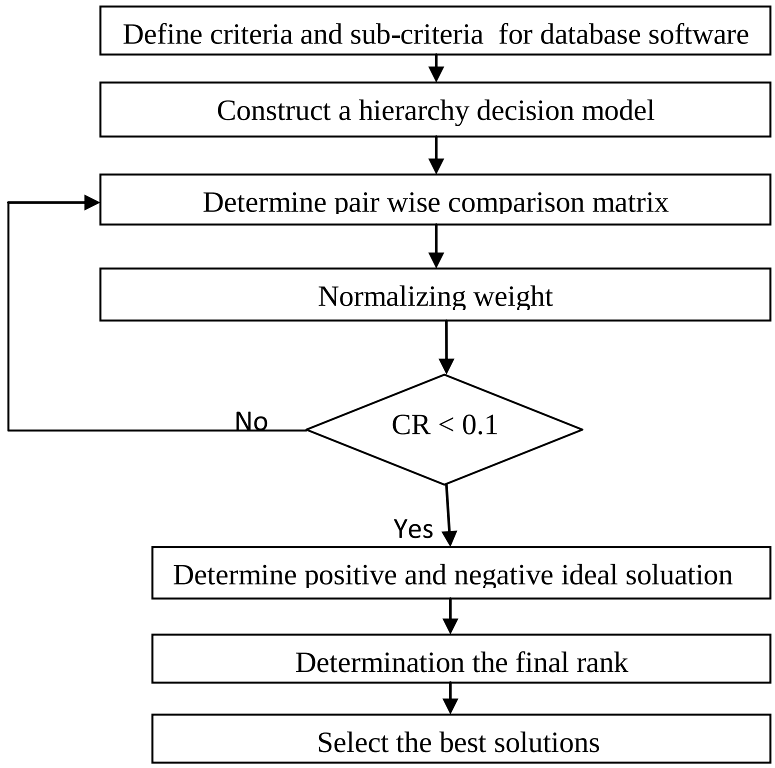

Figure 1 proposed integrated methodology to evaluate and select the Database software.

VI. Defining the Attributes and Assigning their Appropriate Metrics

In this section, to better understand of the proposed integrated methodology, an application is provided. The Database software selection decision is very important in long-term planning for any Business. Efficiency is the capability of the software product to provide appropriate performance, relative to the amount of resources used, under stated conditions. Efficiency is the degree to which something effectively uses (i.e., minimizes its consumption of) its resources. These may include all types of resources such as computing (hardware, software, and network), machinery, facilities, and personnel [8]. Our suggested framework is useful for its integrated approach to quality. Each high-level characteristic of the database software product is associated with a set of sub-characteristics. A sub-characteristic is, further, represented by sets of software quality attributes. This chain of software quality attributes can be classified into a hierarchy of three levels as shown in Figure 2. At the top level the so-called "characteristic" from a customer or stakeholders perspectives:, Efficiency. At the second level the so-called " Sub-characteristics" or quality factors from a customer or stakeholders perspectives: Time-behavior, Resource-behavior. At the third level are the quality criteria (attributes), which represent technical concepts. At the fourth level the "metrics" that measure the quality criteria (attributes) of database software product. It can be seen that the top, second and third levels are from engineering perspectives. Attributes associated to "Time Behavior": Which can be described as the capability of the software product to provide appropriate response and processing time and throughput rates when performing its function [6]. Herein we believe that Time Behavior attributes can be decomposed into: (i) Response Time: Is the time between the arrival of an event and the generation of responses to it [1]. This attribute can be associated to any of the methods implemented in any of the database component interfaces, and measures the time taken for a request is received until a response has been sent. (ii) Scalability: is the ease with which an application or component can be modified to expand its existing capacities [4]. Scalability is the ability of a system to continue to meet it performance as the demand for the software functions increases (ii) Capacity: Is the minimum number of things (e.g. transactions, storage) that can be successfully handled [4]. Attributes associated to "Resource Behavior": Which can be described as the capability of the database software product to use appropriate amounts and types of resources when the database perform its function under stated condition Here in we believe that Resource Behavior attributes can be decomposed into: (i) Memory Utilization: The amount of memory needed by a component to operate.. (ii) Disk Utilization: This attribute specifies the disk space used by a database component, including both space used for storing its code and the space used during the execution.

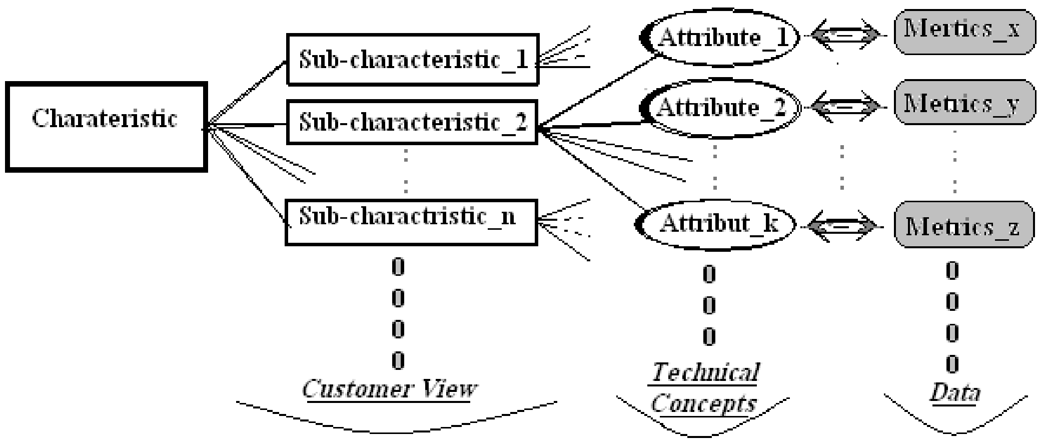

Figure 2: Framework of COTS Quality Attributes

The undertaken approach led us to construct a framework that is original, unique and dedicated for selecting database components. Along with each specified attribute, a set of associated sub-attributes has been identified to further facilitate precise quality measurements.

The attributes and the sub-attributes are put together to form a top-down hierarchy, which will be used as an evaluation criteria and tool metrics for database components figure 3.

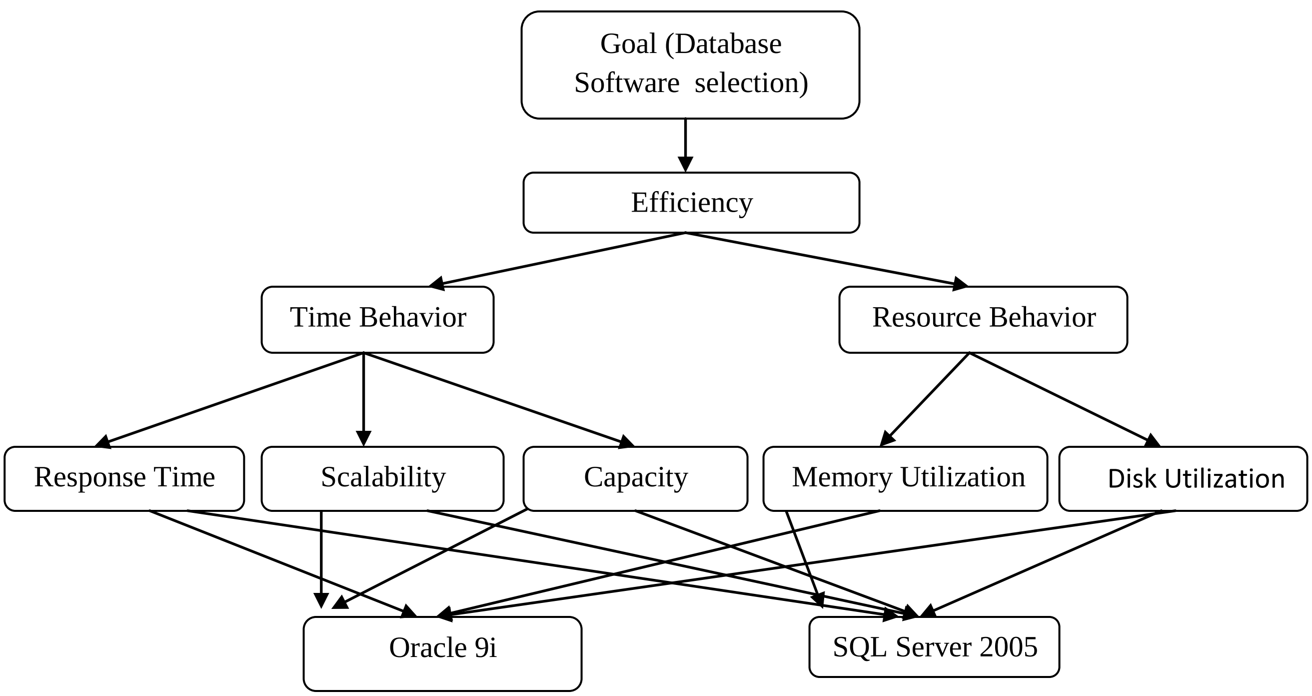

Figure 3: charactrsitics and sub-characteristics for efficiency attribute

Using Saaty scaling-table, and the AHP six steps, a weight value is assigned for each of the characteristics: Time Behavior, Resource Behavior. The outcome is shown in Matrix-1.

Efficiency	Time behavior	Resource behavior	Priority
Time behavior	1	3	0.75
Resource behavior	0.33	1	0.25
Consistency Ratio = 0.0			∑Priority =1

Matrix-1: Pairwise Comparisons Judgment for the Sub-Characteristics According to Efficiency

A weight value is assigned for each of the sub-characteristics: Response time, scalability, capacity. The outcome is shown in Matrix-2. A weight value is assigned for each of the sub-characteristics: Response time, scalability, capacity .The outcome is shown in Matrix-3

Time Behavior	Response time	Scalability	Capacity	Priority
Response time	1	2	2	0.5
Scalability	0.5	1	1	0.25
Capacity	0.5	1	1	025
Consistency Ratio = 0.0				∑Priority =1

Matrix-2: Pairwise Comparisons Judgment for the Attributes According to Time Behavior

Resource Behavior	Mummery Utilization	Disk Utilization	Priority
Mummery Utilization	1	3	0.75
Disk Utilization	0.33	1	0.25
Consistency Ratio = 0.0			∑Priority =1

Matrix-3: Pairwise Comparisons Judgment for the Attributes According to Resource Behavior

VII. Weights Generation Methods with TOPSIS Approach in the AHP

TOPSIS method is applied in order to rank the alternative database software. The first step, the global weights of each Criteria and sub-criterion' Time behavior, Resource behavior, Response time, scalability, capacity, Mummery utilization, Disk utilization are calculated by AHP as shown in Table 3 below, and thus can be used as the input to the TOPSIS method. Therefore, by using the scale in Table 1, the decision-makers are asked to evaluate the alternatives according to each sub-criterion, as illustrated in Table 4, below

. Table 3 the normalized sub-criteria weightings

Criteria	weight	Sub-criteria	Weight	Level two
Time behavior	0.75	Response time	0.5	0.375
		scalability	0.25	0.1875
		capacity	0.25	0.1875
Resource behavior	0.25	Mummery utilization	0.75	0.1875
		Disk utilization	0.25	0.0625
Total	1			1

Table 4 Input values of the TOPSIS analysis

	Response time	scalability	capacity	Mummery utilization	Disk utilization
Oracle 9i	8	7	6	7	5
SQL server 2005	6	5	8	8	6
Weight	0.375	0.1875	0.1875	0.1875	0.0625

The second step in TOPSIS technique is to calculate $(\Sigma x^2_{ij})^{1/2}$ for each column as illustrated in Table 5 below

Table 5 calculate $(\Sigma x^2_{ij})^{1/2}$ for each column

	Response time	scalability	capacity	Mummery utilization	Disk utilization
Oracle 9i	64	49	36	49	25
SQL server 2005	36	25	64	64	36
$\sum X_{ij}^2$	100	74	100	113	61
$(\sum X_{ij}^2)^{0.5}$	10	8.6	10	10.63	7.81

The third step is divide each column by $(\Sigma x^2_{ij})^{1/2}$ to obtain r_{ij} as illustrated in table 6 below

Table 6 Dividing Each column by $(\Sigma x^2_{ij})^{1/2}$ to obtain r_{ij}

	Response time	scalability	capacity	Mummery utilization	Disk utilization
Oracle 9i	0.8	0.81	0.6	0.66	0.64
SQL server 2005	0.6	0.58	0.8	0.75	0.77

The fourth step is multiply each column by w_j to obtain v_{ij}. as illustrated in table 7 below

Table 7: Multiplying Each Column by w_j to Obtain v_{ij}

	Response time	scalability	capacity	Mummery utilization	Disk utilization
Oracle 9i	0.3	0.15	0.11	0.12	0.04
SQL server 2005	0.23	0.11	0.15	0.14	0.05

The fifth step is to determine ideal solution $A^* = \{ v_1^*, \ldots, v_n^*\}$, where $v_j^* =\{ \max (v_{ij}) \text{ if } j \in J ; \min (v_{ij}) \text{ if } j \in J' \}$ so $A^* = \{0.3, 0.15, 0.15, 0.14, .05\}$. The sixth step is to find the negative ideal solution $A' = \{ v_1', \ldots, v_n' \}$, where $v' = \{ \min (v_{ij}) \text{ if } j \in J ; \max (v_{ij}) \text{ if } j \in J' \}$ so $A' = \{0.23, 0.11, 0.11, 0.12, 0.04\}$. The seventh step is to determine separation from ideal solution: $S_i^* = [\Sigma (v_j^* - v_{ij})^2]^{½}$ for each row, as illustrated in Table 8, below

Table 8: The Separation from Ideal Solution

	Response time	scalability	capacity	Mummery utilization	Disk utilization	S_i^*
Oracle 9i	0.0	0.0	0.0016	0.0004	0.0001	0.0460
SQL server 2005	0.0049	0.0016	0.0	0.0	0.0	0.0810

The eighth step is to find the separation from negative ideal solution:
$S_i' = [\Sigma (v_j' - v_{ij})^2]^{½}$ for each row as illustrated in table 9 below

Table 9: The Separation from Negative Ideal Solution

	Response time	scalability	capacity	Mummery utilization	Disk utilization	S_i'
Oracle 9i	0 .0049	0.0016	0.0	0.0	0.0	0.0810
SQL server 2005	0.0	0.0	0.0016	0.0004	0.0001	0.0046

The final step is to calculate the relative closeness to the ideal solution $C_i^* = S'_i / (S_i^* + S'_i)$ as illustrated in Table 10, below.

Table 10: The Relative Closeness to the Ideal Solution

	S_i^*	S_i'	C_i^*
Oracle 9i	0.0460	0.0810	0.638
SQL Server 2005	0.0810	0.0046	0.054

VIII. Reasoning the choice of best alternative

Once computing the normalized priority weights for each Pairwise Comparison Judgment Method (PCJM) of the Integrated AHP-TOPSIS Methodology has been carried out, the next step is to synthesize the solution for the database selection problem. As mentioned in Section VII above, the normalized local priority weights of the characteristics, sub-characteristics and attributes are added together to obtain the global composite priority weights. Accordingly, for Oracle 9i, the formula will be applied as follows: $C_i^* = S'_i / (S_i^* + S'_i)$. $C^* = 0.081 / (0.046 + 0.081) = 0.638$. On the other hand, for SQL Server 2005, the formula will be applied as follows: $C^* = 0.0046 / (0.081 + 0.0046) = 0.054$. It can be seen that AHP-TOPSIS integration projects the winner component as to have a value 0.638; while the other component is 0.054. Therefore, Oracle 9i is the winner of this evaluation process and thus would be selected as the best COTS database component.

Consequently, our methodology produces a clear cut numeric value which contributes to an easy decision to make. In addition, adopting the hybrid approach of AHP and TOPSIS in our methodology overcomes the limitation of previous work as mentioned in the Literature Review. Thus, the distinction here is the computation that leads to a numeric preference value which facilitates the decision-making process.

IX. CONCLUSION AND FUTURE WORK

The objective of the proposed methodology for database software selection is to find the best database software component among the available ones in Commercial Off The Shelf (COTS) systems by using the appropriate decision-making technique. After checking the aggregations on various process parameters under different circumstances, as illustrated in Sections VI and VII above, it can be observed that the proposed model is rather simple to use and meaningful for any aggregation of the process parameters. As described in the literature review, there are several existing techniques used to assess decision makers to evaluate COTS alternatives, however, none of them used three levels of critera for alternatives, and there was no attempt to integrate AHP with another technique. Our methodology herein overcomes previous shortfalls through applying the three levels of critera, characteristics, and sub-characteristics along with the concept of integrating two techniques.

Our contribution presents an application of methodology based on a hybrid multi-criteria decision-making process. The methodology consists of two techniques: Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) for order preference. Although our testing sample only used two COTS components, the proposed methodology can be applied for any other software selection problem involving several COTS components with multiple and conflicting criteria. In addition, the hybrid concept in our model and the fact that the preference indication computed as an explicit numeric value does facilitate the decision-making process and overcomes the limitations encountered in previous research work mentioned in the Literature Review Section.

For further work, there are several different techniques of MCDM, these include: The ELimination Et Choix Traduisant la Realite' (elimination and choice expressing reality – (ELECTRE)), Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH), Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE), and Višekriterijumsko Kompromisno Rangiranje (VIKOR). Each of these techniques can be integrated with AHP and adopted to carry out a comparison based on 'Usability' in a similar fashion as it has been accomplished in this research work, however with multiple integrated mechanisms. We believe that, analyzing and exploring the possible results will bring useful recommendations for decision makers in organizations. In addition, considering the AHP with the fuzzy environment would be a promising line of research.

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