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INTELLIGENT BROKER FOR ERP CLOUD SYSTEM USING MACHINE LEARNING

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ABSTRACT

As any business grows, the workload of its administrators also grows exponentially and the need to monitor all parts of the business to ensure efficiency increases. Initially, companies will work with spreadsheets and email, and eventually the boredom of manual logistics will affect their losses. That creates the need for a new smart alternative to help administrators. And from here the light was shed on the enterprise resource planning as an ideal solution. Enterprise resource planning led to the ability of administrators to monitor growth and facilitate work for employees, thus obtaining more clients and more growth. Once that need has been raised, many software companies began to make many programs to fill this gap, and this resulted in giant programs such as (Oracle, SAP, Microsoft, etc.).

This need created an urgent necessity, namely, how to choose the appropriate software capable of providing the software to the client in the required manner.

The proposed approach explored the application of a multicriteria decision making method (MCDM) that is best worst method (BWM) with k-nearest neighbors (K-NN) algorithm which is one of machine learning (ML) technique used for the evaluation of various enterprise resource planning (ERP)software. First, the BWM model is applied to calculate the weights of criteria, and then, the obtained weights are used in the K-NN method for getting the best alternative. This study will help decision-makers select the best ERP software for all various industries.

Keywords: *MCDM, ML, BWM, K-NN, ERP*

1. INTRODUCTION

Enterprise Resource Planning is a tool to standardize and integrate business processes to accelerate access to common resources across the organization so that ERP systems help organizations facilitate information sharing and improve operational efficiency [1]. ERP is the biggest and most intricate enterprise system that supports business processes throughout the organization and offers cost-effectiveness, enhanced operations, and corporate growth[2]. As an instrument for managing processes and resources, an ERP system is essential for enterprises to have in order to help coordinate several operations within the firm, according to Petter, DeLone and McLean[3]. Organizations view ERP as a dynamic tool for company success since it connects many business processes and makes perfect transactions and products possible, according to Levi and Doron[4].

From those we can declare the ERP as it is an application that automates company activities and offers insights and internal controls, With the use of a central database that compiles inputs from several departments, including accounting, manufacturing, supply chain management, sales, marketing, and human resources (HR).

Let's have a look for the history of ERP, businesses began utilizing computers for accounting and financial solutions as early as the 1960s. In order to consolidate all of these activities in one location, new software was created in the 1980s when the manufacturing sector began to flourish. ERP, which combines accounting, finance, sales, manufacturing, inventory, human resources, and project management, was first introduced in the 1990s.

Early in the 2000s, cloud ERP software became popular, and today, machine learning and other supplementary technologies are assisting businesses in operating even more effectively to keep up with the competition.

It is so challenging to overstate the business value of a successful ERP. Here are just a few advantages of an ERP. It reduced risk, ERP helps businesses run their daily operations more efficiently by removing the possibility of data duplications and mistakes. It helps to increase efficiency, reduce expensive, pointless repeats, ERP automates business activities across departments. It gives you reliable access to reliable data wherever in the world, ERPs help maximize yours. To evaluate important data using a cloud-based ERP, all you need is an internet connection.

According to Palaniswamy ERP grow from 13.4$ billion in 2003 to a projected 15.8$ billion in 2008, a compounded annual growth rate of 3% [5]. The typical mean investment for an ERP implementation

in Small and Medium Enterprises could be close to a million dollar or more, depending on the ERP implementation effort based on Galy (2014) view [6] which should be duplicated now. According to Angela (2021) [7], at least 50% of companies will get ERP system and ERP market will exceed 49.5 billion dollar by end of 2024.

ERP systems have been widely employed by enterprises in developed regions, as per Hatamizadeh and Aliyev [8]. In order to successfully adopt ERP systems, regions like Asia and the Middle East need to have a deeper awareness of the crucial elements that contribute to ERP success. In the context of regions other than industrialized regions, Zaglago et al. [9] claim that elements that affect ERP success have not been well examined.

Although several firms declared success with ERP system implementation, Iskanius [10] predicted that up to 70% of ERP system implementations fail. Top management has realized that establishing ERP success is a very complicated endeavor, given the high failure rate. If we calculate the amount spent on failed attempts, we may estimate that at least $15 million has been wasted, without including labor costs and lost business chances (770 economic units multiplied by a minimum dollar spend of $50,000 each try multiplied by a 40% failure rate). The significance of a proper selection procedure in this case may be obvious.

Accordingly, in this paper, to select the best ERP software that meets customer requirements, we present a new approach from “Best Worst Method” and “k-nearest neighbors” algorithm. The main contributions of this paper are summarized in the following points:

- Constructing expert-based annotated datasets for all ERP software’s.
- Testing previous approaches for selecting ERP software.
- Developing a new approach based on compilation of BWM and K-NN.
- Testing and validating the performance of the proposed approach and comparing it to previous approaches.

The remaining of this paper is organized as follows. Section II presents relevant literature about ERP selection process. standard algorithm of multicriteria decision making method for classification (BWM) and machine Learning algorithm (K-NN) both are explained in section III. proposed selection flow based on combination of (BWM and K-NN) and gives out a new evaluation system for ERP selection are described in sections IV. Section V presents and discusses the obtained experimental results. Conclusions and future work are introduced in section VI.

2. LITERATURE REVIEW

A variety of fields have used the multi-criteria decision-making paradigm to support decision-making [11-16]. Select best ERP system can be solved using multi-criteria decision-making model.

Razmi [17] offered a hybrid multi-criteria methodology that assessed five factors in two waves. the initial evaluation using TOPSIS, or Technique for Order Preference by Similarity to Ideal Solution. The second one with PROMETHEE. successfully found the best ERP system between many alternatives. While Llal [18] suggested a data envelopment analysis "DES" method that compares and measures the relative efficiency of decision-making units using linear programming. Meets business needs and vendor qualities are the two sets of criteria used in this evaluation approach. A 100% efficient ERP solution is considered efficient; inefficient alternatives fall into another category.

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Just the same but with different algorithm Karaarslan [19] suggested the Analytic Hierarchy Process (AHP), which defined the problem's hierarchical structure and created a pairwise comparison matrix to calculate the weight of each element individually and collectively. They selected the program that best suited their demands from a pair of pre-chosen candidate systems. The last system option was developed to support a factory that planned to implement ERP software that met its needs and features. Also Kahraman [20] suggested same algorithm but with a fuzzy heuristic multi-attribute conjunctive strategy, which first uses fuzzy heuristics to eliminate the worst options and a fuzzy conjunctive method to choose the best option among the options. The technique is based on the analytical hierarchy process (AHP) under fuzziness. Decision-makers can communicate their assessments verbally or through clear or fuzzy figures. Market leadership, functionality, quality, price, speed of implementation, interface with other systems, and international focus were the seven primary criteria that were used.

On the other hand Ayag [21] tried another complex way he suggested using a Fuzzy Analytic Network Process (ANP) to analyze ERP software solutions by taking into account both quantitative and qualitative factors. Fuzzy logic was incorporated since the traditional ANP's pairwise comparison using a nine-point scale can be either vague or insufficient to accurately represent decision makers' correct decisions. The resulting fuzzy ANP improves on the capabilities of the traditional ANP in handling vague and imprecise human comparison judgments. Also Harun and Semra [22] proposed a model that combines an ANN and an ANP combination. Initially, the ERP selection problem is represented by an ANP. Each factor's weighted values as well as the ERP software's priority values are determined. Next, the values from the previous ANP model are employed in the training step of an ANN model. They used thirteen criteria to make ANP tables. Contrariwise Ya-Yueh [23] evaluates a useful ERP system based on six criteria. On the basis of pair-wise comparisons, the fuzzy AHP approach is used to quantify the associated weights between distinct components. While Gürbüz et al. [24] used employed the MCDM technique to assess several ERP alternatives. In this study, the authors used three models: the Choquet integral (CI), the Analytic Network Process (ANP), and Measuring Attractiveness with a Categorical Based Evaluation Technique (MACBETH).

While Park et al. [25] tried a new approach . they integrated the MCDM paradigm with the Quality of Service (QoS) for SaaS ERP apps with Social Network. According to their alignment with the criteria, the study's findings provide a helpful framework for choosing the best SaaS ERP system.

From another point of view Hinduja and Pandey [26] proposed a hybrid fuzzy MCDM model using the DEMATEL, IF-ANP, and IF-AHP models to help small and mid-size businesses choose a cloud-based ERP system. The suggested fuzzy MCDM model successfully addresses the ERP selection problem, according to the results. Also Kazancoglu and Burmaoglu [27] Used the TODIM approach to choose their ERP software for a steel forming and hot dip galvanizing company. The suggested ERP selection model is applicable to businesses in a variety of sectors, including the manufacturing sector. With similar thinking to his counterparts Jafarnejad et al. [28] Suggested an MCDM model incorporating the DEMATEL approach and fuzzy AHP technique, for addressing the challenge of choosing an ERP system with application to the steel sector. In this work, the Shannon entropy approach was used to pinpoint the most crucial selection criterion for ERPs. While Naveed et al. [29] Adopted the same idea but with a slight change. They take five options and twenty sub-criteria variables in the decision-making process, and suggested the group decision-making (GDM) based AHP model for evaluating and ranking essential success factors of the cloud ERP system. Just the same with slight changes Amirkabiri and Rostamiyan [30] The authors obtain importance and relative weighed criteria using the AHP model. Then, choice options are ranked according to how closely they resemble priority in the best-case scenario using the weighted criteria as inputs. on another view Aya ˘g and Yucekeya [31] used the MCDM model together with a grey relational analysis (GRA) approach based on fuzzy analytic network process (ANP) to analyze the ERP system. In order to reflect the uncertainty and ambiguity of the decision maker(s) facing challenges and arrive at a more trustworthy solution, the authors of this work adopted the fuzzy extension of the ANP method. While Mohd. Raihan Uddi et al. [32] used the AHP-TOPSIS integrated model, which is based on a multi-criteria analysis, to pick the top ERP systems. Also Nguyen Van Thanh [33]used AHP integrated with TOPSIS with some changes as they use the fuzzy logic on each, the new model is used to get best ERP systems for various industries.

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This study of the literature led researchers to the conclusion that MCDM is the best technique for use in complicated scenarios with many criteria and competing aims. Because it may be used by decision-makers to solve a variety of issues, this technology has drawn interest from all industries.

Table 1 below summarizes the different MCDM methods, and their main strengths and weaknesses based on our research for many algorithms that was used on selecting best ERP software with different criteria.

Thus, in this study, we propose a MCDM model for get ERP systems matched with customer requirement, a machine learning technique is used then for predicting best ERP system.

Table 1: MCDM Algorithms strengths and weaknesses.

Method	Strengths	Weaknesses
AHP [19]	excels at describing the significance of qualitative and intangible metrics.	Absence of indications, values, and numerical measures.
ANP[21]	Simplify complex situations, take into consideration both tangible and intangible elements, and give priority to indicators	depending on the judgments of decision-makers and may be biased or risky.
Fuzzy AHP + TOPSIS [33]	Values are components that are both objective and subjective. Alternatives are ranked according to how far apart ideal conditions are from one another. considers hazy or ambiguous elements.	disregards judgment checks and weight elicitation.
TOPSIS[19]	Very simple on implement and can be integrated with many other algorithms	Weakness on weight elicitation.
DEMATEL[26]	The decision-making problem is efficiently analyzed with respect to the mutual influences (direct and indirect effects) among various components, and the complex cause and effect linkages are comprehended.	The decision-making issue does not take into account any additional criteria instead, it ranks the alternatives according to how reliant they are on one another.
TOPSIS +PROMETHEE[17]	a scalar score based on ranking completeness that simultaneously takes into account the top and worst options	does not offer the opportunity for weight elicitation, nor does it offer consistency checking for judgments. When there are several criteria (more than seven), it might be quite challenging for the decision-maker to understand the issue and assess the outcomes.

3. BWM AND KNN METHODOLOGY

3.1 BWM Method

An MCDM problem consists of a number of alternatives ($a_1, a_2, a_3, \dots, a_m$), a number of criteria ($c_1, c_2, c_3, \dots, c_n$), and a score for each alternative in relation to each criterion ($p_{11}, p_{12}, p_{13}, \dots, p_{mn}$). Therefore, MCDM issue can be represented as the following matrix:

$$A = \begin{array}{c} \\ a_1 \\ a_2 \\ \dots \\ a_m \end{array} \begin{array}{c} \begin{array}{cccc} c_1 & c_2 & \dots & c_n \end{array} \\ \begin{pmatrix} p_{11} & p_{12} & \dots & p_{1n} \\ p_{21} & p_{22} & & p_{2n} \\ \vdots & & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{pmatrix} \end{array} \quad (1)$$

Finding best alternative with the best overall score is the major goal of a MCDM problem (V_i).The simplest technique to determine the overall score for each alternative is to apply an additive weighted value function, as in the formula below (Keeney & Raiffa, 1993)[34].

$$v_i = \sum_{i=1}^{n} w_j p_{ij} \quad (2)$$

The best-worst method (BWM) (Rezaei, 2015) [35] is used to calculate the weights assigned to each criterion(w_j). The overall score may be simply obtained as we have the scores for each choice in relation to each criterion (p_{ij}). To calculate the vector w = {w_1, w_2, w_3,… , w_n} using BWM, we must keep track of the subsequent stages (Rezaei, 2015)[35].

Step 1: Establish a set of criteria. The decision-maker should develop a set of criteria ({c_1, c_2, c_3,…, c_n}) that will be used to choose amongst alternatives in this step.

Step 2: Establish the best and worst criterion. We now ask the decision-maker to rank the criteria in terms of priority, choosing the best and worst options.

Step 3: Establish the best criterion's preferences over the other criteria. This stage involves choosing a vector known as Best-to-Other (BO), which looks like this:

$$A_B = (a_{B1}, a_{B2}, a_{B3}, \ldots, a_{Bn}) \quad (3)$$

Where a_{Bj} is the preference of the best criteria *B* over the criterion *j* and its value is an integer number in the range of 1 to 9. Keep in mind that $a_{BB} = 1$.

Step 4: Determine how much each criterion (*j*) values the worst criterion W.The decision-maker chooses a vector called Other-to-Worst (OW) in this step, which is comparable to the vectors below:

$$A_W = (a_{1W}, a_{2W}, a_{3W}, \ldots, a_{nw})^T, \quad (4)$$

where a_{jW} is an integer value between 1 and 9 that represents the preference of criterion *j* over the worst criterion W. Be aware that $a_{WW} = 1$.

Step 5: Look for the best answer. This stage involves determining the best weights for the criteria (vector W). To do this, we must identify a solution that minimizes the largest discrepancies between the decision-maker's judgment and the weights that were collected. a_{jw} (a_{Bj})stands for the choice of criterion j over criterion W (criterion B over criterion j) This is based on DM's opinion.

The preference for each criterion is actually determined when we find its weight, thus we may say that w_j = preference j. With preference j / preference W = w_j/w_w (preference B preference j = w_B/w_j).

The goal of BWM is to identify the vector of weights that minimizes the absolute gaps $|w_j/w_B — a_{jw}|$ and $|w_B/w_j — a_{Bj}|$ for each j. A mini-max formulation is offered, followed by the creation of a linear model, to achieve this objective. (Rezaei, 2016)[36].

The final linear model of BWM that we have is as follows:

$$\min \xi^L$$

s.t.

$$\left|w_B - a_{Bj} w_j\right| \le \xi^L, \textit{for all } j \quad (5)$$

$$\left|w_j - a_{jw} w_w\right| \le \xi^L, \textit{for all } j$$

$$\sum_{j=1}^{n} w_j = 1$$

$$w_j \ge 0, \textit{for all } j$$

By resolving the issue (5), we will be able to determine the ideal weights (W*) and ξ^{L*}. We can look at ξ^{L*} as a sign of the comparability of the comparisons. Higher consistency is represented by lower values of ξ^{L*}.

3.2 K-NN Method

The KNN algorithm, like Artificial Neural Networks (ANN) and Support Vector Machines (SVM), is a reliable and versatile classifier that is utilized for the majority of classification problems. Despite being straightforward, KNN can outperform more effective classifiers and is utilized in a variety of applications, including genomics, data compression, and economic analysis [37]. KNN is a member of the supervised learning algorithmic family and is widely used in pattern recognition and data mining.

Supervised learning is a sort of machine learning in which the provided data consists of a few features and labels, with each input corresponding to a certain output. This is how supervised learning functions mathematically: Given a collection of N data items with the form {(x_1, y_1),..., (x_N, y_N)} with x_i and y_i are, respectively, the feature vector and the target of the i-th data point. Learning is done to understand the relationship between the feature vector and the target. The function is given as h:xy such that, given an unknown observation x, h(x) can accurately predict the corresponding output y.

In the supervised learning strategy, the objective is to learn mapping from inputs x to outputs y from a labeled input-output pair. Working methodology for supervised learning is shown in **Figure 1**.

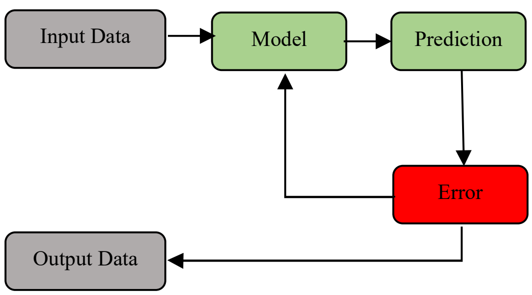

Figure 1: Supervised Learning models

The pattern shown above is commonly followed by all supervised learning models, the task is where they diverge the most. Accordingly, we can categorize machine learning algorithms into a group of similarities. First, where the function is the same, for instance, one example is the tree-based methods and neural networks. Additionally, we have the regression algorithms, The technique in this scenario is to create a relationship between the variables that is then iteratively modified using a measure of the inaccuracy in the model's predictions. The most popular regression algorithms are logistic regression and linear regression. The KNN algorithm falls into the third category of instance-based algorithms, which are algorithms that employ the training data that the model determines to be significant to forecast the new samples.

Non-parametric, instance-based learning algorithms are preferred when all the characteristics are continuous, such as the KNN classifier. Because it is non-parametric, it does not make any explicit assumptions about the characteristics of the sample, avoiding the dangers of changing the underlying data distribution. Assume, for instance, that while our data is largely non-Gaussian, the learning model we choose has a Gaussian appearance. By using learning based on instance, our technique avoids explicitly learning a model. Instead, it favors memorizing the training examples that are used as "information" during the prediction process. In more concrete terms, when a query is performed to our database, the algorithm will only spit out the response using the training examples. Numerous applications, such as dynamic web mining for a big repository, are prohibited by the algorithm, which employs a slow learning technique [38].

The method is set up so that it identifies the nearest neighbors by selecting a value at random, but the most crucial thing is to figure out how to determine how far apart two data points are from one another. It is then placed in the most popular class of its closest K neighbors. If K = 1, the case belongs to the class of its nearest neighbor in distance functions. The three most popular formulas for determining the separation between two points are as follows: three distances: the Minkowski, the Manhattan, and the Euclidian distances.

Euclidian distance is the separation of two points. It is the length of a line segment between them, and for points in k-dimensional Euclidian space with Cartesian coordinates, the distance is:

$$\text{Euclidean} = \sqrt{\sum_{i=1}^{k}(X_i - Y_i)^2} \qquad (1)$$

Manhattan distance: The Manhattan distance is the one-norm of the distance between two vectors (city blocks), we are interested in the abs value in this distance.

$$\text{Manhattan} = \sum_{i=1}^{k}|X_i - Y_i| \qquad (2)$$

The Euclidian distance and the Manhattan distance are both regarded to be generalized by the normed vector space, or Minkowski distance. The following is a detailed explanation of how KNN algorithm works in classification:

i. Load training data set.
ii. Set initial value of k.
iii. Measure the distance between the new instance and each of the training data set's instances.
iv. Select only the top k (lowest) distances and their class labels after sorting the distances list in ascending order.
v. The most frequent class of the top k picked examples will be the class of the new instance.

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4. PROPOSED MODEL

In this study, based on our experiences, literature research, software reports and 30 expertise from ERP software partners of (Oracle, SAP, Odoo) that there are 20 criteria which all agreed on it that it affects the process of making ERP software suitable or not for any customer. Those 20 criteria are splitted into 2 groups.

1 Criteria used to filter in preprocessing phase to minimize the size of data which is [Business Sectors, Industry, ERP software Features, Customer suitability, Additional product info, Mobile capabilities, System hosting, Training services, Support services, Support locations].
2 Criteria used to predict optimal ERP [License Cost, reliability, efficiency, ease of customization, ease of implementation, security, user friendly, functionality, easy of data migration, integration of legacy Systems].

The database of the proposed model consists of 2 files:

a- File contains 207 columns for different ERP software and 81 rows for the criteria.81 rows can be grouped to 10 main criteria [Business Sectors, Industry, ERP software Features, Customer suitability, Additional product info, Mobile capabilities, System hosting, Training services, Support services, Support locations].
b- File contains 6418 rows and 11 columns. 10 columns for criteria and 1 column for the name of ERP software. Those 6418 rows represent 207 ERP software, each alternative is repeated 31 times. All the criteria software; from 1 to 9 as proposed by (Satty and shown) at **Table 2**.

Table 2: Scale of relative importance (Adapted from Saaty (1980)).

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Essential or strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate value between adjacent scale values

Data collected based on 31 consultants from 3 different ERP partner:

- Arete Consulting: SAP Partner.
- Mashreq Arabia : Oracle Partner.
- New Tech Software : Odoo Partner.

The proposed model consists of integration of BWM and KNN. At first the customer entered his requirements to filter ERP alternatives that didn't match customer requirements. Then based on remains ERP alternatives BWM used to get the weights of each criterion. Then, calculated weights from BWM are used on KNN to get the best alternative.

The following steps make up the general approach of this study:

- Customer Requirements: A set of criteria which are essential for an ERP implementation is first chosen by the customer. 20 criteria grouped into two groups as mentioned below in figure 2. In the first criteria group customer chose the required criteria from the list. In second group customer entered the priority of each criteria from 1 to 9 where 1 is the lowest priority and 9 is the highest.

- Preprocessing step: In this step ERP dataset is filtered based on data entered in the first criteria group to minimize the size of data.
- Application of BWM: Each of the criteria listed in the second criteria group be ranked and weighted separately.

- Application of KNN: The final step is to apply KNN to rank the candidate systems, which will aid decision-makers in selecting the best candidate.

5. RESULTS AND DISCUSSION

As you can see in (Table 3) the proposed model of BWM and KNN combination get the best accuracy in prediction of ERP.

We used "Euclidean" metric and the testing result is "1.15e-28". The test results demonstrate that the trained network can predict priority values with the greatest degree of accuracy.

80% of the database file is used for training and 20% is used for testing. The performance calculated based on the right prediction through 1000 various iterations.

Table 3: ERP selection results

Approach	Accuracy	F-measure
AHP with TOPSIS	Ranges between46.09% to 71.52%	0.45

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ANP with ANN	Ranges between 56.31 to 93.46%	0.65
FAHP with FTOPSIS	Ranges between 66.08 to 87.23%	0.69
AHP with SVM	Ranges between 72.02 to 91.17%	0.72
Saw	Ranges between 55.37 to 82.12%	0.58

IDOCRIW	Ranges between 74.46 to 88.61%	0.69
VIKOR	Ranges between 59.71 to 79.87%	0.57
BWM with KNN	Ranges between 84.06 to 98.20%	0.88
DEMATEL	Ranges between 73.35 to 81.50%	0.60

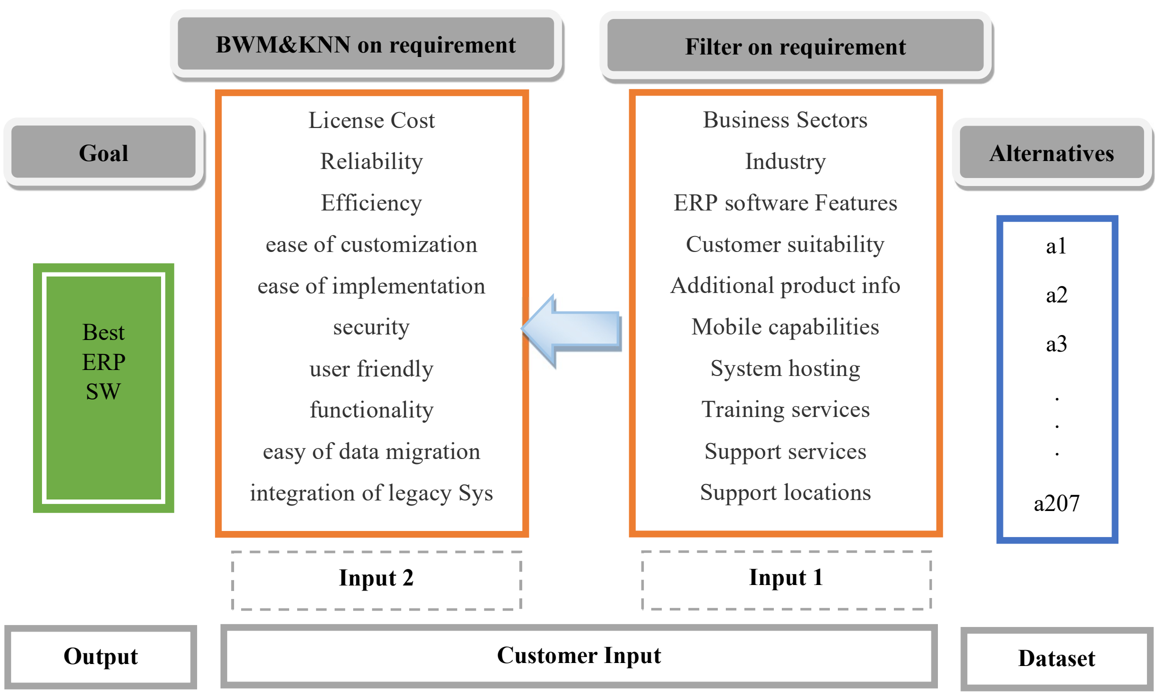

Figure 2: Hierarchical model structure

6. CONCLUSION

Successful implementation of an ERP project depends on choosing an appropriate ERP system. The paper introduces a new model for choosing an ERP that is based on BWM integrated with KNN.A set of criteria for judging ERP software has been taken into consideration, based on the advice of experts and literature. Following is a list of the main conclusions of this research:

- The decision-making model is used to assess and choose appropriate ERP software to be utilized in any industry.
- This is the first study to use a methodology that incorporates data from real life situations where a proper ERP deployment was required but was ambiguous due to a wide range of ERP vendors on the market.

As shown from results of testing and the previous approaches proposed model have the best performance.

Future studies may look towards using machine learning in conjunction with fuzzy multicriteria decision making (FMCDM).

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