Ranking the Multiple Intelligences of People with Epilepsy Using Analytical Hierarchy Process and Data Envelopment Analysis

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Abstract—**A person intelligence can be enhanced when he or she focuses and practices regularly. This paper aims to introduce an integrated Analytic Hierarchy Process and Data Envelopment Analysis (AHP-DEA) method for ranking the intelligence parameters of People with Epilepsy (PWE). In order to develop the ranking process, investigation of the effects of the patients' demographic aspects and the illness background on the intelligence parameters is essential. The proposed method is to rank the suggested intelligences that need to be improved which were obtained from ATIE©, a psychometric test based on the Howard Gardner's Multiple Intelligence (MI). The result from this study is very important to improve the chances of PWE to be employed.**

Index Terms— **Multiple Intelligence, Data Envelopment Analysis, Analytic Hierarchy Process, People With Epilepsy.**

I. Introduction

Intelligence is defined as a distinct collective ability which can act and react in response to the surrounding environment. The existence of one or more intelligences was a question during last two centuries. Howard Gardner, who is a contemporary psychologist, believes on the multiple intelligences theory in which any person has a combination of several intelligences with different strength. Gardner presented his first Theory of Multiple Intelligence in a book, 'Frames of Mind: The Theory of Multiple Intelligence' [1]. Gardner expressed the intelligence as "ability to solve problems or to create products that are valued within one or more cultured settings" [2, 3]. At the beginning, he introduced musical, kinesthetic, verbal, math/logic, spatial, interpersonal, and intrapersonal as seven elements of intelligence in 1983. Then, he added the "naturalist or nature smart" as the eighth intelligence in 1997. Although he introduced the spiritualist as another element of intelligence, only the first eight intelligences are used in this study.

Epilepsy, which is one of the oldest diseases in history has affected numerous people for several centuries [4, 5]. Epilepsy is not a mental disorder, but it is related very much to the brain. Epilepsy can attack any people in any social position and nothing to do with one's level of intelligence. Various studies have been performed related to the effects, types of epilepsy, and the quality of life of people with epilepsy (PWE). The brain is an extraordinarily complicated organ in the body with unique characteristics. All of the human activities such as movement, thought and emotion, memory and personality, are controlled by the brain. There exist two concepts about the brain related to the epilepsy. The first one emphasizes that the brain works on electricity, and the second one expresses that different activities are controlled by different areas of the brain. In some cases, the electrical activities lead to a pulse greater than expected, which cause a seizure. Based on the International League Against Epilepsy (ILAE) seizures are classified into two generalized and partial seizures [6, 7].

Unfortunately, the PWE lose their self-confidence, sense a large gap between themselves and other people, and leave their normal activities in the society. Therefore,

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employment is one of the most challenging issues for PWE. Based on the studies, PWE show high unemployment rates, underpaid, and cannot keep their jobs because of the stigma, severity of seizure and other psychological deficiencies. However, there are numbers of PWE, who have regular education and have successful careers in various fields.

There is a study that focused on identifying intelligence profiles of people with epilepsy in order to improve the probability of employment. Awang et al. [8] explored the attitudes and perception of human resource personnel toward the epilepsy and unemployment of PWE. She classified PWE's intelligence patterns and characteristics based on a developed intelligence scale namely Ability Test in Epilepsy (ATIE©).

The remainder of this paper is as follows. In the next section, Awang's work is briefly reviewed [8, 9, 10, 11]. Section III introduces the Data Envelopment Analysis (DEA) and Analytic Hierarchy Process (AHP) methods. Section IV proposes a conceptual framework for ranking the multiple intelligences for people with epilepsy. Finally, some conclusions are drawn in section V.

II. Review of ATIE

Ability Test in Epilepsy (ATIE©), a psychometric test, was developed based on the Multiple intelligence (MI) theory proposed by Howard Gardner to measure eight types of intelligence skills [10]. In this test, 5-point Likert scoring system was used in which the score domains from 1-not at all like me to 5-definitely me. The research subjects were needed to respond to items that best describe their views, feeling and opinions towards their mental capacity or level of intelligence. Based on the test scores, they were classified into eight types of intelligence [11]. Based on ATIE©, inverse Ability Test in Epilepsy (i-ATIE) system was designed. This system was developed based on Fuzzy Inverse ATIE (FIA) algorithm. Then, the algorithm was incorporated into a crisp Logistic Regression model in order to get the best intelligence elements which would be obtained to maximize the employment chances of PWE (Fig. 1).

Although i-ATIE can be used solely, it is purposely introduced to be a part of a full-fledged software system. Based on Gardner, the intelligence of a person can be enhanced if the person focuses and practices regularly [1]. In i-ATIE, fuzzy algorithms are applied in order to show how the chances of PWE getting hired could be improved. PWE need to undergo ATIE©, have the result analyzed using the FIA, whereby their intelligences are identified. Based on this diagnosis, the PWE concerned could then embark on specific remedial actions to overcome their weaknesses and improve their chances of being hired. The FIA can successfully determine the best parameters of the eight intelligence elements and may enhanced the employment probability of PWE.

i-ATIE can be used in order: (1) to identify multiple intelligences in PWE (2) to evaluate multiple intelligences parameter of PWE quantitatively (3) to introduce the most suitable parameters of the eight

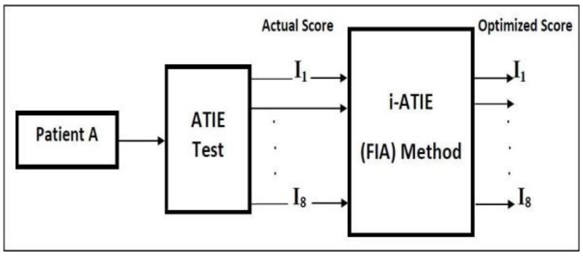

Figure1. The Awang's study framework

intelligence skills for the purpose of employability. Furthermore, i-ATIE can determine the amount of intelligence of PWE quantitatively based on Howard Gardner's Multiple Intelligence. With this, it is now possible to recommend the skills of PWE which must be improved, thereby increasing their chances of securing suitable employment.

III. Review of AHP and DEA

Data Envelopment Analysis (DEA) gives a systematic methodology to analyze productive efficiency [12]. In the relatively short span of 25 years, DEA has established itself as a popular analytical research instrument and practical decision support tool. An increasing number of applications is an evidence of its popularity among researchers in Economics, Econometrics and Operations Research, Management Science, as well as practitioners in the business community and government institutions.

DEA is a nonparametric method which measures the efficiency of Decision Making Units (DMUs) with common input and output terms [12]. The DEA model formulated by these scholars was called the CCR model. In 1984, the model was further improved by Banker et al. [13] and named it as BCC model. The basic DEA models divide DMUs into efficient and inefficient categories.

The original CCR model which was introduced by Charnes et al. in 1978 [12] evaluates the relative efficiency of DMU_o from a set of DMU_j (j=1,...,n) with x_i $(i=1,...,m)$ and y_r $(r=1,...,s)$ as input and output vectors. The input oriented CCR model for assessing the relative efficiency of DMU_o with the infinitesimal ε is shown as follows:

$$\begin{aligned} & Min\ \ \theta-\varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\ & s.t.\ \ \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{io},\ \ i=1,\ldots,m, \\ & \qquad \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{ro},\ \ r=1,\ldots,s, \\ & \qquad \lambda_j, s_i^-, s_r^+ \ge 0,\ \ \ j=1,\ldots,n,\ i=1,\ldots,m,\ r=1,\ldots,s. \end{aligned} \tag{1}$$

Where θ represents efficiency score and s_i^- and s_r^+ are input and output slacks. The dual version of model (1) is as follows:

$$
\begin{aligned}
& Max \quad \sum_{r=1}^{s} u_r y_{ro} \\
& s.t. \quad \sum_{i=1}^{m} v_i x_{io} = 1, \\
& \qquad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0, \ \ j = 1, \ldots, n, \\
& \qquad u_r \ge \varepsilon \ge 0, \qquad r = 1, \ldots, s, \\
& \qquad v_i \ge \varepsilon \ge 0, \qquad i = 1, \ldots, m.
\end{aligned} \tag{2}
$$

Definition [12]: A DMU_o is CCR-Pareto-efficient if and only if it satisfies the following two conditions:

$$(i)\ \theta^*_{CCR} = 1,$$

$$(ii)\ s_i^{-*} = 0, \forall i \in \{1, \ldots, m\} \ and \ s_r^{+*} = 0, \forall r \in \{1, \ldots, s\}$$

Banker et al. in 1984 [13] developed the BCC model to estimate the pure technical efficiency of decision making units with reference to the efficient by adding the below constraint to model (1) namely:

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

The input oriented BCC model for assessing the relative efficiency of DMU_o in variable return to scale case is shown as follows:

$$
\begin{aligned}
& Min \quad \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right) \\
& s.t. \quad \sum_{j=1}^{n} \lambda_j x_{ij} \le \theta x_{io}, \ \ i = 1, \ldots, m, \\
& \qquad \sum_{j=1}^{n} \lambda_j y_{rj} \ge y_{ro}, \ \ r = 1, \ldots, s, \\
& \qquad \sum_{j=1}^{n} \lambda_j = 1, \\
& \qquad \lambda_j, s_i^-, s_r^+ \ge 0, \quad j = 1, \ldots, n, i = 1, \ldots, m, r = 1, \ldots, s.
\end{aligned} \tag{3}
$$

In basic DEA methods, all the input and output data are considered to be quantitative, with numerical values. In reality, there are issues where the data are introduced by qualitative factors, which only have ordinal relations, without any exact numerical values.

There exist different mathematical methods for evaluating the systems with qualitative and quantitative data in the literature, such as analytic hierarchy process (AHP) [14], fuzzy AHP [15, 16], fuzzy goal programming [17], fuzzy analytic network process (ANP) [18], and Multi Criteria Decision Making (MCDM). By using these methods, both qualitative and quantitative factors can be considered in order to evaluate the systems.

Since making the right decision at the right time can play a vital role in the personal and social life of individuals, the need for a powerful technique to assist in this field is extremely felt. One of the most effective techniques is the AHP. This method mimics the human's brain process for solving complicated and fuzzy problems which helps to simplify the decision making problems [19]. Based on the literature, there are a significant number of AHP applications for strategic decisions on operations management issues when problems involve both quantitative and qualitative factors. Ho [20] reviewed the applications of the integrated AHPs. Based on his findings, the integration of AHP with other models is more efficient than using the stand-alone AHP. This study can be considered as a reference for decision makers who want to apply the integrated AHP as an efficient evaluation and classification method.

Saaty [21] was the first person who introduced the Analytic Hierarchy Process (AHP) in 1977. He developed AHP in 1980 [22]. AHP has proven to be a very effective decision-analysis and multiple criteria decision making tools in the last decades. Forecasting, selecting the best alternatives, investment decisions, resolving conflicts, resource allocations, and socioeconomic planning issues are different applications of this technique [23, 24]. Decomposition, comparative judgments, and hierarchical composition or synthesis of priorities were introduced as the basic principles of AHP [25]. To demonstrate a decision problem in AHP, the structure in a hierarchical fashion is used in which the ultimate goal is placed at the first level of the hierarchy. The criteria, sub-criteria, and alternatives are located at the next levels of the hierarchy.

The decision maker constructs various comparison matrices at different levels of the hierarchy in order to make comparative judgments. One of these matrices, which is constructed at the upper levels of the hierarchy, includes the weights of criteria considering their influence on or contribution to the ultimate goal. Another matrix, which is also constructed at the upper levels of the hierarchy, includes the weights of sub-criteria with respect to their importance for the criteria. At the lowest level of the hierarchy, each pair of alternatives are compared with respect to each criterion or sub-criterion immediately above and construct the covering criteria matrix.

A pairwise comparison matrix can be shown as follows:

$A =$

	F_1	F_2	$\ldots$	F_n
F_1	a_{11}	a_{12}	$\ldots$	a_{1n}
F_2	a_{21}	a_{22}	$\ldots$	a_{2n}
$\ldots$	$\ldots$	$\ldots$	$\ldots$	$\ldots$
F_n	a_{n1}	a_{n2}	$\ldots$	a_{nn}

Where F_i's are factors which can be either criteria or alternatives, whose weights will be determined,

$$a_{ij} = \frac{w_i}{w_j}, \quad for\, all \ \ i, j.$$

In which $w = (w_1, w_2, \ldots, w_n)^T$ is a vector which shows the underlying weight for the *(n)* factors. Each entry *aij* of ***A*** determines that, "between the two factors F_i and F_j which of them is more important and what is the level of this importance?" [26].

Saaty also introduced the nine-point scale standard comparison judgments [27].

Some researchers indicated that the selection of this nine-point scale depends on the person and the decision problem [28, 29].

Several methods have been suggested in the literature for synthesizing the set of pairwise comparisons to obtain the weight vector, $w=(w_1,w_2,\ldots,w_n)^T$. The Least-Squares Method (LSM) [30, 31], Logarithmic Least Squares Method (LLSM) [32, 33], and the Eigenvector Method (EM) [21, 34] are the most known proposed methods in the literature.

Saaty has proposed the eigenvector method (EM) which is one of the most famous and proper methods for finding out the weights from pairwise comparison matrices [35]. With respect to the special construction of a square reciprocal matrix, the eigenvectors can be found, and the largest eigenvector can be normalized to perform a vector of relative weights [36].

Considering the definition of $a_{ij}=w_i/w_j$ and $a_{ij}=1/a_{ji}$, it can be stated:

$$a_{ij}.a_{ji}=a_{ij}.\frac{1}{a_{ij}}=a_{ij}.\frac{1}{w_i/w_j}=a_{ij}.\frac{w_j}{w_i}=1 \quad (4)$$

In a consistent case, then:

$$\sum_{j=1}^{n}a_{ij}\frac{w_i}{w_j}=n,\quad i=1,\ldots,n \quad (5)$$

In other words, multiplying equation (5) by w_i:

$$\sum_{j=1}^{n}a_{ij}w_j=nw_i,\quad i=1,\ldots,n \quad (6)$$

The above statements can be shown in the matrix notation as follows:

$$Aw=nw \quad (7)$$

Here, *(n)* is the order of the matrix which is equal to the number of factors that has been compared. Therefore, the weight vector *(w)* can be recovered from (7), provided $(\boldsymbol{A}-nI)w=0$ has a non-trivial solution, i.e., $det(\boldsymbol{A}-nI)=0$, i.e., *(n)* is the eigenvalue of ***A***. In the present case, trace of $\boldsymbol{A}=n$. Hence *w* can be obtained by solving the eigenvalue problem (7).

The cardinal consistency relation is defined as follows:

$$a_{ij}=(\frac{w_i}{w_k})(\frac{w_k}{w_j})=a_{ik}a_{kj} \quad (8)$$

In case that all the arrays of ***A*** satisfy the equation (8), the matrix ***A*** is a consistent matrix, otherwise it is inconsistent.

In the inconsistent case, equation (7) changes to:

$$Aw=\lambda_{\max}w \quad (9)$$

Where λ_{max} demonstrates the largest eigenvalue of ***A***. In order to achieve the weights, at first the largest eigenvalue, $\lambda_{\max}$ of ***A*,** is determined. Then, solving the following system of linear simultaneous equations determines the weights w_i's:

$$w_i=\frac{1}{\lambda_{\max}}\sum_{j=1}^{n}a_{ij}w_j,\quad i=1,2,\ldots,n \quad (10)$$

For uniqueness, the set of weights is normalized such that

$$\sum_{i=1}^{n}w_i=1$$

Based on Saaty [21], in case that $\boldsymbol{A}=(a_{ij})$ is an $n\times n$ matrix of the positive coefficients with $a_{ji}=1/a_{ij}$, then ***A*** is consistent if $\lambda_{\max}=n$.

In AHP, the deviations from both ordinal and cardinal consistency to a certain extent are allowed. For ordinal consistency, in case that *x* is more important than *y* and *y* is more important than *z*, then *x* must be more important than *z*. For cardinal consistency, a stronger condition must be satisfied. In case that the importance of *x* is 2 times greater than the importance of *y*, and *y* is 3 times more important than *z*, then the importance of *x* must be 6 times greater than *z*. When ***A*** is cardinally consistent, then $a_{ij}=a_{ik}.\,a_{kj}$. When $a_{ik}.\,a_{kj}\neq a_{ij}$ then ***A*** is called cardinally inconsistent. AHP has been introduced to address the inconsistency in both cardinal and ordinal case.

To address the inconsistency, researchers have proposed various methods. For example, the following consistency index (C.I) was suggested by Saaty [21]:

$$C.I=\frac{\lambda_{\max}-n}{n-1} \quad (11)$$

In which, *n* is the number of compared elements and $\lambda_{\max}$ is the largest eigenvalue of ***A***. In case that ***A*** is cardinally consistent, then $\lambda_{\max}$ has its minimum value, which is equal to *n*. By this value of $\lambda_{\max}$, the C.I is equal to zero. When inconsistency increases, $\lambda_{\max}$ increases, and a larger value of C.I will be produced. This consistency index can also be shown as a consistency ratio:

$$C.R=\frac{C.I}{C.I_R} \quad (12)$$

In which, $C.I_R$ is defined as the consistency index for a random square matrix with the same order. Also Saaty has introduced a threshold less than or equal to 0.1 for C.R [22], but the choice is voluntary. After completion of a pairwise comparison matrix, C.R must be checked. In case that the C.R exceeds the introduced threshold value, the decision maker must reconsider the comparisons until the acceptable value of C.R is achieved.

After computing the alternatives local weights from comparison matrices, the last step of AHP is to synthesize these sets of weights in order to get a global set of weights. The ultimate weights of any alternative are obtained by the products of its local weights with associated attribute weight of the alternative across each branch of the hierarchy.

Based on Saaty [37], the theoretical basis of AHP is found based on a set of basic axioms. This set of axioms is explained in detail by Harker and Vargas [23].

IV. PROBLEM STATEMENT

The problem in this study is to rank the intelligence parameters which need to be improved based on the demographic aspects and the illness background of the PWE such as educational level, age, employability status, onset age, gender, seizure type, ethnicity, and marriage status (Fig. 2). As already mentioned, in Awang's work, she characterized several intelligence parameters which the PWE could improve without considering the patient capabilities and other specifications which some of them were qualitative and quantitative. So, this is the limitation of the Awang's work. In this study, we want to present a method to rank intelligence parameters which considers all the above aspects and specifications which include qualitative and quantitative criteria. Based on the final ranking results, we can suggest which intelligence parameters need to be improved first. So, there is a need to use a combination of both qualitative and quantitative criteria to rank the eight intelligence parameters. The number of intelligence parameters, that need to be improved is different from one patient to another. The goal of this work is to prioritize the best intelligence parameters that need to be improved based on criteria suggested by Awang [38]. Hereafter, we refer to these qualitative and quantitative factors as the demographic aspects throughout the paper.

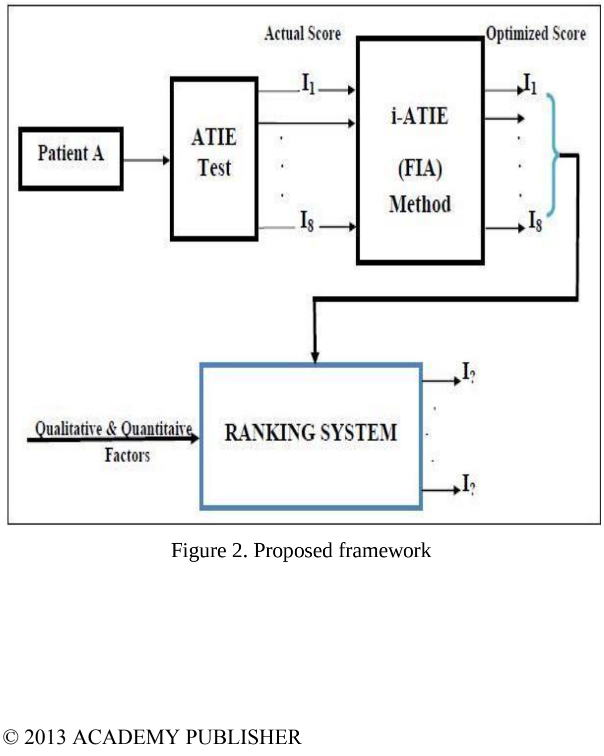

Figure 2. Proposed framework

V. PROPOSED FRAMEWORK

There exist various evaluation methods for jointly evaluating both quantitative and qualitative criteria. Fig. 3 shows the proposed framework for ranking the multiple intelligence parameters. Based on this framework, the ranking will be performed in three different steps.

A. Step 1

Step 1 is to identify the influential demographic aspects such as age, onset age, and educational level on the intelligence parameters (Fig. 4). The process will be done based on AHP with four steps: problem modeling, weights valuation, weights aggregation, and sensitivity analysis.

The hierarchical modeling and verification of consistency is the major assets of this stage. Fig. 4 also shows the hierarchical model for this process. Based on this model, selecting the best intelligence parameter is placed at the first level of the hierarchy as the ultimate goal. The demographic aspects of the PWE are located at the next level of the hierarchy as the criteria. These criteria are age, onset age, educational level, gender, marriage status, seizure type, employment status, and ethnic. Any of these criteria are divided into some categories as sub-criteria. For instance, based on Awang's database, age is classified into four categories which are less than 20, less than 30, less than 40, and above 40. The intelligence parameters are musical, bodily/kinesthetic, math/logic, visual/spatial, verbal/linguistic, interpersonal, intrapersonal, and naturalist intelligences which are placed at the lowest level of the hierarchy as alternatives. As explained in section ш, the decision maker can construct various comparison matrices at different levels of the hierarchy in order to make comparative judgments. The data in Awang's database will be used in order to complete the comparison matrices.

To obtain the weight vector, the set of pairwise comparisons will be synthesized. As mentioned before, there are several methods to synthesize the set of pairwise comparisons. In order to support and verify the results of the AHP model and to explain how the demographic aspects affect the alternatives, the sensitivity analysis will be done. In the sensitivity analysis, the weights of criteria are slightly changed to observe their impact on the results. Expert Choice as the Multi Criteria Decision Making (MCDM) software is used to integrate the insightful graphical user interfaces, automatic calculation of preferences and inconsistencies to perform the sensitivity analysis.

B. Step 2

At this stage the integrated AHP-DEA model is applied in order to derive the most favorable AHP-DEA ranking method for the intelligence parameters.

In order to perform this step, the DMUs must be determined. Then, the inputs and outputs for each DMU will be identified. For example, each patient can be considered as a DMU. The calculated weights for demographic aspects obtained in Step 1, will be considered as the inputs and outputs for each DMU. The output of this step will give the prioritized ranking for the intelligence parameters.

C. Step 3

Finally, Awang's results and the output from Step 2 will be used to determine the final ranking of intelligence parameters for each patient. For example, in Awang's work, she suggested three intelligence parameters need to be improved by patient A. But, she did not rank which intelligence need to be prioritized. Therefore, with the help of this proposed work, we will suggest which intelligence should be improved by giving a specific ranking according to its priority (Fig. 2).

Steps 1 to Step 3 above will lead to a systematic ranking procedure of PWE's intelligence parameters. The procedure will be summarized as a mathematical model. The propose procedure can lead to a new application of the AHP-DEA method, that is, identify the order of intelligence parameters of PWE based on the epileptic patients' demographic aspects. The result will help PWE to have a better understanding of their intelligence, which can improve their chances of being employed.

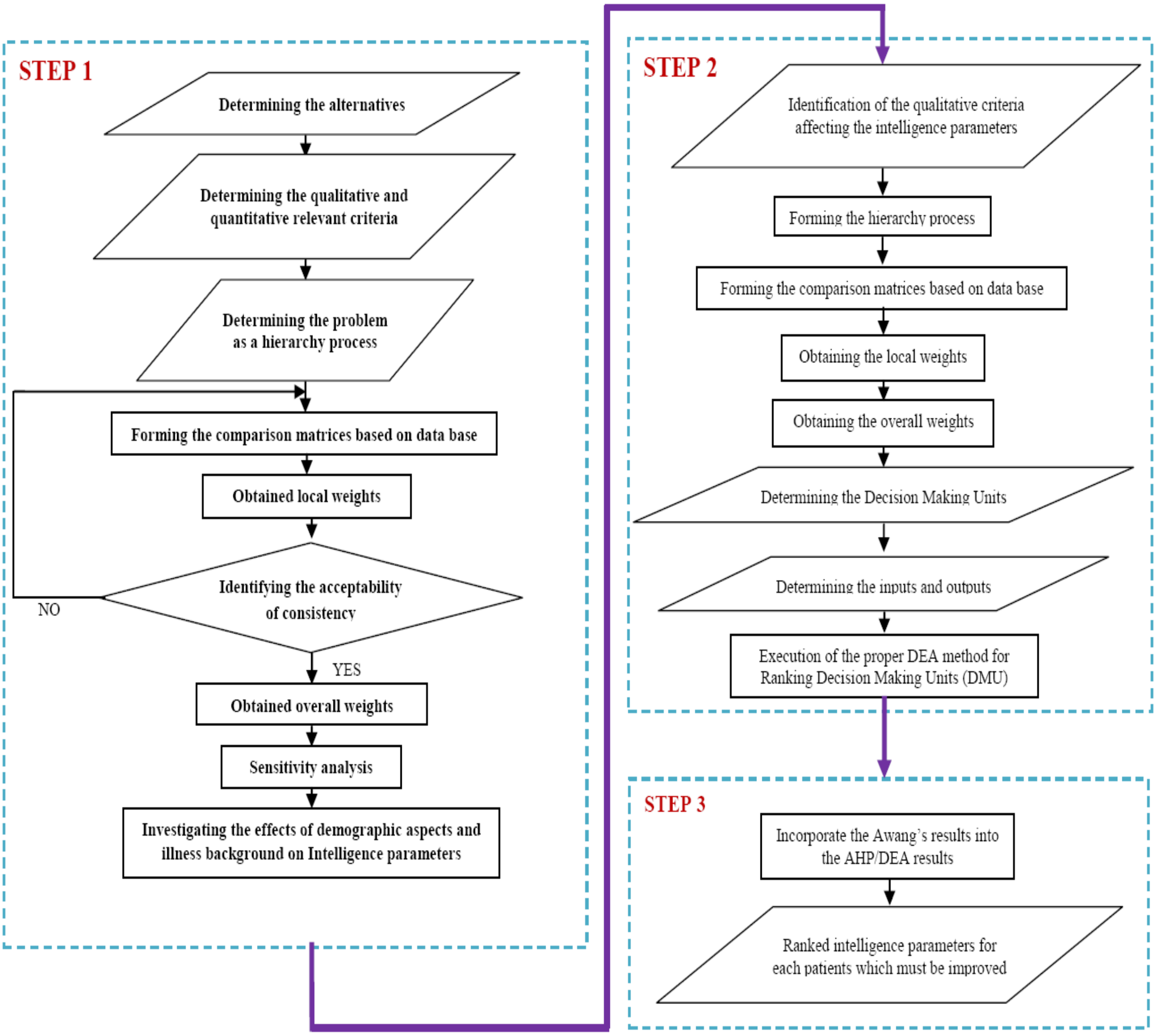

Figure 3. Operational framework

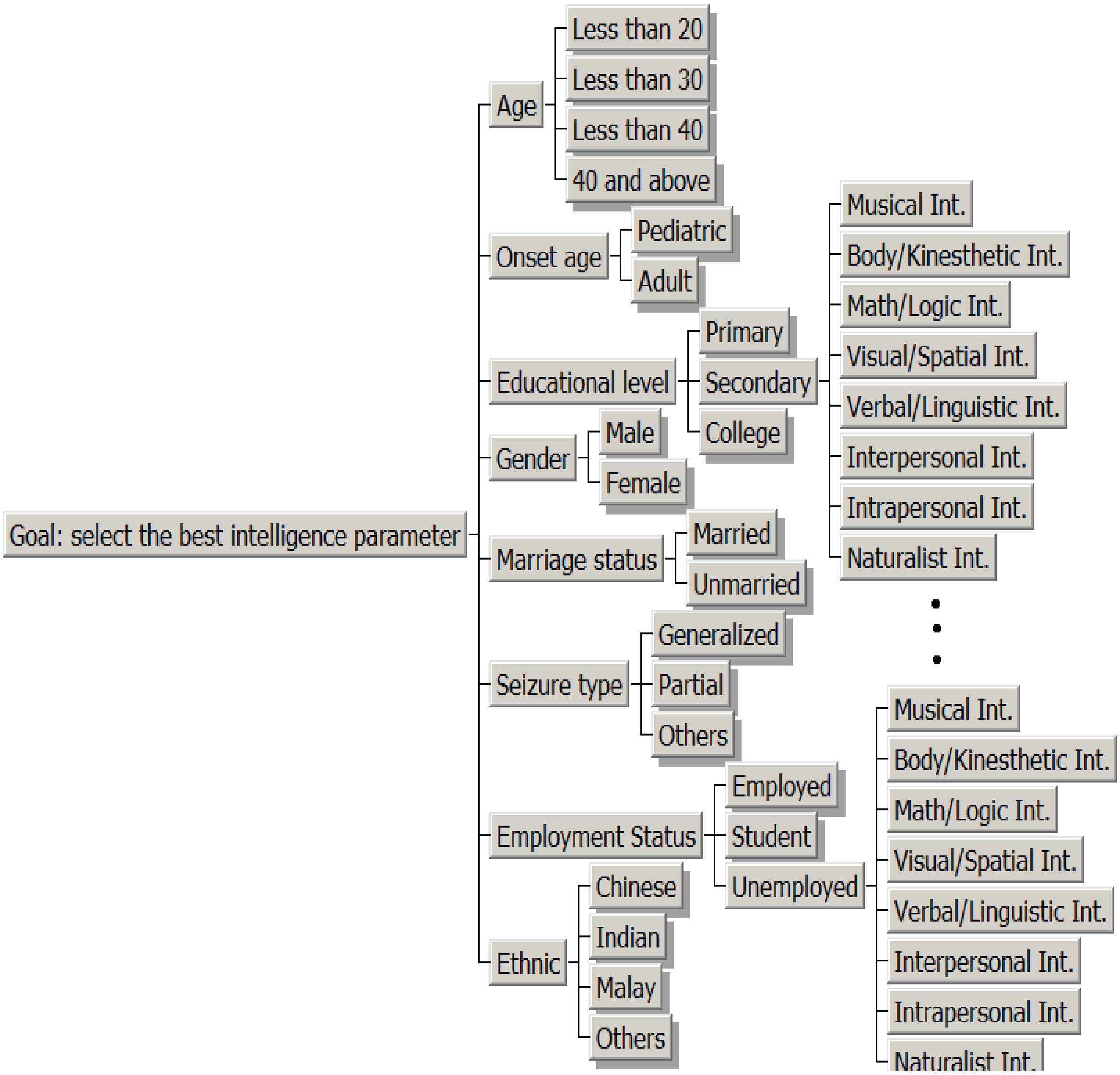

Figure 4. Hierarchical Model

VI. CONCLUSION AND FUTURE WORK

Demographic information such as educational level, age, employability status, onset age, gender, seizure types, ethnic, and marital status of epileptic patients are essential in order to explore PWE's potentials.

Having different background, the intelligence parameters that PWE need to improve are also varies. Therefore, a systematic ranking procedure of PWE's intelligence parameters which need to be improved is needed. In this work, a conceptual framework was proposed to construct an integrated AHP-DEA method for ranking the intelligence parameters of PWE which include both qualitative and quantitative factors. To develop the ranking method, identification of the effects of demographic aspects given the intelligence parameters is essential. To investigate the effects of demographic aspects on the intelligence parameters, AHP is useful for the sensitivity analysis, which can be performed on three aspects: weights, local priorities and comparisons. Sensitivity analysis can show the robustness of the decision made through this method. In the future work, the application of the method discussed in this paper will be performed by using data collected from the epilepsy patients.

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