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A Weighted Euclidean Distance - Statistical Variance Procedure based Approach for Improving the Healthcare Decision Making System in Yemen

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Abstract

Objectives: To present the Weighted Euclidean Distance – SVP based approach to support decision-making processes related to the prioritization problems in the health management with the Yemeni context. **Methods/Statistical Analysis:** The presented approach is applied to the field of healthcare decision making in Yemen. The healthcare ranking problems with the Yemeni context are discussed, some possible applications of MADM technics in the general healthcare sector are illustrated, two of them are conceded as case study examples under both incommensurate and commensurate attributes. Pearson Correlation Coefficient (PCC), the total number of the position's shifts of the alternatives and the overall level of change (CL) in them are used to compare the results obtained by the proposed approach with the other ranking methods. **Findings:** The results show the applicability of the using of proposed approach for dealing with ranking problems under commensurate and incommensurate attributes. It also presents that different variant of ranking approaches leads to different ranking's result. Very high level of numerical correlation coefficients and very small change level in the positions of alternatives are observed between results those determined by the presented approach and those which were obtained by other ranking methods in both cases under study. **Application:** Two ranking problems were considered in this study, many other problems are existed in the Yemeni healthcare sector, and they almost have the same general structure of the solved ranking problem and it is recommended to use the proposed approach to deal with them.

Keywords: Decision Making in Healthcare Health, Euclidian Distance, Healthcare Ranking Problems, Objective Weighting Method, Population Coverage of Health Services

1. Introduction

Health and quality and adequacy of health services are one of the most important things for which the health systems are struggling all over the world, but they face a lot of challenges. One of these is the global political crises which have several divergent effects on them. These effects increase when the health system relates to one of the third world countries. Yemen is one of these countries which has been affecting by these crises. It has become a global area for conflict which led to a war causing an economic crisis in the country. The later has led to reducing the expected functionality level of the health system, lacking the operational budget for its institutions and programs to work, increasing the gap between the population and their health needs, as well

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as lacking to the minimum level of healthcare and creating lots of hygienic problems.

This crisis has also led to many other problems, such as immigrating of lots of good physicians and medical specialists, and destroying several hospitals, health institutions and facilities, which caused the imbalance between the increasing population density and the number of the facilities, health services and resources needed to be achieved according to the minimum requirements of related health standardizes. Evacuated people can't be forgotten in this crisis. The inability to provide them with their needs like shelters, health facilities, doctors, medicines, protection, etc. increase the risk of epidemic and hygienic problems. As a consequent of all these challenges, unless taken into consideration, the socio- economic welfare will not be achieved and the future constant plans of health are going to fail.

Taking into consideration the above mentioned challenges only is not going to make magic solutions or decisions, because the process of taking decisions is a problem itself. It needs to be fixed first to help the health sector stakeholders, decision makers, and health cluster members to make the right decisions. Decisions those help in analyzing data, arranging the rudiments, and evaluating the alternatives. Decisions those guarantee continuity and rational distribution of human and budget resources. So they need an advanced technique that helps them choose their right alternative applying definite procedures. MADM (The multi-attributes decision making) approaches are some of the solution and modern decision making instruments that have been widely and increasingly used to help DMs make their adjudge right. It is considerd as a one of the main components of the medical decision making systems.

It can be used to determine the significance of the surrounding factors that affect the performance of health systems in general, health components such as health facilities and sectors spatially, the relative importance of factors that affect quality, availability and functionality level of resources and services in these facilities, sectors and systems. It may be used to measure and evaluate the real state of local and distributed regional facilities and systems - with attention to the affected factors and theirs relative weights. Also, it helps DMs to determine the performance order (ranking) and prioritization of these facilities and systems by the various decision making measurement models (objectives). The main purpose of this study is to present the Weighted Euclidean Distance – Statistical Variance Procedure (WED – SVP) based on MADM approach to support and improve decision-making processes related to the prioritization (ranking) problems in the field of general health management in general, and in the health management with the Yemeni context spatially.

It aims to help DMs identify the governorates that should be taken into account in the future improvement plans, to decide either the healthy environments meet or doesn't meet the current and future health services requirements of the population, to provide the possible data and recommendations that help them to ensure equitable and optimal distribution of resources, services taking into consideration the circumstances, the economic factors, the limited resources and other factors have been mentioned. Generally, this study is organized in six sections. Section I contains the introduction, Section II contains the review of the previous related works associated with the various MADM approaches, methods and its some applications in healthcare management and the basic theoretical and practical issues related the technics that will be used. Section III describes the methodology of the research, Section IV describes the practical implementation steps, results ranking, comparing issues and discussion for two ranking case study problems. Section V contains conclusions of the research work. The last section contains the references.

2. Background

2.1 MADM Application in Healthcare Management

Provision the high level of value by any health care resource (High quality healthcare) is an important issue[1], because its consequences are relief from suffering[2], improved health status and quality of life in humans[3,4]. Conversely, the consequences of poor quality can be dire. The provision of high-quality, health care services, especially in the light of the circumstances referred to the above, from which Third World countries suffer, is an increasing difficult challenge. Quality in healthcare, as in any other quality areas, can be determined by some measurements.

For instance, assessing the health status of the population, healthcare performance, the quality and availability of provided services, the availability and functionality of the health facilities, sectors and systems and/or its partial components or/and resources. Such management processes in most of the developed countries have a considerable portion in HC management systems and this portion is increasing day by day. The increment is also accepted as a sign of being full-grown and the high quality of the life standards. It has become increasingly significant for various stakeholders, for instance, decision making bodies and health cluster members, because the assessment results are one of the primary inputs of improvement possesses that can help them in planning, monitoring, measuring gaps, determining the weaknesses, and strengths in the performance practices, prioritization the possible initiatives, strategies, policies, and procedures to be taken or developed to fill those gaps[4], prioritization and ordering the needs of health sector, as well as responding to the urgent needs of them[5].

Also, It can be helped ensuring whether something (such as services, human resources, equipment, etc.) adequate enough, and whether it is suitable for its purpose. It also helps DMs to know if the performance of the health system overall in the countries is good and if it is getting better or worse over time, if it is getting better or worse over time. In[6] proposed, points out that objective metrics about HC performance can also assist individuals with their own healthcare decisions. Furthermore, it can provide context for state and national policy discussions about healthcare programs and investments, and point to where and how the system can be improved. Many studies are available, and can be consulted to find out more about the importance of quality measurement in healthcare, such as studies[7–9]. Internationally, many standards, best practices and projects have been developed by accreditation organizations, regulators payers and various healthcare stakeholders to measure specific areas of practice and performance. Their goals, strategies and application scope are very diverse. The most important of these are Performance Assessment Tool for Quality Improvement in Hospitals (PATH); Australian Council on Health care Standards (ACHS); Clinical Indicators Support Team (CIST); Quality improvement Scotland (NHS); International Quality Indicator Project (IQIP); Joint Commission Accreditation of Health Care Organization (JCAHO); The National Indicator Project (NIP); Ontario Hospitals Association (OAH); Organization for Economic Co-operation and Development (OECD).

The international application of these projects had a positive and effective impact on the quality of health. Additionally, In practice, the Health Resources and Services Availability Mapping System (HeRAMS)[10] and the USAID-funded projects[11] are an another international projects those designed specifically to help developing countries to improve their health status, and have been used in Yemen.

HeRAMS is a Survey that is used to collect and summarize information on the health facility status including functionality, damages, available utilities, human resources and services in 16 Yemeni governorates. It has been developed by World Health Organization in 2008. It has been used in several emergency contexts such as; Sudan (2008), Haiti (2009), Pakistan (2010) and Central African Republic (2014), Syria (2014) Yemen (2016)[10]. NHDS, (The National Health and Demographic Survey)[11] is another instrument that can be used in this field. It also applied in Yemen in (2013) aiming at providing data for monitoring the population and health situation in the country, such as information on chronic illness, disability, knowledge and use of family planning methods, awareness and attitudes regarding HIV/AIDS, female genital cutting, and domestic violence[11]. The analyzed instruments, works and other similar works which depend on quantitative, qualitative methods or a combination of them to evaluate priorities based on arithmetic averages and other traditional statistical methods are appealing and helpful in that they relate to some outcomes which decision maker care about. In addition to the above, these techniques are good in dealing with decision-making problems that are solved in clear circumstances (Analyzing of alternatives and ranking them based on some selected attributes using unified scales (units), where the values of each attribute have the same measurement unit (scale) and values of different attributes have the same types of them).

On the contrary, they have also got drawbacks. They doesn't deal with (MADM) problems, which refers to prioritizing, screening, ordering or choosing a set of alternatives usually under independent, incommensurate or conflicting attributes. For instance, they don't deal with the objective aspect of evaluation based on amount of information for each certain, ranks alternatives with the incommensurate or non-similar types of attribute's data using the classical static methods. They give equal priority to the indicators despite different national influences on the evaluation and ranking problems. Hence, there is a growing interest in using of MADM approaches and instruments for healthcare management purposes. The application of these approaches have been increased in many developing countries to measure and choose between alternatives over others. Some Examples of this application in healthcare management are: Application of MULTIMOORA method for selection of health-care waste treatment[12]; Priority Setting for Healthcare Facilities maintenance using AHP[13]; and Strategic analysis of health-care service quality using fuzzy AHP methodology[14], the health-care waste disposal alternatives are evaluated using Fuzzy VIKOR[15], the healthcare centers ranked by integrating FAHP and TOPSIS approaches[16]; Health-Care performance is assessed by integrating VIKOR and TOPSIS approaches[17]. Researchers[18] evaluated the hospital organizational performance using Delphi and fuzzy sensitive analysis-based approaches, the AHP and ANP are applied to determine a weight for SERVQUAL dimension in the hospital service quality measurement study[19]. Researchers[20] combined fuzzy AHP and TOPSIS technique for Strategic Analysis of Electronic Service Quality in Healthcare Industry.

From the reviewed literatures, we can conclude that MADM techniques are getting widely used to deal with the priority and ranking decision making problems under independent, incommensurate attributes, such as approaches play an important role as an effective systematic tools to solve many other decision making problems in established health care management system. It also can be conclude that, the implementation of MADM approaches helps healthcare decision makers to enhance the quality and accuracy of their decision. Accordingly, we have established the utmost importance to take implementation advantages of a one of these techniques, and to represent the applicability of its implementation to solve some of the healthcare decision making ranking problems in Yemen.

2.2 General Form of MADM Problem

The presented above problematic prioritization and ranking's examples and other similar problems can be conceded as a Multi-Attribute Decision Making problem. For (Y) MADM ranking problem, If (A) is a set of alternatives, (C) is a set of attributes (Criteria) according which alternatives should be ranked, (X) is the performance rating matrix, x_{ij} is the i^{th} performance rating with the respect to the i^{th} criterion, and w_j is the weight of i^{th} criterion of X, the (Y) can be concisely expressed in the matrix format as shown (1-4):

$$A = \{a_i | i = 1,2,\ldots\ldots,m\} \tag{1}$$

$$C = \{c_j | j = 1,2,\ldots\ldots,2\} \tag{2}$$

$$W = \{w_1, w_2, \ldots w_n\} \tag{3}$$

$$x = \begin{matrix} x_{11} & \cdots & x_{1n} \\ \vdots & \vdots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{matrix} \tag{4}$$

2.3 Normalization and Standardization Techniques in MADM

Normalization of the variables is one of the main stages of the WED ordering, the normalization process is required to bring the elements of the (X) decision matrix to have a compatible measurement unites. In this study, the normalization process is required to derive the Normalized Decision Matrix (NMD), which can be used for calculating the objective weights of attributes using SVP and for calculating the standardized DM, which considered as a main input to define the positive ideal solutions and negative ideal solutions for the ranking process using ED-SVP approach.

Unitization normalization formula, which is one of the most commonly used normalization forms[21–23], is considered for these purposes in this study. If (X) is a performance decision matrix for Y ranking problem, then the NMD (Z) can be formulated as shown below:

$$z = \begin{matrix} z_{ij} & \cdots & x_{in} \\ \vdots & \vdots & \vdots \\ z_{mj} & \cdots & z_{mn} \end{matrix}$$

where, z_{ij} is the i^{th} observation with the respect to the j^{th} criterion, and is calculated using (5)

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{x_j^{max} - x_j^{min}} \tag{5}$$

where, $\overline{x}_j$ is the mean value of attribute j, x_j^{max} the maximum value of attribute j, while the x_j^{min} is the minimum.

If (Z) is a normalized DM then the standardized decision matrix S is given as follows:

$$s = \begin{matrix} s_{ij} & \cdots & s_{in} \\ \vdots & \vdots & \vdots \\ s_{mj} & \cdots & s_{mn} \end{matrix}$$

where, $s_{ij} = (z_{ij} - \overline{z}_j) / \sigma_j \quad (6)$

where, $\overline{z}_j$ the expected mean value of is attribute j and σ_j is the standard deviation of the attribute j.

2.4 Objective Weighting Technics in MADM

Determining the criteria weights (CWs) - the relative importance of criteria - is one of the main in the rank ordering decision making processes. There are three different methods to determine weights, Equal weights (EW), subjective (SW) and objective (OW). Equal weights (EW) method is a type of weighting that gives the same weight to each criterion.

The equal weight method (EW) requires minimal knowledge about priorities of the criteria and minimal input of decision maker, but it lacks the support of the objective decision information. In the SW method, the criteria weights are usually assigned by the decision makers based on their own knowledge, experiences and perception of the DM problem.

This assignment may be made via a preference elicitation technique such as the Analytic Hierarchy Process AHP and Fuzzy AHP. However the DMs is concerned with the decision process, It usually have different opinion and can seldom cut a deal with the relative importance of criteria.

The inconsistency between expressed attitudes and actual behavior of DMs, is consider as an another difficulty problem associated with this weighting method. The third problem is that such types of weighting are based totally on the DM's preference and they lack the support of the objective decision information. In addition, according to[24], AHP includes a difficult procedure for weighting or evaluating alternatives; limitation on subjective judgments and requires repetitive pairwise comparisons that confuse DMs and bewilder their judgmental abilities.

To overcome such problems, another type of weighting - an objective weighting method - can be used, which is executed independently from the subjective predilections of the decision makers. Shannon Entropy, CRITIC and the Statistical variance procedure (SVP) are some of the most popular and widely used techniques for this purpose. In this study the SVP method will be used to determine the objective weights of attributes.

SVP is an objective weighting methods based on the variance to assign the objective weight to each criterion. This method is suitable for comparing the criteria weights after normalization[24]. So the U normalization method will be used to find the weights by SVP. If (Z) is a normalized decision matrix, and z_{ij} is the ith observation with the respect to the jth criterion, then the weight of jth criterion of Z can be calculated as follows:

$$w_j = \frac{V_j}{\sum_{j=1}^{k} V_j} \tag{7}$$

Where:

$$V_j = \frac{\sum_{i=1}^{m}\left(z_{ij} - \overline{z}_j\right)^2}{m-1} \tag{8}$$

2.5 WEDA as A Ranking Method

The Euclidean distance is an established concept in the field of Mathematics[25]. The proposed WED approach is based on the concept that the chosen alternative (optimum) should have the shortest distance from the ideal solution and longest distance from the anti-ideal solution. In[26], the WED approach is suggested with the same procedures of ranking in this study, but the normalization and objective weighting methods are deferent. The ranking ordering of the WED method is given as follows[26]:

Step 1 - Define and state the problems objectives (O) and Define alternatives (M) and criteria (M) factors for evaluating.

Step 2 - Establish a decision matrix DM – (X) for alternative performance.

Step 3 - Normalize the original decision matrix (X) to obtain the Normalized decision matrix (Z)

Step 4 - Standardize the normalized attribute data using 6.

Step 5 - Determine the positive ideal solution A^* and negative ideal solution A^- from standardized decision matrix as:

$$A^* = \left(s_j^+\right) = \begin{cases} S_{ij}^{max}, j = benefical\ attribute \\ S_{ij}^{min}, j = non-benefical\ attribute \end{cases} \tag{9}$$

$$A^- = \left(s_j^-\right) = \begin{cases} S_{ij}^{min}, j = benefical\ attribute \\ S_{ij}^{max}, j = non-benefical\ attribute \end{cases} \tag{10}$$

Step 6 - Determine the criteria weights.

Step 7 - Measure distances from the ideal and nadir solutions. The two Euclidean distances for each alternative are calculated as:

$$D_j^* = \left[\sum_{i=1}^{m}\left\{w_j \cdot \left(s_{ij} - A_j^*\right)\right\}^2\right]^{0.5}, i = 1,2,\ldots,m \quad (11)$$

$$D_j^- = \left[\sum_{i=1}^{m}\left\{w_j \cdot \left(s_{ij} - A_j^-\right)\right\}^2\right]^{0.5}, i = 1,2,\ldots,m \quad (12)$$

Step 8 - Calculate the relative closeness to the ideal solution. The relative closeness to the ideal solution can be determined by as:

$$RC_j^* = \frac{D_j^-}{D_j^* - D_j^-}, j = 1,2,..,n \quad (13)$$

3. Methodology of Research

To achieve the goal of this study the following stages are implemented:

STAGE 1: Definition of the ranking problem,

STAGE 2: Determination of the normalized and standardized decisions matrixes: This stage consists of the following sub-tasks:

2.1 Constructing the ranking problem model,
2-2 Collecting necessary data,
2-3 Normalizing collected data using (5), and
2-4 Standardizing the obtained normalized decision matrixes using (6).

STAGE 3: Calculating the importance of criteria (Weighting them by SVP method) using (7and 8).

STAGE 4: Ranking Alternatives using WED approach as based on (9-13).

STAGE 5: Analyzing the ordering results:

5-1 Analyzing and discussing the real states of the ranked items.
5-2 Comparing the results obtained with the ED-SVP ranking approach and the results obtained by one of the other ranking methods (suggested TOBSIS method), using the Pearson Correlation Coefficient (PCC) and the change and the total position change level evaluation.

STAGE 6: Concluding the study and giving the appropriate recommendations.

4. Case Study Examples, Results and Discussions

4.1 Ordering under Incommensurate Attributes

STAGE 1: let's define the ranking problem in the first case study example as fellows: the way of ordering the selected number of governorates in Yemen (16 governorates) by the population coverage of the main services provided by its health system using WED-SVP approach based on unitization formula, standardization scoring methods and the SVP weighting objective method.

STAGE 2: Task 2-1: The main structure of the defined problem is constructed as follows:

The top level determines the objective, the next level includes the criteria affecting the decision (the basis on which the alternatives are ranked). Six major criteria are selected for this objective according to the International Health Services and Resources Availability Mapping System[10]. C1: The population coverage per one hospital unit; C2: The population coverage per one health center unit; C3: The population coverage per one health unit; C4: Number of health staff per 10,000 people; C5: Number of beds per 10,000 people and C6: Number of basic emergency obstetric care (BeMOC) per a population of 500,000 people.

Hence, we can state that the recommended number is one hospital per a population of 60,000-150,000 people; one health center per a population of 5,000-20,000 people; 1 health unit per a population of 1,000 to 5,000 people; 22health workers; at least 10 beds or more for every 10,000 people and 4 BeMOCs for every 500,000 people[10].

Task 2-2: The last possible and available version of targeted data is reported in 2016, by the WHO office in Yemen[10]. This dataset are used to construct the performance decision matrix (*X*) of the attributes with *m* number of alternatives (16 governorates) and *n* number of criteria (6). Table 1 represents the DM (*X*) values, collected based on the summarized data of the above mentioned source (report[10]).

Task 2-3: Using formula 5, the decision matrix is normalized as shown in the Table 2.

Task 2-4: This task is considered to obtain the standardized decision matrix (SDM). SDM matrix S was defined using 6. Standard scores are as presented in Table 3.

STAGE 3: In this stage the relative importance of each factor criteria is calculated using SVP by

Table 1. The decision matrix values of 16 governorates

Alternatives	C1	C2	C3	C4	C5	C6
Abyan	71707	30192	5361	27	6.8	10.4
Aden	177630	27755	444074	42.7	14	4.5
Al Amana	345988	55605	622778	20	6.9	2.24
Al Baydha	91684	17890	8529	11.2	2.4	4.6
Al Dhalae	137926	22988	7110	11.8	3.2	5.07
Al Jawf	207626	62288	21479	6	1.6	1.6
Amran	88164	37784	6451	11.7	2.9	7.3
Hajah	187352	57246	8770	10	4.8	8.47
Hodeida	192453	45959	10655	8	2.1	1.5
Ibb	175288	24388	15581	10.7	4.16	7.7
Lahj	64915	44260	5762	21.9	7.45	4
Ma'areb	18291	29930	6331	34	24.7	3.05
Sa'adah	171206	57069	13341	6.3	2.3	3.8
Sana'a	143812	13861	7934	13.1	2	6.05
Shabwah	40662	23459	5398	24.5	12.4	23.2
Taiz	126229	27205	14279	16.1	4.5	38

Source (Final report of Service Availability and Health Facilities Functionality in 16 Governorates[10])

Table 2. The Normalized DM

Alternatives	C1	C2	C3	C4	C5	C5
Abyan	-0.209	-0.122	-0.113	0.267	0.018	0.060
Aden	0.115	-0.173	0.597	0.695	0.330	-0.102
Al Amana	0.628	0.402	0.887	0.077	0.022	-0.164
Al Baydha	-0.148	-0.376	-0.108	-0.163	-0.173	-0.099
Al Dhalae	-0.007	-0.271	-0.110	-0.147	-0.138	-0.086
Al Jawf	0.206	0.540	-0.087	-0.305	-0.207	-0.181
Amran	-0.158	0.034	-0.111	-0.150	-0.151	-0.025
Hajah	0.144	0.436	-0.108	-0.196	-0.069	0.007
Hodeida	0.160	0.203	-0.105	-0.250	-0.186	-0.184
Ibb	0.108	-0.242	-0.097	-0.177	-0.096	-0.014
Lahj	-0.229	0.168	-0.113	0.128	0.046	-0.116
Ma'areb	-0.372	-0.128	-0.112	0.458	0.793	-0.142
Sa'adah	0.095	0.433	-0.100	-0.297	-0.177	-0.121
Sana'a	0.011	-0.460	-0.109	-0.111	-0.190	-0.059
Shabwah	-0.303	-0.261	-0.113	0.199	0.260	0.410
Taiz	-0.042	-0.184	-0.099	-0.030	-0.082	0.816

applying (7 and 8). To determine the weights by the SVP, the normalized decision matrix are calculated first. Then, the SVP weighting vector is calculated. It is obtained as follows:

Table 3. The Standardized DM (SDM)

Alternatives	C1	C2	C3	C4	C5	C5
Abyan	-0.883	-0.393	-0.397	0.967	0.070	0.238
Aden	0.485	-0.555	2.095	2.514	1.289	-0.405
Al Amana	2.661	1.293	3.109	0.277	0.087	-0.651
Al Baydha	-0.625	-1.209	-0.379	-0.590	-0.676	-0.394
Al Dhalae	-0.028	-0.871	-0.387	-0.531	-0.540	-0.343
Al Jawf	0.873	1.736	-0.305	-1.102	-0.811	-0.721
Amran	-0.670	0.111	-0.391	-0.541	-0.591	-0.100
Hajah	0.611	1.401	-0.377	-0.708	-0.269	0.028
Hodeida	0.677	0.653	-0.367	-0.905	-0.726	-0.732
Ibb	0.455	-0.778	-0.339	-0.639	-0.377	-0.056
Lahj	-0.971	0.540	-0.395	0.464	0.180	-0.460
Ma'areb	-1.573	-0.410	-0.391	1.657	3.102	-0.563
Sa'adah	0.402	1.390	-0.352	-1.073	-0.693	-0.481
Sana'a	0.049	-1.476	-0.382	-0.403	-0.743	-0.236
Shabwah	-1.284	-0.840	-0.397	0.720	1.018	1.633
Taiz	-0.179	-0.591	-0.346	-0.107	-0.320	3.245

W (SVP) = {0.127, 0.221, 0.185,0.174,0.149, 0.147} for C= {C1,.., C6} respectively.

STAGE 4: Results of the first case study example

The standardized decision matrix of data, presented in Table 3 is used to determine the ideal and anti-ideal points obtained. The ideal and anti-ideal points are obtained as it is summarized in Table 4. Then, the distance of each alternative is determined using[11-12] and the relative closenessto the positive ideal solution is calculated using[13]. Finally all alternatives are ranked as it presented in Table 5.

STAGE 5: Discussion of results for the first case study example

Task 5 - Ordering positions of the 16 target governorates were calculated. Table 5 outlines the order of the governorates concerned through the population coverage of its main services using WEDA-SVP. The data presented in these tables shows that: Al-Amanah governorate (the capital) is the best alternative, due to the high level of population coverage of hospitals, health centers and health units. As it holds 230 %, 278%, 124 % of the minimum international requirements for this factors

Table 4. The positive and negative ideal solution vector

	C1	C2	C3	C4	C5	C6
A*	2.661	1.736	3.109	2.514	3.102	3.245
A-	-1.57	-1.47	-0.397	-1.102	-0.811	-0.732

respectively. It has almost the minimum international requirements associated with the coverage of health personnel, with a deficit of no more than 9%. Results also indicate that the second place in the ranking was obtained by the governorate of Aden, and that's because it has 118, 134, 194, 140 and 112 present of the minimum population cover requirements with its hospitals, health centers, health workers, beds numbers and BeMOC services. Followed by Ma'reb, Hajah, Aljawf, Taiz and Sa'adah respectively. In Al-Bayda governorate, the large gap between the population density and the services provided is obvious. It is equivalent to 61, 89, 50 and 24 percent of the minimum international requirements for population coverage with Hospitals, health centers, health workers and bed numbers. The three lowest governorates before Al-Baida are Sana', Al Dhalea and Ibb respectively. There are some reasons for this low ranking order. The lack in the distribution of health human resource in these governorates, with the deficit around 41, 47 and 42 present of requirements respectively. The low level of coverage of the beds in the health facilities of these governorates is the second reason, which falls below the minimum required by 80,68 and 58 respectively. Moreover, the low number of hospitals in these governorates compared to the high population density may be another reason for these low levels of ranking. In the middle ordering levels (8-12), the following governorate are existed respectively: Shabwah, Lahj, Hodaida, Abian, and Amran respectively.

Table 5. The results of ranking using wed-SVP

Alternative	Order
Abyan	11
Aden	2
Al Amana	1
Al Baydha	16
Al Dhalae	14
Al Jawf	5
Amran	12
Hajah	4
Hodeida	10
Ibb	13
Lahj	9
Ma'areb	3
Sa'adah	7
Sana'a	15
Shabwah	8
Taiz	6

Task 5-2: To compare the result's rankingswith the results obtained by the TOPSIS method, the ranking process with this technique is carried out first. The same importance vector are used. Weights are obtained using SVP. Then the TOPISIS ranking procedures are applied. The following result's rankings are achieved (see Table 6).

Comparison matrixes of the results obtained by the proposed variants and TOPSIS are presented in Table 7.

The table shows that some governorates have changed their positions in the presented classifications even by a few places. Pearson correlation coefficients are calculated between result's rankings obtained by the EDA-SVP and TOPISIS – SVP, whose value is (0.958). Despite a very high degree of correlation by means of different ranking methods, we can observe significant differences in the results of rankings by the number of governorates whose positions have changed in relation to their position in the ranking obtained by the TOPSIS method. It is in the range of (0-3).

As a consequence, we conclude that the proposed ED-SVP approach is an applicable approach for dealing with ranking MADM problems under incommensurate attributes, where the statistical classical arithmetic meansbased approaches are not suitable to be used. The ranking's result obtained by the proposed method is very similar (closely) to those obtained by the TOPSIS.

Table 6. The positions of the governorates based on tops is –SVP

Alternatives	Order
Abyan	9
Aden	2
Al Amana	1
Al Baydha	16
Al Dhalae	14
Al Jawf	7
Amran	12
Hajah	6
Hodeida	11
Ibb	13
Lahj	10
Ma'areb	3
Sa'adah	8
Sana'a	15
Shabwah	5
Taiz	4

Table 7. Comparison matrixes of the results obtained by the proposed variants and TOPSIS

Method	TOPSIS-SVP	ED-SVP
Abyan	9	11
Aden	2	2
Al Amana	1	1
Al Baydha	16	16
Al Dhalae	14	14
Al Jawf	7	5
Amran	12	12
Hajah	6	4
Hodeida	11	10
Ibb	13	13
Lahj	10	9
Ma'areb	3	3
Sa'adah	8	7
Sana'a	15	15
Shabwah	5	8
Taiz	4	6

4.2 Case Study Example 2: Ordering under Commensurate Attributes

STAGE 1: let's define the object of the second ranking problem as follows: how to rank number of governorates by means of the health educational awareness programs provided by their health systems about diseases. MADM approaches that addressed analyzing respondent's knowledge about diseases and their awareness of modes of the transmission of these diseases and prevention are some methods to adjust such as problems. In this study, we will use the SVP- WED to rank 21 governorates by means of the respondent's knowledge about HIV and AIDS and their awareness of modes of HIV transmission and prevention.

STAGE 2: Applying the same procedure, that was implemented to solve the first case study example, The main structure of the defined problem is summarized as follows: the top level determines the objective, the next level includes the criteria affecting the decision. The following criteria are considered: Percentage of women

Table 8. The decision matrix values of governorates[11]

Governorate	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Ibb	57.6	61.7	62.3	54.9	45.7	53.6	11.4	15.1	17.1	24.3
Abyan	62.4	61.9	61	52.9	37.1	46.6	19.4	19.2	23.6	31.1
Sanaa City	90.8	91.4	91.4	79.3	67.4	49.8	36.7	45.8	53.6	50.4
Al-Baidha	69.3	70.5	70.3	63.3	46.8	59.4	30	29.7	32.4	28.2
Taiz	72.8	75.1	74.7	63.1	48.4	57.3	17.6	23.6	26.2	36.7
Al-Jawf	55	57.1	55.6	46.6	39.9	43.4	17.9	24.7	24.6	20.7
Hajjah	50.4	49.8	48.1	49.1	38.5	36.4	15.9	18.1	20.3	15.3
Al-Hodiedah	64.4	66.9	68	59.5	50.9	55.6	17.6	20.7	24.1	22.2
Hadramout	66.2	65.8	62.8	64.5	42	41.2	28.3	33.6	36.3	29.1
Dhamar	58.4	57.1	57.4	47.1	43.9	43.6	18	19.4	22.6	26.7
Shabwah	67.9	70	69.4	52.9	56.4	50.6	14.1	27.7	31.5	30.8
Sadah	23.7	23.8	24.3	21.3	19	16.6	7.6	6.7	8.2	7.1
Sanaa	51.1	52.3	51.4	46.5	39.9	43.8	9.5	10.6	13	15.6
Aden	88.7	90.6	89.9	76.3	58.9	51.1	32.1	47.1	53.3	38.5
lahj	64.2	61.3	64.2	57.8	35.4	41.9	20.5	27.2	32.2	30.2
Mareb	68.5	69.9	71.4	63.2	56.2	62.1	13.3	17.1	20.5	34.9
Al-Mhweit	51.2	56.4	56.9	49.1	38.9	46.2	10.8	12.7	17.9	24.9
Al-Mhrah	61.5	62.3	59.9	56.9	34.8	48.1	33.1	36.4	39.5	36.3
Amran	62.7	62.7	61.1	59.1	54.5	52.6	12.8	16.3	20.7	22.9
Aldhalae	59	60.9	60.9	53.5	45.9	48.8	13.9	20.9	23.1	31.6
Reimah	50.7	52.5	49.7	42.4	39.9	36.5	9.8	12.9	21.7	14.8

Table 9. Normalized DM for example 2

Governorate	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Ibb	-0.062	-0.017	-0.002	-0.005	0.019	0.147	-0.247	-0.198	-0.213	-0.068
Abyan	0.010	-0.014	-0.021	-0.040	-0.159	-0.007	0.028	-0.097	-0.070	0.089
Sanaa City	0.433	0.422	0.432	0.415	0.467	0.063	0.622	0.561	0.591	0.535
Al-Baidha	0.113	0.113	0.118	0.140	0.042	0.274	0.392	0.163	0.124	0.022
Taiz	0.165	0.181	0.183	0.136	0.075	0.228	-0.034	0.012	-0.013	0.218
Al-Jawf	-0.100	-0.085	-0.102	-0.148	-0.101	-0.077	-0.024	0.039	-0.048	-0.151
Hajjah	-0.169	-0.193	-0.213	-0.105	-0.130	-0.231	-0.092	-0.124	-0.143	-0.276
Al-Hodiedah	0.040	0.060	0.083	0.074	0.126	0.191	-0.034	-0.060	-0.059	-0.117
Hadramout	0.066	0.044	0.006	0.160	-0.057	-0.126	0.334	0.259	0.210	0.043
Dhamar	-0.050	-0.085	-0.075	-0.140	-0.018	-0.073	-0.020	-0.092	-0.092	-0.013
Shabwah	0.092	0.106	0.104	-0.040	0.240	0.081	-0.154	0.113	0.104	0.082
Sadah	-0.567	-0.578	-0.568	-0.585	-0.533	-0.666	-0.378	-0.406	-0.409	-0.465
Sanaa	-0.159	-0.156	-0.164	-0.150	-0.101	-0.068	-0.312	-0.310	-0.304	-0.269
Aden	0.402	0.410	0.410	0.364	0.292	0.092	0.464	0.594	0.584	0.260
lahj	0.037	-0.023	0.027	0.045	-0.194	-0.110	0.066	0.101	0.119	0.068
Mareb	0.101	0.104	0.134	0.138	0.236	0.334	-0.182	-0.149	-0.138	0.177
Al-Mhweit	-0.157	-0.096	-0.082	-0.105	-0.122	-0.016	-0.268	-0.258	-0.196	-0.054
Al-Mhrah	-0.004	-0.008	-0.037	0.029	-0.206	0.026	0.499	0.329	0.280	0.209
Amran	0.014	-0.002	-0.020	0.067	0.201	0.125	-0.199	-0.169	-0.134	-0.101
Aldhalae	-0.041	-0.029	-0.023	-0.029	0.023	0.041	-0.161	-0.055	-0.081	0.100
Reimah	-0.165	-0.153	-0.189	-0.221	-0.101	-0.229	-0.302	-0.253	-0.112	-0.288

who have background that HIV can be transmitted throw Blood transfusion (C1); Sexual intercourse with infected husband (C2); Contaminated sharp instruments (C3); Percentage of women who know that HIV can be transmitted during: pregnancy (C4); Delivery (C5) and Breast feeding (C6); Percentage of women who know that HIV cannot be transmitted through Mosquito bites (C7); Swimming with infected people (C8) and Sharing food with a person who has AIDS (C9); Percentage who say that HIV can be prevented by using condoms (C10)[11].

Based on the summarized data of the above mentioned source (report[11]). The Decision matrix is defined as shown in the Table 8, and then it was normalized as presented in Table 9. After that, the scoring standardized matrix is calculated as illustrated in Table 10.

STAGE 3: The relative importance of attributes is calculated using SVP as it shown in Table 11.

STAGE 4: The same procedure of ranking in the first case study is applied. The ideal and anti-ideal points are obtained as it is summarized in Table 12. Then, the distance of each alternative is determined and the relative closeness to the positive ideal solution is calculated and finally all alternatives are ranked as it presented in Table 13.

STAGE 5: Discussion of results for the second case study example

Task 5-1: Ordering positions of the 21 target governorates were calculated. Table 12 illustrates the ranking positions of 21 governorates in term of the respondents awareness about HIV/AIDS transmitting mods (methods) using WED-SVP. The data reflects level of health education services provided by those governorates, and identifies the highest priority areas that should be taken into account during the development of health awareness plans. According to the evaluation results, the governorates most in need to provide such services are S'adah, Reimah, Sana'a, Hajjah, Al-Mhweit, Al-Jawf,Dhamar respectively. On the other hand, the best seven governorates are Sana'a City (Alamanah), Aden, Taiz, Al-Baidha, Shabwah, Hadramout and Mareb respectively.

Task 5-2: To compare the ranking's result with the arithmetic mean of the measurements obtained by the survey proposedby YNHDS[11], and by the TOPSIS-SVP method, the ranking's result obtained by YNHDS[11]

Table 10. Standardized DM for example 2

Governorate	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Ibb	-0.062	-0.017	-0.002	-0.005	0.019	0.147	-0.247	-0.198	-0.213	-0.068
Abyan	0.010	-0.014	-0.021	-0.040	-0.159	-0.007	0.028	-0.097	-0.070	0.089
Sanaa City	0.433	0.422	0.432	0.415	0.467	0.063	0.622	0.561	0.591	0.535
Al-Baidha	0.113	0.113	0.118	0.140	0.042	0.274	0.392	0.163	0.124	0.022
Taiz	0.165	0.181	0.183	0.136	0.075	0.228	-0.034	0.012	-0.013	0.218
Al-Jawf	-0.100	-0.085	-0.102	-0.148	-0.101	-0.077	-0.024	0.039	-0.048	-0.151
Hajjah	-0.169	-0.193	-0.213	-0.105	-0.130	-0.231	-0.092	-0.124	-0.143	-0.276
Al-Hodiedah	0.040	0.060	0.083	0.074	0.126	0.191	-0.034	-0.060	-0.059	-0.117
Hadramout	0.066	0.044	0.006	0.160	-0.057	-0.126	0.334	0.259	0.210	0.043
Dhamar	-0.050	-0.085	-0.075	-0.140	-0.018	-0.073	-0.020	-0.092	-0.092	-0.013
Shabwah	0.092	0.106	0.104	-0.040	0.240	0.081	-0.154	0.113	0.104	0.082
Sadah	-0.567	-0.578	-0.568	-0.585	-0.533	-0.666	-0.378	-0.406	-0.409	-0.465
Sanaa	-0.159	-0.156	-0.164	-0.150	-0.101	-0.068	-0.312	-0.310	-0.304	-0.269
Aden	0.402	0.410	0.410	0.364	0.292	0.092	0.464	0.594	0.584	0.260
lahj	0.037	-0.023	0.027	0.045	-0.194	-0.110	0.066	0.101	0.119	0.068
Mareb	0.101	0.104	0.134	0.138	0.236	0.334	-0.182	-0.149	-0.138	0.177
Al-Mhweit	-0.157	-0.096	-0.082	-0.105	-0.122	-0.016	-0.268	-0.258	-0.196	-0.054
Al-Mhrah	-0.004	-0.008	-0.037	0.029	-0.206	0.026	0.499	0.329	0.280	0.209
Amran	0.014	-0.002	-0.020	0.067	0.201	0.125	-0.199	-0.169	-0.134	-0.101
Aldhalae	-0.041	-0.029	-0.023	-0.029	0.023	0.041	-0.161	-0.055	-0.081	0.100
Reimah	-0.165	-0.153	-0.189	-0.221	-0.101	-0.229	-0.302	-0.253	-0.112	-0.288

Table 11. The relative importance of attributes

j	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
wj	0.142	0.145	0.148	0.109	0.080	0.070	0.053	0.085	0.098	0.069

Table 12. Ideal and anti -ideal Solutions

j	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
A*	0.433	0.422	0.432	0.415	0.467	0.334	0.622	0.594	0.591	0.535
A-	-0.567	-0.578	-0.568	-0.585	-0.533	-0.666	-0.378	-0.406	-0.409	-0.465

is calculated based on the decision matrix presented in the first table, while the ranking's result of the TOPSIS- SVP ordering are calculated by the same persuader presented for this purpose in the first case study example. Table 14 shows the results. For Simplicity, these results well be abbreviated with the AM an TOPSIS-SVP respectively.

The table shows that, some governorates changed their positions in the presented classifications even by a few places. Pearson correlation coefficients were calculated between result's rankings obtained by the EDA-SVP and TOPISIS – SVP, and between result's rankings obtained by the TOPSIS and AM method proposed by YNHDS[11], whose values are (0.968 And 0.961) respectively. The PCC value is also calculated between the results obtained by the proposed approach and those obtained by the AM. The result equals (0.994).

Despite a high degree of correlation by means of different ranking methods, we can observe significant differences in the results of rankings by the number of governorates whose positions have changed using WED-SVP and AM in relation to their position in the ranking obtained by the TOPSIS method. It also could be observed by comparing the number of governorates

Table 13. Ranking's result

Governorate	D_j^*	D_j^-	RC_j^*	Ranking
Ibb	0.176828	0.17157	0.492453	14
Abyan	0.165011	0.173816	0.512993	12
Sanaa City	0.01912	0.328518	0.945001	1
Al-Baidha	0.114723	0.224017	0.661324	4
Taiz	0.116737	0.230318	0.663636	3
Al-Jawf	0.183331	0.151389	0.452286	16
Hajjah	0.211926	0.124144	0.369398	18
Al-Hodiedah	0.145413	0.199364	0.57824	9
Hadramout	0.129855	0.205956	0.613309	6
Dhamar	0.179386	0.156873	0.466524	15
Shabwah	0.128557	0.211181	0.6216	5
Sadah	0.332676	0	0	21
Sanaa	0.218271	0.127396	0.368551	19
Aden	0.031296	0.315333	0.909714	2
lahj	0.148748	0.186995	0.556958	10
Mareb	0.138107	0.21839	0.6126	7
Al-Mhweit	0.19885	0.144112	0.420198	17
Al-Mhrah	0.140316	0.199205	0.586724	8
Amran	0.164194	0.18379	0.528156	11
Aldhalae	0.165414	0.173511	0.511944	13
Reimah	0.215841	0.12281	0.362645	20

whose positions have changed using WED-SVP and TOPSIS – SVP methods in relation to their position in the ranking obtained by the AM method. A Table15 illustrates the comparisons.

The juxtaposition presented in Table 15 illustrates that with the change in the ranking procedure, positions of the evaluated governorates have changed as well. Comparing the number of governorates whose positions have changed using WED-SVP and AM methods in relation to their position in the ranking obtained by the TOPSIS_SVP, we can conclude that the biggest changes occurred in the case of using AM, with the 4 position changes.

Comparing the number of governorates whose positions have changed using WED-SVP and TOPSIS – SVP methods in relation to their position in the ranking obtained by AM, we can conclude that the biggest changes occurred in the case of using the TOPSIS-SVP method, and also with the 4 position changes.

Identical calculations were performed to demine the overall level of the Change in the positions of governorates in the rankings, to compare the results. The following formula is used:

$$CL = \sum_{i=1}^{n} \frac{i \cdot N_1}{m} \tag{14}$$

where, i is the number of "shifts" position in the ranking of governorates. And Ni is the number of governorates whose position has changed by i –th number. The overall position changing levels are summarized in the Table 16.

The data presented in the table summarizes the following:

The overall level of change in the position of governorates ranked using WED-SVP is a smaller than the level obtained by using AM when they are compared with the TOPSIS-SVP.

IT is also represent that the WED –SVP has a better CL value and is smaller than the CL value obtained when the TOPSIS-SVP is used, when they are compared with the results obtained using AM.

From the second study we can summarize the following results:

Table 14. Ranking's results by TOPSIS and by YNHDS[11]

Governorate	SCORING VALUES			Ranking of alternatives		
	TOSIS-SVP	*AM*	*Proposed approach*	*TOSIS-SVP*	*AM*	*Proposed approach*
Ibb	0.334492	40.37	0.492453	16	14	14
Abyan	0.361039	41.52	0.512993	11	13	12
Sanaa	0.86558	65.66	0.945001	1	1	1
Al-Baidha	0.449491	49.99	0.661324	3	3	4
Taiz	0.427494	49.55	0.663636	6	4	3
Al-Jawf	0.343558	38.55	0.452286	15	16	16
Hajjah	0.307887	34.19	0.369398	18	18	18
Al-Hodiedah	0.379497	44.99	0.57824	10	9	9
Hadramout	0.436598	46.98	0.613309	4	7	6
Dhamar	0.344027	39.42	0.466524	14	15	15
Shabwah	0.420458	47.13	0.6216	7	6	5
Sadah	0.217053	15.83	0	21	21	21
Sanaa	0.291969	33.37	0.368551	20	19	19
Aden	0.754432	62.65	0.909714	2	2	2
lahj	0.39696	43.49	0.556958	8	10	10
Mareb	0.381856	47.71	0.6126	9	5	7
Al-Mhweit	0.314638	36.5	0.420198	17	17	17
Al-Mhrah	0.429518	46.88	0.586724	5	8	8
Amran	0.35069	42.54	0.528156	13	11	11
Aldhalae	0.359747	41.85	0.511944	12	12	13
Reimah	0.301109	33.09	0.362645	19	20	20

Table 15. Change in the positions of governorates

	Comparing with TOPSIS		AM	
Position changed	*AM*	*ED-SPV*	*TOPSIS*	*ED-SPV*
No change	5	4	5	10
One position	5	6	5	5
2 positions	4	5	4	1
3 positions	1	1	1	0
4- positions	1	0	1	0

Table 16. The overall position changing levels

	Comparing with TOPSIS		Comparing with AM	
method	*AM*	*ED-SPV*	*TOPSIS*	*ED-SPV*
CL	0.952	0.905	0.952	0.333

All the WED- SVP, TOPSIS, and AM are applicable approaches for dealing with ranking problems under commensurate attributes.

Comparing with the results obtained by the TOPSIS-SVP, the results obtained by using the WED-SVP (PCC = 0.968)is closer than those obtained by the AM (PCC = 0.961).

Comparing with the results obtained by the TOPSIS-SVP, the ranked governorates have changed their positions in the ranking by the 4 positions, with the overall level of change equals 0.925, when the AM method is used, while the governorates are changing their positions by a 3 positions with the CL equals 0.905,when the AM method is used. So the results obtained with SVP-WED are more similar to those obtained by the TOPSIS-SVP than those obtained by the AM.

Comparing with the results obtained by the AM approach, the results obtained by using the TOPSIS-SVP (PCC = 0.994) is closer than those obtained by AM (PCC = 0.961), but the gap between TOPSIS-SVP and WED-SVP is very small, as it is shown above (PPC = 0.968).

Comparing with the results obtained by the AM, it is also observed that the ranked governorates have changed their positions in the ranking by the 4 positions, with the overall level of change equals 0.952, when the TOPSIS –SVP is used, while the governorates are changing their positions by only 2 positions with the CL equals 0.33, when the WED – SVP is used. So the results obtained with SVP-WED are more similar to those obtained by the AM than those obtained by the TOPSIS-SVP.

5. Conclusion

The first case study example shows that the very high values of PPC, very small CL values between WED - TOPSIS compared technics that both methods are applicable to solve the ordering MADM problems if they are solved under incommensurate attributes. The second case study example shows that the all methods,, the very high values of PPC, very small CL values between all three compared technics (WED - TOPSIS – statistical methods based on the mean average of values), are applicable to solve the ordering MADM problems if they are solved under commensurate attributes.

MADM approaches are very important and required techniques for enhancing and improving the DM processes in healthcare management. The presented WED-SVP MADM approach can help healthcare DMs in Yemen to deal with priority, weighting, measuring and ranking problems. It is one of the applicable MADM approaches which deals with such problems under both commensurate and incommensurate attributes. Also, it can be stated that different variants of ranking approaches leads to different ranking's result, very high level of numerical correlation coefficients, and very small change level in the positions of alternatives are observed between results those determined by the presented approach and those which were obtained by TOPSIS in both cases under study.

The proposed approach is better than the TOPSIS-SVP by means of similarity of ranking's result according to the PCC, number of position shifts and overall position change level in the positions of alternatives relative to the results obtained by the AM approach proposed by YNHDS[11].

Two ranking problems were considered in this paper, many other MADM problems were existing in the Yemeni healthcare sector, and they almost have the same general structure of the solved ranking problem and it is recommended to use the proposed approach to deal with them. In future we are planning to study another types of integrated normalization, weighting and ranking approaches and analysis the impacts of its implementation on the ranking process; we are also planning to study the application of other types of MADM methods aiming to enhance the healthcare decision making field in Yemen.

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