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Ardışık SWARA TODIM Yöntemleri ile Bir Ağız Sağlığı Merkezi için Global Lokasyon Seçimi

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ÖZ

Bir sağlık kuruluşu yatırımı yapılması planlandığında atılması gereken ilk adım, en doğru kuruluş yerinin seçilmesidir. Bu önemli seçim süreci ekonomik, ekolojik ve çevresel etkileri göz önünde bulunduran bir planlama süreci olup kuruluş aşamasında karar verici konumundaki yöneticilerin, kuruluşlarının yerleşim planlamasını analitik yöntemleri kullanarak gerçekleştirmeleri ise bir zorunluluktur. Bu çalışmada uluslararası bir diş kliniği yatırımı için sağlık sektörünün ilk adımı sayılabilecek yer seçimi probleminin çözümünde çok kriterli karar verme tekniklerinden Ağırlıklı Toplam Modeli ve Ağırlıklı Çarpım Modeli (Weighted Aggregated Sum Product Assessment - WASPAS) adımı yardımıyla Adım Adım Ağırlık Değerlendirme Oran Analizi (Stepwise Weight Assessment Ratio Analysis - SWARA) ve Etkileşimli ve Çok Kriterli Karar Verme Yöntemi (Interative Multi-criteria Decision Making - TODIM) yöntemleri uygulanmıştır. Çalışma kapsamında 4 ana kriter, 17 alt kriter ve 6 alternatif ülkeden oluşan çok kriterli karar verme modeli önerilmiştir. Almanya, İspanya, Hollanda, İngiltere, İrlanda ve Belçika'nın da aralarında bulunduğu alternatif ülkeler ülke yapısı, ülkenin demografik yapısı, maliyet ve risk başlıkları altında toplanan kriterler bazında değerlendirilmiştir. Önerilen modelin, önerilen sıralı yöntemle çözülmesi ile Almanya böylesi bir diş sağlığı merkezi yatırımı için en uygun lokasyon olarak bulunmuştur.

Global Location Selection for an Oral Health Center with a Sequential Method by SWARA&TODIM

Research Article

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ABSTRACT

The first step to take when a healthcare facility investment is planned is to choose the most appropriate facility location. This important selection process is a planning process that takes into account economic, ecological and environmental effects, and it is necessary for managers who are decision-makers at the establishment stage to carry out the settlement planning of their organizations using analytical methods. In this study, Stepwise Weight Assessment Ratio Analysis (SWARA) and Interative Multi-criteria Decision Making (TODIM) methods with a help of Weighted Aggregated Sum Product Assessment (WASPAS) step, which are among the multi-criteria decision-making techniques, have been applied to the solution of the location selection problem, which can be considered as the first step of health sector investments for an international dental clinic. Within the scope of the study, a multi-criteria decision-making model consisting of 4 main criteria, 17 sub-criteria and 6 alternative countries has been proposed. Alternative countries including Germany, Spain, Netherlands, England, Ireland, and Belgium were evaluated on the basis of criteria gathered under the headings of country structure, demographic structure of the country, cost and risk. By solving the proposed model with the proposed sequential method, Germany was found to be the most suitable location for such a dental health center

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1. Introduction

The health sector, or in other words the medical sector and healthcare industry, is one of the leading needs for individuals, societies, and countries. Although the health sector is an important business line in the establishment of public health of nations, it is a sector that directly affects economic development due to mutual benefit. This economic development can be in two forms. The first form of economic development is to have an efficient and more effective workforce that has been obtained with the establishment of public health. The second form of economic development is that the sub-sectors connected to the health sector are in constant interaction and they strengthen the economic community by continuously feeding each other due to business partnerships.

The healthcare industry is one of the most important sectors for which all countries, especially developed countries, allocate the most budget. In addition, the sector is among the fastest growing industries in the World.

Determination of health institutions' facility locations correctly in the sector, which grows so fast and has a high economic contribution to the countries, has a great importance because providing sufficient services without delay to individuals in a need and contributing to the company in economic terms.

Oral and dental health have become more important day by day in line with the increasing awareness of the effects of oral and dental health on general body health, the spread of aesthetic dentistry treatments and socio-economic developments. With this increased importance, the demand of dental treatments increases and at this point oral and dental health centers and dental clinics becomes insufficient.

A study on the effect of oral and dental health on cardiovascular diseases and systemic inflammation indicated that poor oral health has negative effects on heart disease and systemic inflammation (Frisbee et al., 2010). Along with the physical effects of dental health, there are also psychological effects on human health. Kenealy et al. (2007) determined that orthodontic treatment contributed positively to self-confidence in their study.

The global disease burden study carried out in 2017 indicated that oral and dental diseases affected 3.5 billion people in the same year and that there were not enough institutions for dental treatment (Murray et al., 2018). Similarly, the World Health Organization emphasized that healthcare services in most countries are inadequate, access to treatment is low due to the inadequate and unequal distribution of oral health centers and clinics, and that oral health institutions are generally needed. In addition, another study showed that only 63% of the patients' needs could be met due to the insufficient number of institutions providing dental treatment and due to determination of clinics' locations wrongly (Hosseinpoor et al., 2012). Researches show that the demand for treatment cannot be met due to the increasing demand for treatment, insufficient number of health institutions and wrong institution locations with the better understanding and gaining importance of the effects of oral and dental health on mental and physical health.

This study is conducted on the global location selection decision in a new hospital investment for a multinational dental group. For this purpose, a multi criteria decision-making (MCDM) model consisting of 4 main and 17 sub-criteria was proposed for 6 alternative countries in which the dental group is planning to invest, using the literature and expert opinions. The proposed model was solved by using SWARA and TODIM methods consecutively. Differ from literature WASPAS method's normalization step also integrated to the solution steps and the best alternative location was determined among 6 countries based on criteria. All these used techniques are included by MCDM techniques.

In the literature, it is seen that the SWARA method, which has increased its usage rate in recent years is used in the weighting of decision criteria in different MCDM problems. Nevertheless, the number of studies on location selection with the SWARA method is not more than a few studies. For example, Mostafaeipour et al. (2020) ranked the locations for producing hydrogen, and Popovic et al. (2019) selected a hotel location.

Another method used in the solution phase of the study is the TODIM method. While determining the criterion importance weights with the SWARA method, with the TODIM method, decision criteria are evaluated hierarchically, and the most suitable alternative is found. In the literature, examples of location selection problem that using the TODIM method can be listed as follows: Rezaeisabzevar et al. (2020) determined a landfill site, Guo et al. (2020) solved a storage site selection problem and Wu et al. (2019) selected an optimal location for offshore wind-PV-seawater pumped storage power plant.

In the literature, there are few studies in which SWARA and TODIM methods are used together. For example, Aydoğan and Özmen (2020) analyzed a travel and tourism competitiveness of economies around the World, Dahooie and Dehghan (2018) proposed a framework to rank and select volleyball players and Ruzgys et al. (2014) evaluated the external wall insulation in residential buildings.

Finally, in the literature about location selection in the health sector, examples of studies carried out with the help of MCDM techniques are as follows: in hospital location problems Kaveh et al. (2020) used genetic algorithm, Şahin et al. (2019) used analytic hierarchy process, Miç and Antmen (2019) and Senvar et al. (2016) used fuzzy TOPSIS, Eldemir and Önden (2016) used geographic information system and fuzzy analytic hierarchy process. Moreover, Zolfani et al. (2020) used CRITIC and CoCoSo methods for a location selection of a temporary hospital during COVID-19 pandemic.

In the light of all these researches, it is clear that there is no sample study on the problem of choosing the suitable location in global market for a dental clinic by using SWARA and TODIM methods together in literature.

This study is important in terms of being a source for dental health researchers with the MCDM model it proposes and guiding future studies with the sequential solution methods it uses. This study will contribute to the literature with its proposed MCDM model. Furthermore, it will guide future studies with the usage of sequential SWARA and TODIM methods for the first time in the solution of a global scale location problem in the dental health sector and including WASPAS method normalization step in the solution phase.

2. Materials and Methods

In the literature, there is no location selection study conducted for dental clinics and oral health centers until today. In this study, in order to contribute to the literature, the problem of location for the globally needed oral and dental health centers was discussed and the MCDM model was proposed for the globally location selection problem of a multinational dental health center. The proposed model consisting of 4 main, 17 sub-criteria and 6 alternatives were evaluated using SWARA and TODIM methods, which are among the MCDM methods, and the solution methodology with the normalization step of the WASPAS method included in the solution phase is shown in Fig. 1.

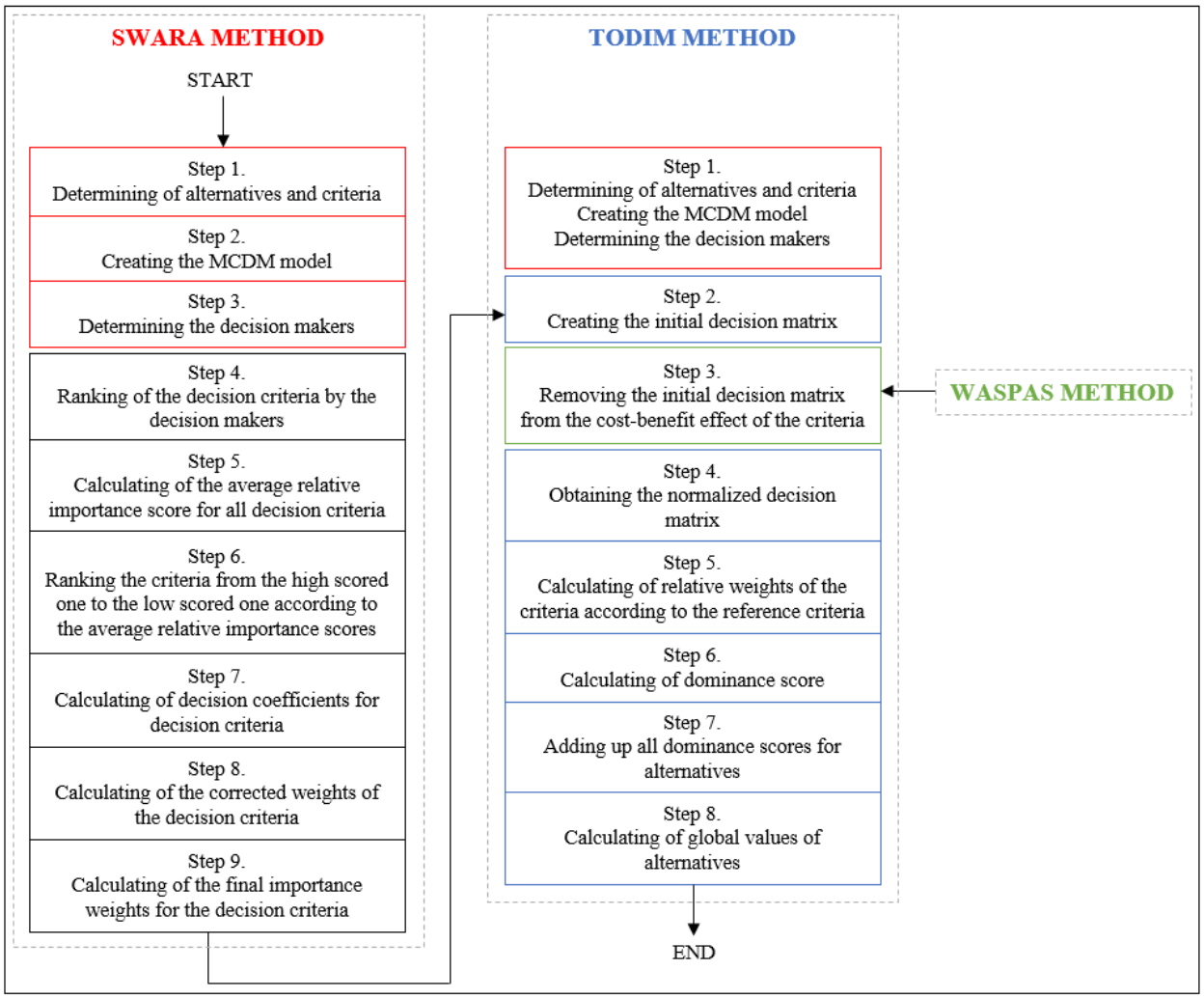

Figure 1. Schematic representation of the proposed solution process

2.1 Definition of the Research Problem

Determination of the right location for the healthcare institutions that want to provide services in the global market will enable the service operations to be offered more effectively in accordance with the patient population, while minimizing the costs to be encountered in the operating processes. Thus, health institutions will gain an economic advantage and will be able to reach an advantageous position against their competitors in the market.

This study was carried out to solve the problem of globally location selection problem of a multinational oral and dental health center, which is one of the healthcare institutions with increasing global investments in the healthcare industry. The aim of the study is to help location selection, which has a great importance in investment plans, to be made correctly and to contribute to the literature.

2.2 Determination of Research Decision Criteria

While creating the proposed research model for the solution of the globally location selection problem, dental clinics and oral dental centers operating in the global market were examined in detail in determination the criteria and sub-criteria. The research model was created as a result of the information obtained from these organizations, literature research and expert opinions of dental health professionals.

Information about the oral and dental health professionals, whose opinions were taken in determining the model criteria and in evaluating the alternatives on the basis of the criteria, are shown in Table 1.While 2 of the 5 dental health specialists whose opinions were taken in the study work in public institutions, 3 of them work in private polyclinics.

Table 1. Academic and sectoral information about experts

Experts	Title	Experience (year)	Education
1	Clinic owner / Orthodontist	32	PhD
2	Clinic owner / Endodontist	14	PhD
3	Prosthesis specialist	12	PhD
4	Dentist	18	M.Sc.
5	Dental clinic financial officer	27	M.Sc.

The determined criteria of the research model are as follows:

- Criteria about *COUNTRY STRUCTURE*:
  - C_1 *Rivals:* Rivals: The effectiveness of other dental clinics and oral dental health centers in the area planned to be selected (Şahin et al., 2019; Senvar et al., 2016).
  - C_2 *Medical technology:* This criterion, which expresses all manual and electronic treatment equipment required by the dental clinic, directly affects the quality of treatment (Şahin et al., 2019; Chiu and Tsai, 2013).
  - C_3 *Eligibility for health tourism:* Investments to be made in countries that are suitable for health tourism will be able to provide treatment services to the local patient population as well as to the foreign patient population who may come to the country.
  - C_4 *Qualified workforce:* Qualified dental health professionals and associate professionals should be available to conduct to clinical activities effectively and to ensure high service quality.
  - C_5 *Market growth rate:* While the market growth rate represents the increasing demand within the region, high demand will directly affect the profitability of the dental clinic.
  - C_6 *Government incentives:* Government incentives for foreign investment will be supportive for company activities and shorten the return-on-investment period for the dental clinic (Şahin et al., 2019; Wu et al., 2007).

- C_7 *Development of the pharmaceutical industry:* The developed pharmaceutical industry will facilitate access to supportive care and increase the quality in the treatment process (Chiu and Tsai, 2013; Wu et al., 2007).
- C_8 *Economic stability:* Stability of the economy of the country to be invested will create a lower risk for investment costs and will allow the patients to have a continuous and sufficient economic power to reach treatment.
- C_9 *Political stability:* This criterion represents the political order and continuity in the government of the country to be invested. Since political uncertainties will adversely affect macroeconomic performance, it will cause the dental clinic to be exposed to economic risks.

- Criteria about *DEMOGRAPHIC FEATURES*:
  - C_{10} *Income:* Income status represents the economic power of the population and will directly benefit the dental clinic as high income will create high purchasing power (Şahin et al., 2019).
  - C_{11} *Population:* It represents the number of people living in the region and the potential demand for dental treatments can be guess by this number (Şahin et al., 2019; Senvar et al., 2016; Chiu and Tsai, 2013).
  - C_{12} *Population age:* It represents the average age of the population living in the area to be invested. High average age affects the demand positively (Şahin et al., 2019; Senvar et al., 2016; Chiu and Tsai, 2013; Wu et al., 2007).
- Criteria about *COST*:
  - C_{13} *Investment cost:* It is a one-time cost that includes land and construction costs (Senvar et al., 2016).
  - C_{14} *Labor cost:* It represents the annual average wage of a qualified workforce and is a continuous cost (Senvar et al., 2016).
  - C_{15} *Operation cost:* It is a permanent cost created by the ongoing activities of the dental clinic.
- Criteria about *RISK*:
  - C_{16} *Terror:* These are political, ethnic and historical problems that affect the business world negatively as well as affecting the whole society. The risk of terrorism will adversely affect businesses and employees and will put the dental clinic's continuity into an unpredictable process.
  - C_{17} *Natural disasters:* These are natural disasters that can adversely affect all kinds of activities of dental clinic, especially earthquake.

2.3 Determination of Research Alternatives

Today, health institutions provide health services to foreign patients who come to the country within the scope of health tourism as well as the local population. Some difficulties encountered in meeting the increasing demand of health tourism encourage health institutions to invest in foreign countries. Health institutions try to establish new hospitals, oral and dental health clinics in the most suitable places of the World due to reasons such as the time lost by the person requesting treatment in transportation, the treatment processes to be continued in more than one session and cost.

In this study, the problem of globally facility location selection for an oral and dental health clinic within sufficient service capacity in response to foreign patient demand was examined based on its limitations and criteria. The 6 alternative countries identified by experts for the solution of the problem are as shown below, together with their characteristics.

- *A_1Germany*: It is one of the leading countries in Europe in terms of economic and technological development. Due to the rapidly increasing number of academic studies and qualified health professionals within the scope of dental health and dental treatment, it has the necessary competencies in meeting oral and dental health needs and providing dental health services. The high number of English-speaking people in Germany, the high level of quality of life and economic opportunities, makes this country advantageous for global investments. Providing economic stability in the country has a great importance for investors and employees. The increasing number of organizations providing dental health services is a disadvantageous feature for this country.
- *A_2 Spain:* Spain is one of the countries with a high welfare level in Europe. One of the advantageous features of the country is that it is one of the countries with the lowest operation costs in Europe in providing dental health services. Furthermore, its cultural wealth is an important tourism advantage for this country. Easy transportation facilities are also an important factor that contributes to accessing health services. The disadvantages of the country compared to other European countries are that the economic stability is lower and the number of English-speaking people in Spain is lower.
- *A_3 Netherlands:* The Netherlands is the country with the lowest operation cost in Europe in terms of dental health services, and this feature is considered among its sectoral advantages. The welfare level is also high in the Netherlands, which has one of the highest values in Europe in terms of GDP per capita. High number of English-speaking people, economic and political stability are other advantageous features of the country.
- *A_4England:* England, located on the island of Great Britain in the west of Europe, is known for its universities with high education quality. Its highly qualified workforce and being suitable for health tourism are among the important advantages of the country. On the other hand, the country may be insufficient in terms of the capacity to provide oral dental health services, because of its fewer qualified dental health professionals than other European countries.
- *A_5 Ireland:* Ireland located in Northwest Europe is one of the leading countries in terms of medical technology development. The country has a great advantage in the high number of personnel employed in medical technology, the production and supplying of the treatment equipment needed in health institutions. High income and high welfare level are other advantageous features of the country. The lack of need for health tourism in Ireland is a disadvantage. However, although high medical technology is an advantage, the inadequacy of the pharmaceutical industry is a disadvantage. There is no average operation cost across the country in terms of the services provided by health institutions, there are also serious price differences between the east and west of the country. This unbalanced pricing may cause negativity accessing to the health service.

- *A_6 Belgium:* Belgium's strong global economy and transportation facilities are integrated with other regions of Europe. The pharmaceutical industry in the country, which has a high workforce and advanced medical technology facilities, is also at a level that can meet the demand. Being one of the countries with the highest urbanization rate in Europe, Belgium is advantageous in terms of access to health services with this feature. However, it is disadvantageous for investors in terms of health demand expectation due to its low population and young average age.

Fig. 2 shows the proposed research model of the study.

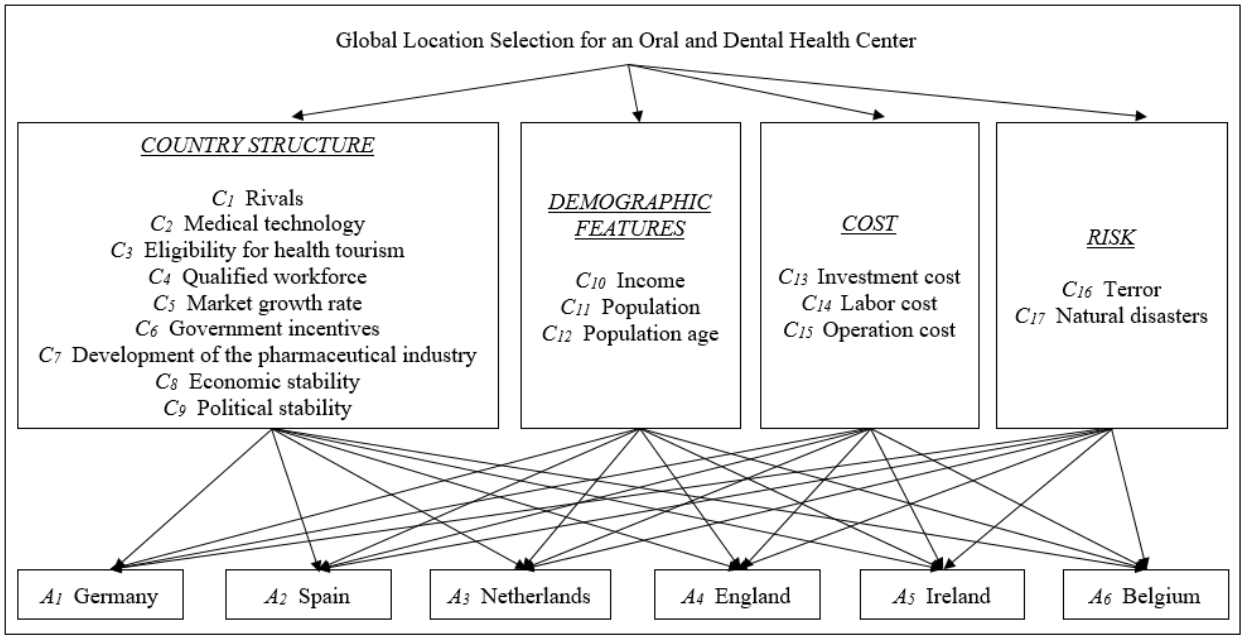

Figure 2. Proposed Research Model

2.4 The Assumptions of the Research

There are some assumptions that need to be made for the implementation and evaluation processes of the proposed model. There is no relationship between research criteria. The sample dental clinic planned to be established in each country is in the same size. All alternatives have equal number of oral and dental health professionals and patient chairs. In addition, for opening a dental clinic in alternative countries it is assumed that the sample oral and dental health center meets the legal responsibilities and has the permits required.

3. Application of Proposed Solution Method to Research Problem

The location selection for healthcare organizations is of great importance for businesses to achieve their profitability goals and is also very important for the community to reach healthcare services on time. The proposed research model in this study, which deals with the problem of location selection for a multinational dental clinic, was solved with the help of MCDM techniques such as SWARA and TODIM.

In the proposed solution methodology, SWARA and TODIM techniques were used sequentially. In the first stage of the proposed solution methodology, the importance weights of the criteria were determined with

SWARA technique, and in the second stage, the most suitable alternative was selected by evaluating the alternatives with TODIM method.

In the solution approach, alternatives were evaluated with both quantitative and qualitative data in terms of criteria, and this feature protected the study from possible evaluation limitations.

Moreover, in the normalization process of the criteria that are expected to be both maximized and minimized, the criteria for minimization were normalized with the WASPAS method, unlike the SWARA/TODIM studies in the literature. This addition to the proposed solution methodology is an important contribution to the literature.

3.1. The First Stage in Problem Solution: SWARA method

SWARA method, which is among the MCDM methods, is a method used in determining criteria weights, which is very important in decision making processes. The method was developed by Keršuliene, Zavadskas and Turskis in 2010 (Keršulienė et al., 2012). Utilizing expert opinion in determining decision criteria weights, the method allows each decision-maker to choose their own priorities and rank the criteria according to their proximity to each other instead of a scale that uses intervals like Likert scale. For this reason, expert opinions are more important in SWARA method than others.

The 17 decision criteria of the proposed research model in solving the global location selection problem for the oral and dental health clinic were weighted by following the steps of SWARA method (Ulutas et al., 2020; Keršulienė et al., 2012; Zavadskas et al., 2018):

- ***Step 1.*** *Determining of alternatives and criteria:* A problem consists of criteria and alternatives. In decision problems, n is the number of criteria and C_j is the set of criteria ($j = 1,\ldots, n$). Also, while m is the number of alternatives, A_i is the set of alternatives ($i = 1,\ldots, m$). The research problem consists of 17 decision criteria and 6 country alternatives.
- ***Step 2.*** *Creating the MCDM model:* After determination of the decision criteria and alternatives, the MCDM model is created.
- ***Step 3.*** *Determining the decision makers:* In the decision problem, l is the number of decision makers, k_l is the set of decision makers ($k = 1,\ldots, l$). The research problem evaluated by 5 decision makers.
- ***Step 4.*** *Ranking of the decision criteria by the decision makers:* For determination of the importance weights of the criteria, first the criteria are ranked from the most important one to the least important by decision makers. Then all criteria are reordered from 1.00 to 0.00 to match the first ordering. The most important criterion has 1.00 value in second ranking. Later, the scores of the other criteria are determined according to the most important criterion. By subjecting all criteria to this process, relative importance weights are obtained for each criterion. The scores assigned to the decision criteria are expressed as $P_j^k (0 \leq P_j^k \leq 1)$.

In the first solution stage of the proposed problem in this study, 17 decision criteria were ranked by 5 healthcare professionals with work experience in the dental health sector from the most important to the least important. As a result of these evaluation processes, the P_j^k values shown in Table 2 were obtained.

- ***Step 5.*** *Calculating of the average relative importance score for all decision criteria:* Using Eq. (1), the average relative importance scores ($\overline{P_J}$) are calculated for all criteria.

$$\overline{P_J} = \frac{\sum_{k=1}^{l} p_j^k}{l} \quad (1)$$

Table 2 shows the calculated $\overline{P_J}$ values.

Table 2. The ordering of the decision criteria by experts and calculated $\overline{P_J}$ values

Criteria	Experts										$\overline{P_J}$
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	
1	10	11	10	7	10	0.55	0.50	0.55	0.70	0.55	0.57
2	9	10	9	5	11	0.60	0.55	0.60	0.80	0.50	0.61
3	15	12	17	14	14	0.25	0.45	0.20	0.35	0.35	0.32
4	3	3	1	8	2	0.90	0.90	1.00	0.65	0.95	0.88
5	11	7	5	15	6	0.50	0.70	0.80	0.30	0.75	0.61
6	16	15	16	16	15	0.20	0.30	0.25	0.25	0.30	0.26
7	12	8	11	10	12	0.45	0.65	0.50	0.55	0.45	0.52
8	7	14	12	9	7	0.70	0.35	0.45	0.60	0.70	0.56
9	17	17	15	12	16	0.10	0.15	0.30	0.45	0.25	0.25
10	1	2	8	6	1	1.00	0.95	0.65	0.75	1.00	0.87
11	2	1	6	4	8	0.95	1.00	0.75	0.85	0.65	0.84
12	14	9	7	13	9	0.30	0.60	0.70	0.40	0.60	0.52
13	5	4	2	1	3	0.80	0.85	0.95	1.00	0.90	0.90
14	4	5	4	3	4	0.85	0.80	0.85	0.90	0.85	0.85
15	6	6	3	2	5	0.75	0.75	0.90	0.95	0.80	0.83
16	8	13	13	11	13	0.65	0.40	0.40	0.50	0.40	0.47
17	13	16	14	17	17	0.35	0.20	0.35	0.20	0.20	0.26

- ***Step 6.*** *Ranking the criteria from the high scored one to the low scored one according to the average relative importance scores:* The decision criteria are ranked in descending order, based on the $\overline{P_J}$ values obtained with Eq. (1), the decision criterion with the highest $\overline{P_J}$ value written at the top. After this ordering is made, the means of the comparative weights (s_j) for each criterion are calculated. For example, s_1 shows the average value of the comparative weight between the first important criterion and the second important criterion.

For sample problem, the new order of the criteria created according to $\overline{P_J}$ values is $C_{13} > C_4 > C_{10} > C_{14} > C_{11} > C_{15} > C_2 = C_5 > C_1 > C_8 > C_{12} = C_7 > C_{16} > C_3 > C_6 = C_{17} > C_9$. Table 3 shows this ordering and calculated s_j values of the criteria.

- ***Step 7.*** *Calculating of decision coefficients for decision criteria:* The decision coefficient expressed as c_j is calculated for each decision criterion using Eq. (2).

$$c_j = S_j + 1 \quad (2)$$

The c_j values obtained for the sample problem are shown in Table 3.

- ***Step 8.*** *Calculating of the corrected weights of the decision criteria:* The corrected weight value (S_j') is calculated using Eq. (3) for all decision criteria. While calculating the S_j' value, the ranking obtained according to $\overline{P_J}$ is taken into consideration and S_j' value of the first ranked criterion is equal to 1.

$$S_j' = \frac{S_{j-1}'}{c_j}, S_{j-1} > S_j \quad (3)$$

The S_j' values obtained for the sample problem are shown in Table 3.

- ***Step 9.*** *Calculating of the final importance weights for the decision criteria:* The final importance weight value (w_j) for all decision criteria is calculated using Eq. (4).

$$w_j = \frac{s_j'}{\sum_{j=1}^{n} s_j'} \tag{4}$$

The w_j values obtained for the sample problem are shown in Table 3.

Table 3. For all criteria $\bar{P}_j$, s_j, c_j, S_j' and w_j values

Criteria	$\bar{P}_j$	s_j	c_j	S_j'	w_j	*Criteria*	$\bar{P}_j$	s_j	c_j	S_j'	w_j
13	0.90	-	1.00	1.000	0.0766	*8*	0.56	0.01	1.01	0.728	0.0558
4	0.88	0.02	1.02	0.980	0.0571	*12*	0.52	0.04	1.04	0.700	0.0536
10	0.87	0.01	1.01	0.971	0.0744	*7*	0.52	0.00	1.00	0.700	0.0536
14	0.85	0.02	1.02	0.952	0.0729	*16*	0.47	0.05	1.05	0.667	0.0511
11	0.84	0.01	1.01	0.942	0.0722	*3*	0.32	0.15	1.15	0.580	0.0444
15	0.83	0.01	1.01	0.933	0.0715	*6*	0.26	0.06	1.06	0.547	0.0419
2	0.61	0.22	1.22	0.765	0.0586	*17*	0.26	0.00	1.00	0.547	0.0419
5	0.61	0.00	1.00	0.765	0.0586	*9*	0.25	0.01	1.01	0.541	0.0415
1	0.57	0.04	1.04	0.735	0.0563						

According to the values in Table 3, investment cost, income and qualified workforce criteria are the most important criteria for this problem. Operation cost, population and labor cost criteria are relatively less important among these criteria.

After determining the importance weights of the decision criteria with the SWARA method, TODIM method was used in the evaluation of 6 alternative countries in the proposed model and the alternatives were ranked.

3.2 The Second Stage in Problem Solution: TODIM method

The foundations of the TODIM method, which is one of the MCDM methods, were laid by Salminen (1994). The first successful applications of the method were made by Gomes and Lima (1992). TODIM is based on the expectation theory developed by Kahneman and Tversky (1979). With TODIM method, a ranking among the alternatives in the MCDM problem is aimed to obtain. To achieve this goal in the method, a value function is used, and the shape of this function is same as the gain and loss function in the expectation theory. With this function, the concepts of gain and loss can be expressed at the same time. In addition, this function can reflect the behavioral characteristics of the decision maker such as the selection of reference criteria or risk a version. This is an advantage of the method.

The 6 alternative cities of the proposed research model in solving the global location selection problem for the oral and dental health clinic were evaluated by following the steps of TODIM method (Guo et al., 2020; Aydoğan and Özmen, 2020; Dahooie and Dehghan, 2018):

- ***Step 1.*** *Determining of alternatives and criteria:* In the TODIM method, as in the SWARA method, n is the number of criteria and C_j is the set of criteria ($j = 1,\ldots, n$). Also, while m is the number of alternatives, A_i is the set of alternatives ($i = 1,\ldots, m$).
- ***Step 2.*** *Creating the initial decision matrix:* Using the values obtained for alternatives on the basis of criteria, the initial decision matrix is created with the help of Eq. (5).

$$X = [x_{ij}]_{m\times n} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (5)$$

The initial decision matrix for the sample problem is shown in Table 4. For preparing the decision matrix, objective data were collected for 15 of the 17 criteria within the scope of the problem. After the objective evaluation, the opinions of the experts, whose academic knowledge and work experience were given in Table 1, regarding C_1 and C_6 criteria were taken. Thus, these criteria have been evaluated by subjective data. In this subjective assessment, the criteria are scored between 1 and 5. If the alternative the more meets the relevant criterion, than takes higher score.

Table 4. Initial decision matrix of the sample problem

		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Condition		*min*	*Max*	*max*	*max*	*max*	*max*	*max*	*max*	*min*
w_j		*0.0563*	*0.0586*	*0.0444*	*0.0751*	*0.0586*	*0.0419*	*0.0536*	*0.0558*	*0.0415*
Alternatives	*1*	3	25	5.2	73855	6	4	30815	1.5	62
	2	3	5	5.3	11689	14	4	15595	2.4	78
	3	3	9	4.7	9675	33	4	5052	2.6	37
	4	4	15	5.1	35000	1.3	3	20774	1.4	80
	5	4	74	4.5	3217	72	3	1977	8.2	29
	6	3	15	4.5	8516	14	4	4771	1.5	68

		10	*11*	*12*	*13*	*14*	*15*	*16*	*17*
Condition		*max*	*Max*	*max*	*min*	*min*	*min*	*min*	*min*
w_j		*0.0744*	*0.0722*	*0.0536*	*0.0766*	*0.0729*	*0.0715*	*0.0511*	*0.0419*
Alternatives	*1*	47603	83019200	47	5907	45675	67	1547	2.95
	2	30370	46714997	42	4978	175961	125	1639	3.05
	3	53024	17333790	43	6902	65466	64	1530	8.24
	4	42943	55977000	41	21179	80443	156	1801	3.54
	5	78806	4921500	36	3170	65560	72	1390	4.6
	6	47518	11480534	41	4500	65012	69	1533	3.07

Step 3. *Removing the initial decision matrix from the cost-benefit effect of the criteria:* In MCDM problems, depending on the structure of the problem, some of the decision criteria used in the problem are benefit-based and some are cost-based. While benefit-based criteria are intended to be maximized, cost-based criteria should be minimized. With the help of Eq. (6) and Eq. (7) which are used in the WASPAS method this affect is removed for all benefit and cost criteria.

$$\overline{x_{ij}} = \frac{x_{ij}}{max_i x_{ij}} \quad \text{(for benefit criteria)} \quad (6)$$

$$\overline{x_{ij}} = \frac{min_i x_{ij}}{x_{ij}} \quad \text{(for cost criteria)} \quad (7)$$

In the sample problem, while Eq. (6) was used for 10 benefit-based criteria, Eq. (7) was used for 7 cost-based criteria.

- ***Step 4.*** *Obtaining the normalized decision matrix:* Normalization process is applied to the matrix that is cleared from the maximization and minimization effects of the criteria.

The normalized decision matrix for the sample problem are shown in Table 5.

Table 5. Normalized decision matrix without maximization and minimization feature of criteria

		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Alternatives	*1*	0.182	0.175	0.178	0.520	0.043	0.182	0.390	0.085	0.137
	2	0.182	0.035	0.181	0.082	0.100	0.182	0.197	0.136	0.109
	3	0.182	0.063	0.159	0.068	0.235	0.182	0.064	0.148	0.230
	4	0.136	0.105	0.174	0.247	0.009	0.136	0.263	0.080	0.106
	5	0.136	0.517	0.154	0.023	0.513	0.136	0.025	0.466	0.293
	6	0.182	0.105	0.154	0.060	0.100	0.182	0.060	0.085	0.125
		10	*11*	*12*	*13*	*14*	*15*	*16*	*17*	
Alternatives	*1*	0.159	0.378	0.187	0.154	0.255	0.204	0.168	0.210	
	2	0.101	0.213	0.169	0.183	0.066	0.109	0.159	0.203	
	3	0.177	0.079	0.170	0.132	0.178	0.213	0.170	0.075	
	4	0.143	0.255	0.162	0.043	0.145	0.087	0.145	0.175	
	5	0.262	0.022	0.146	0.287	0.178	0.189	0.187	0.135	
	6	0.158	0.052	0.166	0.202	0.179	0.198	0.170	0.202	

- ***Step 5.*** *Calculating of relative weights of the criteria according to the reference criteria:* After the calculation of importance weights (w_j) for all criteria, the reference criterion is decided by the decision maker. The reference criterion is the most important criterion for the decision maker. The relative weights of the criteria (w_{jr}) are calculated using Eq. (8).

$$w_{jr} = w_j / w_r \tag{8}$$

In the sample problem C_{13} (investment cost) was determined as a reference criterion. For all criteria, w_j values found by SWARA method and w_{jr} values found with TODIM method's step are shown in Table 6.

Table 6. w_j and w_{jr} values for all decision criteria

Criteria	w_j	w_{jr}	*Criteria*	w_j	w_{jr}	*Criteria*	w_j	w_{jr}
1	0.0563	0.7353	*7*	0.0536	0.7000	*13*	0.0766	1.0000
2	0.0586	0.7647	*8*	0.0558	0.7280	*14*	0.0729	0.9517
3	0.0444	0.5797	*9*	0.0415	0.5415	*15*	0.0715	0.9329
4	0.0751	0.9804	*10*	0.0744	0.9707	*16*	0.0511	0.6667
5	0.0586	0.7647	*11*	0.0722	0.6422	*17*	0.0419	0.5469
6	0.0419	0.5469	*12*	0.0536	0.7000			

- ***Step 6.*** *Calculating of dominance score:* When considering the C_j criterion, the dominance score of the A_i alternative over the $A_{i'}$ alternative is calculated using Eq. (9).

$$\varphi_j(A_i, A_{i'}) = \begin{cases} \sqrt{\dfrac{w_{jr}\left(r_{ij} - r_{i'j}\right)}{\sum_{j=1}^{n} w_{jr}}} & , \quad if \quad r_{ij} - r_{i'j} > 0 \\ 0 & , \quad if \quad r_{ij} - r_{i'j} = 0 \\ -\dfrac{1}{\theta}\sqrt{\dfrac{\left(\sum_{j=1}^{n} w_{jr}\right)\left(r_{i'j} - r_{ij}\right)}{w_{jr}}} & , \quad if \quad r_{ij} - r_{i'j} < 0 \end{cases} \tag{9}$$

$r_{ij} - r_{i'j} > 0$ and $r_{ij} - r_{i'j} < 0$ show the gain or loss of the A_i alternative versus the $A_{i'}$ alternative for the first criterion. Here θ is the factor for reducing losses. It is $\theta > 0$ and as this value changes, the shape of the expectation value function changes in the negative region of the coordinate system (Sen et al., 2015).

- ***Step 7.*** *Adding up all dominance scores for alternatives*: The dominance scores of the A_i alternative over the alternative $A_{i'}$ calculated for all criteria are summed up by using Eq. (10).

$$\delta(A_i, A_{i'}) = \sum_{j=1}^{n} \varphi_j (A_i, A_{i'}) \tag{10}$$

- ***Step 8.*** *Calculating of global values of alternatives:* By normalizing the dominance scores calculated in the previous step, the global dominance score (ζ_i) of the A_i alternative is calculated by Eq. (11).

$$\zeta_i = \frac{\sum_{i'}^{m} \delta(A_i,A_{i'}) - \min \sum_{i'}^{m} \delta(A_i,A_{i'})}{\max \sum_{i'}^{m} \delta(A_i,A_{i'}) - \min \sum_{i'}^{m} \delta(A_i,A_{i'})} \quad (11)$$

The alternatives are ranked in descending order according to their calculated global dominance scores. The alternative with the highest global dominance score is the most suitable alternative.

In the sample application, for each alternative the dominance scores based on all criteria relative to each other were calculated and then the global dominance scores of alternatives were determined. The global dominance score for each alternative and the rankings of the alternatives according to this score are shown in Table 7.

Table 7. δ and ζ values and the ranking

Alternatives		δ	Z	Ranking
1	*Germany*	-18.839	1.000	**1**
2	*Spain*	-47.704	0.310	5
3	*Netherlands*	-41.821	0.451	3
4	*England*	-60.660	0.000	6
5	*Ireland*	-38.907	0.520	2
6	*Belgium*	-42.009	0.446	4

Ranking among alternative cities according to the global dominance scores given in Table 7 was found as $A_1 > A_5 > A_3 > A_6 > A_2 > A_4$. Accordingly, Germany has been determined to be the most suitable alternative for the solution of sample problem.

For the oral and dental health center, which is planned to be established to serve in the global market, according to the model proposed within the scope of this study, it has been found that Germany is the most suitable alternative city by using the SWARA-TODIM methods, which are used sequentially. According to the data obtained with solution phases, Ireland is the second most suitable country after Germany and the Netherlands is the third most suitable country for such an investment.

Based on all these results income, qualified labor force and investment cost criteria have played an active role in the evaluation.

4. Conclusion

In this study, MCDM model was proposed for the solution of global location selection problem for an oral dental health center and this proposed model was solved by using SWARA and TODIM techniques together. Within the scope of the study carried out, the importance weights of the criteria in the problem were determined by using the SWARA technique and the city location alternatives were evaluated within the scope of these criteria and ranked by the TODIM method.

The establishment and solution phase of the problem addressed within the scope of the study were conducted based on previous research in literature and the help of oral and dental health sector managers, professionals, and dentists. According to all the data and information obtained, alternative countries were evaluated for both subjective and objective criteria.

As a result of all evaluations, investment and labor costs, qualified workforce opportunity and country income status were determined as the most important criteria among 17 criteria determined for the global location problem of an oral and dental health clinic. These criteria were followed by the population of the country, operation cost and medical technology criteria. After determining the importance weights of the criteria by using SWARA method, Germany with 0.9845 global dominance score, was found to be the most suitable country for such a center by using TODIM method. The result, which is obtained by TODIM method that is based on the expectation theory and measures the sensitivity of the solution, is compatible with Germany's population, income status, operation, investment and labor costs structure. According to the data obtained, the most suitable cities for this investment that can be made in the global market are Ireland with 0.8467 global dominance score and the Netherlands with 0.6800 global dominance score after Germany.

This study is the first study in the literature for the selection problem of global location in the oral and dental health sector. By establishing a model that does not exist in the literature, the integrated SWARA-TODIM technique has been applied to this problem for the first time in a sectoral sense. This model created can be integrated into different sectors that want to invest in the global market, and the solution technique of the study can guide and be a solution for other MCDM problems.

For elimination of the experienced due transportation problems of existing oral and dental health centers due to the wrong location selections and accordingly the insufficient service capacity problems, in future of increasing the number of these and similar studies will be beneficial for public health. In future studies to be carried out in this context, increasing the number of alternative countries and the number of criteria will support the model. Increasing the number of experts whose knowledge are consulted in the method will provide a significant gain in determining the importance of the criteria. Moreover, the proposed or developed model can be used in both the same and different sectors to make a wider evaluation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Author's Contributions

Authors contribute equally to the article.

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