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AN INTEGRATED FUCOM-RAFSI MODEL FOR ASSESSING THE POTENTIAL OF A NEW GATEWAY PORT IN LIBYA FOR SOME AFRICAN LANDLOCKED COUNTRIES

Abstract: *The present paper aims at suggesting a multi-criteria decision-making model that would help in making the appropriate decision regarding the selection of the best gateway port for landlocked countries. There are 44 landlocked countries around the world, which do not have a seaport directly linked to the rest of the world. Sixteen of these countries are located in Africa, making it weak to compete in the global market, in addition to the high costs of its imports. The model proposed in this paper was applied to two landlocked countries in the African continent: Chad and Niger. The paper proposed 8 evaluation criteria related to evaluating the ports themselves in terms of infrastructure and services tariffs, as well as to the level of safety and the transport infrastructure from the transit country to the landlocked one. The Full Consistency Method (FUCOM) was used for the purpose of evaluating such criteria, and the number of navigation lines was the most important one. Ranking of Alternatives through Functional mapping of criterion sub-intervals into a Single Interval (RAFSI) method was used for the purpose of comparing 6 ports to conclude that the Misurata seaport is the best alternative.*

Keywords: *Land locked Countries; Africa; Supply chain management; Sea ports*

1. Introduction

Maritime shipping accounts for around 80% of global trade by volume (Dellink et al., 2017). Hence, there is an extra burden on international trading for landlocked countries. The geographical location has a great impact on their economic status. It can be said that countries differ from each other in terms of their geographical characteristics. Landlocked countries stand for those countries that are surrounded by land from all directions and have no sea port. Therefore, such countries depend for their trade on the neighboring countries, by exploiting the shores of those countries at the disposal of their trade. They seek to obtain facilities from the ports of coastal states and the means of transportation to connect them to these ports. It then becomes difficult when the number of neighboring countries increases or the country in question is surrounded by other landlocked countries as well. It would lead to high transportation costs and difficulty of import and export, as landlocked countries may become hostages to coastal countries (Yang & Chang, 2019).

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Forcing landlocked countries to ship their goods through neighbouring maritime countries as their only outlet to the world; make them face many difficulties and challenges in terms of logistics. These challenges include weak infrastructure, high transport costs or inefficient transport networks, and corruption on land borders between countries crossed by shipments. Besides, bureaucracy in procedures, both at the ports of neighbouring maritime countries and at borders between them, is also a problem for transport operations (Pérez-Salas et al., 2014; Yang & Chang, 2019). It can also be argued that landlocked countries will be subject to the conditions of their neighbouring countries. Disturbances, strikes or congestion in the port of neighbouring countries will force the landlocked country to consider other alternatives to transportation, such as using a seaport in another country that may be further away, or using air transport for the purpose of transporting its goods (Radović et al., 2018b). These difficulties often result from the fact that the neighbouring countries of landlocked countries, such as landlocked countries in Africa or Latin America, are often developing countries, and thus suffer from poor potential and weak logistics services. They also suffer from the fact that their staffs often lack the required logistical expertise, which in turn raises logistical operating costs. This, in turn, will often cause landlocked countries to bear international transportation costs about 50% higher than their maritime neighbours (Fanou & Wang, 2018). In addition, the lack of infrastructure is a major consequence of delays in delivery. If a landlocked country chooses another alternative to transportation, it would increase transport time and associated costs mostly.

All of abovementioned points will affect the final cost of both exports and imports to landlocked countries. While the value of wages in many African countries is low, logistics costs affect their competitiveness in international markets, where the cost of transport logistics in some African landlocked countries amounts to more than 60% of the value of their exports (Buyonge & Kireeva, 2008). Perhaps the weakness of the infrastructure in Africa, whether at the level of ports or at the level of transport networks between countries, exacerbates the crisis of the landlocked countries (Kawasaki et al., 2020). It therefore prompts many of such countries to seek more effective solutions to logistics and transport problems, as well as new outlets that have more effective procedures for completing their cargo plans.

The number of landlocked countries in the world is now 44 countries, including 16 countries in the African continent: Botswana, Burundi, Central Africa, Chad, Lesotho, Malawi, Mali, Niger, Zimbabwe, Rwanda, Swaziland, Uganda, Burkina Faso, Zambia, Ethiopia and South Sudan. The geographical conditions of Africa's low, meandering coasts have impeded the establishment of natural ports, in addition to the high mountains that have no passages in its coasts, as well as the presence of sand depressions, swamps and forests (Acquah, 2018).

Primary materials represent a great part of exports of the landlocked states in Africa. For instance, agricultural exports reach up to 60% of the total. This might be due to the fact that most African countries are extremely poor, with a high illiteracy rate, making industrial production and exports exceptionally frail. Perhaps the weakness of the infrastructure in Africa, whether at the level of ports or at the level of transport networks between countries, exacerbates the crisis of the landlocked countries

In many cases, shippers opt to export through ports with favorable transportation costs (Kashiha et al., 2016). Four forms of contact with transit neighbors were discussed by Faye et al. (Faye et al., 2004). They entail dependence on the facilities of neighbors, dependence on the institutional activities of neighbors, dependence on sound cross-border diplomatic ties, and dependence on the peace and security of neighbors.

In this paper, a hybrid model will be used for the purpose of evaluating a group of ports to be used as sea ports for the landlocked countries under study. The first model is FUCOM, which is used for the purpose of weighing the suggested standards, and the second model is RAFSI, which is used for evaluating the proposed ports.

2. Landlocked countries in Africa

African landlocked countries, shown in Figure 1, encounter many issues affecting the logistics of operations. These issues range from external risks, transport capabilities, logistics infrastructure, information integration, local agents' logistics capabilities to national law and policy (Yang & Chang, 2019). In addition to the challenges mentioned earlier, African landlocked countries face another challenge, namely, the long distance between transit ports and their capitals; the least distance is about 1000 km, as shown in Figure 2. Figure 2 illustrates the distances between the capitals of the African landlocked countries and the nearest port. As a matter of fact, the distance travelled will straightforwardly influence costs. More than that, transport decisions are impacted by the nature of relations with neighbouring countries. They also suffer from the high cost of transportation in their territories due to poor infrastructure. In terms of port delays, African landlocked countries suffer from the fact that waiting periods in transit ports for the purpose of completing procedures can reach up to 40 days (AfDB, 2010). For example, approximately 50% of transport time in many sub-Saharan African ports is spent by neighbouring countries' ports to complete the required routine customs clearance procedures related to shipped goods. This significantly affects exports of perishable products. Some studies suggest that a day's delay is equivalent to an additional 85 km transport cost, and a one-day reduction in transit time could expand exports by up to 7%. A weak infrastructure of 25% contributes to delays on the African continent, while 75% is due to bureaucracy and weak procedures. African countries also suffer from the fact that their trucks are not allowed to pass through transit States, which means that the trucks will be empty on return trips, resulting in higher costs (UN, 2013).

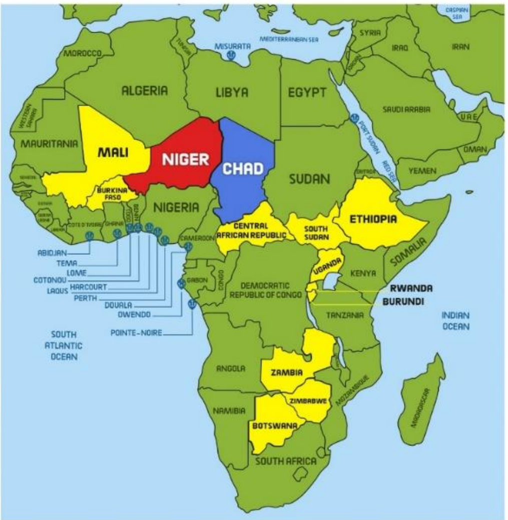

Figure 1. Landlocked countries in African continent.

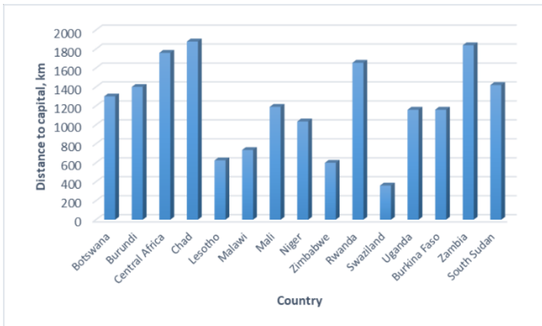

Figure 2. Distance between landlocked countries capitals and the nearest seaport.

In the present paper we will focus on two landlocked countries: Chad and Niger, where we will present the current transit ports of these two countries. Although the two countries are currently using different ports of entry, we will study them together for the purpose of comparison with another port that may be a suitable opportunity as a new access point for both countries.

Niger: Studies show that Niger is among the poorest countries in the world. Figure 3 shows five different transit ports to reach the Nigerien capital:

- The port of Cotonou: The railway can be used until the Nigerien borders and then the road.
- Port of Laqus, Nigeria: Road routes can be used.
- The port of Lome in Togo: From the port of Burkina Faso to the Niger
- Port of Tema in Ghana: From Burkina Faso to Niger.
- Abidjan, Ivory Coast: From Burkina Faso to Niger.

Figure 3. Current transient ports to reach Nigerian capital

As far as this area is concerned, certain observations are made as follows:

- The existence of civil conflicts that have damaged transport infrastructure, in addition to the difficulty of mobility due to heightened security measures, lead to delays in arrival.
- The poor infrastructure and port facilities in West Africa make it difficult to receive large ships.

Chad: It is also one of the poorest countries in the world and has three ports, as shown in Figure 4:

- Port of Douala in Cameroon: Road and railways can be used.
- Nigeria's port of Perth: Rail and road can also be used here for transportation.
- The Port of Pointe Noire in Congo: The longest reaches Chad, where it passes through Central Africa.

Figure 4. Current transient ports to reach N'Djamena

It can also be said that ports in the eastern region have increased insurance costs as a result of occasional piracy, and their geological damage is rough. Table 1 shows the distance from the ports proposed in the study to the capitals of Chad and Niger.

Table 1. Distance from the proposed ports to the studied capitals

Port / Capital	Niamey	N'Djamena
Douala	1300	1050
Cotonou	790	1500
Misrata	2400	2100
Harcourt	1100	1200
Port Sudan	3800	2500
Laqus	780	1400

3. METHODS

In recent years, there has been an increase in interest in studies in multi-criteria decision-making problems. These decisions are complex in nature as a result of the lack of information on the problem, the often different nature of the criteria and the difficulty of determining the relevance of a criteria to another. In the area of logistics and transportation, many applications have emerged (Vesković et al., 2018; Blagojević et al., 2020). To identify the most important factors that affecting the gateway selection for landlocked countries, a two-step multi criteria model including a case study of two countries in Africa were conducted in this paper. The first step includes the definition of the influencing criteria on selecting the the best gateway. This step was done by comprehensive reviewing the literature conducted in this area, as well as contacting a group of experts. The second step was the ranking of the alternatives. The multi criteria decision making techniques are very appropriate for such complicated problems.These problems require dealing with more than one criterion in order to solve them and reach an appropriate decision regarding them (Radović et al., 2018). Several methods have recently been developed that can solve these complex problems (Eshtaiwi et al., 2018; Badi & Ballem, 2018; Pamučar et al., 2018; Badi & Pamucar, 2020). The method used in this research is a compined FUCOM-RAFSI method.

3.1 FUCOM method

One of the most used methods is the hierarchical analysis method (AHP), which is based on the principle of pairwise comparison (Bouraima et al., 2020). In order to eleminate some of the deficiencies of this method, new methods have been proposed, including the Best Worst Method (BWM) and the Full Consitency Method (FUCOM) (Badi & Abdulshahed, 2019). One of the most important features of the FUCOM method is the need for a few number of pairwise comparisons, as well as the calculation of the deviation from maximum consistency (DMC), which helps in validating the results (Badi & Kridish, 2020). With the FUCOM method, decision-makers can rank and compare their preferences. This clearly leads to much fewer comparisons than needed by the AHP method. This method has been widely used during the past two years in many applications, and has been combined with many other MCDM methods (Nunić, 2018; Đorđević et al., 2019; Fazlollahtabar et al., 2019; Durmić, 2019).

In order to illustrate the steps of the FUCOM method for determining weights in multi-criteria models, n parameters are assumed. The decision-makers will determine the weights of these parameters. The FUCOM algorithm can be explained as follows (Pamučar et al., 2018).

Algorithm: FUCOM

Input: The pairwise comparison of criteria by experts

Output: Optimal values of the criteria/sub-criteria weight coefficients

Step 1: Ranking the criteria/sub-criteria by the experts.

Step 2: Determining the significant comparative vectors of the criteria.

Step 3: Defining the model constraints.

Constraint 1: The ratio of the criterion weight coefficients is equal to the comparable value of the parameters found, i.e. $\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)}$.

Constraint 2: The coefficients weight values should meet the mathematical transitivity condition, i.e. $\varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} = \varphi_{k/(k+2)}$.

Step 4: A model is defined to determine the final value of the weight coefficients of the criterion for assessment:

$$\left|\frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)}\right| \leq \chi, \forall j$$

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

$$w_j \geq 0, \forall j$$

Step 5: The final values of evaluation criteria/sub-criteria is calculated: $(w_1, w_2, \ldots, w_n)^T$.

3.2 RAFSI method

RAFSI method is one of the newest MCDM methods developed by Žižovi´c et al. (Žižović et al., 2020). For m alternatives A1, A2, …. An which have different weights wj, where j=1, 2, …, n, the initial decision matrix can be written as follows (Žižović et al., 2020):

$$N = \begin{bmatrix} n_{11} & n_{12} & \ldots\ldots\ldots & n_{1n} \\ n_{21} & n_{22} & \ldots\ldots\ldots & n_{2n} \\ & & \ddots & \\ n_{m1} & n_{m2} & \ldots\ldots\ldots & n_{mn} \end{bmatrix}$$

The criteria can be of maximizing type (max) or minimizing type (min). Using such data and applying the model R based on the following steps:

Step 1: Define ideal and anti-ideal values. For each criterion $C_j (j = 1,2,..,n)$ the decision-maker defines two values a_{I_j} and a_{N_j}, where a_{I_j} represents ideal value of criterion C_j, while a_{N_j}represents anti-ideal value of criterion C_j.

Step 2: Mapping of elements of initial decision matrix into criteria intervals. Based on the defined ideal and anti-ideal values, functions $f_{A_i}(C_j)$ are defined, which map the criterion intervals from the aggregated initial decision matrix (N) to the criterion interval$[n_1, n_b]$. Criterion functions are defined for each criterion from the set C_j $(j = 1,2,\ldots,n)$.

$$\tilde{f}_{A_i}(C_j) = \frac{n_b - n_1}{n_{I_j} - n_{N_j}} n_{ij} + \frac{n_{I_j} \cdot n_1 - n_{N_j} \cdot n_b}{n_{I_j} - n_{N_j}} \quad (1)$$

where n_b and n_1 represent the ratio that shows how much the ideal value is better than the anti-ideal value, while n_{ij}denotes the value of the i-th alternative for the j-th criterion from the initial decision matrix.

It is suggested that the ideal value is at least six times better than the anti-ideal (barely acceptable value), or $n_1 = 1$ and $n_b = 6$. However, the DM can use the other preferred values, for example $n_1 = 1$ and $n_b = 9$. In this way, the standardized decision matrix$S = [s_{ij}]_{m \times n}$ $(i = 1,2,\ldots,m,\ j = 1,2,\ldots,n)$ is obtained in which all elements of the matrix are mapped into the interval $[n_1, n_b]$.

Step 3: For the minimum and maximum sequence of elements, n1 and n2k, the arithmetic and harmonic means are determined using the expressions (2) and (3).

$$A = \frac{n_1 + n_{2k}}{2} \quad (2)$$

$$H = \frac{2}{\frac{1}{n_1} + \frac{1}{n_{2k}}} \quad (3)$$

Step 4: Form normalized decision matrix $\hat{S} = [\hat{s}_{ij}]_{m \times n}$ $(i = 1,2,\ldots,m, \quad j = 1,2,\ldots,n)$. Using expressions (4) and (5), elements of matrix S are normalized, and transferred into the interval [0,1]:

a) for the criteria C_j $(j = 1,2,\ldots,n)$ max type:

$$\hat{s}_{ij} = \frac{s_{ij}}{2A} \quad (4)$$

b) for the criteria C_j $(j = 1,2,\ldots,n)$ min type:

$$\hat{s}_{ij} = \frac{H}{2s_{ij}} \quad (5)$$

In this way, a new normalized decision matrix is created, as shown below:

$$\hat{S} = \begin{matrix} & C_1 & C_2 & \ldots & C_n \\ A_1 & \hat{s}_{11} & \hat{s}_{12} & \cdots & \hat{s}_{1n} \\ A_2 & \hat{s}_{21} & \hat{s}_{22} & \cdots & \hat{s}_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & \hat{s}_{m1} & \hat{s}_{m2} & \cdots & \hat{s}_{mn} \end{matrix} \quad (6)$$

where$\hat{s}_{ij} \in [0,1]$represents normalized elements of matrix$\hat{S}$.

Step 5: Calculate the function parameters of the alternatives V(Ai). Expression (7) is used to calculate the criteria functions of the alternatives. Calculated V(Ai) is then used to rank the alternatives in descending order.

.

$$V(A_i) = w_1\hat{s}_{i1} + w_2\hat{s}_{i2} + \ldots + w_n\hat{s}_{in} \quad (7)$$

4. Results and discussion

The selection between ports requires the existence of a set of criteria. We have established an initial group of criteria to fit the African continent situation, with reference to the past research in the field, in addition to experts' perspectives on maritime transport and supply chain management. We have set out eight criteria, as follows:

C1: Number of navigation Lines

C2: Port's Service-Level

C3: Port fees

C4: Distance between the seaport and the capital of the landlocked country

C5: Transport Infrastructure Availability

C6: Safety-Level and relations with neighboring countries

C7: Number of countries through which the shipment will pass

C8: Nature of the terrain

Where Ci is the criteria number i.

Where C3, C4, and C7 are cost criterion, while other criterion are benefit.

It can be noted that the first three criteria are port-related in the transit country, centered on the level of services provided in those ports, the value of port fees and the existence of regular navigation lines on those ports. The rest of the criteria are related to transport to and from the capital of the landlocked country, such as the distance from the port to the capital of the country, as well as the availability of infrastructure relative to roads, railways and a fleet of land transport.

Step 1. Decision made on the ranking of the criteria is performed as follows: C1> C2> C4> C7 >C3>C5>C6>C8.

Step 2. From the first step, the decision-maker compares the rating parameters pairwise. The comparison is made with respect to the first graded criteria of C_1 on the scale [1,9]. The priorities of the criteria ($\varpi_{Cj(k)}$) were therefore obtained for all the criteria ranked in the first level as follows:

$\varpi_{Cj(k)} = \{1.0, 2.6, 3.5, 4.0, 5.0, 6.0, 6.5, 7.0\}$

Based on the obtained priorities of the criteria, the comparative priorities of the criteria are calculated:

$\varphi_{C_1/C_2} = 2.6/1.0 = 2.6$, $\varphi_{C_2/C_4} = 3.5/2.6 = 1.35$, $\varphi_{C_4/C_7} = 4.0/3.5 = 1.14$

$\varphi_{C_7/C_3} = 5.0/4.0 = 1.25$, $\varphi_{C_3/C_5} = 6.0/5.0 = 1.2$, $\varphi_{C_5/C_6} = 6.5/6.0 = 1.08$

$\varphi_{C_6/C_8} = 7.0/6.5 = 1.08$

Step 3. The final weight value coefficients shall comply with the following conditions:

a) The final values of the weight coefficients should meet the condition (3), i.e., that:

$$\frac{w_1}{w_2} = 2.6, \frac{w_2}{w_4} = 1.35, \frac{w_4}{w_7} = 1.14, \frac{w_7}{w_3} = 1.25, \frac{w_3}{w_5} = 1.2, \frac{w_5}{w_6} = 1.08, \frac{w_6}{w_8} = 1.08$$

b) Additionally, the final weight coefficient values should comply with the mathematical transitivity:

, i.e., that

$$\frac{w_1}{w_4} = 3.5, \frac{w_2}{w_7} = 1.54, \frac{w_4}{w_3} = 1.43, \frac{w_7}{w_5} = 1.5, \frac{w_3}{w_6} = 1.3, \frac{w_5}{w_8} = 1.17$$

By applying the expression (5), the final model for determining the weight coefficients can be defined as:

min χ

$$\text{s.t}\begin{cases} \left|\frac{\omega_1}{\omega_2}-2{,}6\right|\le\chi, \left|\frac{\omega_2}{\omega_4}-1{,}35\right|\le\chi, \left|\frac{\omega_4}{\omega_7}-1{,}14\right|\le\chi \\ ,\left|\frac{\omega_7}{\omega_3}-1{,}25\right|\le\chi, \left|\frac{\omega_3}{\omega_5}-1.2\right|\le\chi, \left|\frac{\omega_5}{\omega_6}-1{,}08\right|\le\chi \\ \left|\frac{\omega_6}{\omega_8}-1{,}08\right|\le\chi, \left|\frac{\omega_1}{\omega_4}-3{,}5\right|\le\chi, \left|\frac{\omega_2}{\omega_7}-1{,}54\right|\le\chi \\ \left|\frac{\omega_4}{\omega_3}-1{,}43\right|\le\chi, \left|\frac{\omega_7}{\omega_5}-1{,}5\right|\le\chi, \left|\frac{\omega_3}{\omega_6}-1{,}3\right|\le\chi \\ \left|\frac{\omega_5}{\omega_8}-1{,}17\right|\le\chi; \\ \sum_{j=1}^{5}\omega_j=1, \omega_j\ge 0, \forall j \end{cases}$$

Solving the above model using MS excel solver and according to the values of criteria marks are given, establishing the final values of the weight constants and DFC of the results as χ = 0.0.

Figure 5 shows that the first criterion, the number of navigation lines, was the most important one, which can be justified by the fact that it has an impact on the cost of transportation as well as the timely provision of goods. The second criterion, exemplified in the level of service, also obtains the following importance as it influences the quality and speed of the service, and hence affecting the total cost of goods. The aforementioned two criteria represent approximately 50% of the selection decision between sea ports in the proposed model, which was done using FUCOM method.

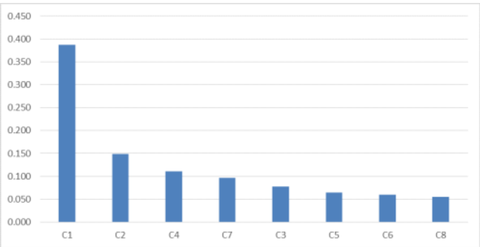

Figure 5. The value of decision criteria

In order to find the best alternative among the suggested sea ports using RAFSI method, the initial decision matrix is firstly created by experts as follows:

$$N=\begin{bmatrix} 80 & 60 & 60 & 1200 & 60 & 45 & 40 & 6\\ 75 & 55 & 65 & 1100 & 60 & 45 & 80 & 5\\ 85 & 85 & 30 & 2300 & 75 & 65 & 40 & 8\\ 80 & 50 & 60 & 1200 & 50 & 40 & 40 & 7\\ 70 & 60 & 55 & 3100 & 50 & 50 & 80 & 6\\ 70 & 60 & 55 & 1100 & 50 & 50 & 80 & 5 \end{bmatrix}$$

RAFSI method can be implemented following the steps below.

Step 1: The definition of ideal and anti-ideal values of the criteria has been set by DMs.

a_{I_j} = [100, 100, 20, 750, 100, 100, 50, 10]

a_{N_j} = [30, 20, 100, 4000, 30, 20, 30, 3]

Step 2: The criteria interval now can be formed as follows:

(a) For criteria with maximization objective

$C_1 \in [30,100]$; $C_2 \in [20,100]$; $C_5 \in [30,100]$; $C_6 \in [20,100]$; $C_8 \in [3,10]$

(b) For criteria with maximization objective

$C_3 \in [20,100]$; $C_4 \in [750, 4000]$; $C_5 \in [30,100]$

Step 3: Calculating the arithmetic and harmonic means of minimum and maximum elements n_1 = 1 and n_{2k} = 6.

Step 4: The elements of matrix S are now normalized and transformed. New matrix is developed as follows:

$$\hat{S} = \begin{bmatrix} 0.65 & 0.50 & 0.24 & 0.51 & 0.45 & 0.37 & 0.12 & 0.45 \\ 0.60 & 0.46 & 0.22 & 0.56 & 0.45 & 0.37 & 0.29 & 0.35 \\ 0.70 & 0.72 & 0.53 & 0.25 & 0.60 & 0.54 & 0.12 & 0.65 \\ 0.65 & 0.41 & 0.24 & 0.51 & 0.35 & 0.32 & 0.12 & 0.55 \\ 0.55 & 0.50 & 0.27 & 0.19 & 0.35 & 0.41 & 0.29 & 0.45 \\ 0.55 & 0.50 & 0.27 & 0.56 & 0.35 & 0.41 & 0.29 & 0.35 \end{bmatrix}$$

Step 5: Table 2 shows the criteria functions $V(A_i)$ of the alternatives. These values are used to rank the alternatives.

Table 2. Ranking of the studied ports

Alternative	V (A_i)	Rank
P1	0.4900	**2**
P2	0.4779	**3**
P3	0.5686	**1**
P4	0.4730	**4**
P5	0.4287	**6**
P6	0.4643	**5**

The results of the model show that the sea port of Misrata represents a good opportunity for such landlocked countries, as it is located on a path with high navigation traffic, and the level of services at this port is acceptable. Transport to southern Libya is currently carried out by convoys of freight trucks, and no railways are available. To the best of our knowledge, so far there is no clear study from the Libyan state on the construction of a railway line. The city has a fleet of about 6,000 trucks, an iron and steel factory, an industrial activity and a port. Given the exchange with European countries, Misrata sea port is certainly the best option as it is within a very close proximity to European ports. The fact that West African ports are away from the denser (Mediterranean) navigation lines makes them the best option for exchanges with East Asia. There are paved roads of approximately 600 kilometers from Chad's border, and then there is a dirt road. Hence, it requires the completion of the road construction to facilitate transport movement. However, future reliance on railways may be technically difficult because of the desert nature, which results in the sand moving continuously and dramatically, leading to railway tracks being covered with wind-blown sand.

Because of the complexity of the decision-making process and the use of human assessment in this process, which includes the possibility of human errors, a sensitivity analysis of the results obtained is resorted to. There are several ways to perform this analysis such as changing the weight of the criteria, comparing with other methods as well as making changes in criteria types (cost / benefit). The results obtained here will be compared with the results obtained from other methods. Figure 6 illustrates the comparison of results with three other methods: TOPSIS, VIKOR and SAW. It is noted that the results obtained here are very similar to the previous findings, except for one difference between the order of the second and fourth alternatives, which indicates the reliability of the model outcomes.

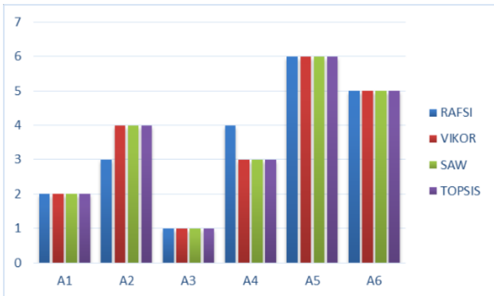

Figure 6. Sensitivity analysis

5. Conclusion

There are several African countries that face the problematic status of being landlocked; they are not directly coastally accessible. This results in several issues like the high cost of imports, and the low ability to compete international markets. In order to reduce such problems, it is required to create methods for integrating regional infrastructure so as to build global commercialism and make such nations easily accessible. Therefore, it is advised to conclude regional deals between landlocked and transit nations. Port development in the African continent is also a key to the growth of international trade for its countries. The study has developed a multi-standard model that contributes to the appropriate decision regarding the selection of the sea port that is most suitable for the landlocked countries. Such model has been based on eight evaluation criteria, and has been applied to six alternatives as substitute ports for two states in Africa. The same model can also be used for the rest of Africa's landlocked countries or the rest of the world's continents.

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