Supporting the decision for new pharma manufacturing facility location: the African case

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Abstract: COVID19 emphasized the already existing vulnerability of Africa's pharmaceutical industry, mainly due to the limited local production of health products. The pharmaceutical industry is a priority sector under different global frameworks and initiatives. Besides, the free trade area within the African continent recently took effect; hence there is a need to accelerate and sustain local production. One of the main objectives being promoted is to leverage the private sector, attract investment and support SMEs in local production. A fundamental factor in encouraging companies to settle the production in the continent is providing them with recommendations on the location choice to seize opportunities and limit risks. This research aims to identify critical criteria that pharmaceutical companies need to assess to start local production in developing countries, focusing on African ones. Specifically, the identified criteria can be integrated into a previously developed Multi-Criteria Decision-Making (MCDM) model and applied to a leading pharmaceutical company. To identify the criteria, a literature review on the African pharmaceutical sector was carried out first, followed by a questionnaire and interviews with pharmaceutical industry representatives. The results lead to adding one new macro-criterion, i.e., the market access, and 14 additional sub-criteria to the existing model. Furthermore, model application results show South Africa as the ideal African country for pharmaceutical manufacturing settlement, finding a congruent correspondence in reality. This paper gives recommendations on key elements on which the African government should focus to advance Africa's pharmaceutical and health industries investments and proposes an effective model boosting local production investments giving companies more confidence in setting pharmaceutical industry in Africa.

Keywords: Facility Location Problem, Multi-criteria Decision-Making Model, Pharmaceutical African manufacturing, Pharma Location

I. INTRODUCTION

Local Pharmaceutical Production (LPP) is progressively more vital for developing countries. Indeed, LPP allows access to quality medicines, contributing to people's health and Inclusive and Sustainable Industrial Development (ISID): United Nations Industrial Development Organization (UNIDO) has continued to provide technical cooperation and consultant to promote LPP in developing countries with public and private partners [1]. Technical guidance to companies to incentive LPP is needed to achieve the third goal of the Sustainable Development Goals (SDGs), namely universal health coverage [2]. The pharmaceutical plant location choice is among the technical guides encouraging private companies to invest in developing countries to best suit their requirements and industrial processes. The most significant number of developing countries is found on the African continent. Regardless, Africa is still strongly dependent on imports for many health products; hence strengthening Africa's health care industries requires addressing several interconnected challenges, primarily to support local manufacturing and attract private sector investment [3]. Existing facility location Multi-Criteria Decision-Making (MCDM) models are unsuitable for pharmaceutical industries in developing countries. Specifically, a facility location MCDM model to support manufacturing companies in developing countries exists [4]; however, the criteria are not specific enough for the pharmaceutical industry, which has the most stringent process requirements among all manufacturing industries.

Therefore, this paper aims to redesign the existing model with more appropriate criteria for the pharmaceutical industry and then apply it to a case study, obtaining the ranking of countries to locate the production site.

First, a review of the limitations and opportunities of the pharmaceutical sector in African countries has been conducted to collect the most relevant criteria for pharmaceutical companies when choosing the location of their production plant in developing countries. Then, the identified criteria were validated and integrated through interviews with a representative of a leading company in the global pharmaceutical market. Finally, the model was applied to a pharmaceutical company and African countries, generating effective results once integrated. After the literature review, the identified macro-criteria and sub-criteria are presented. Next, the multi-criteria decision model is applied to a leading pharmaceutical company, and the gathered criteria weights are discussed. Subsequently, the model results and three sensitivity analyses are reported. Finally, conclusions and further development are highlighted.

II. LITERATURE REVIEW

First, the limitations and opportunities that characterize the pharmaceutical sector of the African continent are examined. Second, the existing facility location models are described, highlighting their limitations in applying to pharmaceutical industries. According to an analysis proposed by McKinsey [5], Africa could be the only pharmaceutical market where high growth can still be achieved. Even though Africa is growing strongly and rapidly, not all nations have the same level of development. Access to basic infrastructure is critical for the sustainability of a pharmaceutical manufacturing sector: variables such as access to water and energy sources and ease of product distribution through timely logistics are crucial [6]. Despite the recent expansion of its manufacturing sector, Manufacturing Value Added (MVA) per capita in Africa is still relatively low. These problems indicate how challenging it is to invest in manufacturing in all African regions regarding the quality of human capital, infrastructure and policy gaps, and regulatory failures [7]. First, despite abundant cheap and underpaid labor, Africa's workforce lacks skills and efficiency [8]. Only 10 African countries are ranked in the top half for "Wages versus Productivity" in the World Economic Forum's Global Competitiveness Index [9]. Unable to locate sufficiently skilled workers in local labor markets, many companies have endorsed this problem by using foreign workers or investing in intensive training courses [10]. Although spending on infrastructure has more than doubled since the turn of the century, amounting to $80 billion in 2015 [11], gaps in energy infrastructure remain persistent in many countries, often resulting in frequent power outages. In most African countries, pharmaceutical production is considered a national priority [3], but many countries have incomplete information about the size of their pharmaceutical market [6]. In addition, COVID-19 stressed the vulnerability of African developing countries: these still rely on imported medicines and vaccines [3] [12]. More generally, for all developing countries, UNIDO has gathered lessons from industry leaders on creating a thriving vaccine production business in low and middle-income nations: among the aspects that have driven sustainable vaccine production like human capital, technical know-how, salaries, location, local regulatory functionality, financial viability, market, and commercial considerations [13]. Another fundamental characteristic to consider is the process involved in starting pharmaceutical production. On average, it takes 24 days to register a company in the countries surveyed, and foreign ownership of 100% of companies is allowed only in 60% of countries. Despite the limitations, several authors [14] [5] [15] [16] [17] [18] [19] and reports compiled by organizations [2] [20] have highlighted the numerous opportunities in starting pharmaceutical manufacturing in Africa. The pharmaceutical manufacturing establishment in Africa represents an opportunity for companies as the pharmaceutical market is currently far from saturated. There is a considerable growth prospect due to urbanization, healthcare capacity, and the business environment progressing rapidly. There have been plans to strengthen policies to encourage local production in the last decade. Many African factories obtain World Health Organization (WHO) prequalification, which helps the most advanced manufacturers adhere to Good Manufacturing Practice (GMP). National strategies are currently being developed to promote the pharmaceutical industry. In addition, plans have been established to strengthen regulatory systems that represent a significant opportunity for improvement for the pharmaceutical sector in Africa. Indeed, each country has a National Medicines Regulatory Agency (NMRA). However, these opportunities are rarely taken up by companies looking to expand their pharmaceutical production due to the enormous misinformation about developing countries. Specifically, there are no quantitative methods in the literature to help these companies choose the optimal location of a pharmaceutical manufacturing plant in these countries. A previous study [4] presents the multi-criteria decision-making model for manufacturing companies in developing countries. However, a focus on the more stringent requirements of the pharmaceutical sector is absent in the literature. Indeed, the first way to overcome the barriers to entry is to identify decision-making criteria that contribute to the choice of the territory to set up a manufacturing plant for any manufacturer [21]. The existing literature on Facility Location Problems and Multi-criteria Decision-Making Models, contextualized in the pharmaceutical sector of developing countries, are more focused on studying the optimal location of public facilities, such as hospitals and ambulance stations, and private facilities, such as pharmacies and doctors' offices [22] [23]. Also, a multi-criteria decision-making model has been used to assess the capacity of the existing healthcare facility in Surakarta, Indonesia, to meet the public demand [24]. Another part of the literature focused on studying the optimal location of pharmaceutical warehouses but rarely of manufacturing facilities [25] [26]. Another study used a multi-criteria decision-making model to identify the location of additional Molecular Laboratories of the National Center for Disease Control (NCCDC), for adequate coverage of Local Government Areas (LGAs), during the COVID-19 pandemic in Nigeria [27]. Therefore, the literature review revealed the absence of multi-criteria decision models to support the plant location choice of the pharmaceutical industry, which, due to complex manufacturing processes, holds the most stringent manufacturing requirements. Therefore, it is as necessary as innovative the realization and implementation of a model that can guide companies in choosing the optimal location of a pharmaceutical manufacturing plant. An error in this choice would generate enormous problems for the entire community, such as increased mortality due to difficult access to medicines.

III. METHODOLOGY

As mentioned, this study aims to create a model for the location of pharmaceutical plants in developing countries, with a focus on African countries. The starting point is a previous model for manufacturing industries in general, trying to integrate it with more peculiar criteria for pharmaceutical production. In association with the criteria, there are indicators with country characteristics. As new criteria can be added to the model, it is also necessary to enrich the model with the indicators associated with these new criteria. Specifically, the existing multi-criteria decision-making model to support the location of manufacturing plants in Africa combines the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Indeed, AHP and TOPSIS have always found great favor from the academic community to be widely used and combined to collect the weights with AHP and generate the ranking of alternatives with TOPSIS. Specifically, AHP is one of the most widely used due to its ability to compare performance among numerous alternatives based on a complex hierarchical structure. TOPSIS can treat several criteria with different measurement units and efficiently process the decision-maker's preferences. Hence, using the AHP questionnaire, criteria weights can be collected; using TOPSIS, which takes indicators and criteria weights as input, a ranking of the most suitable countries for setting up the production facility can be generated. Precisely, the used TOPSIS methodology consists of five steps [28]:

I. Calculation of the normalized matrix of indicators.
II. Calculation of the weighted normalized matrix.
III. Calculation of best and worst ideal solution values.
IV. Calculation of Euclidean distances from the best and worst ideal solution.
V. Calculation, for each country, of the Si-, Si+ and the Performance Index, that is the ratio between Si- and the sum of Si- and Si+.

In the following paragraphs, it is first shown how the specific criteria for the pharmaceutical sector were integrated and validated. Then it is highlighted how the new country indicators associated with the criteria were identified.

A. Model Integration

The following steps have been followed to integrate and validate the new specific criteria for pharmaceutical production. First, through the literature analysis regarding the panorama of the developing countries, limits and opportunities are identified and listed. Also, existing multi-criteria facility location models were analyzed. Secondly, this gathered list of limitations, opportunities, and existing criteria can be collected and translated into new criteria suitable for choosing the location of a pharmaceutical manufacturing plant. In the third phase, following the criteria identification, a panel of pharmaceutical sector experts is requested to integrate and validate the proposed criteria to make the model as complete as possible. This step is carried out using questionnaires and interviews. A final list of criteria and sub-criteria can then be generated. Lastly, in the fourth phase, a dataset of indicators representing the characteristics of the African countries under analysis is identified to cover the criteria majority.

B. Macro-criteria and sub-criteria integration

This section analyses the first three steps, i.e., those that contribute to defining the criteria and sub-criteria. In the MCDM model previously developed [4], 7 macro-criteria and 34 sub-criteria for the location choice of a manufacturing plant in a developing country have been identified through literature reviews and several interviews with a panel of experts using the Delphi method. However, these criteria were validated considering manufacturing industries such as textiles, chemical cosmetics, or beverages, thus with much less stringent production requirements than the pharmaceutical industry. Following an in-depth literature review regarding the pharmaceutical sector's opportunities and limitations, the following criteria have been added:

- 1 new macro-criterion "Market Access", comprising six sub-criteria.
- 6 sub-criteria to be added among the macro-criterion "Policy Aspects".
- 1 sub-criterion to be added to the "Supply and Sales Logistics" macro-criterion.
- 1 sub-criterion to be added to the "Labor Qualification and Cost" macro-criterion.

Subsequently, these macro-criteria and sub-criteria were validated through a questionnaire and an interview with a leading pharmaceutical company representative. The aim was to validate the established criteria and investigate whether other criteria were to be considered. As a result, all macro-criteria and sub-criteria were validated and, in addition, the following were integrated:

- 1 sub-criterion for "Supply and Sales Logistics".
- 2 sub-criteria for "Market Access".

Among the “Logistics of supplying and sale” criterion, quality of roads in terms of paved roads information has been added. Within the macro-criterion “Labor qualification and cost”, the relation between the religion of the country and the use of excipients was added: some religions do not approve certain excipients. Within the macro-criterion “Political Aspects”, it is essential to consider the timing of the registration of a new business and a new pharmaceutical product, the incentives in terms of taxes, the freedom of capital inflow and profit remittance, the efficiency of the state regulator in avoiding falsified and out of standards medicines. Furthermore, it is crucial to consider that some countries restrict local production if it has not established a partnership with a local company. Finally, the added macro-criterion “Market access”, contains all information regarding how a pharmaceutical company makes its product available after obtaining marketing authorization from a regulatory agency and the size of the pharmaceutical market itself [29]. It is essential to analyze several aspects, including the size of the market to start production, its productivity, its distance from the final consumers, the purchasing power of consumers, and the taxation of profits. Below in Table 1, all the model criteria and related directions have been reported.

TABLE 1
CRITERIA AND SUB-CRITERIA OF THE MODEL

Macro-criteria	Sub-criteria	Direction
C1 Supply and sales logistics	C1.1.: Adequacy of costs to export finished products	Min
	C1.2: Adequacy of costs to import raw materials, components, semi-finished goods, and parts	Min
	C1.3: Adequacy of lead-time to export finish products to destination markets	Min
	C1.4: Adequacy of lead-time to import raw materials, spare parts, and semi-finished products	Min
	C1.5: Accessibility to major freight transport infrastructures (airports, ports, railways, and highways)	Max
	C1.6: Viability in terms of paved local roads	Max
	C1.7: Minimal risk of theft, damage, extortion during transport	Min
C2 Qualification and cost of workforce	C2.1: Adequacy of the education level	Max
	C2.2: Adequacy of the knowledge level of the language of interchange	Max
	C2.3: Adequacy of the professionalization level	Max
	C2.4: Adequacy of cost of specialized workforce	Min
	C2.5: Adequacy of cost of non-specialized workforce	Min
	C2.6: Minimality of religious and cultural restrictions on the use of certain excipients	Min
C3 Demographic features	C3.1: Adequacy of the workforce age	Max
	C3.2: Adequacy of family unit composition	Min
	C3.3: Adequacy of the gender mix	Min
C4 Environmental and territory conditions	C4.1: Adequacy of the temperature	Max
	C4.2: Adequacy of the humidity level	Min
	C4.3: Adequacy of the rainfall level	Min
	C4.4: Adequacy of air quality	Max
	C4.5: Adequacy of water resources quality	Max
	C4.6 Accessibility to water resources (underground and surface)	Max
	C4.7: Accessibility to natural sources of raw materials (such as deposits, rare earths, cotton)	Max
C5 Technology and logistic supplier	C5.1: Accessibility to suppliers of raw materials, components, semi-finished and parts	Max
	C5.2: Accessibility to suppliers of maintenance services and spare parts	Max
	C5.3: Accessibility to suppliers of goods logistics services	Max
	C5.4: Accessibility to public transport systems	Max
C6 Local infrastructure	C6.1: Accessibility to electrical infrastructure	Max
	C6.2: Accessibility to gas distribution infrastructure	Max
	C6.3: Accessibility to water infrastructure	Max
	C6.4: Accessibility to public or private health services	Max
	C6.5: Adequacy of distance from industrial zones	Min
	C6.6: Accessibility to infrastructures for the treatment of industrial waste	Max
	C6.7: Accessibility to sewerage system	Max
	C6.8: Accessibility to telecommunication networks	Max
C7 Political aspects	C7.1: Political stability	Max
	C7.2: Minimality of the corruption level	Min
	C7.3 Adequacy of time to register a new business	Min
	C7.4: Adequacy of government tax incentives	Max
	C7.5: Adequacy of prevention of substandard and falsified medicines	Max
	C7.6: Adequacy of time to register a new pharmaceutical product	Min
	C7.7: Accessibility to facility ownership without the requirement to establish a partnership with a local company	Max
	C7.8: Freedom of capital inflow and profit remittance	Max
C8 Market access	C8.1: Adequacy of the pharmaceutical market size	Max
	C8.2: Adequacy of distance from end customers	Min
	C8.3: Adequacy of final clients' purchasing power	Max
	C8.4: Adequacy of the competitiveness level	Min
	C8.5: Adequacy of health care spending % of Gross Domestic Product (GDP)	Max
	C8.6: Affordability in importing goods that can be produced locally	Max
	C8.7: Minimality of taxation on profits	Min
	C8.8: Adequacy of guarantees by the government on the purchase of products	Max

It can be concluded that, versus the previous model's 7 macro-criteria and 34 sub-criteria, now, through the integration, there are 8 macro-criteria and 51 sub-criteria.

C. Indicators integration

After identifying and validating the criteria for choosing a pharmaceutical industry location, indicators have been identified. Indeed, to obtain a ranking of the countries based on the company criteria evaluation, it is necessary to associate with each criterion an indicator of the country's characteristics. For example, to get an indication of each country's temperature, there is a dynamic indicator on World Bank "Temperatures in Celsius (C°)." The search for the indicators was carried out by analyzing open-source databases such as "World Bank Open Data", "Statista", "Transparency International", "Trading Economics", "The Global Economy". Using databases that continuously update indicators allows a ranking congruent with countries' current status, not just a one-time status. Thus, the constructed model is also applicable in the future and does not just provide a report of point-in-time conditions. Indicators were searched for the new criteria and those for which no indicator had been found in previous work, i.e., 11 criteria. This process led to 46 indicators out of the 51 sub-criteria identified. The identified indicators can be: Dynamic, e.g., with temporal evolution, Static, e.g., with one-time status, Binary, which can have a value of 1 or 0, i.e., be active in the country or not. Specifically, 17 additional criteria have been added compared to the previous model, and 23 additional indicators have been identified. There were 23 indicators out of 34 sub-criteria in the previous model, so 11 indicators were missing, i.e., 32%. With integration, having 46 indicators out of 51 sub-criteria means that 5 indicators are missing, i.e., less than 10%. It is fundamental to consider that a sub-criterion can not have the country's related indicator; for this reason, the "Reliability" indicator has been introduced. The reliability of country *i* is calculated as the complement of the sum of the weights of criteria *j* for which the value of country *i* is not available.

IV. Application

The model was applied to one of the most reputed companies in the global pharmaceutical industry. Specifically, a company's representative engaged in location choices in developing countries was asked to fill out an online AHP questionnaire. It generates the criteria weights as output through comparative judgments among criteria and sub-criteria. The used scale to pairwise compare the criteria is a discrete one from 1 to 9 where 1 represents the equal importance of two criteria and 9 is the highest possible importance of one criterion over another. Downstream the weights and African countries indicators collection, the TOPSIS technique was implemented, generating the ranking of the most suitable African countries to locate the pharmaceutical facility of the interviewed company.

A. Criteria Weights Collection

The relative and absolute weights have been calculated through pairwise comparisons among the macro-criteria and sub-criteria. The respondent was also asked to confirm or not the ideal sub-criteria direction, to understand whether, for the respondent company, the sub-criterion is to be maximized or minimized. Indeed, it is impossible to determine a priori the impact of a criterion on the objective function: two distinct decision-makers may confirm the importance of a given criterion, but the first may intend to minimize it, the second to maximize it [21]. From the results of the questionnaire and the application of the AHP methodology, the respondent confirmed all criteria directions. Fig. 1 shows the criteria weights distribution.

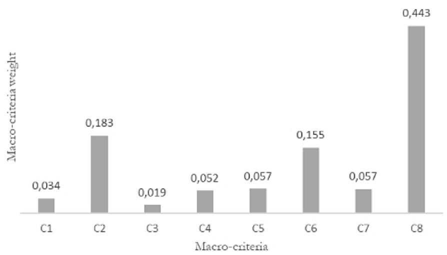

Fig. 1. Macro-criteria weights

It emerges that, for the interviewee, the most significant macro-criterion in the location in a developing country is the "Access to the market", weighting 0.443. The second most crucial macro-criterion is the "Qualification and cost of labor" one, weighting 0.183, so still a long way from the first one. Hence, the criterion that turned out to be the most important is the one not present in the previous model: it is the first indication that the integration covered by this paper was necessary. It is interesting to note that political stability is not among the highest weighted criteria. In fact, for the interviewed company, the political factors that primarily influence the business are the characteristics already present in the "market access" criterion, such as taxation on profits and government guarantees on the sale of products. In addition, giving less weight to a criterion does not imply disregarding it. A very politically unstable country will never be among the first ranked in the ranking. It is also essential to specify that the obtained weights are not generalizations of all companies but are due to strategic choices of the specific surveyed company. This result reinforces the importance of criteria evaluation.

B. TOPSIS Results

Then, the criteria weights and the respective indicators are used as input for the model that uses the "Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)". Finally, the ranking of the best countries to locate the interviewed company's pharmaceutical production plant is determined as output. As mentioned in the Methodology paragraph, the indicators used to generate the country rankings are the Performance Index and the Reliability. The country Reliability is a piece of necessary information since not all indicators have all the values for the 52 African countries, and not all African countries have a value for each sub-criterion. As a result, it has been calculated the ranking of the African countries that best reconcile the company's pharmaceutical requirements with the country's characteristics based on the Performance Indexes and the reliability of the countries. Fig. 2 shows the distribution of the Performance Indexes of the 52 African countries. Most countries have the Performance Index between (0.423; 0.505]. It is positive to observe that the countries positioned in the right-hand tail are more significant in number than those positioned in the left-hand tail, testifying to an upward trend in Pi.

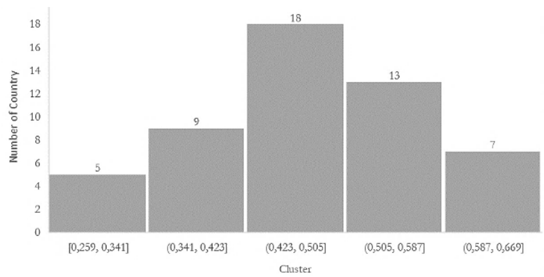

Fig. 2. Performance Index histogram

As a result, only 21 countries out of 52 have reliability greater than or equal 80%. Accordingly, the most suitable country to locate the case study's pharmaceutical facility in Africa is South Africa, with a Pi of 0.6421 and a reliability of 90%. Therefore, considering only the

Reliability indexes more significant than 80%, Table 2 shows the ranking of the top 10 countries.

TABLE 2
RANKING OF COUNTRIES

Ranking	Country	Pi	Ri
1	South Africa	0,6421	90%
2	Mauritius	0,6214	85%
3	Tunisia	0,6032	82%
4	Namibia	0,6018	80%
5	Zambia	0,5306	81%
6	Senegal	0,5094	88%
7	Cote d’Ivoire	0,4987	83%
8	Egypt, Arab Rep.	0,4977	84%
9	Mali	0,4944	88%
10	Ghana	0,4916	87%

One of the reasons the performance index and reliability index are lower than the previous model result is the higher accuracy achieved thanks to identifying a high number of sub-criteria and related indicators. In addition, the pharmaceutical industry is one of the most advanced production, development, and research industries, so it is appropriate to have hardly suitable countries for this production. Furthermore, the industrial reality of the top-ranked country, South Africa, was analyzed to confirm the model's robustness. South Africa is one of the most highly developed African industries, thanks to numerous initiatives promoting industrialization [30] and the development of the pharmaceutical industry [31]. Also, 84% of the population has access to water, and electricity consumption is 1,356 kWh per capita [6]. Furthermore, a report by BMI Research estimated $3.428 billion in total pharmaceutical sales in South Africa in 2018 and $1.251 billion in generic drug sales [32]. In addition, according to the World Bank database, South Africa is still the leading African country in terms of accessibility to significant freight infrastructures, adequacy of interchange language knowledge, adequacy of humidity level, accessibility to telecommunications networks, and adequacy of skilled labor average cost. For these reasons, it can be stated that the results are congruent with the case study context.

C. Sensitivity Analysis

Two sensitivity analysis have been carried out. The first analysis was conducted by running the model considering only the criterion with the most significant weight, i.e., the “Market access”. As a result, the best-ranked country was Seychelles, with a Pi equal to 0.667 and reliability equal to 96%. Hence, if the company would only consider market access, it would be recommended to start production in Seychelles. On the other hand, South Africa, the best country in the original analysis, was ranked third with a Pi equal to 0.605 and a reliability of 100%. Table 3 shows the ranking of the top 5 countries. In this context, the acceptable reliability was greater than 95% because the sub-criteria were significantly reduced.

TABLE 3
RESULTS CONSIDERING ONLY THE “MARKET ACCESS”

Ranking	Country	Pi	Ri
1	Seychelles	0,667	96%
2	Mauritius	0,641	100%
3	South Africa	0,605	100%
4	Tunisia	0,593	96%
5	Namibia	0,591	96%

However, even in the original analysis, Seychelles would have been the best-ranked country without the reliability discriminant. Indeed, the Seychelles archipelago has the highest Human Development Index among African countries and the highest Gross Domestic Product (GDP) per capita within the African continent. Furthermore, it currently has the highest healthcare spending in the entire African continent, and, in addition, it also has the highest level of education. Finally, the country is among the best in terms of accessibility to electrical infrastructure, level of political stability, and level of corruption [6]. The second analysis applies the model considering only those countries with a Coverage Index more significant than 90%, i.e., with most of the available criteria. The coverage index of country i is calculated as the ratio between the number of sub-criteria for which there is a value for country i and the total number of sub-criteria.
This consideration removes all those countries where, for example, very few criteria are available. Of course, if the few available criteria have a high weight for the respondent, the reliability would be high. Nevertheless, it is good to remove these countries because they could have awful situations on the other unavailable criteria, which are still necessary for the company's sustainability, although having a low relative weight. This analysis results again show South Africa as the most suitable country, with a Pi of 0.641 and reliability of 90%. Table 4 shows the ranking of the top 5 countries for the Performance and Reliability Index (greater than 80%).

TABLE 4
RESULTS CONSIDERING THE “COVERAGE INDEX”

Ranking	Country	Pi	Ri
1	South Africa	0,641	90%
2	Zambia	0,538	81%
3	Senegal	0,507	88%
4	Cote d'Ivoire	0,506	83%
5	Egypt, Arab Rep.	0,505	84%

As a result, it can be stated that the model has generated outputs congruent with the African countries' pharmaceutical reality.

V. CONCLUSION AND FURTHER DEVELOPMENT

In this study, a multi-criteria decision-making model for the location of a pharmaceutical plant in developing countries is proposed. An in-depth literature review shows how relevant it is to consider specific pharmaceutical industry requirements to determine its location. The critical criteria involved in the pharmaceutical production location choice have been provided. Their evaluation can help developing countries' governments understand which aspects to invest in, increasing attractiveness for foreign investment and reducing investment risk. Specifically, the criteria were first identified by studying the literature, then supplemented and validated through questionnaires and interviews with experts in the field. Subsequently, the model has been applied to a leading pharmaceutical company, considering only African countries as alternatives. South Africa was found to be the most suitable country for the requirements of the case study pharmaceutical company. As a confirmation of the results' robustness, South Africa's current state analysis turns out that it is in the best industrialization position in Africa. It is then essential to point out that this model can be applied in several industrial sectors other than the pharmaceutical sector. Indeed, the model integration can also be helpful for other manufacturing companies because what has been achieved is just a more accurate and robust model that any manufacturing company can use. Although this work contributes positively to literature and businesses, this research also has several limitations that provide opportunities for future developments. First, the model was applied to a single pharmaceutical industry, so it would be interesting to submit the interview to other pharmaceutical companies, comparing the results. Second, expanding the indicators database, transforming into dynamic all those static and binary indicators would ensure more robustness to the use of the model in future applications. Finally, considering other developing countries, such as India or Latin America, would generate compelling results.

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