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An Application of AHP Model in the Selection of a Distribution Center in Cameroon

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Abstract: **The presence of distribution centers in manufacturing today cannot be over emphasized. Most supply chains use distribution centers to distribute their products to the final destinations of their customers. On like warehouses that are meant for the storage of goods, a distribution center is not meant for storage rather its meant for receiving, sorting and redistribution of goods to customers according to their specification. It is of vital importance to note that, a distribution's center location should not be compromised. Vital points that are always considered when considering a distribution centers locations are lead times, transportation networks, proximity to customers, environmental factors, social and cultural factors just to name a few. Companies that mostly use distribution centers are usually manufactures of fast consumable products because the need to reduce logistics cost and satisfy customers requirements are of paramount importance.**

This paper seeks to evaluate a suitable location that a distribution center can be established in Cameroon. Cameroon is a Central African country and its geographical location is good for the establishment of a DC that can serve Cameroon including Central and West Africa. Three cities in Cameroon are being considered which are Yaoundé being the capital city and it is located in the Central Region, Douala the economic city which is located in the Littoral Region and Bamenda located in the North West Region. The paper uses the Analytic Hierarchy Process model to evaluate the three cities to determine which city is the best city for any supply chain to establish a distribution center. There are also some factors that were used to evaluate these three cities which include; transportation facilities, skill labor, land cost and proximity to customers.

Keywords: **Distribution center, Supply chain, AHP, Customers, Location selection.**

1. INTRODUCTION

Manufacturing and distribution of merchandise has developed tremendously over the years from a traditional way of doing business to an integrated way of doing business. The traditional way involved manufacturing companies producing goods and supplying these goods directly to their customers who are usually retailers. An increase in demand often caused the retailers to purchase more goods and stock them which became inventory to them. The development of retail stores gave retailers more purchasing options by looking at locations where they could source their products. A new part of supply chain was developed. Hence, retailers could buy less because there could easily replenish their stock. This transition caused retailers to easily maintain a level of inventory. As retail space became limited due to a growing level of customer demands, the concept of warehousing was introduced. This created an intermediary location for inventory storage which allowed companies to fulfill demand to match customer order. This means that retailers could now reduce their inventory levels and the manufacturers maintained the inventory [1].

The major issue in the evolution of manufacturing and distribution overs years has been the cost of holding inventory which has led to the integrated way of doing business through the optimization of supply chains. Nowadays, companies are developing distribution centers to temporally hold and distribute products rather than storing them [1].

A distribution center however is a facility that is sometimes smaller than a firm's warehouse and it's used for receipt, temporal storage and redistribution of goods according to the customer orders as they are received [2]. The fact that a distribution center's primarily is not for the storage of goods but for the redistribution of goods according to customers' requirements, its location decision should be of utmost importance. Companies in supply chains always have to locate their distribution centers in strategic locations that does not only ensure an efficient and effective distribution of goods but also optimizes total logistics cost. The strategic positioning of distribution centers should also be able to reduce lead times which will render inventory control much easier hence increasing service levels [3].

To determine a strategic location for a distribution center, other vital factors are taken into consideration such as the surrounding environment consisting of the society, culture and infrastructures among other things which poses a significant impact to the functionality of the location [5]. If the infrastructures that are around a distribution center are week, ostensibly short distances may be more time consuming than longer distances in an area with strong infrastructures [4].

The aim of this paper is to evaluate three major cities in Cameroon so as to determine the most suitable city for the establishment of a distribution center within a supply chain to serve locally or regionally. The three cities to be evaluated are Yaoundé, Douala and Bamenda. The Analytic Hierarchy Process (AHP) model as proposed by Thomas Saaty will be used for the evaluation of these cities and the factors to be considered for the evaluation will include transportation networks, skilled labor, customer proximity and Cost of land. Cameroon's location within the Central African Region makes it geographical position suitable for companies in international supply chain to establish a distribution center in Cameroon to serve within the West and Central African Region.

Source: world atlas

Figure 1: Map of Cameroon

2. OPTIMIZATION OF DISTRIBUTION CENTER

When planning for an efficient supply chain, the crucial part is dealing with the location decision. For this to be done successfully, there are some vital key factors that should be considered which includes, distance, transportation facilities, customer service, cost of land, skilled and cost of labor and environmental factors just to name a few. There are some methods that have been developed to help evaluate some of these factors.

2.1 Center of gravity method

The center of gravity is a method that is mostly used in locating a single facility [7]. This method is used to determine a location's optimal coordinates for a facility. It seeks to minimize the total distance that a load will travel and also provides the x and y coordinates for the location. It adopts the following formulas:

$$x^* = \frac{\sum_i l_i x_i}{\sum_i l_i}$$

$$y^* = \frac{\sum_i l_i y_i}{\sum_i l_i}$$

Where;

x*= actual longitude coordinate for the optimal location

y*= actual longitude coordinate for the optimal location

li = load of each location

xi = x coordinate of the load point

yi = y coordinate of the load point.

Murphy and Wood (2008, p. 204) use the term weighted center of gravity for this method presented by Krajewski et al. (2007) as the approach pays attention also to the volumes and not only the locations [4].

When evaluating locations in the target area, the Center of Gravity method is a good starting point [8]. Nevertheless, they explain that the location obtained by the center of gravity method is not generally the optimal one. Neither Murphy nor Wood (2008, p. 205) had into consideration that the weighted center of gravity method was a sophisticated approach [4]. They took other factors into considerations such as taxes, volume discounts and the fact that transport rates are not linear with distances.

Transportation rate is always considered as a variable for the center of gravity method [9]. This idea therefore diminishes the difference between the center of gravity method and the real world. The center of gravity formula is then adjusted as follows [9]:

$$x^* = \frac{\sum_i l_i R_i x_i / d_i}{\sum_i l_i R_i / d_i}$$

$$y^* = \frac{\sum_i l_i R_i y_i / d_i}{\sum_i l_i R_i / d_i}$$

Where;

x*= x coordinate of the located facility

y*= y coordinate of the located facility

li = total load at point i

Ri = transportation rate to point i,

di = distance to point from the facility to be located

xi = x coordinate of point i

yi = y coordinate of point i.

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However, because the earth has a spherical shape, it definitely will have an effect on the function of distance. This also affects the traditional center of gravity method: it is logical on a plane surface but does not consider the curvature of the Earth [4]. This therefore means that practically, the target area's size greatly affects the functionality of the traditional method. If the area is large, it should not be considered as a plane. Nevertheless, with the necessary modifications, the Center of Gravity method could still be used [10].

The main difference when considering the traditional and the spherical center of gravity method is that the spherical method does not consider latitudes and longitudes as simple coordinates but rather as directions from the center of the sphere. The first step to consider with this method will be to express longitudes and latitudes, minutes and seconds as decimal values. The second step will be to convert West Longitudes and South Latitudes as negative values. Also, degree values should be expressed in radians. When that is done, finding the correct center of gravity will be an iterative process which will require the usage of a special optimization program [10].

2.2 Evaluating distance function in location selection

This paper presents two methods of measuring distance as proposed by Mwemezi and Huang (2011) [10]. The first method measures the rectilinear distance representing a distance measured along orthogonal paths mostly in Metropolitan cities which have orthogonal streets. The mathematical formula for rectilinear distance is

$$d_r = |x_a - x_b| + |y_a - y_b|$$

Where;

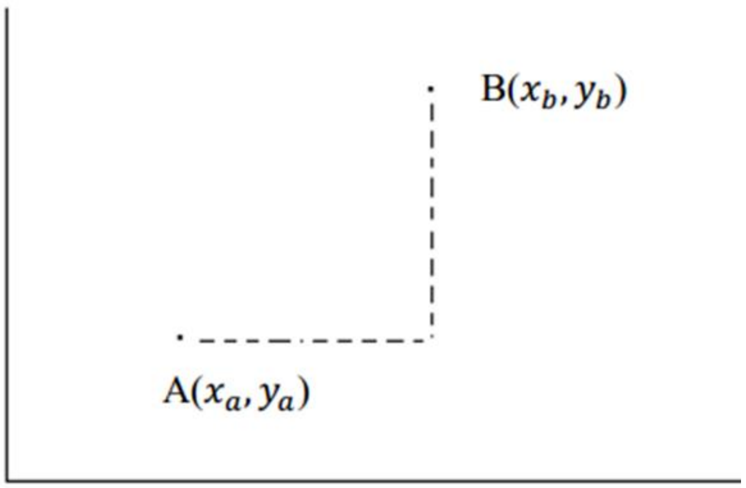
dr = the rectilinear distance

xa = x coordinate of point A

ya = y coordinate of point A

xb = x coordinate of point B

yb = y coordinate of point B



Source: Mwemezi and Huang (2011)

Figure 2: Rectilinear distance between points A and B

The second method measures the Euclidean distance which is a straight distance between two points. It assumes that it is possible to travel directly from point A to point B. This Euclidean distance measure is mostly useful for example in air traffic, where distances are almost straight. The mathematical formula for the Euclidean distance is

$$d_e = \sqrt{(x_a - x_b)^2 + (y_a - y_b)^2}$$

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Where;

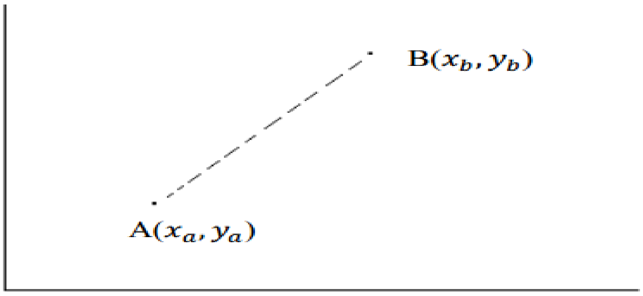
de = Euclidean distance,

xa = x coordinate of point A

ya = y coordinate of point A

xb = x coordinate of point B

yb = y coordinate of point B



Source: Mwemezi and Huang 2011

Figure 3: The Euclidean distance between points A and B

These methods of measurements are suitable for measuring distances on a plane because it has linear coordinates and especially because the length of a degree of longitude depends strongly on the latitude. But because the earth has a spherical shape, these methods are not suitable. Near the geographical poles of the Earth the length of a degree of longitude is significantly smaller than on equatorial locations [4].

However, by using spherical trigonometry, it will be possible to achieve a more realistic distance measures. The shortest possible distance between two points on the Earth's surface lies always along the arc of the great circle between these two points. In comparison, when the Euclidean distance is the length of a straight line between two points, in spherical geometry, great circle paths are used instead of straight lines [10]. The mathematical formula, as stipulated by Mwemezi and Huang (2011), for great circle distance in spherical geometry is

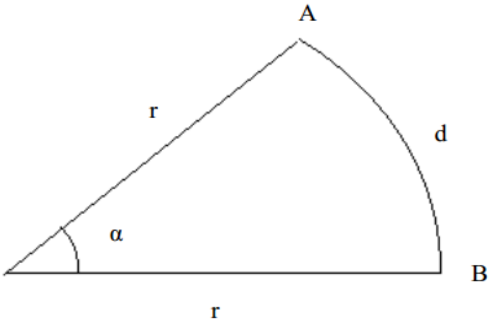
$$d_s = \alpha r$$

Where;

ds= Great circle distance between two points

α = central angle measure

r = radius of the Earth



Source: Mwemezi and Huang 2011

Figure 5: Great circle distance on the sphere

Applying spherical trigonometry to a facility location planning provides more realistic distance estimations for real life problems due to the nature of the earth [10].

2.2 Analytic hierarchy process in location decision

The Analytic Hierarchy Process (AHP), developed by Saaty (1987), enables assessing, prioritizing, ranking, and evaluating decision choices and different factors behind them. It is a technique which combines mathematics and psychology in order to organize and analyze complex decisions [11].

When using the first AHP, the first step is to structure the hierarchy of the problems. The top level consist of the main goal of the whole decision making process. The second level consists of the criteria which contribute to the goal, and the different candidates are in the bottom level [11].

It is of utmost importance that the overall objective and the scope of decisions are well understood before dividing the problem into hierarchies. In order to clarify the goal, there is the need for extensive collection of information [12]. There is also the need to emphasize the role of strategic thinking, strategies and a variety of constraints in order to achieve the objective. Thus, the main strategy should be kept in mind also when utilizing the AHP method.

The second step involves arranging the elements in the second level into a matrix form. Judgments are then made on the relative importance of the criteria. The fundamental scale ranges from 1 to 9. The table below shows the scale used in making the judgments.

Table 1: The fundamental scale used in the AHP

Intensity	Definition	Explanation
1	Equal	Two objectives contribute equally to the objective
3	Moderate	Experience and judgment slightly favor one activity over another
5	Essential or strong	Experience and judgment strongly favor one activity over another
7	Very strong	An activity is favored very strongly over another and its dominance is demonstrated in practice
9	Extreme	The evidence favoring one activity is of the highest possible order of affirmation
2,4,6,8	Intermediate values	When compromise is needed

Source: Saaty (1990)

The scale presented in table 1 is used in pairwise comparisons of the criteria. The basic idea is to compare two elements at a time. For example, if element x has number 3 assigned to it when compared with element y, then y has the reciprocal value of 1/3 when compared with x. Possible candidates are then compared also in pairs under each criteria. The aim is to judge how much better one candidate is than the other, satisfying each criterion in level 2 [13].

The pairwise comparisons are put into matrices whose sizes are equal to the amount of candidates or the factors compared. Then, a priority vector is calculated for each factor as a measurement of their relative strengths. Mathematically, priorities are the values in the matrix's principal right eigenvector. These values can be calculated by hand or by using specialized AHP software. Basically, the idea is to calculate the product of each row by multiplying its elements with each other. Then, the root of the product is calculated. The final step is to normalize roots so that their sum is equal to 1. The results, then, are the priorities of each factor or candidate [14].

The third step is to establish the composite priorities for the candidates. Local priorities are laid out with respect to each criterion in a matrix and multiplied each column of vectors by the priority of the corresponding criterion and the added

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across each row. Actually drawing a figure of the hierarchies makes often it easier to understand the structure and dependencies between candidates and criterion [13].

The consistency index is, then, divided by a coherent value of Random Index (RI) which is an average random consistency index derived from a sample of randomly generated reciprocal matrices using the scale 1/9, 1/8,…,8, 9 [14]. The table below represents the values for RI for matrixes of size between 1 and 10.

Table 2: Random Consistency Index for matrixes of different size

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Source: Saaty and Vargas 2012

In order to get the final consistency ratio, the correct RI value is chosen from the table and the Consistency Index is then divided with it. The formula for that is simply as follows:

$$CR = \frac{CI}{RI}$$

Where;

CR= consistency ratio,

CI= consistency index

RI= random consistency index

3. METHODOLOGY

The model that is used in this paper is the AHP model. The first step in choosing the type of method to use was to determine all the factors that were to be considered for the location decision. The location of customers in Africa and in Cameroon was considered as the most important factor since the location of the Distribution Center has the biggest impact on the lead times and transportation costs. Three cities are to be evaluated which are Yaounde, Douala and Bamenda using four factors which include;

- Transportation facilities such as roads, rails, air and inland water way networks.
- Customer proximity
- Availability and the cost of labor
- Cost of land

3.1The Analytic Hierarchy Process Model Method

1. Building AHP Model
2. Assign a weight to each factor
3. Develop a score for each factor (e.g. 1 to 10 points).
4. Have experts score each location for each factor by using the scale in step 3.
5. Multiply the score by the weights for each factor and total the score for each location.
6. Make a recommendation based on the maximum point score.

Factors to consider

- Transportation facilities

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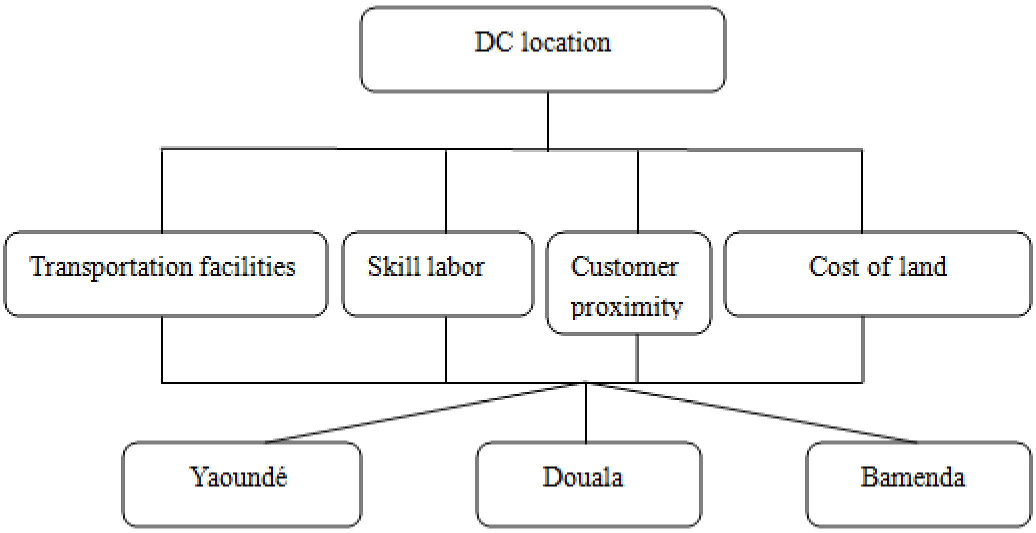
- Skill labor
- Land cost
- Customer proximity

3.1. 1: Build AHP model



3.1. 2: Determining each factor's weight

1) Building pairwise comparison matrices

Let, transportation facilities = Tp

Skill labor =SL

Land cost =Lc

Customer proximity =C

$$\text{Matrix A} = \begin{array}{c c} & \begin{array}{cccc} Tp & SL & Cp & Lc \end{array} \\ \begin{array}{c} Tp \\ SL \\ Cp \\ Lc \end{array} & \begin{pmatrix} 1 & 5 & 2 & 4 \\ 1/5 & 1 & 1/2 & 1/2 \\ 1/2 & 2 & 1 & 2 \\ 1/4 & 2 & 1/2 & 1 \end{pmatrix} \end{array}$$

2.) Normalizing pairwise comparison matrices A to get A*

$$a_{ij}^{*} = \frac{aij}{\sum_{i=1}^{n} aij}$$

$$A_{NORM}^{*} = \begin{pmatrix} 0.5128 & 0.5000 & 0.5000 & 0.5333 \\ 0.1026 & 0.1000 & 0.1250 & 0.0667 \\ 0.2564 & 0.2000 & 0.2500 & 0.2667 \\ 0.1282 & 0.2000 & 0.1250 & 0.1333 \end{pmatrix}$$

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3.) Estimating the weight for factor i.

$$\mathbf{W_i} = \frac{\sum_{j=1}^{n} aij}{n}$$

$$W_{1(\text{Transport})} = \frac{0.5128+0.5000+0.5000+0.5333}{4} = 0.5115$$

$$W_2 = \frac{0.1026+0.1000+0.1250+0.6667}{4} = 0.0986$$

W_3 =0.2433

W_4 =0.1466

3.1. 1: Checking for consistency

I. Computing AW

$$Aw = \begin{pmatrix} 1 & 5 & 2 & 4 \\ 1/5 & 1 & ½ & ½ \\ ½ & 2 & 1 & 2 \\ ¼ & 2 & ½ & 1 \end{pmatrix} * \begin{pmatrix} 0.5115 \\ 0.0986 \\ 0.\ 2433 \\ 0.1466 \end{pmatrix}$$

$$= \begin{pmatrix} 2.0774 \\ 0.3958 \\ 0.9894 \\ 0.5933 \end{pmatrix}$$

II. Calculate λ_{max}

$$\Lambda_{max} = \sum_{i=1}^{n} \frac{(AW)}{nWi}$$

$$= \frac{2.0774}{4*0.5115} + \frac{0.3958}{4*0.0986} + \frac{0.9894}{4*0.2433} + \frac{0.5933}{4*0.1466} = 4.0477$$

III. Computing the constancy index (CI)

$$CI = \frac{\lambda\max - n}{n-1} = \frac{4.0477-1}{3} = 0.0159$$

IV. Computing the constancy ratio(CR)

Saaty suggests that if CR=CI/RI<0.10, then the degree of consistency is satisfactory.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

$$CR = \frac{CR}{RI} = \frac{0.0159}{0.89} = 0.0178$$

So the pairwise matrix A does not exhibit any serious inconsistencies.

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3.1. 2: Determining the scores of each alternative on each factor

	Transportation facilities	skill labor	Customer proximity	Cost of land
Yaoundé	4	2	3	1
Douala	3	3	5	2
Bamenda	2	3	4	4

3.1.3: Calculating an overall score for each city, determining the best alternative

Yaoundé score =4*W1+2*W2+3*W3+1*W4

=4*0.5115+2*0.0986+3*0.2433+0.1466=3.12

Douala score =3*0.5115+3*0.0986+5*0.2433+2*0.1466=3.34

Bamenda =2*0.5115+3*0.0986+4*0.2433+4*0.1466=2.87

4. RESULT ANALYSIS

Since Douala has the largest overall score, AHP model suggest that the distribution center should be located in Douala which is in the Littoral Region.

Therefore, the Analytic Hierarchy Process (AHP), developed originally by Thomas Saaty, is a powerful tool that can be used to make decisions in situations where multiple objectives are present.

Douala has one of the leading concentrations of warehouses in Cameroon. These facilities support businesses and consumers throughout the Littoral region, the city of Douala, the nation and the world. Warehouses add value to the freight moving through them and represent a substantial economic activity in Douala.

Distribution centers and warehouses generate more employment than in the past because these facilities have become the location for the last steps in the manufacturing process. In an era of global sourcing, production and marketing, the current practice is to do final assembly and customization closer to the marketplace. This practice results in greater flexibility and responsiveness to changing product demands.

4.1 Projected demand for DC and warehouses

The demand for warehousing activity is affected by three factors – the state of the economy; growth in international trade; and the availability of land. The outlook for warehousing activity in the Littoral region is strong. While the economy is expected to be stable in the near future, the region’s population growth and density, combined with an increasing labor force, provides a foundation for continued prosperity. In addition, international trade through the Littoral region is anticipated to grow substantially. The Port Authority anticipates that cargo movements through the port of Douala will grow. Air cargo activity at the Douala International Airport is also expected to grow. The limiting factor in harnessing the economic value of this growth in commerce appears to be the availability of land in the Littoral region for warehousing. Already, the distance ring for selecting warehousing sites extends beyond the Littoral region. While locations continue to be developed for warehouses within the region, it is possible that a distribution center and warehouses that will support and benefit from the increased trade through the Port could be located outside of this area.

5. CONCLUSION

In most supply chains, the need for a distribution center is a crucial factor which always needs planning especially in terms of its location. Distribution centers should be able to add value through effective and efficient distribution of goods to customers. This paper has evaluated three major cities in Cameroon to determine which city is most suitable to establish a distribution center through the use of AHP model and after taking some factors into consideration, Douala which is the economic city of Cameroon was selected as the best city to establish a DC that will not only serve customers in Cameroon but also other customers in the West and Central African region.

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