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SELECTION OF DRY PORT LOCATION FOR COSCO SHIPPING LINE GHANA COMPANY LIMITED USING CENTER OF GRAVITY (COG) AND ANALYTIC HIERARCHY PROCESS (AHP) MODELS

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Abstract: **The aim of this research was to select an optimal location for a Dry Port to increase responsiveness and efficiency to meet customer demand. The method used to acquire information was qualitative where reference was made from publications and websites. This research revealed that transport cost to landlocked countries (Burkina Faso, Mali and Niger) from Tema port is high. With this and other related circumstances urged the search for an optimal location of Dry Port for COSCO shipping line to satisfy their customers.**

The Center of Gravity and Analytic Hierarchy Process models were used together with forecasting model and time series regression analysis. This gave a thorough guide in the selection of the optimal location.

Keywords: **Dry Port, Center of Gravity, AHP.**

1. INTRODUCTION

Within the maritime supply scenery, dry ports functions as an extension of seaport which facilitates cargo flows between seaports and the hinterlands. Conventional knowledge evidence the fact that, in develop economies like North America and Europe dry port aids to resolve the problem of congestion, natural constraints and enlivening hinterland access. This paper aims at selecting an optimum dry port location for Cosco Ghana Shipping Company Limited as an extension of the Tema seaport to unleash the international trade potential landlocked countries in the West Africa sub-region. The study carries out this task through the consideration of divergent model objective.

"An inland intermodal terminal directly linked to seaport(s) with high capacity transport connectivity, where importers and exporters can leave or pick up their standardized unit as if directly as a seaport" is termed as dry port according to (Leveque & Roso, 2002). Additionally, (Wang & Wei, 2008) specified that dry port functions include distribution, consolidation, storage, customs services, and possibly equipment maintenance. This definition takes into consideration other functions of a dry port such that, a dry port does not only do the traditional role of transshipment as inland terminals but also provide other services like; consolidation, storage of both laden and empty containers, maintenance and repair of containers, and customs clearance. (Roso, Woxenius, & Lumsden, 2009) also defines dry port as "an inland intermodal terminal that is directly connected to seaport(s) with high capacity transport means, where customers can leave or pick up their standardized units as if directly to a seaport".

2. LITERATURE

The emergence of dry ports is considered to be much influenced by the containerization trend thanks to the visionary novelty of Malcolm Maclean, as well as the increasing integration between seaports and hinterland networks. Within the supply chain, in some instances, dry ports might work as inland hubs to harness the physical flow of cargo in the hinterland, or extensions of seaports to resolve the problems of space consuming activities that limit capacity, natural constraints and diseconomies of scale such as congestion and environmental issues. Many gateway ports continue to face numerous development constraints. The most pressing hindrance or constraints in seaports are land availability, congestion and environmental problems, pollution to be precise. Encountering these constraints has caused many seaport authorities to developed dry ports as a solution to eradicate the burdens and improve efficiency and the modal split by moving space-consuming activities to satellite locations.

Another reason for the emergence of dry ports is to expand hinterland access and gain a stronger competitive advantage. (Notteboom & Rodrigue, 2005), as discussed in their paper, point out that, many seaports have reached or on the way to reach a phase of port regionalization which is characterized by a high level of hinterland integration through a system of transport corridors and inland nodes. This trend is driven by competition and market forces, such as the demand for door-to-door services, and can result in hinterland solutions such as 'extend gates' (Rodrigue & Notteboom, 2009).

Global supply chains establishment and explosion in the 1990s, coupled with export oriented growth strategies adopted by developing countries resulted into a paradigm shift in freight distribution systems. Multimodal transport connectivity and dry ports turned out to be the focal point in the new supply chain and logistics strategy formulation. Its implementation was first seen in the United States and developed Europe, next, to East Asian countries and then more recently Africa. This happening was mainly due to the avid focus on trade, which resulted into diminishing returns, congestion at sea ports and a significant fall in efficiency (Wanzala & Jin, 2015).

Conversely, many landlocked developing countries continuously face the challenge of economic development with respect to their geographical location or physical isolation which constrains them from direct maritime access. The physical flow of cargoes and its related barriers from the sea and the high transport costs of trading with the rest of the world is also a bottleneck (United Nations Economic Commission for Africa, 2011).

In order to resolve these challenges associated with being landlocked, the dry port concept emanate not only for the purpose of landlockedness but also to mitigate the challenges that faced existing seaports. These challenges can be ascribed to the increase in container vessels size and capacity, seaports continuously encounter the challenge of inability to handle import and export cargo in a timely manner. This generates congestion often times at different seaports due to long waiting time of vessels, trucks and haulage vehicles (Woxenius, Roso, & Lumsden, 2004). In addition, high inland transport cost is also another cost of being landlocked. (Elbadawi, Mengistae, & Zuefack, 2001) itemized that inland transport costs act as a strong constraint to exports in Africa. Prominently, the authors indicated that it is a constraint that is even stronger than that of international transport costs. The researcher therefore have confidence to a high degree that, lowering inland transport cost through the establishment of dry port that is proximate to the location of importers and exporters will cause a significant cost reduction, which will have its ripple effects on international trade as a whole.

3. METHODOLOGY

3.1 The Center-of-Gravity Model

The center of gravity is a mathematical technique used for finding the location of a distribution center that will minimize distribution costs, in other words, to locate a facility that will minimize the distance that large loads travels. The method takes into account the location of hinterlands, the volume of goods shipped to those hinterlands and shipping costs, in finding the best location for the dry port.

When locating a facility there are a number of methods to choose from. The center-of-gravity approach is a method used for locating a single facility (Murphy and Wood 2008). The center of gravity method is a refined version of the load-distance method (krajewski, Ritziman, & Malhotra, 2007).

Finding the center of Gravity, using the equations below

$$x^* = \frac{\sum_i liRixi}{\sum_i liRi} \qquad \textbf{(1)}$$

$$y^* = \frac{\sum_i liRiyi}{\sum_i liRi} \qquad \textbf{(2)}$$

Where,

x^*= x coordinate of the located facility.

y^*= y coordinate of the located facility.

l_i= total load to point i

R_i= transportation rate to point i

d_i= distance to point i from the facility to be located

x_i= x coordinate of point i

y_i= coordinate of point i

3.2. Forecasting Model (Time series method)

A forecasting model will also be used to determine the future demands of the customers of COSCO Shipping Line Ghana Limited. This is of the reason that it will not make any logistics sense when a past throughput is used to determine the location of a facility like a dry port, which will be serving future demands. However, the forecast will be done based on past throughput.

Time series method is used as forecasting model; the trend type to be precise is the one that will be used for this research.

Time series regression analysis:

$$Y = a + bx$$

Where;

Y = Dependent variable (actual sales)

x = Independent variable (time periods in this case)

a = y - Intercept [value of y when ($x = 0$)]

b = Slope or Trend

$$b = \frac{N\sum xy - \sum x \sum y}{N\sum x^2 - (\sum x^2)} \quad \textbf{(3)} \qquad a = \frac{\sum y}{N} - b\frac{\sum x}{N} \quad \textbf{(4)}$$

Where N = the Number of periods of data

3.3. The Analytic Hierarchy Process

AHP is a multi-criteria decision-making approach and was introduced by Saaty (1977 and 1994). The AHP has attracted the interest of many researchers mainly due to the nice mathematical properties of the method and the fact that the required input data are rather easy to obtain. The AHP is a decision support tool which can be used to solve complex decision problems. It uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data are derived by using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency (Winston & albright, 2014).

4. DATA ANALYSIS AND PRESENTATION OF RESULTS

4.1 Table 1: Ten (10) years data of actual Throughput to the various Countries

Country	Niger	Burkina Faso	Mali	Ghana
2006	1.52	0.42	1.58	5.35
2007	1.85	0.54	1.34	6.18
2008	2.19	0.57	1.42	6.27
2009	2.77	0.54	1.76	6.95
2010	2.45	0.56	1.84	8.01
2011	2.98	0.72	2.11	8.25
2012	2.82	1.02	2.27	7.77
2013	2.9	1.04	2.55	8.7
2014	2.99	1.07	4.99	9.28
2015	3.37	1.15	3.82	9.89
2016	3.55	1.24	4.14	10.35
2017	3.69	1.2	4.64	10.80

Source: (vanDyck & Domfeh, 2017)

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4.2 Table 2: Transportation Distance from Port to Destination

Corridor	Road distance (km)	Cost/Ton per km
Tema – Ouagadougou	1057	0.14
Tema – Niamey	1121	0.14
Tema – Bamako	1973	0.14
Tema -Tema	0	0.14

Source: (vanDyck&Domfeh, 2017)

4.3 Table 3: Forecasted Demand

Country	Niger	Burkina Faso	Mali	Ghana
2018	3.8718	1.340302	5.015078	11.25712
2019	4.04415	1.425202	5.382829	11.71178
2020	4.2165	1.510102	5.75058	12.16644
2021	4.38885	1.595002	6.118332	12.62109
2022	4.5612	1.679902	6.486083	13.07575
2023	4.73355	1.764802	6.853835	13.53041
2024	4.9059	1.849702	7.221586	13.98507
2025	5.07825	1.934602	7.589338	14.43973
2026	5.2506	2.019502	7.957089	14.89439
2027	5.42295	2.104402	8.324841	15.34905
2028	5.5953	2.189302	8.692592	15.80371

Table Source: Researchers' computation.

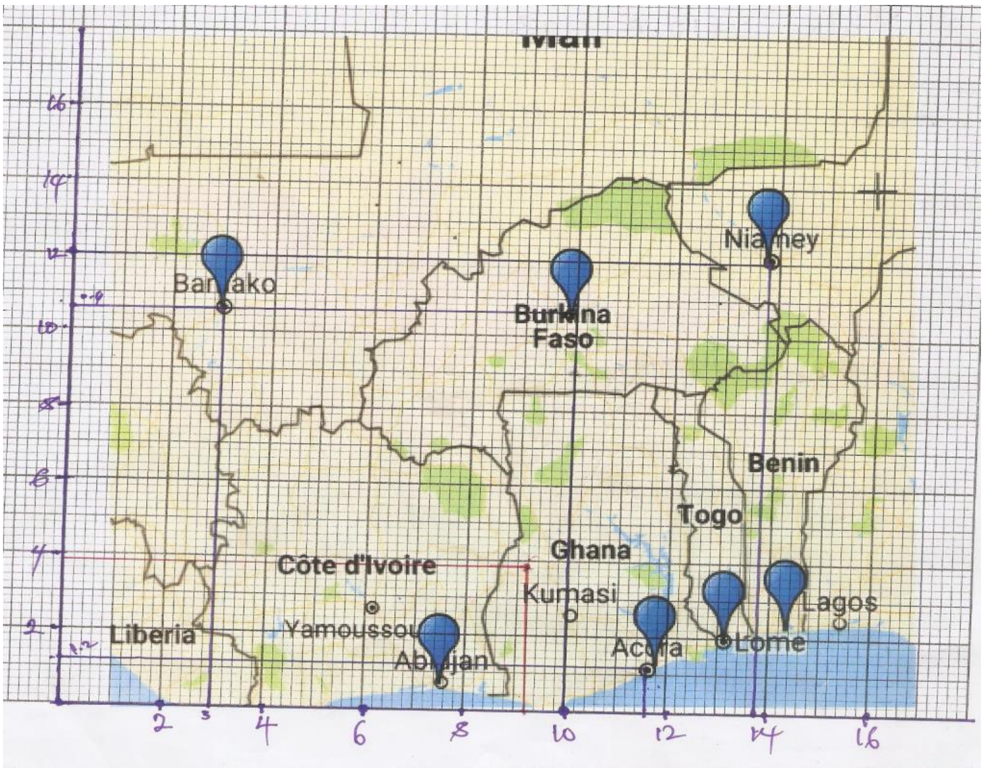

Figure 1: COG Location

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4.4 Table 4: Data for center of gravity computation

		Forecasted data	Coordinates		Cost/ton/km	Distance from (site to destination)
			x_i	y_i		
Source	Tema		9.25	3.92		
Destinations						
Ghana		159.637	11.6	1.2	0.14	0
Burkina Faso		20.6682	10	10.6	0.14	1057
Mali		80.0395	3	10.6	0.14	1973
Niger		55.7685	11.6	1.2	0.14	1121

Source: Researchers computation

$x^* = \frac{\sum_i liRixi}{\sum_i liRi}$ $\qquad y^* = \frac{\sum_i liRiyi}{\sum_i liRi}$

X = (13.8*52.06905*0.14) + (10*19.41282*0.14) + (3*75.39218*0.14) + (11.6*148.8345*0.14)

X = $\frac{383.375}{41.3992}$

X = 9.252293

Y = (12*52.06905*0.14) + (10.6*19.41282*0.14) + (10.6*75.39218*0.14) + (1.2*148.8345*0.14)

Y = $\frac{162.4437}{41.3992}$

Y = 3.923837

Therefore, the coordinate for the center of gravity location is;

x = 9.252293

y = 3.923837

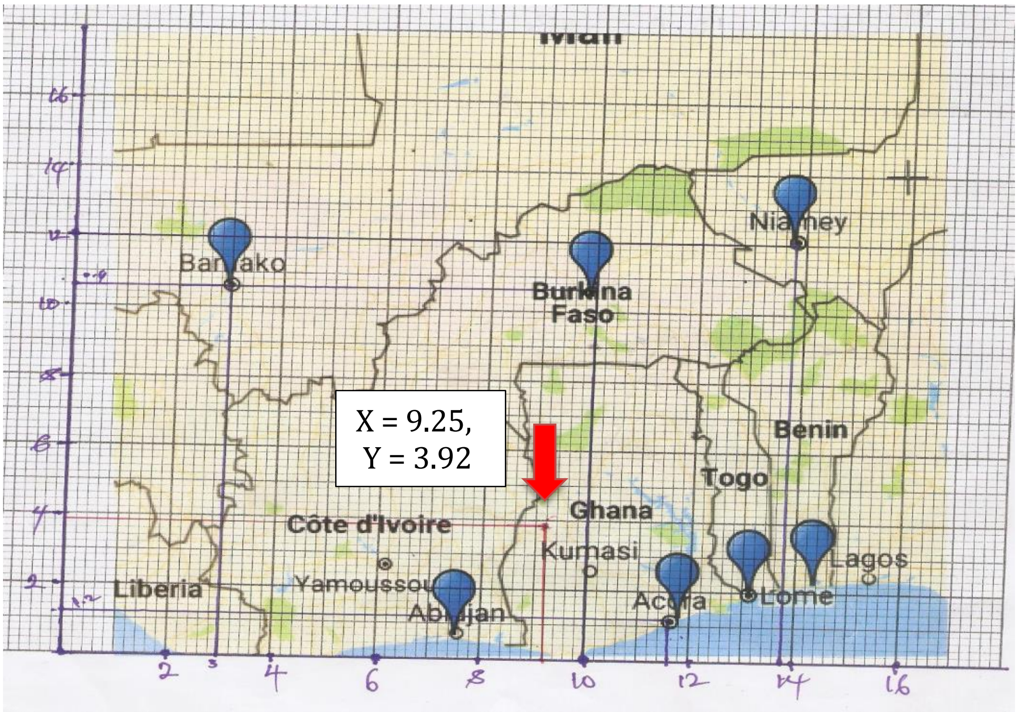

Figure 2: COG Coordinate

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4.5: Analytic Hierarchy Process

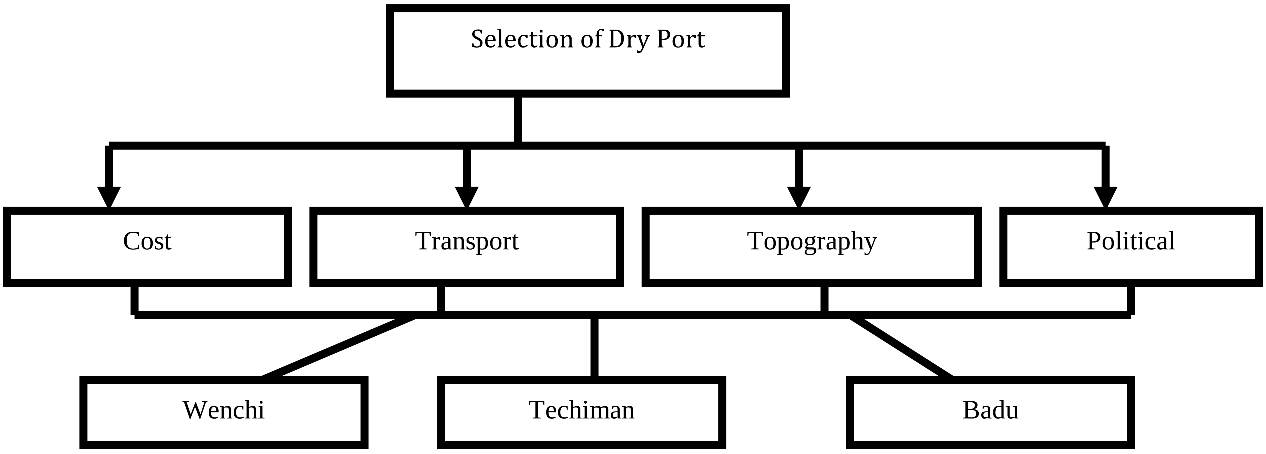

Figure 3: AHP Network Structure

Table 5. Pairwise Comparison

	COST	TRANSPORT	TOPOGRAPHY	POLITICAL
COST	1	5	2	4
TRANSPORT	1/5	1	1/2	1/2
TOPOGRAPHY	1/2	2	1	2
POLITICAL	1/4	2	1/2	1

4.5.1. Normalized pair wise comparison matrix A to get new A*

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

$a_{11}{}^{*} = \frac{1}{1+1/5+1/2+1/4} = 0.5128$

$a_{12}{}^{*} = \frac{5}{5+1+2+2} = 0.5000$

$a_{21}{}^{*} = \frac{1/5}{1+1/5+1/2+4} = 0.1026$

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

4.5.2. Estimate the weight for criterion i

$$W_i = \frac{\sum_{j=1}^{n} a_{ij}{*}}{n}$$

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

$$W_{2(Transp.)} = \frac{0.1026 + 0.1000 + 0.1250 + 0.6667}{4} = 0.0986$$

$$W_{3(Topog.)} = \frac{0.2564 + 0.2000 + 0.2500 + 0.2667}{4} = 0.2433$$

$$W_{4(Political)} = \frac{0.1282 + 0.2000 + 0.1250 + 0.1333}{4} = 0.1466$$

4.5.3. Checking for consistency

$$AW = \begin{bmatrix} 1 & 5 & 2 & 4 \\ 1/5 & 1 & ½ & ½ \\ ½ & 2 & 1 & 2 \\ ¼ & 2 & ½ & 1 \end{bmatrix} * \begin{bmatrix} 0.5115 \\ 0.0986 \\ 0.2433 \\ 0.1466 \end{bmatrix}$$

$$AW = \begin{bmatrix} (1*0.5115) + (5*.0986) + (2*.2433) + (4*0.1466) \\ (1/5*0.5115) + (1*0.0986) + (1/2*0.2433) + (1/2*0.1466) \\ (1/2*0.5115) + (2*0.0986) + (1*0.2433) + (2*0.1466) \\ (1/4*0.5115) + (2*0.0986) + (1/2*0.2433) + (1*0.1466) \end{bmatrix}$$

$$AW = \begin{bmatrix} 2.0774 \\ 0.3958 \\ 0.9894 \\ 0.5933 \end{bmatrix}$$

4.5.4. Calculate $\lambda_{\max}$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

$$AW = \begin{bmatrix} 2.0774 \\ 0.3958 \\ 0.9894 \\ 0.5933 \end{bmatrix} \qquad W = \begin{bmatrix} 0.5115 \\ 0.0986 \\ 0.2433 \\ 0.1466 \end{bmatrix}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)_i}{nW_i}$$

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

4.5.5. Computing the constancy index (CI)

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{4.0477-4}{3} = 0.0159$$

4.5.6. Computing the constancy ratio (CR)

Compare CI to the random index (RI) in following table for the appropriate value of n.

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

$$CR = \frac{CI}{RI} = \frac{0.0159}{0.90} = 0.0177$$

4.7 Table 6: Determining the scores of each alternative on each criterion

	COST	TRANSPORT	TOPOGRAPHY	POLITICAL
WENCHI	3	3	4	3
TECHIMAN	2	3	4	2
BADU	4	2	3	4

Calculating the overall score for each job, determining the best alternative

WENCHI = (3*0.5115) + (3*0.0986) + (4*0.2433) + (3*0.1466) = 2.2701

TECHIMAN = (2*0.5115) + (3*0.0986) + (4*0.2433) + (2*0.1466) = 1.6120

BADU = (4*0.5115) + (2*0.0986) + (3*0.2433) + (4*0.1466) = 2.9731

5. CONCLUSIONS AND RECOMMENDATION

The aim of this research was to find the optimum location for a new centralized dry port for COSCO Shipping Line Ghana Limited. With the help of the models adopted, the COG employs load, transport rate and coordinate (x, y) as criterion. Also, the Time series regression (trend) was used to determine the trend of future demand while the AHP analysis considered Cost, Transport, Topography and Political state of the three (3) locations (Techiman, Wenchi and Badu) within that specific radius considered in the Brong Ahafo region. In the end the optimum location was found to be Badu precisely.

It is of recommendation for the benefit of COSCO Shipping Line Ghana Limited, to construct a centralized Dry port at Badu in the Brong Ahafo region to facilitate the company and customers to enjoy following benefits;

- Reduced transport cost from the landlocked countries' perspective
- Meeting customer satisfaction by getting goods closer to customers, especially those in the northern and central belt of the region
- Reduction in distance travelled by customers to get access to cargo, hence improved lead time
- Easing port congestion and creating space of port terminals.

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