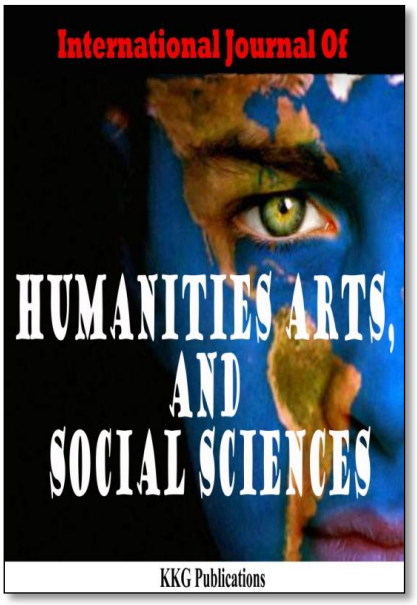


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# HINTERLAND DEMARCATION BETWEEN TWO WEST AFRICAN PORTS

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**Abstract.** Seaports play an important role in the economic integration of any port state even beyond the vital role they play in international trade and maritime transport by offering harbors for the safe berthing of ships that call on them. But for a port to be viable, it needs to know its clients and inter alia; their geographical locations in order to serve them well. The port must therefore, segment its hinterlands so that it will be able to do a thorough analysis of the needs of such hinterlands in order to improve port efficiency and to avoid cargo shifting to other neighboring ports. In doing this segmentation it is imperative to use quantitative analysis with a scientific theory model and method so that the reasonable hinterland of a particular port can be determined. Hinterland segmentation is defined in a scientific and rational manner after which port hinterland is described in a concise way, differentiating the different types of port hinterlands after which factors, which may determine the classification of port hinterlands, are also discussed. The gravitational model is thereafter, used to do an analysis of the hinterlands of the ports of Abidjan and Tema, both situated in the West African sub-region, then an empirical analysis is done based on the actual situation of the two ports under study.

## INTRODUCTION

The hinterland of a port is basically made up of areas where the port serves and can be served from. To wit, a hinterland is the area over which a port extracts its main clientele base (Notteboom, 2008). Delimitation of a port's hinterland is almost an impracticable agenda as the limits of the port's hinterland vary in terms of several factors such as transport network, seasonal changes in commodities, technological changes and in the special case of Africa, political stability and instability.

It must however be emphasized that political stability or instability may be a temporary factor in determining the hinterland of any said port. For example, when there was civil unrest and war in Ivory Coast, transit cargoes bound to the Sahel regions of Mali, Niger and other countries, shifted to the Tema port in Ghana, but as soon as Political stability gained grounds in Ivory Coast, those transit cargoes shifted again to the port of Abidjan (Patton, 1958). Because of divine providence, it's almost rare to have a static concept in the behavior of market dynamics of port hinterlands.

### Objective of the Study

The current study is aimed at segmenting the hinterlands of two West-African ports, using the Gravitational model, in order to produce a more scientifically based result.

## LITERATURE REVIEW

In 1963, BIRD postulated the Anyport model, which examines how ports develop in time and space. In the expansion stage of any port, industrial growth impacts directly on the growth of that port and further widens its hinterlands. The specialization stage of port development make ports to develop specialized terminal such as dedicated container terminals, dedicated oil/ore terminal, etc. Because of this fact, containerization has increased rapidly, especially in the West African sub-region and this has expanded the hinterlands reach of ports due to the relationship between gateways and hinterlands and this has also increased port competition (Hayuth, 1988; Slack & Starr, 1995).

Over the years, significant changes have occurred in the size of ships and the role played by ports. This has made ports to shift their roles in the supply chain and has increased the deliberate development of hinterlands by ports in a significant way. As part of the strategic planning of a port, the port authority must have an extensive research on both the hinterlands of their port and of other neighboring and competitive ports in order to know the factors which may or may not affect the use and non-use of their port by port stakeholders such as Shippers, NVOCCs, etc. In doing so, the port authority will be in a better position to serve its clientele base in its hinterlands very well. Therefore, in doing

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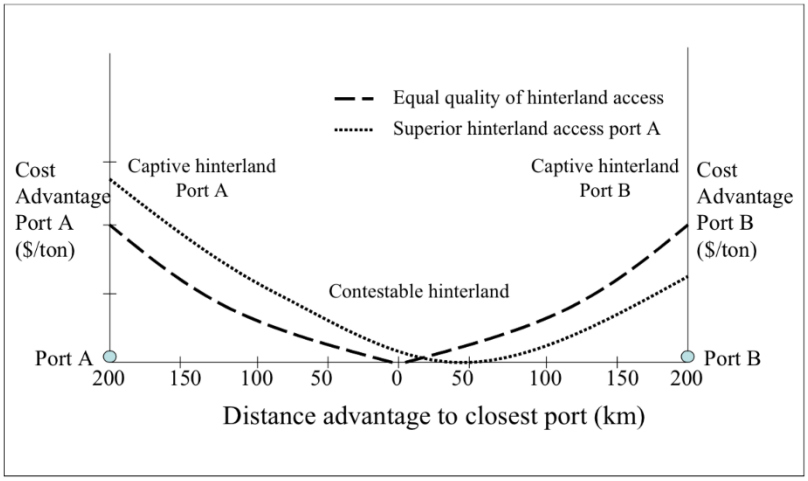
such a research, it is imperative to use scientific based theoretical methods and approaches in order to arrive at a conclusive end. Kenyon (1970) postulated that Proximity of a port in terms of a proposed location can be based on the sea and coastal surroundings but also the areas that the proposed port will serve in terms of economic activities (hinterlands). Jie and Huaqiang (2009) applied the gravitational model to segment the hinterlands of the Ports of Qingdao and Tianjin. Dong and Fan (2002) also used a quantitative analysis to jointly direct the hinterlands of Shanghai and Ningbo port using a location quotient. Jie and Huaqiang (2009) used a Multi-level fuzzy comprehensive evaluation method to segment the ports of Shenzhen and Guangzhou.

The demarcation of port hinterland especially in the whole of Sub-Saharan Africa has colonial antecedents and somehow chronologically out of the partitioning of Africa by the erstwhile colonial powers of the West (Wang, Yang, & Lu, 2005). In this paper, an analysis is made of port hinterlands in the West African sub-region using the gravitational model as a more scientific approach.

**Concise Description of Hinterlands**

Port hinterlands can basically be categorized into Captive hinterlands and Contestable hinterlands. The captive hinterlands are areas where the port is able to reach and serve its customers and clients at a very competitive price. It can also be described as areas where the port has a well-established clientele base and does not face any form of rivalry from neighboring ports. Because of a lower generalized transportation cost, some ports enjoy a considerable amount of competitive advantage over other ports and so in areas where a port enjoys such competitive advantage, such areas or regions can be referred as its captive hinterlands. So consequently, an immense amount of cargoes to/from this region are handled by the port, which considers those areas as its captive hinterlands. In the specific case of the Tema port in Ghana, the four-walls of Ghana could be described as its captive hinterlands because those are the areas that do not receive any competition from any neighboring ports such as Abidjan, Lome and Cotonou. Where no port has a continual cost advantage over other neighboring ports, port competition becomes fiercest, and these areas can be referred to as Contestable hinterlands (De Langen, 2007). To wit, the contestable hinterlands of a port are those areas that the port serves and can be served from but are also up for competition from other ports. Depending on the efficiency of a port, it can lose or maintain or even expand its contestable hinterlands. Taking the Tema and Abidjan ports in Ghana and Ivory Coast respectively into perspective, their contestable hinterlands are the Sahel regions of West, Central and North Africa. These are regions, which are basically land-locked and need the services of these two ports (and other ports) to serve as a gateway for maritime transport (Chan, & Yip, 2011).

**FIGURE 1**
**Captive and Contestable Hinterland**




**Factors that Determine the Classification of Port Hinterlands**

In the classification of a port hinterland, several factors come into play to determine how the hinterland is classified, whether Captive or Contestable. These factors may not be absolute or applicable in some regions of the world but they are a sin qua non to how port hinterlands in Sub-Saharan Africa are classified. These may include inter alia; Geographical barriers, where port hinterlands are segmented by reason of a geographical landmark such as a mountain, river or even the sea such that, a particular port defines a captive hinterland from such barriers. National policy; where a governmental regulation or policy may affect the use or non-use of a particular hinterland. For instance, cabotage laws imposed on a certain region by the government can affect the use of that region by a port as its hinterland. Infrastructure;

Physical structures and facilities may affect the segmentation of a port's hinterlands (Wang, & Liu, 2010). Access roads, transport networks etc. may determine whether an area can be classified as either captive or contestable hinterlands. The port of Abidjan has a direct railway line which links the Northern territory of Burkina Faso, whilst the Tema port does not have a railway line linking its Northern territories. Therefore, although Burkina Faso could be classified as a contestable hinterland between both Abidjan and Tema ports, Abidjan has a slight competitive advantage by reason of its good transport network (Mayer, 1900). Soft element; In international trade, some essential characteristics play a very important although not very explicit role. Language barrier is such an element, which could be used to classify the extent of a port's hinterland, especially in the West African Sub-region. Shippers from Francophone countries, whether Coastal or Land-locked, would prefer to use a Francophone country's port and an Anglophone Shipper is likely to do same. The shipper's choice in using either a Francophone or Anglophone port tends to affect the extent a port can classify a certain landmass as it hinterlands. Port Efficiency; Port efficiency plays a very vital role in maritime Supply chains. For a port to be a preferred port to both shippers and shipping lines, it has to be efficient. Efficiency of a port is measured in terms of Port turn-around time, Delays, clearance procedures, etc. When more shippers and shipping lines call at a particular port, where those shippers are located within the port, the area can be classified as part of the port's hinterland.

**Hinterland Segmentation of 2 West African Ports Based on the Gravitational Model**

**A. The Quantitative Methods of Hinterland Segmentation with Gravitational Models**.

Given there are i $ports^{\,i\in I(i=1,2,\ldots\ldots,n)}$ where 'n' denotes the "efficiency" (that is its gravitation) of the port or the port city. It is important to represent the economic strength of the port city, which can be given as $m_{i.}$ The value of the economic strength of the port city is a coalition of agricultural and industrial output, import and export volume and other natural and geographical factors or even transport linkages (Jinfong, 1990). The strip J, can be denoted as the intermediate zone between the two neighboring ports, port1 and port2 and represented as $^{(j=1,2,\ldots\ldots,n)\ j\notin I}$, and then the gravitation within the intermediate zone, J of the two ports is represented as:

$$F_{1j=}\ k\frac{m_1 m_j}{L_{1j}^2} \qquad F_{2j=K}\frac{m_2 m_j}{L_{2j}^2}$$

Furthermore, the line between port1 and port2 is denoted as the X-axis and the distance covering the straight line denoted as 2a, whereas the middle point of the line is the origin O. From this, the separatrix of the hinterlands of the two neighboring ports, 1 and 2 is denoted as the point J, so j (x, y). When the gravity between the two ports becomes equal, then;

$F_{1j=}\ F_{2j}$

$\frac{m_1 m_j}{L_{1j}^2} = \frac{m_2 m_j}{L_{2j}^2}$, Therefore,

$m_{1[(x-a)^2+y^2]} = m_{2[(x+a)^2+y^2]}$

$x^2 + 2\ \frac{m_1+m_2}{m_2-m_1}\text{ax}+y^2 + a^2 = 0$

$\left[x + \frac{m_1+m_2}{m_2-m_1}a\right]^2 + y^2 = [\left(\frac{m_1+m_2}{m_2-m_1}\right)^2 - 1]a^2$

$x = -\left(\frac{m_1+m_2}{m_2-m_1}\right)a, where\ y = 0, R = \frac{2a\sqrt{m_1 m_2}}{m_2-m_1}$

The set j, which is the separatrix of the hinterland of the two ports can be obtained as:

j ( $j^{\in J}$). When the gravitation range of a port, has a small "efficiency", the center and radius are represented as $[-\left(\frac{m_1+m_2}{m_2-m_1}\right)a, 0]$ and $\frac{2a\sqrt{m_1 m_2}}{m_2-m_1}$ respectively.

**B. Evaluation of the Index System of the Port Gravitation**

'Efficiency' of the two neighboring ports is the essential factor in the gravitational model. This is because; several factors impact the ports' gravitation, making it a complicated method. The port gravitation index system in this paper was evaluated using quantitative methods, and the methods used are not far-fetched. First of all, the evaluation index system of the port gravitation is established by requesting opinions of stakeholders and experts.

Secondly, the Delphi and entropy weight methods are used to determine the combined weight of all the levels' indices and the value of the port gravitation is obtained using fuzzy comprehensive evaluation method (Ying, & Yuan, 1999). Finally, the scale of the hinterlands of the two ports under study is obtained by substituting the value of the port gravitation and the distance between the two ports into the gravity model.

In evaluating the index system of the port gravitation, we have selected 4 first grade indices, based on expert opinions. These indices are based on the basic conditions of the port such as port throughput, Gross Domestic Product (GDP) of the port city, port operational conditions, et al. Thereafter, 12 second grade and 23 third grade indices are selected respectively. Meanwhile, in accordance with the concrete content of the indices, the value of every index is determined by way of subjective and objective weighting methods. Firstly, via subjective weighting method, the weight of the third grade indices is obtained. Secondly, using entropy method, the weight of the third grade indices is obtained.

Entropy is a thermodynamic concept, which is a measure of uncertainty of a system. The steps for entropy weight methods are as follows:

1. According to the principle of qualitative and quantitative analysis, let n-evaluation objects (programs), m-evaluation indices achieve multi-target on multi-indices of evaluation matrix;

$$R= \left(r_{ij}\right)\quad m\times n$$

$$R=\begin{bmatrix} r_{11} & r_{12}\ldots & r_{1n} \\ r_{21} & r_{22}\ldots & r_{21} \\ r_{m1} & r_{m2} & r_{mn} \end{bmatrix}$$

2. According to the definition of entropy, entropy of the ith

indices can be represented as $H_{i=-k\sum_{j=1}^{n} f_{ij}\ \ln f_{ij}}$ and $f_{ij=r_{ij}/\sum_{j=1}^{n} r_{ij}}$, k=$1/\ln n$, $i = 1,2,\ldots.,m, j = 1,2,\ldots.,n.$

**3. Index weight calculation.**

The weight through the specific value of indicators is determined through the entropy weight method.

Therefore, the entropy weight, of the ith index is defined as: $\omega_{i=(1-H_i)/(m-\sum_{i=1}^{m} H_i)}$. The paper uses Delphi method to get the third grade indices of the Tema and Abidjan ports and thereafter, calculates the weight of the port gravitation with entropy weight method, which is weight II.

We finally get the evaluation index's objective weight, which is combined with Delphi method and entropy weight method.

1. The weight of the Delphi method is represented as, $W^1 = (\omega_1^1, \omega_{2,\ldots\ldots,}^1 \omega_k^1)$.

This is then put into $W^2 = (\omega_1^2, \omega_{2,\ldots\ldots,}^2 \omega_k^2)$.

Due to the result of the ith indices, the weight becomes $\omega_{1=}^0\ \omega_i^1 \times \omega_i^1$ and then, a weight vector of $W^0 = (\omega_1^0, \omega_{2,\ldots\ldots,}^0 \omega_k^0)$ is generated.

2. There must be a standardization of the weight vector if normalization of the weight is to be achieved. Therefore,

$\omega_{1=}\ \omega_i^0 / \sum_{i=1}^{k} \omega_i^0$

and the co-weight of the vector is also obtained as

$w = (\omega_{1,}\omega_{2,\ldots\ldots}\omega_k)$. (Table 1).

**TABLE 1**
**Port Gravitation Evaluation Index System**

| First grade indices | Weight I | Weight II | Weight III | Second grade indices | Weight I | Weight II | Weight III | Third grade indices | Weight I | Weight II | Weight III |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Self-acclimatization | 0.15 | 0.29 | 0.19 | Normal situations | 0.5 | 0.88 | 0.88 | Location | 0.5 | 0.03 | 0.06 |
| | | | | | | | | Navigable passage | 0.4 | 0.51 | 0.77 |
| | | | | | | | | | 0.1 | 0.46 | 0.17 |
| | | | | Infrastructure | 0.5 | 0.20 | 0.12 | Draft Depth | 0.5 | 0.69 | 0.69 |
| | | | | | | | | Quay length | 0.5 | 0.31 | 0.31 |
| | | | | Capacity to work | 0.5 | 0.32 | 0.67 | Carriers | 0.2 | 0.04 | 0.03 |
| | | | | | | | | Ship Traffic | 0.2 | 0.20 | 0.15 |
| | | | | | | | | | 0.35 | 0.26 | 0.34 |
| | | | | | | | | Operation efficiency | 0.25 | 0.50 | 0.48 |
| Control Skills | 0.35 | 0.13 | 0.19 | Passing capacity | 0.3 | 0.07 | 0.08 | Container throughput | 0.6 | 0.18 | 0.25 |
| | | | | | | | | Total throughput | 0.4 | 0.82 | 0.75 |
| | | | | Sustainability | 0.1 | 0.55 | 0.23 | Development space | 0.65 | 0.93 | 0.96 |
| | | | | | | | | Creative Ability | 0.35 | 0.07 | 0.04 |
| | | | | Quality control systems | 0.1 | 0.06 | 0.02 | Port efficiency | 1 | 1 | |
| Work power/rate | 0.3 | 0.32 | 0.40 | Profitability strength | 0.15 | 0.12 | 0.13 | Gross Domestic | 0.4 | 0.82 | 0.75 |
| | | | | | | | | Foreign Direct investments | 0.6 | 0.18 | 0.25 |
| | | | | Maritime market | 0.25 | 0.6 | 0.60 | Maritime market | 0.5 | 0.24 | 0.24 |
| | | | | | | | | Financial freedom | 0.5 | 0.76 | 0.76 |
| | | | | Port supply chain | 0.3 | 0.15 | 0.14 | Port supply chain | 1 | 1 | |

**C. The Evaluation Methods**

Many researchers have used Fuzzy comprehensive evaluation method to analyze and achieve accepted results in both economic and social analyses, including scientific researches. This paper construed a three grade index for port gravitation, which indicates a multi-level fuzzy comprehensive evaluation.

The Abidjan and Tema ports are evaluated as follow;

**1. Determination of the Comments Set**

V=$\{v_{1,}v_{2,}\ v_{3,}\ v_4\}$= {Excellent, Good, Fair, Poor}

**2. The Factor Sets are Established.**

U= $\{u_{1,}u_{2,}u_3, u_4\}$ $U_{1=}\{u_{11},u_{12}\}$, $U_{11}=\{u_{111,}u_{112},\ u_{113,}u_{114}\}$

$U_{12}=\{u_{121,}u_{122,}u_{123}\}$

$U_1$= Self conditions
$U_2$= Port Efficiency
$U_3$= Gross Domestic Product of the Port city.
$U_4$= Ship Traffic conditions
$U_{11}$= Natural conditions and Acts of God.
$U_{12}$= Port Infrastructure

### 3. Establishment of Weight Set.

The table of established weight set of port gravitation indicates that;

$$A = \{0.1853735, 0.1935507, 0.4002396, 0.2208362\}$$
$$A_{1=} \{0.8802762, 0.1197238\}$$
$$A_{11} = \{0.0614539, 0.7656984, 0.1728476\}$$
$$A_{12} = \{0.685725, 0.314275\}$$

### 4. Calculate the Evaluation Results

Third-level fuzzy evaluation is done with three grade indices and the weight which belongs to $V = \{v_{1,} v_2, v, v_n\}$. After this, there is a push of one level, and finally, a comprehensive evaluation of the results is obtained. The three-level fuzzy comprehensive evaluation of Abidjan port gravitation is represented as:

$B = A \circ R = (0.192898, 0.456334, 0.33727, 0.013498)$ And the three-level fuzzy comprehensive evaluation of Tema port is also given as:

$B = A \circ R = (0.18208, 0.332726, 0.353354, 0.13184)$

If the value of the comments set $V = \{v_{1,} v_2, v, v_n\} =$ {Exellent, Good, Fair, Poor} with 4,3,2,1 respectively, then the value of the comprehensive evaluation of Tema port gravitation is 2.5650 and Abidjan port is 2.8286.

### D. Calculation of the Hinterland Area of the Two Ports.

**Port Gravitation to the Point J**:

The gravitation of the port reaching the point j is indicated as:

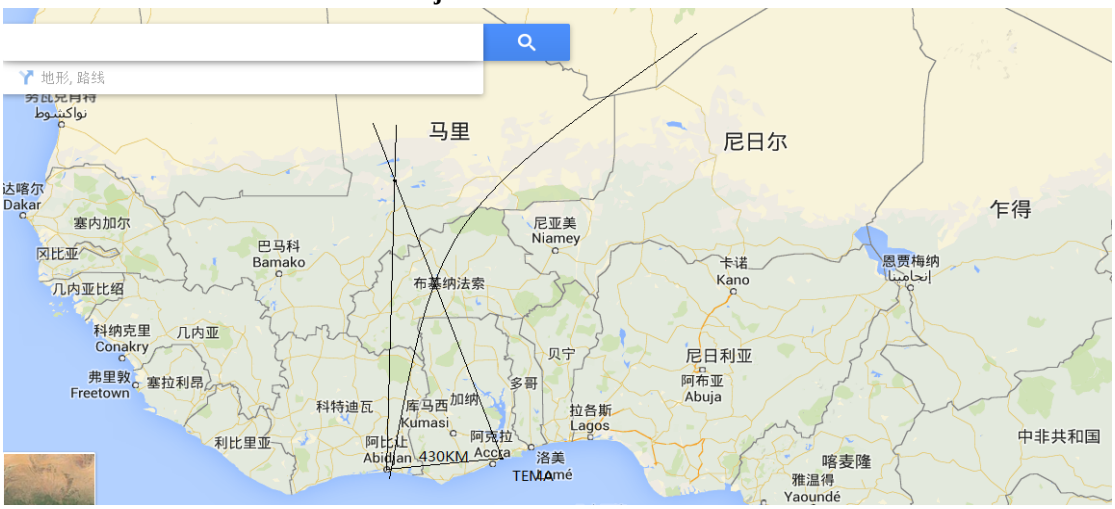
$$F_{1j=} k \frac{m_1 m_j}{L_{1j}^2} \qquad F_{2j=K} \frac{m_2 m_j}{L_{2j}^2}$$

Now, the straight line between the two ports is considered as the X-axis and the distance between the straight line is 2a(430km) and the origin O is taken as the middle point of the line. Therefore, the separatrix of the hinterland of the two ports becomes point j.

When gravity is of the same value, then,

$F_{1j=} F_{2j}, \frac{m_1}{L_{1j}^2} = \frac{m_2}{L_{2j}^2}$. This can be established from the set j ($j \in J$), which is the separatrix of the hinterlands of the two ports. The gravitational area of variation between the lower and upper limits of the port has a minimum ''efficiency'' which is a center that $[-\left(\frac{m_{1+} m_2}{m_{2-} m_1}\right) a, 0]$ is center and $\frac{2a\sqrt{m_1 m_2}}{m_{2-} m_1}$ is radius of the port. When $m_{1=2.5650,}$ $m_{2=2.8286}$ as determined above, the hinterland area of variation between the lower and upper limits of the port of Tema relative to port of Abidjan is a center that (-4399.47,0) is center and 4394.21 is radius.

**FIGURE 2**
**Hinterland Partition of Abidjan and Tema Ports Based on Gravitational Models**




### CONCLUSION

If a port spends a lot of time in planning its development but does not know how to segment its hinterlands in order to be well placed to satisfy its clients, then all its efforts at port planning and development are exercises in futility because hinterland segmentation is a sin qua non to port efficiency and development.

In this research, a more objective evaluation index weight system was used by applying entropy weight and Delphi methods. The comprehensive evaluation of the two West-African ports, Tema and Abidjan was done using Fuzzy comprehensive evaluation method which gave us the ''efficiency'' of the two ports in Gravity model.

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The research further highlighted the area which the studied ports can consider as both their captive and contestable hinterlands and shows from the map that the port of Abidjan has a slight advantage over Tema port in terms of claiming the hinterlands in the Sahel regions by dint of its Geographical location and some other fuzzy technicalities.

The gravity model divided more clearly the hinterland of the two studied ports and threw more light on how it can offer technical support for port planning and development. This was done on the wings of the determination of the "efficiency" in the hinterland segmentation via the theoretical and empirical analyses.

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