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## Optimizing locations in Africa: meet central place theory and Huambo reality

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**Optimizing locations in Africa. Meet central place theory and Huambo reality.**

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***Abstract***

The optimization of the location of public services in the villages and neighborhoods in the city of Huambo in Angola results in a hierarchical system of central places that can be calibrated to give different hierarchies according to the accessibility level. This result is achieved for 300 villages and neighborhoods in the city of Huambo by minimizing the number of centers subject to the restriction that the service is available at a minimum distance. The solutions are used to design roads, local authorities and market shares principles [K=3 (marketing), K=4 (transportation), and K=7 (administrative)]; as Christaller's envisage it, a planning tool, a technology for practicing instrumental rationality or meeting reality with central place theory.

Keywords: location, central places, optimization, Africa

JEL: R58 - Regional Development Planning and Policy

1) **Introduction**

The spatial allocation of public services is a very important issue, not only justified by the tension between territorial cohesion and efficient use of public funds, but also for the long term implications the spatial allocation of public services generates in migration patterns and in cumulative effects on urban growth and hierarchies. This is more so in developing countries which rural areas are very much characterized by subsistence economies with an urban hierarchy that can be very much influenced by the allocation of public services and the related design of infrastructural networks.

In Africa there more than 70% of urban population lives in urban slums with all the environmental, social and economic structural and cumulative problems that the process represents (Baker, 2008). According to the World Urbanization Prospects urban population in Africa will grow from 412 million in 2010 to 566 million in 2020, whereas rural population will grow from 620 million in 2010 to 704 million in 2020. Following the same pattern the Master Plan of Huambo (2012) estimates that the urban population of the provincial capital will grow from 1,2 million in 2010 to 1,5 million in 2020 and rural population from 1,2 million to 1,0 million. Nevertheless, according with an adequate public investment and induced private investment in a suitable network of secondary and

tertiary urban nucleus, the provincial capital can have 1,4 million in 2020 and the rural areas at 1,2 million (Dentinho, 2012), allowing the reduction of the slum area in the city and the improvement in the provision of health, education and urban services in the rural areas. For sure this is only possible in a country like Angola where the main driver of the economy is associated with the royalties on oil exports and public spending; the issue is where the money goes: to Luanda or also to the Provinces? to the main cities of the provinces or also to the rural areas?

The aim of this presentation is to contribute to the design of suitable urban networks by optimizing the number of centers subject to the restriction that different levels of education and health services are available at minimum distances. The solutions can reveal interesting patterns of Christaller hierarchies influenced by the sequential set of minimum distances. The hierarchies are used to design roads, local authorities and market shares based on principles [K=3 (market shares), K=4 (transport optimization), and K=7 (administrative)]; as Walter Christaller (1966) envisage it, a planning tool, a technology for practicing instrumental rationality or, as argued by Trevor Barnes (2012) an instrument of war. The proposal here is to confront the results of the central place theory with the reality of Huambo in Angola.

The presentation will have four major points. In point 2, we justify the selection of the optimization method of spatial allocation of services. In point 3, we present the data on population and distances and optimize the location of services for various minimum accessibilities. In point 4 we discuss the results looking into the spatial structures associated with the modification of the minimum distance for services. Finally, in point 5, we suggest some conclusions and recommendation to support the design of service allocation policies in developing countries.

2)        **Methods to Optimize the Location of Services**

A large literature has been developed to address location problems (Owen and Daskin, 1998), being also one of the pillars of regional science (Isard, 1949). Urbanists, geographers, engineers and economists and politicians, all of them have thoughts and tools on how to allocate services throughout space (Daoqin, 2012). Reville et al (2008) systematize the various approaches into four main groups: i) Analytical models that, based on uniform density, fixed cost of a service and a cost per distance, estimate the number of services for different types of spatial metrics; ii) continuous models, like the Weber Model, that identifies each location with coordinates (x,y) and minimizes the distances weighted by the transport demand of the various origins and destinations; iii)

network models that look at location from the design of a tree composed on optimal nodes;

iv) and discrete location usually formulated as an integer programming problems and

divided into weighted demand models, like ReVelle and Swain (1970), that assumes that

bigger places deserve more service than smaller ones, and, center and covering problems,

that aims at maximize the lowest service standard to any customer in the problem, like

initially proposed by Toregas et. al. (1971).

Since the problem addressed is to cover all the villages in the region the model adopted

follows the Toregas' approach. The objective function (1) minimizes the number of

locations ( $y_i$ ). Constraints ensure that all nodes can reach any service location below a

minimum distance ( $d_k$ ) for each level of service ( $k$ ). Coefficients ( $a_{ij}$ ) are equal to zero if

the distance ( $j,i$ ) is higher than the threshold ( $d$ ) and one if the distance ( $j,i$ ) is lower than

that limit (3).

$$(1) \text{ Min } \sum_i y_i$$

$$(2) \sum_i a_{ij} y_i \geq 1 \text{ for all } (j)$$

$$(3) a_{ij} = 1 \text{ if distance } (i,j) \leq d_k \text{ for all } (i,j)$$

Distances by road are obtained with GIS maps where all villages and roads were mapped

and located. There are 274 villages and neighborhoods to be served by different levels of

public services.

The model is first run for the maximum distance (65 km) resulting in just one location  $y_1$  in Huambo city area. Then, following the market principle ( $k=3$ ) we search for the distance threshold that leads to 3 locations, including the first one, and find out (30 Km).

Once more we fix those three former locations to get (3x3) locations, obtaining the distance of 12 Km. Finally, for (3x3x3) locations we find the distance of 6 km and for (3x3x3x3) places only 3 Km of access radius; the market principle in Huambo Municipality requires 5 levels of services. The same exercise is done following the Transport Principle ( $k=4$ ) associated with 4 service levels and the Administrative Principle ( $k=7$ ) with 3 service levels.

### 3) **Optimizing the Location of Services in Huambo for adjusted distances**

The first hierarchical structure is estimated by calibrating the minimum cover distances so that each higher service area has 3 service areas at its lower level following the Christaller market principle ( $K=3$ ). Results, presented in (Figure 1), shows that this rule requires 5 service levels to cover all the territory. Huambo is the more central place, followed by Sambunde in the North and Caputo in the South.

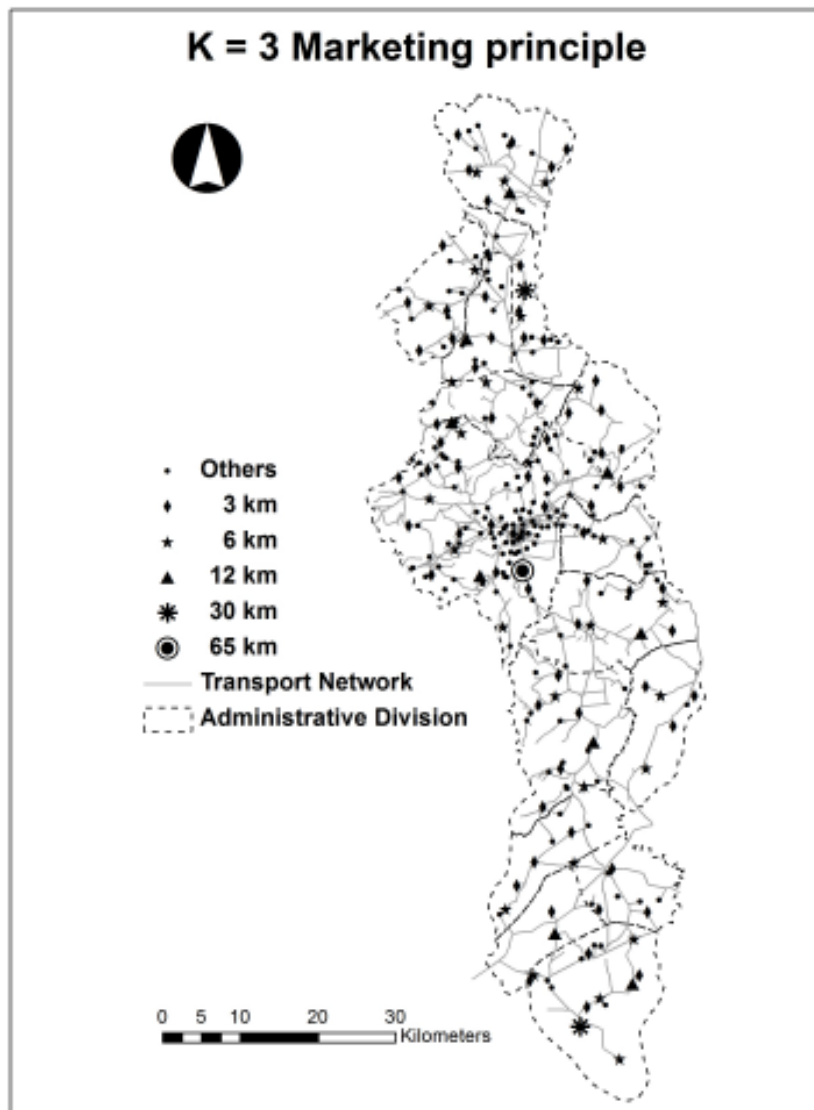


Figure 1: Hierarchy of Centers for the Christaller Market Principle (k=3)

The second hierarchical structure following the Christaller transport principle (K=4).

Results, presented in (Figure 2), shows that this rule requires 4 service levels to cover all the territory. Huambo is the more central place, followed by Lombimba in the North, Caputo in the South, Vilali in the East and also the town of Huambo.



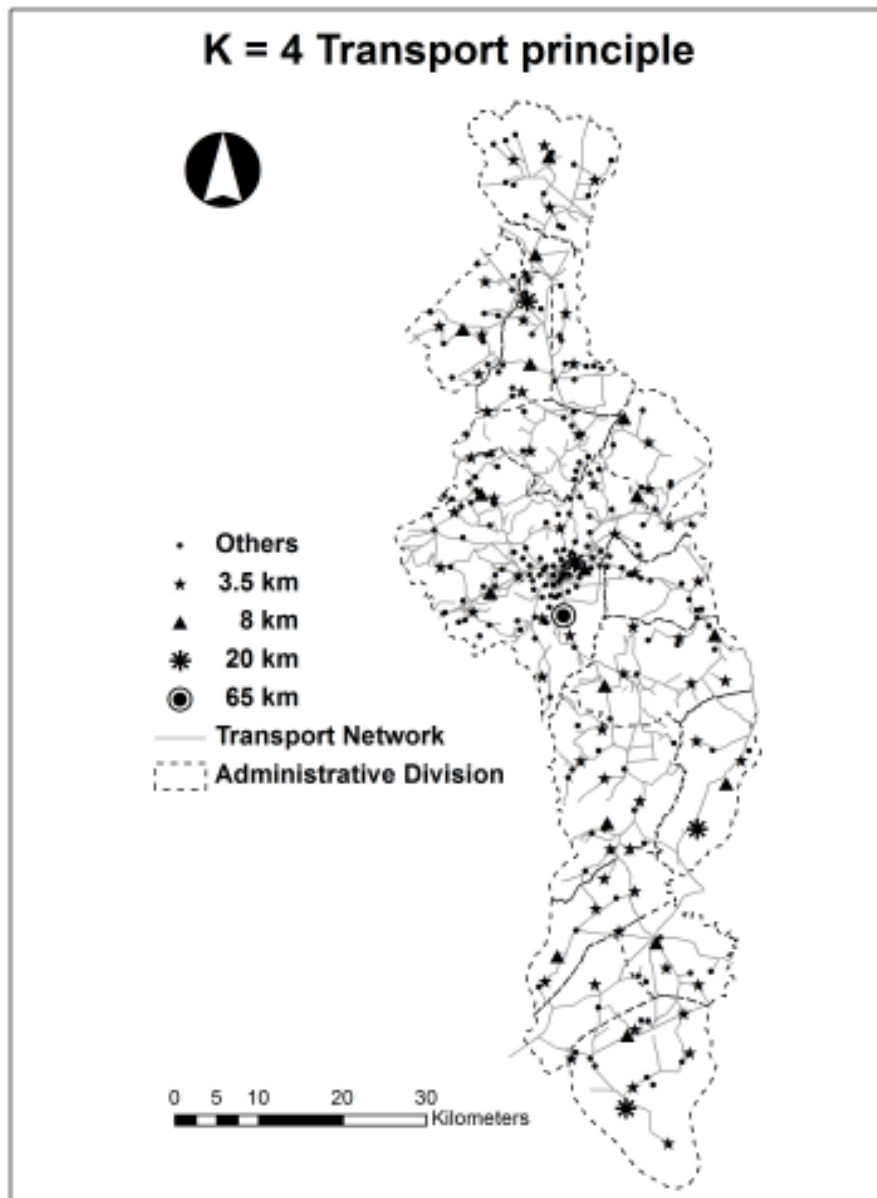


Figure 2: Hierarchy of Centers for the Cristaller Transport Principle (k=4)

The third hierarchical structure following the Christaller administrative principle (K=7).

Results in (Figure 3), demonstrate that this rule requires only 3 service levels to cover all

the territory. Huambo is, once more, the more central place, and only the far north and the

far south centers maintain more or less the same position as they obtained for market and transport principles (Figures 1 and 2)

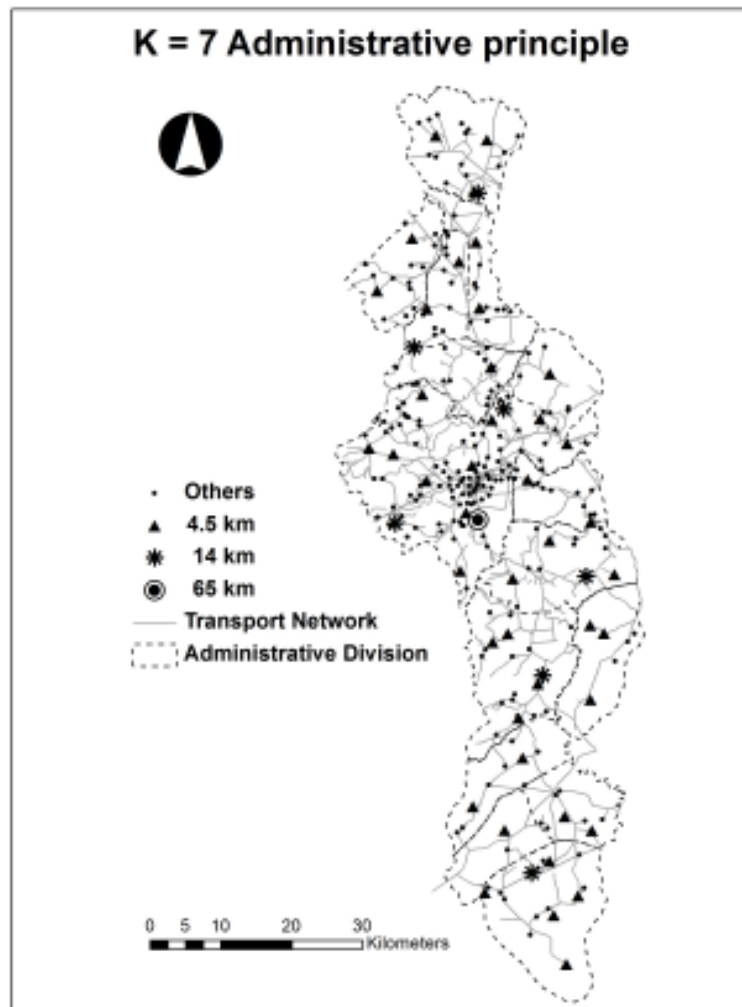


Figure 3: Hierarchy of Centers for the Cristaller Administrative Principle ( $k=7$ )

4) **Discussion**

The combination of location covering optimization models with the Walter Chirstaller analytical framework applied for an African context, for the special case of Huambo

Municipality reveals interesting features that we would like to highlight:

- First, the hierarchical optimization exercise seems quite interesting path to follow in the development of location optimizing models, not only because it fits the hierarchical nature of spatially distributed services by also because it seems to be a promising, and so far as we know, not yet explored methodology for more complex systems.

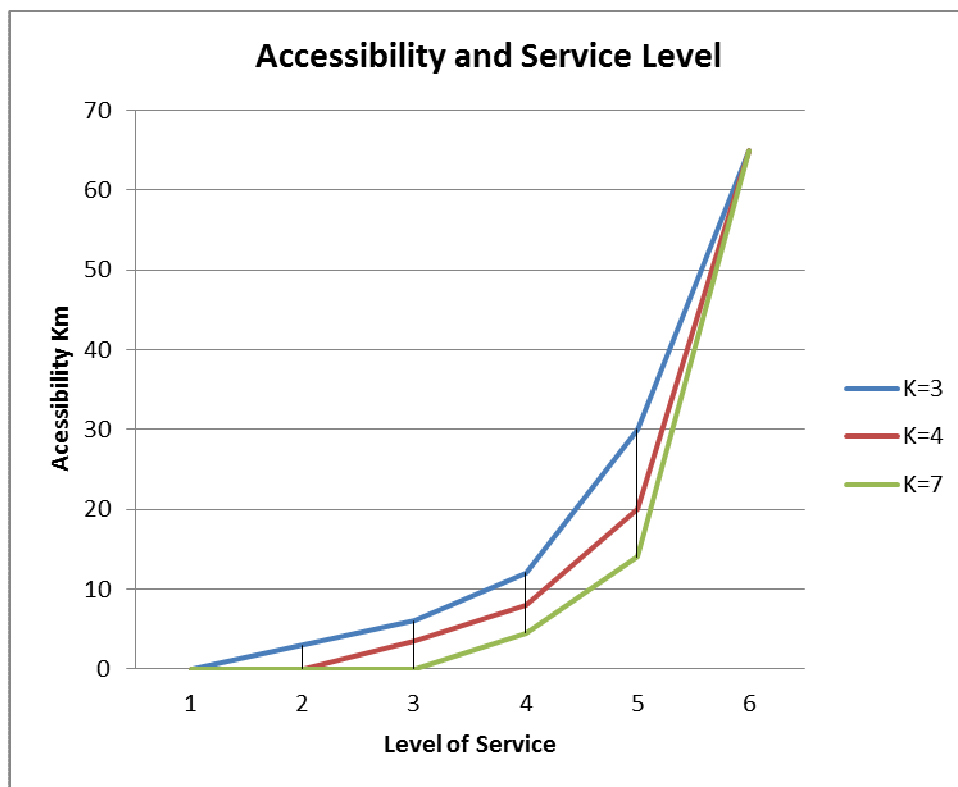


Figure 4: Relations between Accessibility and Service Level

- Second, as presented in Figure 4, it is possible to design a type of Gini Indice that indicates the degree of service coverage of the territory. As expected, higher k leads to more reduced coverage.

- Third, looking into the diversified territory of Huambo, it would be very interesting to calibrate the more adjustable service location model for different areas of the municipality (North, Center and South).

5)        **Conclusions**

The idea of the paper is to confront the central place theory with the reality of Huambo in Angola using optimization methods of spatial allocation of services. We learned that central and remote places are more resilient in their centrality but intermediary locations can vary according to the Christaller hierarchical principle. We also explored the use of hierarchical optimization procedures that can push new ideas in the more complex location optimizing problems. Finally new indicators of regional equity were disclosed. Future work involves the application of the reasoning to the various areas of Huambo municipality, the inclusion of richer objective function that could include costs and benefits associated with population.

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