MULTIDIMENSIONAL MEASUREMENT OF THE CONCENTRATION OF POPULATION

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ABSTRAC

The current way of measuring the concentration of population is mainly based on estimating the ratio between people and territory at a given point in time. It is easy to understand that the way of measuring concentration is subject to sudden changes in migration flows. This paper proposes a new way of measuring the levels of concentration of population in a territory, using a great quantity of information on the characteristics of population as well as housing, infrastructure and services in the region. A new measure of concentration is proposed capable of capturing multiple elements that gives density to a space and in turn allows us to understand the populations as an integral part of system that also gives shape, structure and complexity to the territory. Thus this designed method considers different stages of measurement. During the first stage tangible elements such as the population and the physical elements that fill spaces are quantified using the statistical method known as DP2. This makes it possible to assign a hierarchy level of each of the studied localities, which we understand as a group of one or more occupied dwellings.

In the second stage the relationships between sets of locations are identified. In other words, systems of mapped locations identified as networks are built. It is through the identification of relationships that makes it possible to establish towns as new elements in the system of locations. It is understood that relationships are also elements that increase density in the space, and that the position of a locality within the system changes its degree of centrality and therefore should effectively increase the level of concentration.

Finally, a formula for calculating the concentration index using the hierarchy of the location, the density measurements of the locality systems and surface locationsas inputs, as well as the locality and what occupies the whole system, is proposed.

Keywords: *housing, adobe, reinforcement, structure, safety, earthquake-resistant.*

The spatial distribution of the population, within the territory, gives rise to the problem of measuring the levels of concentration or dispersion, because the distribution is generally heterogeneous. The way the population is distributed in the territory is closely linked to historical, economic, social, political, environmental and culturalfactors. However, the concentration of population in large urban centers is due to a greater availability of resources, infrastructure and services, which in turn determine the living conditions of the population and their standard of living.

The development of a measure of concentration of population depends first on the number of people living in the territory. However, the technical difficulties of quantifying aresident population in a given space and time, as well as the ephemeral nature of measurement, make the development of new techniquesnecessary. This forces us to analyze the relationship between population and territory (the greater the population implies a greater concentration), and supplement this with less dynamic elements that allows for the construction of a more robust estimation.

Not only does the number of people present in a territory make it more dense, but other elements associated with their demographic composition, structure by age and sex, educational level and production capacityshould be considered.In addition, economic elements such as the amount and quality of facilities, housing, and infrastructure in terms other than their number but alsotheir importance and relevance, need to be considered as well.

Therefore a region is dense for its population, but also for all that its presence implies. Numerous population centers involve a higher concentration of housing, basic services and facilities such as potable water, electricity, roads, schools and hospitals, as well as production and communications infrastructure such as factories, shops, banks, shopping centers, ports and airports. In other words, in order to design a new way of measuring the concentration of a population which is robust and stable over time, should consider in addition to the population various elements that comprehensively account the density in land use and the speed with which it can change which involves the measurement of migration, student, and laborflows, among others.

The main problem lies in that the population does not remain static, resulting in two basic difficulties: 1- The measuring of population flows is often very complex the smaller the area 2. -The measurements soon become outdated due to the same dynamics of migration and labor or commuter flows. Therefore it is necessary to analyze the relationship between population and territory and supplement it with less dynamic elements to build a more robust measure of the level of concentration.

The ultimate goal is to build an indicator capable of quantifying the concentration levels grouped in different layers of administrative and / or geographic aggregations, using conceptual bases that are based on theoretical paradigms such as polycentric theory, general systems theory,graphics theory, network analysis [7] and various multivariate statistical methods as tools to reduce the number of variables and data necessary for measuring [4].

The methodology for calculating the index of population concentration has been divided into stages. A brief description of each will be given based on the objectives and tasks required, but also considering the limitations on the availability and quality of data and official information available in the case of Mexico.

The first phase of the methodology is to identify and analyze a set of variables that characterize the towns of Mexico. They are available online (on the official page of the INEGI) and come from the last general census of population and housing as well as information from the economic and agricultural censuses generated by the National Institute of Statistics and Geography (INEGI).

THE PROBLEM OF POPULATION CONCENTRATION IN THE CASE OF MEXICO

Mexico was made up of 192.245 inhabited localities in 2010, although in reality the inventory of locations exceeds 280 thousand. The difference includes inhabited localities. Of all the inhabited localities there are 139,000 sites with less than 100 inhabitants and with only 2.2 percent of the national population (2 million 383 thousand inhabitants), which gives us an idea of the enormous dispersion of the population. Moreover, there are 36 locations with over 500,000 inhabitants. They account for 27.8 percent of the national population (just over 31 million inhabitants), which gives us an idea of the enormous concentration of population. Thus, it is possible to identify a small number of locations with large concentrations of population, but also easy to identify a large number of localities with very small populations. This is a very general overview of the distribution of the population nationwide.

Another factor that is important to analyze is the number and the speed with which localitiesappear or disappear. From the census 2000 and 2010, 45,896localities disappeared and 38,759 locations emerged. It's important to note that of the towns that disappeared, 44,581 had less than 100 inhabitants and a great many of these only changed their name, but it was not possible to distinguish between them.

In this regard, it is important to note that the size of the community is keyfactor to explain the permanence and stability in the survival time of localities. 97 percent of those that disappeared were less than 100 inhabitants. It is also necessary to analyze the characteristics of the localities that did not disappear and even more important to know what are the characteristics of localities which also significantly increased in size. What was the economic, demographic and social dynamics that followed to ensure its permanence over time? Were there physical elements or infrastructure that may explain its evolution? In the next section we will build indicators that will explain the elements associated with the main characteristics present in all localities in the country.

The rest of the paper details a new methodology that provides a measure of concentration of population for localities in Mexico through the calculation of an indicator whose objective is to quantify the population density considering a great quantity of information that refers to housing , facilities, infrastructure and services, and their characteristics in terms of quality and level of accessibility.

ALGORITHM FOR MEASURING CONCENTRATION LEVELS OF POPULATION

The methodology for the development of a concentration-dispersion model revolves around the concept of polycentricity, framed within the general systems theory, and evaluated through mathematical functions developed in order to quantify the concepts of centrality and dispersion from a systemic perspective. In this manner a system will not be seen abstractly or qualitatively, but rather will give a mathematical approach to the traditional methods.

The algorithm used to measure the levels of concentration of population in Mexico will develop in the following phases:

1. Assign a hierarchal level to each locality of the country.

2. Identify centers as abnormally dense areas, with a hierarchy level above two standard deviations from the mean of the analysis area.

3. Define continuous central locations, such as those areas where the continuous space of buildings exceeds the limit of the town, in order to identify rural centers, urban centers and metropolitan centers, among others.

4. Establish an area of influence for each center, through the identification of flows between localities.

5. Characterizenetworks formed by localities made up of centers, sub-centers and localities, at different levels of aggregation. They will refer to metropolitan, urban, rural and dispersed systems.

6. Assign a hierarchy to each system.

7. Calculate the measure of population concentration.

HIERARCHY OF LOCALITIES

The locality hierarchy is an indicator of the importance of a location relative to the locations in their environment, which allows for the comparison of the level of primacy of a town of 800 inhabitants with respect to another with the same number of people, but with different demographic, social and economiccomposition. In other words, the indicator allowsdiscrimination between two or more locations from a very large set of variables grouped into at least four basic dimensions:

1. Population size
    - Total Population
    - Education level
    - Access to health services
    - Average age of the population
    - Demographic dependency
    - Migration

2. Structure and composition of households
    - Total households
    - Average size of households
    - Proportion of female-headed households
    - Proportion of single-person households
    - verage number of children per household

3. Dimension of Housing (number and quality of goods in the households)
    - Total housing
    - Quality of dwellings (ceilings, floors, ...)
    - Services (water, electricity, ...)
    - Goods within the house (refrigerator, ...)

4. Locality services
    - Access to highways
    - Public Transport
    - Access to potable water
    - Access to sewage system
    - Garbage collection
    - Public lighting

- Paved streets
- Public square or garden
- Public registrar's office
- Municipal Agency

5. Economic infrastructure of the locality
    - Services infrastructure (number of hospitals, schools...)
    - Communications Infrastructure (dedicated to communications)
    - Productive infrastructure (primary, secondary, tertiaryindustries)

The development of the hierarchy of locationsindicator requires the support of multivariate statistical analysis techniques, which are intended to summarize large amounts of variables, which are often mathematically and conceptuallycorrelated. Statistical techniques are able to reduce and capture most of the observed complexity and generate new concepts known as latent variables. The design leads to the generation of simple and robust indicators.

Regarding the development of indicators, statistical techniques best suited to the type of requirements listed are: principal component analysis (PCA) and analysis of distances (DP2). To design the hierarchy of locations indicator we have chosen to use the analysis of distances technique, DP2, which main characteristic is to identify and discard non-significant relationships.

The DP2 technique aims to develop syntheticindicators based on the concept of distance, where the partial correlation coefficient, between the ith and the jthcomponent is a measure that reflects the absolute value of the difference between the ideal set of indicators (in other words, a standard measure, which are not necessarily found in reality) relative to a set of simple or observed indicators, standardized by the inverse of the standard deviation of the observed indicator. The redundant information is discarded by including the partial correlation coefficient.

Since the variables that make up each locality hierarchyindicator have different units of measurement and scale, the DistanceAnalysis (DP2) is used in order to reduce the effect of the magnitude of the different scales or metrics. However, the implementation of the DP2 demands compliance with a number of assumptions in order to ensure the consistency of the results based on the proper selection and quality of the data, along with the monitoring of the levels of correlation between the variables involved. The assumptions that need to be considered are completeness and objectivity, which implies that the data that are used should be an objective representation of the modeled variable, free from value judgments or subjective predictions.

The DP2 technique transforms all of the components into comparable units, being sure not alter the order of the indicator of the following formula:

$$DP_2 = \sum_{i=1}^{n} \left\{ \left(\frac{d_i}{\sigma_i} \right) \left(1 - R^2_{i,i-1,i-2,\ldots,2} \right) \right\}$$

It should be understood that the use of the DP2 technique aims to estimate the value of a hierarchy index that summarizes thedimensions of the indicators and all associated variables, according to a conceptual model that, for the case of the concentration measurement, is understood in terms of linear combinations of the variables set forth above, that is:

$$jq_{loc} = DP_2$$

The calculation of the locality hierarchy requires the measurement and evaluation of data at the level of thelocality. The information for its estimation can be obtained from the micro dataof the General Census of Population and Housing, Population Counts, as well as the data added at the AGEB level, which come from the Economic and Agricultural Censuses-information provided by the National Institute of Statistics and Geography (INEGI).

IDENTIFICATION OF CENTERS AND SUB CENTERS

The traditional way to identify urban centers and sub-centers is given by the methodology established by Roca and Marmolejo [12], which performs an analysis of the spatial distribution of the density of land use. Four methods emerge from this analysis:

1. Analysis of layer densities and detection of local disruptions with the use of GIS;

2. Use of a set of massand densitythresholds;

3. Identificationfrom an econometric perspective of areas of possible sub-centers with significantly positive residuals in a regression where the dependent variable is the density of employment and the independent distance to the central business district (CBD), and

4. Nonparametric estimation models using local or geographically weighted regression, in order to detect peaks of density after the layer has been adjusted locally, according to two dimensions and considering the effect of the nearby areas.

A second aspect of a functionalist order explains that the centers or sub-centers are not only unusually dense areas, but are nodes from which the functional relationship between nodes, the CBD and the rest of the system is structured.

The functionalist criteria allowthe characterizing of the centers once the hierarchical, complementarity and synergistic relationships are detected. In this manner the identification of the centers and sub-centers will be the most delicate work in terms of the capacity to quantify the measures of centrality and flow of each of the centers, using the value of the relationships established in terms of their complementarity and synergy from all available information to determine the type, frequency, intensity and direction of the relationships.

There are some other definitions of centers of both functional and economic orderswhich can be seen in [29, 32]:

1. Zone withan employment density significantly higher than its region.
2. An area that has a significant effect on density.

3. Representation of the backbone of an urban subsystem within the metropolitan structure.

The way in which we will identify potential centers shall be based on the idea that a center is an area of abnormally dense space, which is able to build relations with neighboring localities. To achieve the objective identification of potential centers we employ a spatial autocorrelation analysis, the same that will allow the identification of areas of high concentration (high hierarchy) starting from the relationship that the hierarchy reserves for each locality with itself and the space.

The spatial autocorrelation analysis is able to identify the extent to which the locations of geographical units are similar to other locations in nearby geographical units. That is, it is able to identify hot spots or hot areas surrounded by hot areas, and vice versa, cold areas surrounded by cold areas. This feature is essential to identify localities with high hierarchy surrounded by localities with high hierarchies, which of course will be identified as centers or sub-centers.

The centrality of a locality is detected through spatial autocorrelation, measured through the Moran index as well as in a global manner:

$$I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(z_i - \bar{z}\right)\left(z_i - \bar{z}\right)}{S_z^2 \sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}$$

Locally:

$$I_i = \frac{\sum_{j=1}^{n} w_{ij}\left(z_i - \bar{z}\right)\left(z_i - \bar{z}\right)}{S_z^2 \sum_{j=1}^{n} w_{ij}}$$

Where W_{ij} is the weighing factor indicating the relationship of contiguity between spatial units i and j, which can be an indicator of proximity or an assigned measurement.

The local unit will be defined by a concentration, in place of the global space, with particularly high values of the locality hierarchy in comparison with its average value.

The mere observationof the distributionof a variable on a map in space allows one to intuitively grasp the existence of patterns of spatial behavior. This information will always be subjective and highly dependent on the number of established intervals that represent this variable on the map. Therefore, it is essential to have a combination of statistical measures or instruments capable of detecting the presence of significant (global and / or local) spatial autocorrelation.

The design of centrality measures of localities in a systemic structure is made through traditional measures of centrality. In general, the way of measuring the concentration of a system is by measurements where the centrality is an attribute of the nodes (localities), assigned in function of their structural position. In other words, there is not an intrinsic attribute (such as income) but rather it is directly dependent on the shape of the system. For example, in a star shaped system, the central node has a maximumcentrality value whereas the nodes of the tips have lower centrality values. In other words the centrality depends on, in addition to the spatial autocorrelation measure, on the position the center occupies with respect to the sub-centers and the other localities.

DEFINITION OF CONTINUOUS LOCALITIES

During the phase of the identification of continuous localities new analytical units are built based upon the group of contiguous localities. These new units are groupings of localities that share at least one common physical border, where the continuum of buildings is not broken or where the number of infrastructures linking the towns make it possible to think that these form a continuum (due to the amount and intensity of flows) and it is also possible to find evidence of similar levels of spatial autocorrelation between localities of the continuum. At this point a new type of sets of localities is proposed that go beyond the simple separation of urban and rural.

Continuous localities are established through an identification algorithm that takes into account:

- The spatial contiguity
- The hierarchical level of the town
- The observed levels of spatial autocorrelation
- The presence of infrastructures
- Geographic ruptures

The continuous identification algorithm is certainly determined by what is meant by spatial contiguity and the definition of neighborhood that uses polygons that make up the territorial units of analysis. At this point, it should be noted that there are a lot of rural localities, especially dispersed localities, whose limits have not yet been made so there is not a polygon defined for them.

The local spatial autocorrelation tests detect clusters of variables that are spatially referenced. These allow for the testing for the presence of areas of spatial dependence within a general or local area through the Local Indicators of Spatial Association, or LISA for short.

Local Indicators of Spatial Association generate a significance indicator for each point of the group. The sum of significances of all of the points in the study area is proportional to the overall indicator for spatial association of that area. That is, the overallautocorrelation rate decomposes and verifies the contribution of each spatial unit to the formation of the overall value, allowing simultaneous capture of the degree of spatial association and the resulting heterogeneity of the contribution of each spatial unit.

The spatial autocorrelation test seeks to test the null hypothesis of non-local autocorrelation (H_0), for which the alternative hypothesis assumes that the test variable has a random distribution.

$$I = \frac{\sum_{i=1}^{n} w_i I_i}{\sum_{i=1}^{n} w_i}$$

Wherewi is, as before, the weighting factor for proximity or distances.

The use of the LISA test is proposed because some global statistical spatial lag can mask patterns of spatial autocorrelation, while LISA is capable of detecting them and also showing their location. It can also break down overall results into local results and discover local hidden patterns of data contained on overall patterns.

Once identified, the continuums areassigned a hierarchy level such as the sum of the hierarchies of the localities that they make up, plus an adjustment factor due to the integration of the relationships which is defined in the stage of identifying networks of localities as systems.

TYPE OF LOCALITIES

Rural locations are defined as those with less than 2500 inhabitants. This measurement of rural and urban fails to recognize the heterogeneity that characterizes the structure of these populations. The problem is analogous to wanting to define a rainbow as the combination of black and white.

The locality hierarchy is a multidimensional index that captures the heterogeneity in the different stages of the development of localities. However, the question to answer is-What is the minimum threshold in terms of infrastructure at which a village can be considered urban? Beyond trying to resolve such questions, I will focus on proposing a new localitytypology which seeks to capture different stages of development.

Proposed typology of localities:

1. Dispersed locality without blocks (A set of inhabited houses without services or access roads).

2. Hamlet without blocks (This is a group of houses with access to some services and to a dirtroad or some other path).

3. Locality with blocks and scattered hamlets (it is a town with a core of identifiable housing, plus scattered dwellings).

4. Micro regional center (This is a fully blocked town whose built area covers at least 75 percent of the town).

5. Mesoregional center (Thisis a town that has exceeded its limits and is in a phase of conurbation with other localities).

6. Macro regional center (This is a consolidated center in terms of equipment, infrastructure and services covering at least two urbanlocations).

7. Metropolis (consolidated city).

8. Megalopolis (the conurbation of several consolidated cities).

ESTABLISHMENT OF THE AREA OF INFLUENCE

Once the center and sub-centers areidentified either as a single locality or as a continuum of locations, the next step is the definition of its area of influence which will depend of course on their level of hierarchy and the number and importance of the towns with which it shares the same geographical area.

The definition of the area of influence should be estimated for all of the centers and sub-centers that are identified, i.e., those that reach a minimum level of hierarchy in order to choose the category of center or sub-center. However, it is necessary to specify that the hierarchy level is always relative to the environment.

At this point it is necessary to define an algorithm that permits the identification of an area of influence for localities identified as central on a local level terms of elements such as:

1. Location of the center (coordinates)
2. Center hierarchy level
3. The distance between the center and localities
4. Attraction/appeal of the center
5. Position of center within the network
6. Centers geographical region
7. Political boundaries
8. Geographical features
9. Hierarchy of neighboring towns

In general, the area of influence of a center or sub-center as an attraction zone based on the gravitational type agglomeration/ desagglomeration model proposed by Roca C, Josep and Marmolejo, C. (2010)is such that :

$$AT_i = \frac{\int_j A \cdot M_i^{k_1} \cdot M_j^{k_2}}{d_{ij}^{r_1}} - \frac{\int_j B \cdot M_i^{k_1} \cdot M_j^{k_2}}{d_{ij}^{r_2}}$$

Where:

A and B = locality hierarchy (intensity of the attraction)
M = nearby center or sub center localities
i = local attractiveness
j = localityattractor (center or subcenter)
k_1 and k_2 = model adjustment constants
d_{ij}= distance between two localities
r_2 and r_1= the speed at which the attraction of the center distance is diluted with distance

The aim is to identify areas of influence in metropolitan areas, large cities and urban areas but also in smaller centers located in rural and dispersed areas. Furthermore, the validation of the existence of so called zones of influence is sought through the identification of all types of relationships.

A general definition of polycentricity is associated with the idea that within an urban metropolitan area a multinuclear structure is generated from the emergence of peripheral urban areas. That is, a city usually has an identifiable center while other urban sub-centers coexist, with a series of complementary or competitiverelationships. Thus the relationship between the polycentric theory and development of the systems theoryis clear. In this manner the measurement model maps the polycentric model characteristics (centers, sub-centers and flows) to a measurable systemic structure based on the definition of a system composed of subsystems (sets of localities) and the relations between them [3] . Furthermore, each of the various subsystems must be translated into a graph that models the system through a network which will provide the basis for constructing the functions of concentration and flow, as well as allow thevisual identification of systems.

CHARACTERIZINGLOCALITY NETWORKS AS SYSTEMS

At this point the systems that make up each center or sub-center will be identified, as well as their complexity and level of concentration,therefore it is essential to know the level of integration, structure and hierarchy. The aim is to define the different systems observed at the national and state level. Each of the systems consists of a center and a set of locations that interact with the center, or a center, a set of sub-centers and a set of locations within its area of influence.

The importance and hierarchy level of each of the systems depend on the preponderance of the center, the number of towns that make up the system and the amount of relationships and flows that are present.

A network is a graphical representation of a system and can be defined as a set of objects together with a set of connections. A set of hierarchical relationships or one formed by non-hierarchical relationships form a network, and what marks the difference is the direction of flows. The first deals with vertical relationships and dominance, and in the second horizontal or equality relations.

Overall the analysis of a network is based on recognition and evaluation of relationships between nodes(a node is a town, a center, or a sub-center). The characterization of flows allows for the identification of a network as well as its scope according to the opportunities and constraints which are a product of the featuresof the same structure of relationships. The morphology of a network may be identified from the following:

1. Anchor or location: initial starting or reference point for the network , which determines the structure of the opportunity, and determines the ease of access to the resources of other localities;

2. Accessibility: force with which the behavior of a locality is influenced by their relationship with others. It's possible to calculate two types of accessibility: By proximity, which refers to the smallest relative distance with localities; or by intermediation which indicates the localities that are found at the shortest distance.

3. Density: which is a function of the number of connections, and

4. Range: in all systems some localities have direct access to others. A range of first order is given by the number of locations in direct contact with the city on which the network is located.

The identification and characterization of flows in the network (locality systems) will be made based on the following elements:

- Content: refers to the content of the communication flow through the network;
- Direction: there are cases in which the links are reciprocal. However, there are relationships where the flow moves with greater intensity towards a meaning of the relationship or are relations of only one direction;

- Duration: networks have a certain period of life;
- Intensity: this can be understood as the degree of involvement of actors linked to each other and
- Frequency: a relative repetition of the contacts between the actors is necessary in order for such connection to persist.

Flow indicators are estimated in direct and indirect terms with informationabout the locations andhighway flows, bus schedules, the flow of goods and services and the flow of people. Other elements are considered such as:

- Distance, time and transportation costs
- Integration of productive chains

The tangible elements detected within each network are nodes which are defined as localities, centers or sub-centers. They are quantified as:

$$N = \sum nodos$$

Once the nodes and their relationships are known, it is possible to calculate the size of the network, such as

$$S_k = \sum_{i=1}^{N} \sum_{j=1}^{N} f_{ij} \quad \forall\, i \neq j$$

Where fij represents the flow between the i, e, and j nodes, where i indicates the source node and j indicates the destination node.

The density of a network is defined as the number of effective relationships (network size) divided by the number of possible relationships, excluding the main diagonal of the matrix of relationships (i.e., relationships of a node with itself areexcluded). The density is thus an index ranging between 0 and 1 where 0 represents the null-density network and 1 represents a fully connected network.

$$D_s = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} f_{ij}}{N^2 - N} \quad \forall\, i \neq j$$

Once the basic elements and network measurements are identified, it is possible to define general types:

1. Depending on the nature of theexternality of anetwork, it is possible to identify complementary and synergetic networks.

   a. Complementary networks exist between specialized and complementary centers, interconnected through market interdependencies, so that the division of functions between these nodes ensures a large enough area for each center market and enables that scaleand agglomeration economies are achieved.
   b. Synergy Networks: exist between schools with a similar productive orientation, that cooperate between themselves in a unplanned manner. In these centers the key concept is that synergy is obtained through cooperation, and thus the externalities are provided by the same network.

2. Depending on the type of union one can speak of hierarchical, polycentric and equipotentialnetworks.

   a. Hierarchical or hierarchy networks arise from the idea or model of central place. Relationships between network nodes are asymmetrical, and the system consists of polygons, i.e., it is possible to identify patterns of spatial contiguity between nodes and therefore possible spatial relationships can be predicted between neighboring nodes.
   b. Polycentric or stable local specializednetworks. Exchange relationships between nodes can be based on complementarity

or synergy, but may be strongly asymmetric, even dominance-dependence. In this case, the urban functions are divided among multiple nodes, in combinations of various types and dimensions. However, their distribution is not casual, but the nodes are organized seeking to obtain economies of agglomeration.

c. Equipotential networks arise when relationships between nodes are symmetric or nearly symmetric and do not follow a pattern. Urban functions are distributed by chance among the network nodes. The activity does not follow a clear pattern of localization, i.e. activities are distributed randomly between nodes, but on the basis of complementarity, without a center defined in the network.

In practice, the way to detect the type of a network is done through gravity models, while the estimations in the search for complementarities are made using methodologies focused on determining the existence of networks.

Gravity models use data flow networks to identify synergies, whereas complementarities models use estimates based on the search for stock data or the detection of complementary networks.

In general, the detection of synergy networks from a gravity model is done with data on labor mobility and distancemeasures such as travel times between each node. The gravity model relates the masses with the distances (the number of work sites in the town) and are fundamentally considered hierarchical relationships.

The methods for detecting synergy or complementary networks are estimated using:

- Data on disaggregated flows by sectors or activities in order to determine the pairs of localities between those that have strong synergistic and complementary exchanges.
- Identify the network structure and overlapping specializations of localities, so that complementarity or synergetic relationshipsmay be established (between each pair of cities

connected by a network relationship), based on specialization. This procedure utilizes data and stock flow.

If localities have a network connection with the same specialization, it is considered that the network connection is synergistic, and if each have a different specialization the relationship is considered complementary.

ASSIGNING A HIERARCHICAL LEVEL TO EACH SYSTEM

Systems theory provides the basic mathematical tools for working with networks. The instrument is based on matrix calculation and the development of indicators that reveal the characteristics of the network and the nodes that comprise it.

The basic matrices of network theory are the adjacency matrix, the matrix of accessibility and the distance matrix.

The adjacency matrix indicates when a direct connection between two network nodes in a network exists. It is a square, binary matrix where a value of 0 indicates no relationships between two nodes, and a value of 1 indicates that two nodes are directly connected.

The accessibility matrix indicates if a network node is connected to another, either directly or indirectly. The matrix can also be balanced (not binary) when it displays the total number of connections between pairs of nodes.

The distance matrix determines the shortest route through the minimum number of lines to move between the two nodes.

From these matrices can be calculated, as already stated at point eight, statistics such as the size and density of the network. From the size and density of the network can be assigned a hierarchy level for each, detected as the sum of each of the nodes that make up the hierarchy times the density of the network systems.

CONCENTRATION MEASUREMENT

Finally, to calculate the concentration index (CI) of the elements defined within systems of cities or the towns themselves, a means was designed in the form of a model of non-parametric density which includes each of the elements in the above.

The IC of a locality is estimated directly as the ratio of the hierarchy of the locality, multiplied by the number and intensity of the relationships that the locality has with the reference system localities, divided by the area it occupies. That is:

$$IC_{loc} = \frac{jq_{loc}/superficie}{\sum_{i=1}^{N} \Psi\left(loc\right)\ jq_{loc}/superficie\ total} * \frac{D_s}{D_N}$$

(area, total area)

Where the function Ψ is defined as:

$$\Psi\left(loc\right) = \begin{cases} 1 \quad si \quad loc \in S \\ 0 \ si \ loc \notin S \end{cases}$$

Moreover, the IC can be estimated for a system S (a system of dispersed locations, or a system of cities),such as:

$$IC_S = \frac{\sum_{i=1}^{n_S} \Psi\left(loc_i\right)\ jq_{loc_i}/superficie}{\sum_{j=1}^{N} \Psi\left(loc_j\right)\ jq_{loc_j}/superficie\ total} * \frac{D_s}{D_N}$$

(area, total area)

In addition, the IC can be estimated in a specific geographical area such as a state or a municipality, or any other area, from the following expression:

$$IC_a = \frac{\sum_{i=1}^{n_a} \Phi\left(loc_i\right)\ jq_{loc_i}/superficie}{\sum_{j=1}^{N} \Phi\left(loc_j\right)\ jq_{loc_j}/superficie\ total} * \frac{D_a}{D_N}$$

Where the function Φ is defined as:

$$\Phi\left(loc_k\right) = \begin{cases} 1 \quad si \ \ loc_k \in \acute{A}rea \\ . \\ 0 \ si \ loc_k \notin \acute{A}rea \end{cases}$$

Overall, it was decided to use this form of measurement because the nonparametric procedures can be applied to any type of distributions, without any assumptions about the shape of the underlying density. Furthermore, this type of measurement has the capability to accommodate cases where the distribution is multimodal.

CONCLUSIONS

It is important to change the dichotomous conception of population centers. As was previously mentioned, defining the population as rural and urban clusters is equivalent to trying to explain a rainbow in terms of black and white. Itimplies ignoring the reality of a large number of population cores whose developmental stage places it in any of the proposed typologies in the relevant section. Moreover, it is also important to note that a population core is more than just the conglomeration of people, so its definition must include the physical infrastructure and places where there is a tangible and intangible flow of a large accumulation of goods and services that streamline and increase the density of the geographic area that they inhabit. Therefore, the definition and measurement of the concentration of population that is proposed involves a great number of dimensions, and each seeks to capture a different densification of a distinct space.

Finally, the proposed methodology assigns a degree of hierarchy or importance to each population center. This is an intermediate measurement of the concentration, which practical usefulness goes beyond the scope of this investigation. The ultimate goal is to generate a measure of concentration which is achieved by relativizing the specific weight of each locality, with respect to the geographical area in which it is found.

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