Polycentric versus hierarchical tertiary centres: comparing San Diego and Tijuana

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Abstract
This article presents and tests an explanatory model of the size and distribution of intraurban tertiary (retail and services) subcentres/centres in San Diego and Tijuana. The study shows that the determinants of sub-centres differ between cities and are related to differences in the levels of national development. The developed country city is polycentric, with a structure of centres depending mainly on external economies and racial segregation; while the developing country city has a hierarchy of centres *a la* Christaller, and the degree of centrality depends on internal and external economies and the proximity of consumers with diverse preferences and higher income.

Resumen
Este artículo presenta y prueba un modelo explicativo de la intensidad y distribución de subcentros/centros terciarios intraurbanos (comercio y servicios) en San Diego y Tijuana. El estudio muestra que los determinantes de subcentros difieren entre ciudades y están relacionados a las diferencias en los niveles de desarrollo nacional. La ciudad del país desarrollado es policéntrica, con una estructura de centros que depende principalmente de las economías externas y la segregación racial; mientras la ciudad del país en desarrollo tiene una jerarquía de centros *a la* Christaller, y el nivel de centralidad depende de las economías internas y externas y de la proximidad de consumidores con preferencias diversas e ingreso más alto.

Keywords

Polycentric, urban structure, spatial structure, Christaller, Latin American cities, American cities

Word count: 8,138 (with title & name & figures, and without Abstract/Resumen)

The aim of this article is to compare the intra-urban structure of tertiary (retail and service) sub-centres in a developing country city, Tijuana, Mexico, and a city in the most developed country in the world, San Diego in the United States (US). The domestic regional functions of San Diego and Tijuana are similar in some respects. Both cities are among the largest 5% of metropolitan areas in their respective countries (San Diego ranking 17th and Tijuana 6th; see Table 1), are the centres of their respective regional urban systems, and offer high-level services mainly in education and health. For decades both cities have grown faster than the national average and more than half of their populations are migrants. Both cities occupy border locations and are close to one another: from the rooves of some houses in each city, people can observe people in the other. Proximity facilitates cross-border flows in both directions of tourists, workers, migrants, investment and goods[1].

[Table 1 near here]

In spite of their similarities San Diego and Tijuana also differ markedly as they belong to two different national socioeconomic formations. Remunerations, wages, economic structures, prices and relative prices all differ. The differences between these cities and other cities in their respective countries are smaller than the differences between them. In spite of intense cross-border interaction, generated by structural differences between the United States and Mexico (ALEGRÍA 1992), there is no evidence of economic convergence (GERBER, 2014; CERMEÑO et al., 2009) and the causes of urban growth differ on the two sides of the border. Dissimilarities include a great difference in weekly wages which increased from 510 dollars in 1990 to 1,112 in 2010, and the growing tertiary specialization of San Diego and manufacturing specialization of Tijuana (Table 1).

Differences in the level of development influence urban land use and the size and distribution of sub-centres. To examine these differences the next section examines the literature on subcentres and proposes an alternative theory of centrality. The remainder of the articles outlines and tests the proposed model statistically. The final section concludes.

Theories of urban land-use and sub-centres

In the explanation of urban land use the monocentric neoclassical model (ALONSO, 1964; RICHARDSON, 1977) was predominant for about two decades in First World countries. Criticisms to the standard monocentric model were many and diverse (ANAS, ARNOTT and SMALL, 1998; RICHARDSON, 1988) and led to the formulation of alternative land use models examining land use rent trade-offs with two or more centres (polycentrism). These theoretical models are of two types (WHITE, 1999). The first takes employment sub-centres as given (SULLIVAN, 1986; WIEAND, 1987; ROSS and YINGER, 1995); the second determines sub-centres endogenously, is more complex, generally produce numeric solutions, but have not been estimated with real data (FUJITA and OGAWA, 1982; HENDERSON and SLADE, 1993; ANAS and KIM, 1996). In general, these models suggest that the most important determinants of

[1] Due to proximity and close interaction some authors define San Diego and Tijuana as a single cross-border metropolis (HERZOG and SOHN, 2014), but when considering their strong differences other authors consider them as two cities which function as separate but related urban systems (ALEGRÍA, 2012).

employment sub-centres are agglomeration disadvantages in the CBD, transport costs, and population size. These polycentric theories define sub-centres as agglomerations of all types of employment, do not have operational definitions of sub-centres, and do not consider the demand side which is one of the main factors explaining the location of tertiary activities

The difficulties of operationalizing theoretical polycentric models facilitated the emergence of empirical sub-centre definitions, which consider sub-centres as employment centres. The first sub-centre definition from this perspective was proposed by McDONALD (1987) who estimated two indicators for each zone in the city: gross employment density; and the ratio of employment to the resident population, E/R. This definition had a large influence on subsequent research currents that defined sub-centres either in terms of employment density or using the E/R ratio.

In the first sub-current, GIULIANO and SMALL (1991) defined centres as contiguous zones with a density of more than 25 jobs per hectare. Similar research followed (McMILLEN and McDONALD, 1998; CERVERO and WU, 1997; BOGART and FERRY, 1999; McMILLEN, 2001). These definitions are purely empirical and subjective. In the second sub-current influenced by McDONALD, FORSTALL and GREENE (1997) defined sub-centres as employment concentrations with an E/R larger than 1.25. This approach considers centres to be zones of employment with a mix of land uses. As with the first current it lacks theoretical foundations.

Although there were some antecedents (ALEGRÍA, 1997), the study of centres in Latin American cities has only developed in the last decade (FERNÁNDEZ-MALDONADO et al., 2014). Similar to the approach in the USA, most of these studies defined centres empirically as centres of employment of all types, and without a theory of location (AGUILAR and ALVARADO, 2005; RODRÍGUEZ-GÁMEZ and DALLERBA, 2012).

Since most employment in large cities is no longer in their CBD, researchers proposed that centres should no longer be defined as employment concentrations but as activity centres. GORDON and RICHARDSON (1996) found that in the Los Angeles metropolitan area 88% of employment was outside of centres. Employment was widely dispersed and did not reveal a polycentric configuration. Moreover the fact that the trip generation of retailing was sixteen times larger than manufacturing had four implications. First, a zone can act as centre attracting people, even where the density of employment is low. Second, employment dispersion means that places are centres only if they are defined as centres of activity (including final consumption) instead of as employment centres. Third, urban areas are not characterized by segregated land uses with economic activities in some places and residences in others but by mixed land uses. Fourth, theories trying to explain the formation of employment sub-centres formation are looking for ghosts of the past.

RICHARDSON (1977) suggested that the distribution of employment might follow Christaller's central place theory, but BERRY and PARR (1988) identified obstacles to applying this theory to intra-urban space. A few studies of sub-centres apply principles of that theory. These studies indicate that there is a hierarchical structure of centres (WEST et al., 1985; EATON and LIPSEY, 1982; GIULIANO and SMALL, 1991; BOGART and FERRY, 1999; ANDERSON and BOGART, 2001).

A new theory of the size and distribution of urban sub-centres

Consider two facts. First, as the spatial distribution of the tertiary activities is different from manufacturing, the factors that explain them should also differ. Second, zones that contain tertiary activities attract many more trips (per worker) than manufacturing zones and more trips than the number of people employed. In the light of these facts, this research defines a centre as a tertiary centre (without considering manufacturing), departing from the employment centre definition.

The hypothesis is that in each large urban area (as Tijuana or San Diego) tertiary activities are organized in a multi-centre pattern, and that this type of organization can be explained with the aid of central place theory (CPT) in an imperfect market environment. Economic agents responsible for demand and supply decisions develop micro strategic behaviour with the purpose of reducing costs and/or to enlarging sales, generating a macro pattern of sub-centres that corresponds to a modified version of the configuration identified in CPT. In both cities institutional restrictions on markets are few. As a result, the land use pattern (i.e. the spatial configuration of sub-centres) depends mainly on market mechanisms. Land-use policies do not work against this pattern and possibly follow it.

To adjust CPT to the particularities of intra-urban space four modifications are required.
a) Market size. CPT proposes that an activity's market area is the same in every location and is hexagonal in shape. In urban areas however it is not the case since market areas overlap and consumers can buy in zones in areas other than the nearest.
b) Demand varies over space. CPT rests on the assumption that consumers have similar incomes, that density does not vary and that demand depends only on the number of consumers. In reality where income and population density are higher, demand is bigger, and more activities locate nearby.
c) Increasing returns. CPT assumes that perfect competition prevails and that each activity has a single level of sales equal to the minimum necessary to make it viable economically and similar costs. In reality in cities there are increasing returns (coming from scale economies or better technology). As costs and revenues vary with location, each activity has different levels of sales relative to the minimum necessary for economic viability.
d) Agglomeration advantages. CPT does not include an explicit model of the behavior of supply agent, while the co-location of different activities is derived from geometric rather than economic reasoning. In reality many agents decide to co-locate because agglomeration can reduce costs and increase sales.

Demand-side factors

The residential location, strategic behavior, and social and economic characteristics of consumers are determinants of the size and distribution of sub-centres. Consumers act strategically to reduce transaction costs. The prices of goods and services are only a high-priority discriminating criterion in choosing where to purchase when consumers purchase expensive goods and services (with a low purchasing frequency) and compare prices doing little effort (and cost). Consumers reduce transaction costs in four ways: by choosing the shortest distance (and

time) for a purchasing trip; taking advantage of scale economies by buying larger quantities on each trip; taking advantage of scope economies by buying more than one product on each trip (STAHL, 1987); and comparing prices and qualities of goods or services -when they are near substitutes- on each trip (SCHULZ and STAHL, 1996; EATON and LIPSEY, 1982). These types of strategic behavior contribute an unequal spatial distribution of purchasing power.

The size and distribution of sub-centres are determined by consumers' purchasing power which itself depends on three factors: population density, income level and consumption preferences. A high zonal population density leads in a fairly direct way to a concentration of consumption.

In the case of income, consumers with a higher income can buy more of the same product and more types of products, increasing scale and scope economies, and the spatial concentration of consumption. In San Diego however most of the inhabitants are significant consumers reducing the degree of spatial concentration, while in Tijuana only higher income people have a high consumption concentration capacity. In any city, the degree of consumption concentration is limited by the asymptotic characteristic of the income elasticity of demand: the quantity consumed of many goods and services does not increase much with income after certain income level. But this effect differs between cities from developed and developing countries, because the former have a higher average income and a less concentrated income distribution (FÖRSTER and PEARSON, 2002). The goods and services sold in intra-urban centres have a higher income elasticity of demand in poor countries than in rich ones (PARKIN et al., 2006). SEALE et al. (2003) estimated income elasticity for nine aggregate consumption categories in several countries, and found that in all categories' Mexican elasticities were higher than those in the US (six times higher in the case of Food, beverages & tobacco). Since the prices of a number of goods (although of few services) are similar in both cities, for most of the population in san Diego and a minority in Tijuana the income elasticity of demand is close to this asymptotic (almost constant) level (Figure 1). The spatial consequence is the existence of several tertiary concentration zones (polycentric) in San Diego and few or even only one in Tijuana.

[Graph 1 near here]

In the case of preferences people with similar incomes probably have a similar *habitus* (in the sense of BOURDIEU, 1990) and similar consumption preferences, demanding a limited group of types of goods and services. In zones inhabited by people with diverse *habitus*, the concentration of the consumption of a diverse range of goods and services is possible. If centres are defined in terms of the diversity of activities as well as of their capacity to attract people residing in other zones, zones with greater residential diversity have a greater potential to act as centres. A zone's diversity can be captured by an indicator of socio-residential segregation. Low levels of segregation (high population diversity) generate high levels of diversity of activities, and with it centrality grows.

Ethnic and racial diversity in any intra-urban zone should also give rise to potential consumption diversity. However, in an intolerant social environment, people prefer segregated consumption patterns. People of one race prefer to consume in a place where most of the residents are of the same race, although people of that race living in other zones may have to make long trips to purchase in in zones where their own racial group is concentrated. If this type of behavior exists,

centres have a higher degree of centrality when they are located in racially segregated zones. In this case the increase in zone centrality is not due to diversity but to the existence of a larger number of buyers. San Diego is expected to display this type of segregated consumption.

Supply-side factors

Businesses seeking to maximize sales locate in areas where consumption is concentrated. Proximity makes businesses attractive to consumers, allowing them to reduce transport costs and time. Businesses, also, tend to locate near high-income consumers and in areas with a higher population density as sales are higher. At the same time economic activities cluster to reduce costs and increase sales. Three factors are at work: scale economies, better technology, and complementarities among different activities.

For a given technology, an increased volume of sales reduces unit costs for two reasons. First fixed costs (infrastructure, machinery, etc.) increase less rapidly than sales. Second, increased sales make it possible to modify the sales or service organization and increase staff specialization raising productivity. Reaping scale economies depends on an increased volume of sales. In urban areas sales are largest in areas with the highest concentration of potential consumption (i.e. a high-income population, etc.). At the same time scale economies allow a business to reduce sale prices, attracting consumers from more distant zones and increasing centrality. Greater scale economies lead to a higher concentration of activities and a larger market area, increasing a sub-centre's centrality in the hierarchy of centres. The realization of scale economies is spatially varied, and is greatest in the most central zones -close to higher income neighborhoods- enabling them to offer lower prices that have a regressive impact on personal income distribution.

The potential concentration of consumption also affords incentives to increase sales by adopting different and more productive technologies. Similar to economies of scale the introduction of new technologies increases productivity (monthly sales per employee) increasing centrality.

Co-location (agglomeration) of activities of different types also increases the centrality of an activity and of a zone. Firms co-locate to increase sales by taking advantage of the strategic behaviour of consumers (one stop and comparison shopping) and to reduce buyer-supplier logistic costs (money and time). Activities with a smaller minimum size of operation and activities that are highly interdependent are most sensitive to these savings. These two types of incentives for agglomeration are spatially interrelated in the space: the advantages a firm secures from location near activities of other kinds increases the density of tertiary activities in the zone.

Operational definitions and derivation of a statistical model

In this research the centrality of a zone is defined as the volume of central activities located in that zone. Called the Degree of Centrality, GCj, it depends on the joint operation of demand and supply across space. An activity (economic sector) is central in a zone (neighborhood) if after attending to the consumption needs of the zone's inhabitants, it also attends to the needs of people travelling from other zones. An activity is not central if it only sells a product to some of the zone's inhabitants, with the remaining inhabitants purchasing this product in other zones, where that activity would be central.

If it is assumed that the balance of trade between cities in each activity is zero, the employees in a city can be assumed to attend to the needs of all of the inhabitants of that city. The centrality of an activity is then equal to the number of people employed in this activity in the zone per resident (serving the zone and the rest of the city's needs) relative to the same ratio in the city as a whole:

$$C_{ij} = \frac{(E_{ij}/P_j)}{(E_i/P)} \qquad (1)$$

where:
C_{ij} = centrality index of activity (sector) i in zone j
E_{ij} = employment of activity i in zone j
E_i = employment of activity i in the whole city
P_j = population in zone j
P = population in the whole city

An activity is defined as central in a zone when its centrality index is larger than one (Cij > 1). And following CPT, **and a zone** is defined as central when it has one or more central activities. A zone's Degree of centrality in the hierarchy is estimated by the number of central activities in the zone:

$$GC_j = \#(C_{ij} > 1) \qquad (2)$$

The objective of the statistical model in this research is to explain the Degree of centrality GCj for zones in Tijuana and San Diego. The model estimates the Degree of centrality as a combined result of internal economies and external advantages, and demand characteristics. For San Diego the variable segregation by race also appears among the demand characteristics. The model is

$$GC_j = \alpha\left(\frac{V_{sj}}{E_{sj}}\right)^{\beta_1}\left(\frac{V_{cj}}{E_{cj}}\right)^{\beta_2}(De_j)^{\beta_3}(pI_{2j})^{\beta_4}(pI_{5j})^{\beta_5}(pD_j)^{\beta_6}(pS_j)^{\beta_7}(pZ_j)^{\beta_8}_{SD} \qquad (3)$$

where:
GCj = centrality degree in zone j
Supply side:
V_{sj} / E_{sj} = productivity (sales per employee) of service sector s in zone j
V_{cj} / E_{cj} = productivity (sales per employee) of commerce sector c in zone j
De_j = establishment (firm) density in zone j
Demand side:
pI_{2j} = potential in zone j associated with the proportion (workers in Tijuana, families in San Diego) earning less than 2 minimum wages

pI_{5j} = potential in zone j associated with the proportion (workers in Tijuana, families in San Diego) earning more than 5 minimum wages
pD_j = potential in zone j due to population density
pS_j = potential in zone j due to income segregation
pZ_j = potential in zone j due to racial segregation (San Diego only)
α, $\beta 1 \ldots \beta 8$ = regression parameters

The model identifies three characteristics of consumers influencing the Degree of centrality on the: income, density, and the diversity of the population's preferences. Although these three characteristics operate in any market economy, their intensity varies across different socio-economic formations.

Two variables, pI_{2j} and pI_{5j} estimate the influence of income. Exploration of the statistical model showed that the proportion of people earning from 2 to 5 MW was collinear with other independent variables, and had the smallest explanatory role statistically, so that it as excluded. Population density was measured by the number of inhabitants per hectare. Consumers' preference diversity was measured by an indicator of socio-residential segregation by income, on the assumption that people in each range of income have particular preferences for goods and services that differ from those of other income groups.

The segregation index Sj was a measure of the degree of social mix of four income groups whose income was measured as multiples of the minimum wage (0-1, 1-2, 2-5 and more than 5 minimum wages) (ALEGRÍA 1994):

$$S_j = \sum_{i=1}^{n} \left(\frac{n}{n-1} \right) \left(p_{ij} - \frac{1}{n} \right)^2 \qquad (4)$$

where:
S_j = segregation by income index in zone j ($0 \leq S \leq 1$)
p_{ij} = proportion of the population in income group i in zone j
n = number of income groups

This index ranges zero to one, which allows for easy interpretation. If $S_j = 0$, there is no segregation of income groups, and great social heterogeneity in zone j, as all income groups have the same population share in zone j. If $S_j = 1$, there is complete segregation, and complete social homogeneity in zone j, as only one income group resides in this zone.

The indicator of segregation by race in each zone was only considered for San Diego. Similar to the indicator of segregation by income, four groups were identified: white, non black Latino, black (including black Latinos), and other races.

In the exploration of the regression model, each independent demand-side variable had ten variants, but only the variable with the highest statistical significance was included in the final model. The consumption potential associated with the proportion of residents with incomes exceeding five minimum wages in zone j, pI5j, was estimated as:

$$pI_{5j} = \frac{\sum_k \frac{I_{5k}}{d_{jk}^{\phi}}}{\sum_j \sum_k \frac{I_{5k}}{d_{jk}^{\phi}}} \qquad (5)$$

where j and k are zones [j=1,2,.., n] [k=1,2,.., n], d is distance in kilometres from j to k, and ϕ is a distance exponent [ϕ=0.5, 1, 2, 3]. Distance from zone j reduces the influence of the characteristic of zone k on the activity in zone j. For example, when ϕ is 0.5 people make consumption trips to j from distant zones; when ϕ is 3, people coming to j to engage in consumption activities come only from adjacent zones.

On the supply side it is impossible to measure scale effects and externalities directly. In consequence aggregate characteristics that reflect the impact of internal economies and external advantages were used. One was labour productivity (sales per worker, V/E). As it reflects both the impact of scale economies and the proximity of firms to customers and suppliers, the density of commercial and service establishments in each zone was added to separate internal economies and external advantages by unambiguously denoting external advantages. Productivity therefore was let to denote internal economies. As commercial activities appear in more zones than service activities, it is probable that internal and external economies operate in different ways in these two sectors. For this reason, the regression model included two variables of productivity, one for commerce and another for services.

If the mechanisms generating centres in Tijuana and San Diego differ, the regression equations will differ.

Data

For Tijuana, population data was obtained from the Population and Housing Census of Mexico 1990 and economic activities data from the Economic Censuses of Mexico 1993. For San Diego, population data was obtained from the Population and Housing Census of USA 1990, and economic activities data from the Economic Censuses of USA 1992. Official government agency (INEGI and the U.S. Bureau of Census) maps were used for the mapping exercises. The data for Tijuana was at the AGEB scale (census basic geostatistical area). Four-digit economic data was used. For San Diego population and economic data was at ZIP scale (Zone Improvement Plan), a code of the US postal Service. Five digit economic data was used.

Most commerce and service sectors were selected for the analysis. Homologation criteria were specified for both cities as a result of which five-digit economic data were used for San Diego and were aggregated to correspond with the four-digit Mexican classification. INEGI did not publish data for some sectors including banking, finance and real estate and public sector activities. As these sectors account for a small share of local employment they were excluded.

In the end, 6 commerce and 18 service sectors were included. In the case of Tijuana there were in the Census 6 and 29 sectors respectively. The eleven service sectors excluded as they were not included in the corresponding published US ZIP-level data accounted only for 7.2% of service employment.

Estimation Results and conclusions

The GC estimates are reported for three hierarchical levels in Figure 1 for Tijuana and in Figure 2 for San Diego. A comparison of the two maps shows that Tijuana has a centre pattern *a la* Christaller, with just one large linear centre and several lower-tier sub-centres scattered across the city, while San Diego has a multi-centre pattern, with six high-level centres and several lower-tier sub-centres located toward the east and north of the city.

[Figure 1 near here]
Figure 1: Map of Tijuana's 3-levels Centers Hierarchy: Degree of Centrality (GC) by ranges (number of central branches/activities)

[Figure 2 near here]
Figure 2: Map of San Diego's 3-levels Centers Hierarchy: Degree of Centrality (GC) by ranges (number of central branches/activities)

To explain the location and size of centres, the GC regression was estimated first for Tijuana, eliminating variables that were not statistically significant. The same model was then estimated for San Diego (without adding the racial segregation variable). If the variables in the San Diego model were also statistically significant, the conclusion would be that the same mechanisms were responsible for centre generation in the two cities. The results showed however that the Tijuana model (Model 1) was not acceptable with San Diego data. At that point a new model was explored for San Diego. Adding the racial segregation variable resulted in a model (Model 2) that better represented the situation in San Diego data (Table 2).

[Table 2 near here]

In the case of both cities the estimated model, which operationalizes the underlying theoretical model, statistically explains (high coefficients of determination) the degree of Centrality. In Tijuana on the supply side the coefficients of the indicators of internal economies (productivity in each sector) and external advantages (establishment density) were positive and statistically significant determinants of the Degree of centrality (GC).

The demand side results also lend support to the theoretical model. First, all but one of the statistically significant variables are not the direct indicator but their potential (weighted by distance exponents) values, corroborating the theoretical statement that market areas extend beyond the zone where the centre is located. Second, of the two income variables, only the one representing the highest income group (share of residents earning more than 5 MW) is significant. The indicator for the lowest income group was not significant although it is negatively correlated with the degree of Centrality (GC). An explanation for this result is that the

low income group variable is inversely related to the high income group variable (collinearity) so that the latter which has a stronger correlation with GC captures the variance associated with the former. Third, with regard to population density, the most significant variable was the direct indicator (non potential) of density and with negative sign. The Degree of Centrality increases in zones where density is lower. The interpretation to this phenomenon is that centres displace population as a result of competition for land. Fourth, segregation by income gave the expected result because it is significant, with a negative sign for the potential indicator (not the direct indicator). This result indicates that the Degree of centrality of a zone is higher when the area over which it exercises influence is more socially diverse, i.e. when its market area has consumers with diverse consumption preferences.

In general supply and demand jointly determine the Degree of centrality in Tijuana. The most important variables are the presence of a large share of high income groups on the demand side and external economies on the supply side. Internal economies are important but less influential, as the standardized coefficients show.

In San Diego, on the supply side, internal economies (workers' productivity in each sector) are not significant, while external economies (density of establishments) have a positive and significant impact: the Degree of centrality (GC) depends on external advantages that firms obtain in each location, but internal economies do not play a role.

On the demand side in general the results lend support to the theoretical model. First, except for population density, the potential values rather than the direct indicators were significant, indicating that market areas extend beyond the boundaries of the zone. Second, of the two income variables, only the income share of the lowest income group (share of families earning less than two MW) was significant, and with negative sign as expected. This result means that businesses tend to establish centres in the zones with a small proportion of poor residents. In San Diego inhabitants earn higher incomes and enjoy lower transport costs (relative to their income) than in Tijuana. As a consequence, in San Diego a larger proportion of the population are active consumers, these people can travel greater distances to consumption centres, and many zones in the city are associated with sufficient demand and accessibility leading to the establishment of centres in a number of different locations. At the same time the results seem to contradict the frequent arguments in the literature that centres are associated spatially with the presence of low income residents. Third, the direct indicator of population density is more significant than the potential indicator with a negative sign, indicating that centres displace population in the competition for land. Fourth, in contrast to Tijuana and to the expected result, segregation by income in San Diego is not significant, indicating that the Degree of centrality is not influenced by diversity of consumption preferences of the population. This result may suggest either that consumption preferences among social classes are homogeneous (in the Weberian sense) or that each centre's internal diversity does not correspond to the social diversity (measured by income) of nearby residents. Fifth, segregation by race gave the expected result because the coefficient was significant and positive. This result indicates that *Sandiegans* tend to consume in racial homogeneous places and tend to avoid racially mixed centres, suggesting that they prefer to do not share the same space (of consumption, and of free time) with individuals of different races. Another possible reason is that many *Sandiegans* reside in racially segregated neighborhoods and go regularly to consume to the nearest centre to minimize travel time. This factor must however

play a limited role as most *Sandiegans* have more available time because they do not use public transport (that involves more time by trip), suggesting that the more likely reason is that for San*diegans* racially segregated consumption is a matter of choice.

In synthesis, in San Diego supply and demand determine the Degree of centrality. On the supply side the Degree of centrality increases with higher external economies, and this factor is the most important (as variables' standardized coefficients show). On the demand side, there are significant negative factors as the Degree of centraility is higher if centres are in zones where: there are not many residents, the residents are not poor and different racial groups do not share the space. These factors are listed in the order of decreasing importance.

The existence finally of two different models for Tijuana and San Diego suggests that in these two cities there are different mechanisms of centre generation, one for centres in a developing country and one for centres in a developed country.

Final remarks

In this article a comparison of the structure of tertiary (commerce and service) centres in cities in a developed (San Diego, US) and a developing country (Tijuana, Mexico) showed that each city has its own spatial pattern of centres and its own way of generating that pattern. In making this comparison a centre was defined as a place for tertiary activities rather than as a centre of employment as there is not a single theory of location for all economic activities in a city, and as a single theory cannot be formulated as the location factors for manufacturing and tertiary activities differ due to the importance of demand side factors for the latter: manufacturing firms prioritize cost minimization, while tertiary firms prioritizes sales increase. At the same time tertiary activities have a greater impact on some aspects of the functioning of cities in that they generate many more journeys, reinforcing the case for separate treatment.

This research showed that the factors that explain the size and location of intra-urban tertiary centres formation are conditioned by the development level of the country to which the city belongs. In the US incomes are higher and income is more widely dispersed than in Mexico. In 2012, the GDP per capita of the US was 51,457 current dollars compared with 9,703 in Mexico (World Bank), the average annual wage was 56,735 current dollars compared with 12,708 in the second, and the Gini indices were 0.39 and 0.48 respectively (OECD). As a result more people are active consumers in the US and a number of tertiary sub-centres arise in large cities. The economic conditions firms encounter in the US are also better: more vibrant markets, better more advanced and more widely diffused technologies and lower interest rates for working capital for tertiary companies. In Mexico economic characteristics are less advantageous. For example, 53% of Mexico's medium-sized firms are underserved by the domestic financial industry, and the interest rates for loans to Small and medium-sized enterprises (SME) were between 20 and 25 % per year in Mexico compared with 3 and 4 % in the US (MCKINSEY GLOBAL INSTITUTE, 2014). Ease of access to new technologies and credits in US enables tertiary firms to adopt new technologies and realize scale economies making these factors seem irrelevant for sub-centre formation. In Mexico, in contrast, only a few firms with sufficient capital in the most central locations and with a higher volume of sales can take advantage of technological change or scale economies. This is the reason why the formation of centres is explained by these two

characteristics; the higher hierarchy centres will be those that contain firms with better productive technology and a larger volume of sales.

This conclusion allows the formulation of a hypothesis about the role of the accessibility in the explanation of sub-centres in cities from countries at different levels of development. Since the highest potential of localized demand explains the near localization and biggest intensity of centres in Tijuana -city from a developing country- then accessibility at the whole city scale would play a smaller role in this explanation because the main centres needs few consumers residing far from them. In contrast, in San Diego highest level centres are located in several parts of the city and depend on the volume of demand rather than the level of income even when located in peripheral parts of the city. In other words the high level centres depend on good accessibility from other parts of the city. In theoretical land-use models (concentric and polycentric) accessibility is the main factor explaining urban spatial structure. In developed countries these models probably express the real situation correctly. If however the hypothesis identified in this paragraph is correct, in cities with similar level of development to Tijuana, accessibility plays a smaller role.

Theoretically this research indicates the importance of designing urban sub-centre models for each country or at least for countries at a range of levels of economic development. In those models, local income should be considered as one of the relevant characteristics that explain the development of sub-centres, especially in cities in countries having low wages and a polarized distribution of income.

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Table 1. Tijuana and San Diego: Select data

	Manufacturing sector Annual Average Weekly Wage (dollars)		Sector share (%)				Population Metropolitan Area		National Metro Rank
			Manufacture		Tertiary				
Year	1990	2010	1990	2010	1990	2010	1990	2010	2010
San Diego County	588	1,368	13	9	60	71	2,498,016	3,095,313	17
Tijuana *Municipio*	78	256	30	28	51	54	798,938	1,751,430	6
S.D./TJ	7.5	5.3	0.4	0.3	1.2	1.3	3.1	1.8	

Source. For Manufacture data: U.S. Bureau of Labor Statistics and Mexican BIE-INEGI. For Sector data: Population censuses of each country. Tijuana's 2010 wage is actually Baja California state average because lack of data for this city (salaries are similar across the state) and it is author estimation based on BIE-INEGI data.

Graph 1

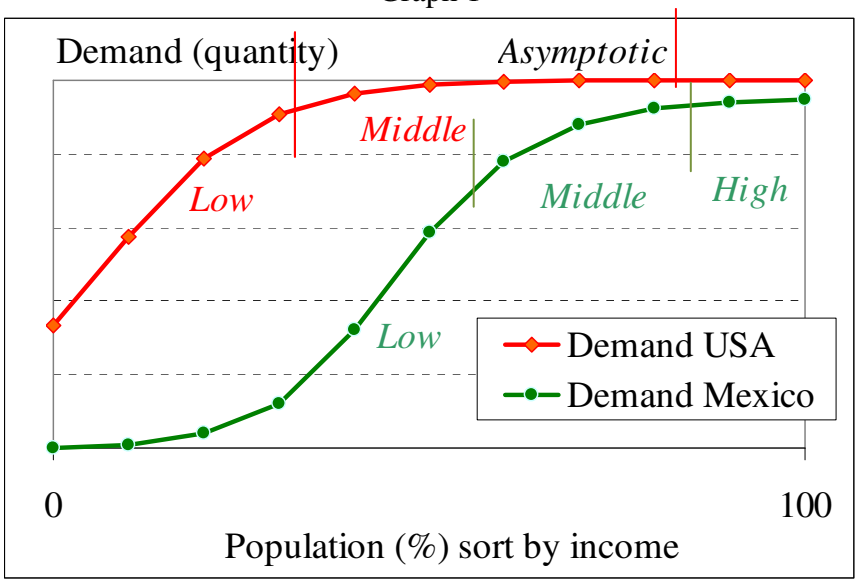

Demand (quantity)
Asymptotic
Middle
Low
Middle
High
Low
Demand USA
Demand Mexico
0
100
Population (%) sort by income

Table 2

Degree of Centrality (GC) Regression Models

Variables	Model 1		Model 2
	Tijuana	San Diego	San Diego
Constant	50.805 *0.00*	187.917 *0.01*	52.932 *0.00*
Service Worker Productivity (V/Es)	0.125 *0.03*	0.245 *0.17*	
Commerce Worker Productivity (V/Ec)	0.173 *0.00*	-0.504 *0.11*	
Establishment Density (De)	0.608 *0.00*	0.792 *0.00*	0.769 *0.00*
P1 Resident workers' proportion (families in San Diego) with more than 5 MW (I_5)	0.755 *0.00*	-0.213 *0.69*	
P1 Resident workers' proportion (families in San Diego) with less than 2 MW (I_2)			-0.505 *0.04*
Resident Population Density (D)	-0.473 *0.00*	-0.739 *0.00*	-0.628 *0.00*
P2 Income segregation (S)	-0.425 *0.00*	2.65E-03 *0.99*	
P2 Race segregation (Z)			0.308 *0.06*
R Square	0.68	0.69	0.71

P1 or P2 means: variable potential with exponent 1 or 2 on distance indicator, respectively. Variable statistical significance in italics.

Figure 1

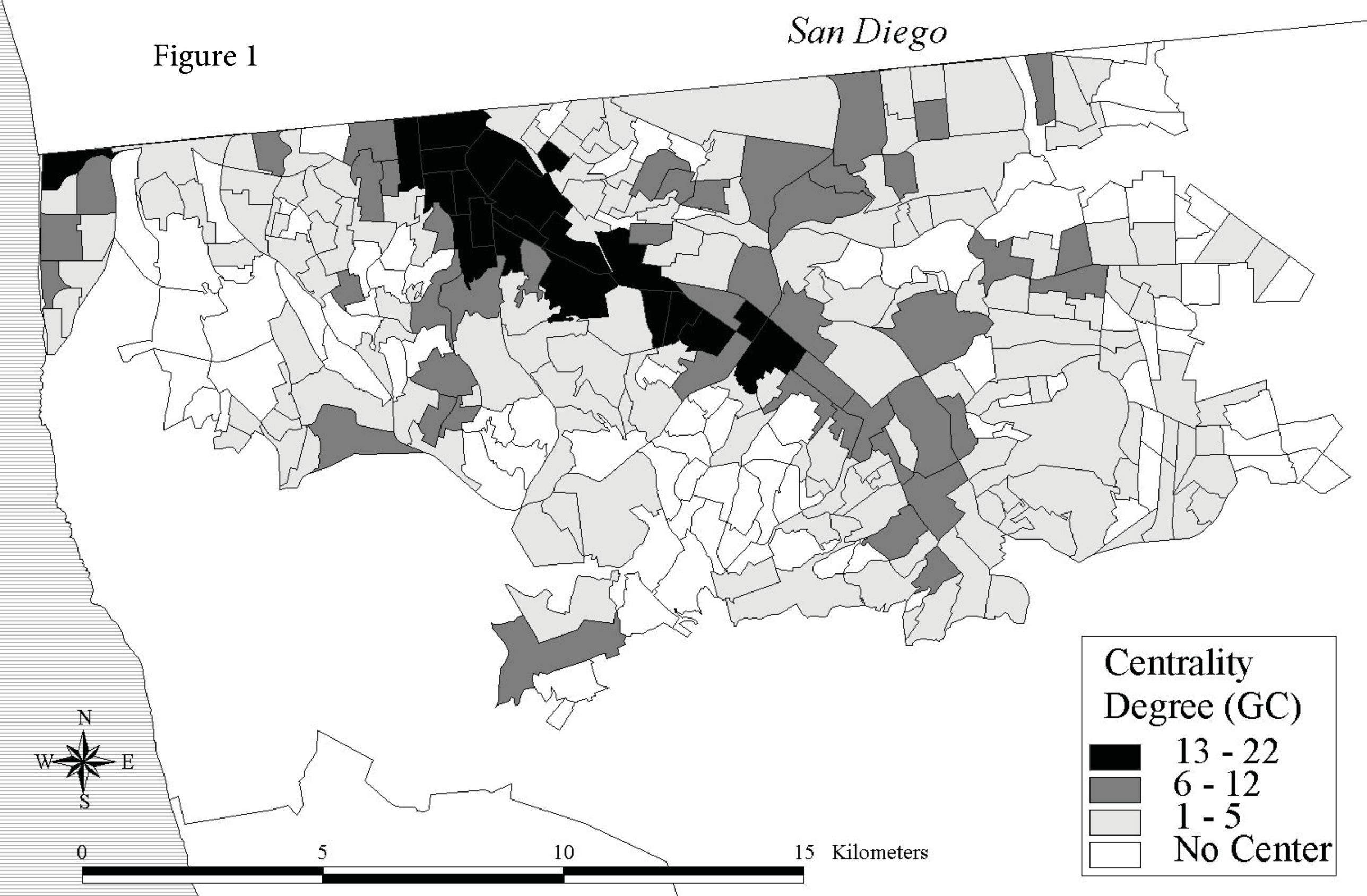
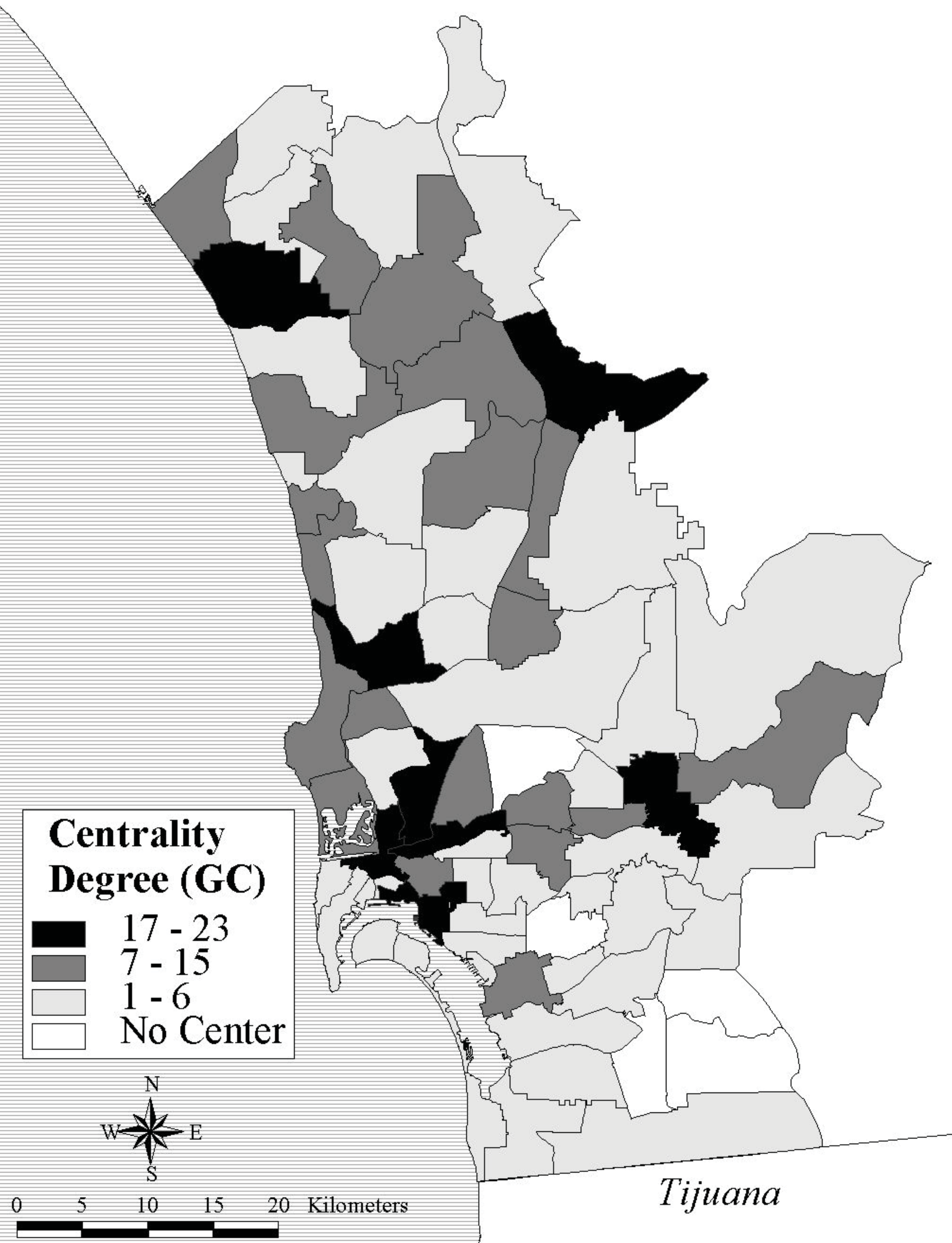

San Diego
N
W
E
S
0
5
10
15 Kilometers
Centrality
Degree (GC)
13 - 22
6 - 12
1 - 5
No Center

Figure 2


Centrality
Degree (GC)
17 - 23
7 - 15
1 - 6
No Center
N
W
E
S
0 5 10 15 20 Kilometers
Tijuana