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OPTIMAL LOCATION OF ELECTORAL MODULES IN THE STATE OF CHIHUAHUA (MEXICO) USING LOCATION-ALLOCATION MODELS AND GIS

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I. INTRODUCTION

This paper offers a proposal for the location of fixed Service Modules for Citizens (SMCs) using a location-allocation model implemented by a GIS. Locations are proposed at the level of electoral sections, taking the state of Chihuahua as a test case for possible replication of this analysis to other Mexican states.

Service modules play a fundamental role in the functions of the Federal Electoral Institute (FEI) as the agency responsible for organizing federal elections, these modules being in charge of providing electoral identification cards. In order to guarantee access to electoral identification cards to all citizens and, therefore, their right to vote, the FEI has established three types of modules: fixed modules, located in large cities in order to serve their high demand, and semi-fixed and mobile modules, mainly devoted to cover the sparse demand in rural areas.

II. GEO-ELECTORAL STRUCTURE OF CHIHUAHUA

The state of Chihuahua was chosen as a pilot study for the complexity of its electoral districts, where large cities like Chihuahua and, in particular, Ciudad Juarez coexist with extensive rural/desert areas with a very sparse population. On the other hand, high immigration in order to work in *maquila* industries or to cross the border to the United State, explains the high demand of electoral identification cards in this state.

In 2009 the state of Chihuahua is divided into eight federal electoral districts and 2,909 federal electoral sections, and has 40 modules (22 fixed, 2 semi-fixed and 16 mobiles).

Thirteen fixed modules are located in Ciudad Juarez, five in the city of Chihuahua and one in the cities of Cuauhtémoc, Delicias, Hidalgo del Parral and Nuevo Casas Grandes, respectively. Although the concentration of supply (fixed modules) in the main cities of the state could be justified by the concentration of demand (citizens), the distribution and location of these modules doesn't follow any official or defined criteria.

III. LOCATION MODELS IN GEOGRAPHY. LOCATION-ALLOCATION MODELS

Location of facilities in space is a basic concern in Geography (Haggett, 1965), locations being explained mainly by the friction of distance or impedance, although this elegant and simple concept hides very different and complex decisions. Many scholars like von Thünen, Weber, Christaller, Lösch, Ullman, Isard or Alonso have developed and use this concept in order to explain different location patterns.

Newton's gravitational model was the departure point for the development of spatial interaction models, where impedance or a set of factors that limit spatial movements plays an important role. Over time, planetary masses were abstracted as factors of attraction and expulsion, and gravitational models evolved to probabilistic and constrained interaction models where multiple factors like multi-purpose trips or intervening opportunities where integrated.

Within location models, location-allocation is the process of determining the 'best'/'optimal' location for one or more facilities in order to serve a demand distributed in space, allocating that demand to the 'closest' facility. Some classic location problems are the p-median location problem, the location set covering problem, the maximal covering location problem or the p-centers problem (Miller y Shaw, 2001:199-209; Moreno, 2004:53-101; Wang, 2006:200-202; Buzai y Baxendale, 2008: 100-102; Daskin, 2008)

IV. IMPLEMENTING DIFFERENT LOCATION-ALLOCATION MODELS

All the information needed to apply the location-allocation analysis was provided by the FEI, being the two main inputs:

1) A road network with an average speed assigned to each arc, being travel time calculated for each arc and used as impedance.
2) A database of procedures carried out by citizens in all modules from July 2006 to January 2009. This database contains the residential location of the citizens (electoral section) and the modules they attended to. The number of these citizens by electoral section is taken as the demand to be served. In order to minimize differences in electoral sections' size, the centroid of each one was placed in the point (group of urban blocks or point of small settlements) where the largest number of citizens lives according to IFE-RFE (2008d).

The applied procedure followed the next steps:

1) Using the mentioned two inputs, as well as the location of electoral sections and fixed-modules, travel time was estimated for those citizens that visited a fixed module from July 2006 to January 2009. 95% of them would have travelled 27 or fewer minutes, being this parameter rounded to 30 minutes and applied as the maximum impedance.

This maximum impedance is an abstraction of real travel times, because many factors are unknown (transportation mode, congestion problems, the exact route, …), but it depicts real trips; for instance, a citizen living within these estimated 30 minutes to a fixed module could have travelled on foot to that fixed module and spend more than 30 minutes.

2) The number of fixed modules to be located was established in 22 as this is the number of existing fixed modules.
3) Only certain electoral sections, those in urban areas and with a demand equal or larger than 500 citizens, were considered as potential locations for fixed-modules.
4) No constrain was imposed in the amount of demand (citizens) to be allocated to each fixed module.
5) Three algorithms were evaluated (MinDistance, MaxAttend and MaxCover; see Esri, 2008) using different variables (coverage, average travel time, total travel time and total weighted travel time) and travel time intervals. The MaxCover algorithm got the best results for the total demand, which is critical given the universal coverage to be provided by FEI in terms of providing electoral identification cards.
6) Finally, three scenarios using the MaxCover algorithm were evaluated in order to maintain the location of certain existing fixed modules or their current location in only six cities.

V. RESULTS

In order to maximize served demand, the MaxCover algorithm reduces the presence of fixed modules in the two largest cities: from 13 to only 1 in Ciudad Juarez and from 5 to 3 in Chihuahua; that, in exchange for replacing these modules with larger ones, with bigger capacity. Better transportation infrastructure and, therefore, shorter travel times in large cities explain this solution, being the creation of macro fixed modules in large cities an idea already considered by the FEI even before this research.

In medium size cities like Cuauhtemoc, Delicias, Hidalgo del Parral and Nuevo Casas Grande the same number of fixed modules already in existence is proposed, one in each city, although their relocation would increase their served demand. Meanwhile, relocation of the surplus of fourteen modules from Ciudad Juarez and Chihuahua would benefit less urbanized areas located in the Mexico-United State border area as well as in the south and west of the state.

In Chihuahua and Ciudad Juarez some proposed modules are close to existing ones, so the enlargement of those already in existence could be a possible solution, along with maintaining two fixed modules in Ciudad Juarez in order to avoid such a drastic reduction in its number of fixed modules and the concentration of all its demand in only one module. Also close to existing modules are the proposed locations in Cuauhtemoc, Delicias, Hidalgo del Parral y Nuevo Casas Grande These options were analyzed in different scenarios, being considered as more realistic, especially the MaxCover2b scenario.[1] In this scenario, and

1 In this scenario the location of nine existing modules remains the same: in Ciudad Juarez and Chihuahua the two and three modules with higher demand, respectively, and modules in Cuauhtemoc, Delicias, Hidalgo del Parral y Nuevo Casas Grande, one in each city.

considering demand located up to 60 minutes, travel time (average, total and total weighted) worse compared to potential demand from current locations, but when total demand is take into account travel time improve: average travel time falls from 84.6 to 64.2 minutes, while total and total weighted travel time decrease from 171 to 130 and from 39,699 to 30,733 days. Coverage also improves for demand located up to 30, 45 or 60 minutes, from 877 thousand to 937 thousand citizens when the up to 60 minutes interval is considered.

The proposed scenarios, except MaxCover3, improve coverage and reduce travel time for total demand. This would contribute to greater spatial justice by increasing the accessibility to such modules in less urbanized areas according to some scenarios. In scenario MaxCover1 the relocation of fixed modules within cities that already have one or more would have a very small impact in terms of served demand located up to 30 minutes from the proposed modules in these cities (less than 1% increase), but the relocation of surplus modules from Ciudad Juarez and Chihuahua would increase that same served demand up to 9.2%, that is, 77 thousand more citizens.

Some proposed sites (La Cruz, Colonia Le Baron and Campo Numero 115) deserve special attention, because modules are been placed in electoral sections with a relatively small demand, but with a strategic location, allowing them to cover the demand of near small cities and surrounding areas. For this reason their attended areas are greater than those of modules in large or medium cities.

VI. CONCLUSIONS AND RECOMMENDATIONS

This research shows the potential for collaboration between Geography and the Federal Electoral Institute, promoting the dissemination of geographic knowledge and techniques like location-allocation models among non-geographers.

The proposed locations of fixed modules would improve the served demand favoring a greater spatial justice by increasing accessibility to the modules from less urbanized areas. However, the applied location model is based on a number of assumptions and data that must be considered with caution when assessing the proposed locations. For example, the distribution of demand and the criteria used to measure accessibility (travel times through a road network) are likely to change over time, and, in the case of the road network, it is necessary to admit that, despite its quality, some improvement could be made with the collaboration of other public and private organizations.

Finally, the importance of variables not included in the model must be taken into account; for instance, the financial cost of the proposed relocations and its short term consequences (attendance decay, for example). For this reasons, and the proximity of some of the proposed locations to existing ones, the possibility of enlarging and/or maintaining some existing modules should be considered. The proposed locations are only a first approach and should be evaluated within a broader discussion where opinion from FEI's local representatives must play an important role.

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