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# Making Invisible City Visible: A Solution for Mapping Hidden Socioeconomic Patterns in Tehran

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## Abstract

Today, urban areas are among the most complex social landscapes. In order to detect and to resolve urban social problems, urban planners require a deep recognition of this complexity. Synthetic homogeneous neighborhoods offer one approach in moving towards reimagining some of the invisible socioeconomic aspects of urban life. In this paper, we use Openshaw's Automated Zone Design (AZD) methods that utilize an array of factors and algorithms to generate new homogenous socio-spatial units based on both statistical and heuristic procedures. The results are polygons (pseudo neighborhoods) which represent a specific underlying socioeconomic patterning across the city. Using Tehran as our case, the hidden socioeconomic patterns are different from the administrative city divisions and cartographic. The consistency of the new zone design was checked through global and local Moran's I; upon given assumption that for the resulted homogenous polygons (neighborhood), there is no spatial autocorrelation in the new zone design map. The results showed the random distribution for all but one socioeconomic indices in the new zone design map. The result converts heterogeneous urban divisions into new homogenous polygons (neighborhoods) by regrouping basic socioeconomic and spatial units.

**Keywords:** Urban social landscape, Tehran, Openshow's AZD algorithm, Moran's I Index,

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# 1. INTRODUCTION

Spatial inequality or socioeconomic disparity is a distinct feature of many urban systems. Usually every visitor or residence can perceive the difference in the socioeconomic quality of each neighborhood and their residents. The neighborhood, as the base unit of analysis in urban planning, is a complex and multidimensional concept. As a result, the demarcation of socially and economically homogenous neighborhoods on a map is not an easy task. Indeed, neighborhood boundaries are a function of sociopolitical factors, historical legacies, and physical constraints (Galster 2001). The concept of neighborhood has attracted the attention of many researchers, and several studies have been performed in different fields such as the geography, planning, urban management, health and environmental studies (Diez Roux 2003; Kawachi and Berkman 2003; Pickett and Pearl 2001; Stafford, Duke-Williams and Shelton 2008), sociologists and health researchers. In spite of the existing large body of research and the different definitions of the neighborhood, it seems difficult to have a common definition of the neighborhood (Chaix et al. 2009; Martin 2003; Matthews 2008). This is mainly because researchers and scholars see this concept from different points of views and various application frameworks (Gieryn 2000).

The neighborhood is not just a spatial unit of analysis per se; it is a proxy for underpinning the sociospatial structure of the city. Usually, people who live in the same neighborhoods belong to similar social classes. Creating synthetic homogeneous neighborhoods (SHN) will allow us to understand the city and will give us a better image of the invisible socioeconomic aspects of the urban life. SHN mapping paves the way for analyzing the social fragmentation in the city and for defining a proper spatial unit of analysis; Modifiable Areal Unit Problem (MAUP) has significant and determinant effects on the SHN mapping. To overcome this problem, Automated Zone Design (AZD) method has been used to create clusters based on the available socioeconomic indices. This method uses similarities in one, two or more groups of variables (such as the income, education, housing ownership) to group a large number of areas into fewer homogenous groups or regions. There are several adaptations of AZD algorithms in the literature; namely, Arisel (Duque, Church and Middleton 2011; Duque, Royuela and Noreña 2012), AZP (Openshaw and Rao 1995), AMOEBA (Aldstadt and Getis 2006), SOM (Kohonen 2001), and Geo-SOM (Bação, Lobo and Painho 2004).

The size and shape of the study area are determinant factors of results of different studies (Fotheringham and Wong 1991; Gehlke and Biehl 1934; OPENSHAW 1984). MAUP is the sensitivity of analytical results to the definition of units for which the data is collected. In other words, according to the way that data are aggregated, results of statistical analysis, such as the correlation and regression, can be different. In fact, different spatial patterns are observable depending on the aggregation of zoning systems often (Fotheringham and Wong 1991).

MAUP is usually classified into two subclasses of the problem. The first one is the scale effect (aggregation problem) and the second one is the edge effect (grouping or zoning effect). The scale effect is related to variations of statistical analysis output based on the level of spatial aggregation of data. It means that depending on the spatial scale of aggregation of data at different spatial resolutions, for the same data set, there would be different results. In addition, edge effect or zoning effect suggests that the method used to define areal unit boundaries has a highly significant effect on the output of the analysis (Blalock Jr 1961).

## 1.1 DESIGN ZONE

One of the most crucial needs for any spatial data in a city is designing and defining areal units of analyses. Some experts use official zoning systems and some other use a purpose-based areal units or new zoning systems regarding their need and goals of the study. Administrative zones are usually designed based on the political and management purposes. Urban researchers study the city in different scales.

However, often neighborhood divisions and zoning systems by municipality are not consistent with the perceived concept of neighborhood for the resident people. Some studies used different approaches (Chaskin 1997; Luginaah et al. 2001; Ross, Tremblay and Graham 2004; Sampson 1997) for defining neighborhood and areal units of analysis. These include a combination of local knowledge, spatial statistics, network analysis, physical maps, socioeconomic landscape of the region and other factors such as the man-made borders and barriers (i.e. river and roads) Moreover, in the real world, the edges between zones and neighborhoods are not very clear and their geographical borders are not the same for everyone. People could draw different maps in their minds for their neighborhood areas.

Zoning system is a significant factor for obtaining useful and relevant outputs from the spatial data. (Sabel et al. 2013) adopted from (Briggs, Daniela Fecht and Kees de Hoogh 2007) and defined four types of criteria for choosing a zone system. These are as follows.

"(a) to provide a uniform basis for mapping, both to aid visual representation and interpretation of the data, and also to facilitate analysis of spatial patterns;

(b) to have a zone system which is sufficiently fine to reflect local variations in exposures and rates of disease, especially in urban areas where such gradients may be steep;

(c) to achieve reasonably large and consistent denominator populations in all zones, to avoid the so-called 'small number problem', which can lead to highly unstable estimates of risk and large variations in uncertainty between zones;

(d) to minimize the need for spatial transformation of data between different spatial units, since this invariably involves some degrees of approximation and is thus a further source of error" (Sabel et al. 2013, p. 112)

Design of reliable areal units of analysis at different spatial scales is an essential part of any planning. System. Several attempts have been made to solve MAUP (Besag and Newell 1991; Flowerdew, Manley and Sabel 2008; Gatrell et al. 1996; OPENSHAW et al. 1987). There are methods used for zone design such as the Automated Zone Design (AZD) and Genetic Algorithm (GA). The main objective of all these methods is the configuration of the optimal boundaries. Each method may use different optimization algorithm to design a spatial configuration within a city such as" maximize equality of size, compactness of shape, homogeneity in social composition, accordance with 'natural' boundaries, and probably many other factors" (Flowerdew et al. 2008). It is necessary to take into account that each method and algorithm would have its own advantages and disadvantages.

## 1.2 AUTOMATED ZONE DESIGN (AZD)

Automated Zone Design (AZD) is a partial solution for MAUP (Cockings and Martin 2005; OPENSHAW 1984). Traditionally, manual zone design used local knowledge and even an intuitive approach. Instead, AZD tools use statistical rules (i.e. intra unit and between class correlations) for setting boundaries between homogenous parts calculated by using specific characteristics such as the physical or socioeconomic variables. One of the most applicable software is AZtool designed by the University of Southampton, Department of Geography and Environment. This tool can help explore the sensitivity of results to different areal units, design purpose-specific zones, investigate spatial patterns, analyze relationships between variables, and design homogenous zones (Cockings et al. 2011). In this research, AZD was used to face MAUP and to generate maps of the Synthetic Homogeneous Neighborhoods (SHN); which represents the underlying hidden socioeconomic structure of the city beyond the official administrative zoning system. Due to the large numbers of indices and the high volume of data, a supercomputer was used to reduce the time of process. Python programing language and the ClusterPy[1] package, a Library of Spatially Constrained Clustering Algorithms (Duque

1. See: https://pypi.org/project/clusterPy

et al. 2011), were used to produce a proper spatial clustering application.

## 2 . CASE STUDY, DATA, AND METHODOLOGY

### 2.1 CASE STUDY

The study area is Tehran, the capital city of Iran. At present, the population is approximately 9 million. The most important feature of the city is the visible and sharp north-south spatial inequality and disparities. The northern part, at the skirt of the Alborz Mountains, enjoys better environmental conditions and is the area that the rich live. Southern part suffers from many problems such as the low access to urban facilities and services, high population density, and environmental pollution. This spatial socioeconomic disparity formed through two main historical transformations of the city in Ghajar era and Pahlavy dynasty. The first transformation happened when Nasser al-Din Shah Qajar (16 July 1831–1 May 1896), ordered that the city be expanded and developed into a much larger city with new borders(Gilbar 1976). The second transformation of the city, took place in the 1930s and was initiated by Reza Shah (founder of the Pahlavi dynasty). He tried to change the city into a new and modern metropolis. Many buildings and all twelve gates of the city were pulled down (Zaka 1970). In addition, a new transport network was built. Yet, the Northern parts tended to display superior characteristics with respect to the Southern one. Tehran has a

In addition, Tehran has a unique socioeconomic (spatial) structure. The high spatial concentration of facilities, of economic and human capital in the capital city attracts people from different parts of the country, not only white collars (highly paid), but also blue collar (lower-paid) workers with different educationional level, language, culture and socioecnomic background. In fact, social fragmentation is a simple and understandable concept. The implemented methodology to present and visualize patterns of above mentioned socioeconomic fragmentation and hidden socioeconomic pattern in the city can be used in other metropolises in Iran such Isfahan, Tabriz and Mashad or even the middle with similar sociospatial configuration. Figure 1 presents Tehran administrative units (109 Nahyeh) in 2002. This research shows a high inconsistency between this map and the map of Synthetic Homogeneous Neighborhoods (SHN) using AZD in terms of shape and formation.

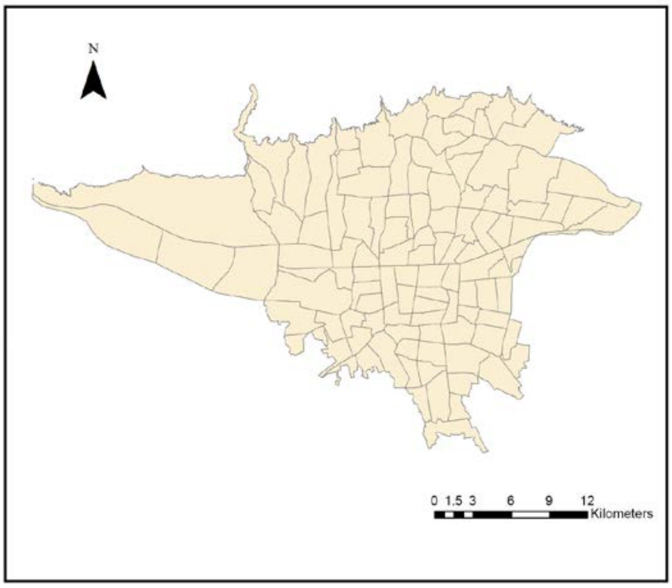


Figure 1: Tehran Administrative Unites (Nahyeh) Map

## 2.2 DATA

All socioeconomic indices used in this research are listed in Table 1. Universal Transform Mercator (UTM) and the WGS84 projection system was used for all maps. Remarkably, Tehran is in zone 39 North in this projection system.

| List | Explanation | List | Explanation |
|---|---|---|---|
| 1 | Total population | 17 | Female Unemployed |
| 2 | Female population | 18 | Female Student |
| 3 | Older than 6 (total population) | 19 | Female Having Income Without Job |
| 4 | Female Older than 6 (total population) | 20 | Female House Keepers |
| 5 | Literate (total population) | 21 | Number of Families |
| 6 | Female Literate (total population) | 22 | Base Area50 |
| 7 | Older than 10 (total population) | 23 | 51≤Base Area≤ 75 |
| 8 | Female Older than 10 (total population) | 24 | 76 ≤Base Area≤80 |
| 9 | Immigrants (total population) | 25 | 81≤Base Area≤ 100 |
| 10 | Female immigrants | 26 | 101≤Base Area ≤150 |
| 11 | Job Holders (total population) | 27 | 151≤Base Area ≤200 |
| 12 | Unemployed (total population) | 28 | 201≤Base Area≤ 300 |
| 13 | Students (total population) | 29 | 301≤Base Area ≤500 |
| 14 | Income Without Job (total population) | 30 | Base Area ≥500 |
| 15 | Housekeepers (total population) | 31 | Number of Residential Units |
| 16 | Female Job Holders | | |

Table 1: List of Socioeconomic Indices used for zoning

This data, at city block level, provided by the Tehran ICT organization, but the source produced by Iran Statistics Center[2] based national census data, year 2002. Some indices are count variables that present the number of variable at associated city block (Variable 1 to 21 in the list). Income without job here means people (men or women) who they do not have official job, but they have other sources to make living such as revenue from rental properties and stocks. Base area indice shows the area of the house in terms of square meter (Variable one to31 in the list).

City blocks are usually heterogeneous in terms of shape, size, area, and other geometrical properties. Socioeconomic indices as outlined in table 1 were used to produce the map of Synthetic Homogeneous Neighborhoods (SHN) using AZ D.

## 2.3 METHODS

### 2.3.1 Creation of Basic Spatial Units.

Map of the city blocks of socioeconomic data consists of the detached vector polygons. However, almost all AZD algorithms work on the attached vector polygons. A fishnet was used to produce a connected vector polygon map. Fishnet is a feature class containing a net of rectangular cells. Production of a fishnet is based on three principal factors, including the spatial extent of the fishnet, the number of rows and columns, and the angle of rotation (Desktop Help 10.0 - How Create Fishnet works). Definition of the size of the fishnet is very crucial in this procedure. There is no specific procedure for the definition of the fishnet size, and the method is more intuitive than being mathematical. Different sizes were tested to define the fishnet size. Finally, the mean distance to 24 nearest neighbors (300 meter) was selected to aggregate the data according to the nearest neighbors method (Clark and Evans 1954). The city map was divided into 6997 cells within a 300 by 300 meter map, as shown in figure 2. All the 31 socioeconomic indices were assigned to the generated fishnet cells using the ratios of areas of the city blocks. This

2. See: https://www.amar.org.ir

means that it was assumed that all related indices are homogeneously distributed on both the city blocks and the fishnet surface. Figure 3 shows overlap of produced fishnet with total population indice.


Figure 2. City Fishnet Map

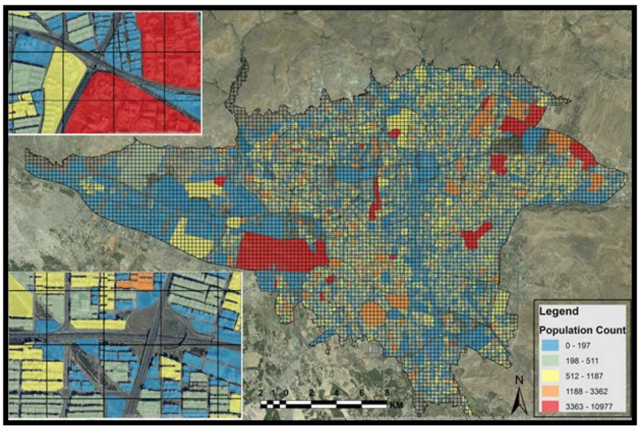


Figure 3. Overlap of Fishnet with Total Population Indice

**2.3.2 Software package.**

ClusterPy, was used to run AZD. Because of the large number of fields and large volume of the dataset, the application was run on a supercomputer to save time.

2.3.3 Regionalization Procedure.

AZTool algorithm takes into account three criteria to produce a new zoning system (Cockings et al. 2011; Sabel et al. 2013).

**1. Homogeneity Constrain;**

**2. Population Constrain: minimum and maximum or target population size;**

**3. Shape Compactness.**

It is worthy to use other algorithms to have a comparison to evaluate the performance of other algorithms. Each of these algorithms has a specific character that increases its application in a specific problem solving. For example, Max-P algorithm has a high capability in producing spatial units with equal population (Duque et al. 2012). One of the most important issues in zoning is the number of zones that need more research. Often, the definition of the number of zones is based on data mining methods without considering the spatial distribution of variables.

## 3 RESULTS

### 3.1 SPATIAL CLUSTRING of SOIOECONOMIC INDICES

The output of spatial clustering process by AZP algorithm and ClusterPy application is presented in figure 4.

This map illustrates the city in 200 SHN (units or clusters). The new zone design map shows the spatial socioeconomic fragmentation in the city, based on the available indices. This map is sensitive to the selected number of classes and the input indices. Clustering procedure can be repeated for each generated polygon (neighborhood) for a more detailed map. This clustered map can have wide applications in urban and regional planning and researchers (especially sociologists, urban economists and geographers), policy makers, and city managers to investigate urban social fragmentation and exclusion. Small polygons can potentially be used to investigate the footprints of sociospatial segregation in the city, especially in southern parts that figure 4 shows a number of small polygons.

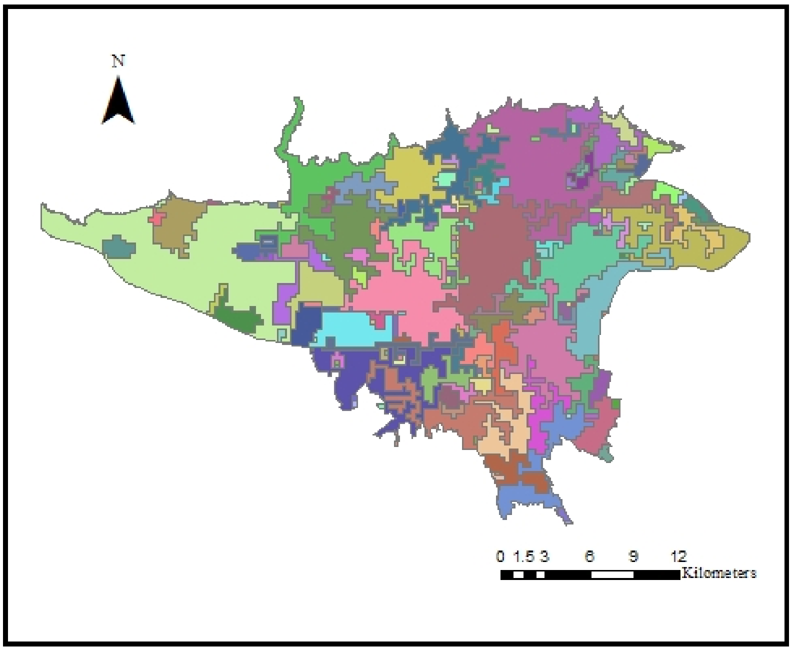


Figure 4. Result of Zone Design by spatial clustering with AZP algorithm.

Figure 4 shows patterns of spatial distribution of people and population in Tehran. Also, it has high practical values for studying the problems of social segregation in the city. The output represents intra-socioeconomic clustered regions in the city and a high level of analysis. As mentioned before, AZD could be implemented to each new cluster to explore the intra-socioeconomic clustering and spatial patterns in more details, within each cluster.

#### 3.1.1 Evaluation of New Zone System.

Consistency of the new zone design was evaluated by using the Global Moran's I (Moran 1950), an indicator of the spatial Autocorrelation. Complete Spatial Randomness (CSR) is used as the null hypothesis for spatial autocorrelation analysis. Tests of z-score and p-value are used to see whether the null hypothesis can be rejected or not. The p-value indicates the probability that the observed spatial pattern is produced by a random process. In addition, the smaller is the p-value, the more likely that an observed pattern is not created by a random process. The null hypothesis can then be rejected.

The high z-scores (negative and positive) are located in the tails of the normal distribution. High values of z-scores pattern has a random state that the observed spatial distribution. Moran's I index was calculated

to evaluate the results and accuracy of spatial clustering for all 31 indices is an example of Spatial Autocorrelation Report for the total population index (the first index). Moran's I Index ranges from -1 to +1, where the former and latter values, respectively indicate perfect negative and positive spatial autocorrelation in the data or map.
In fact, spatial autocorrelation values in the new zone system should be minimum to have a better zone system. Table 2, shows Global Moran's I values and the new zone system parameters for evaluating the new zone system of all 31 selected socioeconomic indices.

Given the z-score of (0.33), the pattern did not appear to be significantly different from the random. The results pinpoint that the second index (female population) is the only index does not have a random distribution in the new zone system. It means that the reliability of the output is acceptable. The error in this spatial clustering is about 3 percent (1/31 percent). Given the z-score of (3.74), there is less than 1 percent likelihood that this clustered pattern is the result of a random process.

| | |
|---|---|
| Moran's Index | 0.0012 |
| Expected Index | -0.0050 |
| Variance | 0.0003 |
| z-score | 0.3266 |
| p-value | 0.7439 |

Table 2 .Moran's I index for the First Index (Population)

### 6.4 SPATIAL PATTERNS of SOCIOECONOMIC VARIABLES

Analyzing spatial patterns can pave the way for understanding relationships between the patterns and processes. Is there any underlying spatial process that creates spatial pattern? Or are the objects (variables) randomly distributed throughout the study area (here the city) or are they clustered? Based on the urban political ecology, the place where people live is associated with their socioeconomic positions; in other words, spatial and socioeconomic positions are related to each other. Social segregation happens when there is a difference in the level of education, occupation and income between groups of people (Knox and Pinch 2010).

## 4 . DISCUSSION AND CONCLUSION

Cities are complex and have different components that traditional analysis are not able to reveal their characteristics. One of the basic stages of each planning is definition of the spatial zones. In traditional zoning methods, spatial dimension of neighborhood and proximities are not considered. Division of space in different units is usually known as the zoning and regionalisation. Basic principle in all of the zoning approaches is the combination of basic spatial units in the form of higher spatial level known as the zone or region. Then, despite the different names, principle of the method is the same. In this paper, the main aim is the introduction of an approach to create essential changes in zoning system or spatial grouping in urban environment using the automated zone design such as the AZP. In this paper, first of all, the dimensions of the problem are defined and different (proper) evaluation approaches and corresponding criteria are extracted. These measures may not be satisfactory and it is better to consider other dimensions for better match with the reality. Basically, the definition of the base units of analysis is based on evaluation of the impacts of different spatial units on the outcomes of the research. This means that at each scale results of spatial analysis can be different. If small spatial units are used, the algorithm may not solve the problem. So, we have to select those spatial units that change of their physical shape, form and dimension has the least impact on the results. In this paper, according to the findings of previous studies, orthogonal spatial unit is used. For Regionalization we use AZP algorithm which is able to simultaneously consider homogeneity and compactness of zones.

The output map and results present underlying spatial structure of the socioeconomic conditions in the city. There are different socioeconomic units (figure 4) in the city that their borders are not consistent with the official administrative districts (figure 1). It means that for designing social policy and urban plans, urban planners and managers should take into account the hidden spatial structure of the city or in other words hey should see the invisible city. The output of this research can be used in area-based target policy and budgeting, social and urban studies as well. This paper shows that we can use new techniques and methods to solve the traditional problems. Finally, for the future research, it is suggested that other zoning methods their capabilities to be tested.

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