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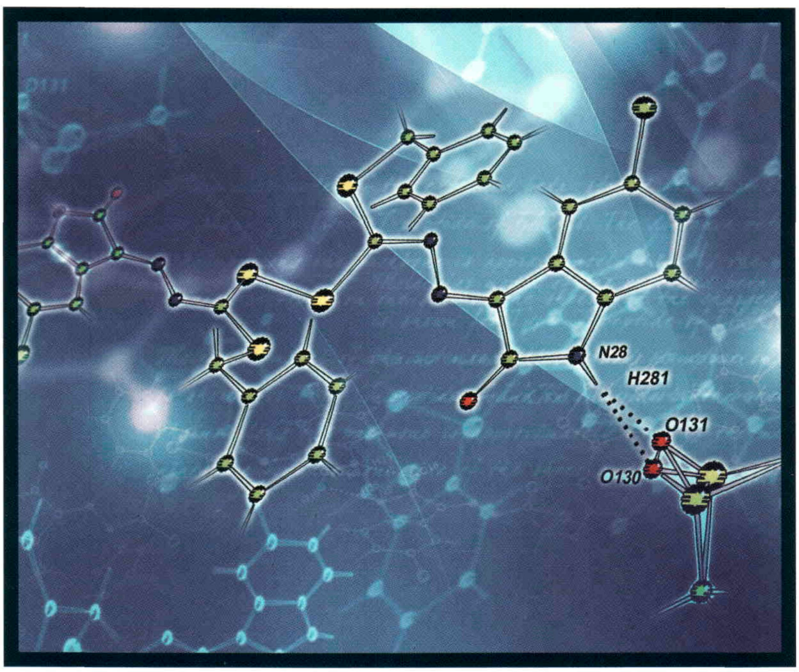

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Spatial Autocorrelation in the Study of Neighbourhoods towards Smart Cities: Empirical Evidence from Kerman, Iran

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ABSTRACT

From earliest cities to the present, spatial division into residential zones and neighbourhoods is the universal feature of urban areas. This study explored issue of measuring neighbourhoods through spatial autocorrelation method based on Moran's I index in respect of achieving to best neighbourhoods' model for forming cities smarter. The research carried out by selection of 35 neighbourhoods only within central part of traditional city of Kerman in Iran. The results illustrate, 75% of neighbourhoods' area in the inner city of Kerman had clustered pattern, and it shows reduction in Moran's index is associated with disproportional distribution of density and increasing in Moran's I and Z-score have monotonic relation with more dense areas and clustered pattern. It may be more efficient for urban planner to focus on spatial autocorrelation to foster neighbourhood cohesion rather than emphasis on suburban area. It is recommended characteristics of historic neighbourhoods can be successfully linked to redevelopment plans toward making city smarter, and also people's quality of life can be related to the way that neighbourhoods' patterns are defined.

Keywords: *Neighbourhoods, Smart Cities, Spatial Autocorrelation, Iranian Traditional Cities.*

INTRODUCTION

From earliest cities to the present, spatial division into residential zones and neighbourhoods is the universal feature of urban areas. The role of neighbourhoods and face-to-face interaction is probably strong in structuring smarter cities. Nowadays its influence on liveability of urban people has become clear and suburban living is often blamed for causing increasing dependence on the car [1]. The dispersal procedure encourages the growth of car traffic and the polarisation of neighbourhoods, low income households in poorer neighbourhoods yet suffer higher levels of traffic and environmental damage, whereas they have far lower levels of car ownership than average [2]. Most probably urban design influence where and with whom people engage in physical activity [3], and the planning criteria for foremost infrastructures such as campuses, shopping centres, etc. will need to be immediately redefined to enable the transformation of cities towards being smarter and the use of renewable energy, readjusted for extreme climatic events such as floods, storm surges, global temperature increases, sea-level rise, water shortages [4,5], the studies show our generation need to conduct more studies on this topic. This study explored issue of measuring neighbourhoods through spatial autocorrelation method based on Moran's I index in respect of achieving to best neighbourhoods' model for forming cities smarter.

LITERATURE REVIEW

The painful story of urban planning development in Iran from 1920 to 1941 is discussed in a paper by Eckert Ehlers and Willem Floor [6]. This research showed how dualism and interstice between traditional city and modern context of that, started 80 years ago under imitation of western urban design and had an effect on the lives of Iranian. They have shown how significant centres such as mosques and schools which were the heart of the city, were changed to places like bank, cinemas and hospitals [6]. There are so many studies that show how neighbourhoods or other urban elements can be useful for built environment and public health, but lack of data could be the limitation of research on this field [7-9].

As studies show, city clusters are denser and compact than their equals in the developed countries in the Europe and United State [10], Life of people can change remarkably in neo-traditional developed area with emphasis on street network and also it reduces congestion or even their health and happiness [11-13]. The critical need for work on sustainable communities and need is obviously recognisable in Table1. Also a research in the context of developing countries found that, higher density, mixed land use and income are not really sufficient to predict pedestrian volume and site-design characteristics including streets, block size, length of sidewalks, and pedestrian route travelled [7]. Kitamura and Mokhtarian with a different view on pedestrian routes and they expressed the attitude of resident influences travel behaviour and they have pointed some key character such as measures of residential density, mixed land use, public transit accessibility and existence of sidewalks in trip generation. Also, they mentioned the promoting of land use with higher density and mixture value is not possible without change of resident's attitude [14], equated with those who don't, impact of urban form on frequency of walking and bicycling as a form of physical activity emphasised [11].

Table 1: Lack of Physical Activities can Cause to Increase the Number of Overweight and Obese People

7,061,475,879	current total **world population**
908,515,628	**undernourished** people in the world right now
1,561,896,966	**overweight** people in the world right now
520,632,322	**obese** people in the world right now
27,328	people who **died of hunger today**
7,196,489	people who **died of hunger this year**
Economics	
$ 425,260,915	money spent **due to obesity** related diseases in the USA **today**
$ 105,082,142	spending on **food purchased and then tossed** by US households today
$ 4,886,108	spending on global **food aid** today
$ 31,767,407	amount that would allow to **feed the hungry** today
$ 168,932,933	**spending on weight-loss** programs and products in the USA today

Sources: World Population Clock, State of Food Insecurity in the World 2006, WHO, Timothy Jones, University of Arizona (UA) in Tucson, August 2012.

In addition, Ewing *et al.* measure urban sprawl and with defining a sprawl index of 448 counties across the United States, they account low development density, segregated land uses, lack of significant centres and poor street accessibility and sparse street network are the main causes of urban sprawl [15]. Even more, a small but detailed study also have shown in two San Diego neighbourhoods which physical activity was assessed by self-report and by accelerometer, residents in the "high workability" neighbourhoods had almost 70 more minutes per week of physical activity and had lower obesity incidence than those in the "low workability" neighbourhoods after regulating for age and education [16]. This comparative study explored how characteristics of historic neighbourhoods can be successfully linked to redevelopment towards making smarter Iranian cities and whether health and happiness of people can be related to the way that neighbourhoods' patterns are defined.

METHODS

Data Processing and Area of Study

As there are many researches on smart growth of cities, neighbourhoods and their measuring in urban areas such as Tehran and Esfahan [17-21] and also there are many studies on neighbourhoods' accessibility measuring, here there is a closer look to spatial dependency in the city of Kerman which has critical situation and facing with lots of challenges in near future. The city of Kerman is a place of historical value with no master plans implemented carefully, in addition to the lack of planning policies the city is located in a critical geographical location. With this regards, the research carried out by selection of 35 neighbourhoods only within central part of urban area which is also traditional part of Kerman. Summaries of its data have offered in Table 2. The location maps of both city and neighbourhoods has presented in Figure 1.

Table 2: Summaries of the Statistical Data

	Kerman	Central Part	%
Population	515,114	27,584	5.4
Men	263,674	14,038	5.3
Women	251,640	13,800	5.5
Ratio	104.7	101.7	-
Families	127,936	6,991	5.5
Area (m^2)	12,611	451.3	3.6
Density Person/ Hectare	40.8	58.2	-

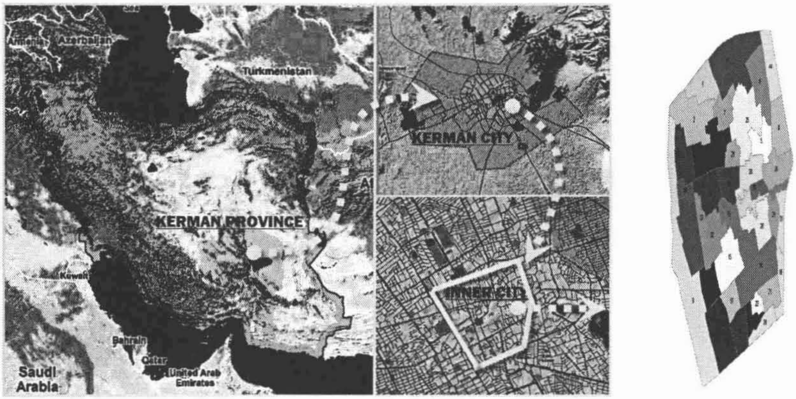

Figure 1: Location Map of Inner City of Kerman and Neighbourhoods Boundaries

Old neighbourhoods boundaries are divided based on the physical and institutional characteristics of the neighbourhood, their class, race, ethnic composition, symbolic neighbourhood identities and resident's sense of dependency which can compromise neighbourhood boundaries and identity [22]. The concept of neighbourhoods in Iran is almost equal to the western definition [21] but with the difference that neighbourhoods in Iranian cities have evolved in an organic, and not a predetermined or planned, manner into an equivalent of quarters in the West.

In 2003, Kerizek discussed and focused on changes in travel behaviour as triggered by change in urban form variables, he presented a model which decreases the total distance of household travel. It referenced the cost of each trip is less for household in areas with more access and strong definition of neighbouring, they may make more of them [23].So neighbourhoods, walking and cycling define as a daily life activity and can be caused to enjoy considerable health benefits Many plans presented for Kerman but yet no plans could organise the area even it caused to destroy it more because of shortage in policies. The first plan for city of Kerman was presented in Oct. 1936, by municipality of Kerman Figure 2.

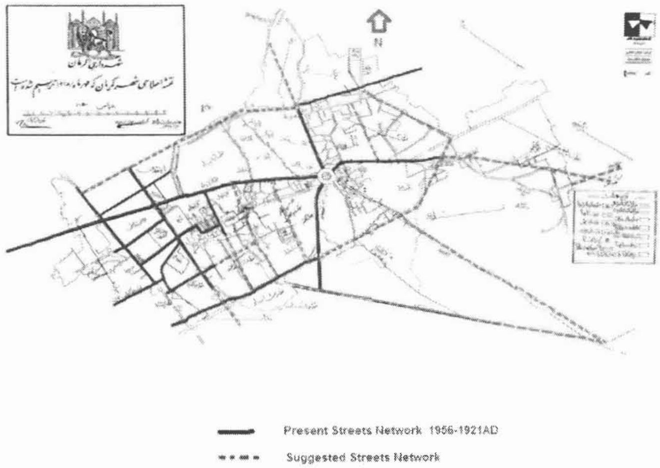

Figure 2: A Suggested Plan for Kerman in 1936, Predicted Streets Network has Presented in Yellow Lines

The main objective of this plan was predicting of construction and development for new streets and alleys in the purpose of easy access to all places over city. There were four more plans for developing Kerman from 1965s, 1975s, 1983s and 1994s respectively from private organisations and even the University of Tehran but all those did not implement in practice. In fact, unsuccessful plans caused to consternation in central part of Kerman, with this regards evaluating of spatial autocorrelation level has a greater impact on the performance of neighbourhoods and whole city structure as well. This is the first attempt to promote spatial autocorrelation method at a neighbourhood scale in a city, especially in developing countries like Iran and it tried to find:

1. which context can spatial autocorrelations have reflection in the city with respect to challenges of the future

2. if there is any inequality between spatial auto correlations in different zones, if the answer is positive what might be the causes

3. if spatial autocorrelation can help the measuring growth of smarter city in developing countries and particularly in Iran

This study will attempt to answer the research questions mentioned above; however analysis of the sources of variation in neighbourhoods and how they can be effectible in smarter city drew on additional methods. The methods which have been proposed in this study will measure spatial autocorrelation based on both feature locations and feature values simultaneously. It evaluates whether the neighbourhood pattern is clustered, dispersed, or random. Previous research have demonstrated that spatial autocorrelation analysis can be used to access measuring network [24] even to determine land use (change) and to give cause to unravel its complexity even more from a spatial perspective [25], also researchers showed with this method we are able to quantity segregation even during time [26-27] and applied to distributional archaeological data [28]. Spatial autocorrelation is characterised by a correlation in a signal among nearby locations in space.

As one of the most challenging issues in Iranian cities is dispersing of urban forms [29], statistically, Moran's I implemented as a degree of measuring of spatial autocorrelation, developed by Patrick A.P. Moran [30]. Indeed, Moran's method can implement for multi-dimensions and it is more complex than one but here I used only the one dimension and it could expand in future research.

Measuring Neighbourhoods' Spatial Autocorrelation

Spatial autocorrelation is a powerful technique for the analysis of the spatial patterning in variant values which has been successfully applied [26] [31-32]. Moran's I for measuring neighbourhoods auto correlation is defined as:

$$I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(X_i - \bar{X})(X_j - \bar{X})}{\sum_i (X_i - \bar{X})^2}$$

where N the number of units in each neighbourhood and it is indexed by i and j; X is the variable of areas; $\bar{X}$ is the mean of X; and w_{ij} is an element of a matrix of spatial weights.

Based on data set if (X [1], X [2],…, X [N]) be spatial units in each neighbourhood boundaries, The mean is:

X = (X [1] + X [2] + ... + X [N])/N.

The deviations would be

R[i] = X[i] - X, i = 1, 2, ..., N.

The variance is

V = (R[1]^2 + R[2]^2 + ... + R[N]^2)/N.

The standard deviation is

S = Square (V).

The normalized values therefore are

Z[i] = (X[i] - X)/S, i = 1, 2, ..., N.

The ordered pairs are entire N*N possible combinations

(Z[i], Z[j]), 1 <= i <= N and 1 <= j <= N.

In general, if we have values Y[1], ..., Y[M] and corresponding weights W[1], ..., W[M], then the weighted average of the Y's is given by multiplying the Y's by the weights, adding them up, and dividing by the sum of the weights.

Let the weight associated with the i,j pair be W[i,j]. We will need the sum of the weights, which is:

W = Sum over all (i,j) of W[i,j].

The weighted correlation--Moran's I--therefore is given by

I = {Sum over all (i,j) of Z[i]*Z[j]*W[i,j]} / W.

That is, it is the weighted average of the products Z[i]*Z[j].

The range of Moran's index starts from -1 indicating perfect dispersion to +1 indicating perfect correlation. A zero value indicates a random spatial pattern. For statistical hypothesis testing, Moran's I values can be transformed to Z-scores in which values greater than 1.96 or smaller than −1.96 indicate spatial autocorrelation that is significant at the 5% level. After calculating z-scores and drawing Moran's I index of neighbourhoods we need to reclassify them. This study was based on Moran's Index I and results of analysis divided neighbourhoods into three categories: clustered, random and dispersed. Afterwards, spatial autocorrelation, neighbourhood structures and forms have been analysed and outcome has interpreted. Also ArcGIS promoted to drawing location maps of neighbourhoods, land use and street network in each neighbourhood for more comparisons and evaluations.

RESULTS AND DISCUSSION

The results have been illustrated, 75% of neighbourhood' areas in the inner city of Kerman have clustered pattern with the Z-score between 2.74 and 12.32. The location of these neighbourhoods presented in Figure 3. Based on the calculation of Moran's I which is presented in Table 3, and it showed Z scores of these boundaries felled outside the range, because the normal range of Z-score is from -2.58 to +2.58, as the pattern exhibited is too unusual to be version of random chance. It is possible to reject the null hypothesis and proceed with figuring out what might be causing the statistically significant clustered pattern.

Table 3: Summaries of the Spatial Autocorrelation Method's Calculations and Moran's I Values in 35 Neighbourhoods of Inner City of Kerman. * Six Random Selected Neighbourhoods which Three of them (1, 12, 35) have Clustered Pattern and Left (14, 15, 16) have Random Pattern

ID	Name	Moran's Index	Z-Score	Area	Length	Density	Patern
1*	Ghobesabz	0.21	6.2	65270.97676	1168.75	High	Clustered
2	Khajekhezr	0.13	4.47	119355.3713	1918.212	High	Clustered
3	Naserieh	0.15	3.62	58777.99785	1154.177	Medium	Clustered
4	Bazarshah	0.16	7.28	159428.506	2052.185	Medium	Clustered
5	Bazarshotor	0.09	2.83	48637.21936	1163.079	Medium	Clustered
6	Shahr	0.07	2.07	79270.59679	1369.649	Medium	Clustered
7	Shahzadeshahrokh	0.13	3.01	46201.43964	1078.941	Medium	Clustered
8	Makraniha	0.17	7.03	264284.32	3897.736	Low	Clustered
9	Dolatkhane	0.19	3.36	22027.12185	700.6496	Low	Clustered
10	Kelimiha	0.19	5.05	64651.38267	1152.248	High	Clustered
11	Ganjalikhan	0.25	3.4	43800.60028	1008.23	Medium	Clustered
12*	Golbazkhan	0.24	7.04	66456.67041	1176.673	Medium	Clustered
13	Valiabad	0.17	3.54	35741.90802	790.1768	Medium	Random
14*	Masjedmalek	0.02	1.32	154152.4174	1980.447	Medium	Random
15*	Meidanghale'	0.01	-0.11	85166.72609	1263.332	Medium	Random
16*	Unnamed	0.04	0.99	31198.32197	1148.4224	Medium	Random
17	Zartoshtian	0.26	4.99	24056.81993	848.0262	Medium	Clustered
18	Shahadel	0.12	2.92	40640.64062	895.6983	Medium	Clustered
19	Ghalibafi	0.09	1.76	16287.2456	565.3321	Medium	Clustered
20	Tahbagh Allah	0.05	1.77	103803.9236	1785.02	Medium	Clustered
21	Bazaraziz	0.19	2.74	25520.58424	653.1906	Medium	Clustered
22	Pamenar	0.2	6.94	121623.4799	1911.742	High	Clustered
23	Tekyekalantar	0.13	4.71	66145.23308	1691.019	High	Clustered
24	Bazarvakil	0.13	1.88	18768.35358	744.6841	Medium	Clustered
25	Sardarnosrat	0.17	4.17	53230.23092	1381.48	Medium	Clustered
26	Charsoghkohne	0.01	0.25	26845.15343	761.5556	Medium	Random
27	Mozaffari	0.37	12.32	64583.50202	1283.027	Medium	Clustered
28	Meidanarg	0.25	4.92	67941.34512	1284.476	Medium	Clustered
29	Davazdahemam	-0.07	-1.07	24473.24805	861.0654	Medium	Clustered
30	Ebrahimkhan	0.34	7.35	48919.7167	1001.269	Medium	Clustered
31	Bazarmozaffari	-0.3	-2.81	11735.57824	873.7723	Medium	Disperse
32	Bazarvakil	0.13	1.07	30290.52744	1792.23	Medium	Random
33	Markazhokoomati	0.15	2.98	99164.72405	1390.084	Medium	Clustered
34	Godalkheshtmalha	0.01	0.94	48664.65908	952.8478	Low	Random
35*	Ghale'mahmood	0.13	5.26	105649.503	1312.535	Low	Clustered

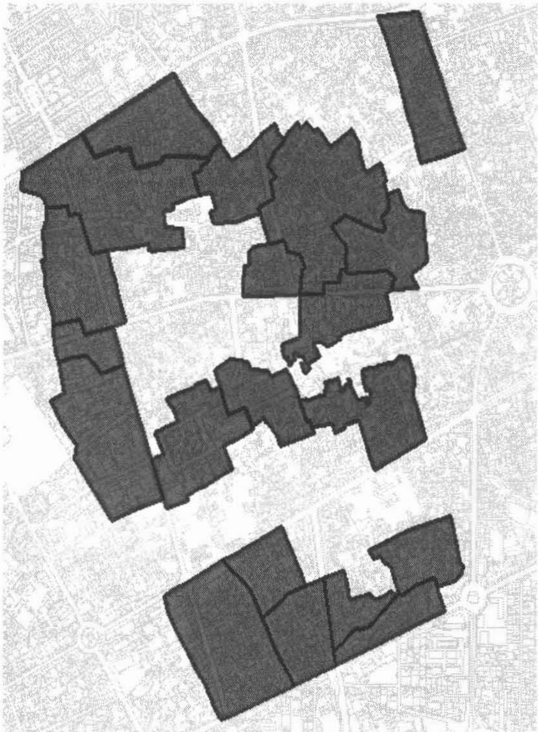

Figure 3: Location Map of Neighborhoods with Clusterd Pattern in Central Part of Kerman

The next category consists of four neighbourhoods with the portion of 8% that fall in a same category of clustered pattern but with different Z-score from 2.07 to 1.76. In the third group, there have been seven neighbourhoods out of thirty-nine which have random pattern with Z-score between 1.32 and -1.07 that it has 16% of total area, as it defined before they are neither clustered nor dispersed. Interestingly, this category located exactly on central part of the city surrounded by two streets, Sharya'ti and Emam, near commercial district of main bazaar. Finally, only one neighbourhood with Z-score -2.81 which is the least one had dispersed pattern.

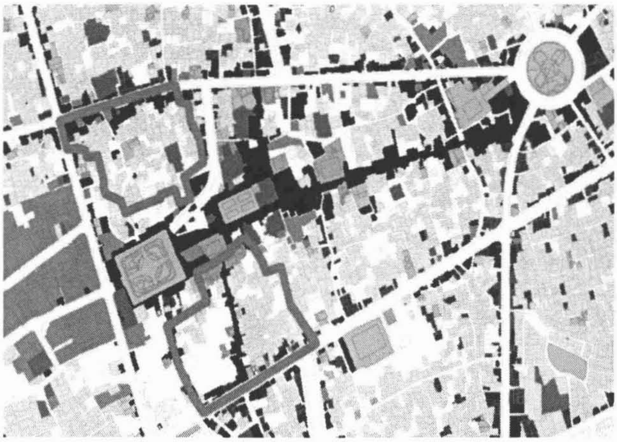

Figure 4: Comparison of Neighbourhoods Meidanghale (above) and Golbazkhan (below) in Central Part of City Kerman, Above Boundaries Show a Clustered Neighbourhood with Moran's Index Near -1 and Below Boundaries Show a Neighbourhood with Random Pattern and Moran's Index Near +1

Six neighbourhoods out of thirty-five selected for further investigation which have presented in Figure 5,which three of the have the clustered pattern (1, 12, 35) and left (14, 15, 16) have the random pattern, it can be founded reducing in Moran's index is associated with disproportional distribution of density. In comparison, two neighbourhoods Meidanghaleh (ID=1) and Golbazkhan (ID=15) Figure 4, though have the same value in Moran's index, area and units as well, but one considered with clustered pattern and other one as dispersed pattern, with considering Z-score, it would be observed neighbourhoods have a big difference in amount of Z-score though they are near each other and almost are same in profile data. Moran's I value and Z-score in Golbazkhan neighbourhood is 7.04, 0.24 respectively and the same for Meidanghale are -0.11 and -0.01. The structure of neighbourhoods boundaries illustrated, scattering of density in Ghobbehsabz neighbourhood (ID=1) with Moran's value 0.21 and Z-score 6.2 is steadier than Meidanghale neighbourhood (ID=15) with Moran's value -0.01 And Z-score 0.11 and it could be said increasing in Moran's I and Z-score have monotonic relation with more dense areas and clustered pattern.

In attempting to find out the reasons for the statistically significant clustered pattern in the neighbourhood of Meidanghale, it was found there is a big difference in density, street pattern and land use. There has been the dilapidated field that is in neighbourhood Golbazkhan. Adversely, land use of neighbourhood Meidanghale with random patterns has more street connection and it has a central part for easy accessibility and blocks are divided nicely and access to other parts is easily possible. In more detail, Figure 5 presents how spatial auto correlations change in different neighbourhood boundaries with change in street pattern and even density.

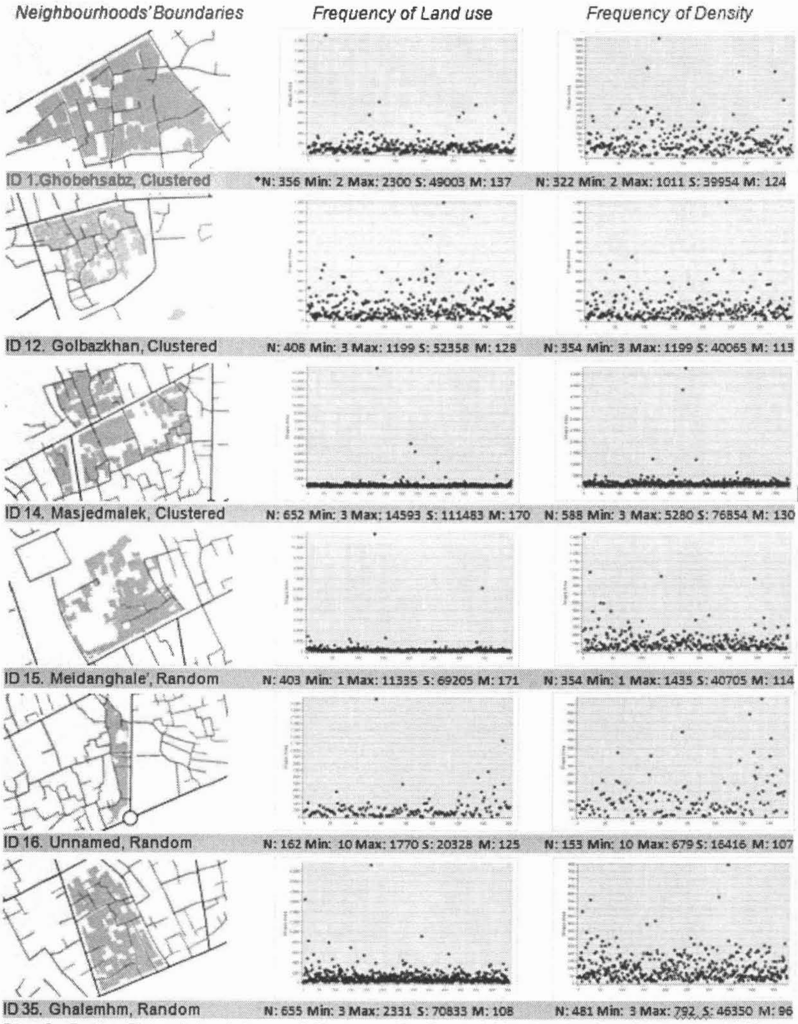

Figure5. Scatter Plots of Land Use and Density in Six Selected Neighbourhood in Central Part of Kerman
*N=Number of Polygons, S=Sum, M= Mean.

As it has claimed level of smart cities has direct relation with density [33-37], it could be concluded that if we raise the pattern with high Z-score, we can make cities smarter. But increasing smarty possible with changing which can be studies in more research. Study of spatial autocorrelation in neighbourhoods showed variety of pattern in a city can cause to have smarter city instead of cost for affordable housing in Iran (Mehr Maskan).

CONCLUSION

This study explored the issue of measuring neighbourhoods' spatial autocorrelation based on Moran's I index in respect of achieving to best neighbourhood's model to forming smarter cities. The results could be very constructive for modelling of smart cities and it enables us to select the best spatial pattern for neighbourhoods depending on the cities conditions and profiles.

This study is the first known attempt to use spatial autocorrelation in the study of neighbourhoods in developing countries and in Iran as well. The statistical and graphical analyses exploit in depth, at first it tried to calculate Moran's I degree and Z-score then to analyse the neighbourhoods based on their spatial autocorrelations and finally to compare neighbourhoods with each other and to expand it for finding appropriate pattern for neighbourhoods especially in cities of Iran. Also this study was carried out to illustrate how spatial autocorrelation measures could be applied to incidents or events in a neighbourhood and having done that, how these could be interpreted. This study suggests it may be more efficient for urban planner to focus on spatial autocorrelation to foster neighbourhood cohesion rather than emphasis on suburban area. It is also recommended characteristics of historic neighbourhoods can be successfully linked to redevelopment plans toward making city smarter, and also people's quality of life can be related to the way that neighbourhoods' patterns are defined.

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