

ANALYSIS OF THE RELATION BETWEEN SPATIAL STRUCTURE AND THE SUSTAINABLE DEVELOPMENT LEVEL. A case study from Mashhad/Iran

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Abstract

This research aims to study the relation between spatial structure and sustainable development level with the case of Mashhad, a city at the north-east of Iran. The literature suggests that there is a positive relation between socio-economic processes and the spatial form in a city, thus in order to comprehend socio-economic processes, understanding the spatial form of the city is essential. Also the socio-economic relations in different parts of a city can indicate sustainable development level of the areas by which the development indicators could be assessed. In order to study this relation, 136 neighbourhoods in Mashhad have been examined in which space syntax is used to study the spatial structure of the city and factor analysis is used to identify sustainable development level. In this study 20 indicators in different subjects including social, economic, physical, environmental, and welfare are combined and are considered in the analysis as the indicator of the quality development.

The results suggest that there is a positive correlation between local integration and integration $r-r$ with the changes in sustainable development level; however, this is not the case for global integration. Thus, one of the main reasons for having inequality in socio-economic conditions in different parts of the city could be a heterogeneous spatial structure in the city.

1. INTRODUCTION AND PROBLEM DEFINITION

The relation between socio-economic development process and spatial forms has been always one of the interests of sociologists and geographers. This issue has been highlighted more when paradigm of spatial science has been introduced and exceptionalism has been criticized by people such as Fred K. Schaefer, Peter Hagget, and David Harvey. Although each of these scientists approached this idea from a different point of view, all of them emphasized on the relation between socio-economic processes and the spatial form of the city which makes them necessary to be considered simultaneously in urban planning and built environment design. However, the main interest of these scientists is the complexity of spatial forms and the qualitative aspects of the city. In this regard, Harvey (1973) highlighted the necessity of having a continuous geometry for spatial analysis by which it could be possible to correlate the qualitative aspects of the city with the spatial attributes of it. Space syntax made this idea applicable in practices and different studies showed that there is a positive correlation between syntactic measures and socio-economic processes in the cities. Different subjects including the effect of spatial structure on socio-economic processes and indicators especially in low-income family settlements have been studied by researchers across the world. However, what is missing is the relation between sustainable development level - which takes all factors including social, economic, physical, environmental, and welfare into account - and the spatial form of the neighbourhood. Thus, an interesting question can be formulated in this regard. Do the neighbourhoods with good quality of development have a better spatial structure in comparison to the less developed and deprived areas? In order to answer this question two main attributes of cities including urban sustainable development and spatial structure of the city are compared in the case of the city of Mashhad in Iran.

2. RESEARCH CONTEXT

The city of Mashhad was surrounded by a city wall until 1890; however by the beginning of urban developments in Iran the city wall was destroyed and the city started expanding towards the west. In the process of urban development many villages joined the city and many self-generated neighbourhoods were developed regardless to the urban structure people migration from villages to the city. The urban development towards the west made the eastern part of the city segregated spatially and socio-economically and led them into a loop of deprivation (Farnahad, 2009).

The city of Mashhad with 200 km square and 2.5 million populations is known as the second main city in Iran. The city is famous for its tourists and pilgrims and recently has been the focus of socio-economic and cultural developments [Figure 1].

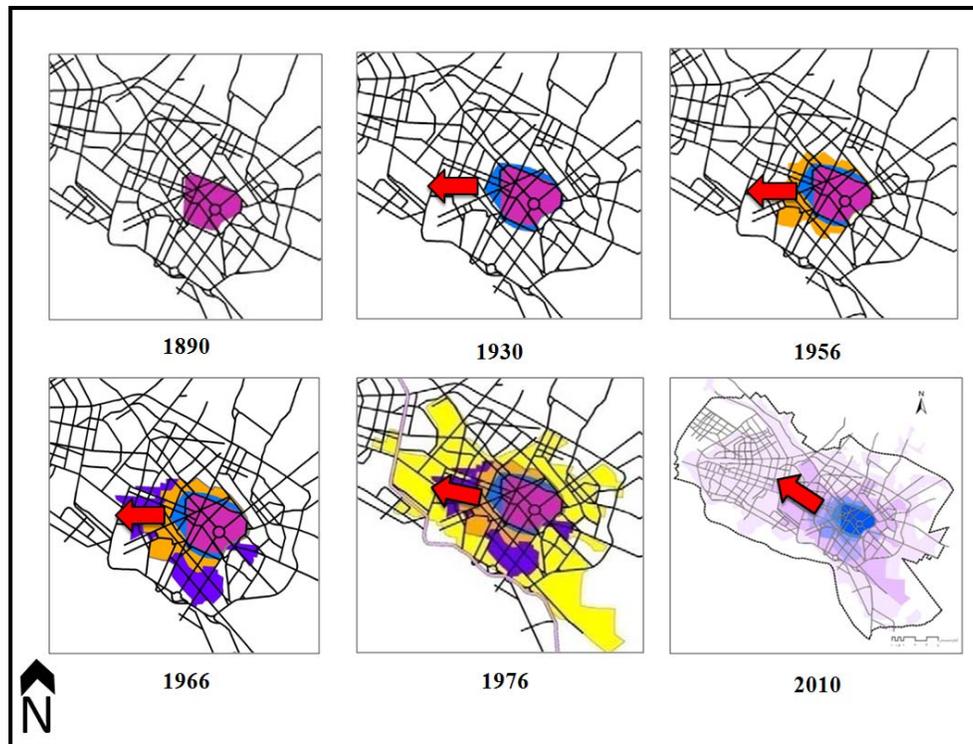


Figure 1: The city expansion process (Farnahad, 2009)

The city has been divided into two parts including the western part with a high level of welfare and access to facilities especially civic infrastructures and the eastern part with a high level of poverty, crime and pollution [Figure 2].

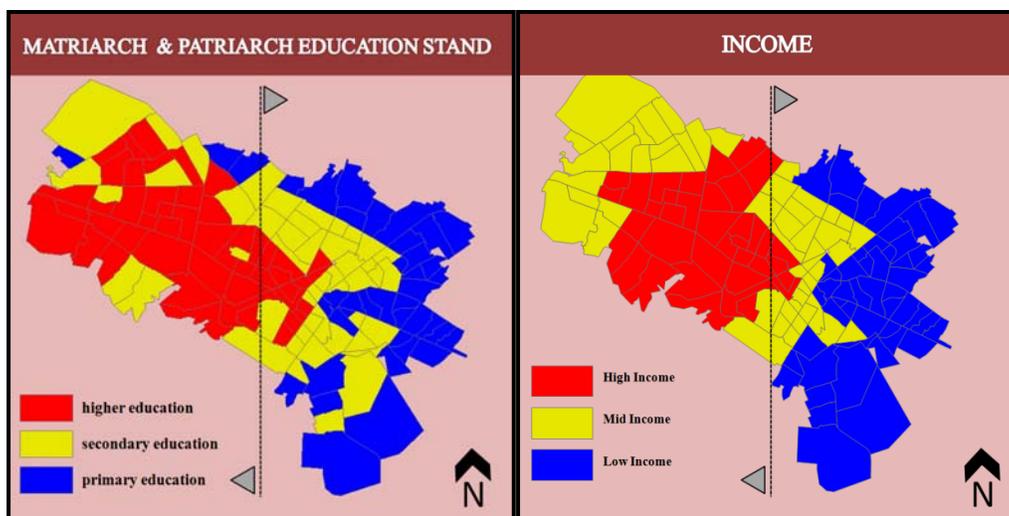


Figure 2: Mashhad socio-economic condition (Farnahad, 2009)

Therefore, it can be said that the city of Mashhad - like other cities in Iran - suffer from socio-economic and spatial inequalities in which the deprived areas are expanding in the eastern part of the city. It seems that these deprived areas suffer from isolation from urban development process [Figure 3].



Figure 3: Mashhad socio-economic condition - left (West Town), right (East Town)

The municipality of Mashhad has divided the city into 12 districts, 38 regions and 136 neighbourhoods in which a socio-economic and spatial gap between different cities is observable at the first look. This research studied the relation between the quality of urban development and spatial form at the neighbourhood scale since the changes in spatial and physical structure of the areas are observable from one neighbourhood to the other; whereas the socio-economic condition of the area is more homogeneous across different neighbourhoods. Moreover, the available data was at the neighbourhood scale.

3. LITERATURE REVIEW

Considering the interest of the research this part is divided into two parts including sustainable development level and space syntax.

3.1. Sustainable development level

Sustainable development planning in different society has a purpose above social, cultural, physical, and economic interest which is the concept of 'social justice'. Nowadays the concept of social justice is about facility distribution and reduction of inequality of access to these facilities and resources. Thus, multidimensional development of deprived areas is one of the main tasks of urban planners in achieving social justice. Considering that different indicators, e.g. social, cultural, economic, environmental, are involve in sustainable development, one could rarely find a neighbourhood which is well developed in every aspect or not developed at all. Therefore, Sustainable development level of one area in comparison to the other areas of the city is advantages of that area in relation to the other areas based on specific indicators (Ministry of Housing and Urban Development, 1991). The main steps in determining the Sustainable development level in different areas in relation to each other are development factors and their indicators, the scale of the study, and comparison method (Ministry of Housing and Urban Development, 1991).

3.1.1. Sustainable development indicators

At United Nation Conference of Environment Development (UNCED) in 1992, the necessity of reviewing the sustainable development indicators in different countries was highlighted as the main interest of the UN. These indicators were published and authorized in 1995 by the Commission on Sustainable Development (CSD). Afterwards, two other sets of sustainable development indicators were authorized by 2001. These indicators were widely examined in different countries internationally in order to be assessed and modified. In 2002 some modifications were applied on the CDS indicators. International collaboration led to changes in the indicators and the third version of the CDS indicators was authorized in 2007. These indicators were produced based on basic subjects such as poverty, security, health, education, population, natural disasters and etc (United Nations, 2007)¹. However, since these indicators are at a holistic level and in the country scale, many studies have modified them based on their local conditions (UNCHS: HABITAT 1998, N.U.R.E.C. 1994, Helsinki 2002, DETEC 2004). These studies have provided a list of sustainable development indicators which follows the CDS indicators but is more local and is based on available data in each region and in many cases are different from provided indicators in other regions. These indicators generally include population, households, families; housing, housing conditions; regional economy, commerce and industries; labour market, employment rate; income, subsistence/livelihood; education; culture, spare time; social services, health care; security; municipal economy; building; traffic; environment.

3.2. Space syntax and socio-economic processes

Space syntax theory is based on evidences suggesting that the spatial configuration of cities and buildings have an underlying social dimension which is in mutual interaction with the spatial nature of the social activities (Hillier and Hanson, 1984). Street network in space syntax is mostly represented as a set of linear elements called 'axial map' and the simultaneous relation between each element and all others is expressed through measures of spatial configuration (Hillier and Hanson, 1984). In this relation, the 'natural movement' theory indicates that configurationally more integrated streets and urban spaces would carry more movement through themselves (Hillier et al., 1993). Consequently the theory of 'movement economy' indicates that the movement flows largely influenced by configuration would affect the distribution of land uses with 'movement demanding' activities tend to be found on more integrated streets (Hillier, 1996). This distribution of land uses is also observable in sufficiently large urban systems when a few long radial streets are connecting the settlement core and the bulk of shorter streets together and to the system's edges called 'deformed wheel pattern'. As a result of this spatial pattern shops and public activities favour the integrated radial streets and the settlement integration core while residential areas would fill the rather spatially segregated interstices between the radials (Hillier, 2001).

The spatial configuration represents the physical and social processes of the city which have interrelationships with each other. However, when the social process and physical process are no longer interacting and where there is a raw confrontation between new forms of space and an absent spatial culture within the same context, spatial segregation may cause socio-economic problems (Hillier & Vaughan, 2007). Hillier illustrated some spatial attributes of this type of segregation by examining a low rise high dense neighbourhood where they found a dramatic reduction of the axial scale of spaces, a more complex spatial pattern and lack of internal structure compared to the surrounding areas.

¹ (www.un.org/esa/sustdev)

Spatial segregation as a problem can also be seen in self-generated urban areas or immigrant settlements. Self-generated neighbourhoods are usually located near the city centre to benefit from the economic situation there whereas they are limited economically and socially within themselves (Vaughan, 2005).

Several studies have investigated whether there is a relation between the deprivation of an urban area with its spatial structure or not. These studies are usually focused on the relation between economic condition of the area and the spatial form of it. The question rises from these studies is that whether the positive correlation between socio-economic condition and spatial structure of deprived areas can be found in well-developed neighbourhoods or not. In other words, do the well-developed neighbourhoods have a better spatial condition in comparison to the deprived areas?

4. MATERIALS AND METHODOLOGY

The methodology of the research consists of three main stages including, determination of sustainable development level in the case of Mashhad, the application of space syntax in Mashhad, and investigating the relation between spatial form of the city and sustainable development level [Figure 4].

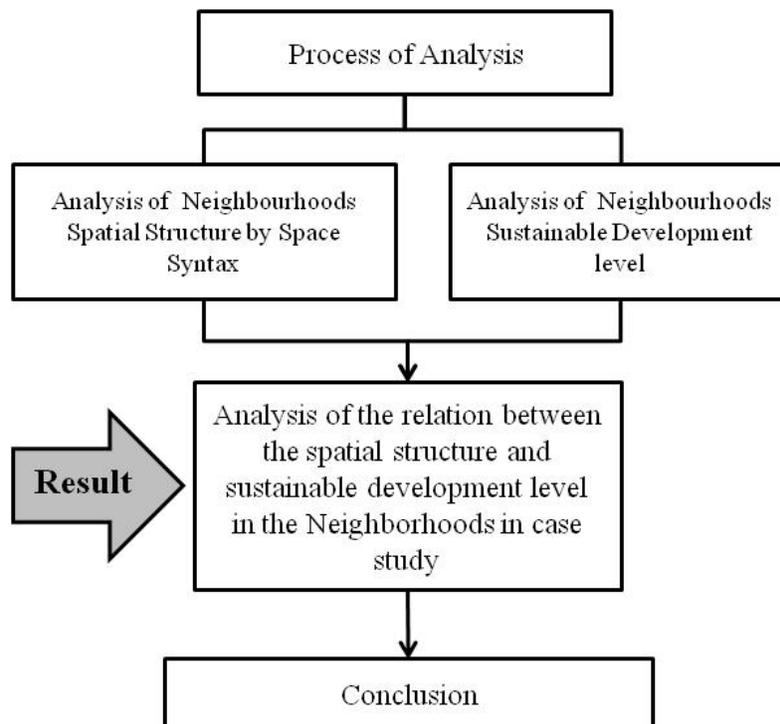


Figure 4: Methodology and the process of the research

4.1. Sustainable development level in Mashhad Neighbourhoods

In order to push the research forward several indicators were needed to study sustainable development level. Therefore, among the CDS indicators the available ones were identified and as a consequence 20

indicators in different subjects including economic, social, physical, environmental, and welfare were selected for further research [Table 1].

Table 1: Sustainable Development Indicators,

main group	by group	main Indicator
Social	literacy	Percentage of literacy (women)
		Percentage of literacy (men)
		Percentage of education levels
	occupation	Stock of employees with respect to different groups
	Housing	Households density in residential unit
		average size of households (division of total population to number of households)
		number of room in each of house
Floor area housing		
Economic	Employ	Employment rate (women)
		Employment rate (men)
	Economic participation	Economic participation rate (women)
		Economic participation rate (men)
	Income	Income Per capita
Economic dependency	Dependency ratio	
Physical	Housing Conditions	Quality of housing (stable & unstable)
Environment	Troublous land use	Percentage of troublous land use
Welfare services	Public services and infrastructures	Education(Per Capita: education area divided by the population)
		Health services (Per Capita: health services area divided by the population)
		Sport (Per Capita : sport area divided by the population)
	Commercial services	Commercial(Per Capita commercial area divided by the population)

4.1.1. The method of determining neighbourhood sustainable development level

In order to determine the neighbourhood sustainable development level in Mashhad two methods including factor analysis and numeric taxonomy analysis were applied. Factor analysis was used for classifying and rating the indicators based on the main attributes of the city and afterwards, the outcomes were again classified based on the attributes of the neighbourhoods.

Factor analysis can identify the underlying factors or the pattern behind a set of a large number of data in order to summarise them in a smaller groups. Also it makes it possible to see the effectiveness of indicator in each group. The application of factor analysis can help to reduce the problems in decision making including rating the indicators and identifying the importance of each, and more reliability of the outcomes of taxonomy analysis (Akbari, Zahedi Keyvan, 2008). Figure 5 shows the process of determining sustainable development level.

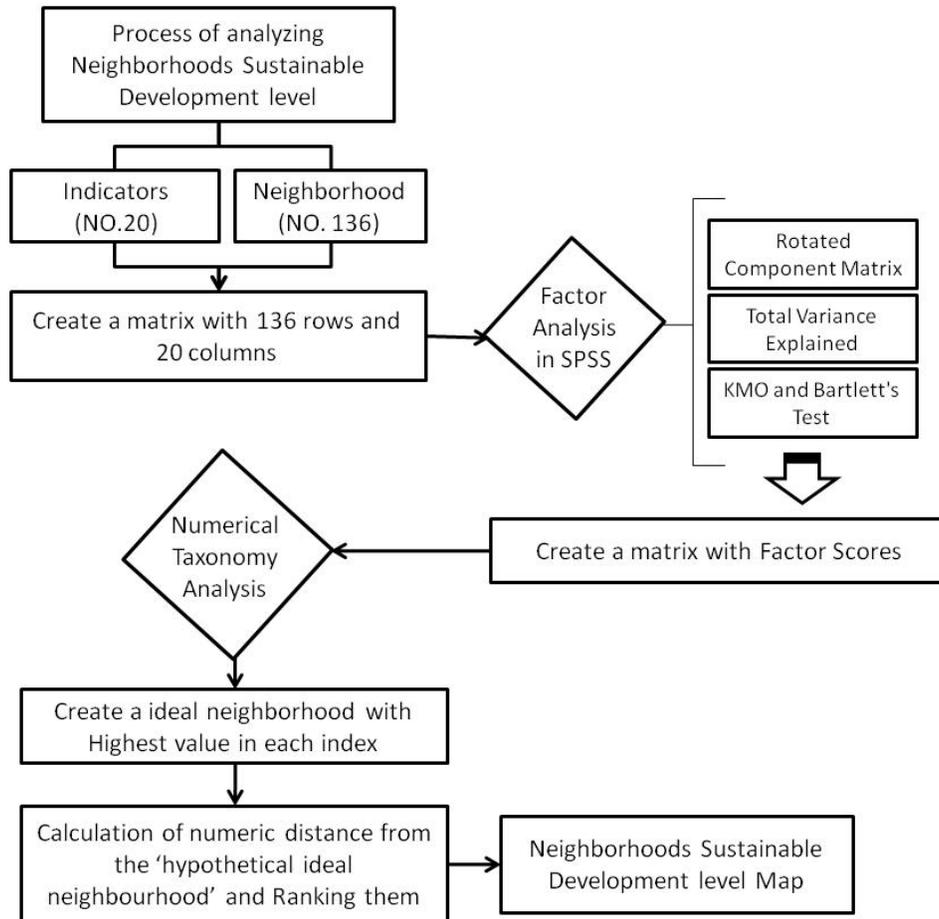


Figure 5: Process of analyzing neighbourhood sustainable development level

At the first stage a matrix including 136 rows (neighbourhoods) and 20 columns (indicators) was made in SPSS [Figure 6] and at then factor analysis was applied and KMO and Bartlett's test and Total Variance was checked. After ensuring that factor analysis is appropriate for this analysis, Indicators were classified according to Rotated Component Matrix and four factors were identified and score of each indicators was determined [Table 2].

After identifying the score of each indicator, it was multiplied by the standardized value of each indicator for the neighbourhoods and a matrix including the weighted indicators was produced.

Table 2: Rotated Component Matrix

Factor name	social development factor	economical development factor	Welfare development factor	environment development factor
Total Variance Explained	6.41	5.61	1.91	1.14
Indicators				
Percentage of education levels	0.950	0.095	0.120	0.013
Stock of employees with respect to different groups	0.946	0.060	0.124	-0.007
Floor area housing	0.866	0.153	0.231	-0.012
Economic participation rate (women)	0.861	-0.153	-0.024	-0.104
Income Per capita	0.810	-0.300	0.081	0.068
number of room in each of house	0.790	0.351	-0.074	0.048
Percentage of literacy (women)	0.736	0.538	-0.072	0.066
Quality of housing (stable & unstable)	0.662	0.405	-0.306	0.006
Employment rate (men)	0.365	0.905	0.037	-0.009
Dependency ratio	0.206	0.859	0.144	0.059
Economic participation rate (men)	-0.070	0.848	-0.111	-0.052
Households density in residential unit	-0.191	0.837	0.132	-0.133
average size of households	-0.057	0.825	-0.083	-0.093
Employment rate (women)	0.224	0.784	0.033	0.067
Percentage of literacy (men)	0.658	0.680	0.005	0.026
Commercial Per Capita	0.145	-0.021	0.875	0.105
Education Per Capita	-0.064	0.061	0.718	-0.192
Health services Per Capita	0.055	0.014	0.570	0.115
Percentage of troublous land use	0.096	0.033	0.127	0.888
Sport Per Capita	-0.345	-0.384	-0.181	0.477

At the next stage the weighted indicators was exported to Excel and Equation 1 was applied for the whole matrix in order to create a 'hypothetical ideal neighbourhood' which could be considered as the most developed neighbourhood in the city of Mashhad. In this equation 'max' refers to the indicators with a

positive effect on the development, e.g. education, and 'min' refers to the indicators with a negative effect on the development, e.g. Households density in residential unit.

Equation 1: the equation was applied to identify the 'hypothetical ideal neighbourhood' in the city of Mashhad (numeric taxonomy method)

$$\begin{array}{c} \text{Neighborhoods (i)} \end{array} \begin{array}{c} \text{Weighted index} \\ \left[\begin{array}{cccc} Z_{11} & Z_{12} & \dots & Z_{1m} \\ Z_{21} & Z_{22} & \dots & Z_{2m} \\ \dots & \vdots & & \vdots \\ Z_{n1} & Z_{n2} & \dots & Z_{nm} \end{array} \right] \end{array} \rightarrow \begin{array}{c} \text{Ideal neighborhood} \\ [MAXorMIN(Z_{i1}), MAXorMIN(Z_{i2}), \dots, MAXorMIN(Z_{im})] \\ i = 1, 2, 3, \dots, n \end{array}$$

At the next stage the neighbourhoods in Mashhad were classified and scored based on their numeric distance from the 'hypothetical ideal neighbourhood'. As a consequence the less the numeric distance from the 'hypothetical ideal neighbourhood' is, the more developed the neighbourhood would be. The numeric distance from the 'hypothetical ideal neighbourhood' was calculated based on taxonomy method and through Equation 2.

Equation 2: The numeric distance from the 'hypothetical ideal neighbourhood', (numeric taxonomy method)

$$C_{io} = \sqrt{\sum_{k=1}^m (Z_{ik} - Z_{ok})^2} \quad i = 1, \dots, n$$

Afterwards, the scores were assigned to each neighbourhood and coloured in GIS to show the distribution of neighbourhood sustainable development across the city [Figure 6]. In this figure the red neighbourhoods are more developed and the blue neighbourhoods are less developed. This map shows that there is a gap between the western neighbourhoods and the eastern neighbourhoods according the neighbourhood sustainable development level.

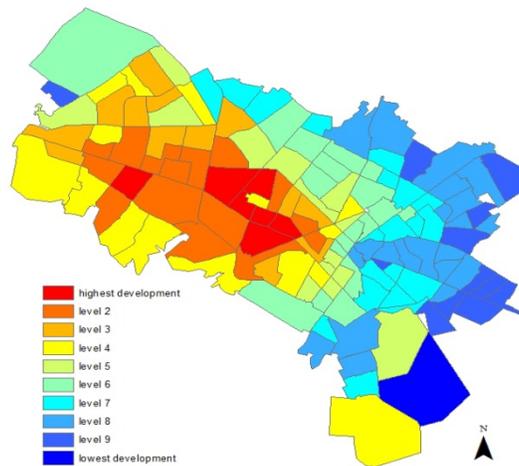


Figure 6: neighbourhood sustainable development level

4.2. Spatial structure analysis of the city of Mashhad using space syntax

In order to study the spatial structure of the city space syntax was applied. Since the road-centre line map was not available for this city, the axial line map was used for analysis. In this process 17000 axial lines were drawn in AutoCAD which covered the whole city and then were exported to the Depthmap software (Turner, 2004). In this study integration measure was investigated at three radiuses including Rn, R3, and R-R – which is R8 in this study (Figueiredo, 2005) [Figure 7].

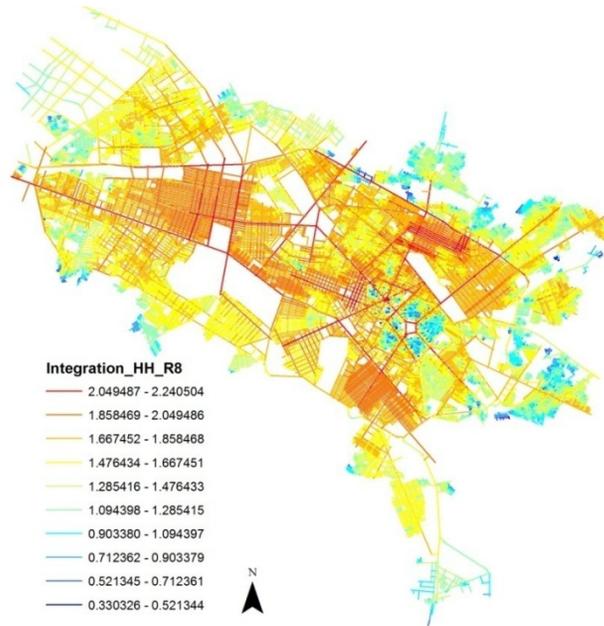


Figure 7: R-R integration for the city of Mashhad

The purpose of studying these measures was to see whether there is a meaningful correlation between syntactic measures and the quality of neighbourhood development in the city. These three measures are introduced in Table 3 for the city of Mashhad.

Table 3: the local, global and R-R integration for the city of Mashhad

	MAX	MIN	MEAN	Std
Integration (Rn)	1.69	0.33	1	0.19
Integration (R8)	2.24	0.33	1.44	0.31
Integration (R3)	5.19	0.33	1.94	0.75

4.2.1. Spatial structure analysis of neighbourhoods

Space syntax produces different measures for each line; however, neighbourhood sustainable development level is an indicator for each neighbourhood. Thus, in order to be able to correlate this indicator with the syntactic measures the mean values of the syntactic measures for each of the 136 neighbourhood of the city were needed. The mean value of integration at the above three radiuses was calculated based on the length of the lines in Depthemap and GIS. Figure 8 and Figure 9 show the changes in integration at three radiuses of local, global and R8 in the neighbourhoods.

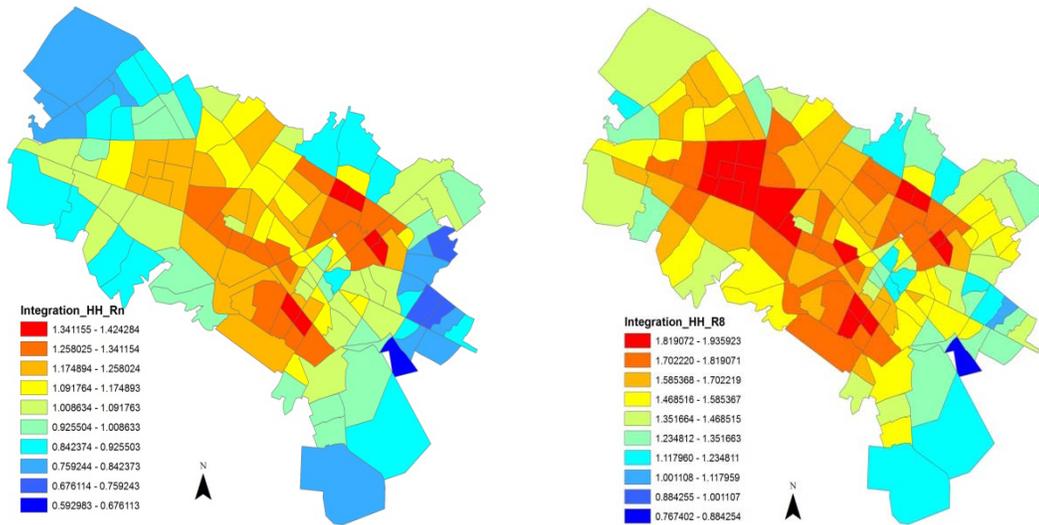


Figure 8: Integration Rn (left) and R8 (right) in neighbourhoods of the city of Mashhad

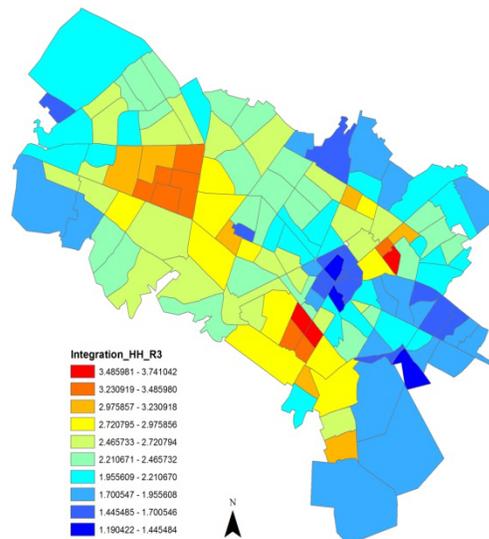


Figure 9: Integration R3 in neighbourhoods of the city of Mashhad

Table 4 shows the changes of integration value for the western neighbourhoods which were developed after 1970s. This table shows that the mean value of integration at all the three radiuses at the western neighbourhoods are more than both the city and the eastern neighbourhoods while the axial maps shows

that the spatial structure at the global scale is almost the homogeneous across the city. This issue shows that the western neighbourhoods have a better inner structure which makes them more integrated with the surrounding neighbourhoods; however this is not the case for the deprived areas located at the eastern part of the city. The inner structure of the deprived areas is more complex and segregated from the surrounding neighbourhoods; however, they are well-connected to the main framework of the city which gives them the opportunity to survive economically. Now the question here would be whether the socio-economic structure – or the sustainability condition - of these deprived areas follows the spatial structure of it and is less than the western neighbourhoods or not which is discussed at the next section.

Table 4: Average value of integration in Mashhad

	Integration (Rn) Mean	Integration (R8) Mean	Integration (R3) Mean
CITY (MASHHAD)	1	1.44	1.97
Western Neighbourhoods	0.99	1.54	2.22
Eastern Neighbourhoods	1.01	1.38	1.82

4.3. Analysis of the relation between neighbourhood spatial structure and the sustainable development level (Result)

In the previous section two measures including the mean value of integration at different radiuses and sustainable development level were assigned to each neighbourhood the correlation of which is shown in table 5.

Table 5: the correlation between quality of Neighbourhood development and Integration

		Integration (Rn)	Integration (R8)	Integration (R3)
Neighbourhood sustainable development level	Pearson Correlation	0.36	0.57	0.46
	Sig. (2-tailed)	0	0	0
	N	136	136	136

The results show that there is a meaningful correlation between integration at three radiuses with sustainable development level; however the correlation between integration R-R with sustainable development level is more than integration Rn and R3. The correlation between integration R3 with sustainable development level is more than integration Rn which shows that inner structure of the neighbourhoods is a stronger determinant for sustainable development level in each neighbourhood.

According to the natural movement theory (Hillier et.al, 1993) if the syntactic measures are considered as the independent variables, and sustainable development level is considered as the depended variable then

the Rsq coefficient and the equation between the three variable of integration and sustainable development level is meaningful in the case of Mashhad [Figure 10]. These results suggest that the socio-economic processes in the city of Mashhad follow the changes in the spatial structure of the city and the spatial form of the neighbourhood is one of the main determinant factors in the creation of the deprived and the affluent neighbourhoods which is also mentioned in the literature by Vaughan (2007) in studying the spatial form of poverty in Charles Booth's London.

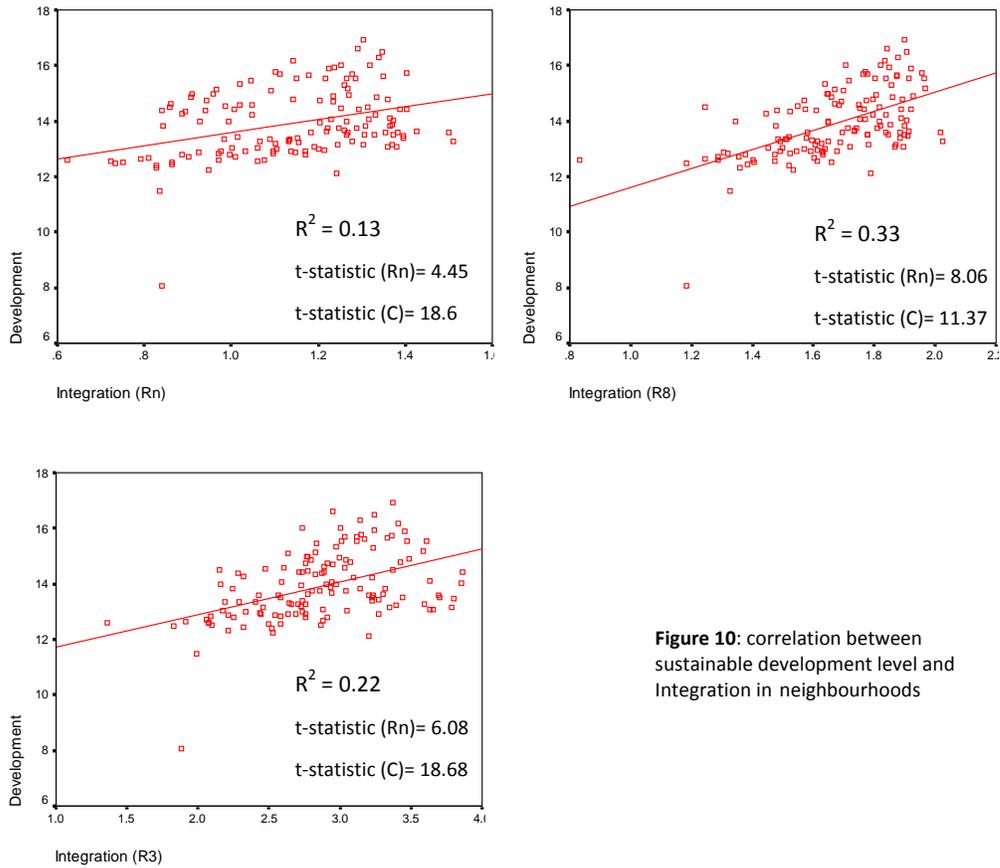


Figure 10: correlation between sustainable development level and Integration in neighbourhoods

In order to have more in-depth analysis, the 20 indicators of the sustainable development level in neighbourhoods were classified in 4 factors using factor analysis and named based on the nature of the indicators in each factor [table 2]. Table 6 shows the relation between integration at three radiuses and each factor. The results show that among the four factors, the social and economic factors have more meaningful correlation with integration at all three radiuses in comparison to environmental and welfare development factors. Also it shows that social factors are more correlated with integration R-R and economic factors are more correlated with global integration. It confirms that the social structure of the city strongly follows the spatial structure of it.

Table 6: correlation between development factors and Integration

Development Factors		Integration (Rr)	Integration (R3)	Integration (Rn)
social development factor	Pearson Correlation	0.56	0.46	0.33
	Sig. (2-tailed)	0	0	0
	N	136	136	136
Economical development factor	Pearson Correlation	0.2	0.13	0.35
	Sig. (2-tailed)	0	0.1	0
	N	136	136	136
Welfare development factor	Pearson Correlation	0.07	0.07	0.2
	Sig. (2-tailed)	0.4	0.5	0
	N	136	136	136
Environmental Development	Pearson Correlation	0.2	0.09	0.16
	Sig. (2-tailed)	0	0.3	0
	N	136	136	136

5. CONCLUSION

This research aimed to study the relation between the spatial structure and sustainable development level in the city of Mashhad. In this regard, the main question was formulated including do the neighbourhoods with good quality of development have a better spatial structure in comparison to the less developed and deprived areas? In order to answer this question two main attributes of cities including urban sustainable development and spatial structure of the city are compared in the case of the city of Mashhad in Iran.

The results of the research suggest that there is a meaningful correlation between neighbourhood sustainable development level and integration in all the three radiuses. The results show that the neighbourhoods which have a more value of integration R8 are more integrated to the whole city structure and are more developed and sustainable. This shows that the street network of these neighbourhoods facilitated accessibility to these neighbourhoods and the socio-economic processes which leads to a better environmental, social, economic, and welfare conditions. It also shows that the neighbourhoods which are segregated from the spatial structure of the city are also more deprived and less developed.

Among the development criteria, the social and economic factors had a more meaningful relation with integration Rn, R3 and R-R and the welfare and environmental factors were not correlated with integration. This result shows that the type of factors which could be developed by urban management and pre-urban planning, e.g. community centre development, are not correlated with the spatial form whereas the factors which are depended to the socio-economic process are more correlated with the spatial form of the neighbourhoods. Thus, the changes in spatial structure of neighbourhoods could lead to socio-economic changes. This highlights the importance of considering the spatial analysis in proposing the city master plans and regeneration of the deprived areas in the city of Mashhad.

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