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Ranking Sustainability of Urban Districts through Factor and Cluster Analyses, Case Study: Municipal Districts of Isfahan

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ABSTRACT: The rapid rate of population growth in developing countries leads to imbalances development in various urban levels. The trend of urban sustainability is declined due to these imbalances. This declination increases concerns of urban planners to improve the sustainability of urban environments. Being aware of sustainability level of urban intervention areas before doing any action is inevitable. For this reason, there are a lot of interests for application of ranking techniques for recognition and analysis of problems before planning. In this paper, the factor and cluster analyses were applied to rank municipal districts of Isfahan in terms of sustainability. At first, indicators for measurement of sustainability were reviewed. After that, according to the data availability criterion, 21 indicators which could be classified in social, economical, physical and infrastructural dimensions were selected. Finally, the study area, factor and cluster analysis techniques were introduced, and the selected indicators were summarized through application of the SPSS software. The result of the factor analysis was reduction of 21 indicators in 5 factors which described 77% of variance. Then, scores of factors and rank of municipal districts were calculated. Rank of municipal districts was determined through calculation of the Compound Index. Finally, the cluster analysis putted on the factors achieved from the factor analysis. The result of clustering was classifying municipal districts in the most sustainable, relative sustainable and the most unsustainable districts. Outputs of the models showed that the 5th, 6th and 3th districts are the most sustainable; the 1th, 2th, 8th and 7th districts are relative sustainable, and 4th, 9th, 10th, 11th, 12th, 13th and 14th districts are the most unsustainable districts of city of Isfahan.

Keywords: Ranking, Urban Sustainability Indicators, Factor Analysis, Cluster Analysis, Municipal Districts of Isfahan.

INTRODUCTION

During the middle of the twentieth century, planning for development was based on the assumption that there were no restrictions for utilization and consumption of natural resources (Mahdizadeh, 2002). After the 1950s, the period of recognizing environmental disasters and resource limitations, environmental discussions became important and the concept of sustainable development emerged in contradictory of development-oriented thoughts (Marsousi & Bahrami, 2011; Bahrainy, 2011). Sustainable development, the goal of each urban development plan, is the dominant concept of urban planning (Ebrahimi, Sarabi & Sani, 2009; Sarai et al., 2010). Urban sustainable development comprised of economical, social, and cultural dimensions is a comprehensive concept which refuses any partial action (Sarai et al., 2010; Nozarpour, 2000). As economical, social, physical and environmental aspects are the most

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important aspects of sustainable development in urban planning (Masoomieshkevari, 2000), approaching to sustainability could not only rely on physical dimension (Kanatschning, 1998). The World Commission on Environment and Development defined sustainable development as proportional and harmonious development in each component of a complete system (WCED, 1987). Owing to this fact, imbalances in urban systems cause to decrease in sustainability. Moreover, recognizing sustainability indicators, measuring correlation between these indices, and ranking geographical levels in terms of sustainability, is necessary to increase implementation of urban development plans, and to discover shortcomings and problems. Therefore, this study aimed at ranking urban districts in terms of sustainability indicators. It must also be noted that ranking urban districts involves numerous indicators and deals with large amount of data. According to the fact that application of quantitative and computer-based methods for analysis of large scale data is unavoidable (Timmermans, 2005), several models such as numerical taxonomy, Gatman scalogram, cluster analysis and factor analysis, were developed to rank geographical districts (Movahed, Firouzi & Roozbeh, 2010). This paper is placed in the category of applied and descriptive-analytical researches in terms of aims and methods respectively. In this paper, at first, the study area is introduced. At second, related researches to the topic are reviewed, and urban sustainability indicators in various studies are classified. At third, appropriate indicators are selected, and the factor and cluster analysis methods are briefly introduced. Finally, the factor and cluster analysis methods are applied in the study area, and results are represented according to the outputs of these models.

STUDY AREA

City of Isfahan was located in 32 ˚, 38’, 38” N and 51˚, 39” E, in the center of Iran. The area, population, the land use per capita and the population density of the city are equal to 17585 hectares, 1621000 persons, 108.48 m^2, and 92.2 people per hectare respectively in 2008. City of Isfahan is divided in 14 municipal districts shown in figure 1 (Zarabi et al., 2009).

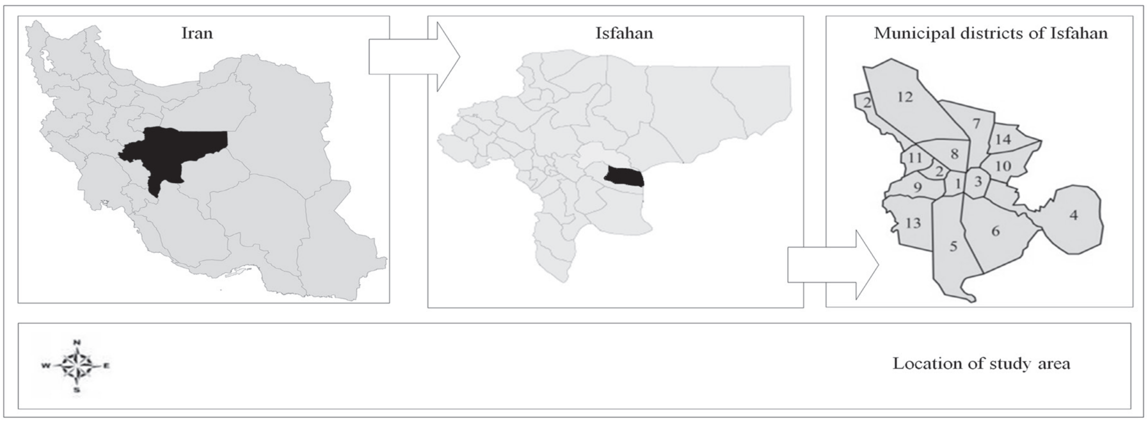

Fig. 1 Study Area

LITERATURE REVIEW AND SELECTION OF INDICATORS TO MEASURE URBAN SUSTAINABLE URBAN DEVELOPMENT

Mohammadi and Izadi (2013), in a research entitled “Analysis of cultural development in the city of Isfahan using factor analysis method”, applied factor analysis to rank cultural development in 14 municipal districts of Isfahan. They selected 35 indicators summarized to 5 factors by factor analysis. Five reduced factors described 93.11% of variance. As described variance was greater than 70%, validity of summarizing processes was demonstrated. They indicated that cultural activities have not been assigned in a balanced pattern in the city of Isfahan.

Taghvaei and Saboory (2012), in a research entitled “Determining and analyzing the development level and degree of townships in Hormozgan province", used factor analysis, and ranked townships of Hormozgan province. They selected 38 educational, cultural, infrastructural and communicational indicators. In addition, they putted cluster analysis on the factors generated by factor analysis to cluster townships which have the most similarity to each other. The result of this study was classification of homogenous townships of Hormozagan province according to development indicators.

Khosravi and Armesh (2012), in their research entitled "Climatic regionalization of Markazi province: application of factor and cluster analysis", reduced 29 selected indicators in 6 factors by application of factor analysis. Generated indicators described 90% of variance. After that, similar zones based on climatic regional indicators were classified by application of cluster analysis technique.

Noshooni and Hamadani (2011), in a research entitled "Urban planning with the aid of factor analysis approach: the case of Isfahan municipality", applied factor analysis to investigate about performance of municipalities in regional scale. This research concentrated on different effects of living circumstances on presented urban facilities by municipalities. The results of this research showed that evaluating different variables in each region could be altered with two simple and informative criteria: situation of community welfare and level of development in each region.

Yay, Alagha and Tuncel (2008) investigated about the modification of soil composition in the urbanized area of Ankara based on wet–dry deposition and pollution-derived particles from the atmosphere. 120 surface soil samples were collected from the urbanized area and its un-urbanized surrounding. These samples were analyzed by factor analysis and two main effecting factors on soil pollution are founded.

Turner, Lefler and Freedman (2005), compared plant biodiversity and community indicators among urban residential areas and more-natural habitats in the vicinity of Halifax, Nova Scotia through cluster analysis. They founded that generally, richness of observed plant species was higher in the residential areas than natural habitats in the study area.

Huang, Lai and Lee (2001), studied the effect of energy flows on the hierarchies and spatial organization of urban zones. In this research, 19 variables of energy flows were condensed into four factors through factor analysis technique. The factor scores of each district were used as inputs of cluster analysis. Similar urban zones were classified in clusters, and the role of energy flows in hierarchical structure of urban zones was discussed.

Before each research it is necessary to review the applied indicators in previous studies and select appropriate indices. Thus, the indicators applied in previous studies to measure urban sustainable development are introduced and classified in table 1.

Table 1. Sustainable Urban Development Indicators

Researches	Indicators					
	Social	Economical	Environmental	Physical	Infrastructural	Governance
(Zakerian et al., 2010)	Percent of literate persons, percent of literate women, percent of literate men, number of births, rate of mortality, rate of population growth, percent of married people	Rate of unemployment, rate of total employment, rate of men's employment, rate of women's employment, rate of men's economic participation, rate of women's economic participation, total rate of economic participation, percent of employees in agricultural sector, percent of employees in industrial sector, percent of employees in service sector	Water consumption capita, waste water production capita, garbage production capita	Percent of vacant lands, percent of green space land use, , percent of educational land use, , percent of medical land use	-	-
(Sarai et al., 2010)	Percent of literate persons, percent of graduated persons, average of academic years, percent of refugees	Percent of employees in agricultural sector, percent of employees in industrial sector, percent of employees in service sector, the average of household income, inverted average of household expenditure, inverted number of tenants, percent of landlords	-	Percent of single family residential units, average of residential unit area, percent of residential units with appropriate structure, inverted percent of residential units with inappropriate structure	Percent of households who have access to telephone, percent of households who have access to cooler, percent of households who have access to electricity, percent of households who have access to heating systems, percent of households who have access to kitchen, percent of households who have access to bathroom	-

(Lynch et al., 2011)	In this study, 60 social indicators are introduced such as: Percent of poor people, percent of homeless, percent of criminals	In this study, 35 economical indicators are introduced such as: Rate of home-based jobs, average of life expenditure	In this study, 49 environmental indicators are introduced such as: volume of CO2 which is generated in year, rate of car ownership, rate of bicycle ownership, average of car occupants	-	-	-
(Shen et al., 2011)	In this study, 48 social indicators are introduced such as: rate of mortality, average area of informal settlements	In this study, 18 economical indicators are introduced such as: number of informal occupations, water expenditures, rate of taxation	In this study, 41 environmental indicators are introduced such as: population growth, green house gas emission, level of sound in environment, average of travelling time	-	-	Rate of participation, number of urban associations, transparency

Based on the data availability criterion, 21 indicators represented below were considered to rank the municipal districts of Isfahan:

Average rate of population growth, percentage of population in age of occupation, residential units per households, average number of rooms per households, number of households who are landlords, percentage of households who have access to tapped water, percentage of households who have access to electricity, percentage of households who have access to telephone, percentage of households who have access to piped gas, percentage of households who have access to heating systems, percentage of households who have access to cooling systems, percentage of households who have access to kitchen, percentage of households who have access to bathroom, average of area of residential units, density of households in residential units, rate of women's economical participation, rate of men's economical participation, rate of occupancy, net dependency burden, gross dependency burden, rate of livelihood. These indicators were described in table 2.

Table 2. Description of Selected Indicators

Number	Indicators	Influencing Type	Description
1	Average rate of population growth	+	-
2	Percentage of population in age of occupation	+	$\frac{\text{Number of people in the age of occupation in district}}{\text{population of district}} \times 100$
3	Residential units per households	+	$\frac{\text{Number of residential units in district}}{\text{population of district}}$
4	Average of number of rooms per households	+	$\frac{\text{Total number of rooms in a district}}{\text{Total number of households in a district}}$
5	Number of households who are landlords	+	-
6	Percentage of households who have access to tapped water	+	$\frac{\text{Total number of housholds living in residenial unit which have access to tapped water in a district}}{\text{Total number of households in a district}} \times 100$
7	Percentage of households who have access to electricity	+	$\frac{\text{Total number of housholds living in residenial unit which have access to electricity in a district}}{\text{Total number of households in a district}} \times 100$
8	Percentage of households who have access to telephone	+	$\frac{\text{Total number of housholds living in residenial unit which have access to telephone in a district}}{\text{Total number of households in a district}} \times 100$
9	Percentage of households who have access to piped gas	+	$\frac{\text{Total number of housholds living in residenial unit which have access to piped gas in a district}}{\text{Total number of households in a district}} \times 100$
10	Percentage of households who have access to heating systems	+	$\frac{\text{Total number of housholds living in residenial unit which have access to heating system in a district}}{\text{Total number of households in a district}} \times 100$
11	Percentage of households who have access to cooling systems	+	$\frac{\text{Total number of housholds living in residenial unit which have access to cooling system in a district}}{\text{Total number of households in a district}} \times 100$
12	Percentage of households who have access to kitchen	+	$\frac{\text{Total number of housholds living in residenial unit which have access to kitchen in a district}}{\text{Total number of households in a district}} \times 100$
13	Percentage of households who have access to bathroom	+	$\frac{\text{Total number of housholds living in residenial unit which have access to bathroom in a district}}{\text{Total number of households in a district}} \times 100$
14	Average of area of residential units	+	$\frac{\text{Total floor area ratio in a district}}{\text{Total number of residential units}}$
15	Density of households in residential units	+	$\frac{\text{Total number of households in a district}}{\text{Total number of residential units}}$
16	Rate of women's economical participation	+	$\frac{\text{Number of women in activity age in a district}}{\text{Number of women working age}} \times 100$
17	Rate of men's economical participation	+	$\frac{\text{Number of men in activity age in a district}}{\text{Number of men working age in a district}} \times 100$
18	Rate of occupancy	+	$\frac{\text{Number of occupant people in a district}}{\text{Number of people who are in age of activity in a district}}$
19	Net dependency burden	-	$\frac{\text{Number of non} - \text{occupied people in a district}}{\text{Number of occupied people in a district}} \times 100$
20	Gross dependency burden	-	$\frac{\text{Number of people aged } 0-14 \text{ and those aged 65 and over in a district}}{\text{Number of people aged } 15-64 \text{ in a district}} \times 100$
21	Rate of livelihood	+	-

(Value of these Indicators were Extracted from the Surveys Published by Department of Planning, Research and Information Technology of Municipality of Isfahan in 2011)

INTRODUCING THE FACTOR AND CLUSTER ANALYSIS METHODS

Analyzing the evolution and ranking urban districts cause to increase in compatibility and better resource allocation (Movahed et al., 2011). For this reason, several methods have been developed to rank geographical areas. In this paper, factor and cluster analysis classified in the category of complex and progressive methods are introduced.

Factor Analysis

Factor analysis, a multivariate statistical method, summarizes (Mohammadi et al., 2012) and reduces large amount of data for easier interpretation and conclusion (Saydai et al., 2012). This method relies on correlations between variables (Kaplunovsky, 2005), and puts numerous indicators in classified factors (Doas, 1987). In factor analysis, primary characteristics of data are not modified during calculation process (Everitt, 1994). Correlation between factors is measured after classification of factors according to similarity criterion (Piraste, 2008). There are two types of factor analysis: Q type which classifies geographic areas in homogenous groups, and R type which classifies indicators in significant factors (Taghvai & GhaedRahmati, 2005). Factor analysis is generally comprised of five steps: 1) formation of data matrix, 2) calculation of correlation matrix, 3) extraction of factors, 4) rotation of factors and 5) naming factors (Kline, 1994). Based on the numerous and complex indicators considered in this study, and ability of factor analysis to deal with complex data, R type of factor analysis will be applied to rank the municipal districts of Isfahan.

Cluster Analysis

Cluster analysis is one of the most important methods applied for multivariable data analysis (Kettenring, 2006). The aim of this method is to classify similar objects into categories (Hasnije, 2007; Chatfield & Collins, 1992). In other words, cluster analysis is applied for classification of a sample with n objects and p specifications through putting same objects on a homogenous group. Cluster analysis is a profitable method for reduction of large scale data (Ashrafi, 2011). This method could be performed in hierarchical, the most applied method in previous studies (Hekmatniya & Mousavi, 2005), and nonhierarchical cluster analysis. For implementation of this technique, firstly, the distance between subgroups is calculated by consideration of Euclidian distance criterion (Kafashpour & Alizade, 2012). Secondly, appropriate method to make the clusters and their linkage is chosen. Finally, the numbers of clusters are determined, and clustering operation is performed. Hierarchical clustering starts with segregation of each variable in a single cluster. In each part of analyzing steps, similar clusters are combined together based on the distance criterion. It could be represented by a Dendrogram diagram. In this paper, the hierarchical clustering method will be applied for classification of municipal districts of Isfahan in terms of sustainability.

APPLICATION OF INTRODUCED METHODS TO RANK ISFAHAN'S MUNICIPALITY DISTRICTS IN TERMS OF SUSTAINABILITY

Application of Factor Analysis

Each data set could be analyzed by factor analysis, but the results may be invalid. For determination of validity of factor analysis, the KMO testing technique is performed. If the value of KMO is about or greater than 0.7, it could be concluded that the factor analysis will be appropriate for further analysis (Taghdisi et al., 2012). In this research, the calculated KMO was equal to 0.69. This value confirms that application of factor analysis is significant (table 3). It must also be noted that all of the analysis were done through SPSS software.

Table 3. KMO Testing for Sustainability Indicators of Municipal Districts of Isfahan

(KMO and Bartlett's Test)		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.69
Bartlett's Test of Sphericity	Approx.Chi-Square	0.051
	Sig	0.000

Preparation of Data Matrix

The data matrix is a matrix with 21 columns (equal to the number of indicators) and 14 rows (equal to the number of municipal districts). The value of each selected indicator for each municipal district was gathered from the department of Planning, Research and Information Technology of Isfahan's municipality.

Calculation of Correlation Matrix

Correlation determines level of linear relationship between variables. Factor analysis puts correlated variables on similar factors. For calculation of correlation coefficient, correlation coefficient matrix or covariance matrix is calculated for each pair of variables. Value of the arrays located in the main diagonal of the matrix is equal to 1, and the numbers located below the main diagonal are repetition of the numbers located up to the main diagonal. In this study, the correlation coefficient matrix which contains 21 rows and 21 columns was calculated.

Extraction of Factors

The aim of this part of factor analysis is to determine which variables are located in each factor. Therefore, the value of variance described by each factor is calculated. The correlation of each variable with each factor is called factor loading which could adopt values between -1 to 1. The described variance called eigenvalue is equal to square of factor loadings. In this paper, the result of application of factor analysis was reduction of 21 indicators to 5 factors which covers 77.569% of total variance. The first, the second, the third, the fourth and the fifth factors describe 20.913%, 16.694%, 14.478%, 13.003%, and 12.481% of variance respectively (table 4). Five main extracted factors are shown in figure 2.

Table 4. The Results of Factor Analysis

Factor	Eigenvalue	Percent of Described Variance by Each Factor	Percent of Cumulative Variance
1	3.762	20.913	20.913
2	2.876	16.694	37.607
3	2.410	14.478	52.085
4	2.311	13.003	65.088
5	2.201	12.481	77.569

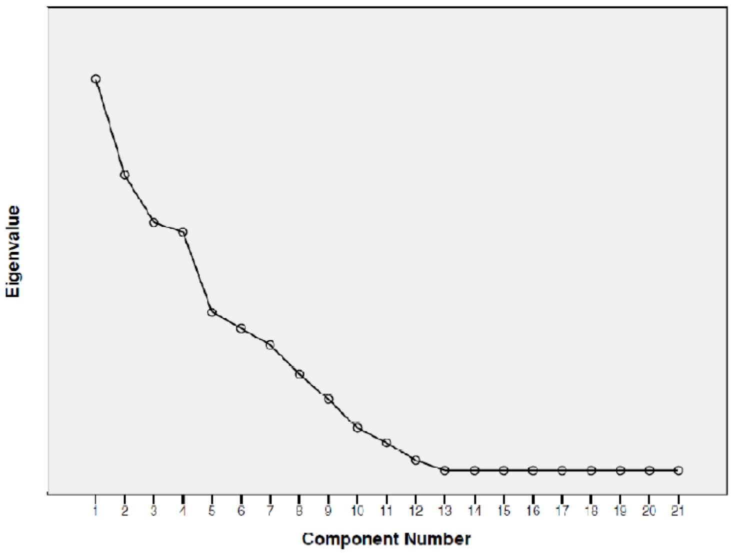

Fig. 2. The Scree Diagram

Factor Rotation

Factors must be rotated for easier interpretation. As the Varimax method is the best rotating method (Talebi & Zangiabadi, 2002), this rotation type was applied for rotating the factors.

Naming Factors

Factors are named according to the correlation between factors and indicators. If factors are rotated and correlation between indicators is calculated, naming the factors will be possible. The result of this process was represented in table 4.

Table 4. Name and Loaded Indicators in Each Factor

Factors	Name of Factor	Described Variance by the Factor (%)	Indicators which are Loaded in Each Factor
1	Infrastructural Factor	20.913	Percentage of households who have access to piped gas Percentage of households who have access to tapped water Percentage of households who have access to electricity Percentage of households who have access to telephone
2	Economical Factor	16.694	Rate of occupancy Net dependency burden Gross dependency burden Rate of women's economical participation Rate of men's economical participation Rate of livelihood Number of households who are landlords
3	Physical Factor	14.478	Average of area of residential units Average of number of rooms per households Residential units per households
4	Social Factors	13.003	Average rate of population growth Percentage of population in age of occupation Density of households in residential units
5	Welfare-Sanitary Factor	12.481	Percentage of households who have access to bathroom Percentage of households who have access to kitchen Percentage of households who have access to cooling systems Percentage of households who have access to heating systems

Calculation of Factor's Score

In this step of factor analysis, score of factors is determined through compound index (CI). The compound index (CI) is calculated by the following equation:

$$CI = \sum_{i=1}^{n} \frac{x_{ij}}{x_i} \times w_{ij}$$

Where CI is the compound index, xij is the value of indicator i in district j, xi is the average of indictor i, and wij is the weight of indicator i derived from the vector of factors.

The output of this step is represented in table 5.

Table 5. Score of Factors for Each Municipal District of Isfahan

Number of District	CI	Rank
5	2.539	1
6	2.47	2
3	1.313	3
1	1.286	4
8	1.058	5
7	0.99	6
2	0.305	7
10	0.273	8
9	-0.878	9
11	-1.345	10
13	-1.466	11
4	-1.547	12
12	-1.711	13
14	-2.243	14

Application of Cluster Analysis

In the cluster analysis, similar districts in terms of factor scores are classified in clusters. The result of application of cluster analysis was shown in figure 2.

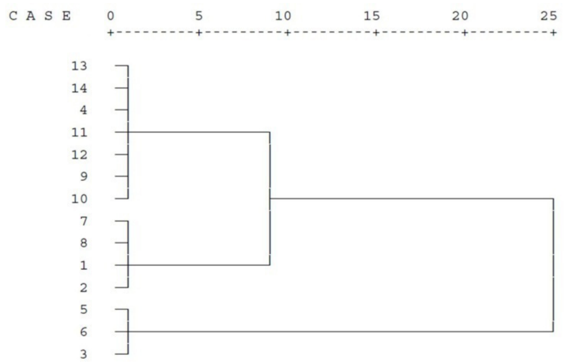

Fig. 2 Dendrogram Diagram of Cluster Analysis

The first cluster was included 4th, 13th, 9th, 10th, 11th, 2th, 12th and 14th districts. The next cluster was consisted of 6th, 5th and 3th districts, and 1th, 7th, 2th and 8th districts were located in the third cluster. Clusters were named based on the result of cluster analysis and rank of each district. In doing so, the first, the second and the third clusters were named "the most sustainable districts", "relative sustainable districts", and "the most unsustainable districts" respectively. Rank of each municipal district was shown in Fig. 3.

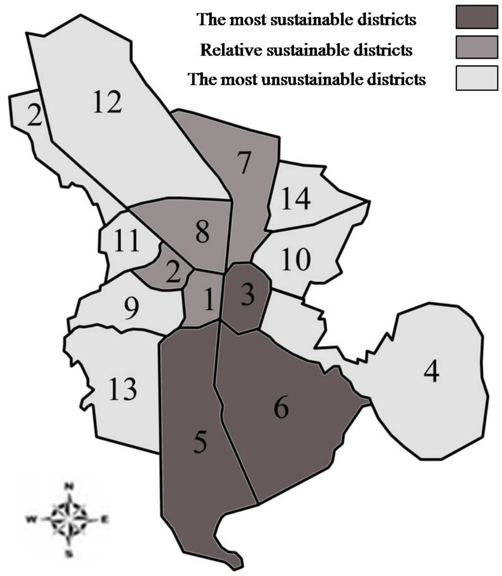

Fig. 3 Rank of Municipal Districts of Isfahan

CONCLUSION

In the present paper, the municipal districts of Isfahan were ranked in terms of sustainability by application of cluster and factor analysis methods. Firstly, appropriate indicators were selected through literature review and available data. The result was selection of 21 indicators reduced in 5 factors through factor analysis. Extracted factors described 77.569% of variance which indicated that the outputs of the model were significant. After naming and calculating the score of factors, the compound index was calculated for each district. Finally, cluster analysis was put on the factor scores and similar districts were classified. The results showed that the 5th, 6th and 3th districts are the most sustainable; the 1th, 2th, 8th and 7th are relative sustainable and the 4th, 9th, 10th, 11th, 12th, 13th and 14th districts are the most unsustainable districts. The results emphasized on the fact that the urban sustainable development is not a partial concept and contain various dimensions with strong correlation between their indicators. In this paper, the imbalances between municipal districts of Isfahan were demonstrated. These imbalances are rooted in the different level of accessibility of districts to urban services. Due to these facts, interwoven nature of urban systems, and possibility of inconsistency permeation from unsustainable districts to sustainable districts, urban management should not concentrate just on reinforcement of appropriate districts. Therefore, below actions are proposed to make the current state better:

- Application of complex and progressive models for recognition and analysis of problems in practical scopes.
- Assignment of urban services with respect to social justice.
- Balanced assignment of financial resources with the priority of unsustainable districts.
- Developing plans in which all of sustainable development dimensions are regarded.
- Balanced distribution of financial resources.
- Emphasizing on compact development through application of brown fields and internal development opportunities.
- Planning based on new theories such as spatial strategic planning and participatory planning.

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