URBAN PLANNING WITH THE AID OF FACTOR ANALYSIS APPROACH: THE CASE OF ISFAHAN MUNICIPALITY

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Abstract
Nowadays municipalities play an important role in offering urban services to the citizens. To investigate performance of regional municipalities, different data on living situation must be considered. Thus, we face a multivariate analysis. In this research regarding capabilities of "Factor Analysis" technique in the area of multivariate analysis, we used this technique to construct latent factors for comparison of different districts of a city. Along these lines we examined the real case of Isfahan municipality. Isfahan is a major city in Iran. The results of our analysis show that instead of evaluating different variables in each region we can concentrate on two simple and informative criteria representing common welfare situation and development situation in each region. The proposed approach shows which factors are more important for each region of the city and how different regional municipalities can apply cost effective policies to improve their performance.
Keywords: Regional Municipalities, Multivariate Analysis, Factor Analysis, Isfahan.

1. INTRODUCTION

Nowadays, along with the extension of cities and population growth in cities, urban planning has become more important than ever. Following population growth in cities, regional municipalities have to provide required services to each district under their boundary. Usually different data under the territory of each regional municipality, such as number of sport centers, number of parks and entertainment centers, number of library and cultural centers, number of parking spaces, etc …, are available. To analyze such information of different regions, regarding multivariate nature of data, it is appropriate to use statistical multivariate techniques such as Principal Component Analysis (PCA), Factor Analysis (FA), Cluster Analysis (CA), etc. PCA is a statistical technique that linearly transforms an original set of variables into a substantially smaller set of uncorrelated new variables that represent most of the information of the original data set (Lewis-Beck, 1994). Through this technique is obtained a small set of uncorrelated variables, which is much easier to understand and use in further analysis than a larger set of correlated variables (Lewis-Beck, 1994). FA is based on the fundamental assumption that some

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underlying factors, fewer than the number of observed variables, are responsible for the covariation of the observed variables (Lewis-Beck, 1994). Cluster analysis is a technique for grouping variables or observations based on their similarities and dissimilarities (Johnson and Wichern, 2007). Through applying these techniques on urbanistic multivariate data, effective policies for promotion of urbanism situations will appear.

In this research, applying realistic data from the city of Isfahan in Iran, it is shown how with the aid of factor analysis technique we can analyze information of regional municipalities. Through this kind of analysis regional municipalities can improve living situation at each region. The previous studies, related to our research can be divided into two main fields: Urban and municipality planning and application of statistical multivariate techniques in urban planning. Our research connects these two subjects applying a realistic case study. The related studies are reviewed briefly, at the rest of this part.

1.1. Researches on Urban and Municipality Planning

Alvarez et al. (2007) proposed a general index for ranking municipalities of the city Badajoz in Spain, with the use of Rasch model as a measurement instrument. They determined the ranking of the municipalities according to their infrastructure needs and, moreover, a ranking of the frequent needs for all municipalities. Johansson et al. (2006), studied the management of risk in conjunction with municipality planning of the physical environments in Sweden. Their aim was to present a descriptive review of what risks regarding health, safety and security that are considered in a set of municipal comprehensive master plan documents prepared and adopted by Swedish municipalities. Niedomysl (2007), examines the campaign efforts of the Swedish rural municipalities and addresses the question of whether they have been successful. Rezessy et al., 2006, performed a research with the aim of reviewing the factors that determine the degree of involvement of local authorities in the market for energy services and energy efficient equipment in three countries in transition: Bulgaria, Hungary and Macedonia. They give recommendations on how to encourage municipal authorities to use market mechanisms more extensively to deliver energy efficiency.

Also, there are several researches in the literature for different subjects of urban planning such as transportation and traffic issues (Abrate et al. 2009; Ubbels and Verhoef, 2008; Boyce, 2007), urban growth and land development (Sims and Schuetz, 2009; Wang et al. 2009; Wu,2009; Xu et al. 2009; Jenkins, 2001; Yeh and Wu, 1996), air pollution (Alberini and Chiabai, 2007; Proost and Dender, 2001), etc. These researches cover different topics such as environmental and ecological issues, urban geographic studies, application of GIS technology in spatial analysis, etc

1.2. Researches on Application of Multivariate Techniques:

In recent years, applications of multivariate techniques have increased tremendously. This is due to multivariate nature of data sets, gathered from real-world complex systems. Usually the data, available on urban planning, are also multivariate data. Thus, it is appropriate to apply multivariate approaches for analysis. Most prominent techniques which are used for urban planning in the literature are Principal Component Analysis (PCA), Cluster Analysis (CA) and Factor Analysis (FA). Melchiorre et al. (2008) performed a landslide susceptibility analysis using Artificial Neural Network (ANN) and Cluster Analysis (CA). Their analysis used ANNs to model the relationships between mass movements and conditioning factors for susceptibility zonation, with the goal to identify unstable areas. Turner et al. (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 found that in general, the observed plant species richness was much higher in the residential areas.

Castillo-Rodriguez et al. (2010) proposed an approach to delineate an environmental units map using a geomorphologic map and a multivariate analysis processed in a GIS on a regional cartographic scale. Applying PCA, they found that temperature and slope are the most important variables controlling the correlation of biophysical attributes for La Malinche volcano.

Goonetilleke et al. (2005) applied PCA to identify linkages between various pollutant parameters and correlations with land use. Their research findings confirmed the need to move beyond customary structural measures and identified the key role that urban planning can play in safeguarding urban water environments. Ares and Serra, (2008), developed procedures to identify environmentally sustainable engineering projects for floodplain restoration and urban waste water management. They used PCA during the testing phase of the multi criteria assessment of environmental projects to determine the underlying structure of multivariate data. Cornelis and Hermy (2004) studied biodiversity relationships in urban and suburban parks in Flanders using PCA and correlation techniques. Tavernia and Reed (2009) examined the nature and strength of relationships between urban metrics at 1105 sites within Massachusetts, USA.. They evaluated the multivariate nature of the relationships among urbanization measures using PCA.

In spite of above researches, we should be aware that analysis of principle components are more of a means to an end rather than an end in themselves, because they frequently serve as intermediate steps in much larger investigations (Johnson and Wichern, 2007). For example PCA may be an input to cluster analysis or factor analysis. For interpretation and discovery of latent relationships among variables, the FA technique is more appropriate. In the literature there are a few researches on

application of FA in urban planning. Huang et al. (2001), studied the effect of energy flows on the hierarchies and spatial organization of urban zonation. In this research 19 variables of energy flows are condensed into four factors through FA technique. The factor scores of each district are then used as input for cluster analysis and discriminate analysis. Yay et al. (2008) investigated the modification of soil composition in the urbanized area of Ankara due to wet–dry deposition and pollution-derived particles from the atmosphere, by analyzing 120 surface soil samples, collected from the urbanized area and its un-urbanized surrounding. Factor analysis was used to identify two polluted factors.

According to our knowledge, we couldn't find any research on urban planning and policy making for municipalities based on factor analysis technique. Thus, our research fills this gap in the literature. In this research at first it is shown, how data reduction is attained through factor analysis. Then by interpreting the summarized data, the situation of each region, with respect to discovered latent variables, is evaluated. Finally, based on calculation of factor score's for each region, appropriate urban planning policies can be made by regional municipalities.

The remaining parts of this paper are organized as follows. In section two, we described the considered problem. In section three different steps of factor analysis approach are explained. In section four, position of each region is evaluated based on discovered factors. Finally section five, concludes the study with major findings.

2. PROBLEM DESCRIPTION

Consider different regions of a city. Each region receives urban services through its regional municipality. In each region different data such as number of sport centers, number of parks and entertainment centers, number of library and cultural centers, number of parking spaces, etc., are available. Considering special relations among some of these variables, we would like to apply a systematic procedure to see whether there are any latent factors, explained by these data and to evaluate the status of each district based on those latent variables. In fact, through this kind of analysis we would like to find strength and weakness points of each region in terms of a few informative and meaningful factors. This information will help municipality managers to consider appropriate strategies that will lead to improvement of living situation at each region.

3. FACTOR ANALYSIS APPROACH

Factor analysis originated from psychology. It was first developed by Spearman, 1994. The purpose of factor analysis is to identify the latent factors within various variables. Regarding the problem at hand, it

is appropriate to perform a factor analysis on the multivariate data. The essential purpose of factor analysis is to describe, if possible, the covariance relationships among many variables in terms of a few underlying random quantities called factors (Harmon, 1976; Johnson and Wichern, 2007). This technique is an extension of principal component analysis. In fact, the main question in factor analysis is whether the data are consistent with a prescribed structure (Johnson and Wichern, 2007). In this section we describe different steps of performing this technique on a realistic data set.

3.1. Data Introduction

The data of 13 regional municipalities of Isfahan are presented in Table one. The data consist of eight variables for each region. The variables are "Number of cultural centers, Number of sport centers, Number of library saloons, Number of firefighting stations, Capacity of auto parkings (in terms of autos), Area of ancient alleys (in Acre), Average of garbage production per day (in Kg) and Area of parks (in Acre) ".

TABLE 1 - DATA ON REGIONAL MUNICIPALITIES OF ISFAHAN

Districts	Cultural centers	Sport centers	Libraries	Ffireplaces	Parkings	Ancient regions	Garbage Production	Parks
1	4.00	1.00	4.00	2.00	2417.00	18.21	50181.00	11.520
2	2.00	2.00	2.00	3.00	0.00	84.24	26949.00	0.8
3	2.00	0.00	4.00	2.00	3594.00	6.28	76302.00	1.1
4	3.00	4.00	2.00	3.00	1700.00	107.95	61992.00	21
5	2.00	4.00	1.00	2.00	3175.00	66.52	91952.00	83.17
6	3.00	7.00	5.00	2.00	1207.00	116.41	71743.00	3.679
7	3.00	3.00	7.00	0.00	569.00	179.23	125300.00	56.613
8	3.00	1.00	4.00	1.00	160.00	202.74	99003.00	32.67
9	1.00	3.00	4.00	1.00	300.00	221.88	32833.00	65.544
10	4.00	2.00	6.00	1.00	200.00	220.82	94591.00	77.728
11	0.00	1.00	1.00	0.00	110.00	89.88	24079.00	0.107
12	2.00	1.00	1.00	1.00	0.00	106.19	49577.00	7.863

Since the variables are in different units, at first we have to standardize them. Also, we have changed the signs of the variables "Area of ancient alleys and Average of garbage production per day", so that large scores are good for all of the variables. Next, to investigate relationships among the variables, we should constitute the correlation matrix. The correlation matrix is presented in Table 2.

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TABLE 2 - CORRELATION MATRICE

Correlation	cultural centers	sport centers	Libraries	fireplaces	parkings	ancient regions	garbage production	parks
cultural centers	1.00000	0.12956	0.53617	0.28375	0.18428	-0.11268	-0.57286	0.17022
sport centers	0.12956	1.00000	0.20428	0.21644	-0.01550	-0.14970	-0.13533	0.23280
Libraries	0.53617	0.20428	1.00000	-0.31395	-0.12235	-0.40227	-0.56375	0.33048
fireplaces	0.28375	0.21644	-0.31395	1.00000	0.46370	0.44100	0.21728	-0.28132
parkings	0.18428	-0.01550	-0.12235	0.46370	1.00000	0.62169	-0.23516	-0.02187
ancient regions	-0.11268	-0.14970	-0.40227	0.44100	0.62169	1.00000	0.31455	-0.54430
Garbage Production	-0.57286	-0.13533	-0.56375	0.21728	-0.23516	0.31455	1.00000	-0.50104
parks	0.17022	0.23280	0.33048	-0.28132	-0.02187	-0.54430	-0.50104	1.00000

Paying attention to the correlation matrix, by the red colored values we find that there are some variables with approximately high correlation. For instance there is positive relation between “Capacity of auto parkings” and “Area of ancient regions”. But, since we changed the sign of variable “Area of ancient regions” at the beginning of our calculations, positive relation means in regions with more auto parkings there are less ancient regions. We expect that such apparent linear relationships among the variables can be explained in terms of some latent factors. Therefore we will be more eager to perform a factor analysis on these data. To perform FA, based on orthogonal factor model, at first we have to estimate factor loadings. Two most popular methods for estimation are principal factor method and maximum likelihood method (MLE) (Harmon, 1976). To apply MLE, we require large data sets and some special assumptions on the distribution of data. In this research due to limited number of regions (13 region), we have to apply the principal factor method for loading estimation. This method is based on spectral decomposition of covariance matrix (Σ) and does not require any precondition on the distribution of variables. To get more information about the orthogonal factor model and principal factor method, refer to Johnson and Wichern, 2007 and Harmon, 1976. We performed this method on the data using SAS v 9.1 (Level 1. MO).

In FA the most challenging part is selection of number of factors. We look for a small number of factors, which are also adequately representative of data and easy to interpret. If we choose lots of factors for explanation of covariance structure, the decomposition of covariance matrix will not be a valuable one. On the other hand, a few factors may not be able to reproduce the covariance matrix with a proper approximation. Thus, we have to find a trade-off between number of factors and proper decomposition of covariance matrix. We tackled this important issue at the next part through different examinations.

3.2. Determination of Number of Factors

In order to determine the appropriate number of latent factors, we have to pay attention to the amount of total sample variance explained, the relative sizes of the eigenvalues and the subject matter interpretations of the latent factors (Johnson and Wichern, 2007; Lawley and Maxwell, 1971). Table three shows eigenvalues of the correlation matrix.

TABLE 3 - EIGENVALUES OF CORRELATION MATRIX

	Eigenvalue	Proportion	Cumulative
1	2.51203285	0.5078	0.5078
2	1.69043807	0.3417	0.8495
3	0.59898842	0.1211	0.9706
4	0.45479117	0.0919	1.0626
5	0.12994684	0.0263	1.0888
6	-.07057461	-0.0143	1.0746
7	-.13195063	-0.0267	1.0479
8	-.23692553	-0.0479	1.0000

Usually to determine factors, those with eigenvalues higher than one are retained (Lin et al., 2002). According to Table three, the first two eigenvalues are greater than one. Moreover, the first two factors collectively account for considerable part of total variation among data (85%).

Figure one shows the scree plot of the eigenvalues. It is a useful visual aid to determine number of factors. We observe that an elbow occurs in the plot in figure one after the first two eigenvalues.

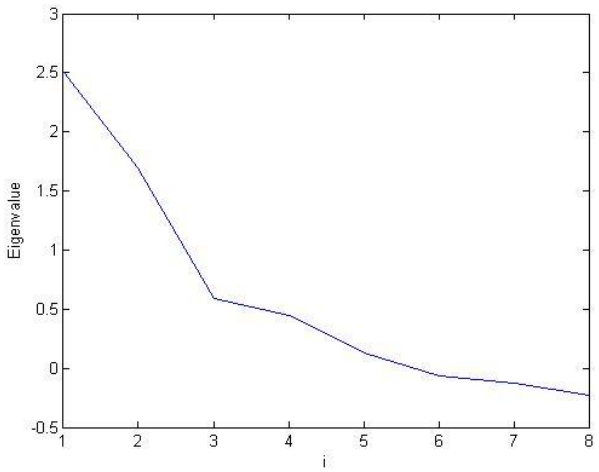

FIGURE 1 - SCREE PLOT

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Based on Table three and Figure one, it appears that considering two factors is an appropriate choice, but we need more evidences to strength our opinion.

Table four shows the residual matrix. It is a criterion that shows how well decomposition of the covariance matrix, by a few factors is performed. Its off-diagonal elements should be approximately small. Regarding Table four, the decomposition of the correlation matrix is performed appropriately.

TABLE 4 - RESIDUAL MATRIX

	Cultural centers	Sport centers	Libraries	Fireplaces	Parkings	Ancient regions	Garbage Prod.	Parks
Cultural centers	0	-0.07093	0.09858	0.13036	-0.14794	-0.03064	0.02284	-0.13346
Sport centers	-0.07093	0	0.02537	0.21534	-0.07915	-0.06376	0.08544	0.09689
Libraries	0.09858	0.02537	0	-0.08681	-0.04549	0.05467	0.02126	-0.12613
Fireplaces	0.13036	0.21534	-0.08681	0	-0.09933	-0.13538	0.14028	-0.00399
Parkings	-0.14794	-0.07915	-0.04549	-0.09933	0	0.10556	-0.12153	0.14398
Ancient regions	-0.03064	-0.06376	0.05467	-0.13538	0.10556	0	-0.03501	-0.08672
Garbage Prod.	0.02284	0.08544	0.02126	0.14028	-0.12153	-0.03501	0	-0.04126
Parks	-0.13346	0.09689	-0.12613	-0.00399	0.14398	-0.08672	-0.04126	0

Moreover, number of factors should be chosen so that, they can be easily interpreted. Along these lines, we performed factor analysis for two, three and four latent factors. To interpret factor loadings, it is usual practice to rotate factor loadings until a simpler structure is achieved. There are both graphical and analytical methods for factor rotation. We used the Varimax method (an analytical method) which is a famous and accurate rotation method. To get information about this method refer to Kaiser, 1958. Table five shows unratated and rotated factor loadings, based on the varimax method.

TABLE 5 - FACTOR LOADINGS

Variables	Factor Loadings before rotation		Rotated Factor Loadings	
	Factor1	Factor2	Factor1	Factor2
cultural	-0.44685	0.63447	0.73674	0.24378
Libraries	-0.71272	0.18773	0.68442	-0.27344
parks	-0.63179	0.03368	0.52770	-0.34905
sport	-0.20602	0.17090	0.26728	0.01468
garbage	0.70413	-0.44300	-0.82949	0.06323
parkings	0.30174	0.73613	0.19578	0.77111
ancient	0.74534	0.39562	-0.36336	0.76158
fireplaces	0.46948	0.57241	-0.03646	0.73942

Based on our intuition we found that the two factors are more meaningful in comparison with three or four factors (we have interpreted them at the next part). Thus, considering examinations and investigations above, we choose two factors as the final decision.

3.3. Interpretation of Latent Factors

Before starting interpretation, we should mention to three important points:

- The explanations here, are based on our knowledge and consultation with urban experts of the city *Isfahan*.
- We ignored the effects of population density in different regions of the city, on our interpretations. Because Isfahan is a major and metropolitan city, all of it's regions are approximately highly populated.
- At the beginning of calculations we changed the signs of the variables "Area of ancient alleys" and "Average of garbage production per day", so that large scores are good for all of the variables. Now, we have to interpret them correctly.

According to the rotated factor loadings, the variables "Number of cultural centers, Number of library saloons, Average of garbage production per day and Area of parks" load highly on the first factor. Also, there is a contrast between "Average of garbage production per day" and other mentioned variables. Whenever the number of parks, green spaces, libraries and cultural centers in a region is high, considering such suitable living facilities, that region will become more attractive for people. People in Isfahan would like to utilize the facilities of these regions, such as parks and green spaces. Therefore, as a consequence of people's attendance, garbage production in such regions increases naturally. Thus, it seems that the first factor, represents kind of "Common *welfare factor*" in the regions.

In the second factor, variables "Number of firefighting stations, Capacity of auto parkings, and Area of ancient alleys" are loaded highly. In Isfahan whenever parking capacity is high, probably it will be a sign of construction of new and more parking spaces. In addition, according to development plans and reconstruction projects of Isfahan, old and ancient constructions have to be devastated and instead of them new constructions and new ways such as highways have to be built in different regions. The greater number of firestations will also be a sign of performing new plans in the regions that concentrate more on safety issues. Thus, based on explanations above, it seems that the second factor represents kind of "*development factor*" in the regions. In fact this factor shows how development plans are progressed at each region.

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Also, regarding loadings of the two factors, we find that the variable “Number of sport centers” is loaded lightly on both factors. Paying attention to the covariance matrix more carefully, we find that there is not any special relation between the variable “Number of sport centers” and other variables. This is the reason that this variable loads lightly on both factors. Since it’s loading on the first factor (0.27) is greater than the loading on the second factor (0.01), it is more likely a component of the first factor. In addition, this coincides more with the interpretations.

Now, the main art of FA approach appears in our research. We would be able to estimate immeasurable, latent factors such as common welfare factor and development factor, indirectly and through measuring a few simple variables. Now, we would like to investigate living situations of each region in terms of such informative factors.

4. EVALUATION OF DIFFERENT REGIONS BASED ON FACTORS

After factor interpretation, it is useful to evaluate and rank the status of each region based on the discovered factors. Along these lines, we computed factor scores for each region according to the weighted least squares method (to get information about this method refer to Lewis-Beck, 1994 and Lawley and Maxwell, 1971). Tables six and seven show factor scores for each region and ordered regions in terms of each latent factor, respectively.

TABLE 6 - FACTOR SCORES

Districts	FACTOR 1	FACTOR 2
1	0.217036	1.522095
2	-1.20531	0.348508
3	0.048205	1.728643
4	0.076696	0.941562
5	0.453124	1.132581
6	0.519121	0.389092
7	1.681652	-1.01228
8	0.763997	-0.87934
9	-0.64859	-1.47531
10	1.534678	-1.00379
11	-2.15017	-0.92696
12	-1.02025	-0.39443
13	-0.27019	-0.37037

In Table 7, different regions are sorted with respect to each factor, in descending order. According to ranking, regions 7, 10, 8 are the best districts in terms of "common welfare" criterion. The regions 3, 1, 5 are regions in which development plans are progressed well.

TABLE 7 - RANKED REGIONS

Ranking	FACTOR 1	FACTOR 2
1	7	3
2	10	1
3	8	5
4	6	4
5	5	6
6	1	2
7	4	13
8	3	12
9	13	8
10	9	11
11	12	10
12	2	7
13	11	9

The rankings coincide with the data of different regions in Table one. For instance, we expect the best region in terms of the second factor, to have considerable parking capacity and new constructions. Region three is the best region in terms of this factor. From Table one we find that it has 3594 parking spaces, 6.28 acre of ancient and old alleys (relatively low) and two firefighting stations. These data coincide with our expectations.

Municipality managers are interested in such information (as reported in Table seven) for policy making. For example, they can find that the "common welfare" situation is not appropriate at the regions 12, 2, 11. Thus, considering budget constraints with regional municipalities in Isfahan, the responsible managers should pay more attention to the related variables and assign more budgets to improve them (in this case by constructing new cultural centers, parks and green spaces, etc ...).

Also, through such information the performance of different regional municipalities can be compared with each other. This would be another useful instrument for central municipality to perform punishment and award policies.

5. CONCLUSIONS

Nowadays, urban planning is from the most important issues for big cities. Gathering data on different regions of a city, propel us to a large database that is hard to analyze. We should apply multivariate techniques to analyze such multivariate data. One of the most useful methods in the field of multivariate analysis is factor analysis. By this method, we will be able to reduce dimensions of data while also, achieving to some informative latent factors. In this study we did not encounter a large data base, but

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the applied procedure (FA technique) is capable to analyze large multivariate data bases, in the area of urban and municipality planning.

We performed a factor analysis on the data of Isfahan's regional municipalities. Our analysis shows that we can compare different regions of the city, based on two simple and informative factors, representing common welfare and development situations at each region. Computing factor scores we ranked status of each region in terms of discovered latent factors, which is a precious input for policy making at each region.

One major limitation with the FA approach is that interpretation of latent factors may not be an easy task. Perhaps one of the reasons for this weakness is dependency of FA technique to linear relations among variables and correlation matrix. Thus, as future research, to account for cause and effect relationships among different variables, we can combine system dynamics approach and FA approach together, to perform an analysis from nonlinear relations point of view. Also, this analysis can be used as an input to further investigations on data, such as clustering different regions based on discovered factors or building regression models that highlight relations between financial variables and the discovered factors.

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