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DETERMINATION OF TRANSPORTATION NETWORKS BASE ON THE OPTIMAL PUBLIC TRANSPORTATION POLICY USING SPATIAL AND NETWORK ANALYSIS METHODS: A CASE OF THE KONYA, TURKEY

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ABSTRACT: Public transportation planning is one of the most important parts of transportation planning and it provides sustainable development for cities. According to only demands of citizen's and decisions of city managers obstruct for public transportation planning also taking policy in the long time period. Citizen's demands and city manager's decisions important factors in transportation planning but the other important factors; city's and citizen's characteristic features. Relational structure to be determining between spatial and network analysis with these features, according to these situation necessary making transportation policies. The purposes of this paper are to determinate of transportation networks base on the optimal public transportation polices using spatial and network analysis methods of an urbanized city: Konya, Turkey.

Keywords: *Network Analysis, Spatial Analysis, Transportation, Vehicle Routing Problem (VRP).*

1. INTRODUCTION

The spatial distribution of transportation networks has considerable implications on the economic and social development of a country. Therefore, it is a major political issue in many parts of the world (Bigotte, et al., 2010). Transportation planners in developing countries face a number of problems that require innovative solutions such as rapidly growing population, traffic congestion and pollution due to the increasing number of vehicles. Transportation sector is the second largest energy consumer sector after the industrial sector and accounts for 30% of the world's total energy (Geng, et al., 2013).

Public transportation in developed countries is a crucial part of the solution to the nation's economic, energy and environmental challenges. Public transportation offers many advantages over individual transport modes. It costs less to the community, needs less urban space, is less energy-intensive, pollutes less, is the safest mode, improves accessibility to jobs and offers mobility for all. Many cities have invested in recent years in the construction, expansion or modernization of public transportation which is rapid transit systems. This is partly in response to increased traffic congestion and to the need to reduce carbon emissions (Gutiérrez-Jarpa, et al., 2013).

Public transportation planning is one of the most important parts of transportation planning and it provides sustainable development for cities. Thus, providing convenient planning strategies in which the travel behaviors of users are well-modeled has become a primary issue due to the influence of public access to urban public transportation systems (Gulhan, et al., 2013). Without the use of spatial analysis capabilities, formed with only basic data transportation plans do not coincide with both cities plans and daily urban mobility. Evaluation of spatial analysis in terms of transportation; social, demographic, economic, road network and urban reinforcement distribution for the current and future factors is to be determined according to the importance degree of the classification.

New technologies such as geographic information systems (GIS) provide a valuable tool to study the spatial structure of the transportation networks. They take into account the spatial autocorrelation in data, to create mathematical models of spatial correlation structures commonly expressed by various models. By development of GIS, it has been increasingly used as an important spatial decision support system for transportation network analysis. A number of GIS methods and techniques have been proposed to evaluate transportation network. Public transportation planning has been discussed in many studies using GIS methods (Caulfield, et al., 2013; DiJoseph, Chien, 2013; Gutiérrez-Jarpa, et al., 2013; Kim, Schonfeld, 2013; Zhou, et al., 2013; Dorantes, et al., 2012; Martens, et al., 2012; Mishra, et al., 2012; Murphy, 2012; Neutens, et al., 2012; Timilsina, Dulal, 2011; Bigotte, et al. 2010; Sayyady, Eksioglu, 2010; Soh, et al., 2010; Yang, Ferreira, 2009).

The purposes of this paper are to determinate of transportation networks base on the optimal public transportation polices using spatial and network analysis methods of an urbanized city: Konya, Turkey. Firstly, "minibus transportation" was evaluated in terms of across the city and transportation policies was attempted to establish accordin to housing-accessibility relationship. Secondly, "bus transportation" was evaluated in terms of northern part of the city and transportation policies was attempted to establish accordin to housing-accessibility relationship. Finally, according to the results of oth studies, foresights have attempted to establish for public transportation policy.



Figure1. The geographical position of Konya Metropolitan Municipality's boundary.

2. Materials and Method

2.1.Study Area

The city of Konya is geographically situated between 36.5°-39.5° north latitudes and 31.5 °-34.5 ° east longitudes. It is the largest province of Turkey. Konya city's area is 38,257 km² (Uyan, 2013). Public transport in study area (Borders of Konya Metropolitan Municipality) comprises a bus network, minibus network and rail systems to serve the more than one million inhabitants of the city spread over an area of 2100 km². Study area is shown in Fig. 1. In Konya, the current state of numerical distribution of public transportation services is shown in Table 1. The average number of daily passengers for the tram as 90,000 people has been identified. In the northern region of Konya, in terms of public transport infrastructure, use of tram and minibus lines are more intense. Buses and minibuses density is usually composed in the city center. Traffic density in the city center is seriously affected this mobility.

Table 1. Public transportation type by current situation in study area.

Transportation Type	Number of vehicles	Passenger capacity	Number of stations	Number of trips (Daily)	Total line length (km)
Tram	60	532	35	285	21
Bus	310	308	1848	203	141
Minibus	530	17	198	411	751

2.2. Methodology

2.2.1. Data collection

Data for this study were acquired from the Social texture map database of the Konya Metropolitan Municipality. Social texture maps provide population, disabled, public transportation needs, working population and vehicleowning density maps (Fig. 2). Social texture maps carried out survey studies to determine the opinions of the citizens. Within the context of GIS to create the fundamental basis of the project, it was organized a survey covering all households in Konya. According to the results, the direct and cross-analysis was performed, and this data is used in many social projects. Frequency of social texture maps was modeled using the kernel density estimator (KDE) calculated in the Spatial Analyst extension of ArcGIS, version 10.0.

KDE are flexible, non-parametric methods and calculates the density of events the overall number of observations within a particular search radius from a target location (Kuo, et al., 2013; Harris, et al., 2012; Poulos, 2010).

A simple KDE is given by:

$$f_h(x) = \frac{1}{nh} \sum_{i=1}^N K\left(\frac{x-x_i}{h}\right) \quad (1)$$

where:

N= The number of observations.

h= The bandwidth.

K(x)= The kernel function.

x and x_i= Observations.

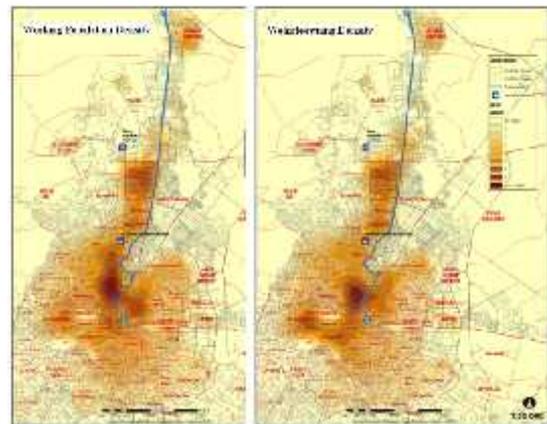
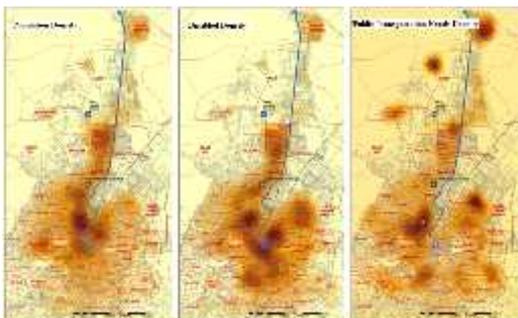


Figure 2. Density maps (left to right: population, disabled, public transportation needs, working population and vehicleowning)

2.2.2. Minibus transportation and GIS-aided production availability parameter across the urban

In this study, types of public transport with minibus transport to analyze the proficiency level on the basis of urban residents and are intended to offer an alternative route. To determine the adequacy of the level of minibus lines, geographically number of people living in buildings and the minibus lines was determined and the necessary database information is processed using GIS software, ArcGIS Desktop 10.0 (Fig. 3). There are 530 minibuses within 28 minibus lines serving Konya's public transportation needs. The total length of these lines is 751 km. Minibuses serve two transfer center throughout the city.



Figure 3. Available minibus lines.

In the study, minibus services to take advantage of every building in the study to determine the value of accessibility to lines 300 m distance; has been identified as the most suitable service distance. 300 m buffer zones were built by ArcGIS software. The domain within 300 m of the buildings were classified according to the degree to which the service. Outside the domain portion were determined the population without adequate benefit levels of minibus transportation services (Fig. 4).

Daily, how many people can be transported by minibus is calculated following formula for production of GIS-based availability parameters of minibus lines.

$$A = p \times q \times 14 \quad (2)$$

Where, A: daily number of transportation people; p: the total number of minibus that uses a line; q: the total number of trips per day and 14: passenger capacity for one minibus.

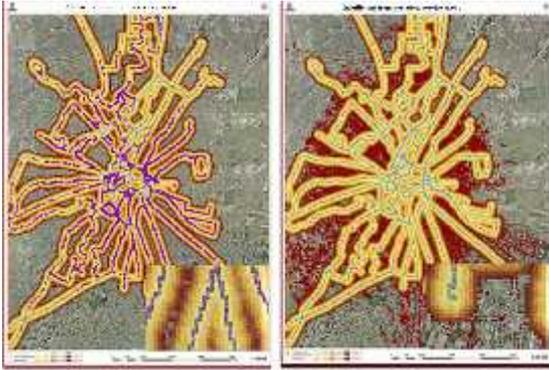


Figure 4. Classification of buildings according to minibus line domain.

Way information which is closest to building and has minibus line is processed in building database. A coefficient for each building is determined with number of people living in the building was proportional to the number of passengers that can be transported. The coefficients obtained for the building was joined with population density (Fig. 5). White area in transportation coefficient density map is transfer center region and minibuses running on all lines pass from this region certainly. When population density map and transport coefficients density map is combined, despite the high population, transport coefficients are seen to be low in the northern region of the city. Again, the difference between population and the transport coefficient values is observed to be higher in the some areas where city's south and west regions. Density analysis was realized for related building in the area that high population density and low transport coefficient. So, priority service areas has emerged (Fig. 6).

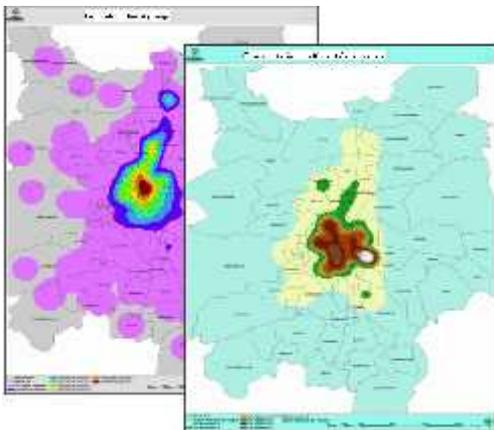


Figure 5. Population and transportation coefficient density maps.

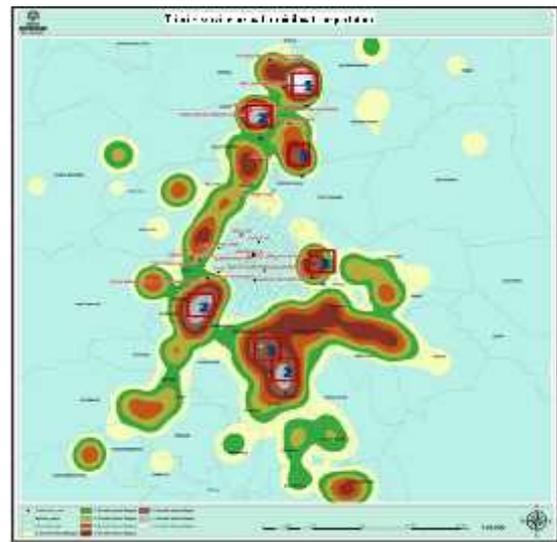


Figure 6. Determined priority service areas for minibus transportation.

2.2.3. Assessment of the current situation of transportation lines and alternative line production with spatial/network analysis methods of northern part of the city

There are 57.3 km total transportation lines using tram and bus of northern part of the city (Fig. 7). Most passengers are transported by tram through these lines. In terms of urban planning, northern part of the city is quite moving. In this region, there is high-density construction.

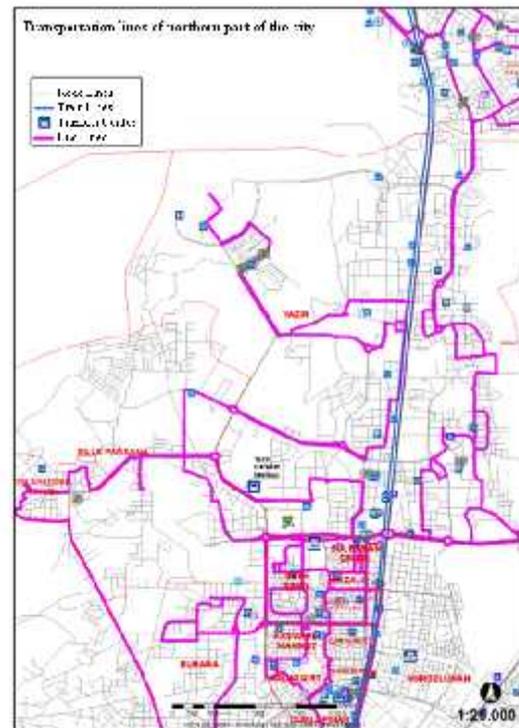


Figure 7. Current situation of transportation lines of northern part of the city.

Obtained analyzes through building using kernel density analysis methods were classified again and the possibility of cross-analysis was obtained. Dominant distribution of data and density distribution according to the load with kernel method were evaluated. The distribution of socio-economic and demographic structure is shown in Figure 8.

Analysis of routing solutions was used Vehicle Routing Problem (VRP) analysis. VRP models and algorithms are vast with many commercial applications. ArcGIS allows users to define a network dataset and a vehicle routing problem (Bozkaya, et al., 2010).



Figure 8. Demographic and socio-economic spatial analysis (Left to right: Population, working population, orthopedic disabilities, vehicleowning and public transportation needs densities)

The VRP is one of the most studied combinatorial optimization problems. VRP is concerned with the optimal design of routes to be used by a fleet of vehicles to serve a set of customers (Golden, et al., 2008). For use in VRP network analysis, generated synthesized map by combining the spatial analysis map in Fig. 8 is shown in Fig. 9. Seen as brown regions indicate areas of appropriate to criteria intersection. The first spatial data is synthesis map for VRP analysis. Active tram line as a second data for VRP analysis was analyzed. Effective service distance of the tram line has been recognized within 3 km considering the existing settlement areas. Also, active usability distance was designated as 300 meters (Fig. 10). 300 m radius was used as the limiting elements for VRP analysis.

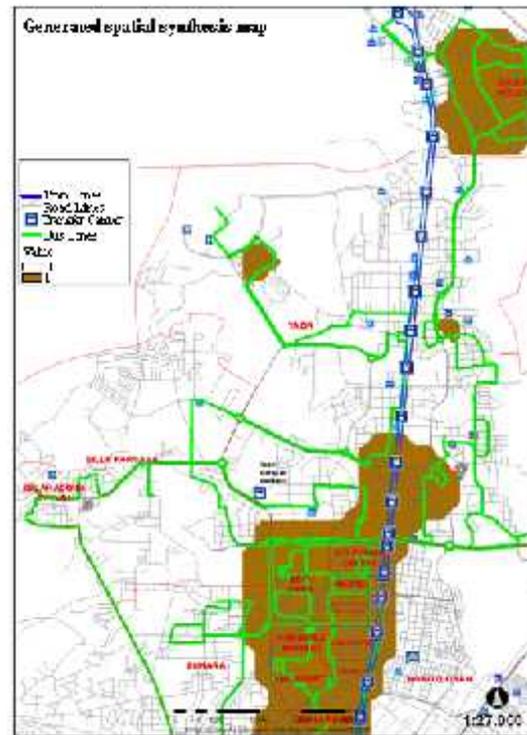


Figure 9. Generated spatial synthesis map for VRP analysis.

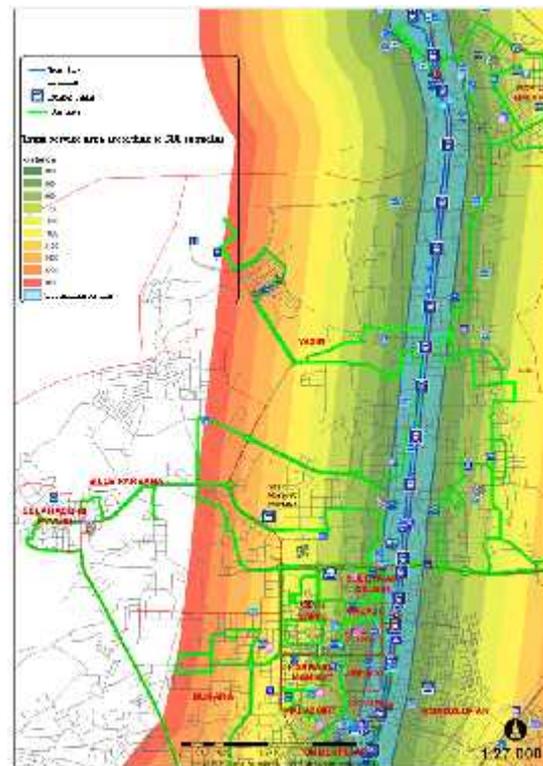


Figure 10. Buffer of tram lines (300 m and 3000 m).

In the northern part of city, the active population areas was determined the third data for VRP analysis. For this process, some regions (such as shopping mall, bus stations, hospital, schools, university, etc.). Evidence needs to be weighted depending on its relative significance. Hence, each location will be evaluated according to weighted criteria, resulting in a ranking on a suitability scale. This method is known as index overlay. In this method, each factor maps will be assigned ranking. Weights are generally assigned to these maps to express the relative importance (Nas, et al., 2010). In this study, highest score have been considered as the most visited for ranking of urban areas. Accordingly, ranking is as follows;

- Shopping mall, city hall, electricity authority, bus stations, hospitals, secondary schools, social welfare institutions, water authority, telecom, university, dormitories=30
- Primary schools, post offices, public enterprises=20
- Military Institute of Health, police stations, , cultural centers, libraries=10

Formed by the ranking density map is shown in Fig. 11. This map with the synthesis map in Fig. 9 was observed overlapping locally.

Generated maps using spatial analysis are base data for VRP analysis. Within the scope of this data, transportation lines were evaluated again. We have selected the ArcGIS 10.0 software Network Analyst tool for VRP analysis. In this study, VRP analysis was created geometrically the shortest road networks and transportation routes automatically. Before VRP analysis, the total bus route length was 153.2 km in northern part of the city. This length has decreased to 86.7 km after VRP analysis (Fig. 12).

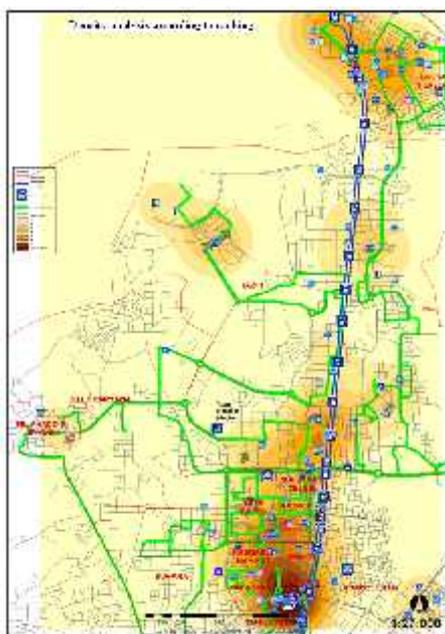


Figure 11. Density analysis according to ranking.

After VRP analysis, structure based transfer center that returning in their own and transferred to the tram line has been proposed for transportation that going to the tram line and the city center, previously. A tram runs every 2 minutes for each tram stations. Transition periods for trams based on the change of the crowd factor based on travel time will be more flexible. Previous case, the cost of only one bus to the municipality for one service is 505.56 Turkish Liras (approximately 243 \$). These cost is 286.11 Turkish Liras with spatial and network analysis methods (approximately 138 \$). Analysis of the spatial sense regulations realization and detailed bus information (cruises start-to-finish time, passenger capacity, vehicle type, stop, not hours, real speed, etc.) by entering passage costs significantly be reduced with repetitive calibration analysis. Realized spatial arrangements and detailed bus information (start-to-finish time for travel, passenger capacity, vehicle type, speed, etc.) must be entered for this process. In this case, both public transportation can be more efficient and public transportation users will be able to travel more cheaply.

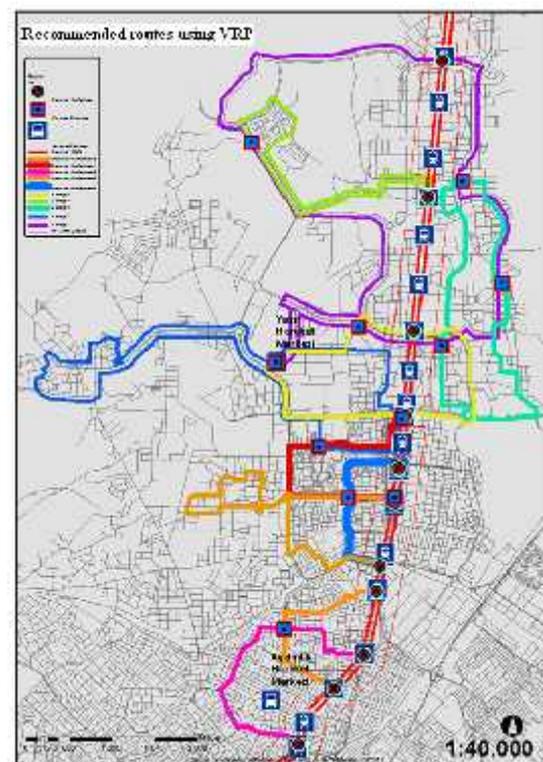


Figure 12. Recommended transportation lines after VRP analysis.

3. RESULTS and DISCUSSION

When adequacy studies was realized for across the city in terms of minibus transportation, most appropriate distance in terms of accessibility to public transportation vehicles for available lines was determined as 300 m walking distance and study was shaped and alternative lines were produced according to the number of persons living in the building for this distance.

Two alternative approaches is developed determining insufficient regions for minibus transportation. The first approach, existing lines is revised within 300 m distance for high density of population and low public transportation services. Another approach, outside walking distance areas without minibus lines is determined and is the creation of a new minibus lines. According to the first approach, the location of the last stopping point was modified and new lines were added to existing lines. According to the second approach, in areas where population density is high and identified wide roads without minibus lines, new lines have been created.

4. CONCLUSIONS

In this study, the effective use of spatial analysis to rehabilitate bus and minibus transportation appears to constitute an important data. Demand for public transportation is the most important input. However, planning of public transportation with only demand or decision-makers' estimates will reveal many problems over time. Performed public transport policies without knowing spatial distribution of demographic and socio-economic structure of society will begin to deteriorate over time. In this study, performed analysis and synthesis brought about applicability alternatives for public transportation. The aim of this study could be used public transport services for all the people living within the city. To ensure this condition is necessary along with a lot of data to understand the characteristics of the population.

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