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GIS-based analysis approach for metro and bus integration in public transportation

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Keywords
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Abstract

In metropolitan cities, public transportation is always a sign of civilization. Geographic information Systems (GIS) aided map-based applications play an important role in studies on public transportation. Within the scope of this study, Istanbul Transportation payment system data, all trip data and public transportation routes are evaluated together. Integration and optimization studies have been carried out between buses and metros with the use of these data sets. Study; the route started by importing the stops, routes and timetables for all modes into the Visum simulation model. All fare systems applied in Istanbul were integrated into the model separately. District-based analyses were made for the randomly selected day of May 22, 2023, and passenger movements were analyzed in hourly breakdowns. The movements of 7,693,856 daily trips made by a total of 4,414,292 passengers were examined. Analyzes of the current model and actual trip values were performed. Hourly-based travel analyses were realized. It has shown that GIS can be used efficiently in integrated transportation for Istanbul.

Introduction

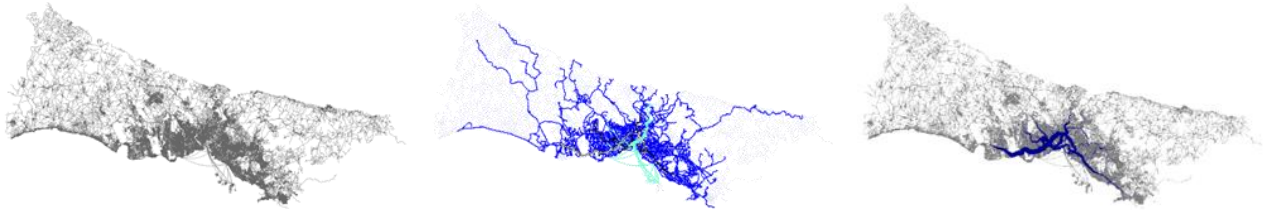
In our changing and developing world; the population of cities that are symbolic in historical, social, economic and touristic terms is increasing day by day. The increasing population also brings with it infrastructure and superstructure investments in many areas. In addition, increment in attraction centers along with population growth and the expansion of the city also cause many problems in terms of transportation. In a time when the analytical world and big data are so developed, it is inevitable to direct investments correctly by making future modeling and simulation studies using all possible data. Integration is a set of practices that will improve the reliability and accessibility of the public transportation system and make it more attractive than the use of private vehicles [1]. Istanbul is a city where 10 metro lines are under construction at the same time. Bus integration is inevitable for subways under construction. Determining integration points and using simulation models and location-based services to reorganize at these points is an efficient method for future planning. Considering the available bus lines in Istanbul, it was planned to have direct lines from the neighborhoods to as many centers as possible.

As a result of lines coming to the center from as many neighborhoods as possible, corridors were formed where 40-50 lines pass from the same point. Since these corridors are on main arteries (Anatolian Side: E-5, European Side: Unkapanı, Millet Caddesi, Şişli), bus lines are exposed to private vehicle traffic. This situation reduces the efficiency of bus lines as a result of extending travel and waiting times at the stop. The main line feeder line model is a model that has been successfully implemented in many countries. Considering the metros as main lines and feeding the metros with bus lines, allows reducing parallel routes and using resources efficiently. This study aims to represent new metro networks in the model and to develop a model that will accurately predict integration points.

Material and Method

The hourly Origin-destination (OD) matrices were created in line with Istanbul Transportation payment system data obtained from trips in the field. It gives the passengers' journeys during the day with determined

algorithms. All roads in Istanbul are divided into 99 types according to the number of lanes and free flow speed. The work was done in ArcGIS base and was imported into Visum with shape format. All stops and lines have been integrated into the Visum network. The stops are divided into zones. Daily OD stop-zone matches have been provided. All lines in the public transportation system are defined in the model with their departure times. Assignments are made based on timetable, not headway. The Visum model can be run with 4 different assignment models. The parameter we chose for Istanbul is the Kirchoff principle [2]. Time-effect impedances that determine the travel time have been created.



Istanbul road network | Istanbul public transportation network | *Istanbul traffic flow density*

Figure 1. Current Istanbul flow chart (Visum Simulation).

In Figure 1, the flow chart created based on the road network, public transportation network and OD matrices integrated into the Visum simulation model is visualized.

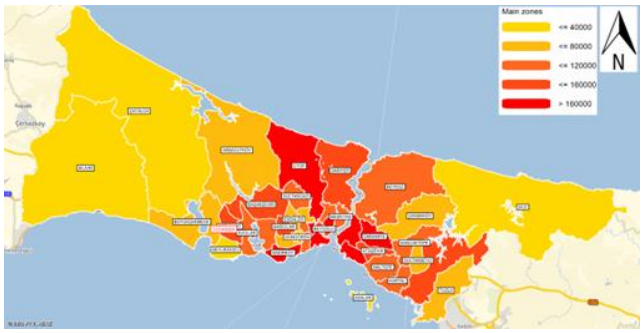


Figure 2. District-based travel density

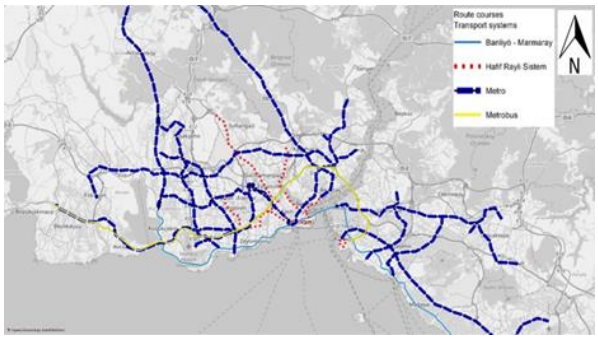


Figure 3. Existing and under-construction metro lines

In Figure 2, the distribution of transportation payment system data according to Istanbul districts is shown, and in Figure 3, the current rail system map of Istanbul and the subways under construction are shown in the Visum model. These maps are an important point in determining the integration points of metros. Integration points were determined by evaluating maps and trip data.

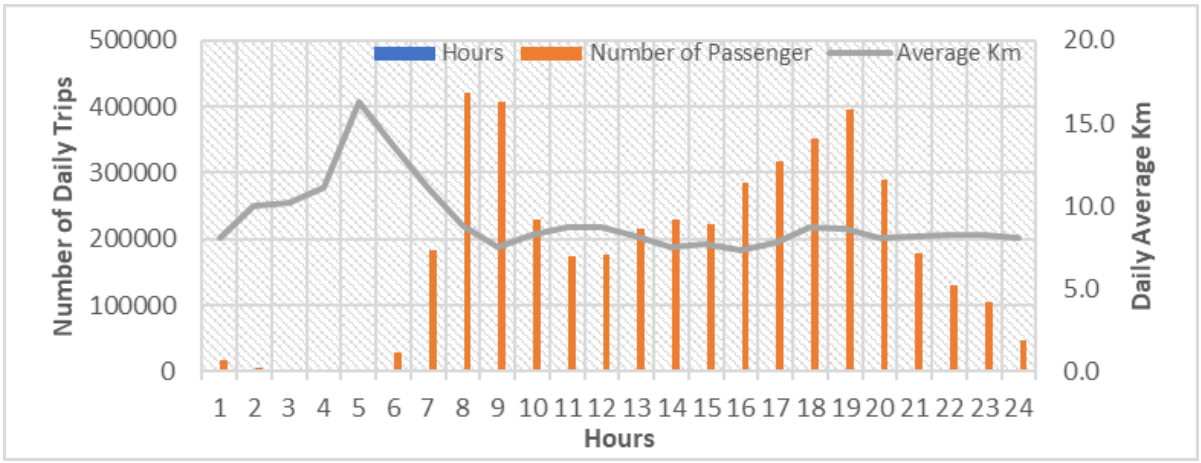


Figure 4 – Average trip and average distance per hour for May 22, 2023.

It was analyzed that there was a total of 4,414,292 trips in the OD matrix created based on transportation payment system data on May 22, 2023. The regions where these passengers are most concentrated are given in Figure 2. The number of trips made by these passengers during the day is 7,693,856 [3]. Average travel distance data was calculated with the OD we created. On average, passengers travel 9.13 km. The hourly average mileage chart of passengers is analyzed in Figure 4.

Results

In the visuals presented, it was determined in which areas the metro lines had dense travel. A representative map was created, with intensity increasing from yellow to red. The routes of the subways and the routes of the new subways to be opened were drawn in the model. Maps and analytics help identify integration points. Prioritization of integration points can also be done with stop-based analysis.

This study could be evaluated as a decisive step in establishing the integration between the metro and bus transportation.

Discussion

Integrating buses into the metro at integration points determined by identifying lines running parallel to the metro can be an efficient method. This reorganization of bus lines provides vehicle savings, unit/km savings, and reduction in CO_2 emissions, traffic congestion and waiting times. With the implementation of the project, short-term travel, high integration, comfortable transportation, sustainable transportation and reduced traffic density will be achieved. Geographic information systems and simulation applications such as Visum play an important role in realizing these projects [4].

By correctly importing the existing model and data into the model, integrated transportation plans can be made in line with planning on a macro scale. Metro and BRT routes can be identified [5].

There are many ways to create an origin-destination matrix. Some studies have used the Gravity model with O-D matrix estimation, generation, attraction, and constraint [6]. In a study conducted in Norrköping, an O-D matrix was created based on traffic counts [7]. In this study, a matrix was created with Istanbul transportation payment system data in order not to miss the daily movements of passengers. The number of passengers to be estimated for origin and destination has been reduced to a minimum.

Conclusion

In this study, the integration of Istanbul with the developing metro networks and all other public transportation modes was examined and the main line feeder line model was proposed. The main lines are determined as the regions where metros pass and the bus lines in regions where there are no metros. As the number of subways increases day by day, passengers will start to use the subways, but buses will come into play in areas where there is no rail system. As a result of the modeling, the integration points of the subways were determined with the origin destination matrix formed by transportation payment system data. It is emphasized that the subways are considered as main lines and that the bus lines operate in a structure that feeds the subways. In the model, analyzes are made using the route, stops for all modes, departure times and routes, and the focus is on identifying the right regions. An integrated transportation model is aimed with the reorganizations made in this area. In Istanbul, it has been determined that traffic density is very high during peak hours and operating speeds of bus lines fall below 15km/h. Ensuring metro and bus integration is very important for efficient use of resources.

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