Mersin Photogrammetry Journal

https://dergipark.org.tr/tr/pub/mephoj

e- ISSN 2687-654X

Light rail line design for East Black Sea region: A case study of Trabzon

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Keywords
Light Rail System
Orthophoto
Landsat
GIS
Trabzon

ABSTRACT

Growing cities need to improve transportation in response to the accessibility needs of ever-expanding urban and metropolitan populations. Metropolitan Municipalities have to find low-cost, nature friendly, bus/train/subway transfer, and socially responsible transportation solutions that can meet the accessibility needs of urban residents and assist future economic development in urban areas. In this study, the light rail network was designed for the province of Trabzon by using orthophoto and Landsat satellite images. While this light rail network is being constructed, many criteria such as regional population density, slope, minimum service interval, integration with other transportation networks, geological structure, and proximity to public institutions and organizations have been used together. These criteria are shown with a GIS-based design model. Analysis maps were created by using the conditions/criteria and synthesis maps used in the design model. The 102 km route features 205 stops, extending from Of along to Besikduzu. A combined bus and light rail network will significantly improve public transport access to major public institutions and organizations, sporting and entertainment facilities, universities, schools, health precincts, bazaars, shopping malls. It is foreseen that the light rail system will provide the most suitable, modern, fast, comfortable and safe transportation in the long term considering the number of passengers and many other criteria. This light rail system designed for the province of Trabzon is thought to be a pioneering work for the Black Sea region through the interpretation of the resulting map and route networks.

1. INTRODUCTION

Traffic is one of the most important problems in developing cities. In particular, if the urbanization and geographical barriers constitute the basis of this problem, different approaches to transportation should be provided to solve the problem. In this case, municipalities need to design new transport networks for public transport. Light rail system is only one of many modes of rapid transit, some of which, including high-capacity bus transit and train/subway, can supply like levels of service to that of rail in certain contexts (Pulido et al., 2018) The Light rail system is an important method of transport all through the world. Every day, it transports a great amount of passengers from one point to another. Light rail networks can be the solution to permanent conversion and traffic. It is basic that passengers use all the accessible and shortest methods of transport to take with a specific end. This new system brings a number of complex cases. Light rail networks have spatial, geographical, technical, economic, political and social aspects. Therefore, it is important to be able to design systems in which multiple conditions are evaluated together.

There are several studies on rail systems in the literature. These studies were mostly conducted on cost, performance, environmental impact, property

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Cite this article

ÇATAL REİS, H , BİRİNCİ, A . (2020). LIGHT RAIL LINE DESIGN FOR EAST BLACK SEA REGION: A CASE STUDY OF TRABZON. Mersin Photogrammetry Journal , 2 (1) , 18-23

DOI: XXXXXXXXXXXX / Research Article

Retrieved from https://dergipark.org.tr/tr/pub/mephoj/issue/52791/650320

Received: 24/11/2019; Accepted: 22/12/2019

impact (Esakov and Vandegrift, 2018) and feasibility (Kołos and Taczanowski, 2016). Love et al. has conducted a research on cost performance evaluation of light rail projects (Love et al., 2017). In another presented study, the demographic and economic characteristics of the city were analyzed before and after the Dallas (Texas) light rail system "DART" (Heilmann, 2018). A green transportation system along the rail line was aimed by creating public transport-oriented settlement system "TOD" and calculating the location, number of stops and size of the region (Peng et al., 2017). In another study, the effect of light rail system on price increase in nearby houses was investigated in Sydney (Mulley et al., 2018). The "URTSOPE" approach to be implemented in China has been prepared by evaluating different criteria. In the study, the operational performance of the rail transportation system is discussed by associating the perspectives of the operator, passenger and the state (Huang et al., 2018). It is possible to reach some studies in the literature about transportation network. These are tram route planning (Alkubaisi, 2014), route selection for light rail system (Banai, 2006; Banai, 2010), metro line design (Ahmed and Asmael, 2016; Dana and Tecim 2007), location selection for metro line (Farkas, 2009) station location selection for rail system network (Blainey and Preston, 2013), Monorail routes for Ankara (Hamurcu and Eren, 2018).

Due to the high demand for travel and the lack of sufficient public transport infrastructure to meet this demand, there are great problems in transportation in the developing Trabzon, which has become a metropolitan city recently. The mountainous structure of the city and the lack of sufficient land bring some problems. Narrow roads that do not meet the needs of the population and the lack of an alternative to these roads bring many problems such as traffic congestion, psychological effects on people, time spent in traffic and expensive transportation.

With all this in mind, it is important to design a fast and comfortable transportation network and project that will reach all the neighbourhoods of the city in an optimum level, which will eliminate traffic congestion. (Arikan et al., 2018) Rail systems are seen as one of the solution methods for reducing the problems in transportation and clean environment.

In this study, light rail system design has been prepared in the most accurate way considering the physical and human geographical conditions of Trabzon. The data used by Geographic Information Technology (GIS) was harmonized in a spatial environment to achieve a consistent scale, extent and uniform co-ordinate system so that the data could be seamlessly integrated prior to analysis. Landsat and orthophoto images were used as a base and rail system route network was created with a Statistical and GIS based model (Kirlangicoglu, 2016), population map, slope map, aspect map, stream map, road map and the use of this information by creating a unique light railway line was designed. The light rail system is crucial for the growing city. This study was therefore undertaken to determine optimal light rail line using orthophoto-Landsat and GIS modelling for the light rail in Trabzon.

The study consists of introduction, material and method, and results sections.

2. MATERIAL AND METHODS

2.1. Study Area

Trabzon is located between 38 ° 30 '- 40 ° 30' eastern meridians and 40 ° 30 '- 41 ° 30' northern parallels in the Eastern Black Sea Region (URL1) (Fig. 1). Behind a narrow coastline, it has a mountainous terrain extending vertically to the sea. The city has a surface area of 4,685 km^2 and a population of approximately 813,044 people (Turkish Statistical Institute-2019) (URL2).

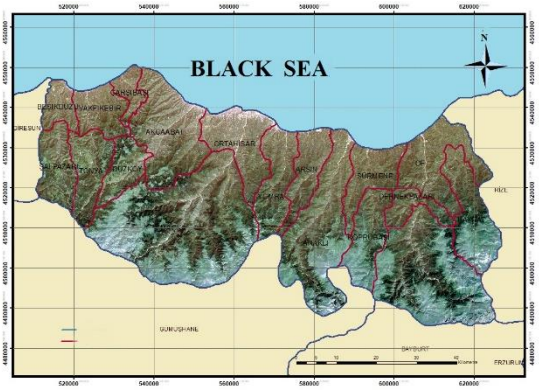


Figure 1. Study Area

2.2. Data Set and Image Processing

Landsat-8 (2018) and orthophoto (2015) were used in the study. It is aimed to design a light rail network by using Multi-Criteria Decision Making methods. Using the GIS and CAD software, all the factors affecting the system were evaluated together and the route was revealed. In determining the optimal light rail line using GIS various constraints and criteria were used to develop a model (Fig.2). We used free maps which were produced by General Directorate of Mapping (GDM). The 1/5000 scale photogrammetric map generated reference data for the Digital Elevation Model. In this study, public institutions and organizations, schools, hospitals, stadiums etc. were determined using the help of google maps. This information was used for line identification, stop selection, bus transfer. The population of Trabzon was downloaded from Turkish Statistical Institute. In the study, the criteria with the highest importance levels are land structure, population density, slope, elevation, and construction cost.

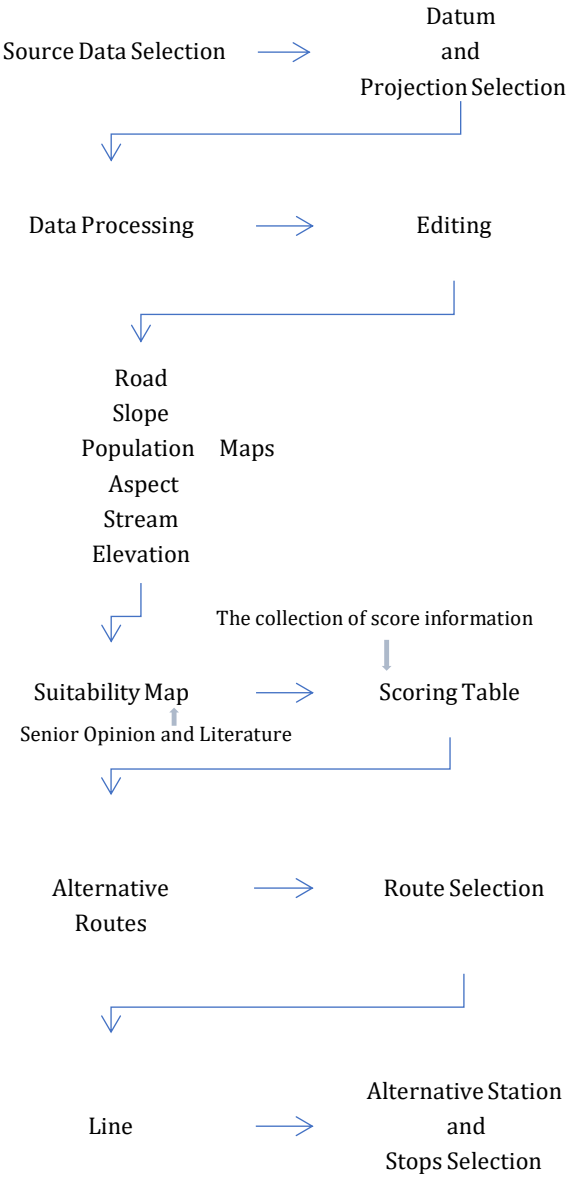


Figure 2. Workflow

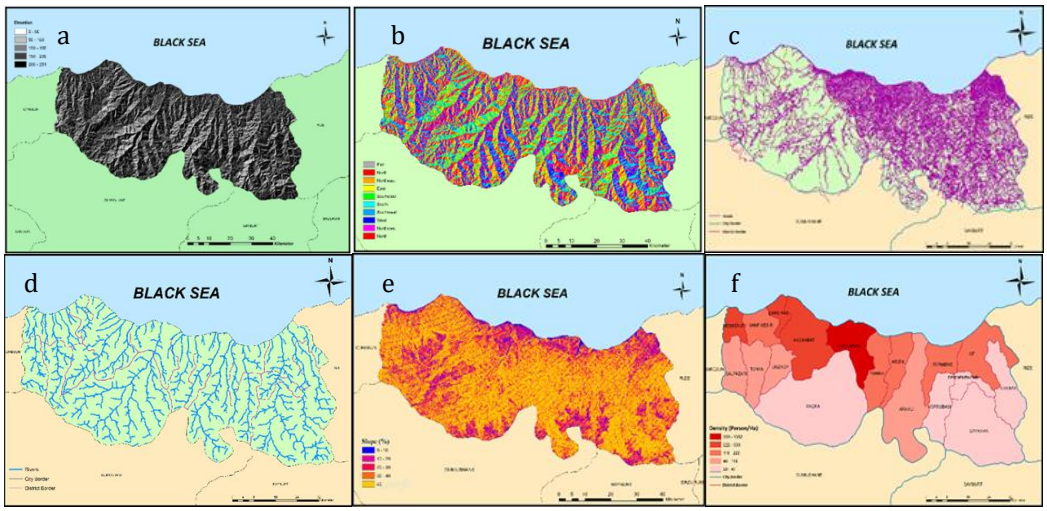


Figure 3. a) The elevation map, b) The aspect map, c) The road map, d) The stream map, e) The slope map, f) The population map (Catal Reis et al., 2019)

Road, slope, population, aspect, stream, elevation maps (Fig. 3) for the study were formed using the scoring system.

In this study, it is aimed to be a noiseless, environmentalist, climate and geological structure suitability, safe, and economical for a light rail network. The criteria such as regional population density, slope, minimum service interval, integration with other transportation networks, geological structure, proximity to public institutions and organizations were used in the rail system planning.

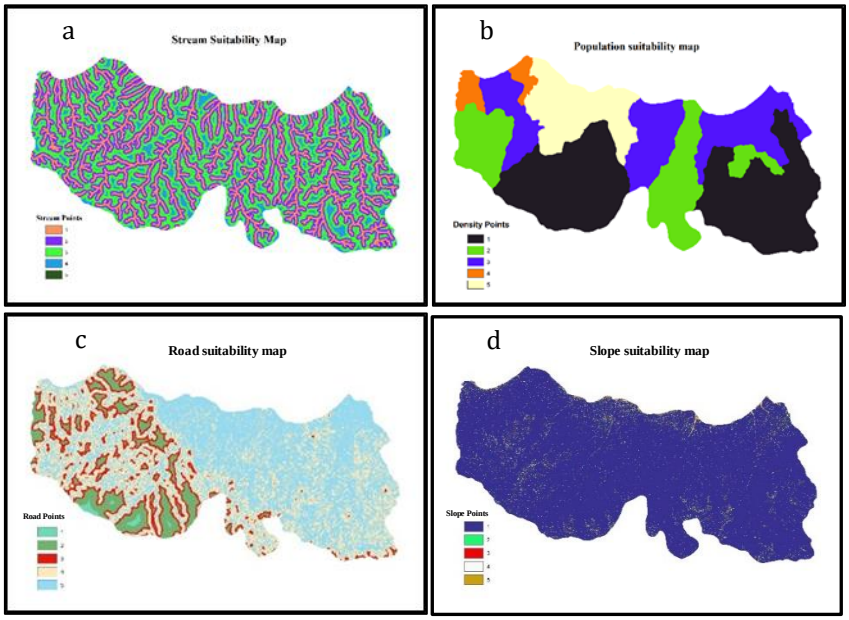


Figure 4. a) Stream suitability map, b) Population suitability map, c) Road suitability map, d) Slope suitability map (Catal Reis et al., 2019)

Table 1. Scoring used in elevation map

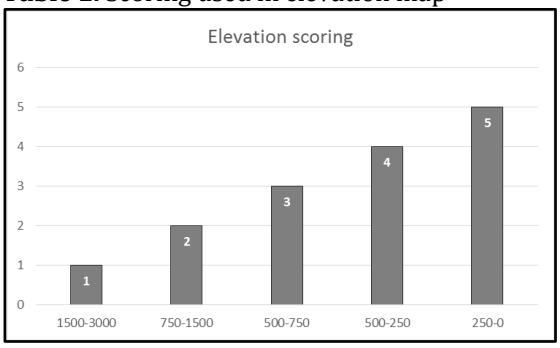


Table 2. Scoring used in aspect map

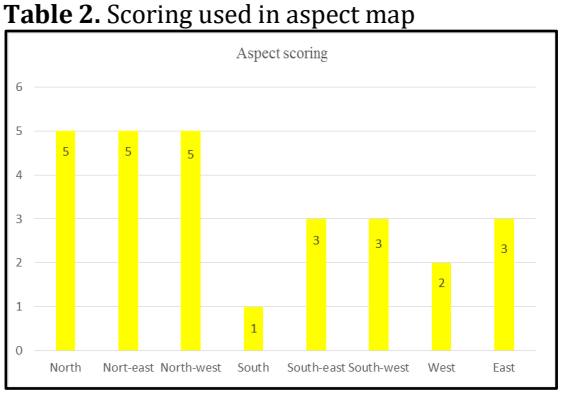
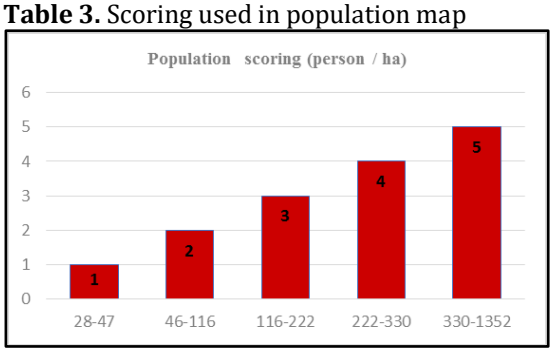


Table 3. Scoring used in population map



In this study; elevation, slope, road, stream, population and aspect maps were created. Then, the score tables were calculated (Fig.4, Table 1, Table 2, Table 3, Table 4, Table 5, Table 6). In this study, 1 point represents the worst and 5 points the best. Places with an elevation between 0 and 250 meters have received 5 points (Fig.3a). It has been observed that the north, northeast and northwest directions have the most favorable aspects (Fig. 3b). Highway, urban roads, and rural roads were considered (Fig. 3c). Streams were detected (Fig. 3d). The places with a population of between 330 and 1352 people/km were calculated as 5 points (Fig. 3f).

Table 4. Scoring used in road map

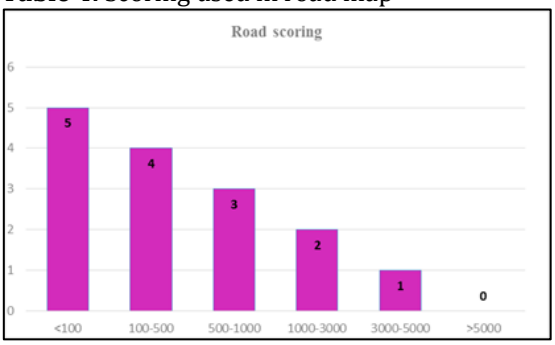


Table 5. Scoring used in stream map

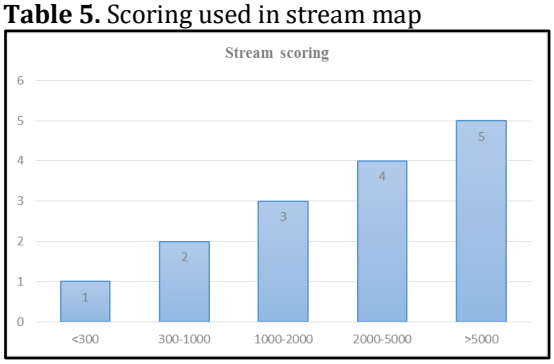
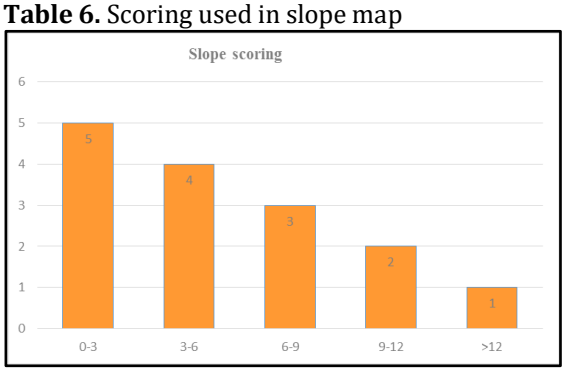


Table 6. Scoring used in slope map



The slope between 0% and 3% indicates the most suitable places for the line and these places are defined as 5 points (Fig.3e, Table 6).

3. RESULTS

The rapid population growth in Trabzon, the rapid urbanization rate and recent interest in highland tourism have increased transportation problems. It is important to design the light rail system urgently as a result of the inability to prevent mountainous terrain and warped urbanization. In this study, a light rail route was designed using orthophoto, which reduces traffic density, is environmentally friendly and suitable for the geological structure of the region (Fig.5 and Fig.6). Additional light rail services will provide extra capacity for major events. Suitability and scoring maps were produced from Landsat images. The Trabzon light rail network (or Trabzon light rail) is a light rail system planning of Trabzon. The network currently has a passenger route, Of-Besikduzu Line. The Trabzon light rail line 102 km and 205 stops were planned.

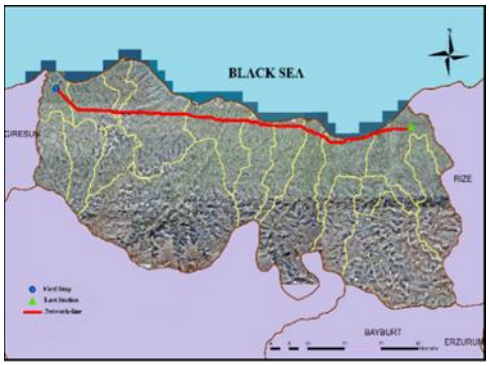


Figure 5. Proposed light rail line (Catal Reis et al., 2019)

Figure 6. Planned light rail stops (Akcaabat-Ortahisar-Yomra/77 stops)

Light rail lines are the most efficient, cost-effective and environmentally friendly means of transport for humans. The research considered a number of criteria that included roads, stream, land cover, geology, elevation, population, aspect, and slope. Used remotely sensed data, orthophoto, and GIS for light rail routing in a small section of the proposed Trabzon network. It has also been demonstrated how an innovative approach, assisted by a GIS was used to analyse the multiple route options to determine an intended line network. If Trabzon light rail system is designed, Of-Besikduzu Line will be Trabzon first passenger route.

Land structure, slope and population are the most important factors affecting project feasibility. Trabzon has got mountainous terrain parallel to the coast, therefore, the province's light rail line has to be close to the coast. In this study, a line of light rail route was designed to cover the whole province but the light rail system should primarily cover Yomra, Ortahisar and Akcaabat districts (77 stops). The light rail network can help to reduce both traffic congestion and vehicular emissions. As suitably planned and properly applied as part of a larger public transport network, light rail systems can help rapid urban mobility and critical access to city centres from surrounding districts. Light rail projects are not only as infrastructure projects, but also as important opportunities for urban improvement.

This study highlights the dynamics of the light rail line and demonstrates the interrelationship among various factors. The effects of geological and public demand can be considered at an important scale and classes of main factors can be incorporated to refine the model and the expected results.

ACKNOWLEDMENT

Some part of this study has been presented at the X. TUFUAB 2019 Symposium.

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