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Determining the location of the urban transport interchanges based on the geographic information system: the case study for İstanbul

İstanbul'da coğrafi bilgi sistemlerini kullanarak aktarma merkezi olabilecek yerleri belirleme

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Highlights

- *Interchange can be either the physical action of transferring between services or modes as part of the passenger's journey or it can be the physical location that provides access to the Public Transport system*
- *An intermodal interchange is an area destined in a permanent way to facilitate the interchange of passengers between different modes of transport.*

Graphical Abstract

All bus stops in Istanbul were scored using geographic information systems. The highest rated 3 interchange stations on the European side and 3 on the Anatolian side were selected.

OBJECTIVE	*CRITERIA*	*INDICATOR*
Integration of interchange with the road transport by wheels	*max. ability to connect with Network*	*Bus line score up to the number of IETT bus lines stopping by the station.*
		Minibus line score up to the number of minibus lines located within a distance of 50 meters (walking distance).
Integration of interchange with the rail transport system		*If the stations intersect with the Rail System station points within a distance of 200 meters, the total line score was multiplied with a coefficient of 2*
Integration of interchange with the metrobus		*If the stations intersect with the Metrobus stations within a distance of 200 meters, then the total line score was multiplied with a coefficient of 2.*
Integration of interchange with the maritime transport lines		*If the stations intersect with the pier points within a distance of 500 meters, the total line score was further multiplied with a coefficient of 2*

Table. Selection of Interchange Location by GIS and Criteria Thereof

Aim

The aim of the study is the arrangement of the interchanges planned to be established in Istanbul by means of GIS and finding the locations of the primary 3 interchanges of top priority in Anatolian part and 3 interchange of top priority in European part.

Design & Methodology

Propose of this study, based upon the scores received by the locations of interchange by means of GIS method.

Originality

This study is a pioneering study in determining the location of interchange stations in Istanbul. This study can be taken as basis when planning the interchange areas in the 2021-2023 Istanbul plans.

Findings

In the study conducted with IETT Directorate of Geographical Systems for 12,394 stations; there are tabs for station code, direction of the station, name of the station, direction of the bus, name of the geographical side, county, quarter, longitude and latitude, number of IETT bus lines stopping by the station, number of minibus lines stopping by the station, metrobus score, railed system score, maritime line score, new high-speed train score and the total score.

Conclusion

Based on the criteria, Eminönü is the fist place shall be more convenient to be established the intercghange at this area. Şirinevler is another area for the establishment of a interchange for the European side. Cevizlibağ is the next location for the establishment of interchange designed as the third one located at the European side. The area at Üsküdar is located received high score due to the existence of the rail transport system. Kadıköy area at the Anatolian side is among the areas with the highest score. Another area located at the Anatolian side is Maltepe.

Declaratıon of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Determining the Location of The Urban Transport Interchanges Based on the Geographic Information System: the Case Study for Istanbul

Araştırma Makalesi / Research Article

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ABSTRACT

Interchange location problem is a problem that depends on different criteria such as population density of the region, transportation facilities, infrastructure services, integration of different transportation modes used in the region. One of the important points to be taken into consideration in the choice of location is the idle areas that the Istanbul Metropolitan Municipality has foreseen. A solution approach that includes the Geographic Information Systems (GIS) method has been proposed in order to determine the most suitable location for the interchanges planned to be carried out in this study. First of all, military lands that could be a interchange places were examined in line with the zoning plan. In line with this review, it was seen that these lands were not enough to integrate with different transportation modes. Locations found by calculating line scores according to constraints were determined by using ArcGIS program. Accordingly, the aim of the study is the arrangement of the interchanges planned to be established in Istanbul by means of GIS and finding the locations of the primary 3 interchanges of top priority in Anatolian part and 3 interchange of top priority in European part.

Keywords: GIS, geographic information systems, urban transport interchange.

İstanbul'da Coğrafi Bilgi Sistemlerini Kullanarak Aktarma Merkezi Olabilecek Yerleri Belirleme

ÖZ

Aktarma merkezi yeri seçimi problemi, bölgenin nüfus yoğunluğu, bölgede bulunan ulaşım imkanları, bölgede bulunan alt yapı hizmetleri, bölgede kullanılan farklı ulaşım modalarının entegrasyonu gibi farklı kriterlere bağlı bir problemdir. Yer seçiminde dikkate alınması gereken önemli noktalardan birisi de İstanbul Büyükşehir Belediyesinin ön görmüş olduğu atıl alanlardır. Bu çalışmada yapılması planlanan aktarma merkezleri için en uygun yerin belirlenmesi amacıyla Coğrafi Bilgi Sistemleri (CBS) yöntemini içeren bir çözüm yaklaşımı önerilmiştir. İlk olarak imar planı doğrultusunda aktarma merkezi olabilecek askeri araziler incelenmiştir. Bu inceleme doğrultusunda bu arazilerin farklı ulaşım modaları ile entegre puanları yeterli gelmediği görülmüştür. Kısıtlara göre hat puanlarının hesaplarak bulunan yerler ArcGIS programı kullanılarak belirlenmiştir. Bu çalışmanın amacı CBS kullanarak Avrupa ve Anadolu yakasında olmak üzere en yüksek puan alan 3'er aktarma merkezi yerlerini saptamaktır.

Anahtar Kelimeler: CBS, coğrafi bilgi sistemleri, toplu ulaşımda aktarma merkezleri.

1. INTRODUCTION

Cities worldwide are undergoing clear and continuous growth. More than half the world's population today lives in urban areas, and this trend is expected to continue rising. According to Heilig, by 2050, 86% of the global population in developed regions will live in urban areas [1]. Cities today are complex systems, with massive numbers of interconnected citizens, businesses, transport modes, services and utilities [2]. In this context, in Istanbul, one of the largest cities in the world, according to the Transport Master Plan Household Research Report (2006) prepared by the Istanbul Metropolitan Municipality, 15% of trips in Istanbul are car and taxi, 32% are shuttle and bus 2% an important part such as railway, 1% by sea and 49% is made on foot. However, according to the estimates made, it is predicted that if nothing is done, the share of pedestrian transportation will decrease to 26% by 2023, and the share of the car will increase significantly, especially with the increased car ownership. In Istanbul, where almost half of its trips are made on foot and 70% of motorized trips are made by public transportation, the infrastructure of the interchanges between modes of transportation is insufficient in many respects. Metro stations, metrobus stops, bus stops, piers etc. The difficulties experienced in terms of pedestrian transportation in and around the spots also limit the accessibility of these public transportation systems and decrease their preferability. In this context, within the scope of 2014-2023 Istanbul Regional Plan [3] "sustainable transportation and accessibility", it is aimed to expand and encourage both public transportation and pedestrian transportation, to provide a safe and reliable

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journey to the public, and to facilitate public transportation in the transition between modes.

For this reason, Istanbul Metropolitan Municipality has added Istanbul's strategic plans to build interchanges on both the Asian and European sides. In order to find interchange areas, Istanbul Metropolitan Municipality transportation department and IETT geographical systems directorate have carried out a joint study.

In this study, determination of the interchange areas, public transportation standards and a scoring study realized by the Directorate of IETT (Istanbul Electric Tramway and Tunnel Establishments) Geographical Systems and Technologies have been revealed accordingly. As a result of the calculations performed with GIS, a scoring map was created for 12,394 stations in Istanbul. On this map, 3 areas on the Anatolian side and 3 on the European side were identified that can serve as interchange and compared with the vacant areas that can currently be provided by the Metropolitan Municipality of Istanbul.

2. LITERATURE REVIEW OF INTERCHANGE

Interchange can be either the physical action of transferring between services or modes as part of the passenger's journey or it can be the physical location that provides access to the Public Transport system. [4]

The Public Transport Network in the most of the cities, both today and as it evolves, offers a very large number of locations where the passenger can change services. Interchange should not therefore merely be thought of in terms of existing or future purpose built Bus/ Rail/ Interchanges but at all physical locations, however large or small, where the action of accessing the Public Transport network or transferring within it takes place.

An ***intermodal interchange*** is an area destined in a permanent way to facilitate the interchange of passengers between different modes of transport. Such term contains both the concept of the mixing of modes (intermodal) for one journey, and the concept of interchangeability of such modes. The entity which links and successfully operates intermodal at the level of interchangeability is the integration. The integration has an institutional level (ticketing, administration, information services, etc.) and a technical level (connecting the different modes of the network together with the urban environment). [5]

Within interchangeability are two related concepts:

· *Activity (transfer)* - what passengers do when they change between modes and services, include getting to/from the public transport network, could include park and ride, kiss and ride, taxis, bicycles, walk and ride, etc.;

· *Location (space)* - the place where the interchange occurs. This includes railway stations, ports, airports, tram, coach and bus stations ("formal interchange"), or also "informal locations" such as between simple bus or tram stops.

2.1. Classification of Interchanges

Interchanges; they differ in the location, function, size and user profile of the modes with which they connect. Within the scope of these features, different classifications have been made for interchanges. For the C. L. Chen, R. And others; The size of the interchange is dependent on the volume of passenger flow, the types of transport modes that need to be catered to, and the role it plays in a local and regional context. In the PRC, rail stations can be classified into super large, large, medium, small, and basic interchanges. [6]

In a study, the classification made in terms of the size of the centres is as follows; [7]

·*Small interchanges:* These are the areas preferred by the people in remote or local areas to reach the nearest central region in order to carry out their business, education, shopping and daily activities. Small interchanges are usually rail and bus; used for transfers between regional trams and buses.

·*Medium interchanges: Medium* interchanges are areas in small or medium-sized town or city suburbs, where there is usually a change between rail or regional trams and a bus or other mode. Users of these centres usually consist of rare visitors such as local residents and tourists who want to reach larger cities or city centres where they can access other facilities in the region and other facilities in the region.

·*Large interchanges:* Large interchanges show the main transportation points in large towns and cities. It usually includes both the national and urban rail services and the transport network that includes all of the other interchanges, and mostly its users are passengers, tourists, and urban users moving from the suburbs to the centre. Since large interchanges are an important part of the public transportation network, access to these areas and the quality of the area are among the issues that are emphasized.

Within the scope of another research, the classification of the interchanges are given below. [8]

·*Global / Regional interchanges*

Among these transfers are:

-Airports, Intercity bus terminals,

-Train stations covering international / long distance services

These transfers are often located in city centres where several modes of transport meet, and have many constraints, including logistics, geographic, operational and financial, outside the scope of public transportation. [9]

·*Major / Specialised interchanges*

The main interchanges are used in areas where the central business zones are intense and where many modes are present.

-It is generally located in places where the journey ends, such as business centres, rather than where the journey begins.

-There are no parking spaces in the interchanges. Access to these interchanges, which are used for returning to the settlements at the end of day is usually provided by foot, bicycle or other modes of public transportation.

Local interchanges

Local interchanges are used to switch from one bus stop on the bus route used by more than one operator to other modes of transportation, especially underground bus station, sea port, rail system station. Local interchanges appeal to the local community and are often the first area where passengers are physically affected by public transport services before vehicles. Therefore, the physical condition and operational success of the interchange have a significant impact on the perception and use of public transport services provided. [10]

Local interchanges, categorize according to their size or users' access types;

Transfer centres that allow access by bicycle or on foot

- Transfer centres that allow access by local and high frequency buses
- Transfer interchanges that directly access local attractions, such as schools, shopping malls, or event centres.

3. METHODOLOGY

Propose of this study, based upon the scores received by the locations of interchange by means of GIS method. In this study established upon searching by the IETT (Istanbul Electric Tramway and Tunnel Establishments) Directorate of Geographical Systems and Technologies. The determination of the alternative interchange locations was performed using GIS. By means of the technologies used, GIS visualizes database procedures such as querying and statistical analysis and combines them with geographic analyses provided by maps [11]. GIS has two data structures named as vector and raster. Vector data type stores geographical data by coding them according to their coordinate values (x, y). Features are rep- resented as points, lines and polygons (area). Raster data are composed of a series of neighbouring cells formatted in a grid structure. Each cell in a raster data is called a pixel. Compared to vector data, raster data offer a more convenient means for performing certain spatial analyses such as the most suitable location analyses. Therefore, vector data were converted into raster data to be used in this study. Modelling graphic and non-graphic information on a coordinate system and interpretation of the results is named as a spatial analysis in GIS [12]. Bus line score was given to each station up to the number of IETT bus lines passing from the station. Minibus line score was given to each station up to the number of minibus lines located within a distance of 50 meters (walking distance). For each station; IETT bus line score and Minibus line score were added. If the stations intersect with the Rail System station points within a distance of 200 meters, the total line score was multiplied with a coefficient of 2. If the stations intersect with the Metrobus stations within a distance of 200 meters, then the total line score was multiplied with a coefficient of 2. If the stations intersect with the pier points within a distance of 500 meters, the total line score was further multiplied with a coefficient of 2. A schedule was then created by using these criteria and the scores thereof were placed within ArcGIS software. The results obtained reveal the areas where the passenger movements are intensified. Following this section, the next section establishes 6 interchanges with the highest scores as 3 located at the European side and 3 at the Anatolian side and compares those with the lands in possession of the Istanbul Metropolitan Municipality that can serve as interchanges.

4.RESULTS

The Geographical Information System (GIS) as a convenient analysis method producing reliable data is used as an effective means for the planning of an interchange and to produce alternatives in location selection. [13]

4.1. Determination of interchange location by using GIS

In the study conducted with IETT Directorate of Geographical Systems for 12,394 stations; there are tabs for station code, direction of the station, name of the station, direction of the bus, name of the geographical side, county, quarter, longitude and latitude, number of IETT bus lines stopping by the station, number of minibus lines stopping by the station, metrobus score, railed system score, maritime line score, new high-speed train score and the total score.

In Table 1, different indicators between different modes and interchange are calculated. The bus line score up to the number of bus lines stopping by the station and the minibus line score within 50 m walking distance to the station were calculated between the road transport by wheels and the integration of the interchange were calculated accordingly. If the stations within the rail transport system integration intersect with Rail transport system station points within a distance of 200 meters, the total line score is multiplied with 2. If the stations within the metrobus integration intersect with the metrobus stations within a distance of 200 meters, the total line score is multiplied with 2. If the stations within the maritime transport line intersect with the pier points within a distance of 500 meters, the total line score is multiplied with 2.

At the end of this study conducted, when the criteria stated in Table 2 are taken as basis, 3 interchange areas were identified each at the Anatolian side and European side. The interchanges identified are located at the counties of Üsküdar, Ümraniye, Kadıköy. When the traffic density is considered, establishment of interchanges at these locations shall ensure facilitation in the mobility of these passengers. Eminönü, Şirinevler,

Table 1. Selection of interchange location by GIS and criteria thereof

OBJECTIVE	CRITERIA	INDICATOR
Integration of interchange with the road transport by wheels	max. ability to connect with Network	Bus line score up to the number of IETT bus lines stopping by the station.
		Minibus line score up to the number of minibus lines located within a distance of 50 meters (walking distance).
Integration of interchange with the rail transport system		If the stations intersect with the Rail System station points within a distance of 200 meters, the total line score was multiplied with a coefficient of 2
Integration of interchange with the metrobus		If the stations intersect with the Metrobus stations within a distance of 200 meters, then the total line score was multiplied with a coefficient of 2.
Integration of interchange with the maritime transport lines		If the stations intersect with the pier points within a distance of 500 meters, the total line score was further multiplied with a coefficient of 2

Restrictions:

-Unsuitable state of the land

-Vacant lands in possession of Istanbul Metropolitan Municipality

-Planning of a different structure for this area by Istanbul Metropolitan Municipality

Zeytinburnu areas located at the European side are considered to be intense areas in terms of passenger mobility and traffic density. Major interchanges are required to be established at these areas by literature review and based on the applicable conditions of Istanbul and criteria adapted in compliance with the Turkish Standards.

As a result of the calculations performed, a scoring map was created for 12,394 stations. In the scoring map, the spots with the lowest points for the European side and the Anatolian side are shown in blue colour in figure 1 and 2, and it is determined that only bus lines or bus-minibus lines are usually located in these areas.

5. Although it may vary for two sides, the green spots with highest scores than the blue spots indicate different combinations particularly for bus-rail system-minibus and bus-metrobus-minibus lines in figure 1 and 2.

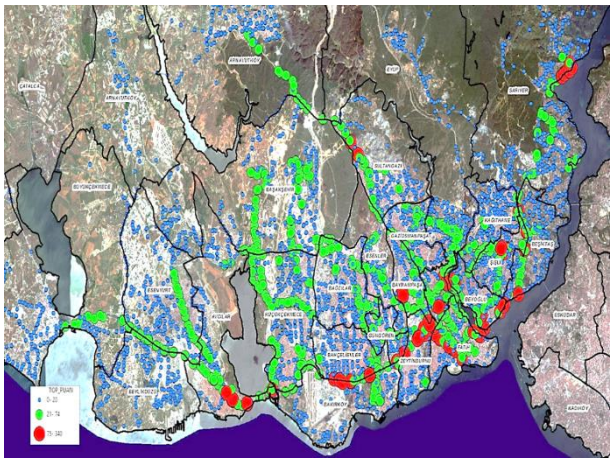

Figure 1. Scoring map of European side transfers

These areas are the ones requiring physical standardization and with the potential of transfer process. The red spots with the highest scores for both sides indicate different intersection points including the rail transport system, metrobus system and maritime transport line systems in particular that form the backbone of the public transportation as well as other transportation modes. The red spots are the areas with the potential of interchanges with the standardized area to facilitate inter-modal access physically or physical facilities.

Table 2. Locations of interchanges at Anatolian aide and European side

ANATOLIAN SIDE											
STATION NAME	**NAME OF THE SIDE**	**COUNTY**	**QUARTER**	**IETT_BUS LINE**	**MINI BUS LINE**	**TOTAL LINES**	**MINI BUS SCORE**	**RAIL SCORE**	**MARITIME SCORE**	**HIGH SPEED TRAIN SCORE**	**TOTAL SCORE**
ÜSKÜDAR MARMARAY	ANADOLU	ÜSKÜDAR	MİMAR SİNAN	32	6	38	1	2	2	1	152
UZUNÇAYIR METROBÜS	ANADOLU	ÜSKÜDAR	ACIBADEM	56	20	76	2	1	1	1	152
GÖZTEPE KÖPRÜSÜ	ANADOLU	ÜSKÜDAR	ÜNALAN	50	16	66	1	2	1	1	132
ALTBOSTANCI	ANADOLU	MALTEPE	ALTINTEPE	10	31	41	1	2	2	1	164
ALTBOSTANCI	ANADOLU	MALTEPE	ALTINTEPE	4	31	35	1	2	2	1	140
ALTBOSTANCI	ANADOLU	MALTEPE	ALTINTEPE	3	31	34	1	2	2	1	136
HAMZA YERLİKAYA	ANADOLU	KADIKÖY	RASİMPAŞA	62	17	79	1	1	2	1	158
ÇARŞI	ANADOLU	KADIKÖY	OSMANAĞA	38	0	38	1	2	2	1	152
ÜSTBOSTANCI	ANADOLU	KADIKÖY	BOSTANCI	12	26	38	1	2	2	1	152
EUROPEAN SIDE											
STATION NAME	**NAME OF THE SIDE**	**COUNTY**	**QUARTER**	**IETT BUS LINE**	**MINI BUS LINE**	**TOTAL LINES**	**MINI BUS SCORE**	**RAIL SCORE**	**MARITIME SCORE**	**HIGH SPEED TRAIN_ SCORE**	**TOTAL SCORE**
EMİNÖNÜ	AVRUPA	FATİH	RÜSTEMPAŞA	47	66	113	1	2	2	1	452
EMİNÖNÜ	AVRUPA	FATİH	RÜSTEMPAŞA	7	66	73	1	2	2	1	292
EMİNÖNÜ	AVRUPA	FATİH	RÜSTEMPAŞA	5	66	71	1	2	2	1	284
ŞİRİNEVLER	AVRUPA	BAHÇELİEVLER	ŞİRİNEVLER	50	35	85	2	2	1	1	340
ŞİRİNEVLER	AVRUPA	BAHÇELİEVLER	ŞİRİNEVLER	8	50	58	2	2	1	1	232
BAHÇELİEVLER	AVRUPA	BAHÇELİEVLER	BAHÇELİEVLER	44	7	51	2	2	1	1	204
ŞİRİNEVLER	AVRUPA	BAHÇELİEVLER	ŞİRİNEVLER	50	35	85	2	2	1	1	340
ŞİRİNEVLER	AVRUPA	BAHÇELİEVLER	ŞİRİNEVLER	8	50	58	2	2	1	1	232
BAHÇELİEVLER	AVRUPA	BAHÇELİEVLER	BAHÇELİEVLER	44	7	51	2	2	1	1	204
ŞİRİNEVLER	AVRUPA	BAKIRKÖY	ATAKÖY 7-8-9-10. KISIM	49	35	84	2	2	1	1	336
BAHÇELİEVLER	AVRUPA	BAKIRKÖY	ZUHURATBABA	43	0	43	2	2	1	1	172
ŞİRİNEVLER	AVRUPA	BAKIRKÖY	ATAKÖY 7-8-9-10. KISIM	8	34	42	2	2	1	1	168

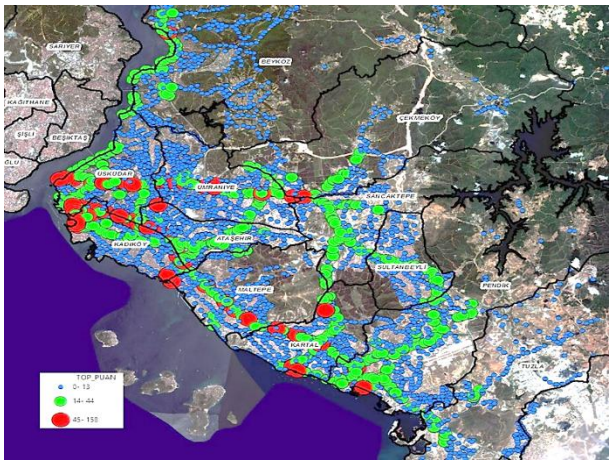

Figure 2. Scoring map of Anatolian side transfers

The score of the bus stations located at the European side is indicated on the following map and the scoring map reveals the interchange areas required.

In this study conducted, integration analysis of physical areas of different modes within the system wa s revealed and the intersections of the bus-stops, piers and stations on the lines based on the mode were reviewed accordingly. As a result of the study conducted within the framework of a specific methodology, 144 red colour areas, 1,374 green colour areas and 10,877 blue colour areas were determined according to the map indicating physical area analyses within Istanbul public transportation system.

5.CONCLUSION

In this case study the approach is executed by using a raster-based GIS data layer. It is proven that DSS using a combination of GIS data, urban model and a computer presentation technique is an effective means for the improvement of planning decisions [14]. By combining the spatial data, Spatial Decision Support System (SDSS) structure and information access enables the "real" visualization of the world and supports the relevant decision-making skills for the planning with respect to analysis, forecast and development[15].

For the selection of the location of the interchange, the number of minibus lines, number of bus lines, the connection of the interchange with the rail transport system, metrobus system, fast-ferry shall be predicated upon. Based on these criteria, Eminönü is among other areas with the number of rail transport system and maritime transport system and total number of lines. Due to the high traffic volume of this area, congestion charge is required to be applied for the vehicles, also park and ride spots should be available at the vicinity of this area that is more convenient to be arrived at by public transportation. When the density of people and the structure of the topography are considered, an underground interchange shall be more convenient to be established at this area shown in the figure3.

Figure 3. Eminönü interchange location

Şirinevler is another area for the establishment of a interchange for the European side. When scoring is performed based on the same criteria, the stations located at Ataköy and Şirinevler closest to the area have the highest score. Passenger intensity and traffic density are at highest levels at this area in where metrobus and rail transport systems are located. An underground interchange is required to be established at this area to cover the Ataköy and Şirinevler stations. By this means, ease of access to the subway and metrobus shall be ensured accordingly. The passengers, by means of park and ride parking lots, shall be able to proceed with their transport processes by public transports after this area shown in the figure 4.

Figure 4. Sirinevler- Atakoy interchange location

Cevizlibag is the next location for the establishment of interchange designed as the third one located at the European side. Due to the fact that there is a rail transport system located at this region and it is connected with the metrobus system and they are considered as highly populated regions, it is necessary to establish a interchange between Topkapı and Cevizlibağ shown in figure5.

Figure 5. Topkapi and Cevizlibag interchange location

The areas selected at the Anatolian side are calculated by taking the same criteria as basis. The area at Üsküdar where the Marmaray (rail transportation system through a tunnel beneath the Bosporus) station is located received high score due to the existence of the rail transport system and in terms of distance to the sea. In case of establishment of a interchange on this area, the passengers shall be able to access to the European side by public transportation or to the Anatolian side shown in the figure 6.

Figure 6. Uskudar interchange location

Kadıköy area at the Anatolian side is among the areas with the highest scores. It is among the areas with the highest passenger volume due to the maritime transport facilities of Kadıköy and numerous bus lines. The establishment of an underground interchange shall ensure the moderation of the transportation at this area shown in figure 7.

Figure 7. Kadikoy interchange location

Another area located at the Anatolian side is Maltepe (Altbostancı). Again, due to the maritime and rail transport facilities at this area, this area is among the ones that can enjoy the facilitation and moderation of the transportation to be provided by the interchange shown in the figure 8.

Figure 8. Maltepe interchange location

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Neslihan İNCİRCİ: Performed the experiments, analyse the results and wrote the manuscript.

İsmail EKMEKÇİ: Performed the experiments and analyse the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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