Research Article / Araştırma Makalesi

EVALUATION OF PARK AND RIDE FACILITIES IN ISTANBUL USING GEOGRAPHIC INFORMATION SYSTEMS (GIS)

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ABSTRACT

The economic growth affects the transportation in such a way that causes traffic problems as well as congestion especially for developing countries. Many different parameters caused the traffic congestion such as insufficient transportation, network infrastructure, network capacity, unexpected increase in traffic demand, unplanned and rapid urbanization, and failure in use of the existing capacity. Essentially, integration of various mode is important to handle the high traffic demand. Park and Ride (PnR) facility is an important application in urban transport planning, that have public transportation priority, because it integrates the private car and public transportation to decrease traffic congestion and the environmental effect of traffic within the downtown. Istanbul Metropolitan Municipality affiliates ISPARK operated PnR facilities in Istanbul. This study examines PnR facilities located in Istanbul using Geographic Information System (GIS). These PnR facilities are classified according to their capacity, connected public transport mode (bus, subway, and maritime) and turnover rates. PnR facilities are evaluated using GIS with these parameters and recommendations are presented for PnR facilities location and integration with other transportation systems.
Keywords: Parking Lot, Park and Ride (PnR), public transportation, GIS.

COĞRAFİ BİLGİ SİSTEMLERİ (CBS) KULLANILARAK İSTANBUL PARK-ET DEVAM-ET TESİSLERİNİN DEĞERLENDİRİLMESİ

ÖZ

Trafik sıkışıklıklarının oluşma sebepleri yetersiz ulaşım ağı, kapasitenin yeterli oranda kullanılamaması, plansız olarak hızlı büyüme, özel araç kullanımına olan talebin yüksek olması gibi birçok farklı parametreye bağlı olmakta ve ekonomide oluşan hızlı büyüme ulaşım problemini de beraberinde getirmektedir. Yoğun ulaşım talebinin karşılanabilmesi için farklı ulaşım türlerinin entegre edilmesine gereksinim duyulmaktadır. Toplu taşıma öncelikli kentsel ulaşım planlarında kullanılan uygulamalardan biri de "Park Et-Devam Et - PnR" tesisleridir. İstanbul'da toplu taşıma sistemi ile özel araçların entegre olduğu noktalarda bulunan park-et devam-et tesisleri İstanbul Büyükşehir Belediyesi iştiraki İSPARK tarafından işletilmektedir. Bu çalışmada, Coğrafi Bilgi Sistemi (CBS) kullanılarak, İstanbul'da bulunan PnR tesisleri incelenecektir. Söz konusu tesislerin kapasite, entegre olduğu toplu taşıma sistemi, devinim gibi farklı parametrelere göre sınıflandırmaları yapılacaktır. Elde edilen sonuçlara göre, PnR tesislerinin kapasite, devinim, entegre olduğu toplu taşıma sistemi ve konumuna bağlı olarak değerlendirmeleri yapılarak ileriye yönelik, PnR tesislerine ilişkin öneriler sunulacaktır.
Anahtar Sözcükler: Otopark, Park Et-Devam Et, toplu taşıma, CBS.

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1. INTRODUCTION

Economic growth brings with transportation problems and traffic congestion for developing counties because of increasing household income, car ownership and the trip rates. Various parameters caused traffic congestion such as insufficient transportation network infrastructure together with unplanned and rapid urbanization, and failure in use of the existing capacity. With growing economies surging up household income, car ownership and car trip rates, this situation requires improvement in transportation network infrastructure. Failure to meet this requirement may cause the traffic congestion.

Traffic congestion is one of the most important problems based on a particular survey for Istanbul just like other metropole cities all over the world. For the purpose of decreasing traffic congestion, public transportation is encouraged with different applications, such as traffic calming, ITS applications like Advanced Traveler Information, Managed Lane, etc. and without increasing capacity of the roadway when it is not possible to implement sometimes because of urbanization. PnR facility is an important application in transit system priority for urban transportation and design. In this application, convenient segments determined for car parks with public transportation system in which various public transit modes are available to transfer by walk. These segments involve parking lots that are safe for drivers' vehicle and they are free or low costed. Personel car drivers can park their vehicles at these parking lots and ride to the transit mode with the aim of completing the travel. In this way, drivers avoid stress caused by traffic, reduce the fuel consumption and reach the destination in a short period of time.

Istanbul Metropolitan Municipality affiliates ISPARK operated PnR facilities in Istanbul. In this study we evaluate the PnR facilities located in Istanbul using Geographic Information System (GIS). These PnR facilities have been classified according to their capacity, connection with transit mode (bus, subway, maritime) and turnover rates. PnR facilities are evaluated using GIS with these parameters, and recommendations are presented for PnR facilities location and integration with other transportation systems.

2. GEOGRAPHIC INFORMATION SYSTEM (GIS) in TRANSPORTATION SYSTEMS

Geographic Information System (GIS) is a decision-support system that involves analysis methods for storage, as well as showing and managing modelling of spatial data. In this system, all kind of data are associated with each other and spatial information. Data sets can be formed in computer or mobile applications and can be presented in hard copy. Also this data set can be recorded in dB (database) format and this format allows individuals to reuse as well as to change old data set [1].

Geographical Information Systems are based on the observations of the location information obtained from the non-graphic and graphic collection, storage, processing and presentation to the user that performs the functions of an information system with integrity [2]. Computer hardware, software, human resource and methods must be organized to obtain all kinds of geographic information. The basic components of Geographic Information System are shown in Figure 1 [3].

Figure 1. The basic components of Geographic Information System [3]

Besides GIS is used for management and planning in Intelligent Transportation Systems (ITS). Designing and planning highway, highway construction management, road safety analysis, ITS systems about reducing traffic congestion and regulating traffic flow, fleet management, vehicle tracking and optimal route planning, the planning of sea and rail transportation are subjects that can be referenced by GIS [4].

Intelligent Transport System Applications used Geographical Information System are outlined as follows; Traffic Intensity Map, Mobile Information System, Online Intersection Control System, Traffic Incident Management System, Public Transportation Management System and Passenger Information System.

3. PARK AND RIDE FACILITY

"Park and Ride" facilities are often integrated or embedded in urban transport plans based on sustainable transport systems. With these implementations, reliable, free or low price parking areas are built in important transfer points located outside of the city center. It can be possible to enter the city center by public transportation system after arriving and parking private cars to this transfer points [5].

PnR facilities serve as transfer between transportation types such as car to bus, to ferry, to metro, to tram and to other mass transit modes. When PnR facilities are planned carefully and integrated with other transportation modes, traffic congestions and harmful gases (such as carbon) can be decreased and trips can be shifted from individual to public transportation. PnR facilities are used by pedestrians and riders as well as car users as transfer point [6]. The transportation options of PnR facilities for Istanbul is shown in Figure 2.

Park & Ride Applications provide some benefits such as; Promoting Public Transport, less harmful exhaust emission, less global warming effect (CO_2 emission) and less fuel consumption, less road occupation, less motor vehicle-oriented stress, saving time in traffic, more opportunity of circulation in roadside parking and economic development [7].

Figure 2. "Park & Ride" options

4. PARK AND RIDE FACILITIES AT ISTANBUL

Within this study, it was analyzed that the daily usage rate of PnR and the capacity of total 43 parking facilities that are 16 in Anatolian side and, 27 in European side in Istanbul for 3 years of records (2013, 2014, and 2015). Capacity of parking lots that are evaluated are given in Table 1 and also the location of parking lots by the highway network are shown in Figure 3.

Table 1. Parking lots analyzed and their capacities

| Parking Lots	Capacity	Parking Lots	Capacity
Old Salı Bazaar	760	Samatya Seaside	73
Kartal 1 - İdo	90	Avcılar İdo	200
Bostancı Open Parking	375	Zeytinburnu Metro Station - Çırpıcı	100
Pendik İdo	92	Bakırköy İdo Pier	145
Maltepe İdo	250	Tatlıcı Kuleleri	100
Kadiköy İski	1000	**Maslak P+R**	**140**
Tuzla İdo Pier	200	Cemal Kamacı Open Parking	50
Acıbadem P+R Open Parking	**85**	Levent Metro Underground Parking	100
Çengelköy Open Parking	1300	Atatürk Airport Street	104
Sabiha Gökçen P+R	**1250**	Darüşşafaka Underground Parking	120
Gülsuyu Metro Underground Parking	100	Hacıosman Metro Underground Parking	427
Kadıköy Marriage Department	160	**Ataköy Metro Metro Station P+R**	**66**
Maltepe Küçükyalı P+R	**90**	**Tüyap P+R**	**320**
Üsküdar Ünalan Open Parking	230	Old İETT Garage - 2	125
Soğanlık Metro Open Parking	500	Bağcılar Meydan Mosque	100
Kadıköy Marmaray Open Parking	400	Bağcılar Meydan Hospital	100
Yenikapı İdo Open Parking	300	Kazlıçeşme Marmaray Open Parking	700
Menekşe Beach	235	Kazlıçeşme Marmaray Large Parking	2000
Güneş Beach 1	260	Kirazlı Metro Station	200
Güneş Beach 2	135	Esenler Menderes Metro Station	69
Kabataş Pier	39	Yenikapı Marmaray Small Parking	60
		Yenikapı Marmaray Large Parking	300
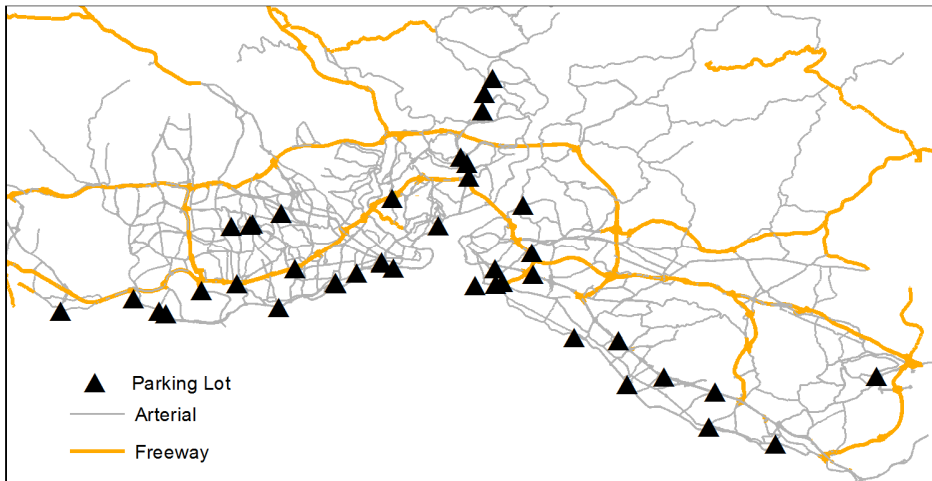
Figure 3. Location of parking lots

Furthermore, it was plotted the location of the parking lots with an existing railway network in Figure 4. As can be seen from the Figure 4, parking lots are located close to the seaside, in other words they are placed in the residential and the commercial areas.
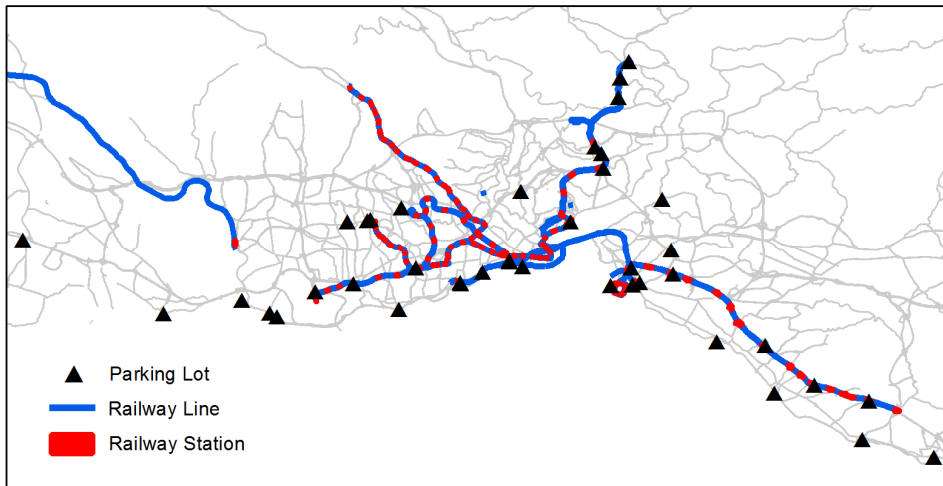

Figure 4. Location of parking lots by railway lines and stations

5. EVALUATION

About the usage of the parking lots, the parking turnover rates, that is the ratio of number of vehicles parked in a day to the number of parking lots available, was calculated for each day. That gives the number of different vehicles using a parking lot in a day [8] (1).

$$parking\ turnover = \frac{parking\ volume\ in\ a\ day}{number\ of\ available\ parking\ lots} \text{(vehicle/day/parking)} \qquad (1)$$

For this study, average parking turnover rates were calculated separately for weekdays and weekends in 2013, 2014 and 2015. Turnover rates based on the location for weekend and weekday are respectively presented in Figure 5 and in Figure 6 for 2015 and, the exact numbers are given in Table 2. Hence, average turnover value on a daily basis for most of parking lots has increased from 2013 to 2015.
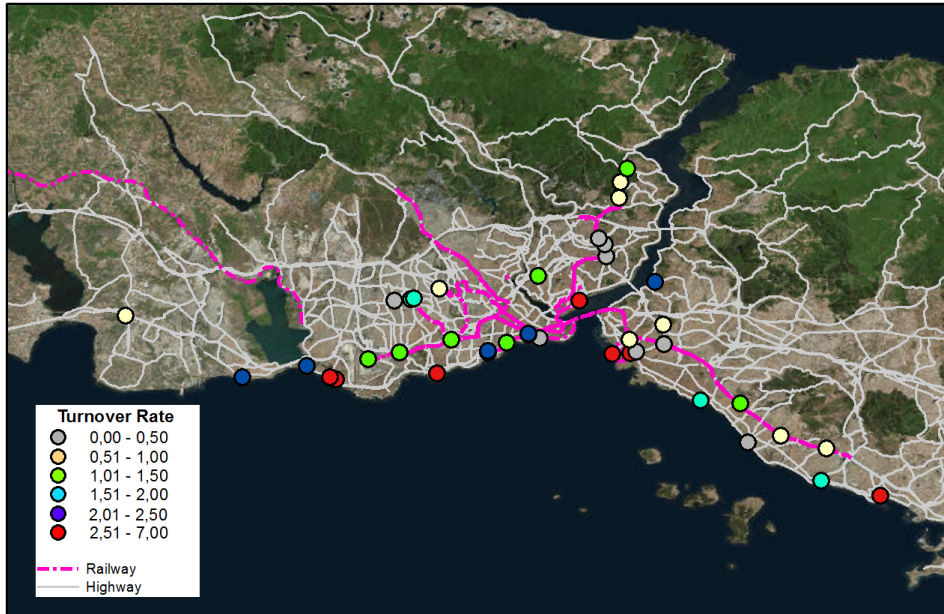

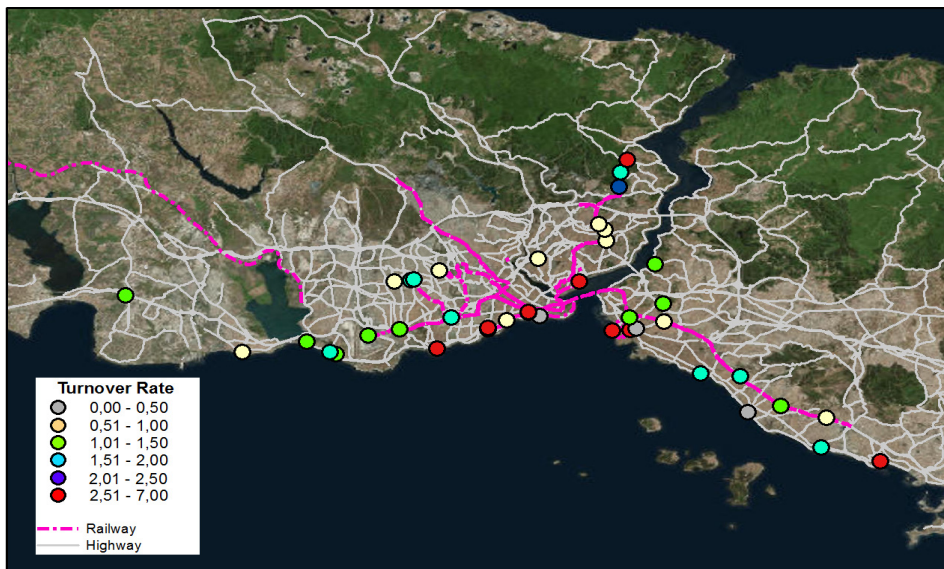**Figure 5.** Turnover rates of parking lots for weekends

Figure 6. Turnover rates of parking lots for weekdays

When Figure 5 and Figure 6 are analyzed, it would be seen that parking areas that are around railway lines have higher turnover rates for weekdays than weekends. Also, there is not any significant difference between weekdays and weekends in terms of turnover rates for locations like Kadıköy, Kartal and Bakırköy that have mixed land use.

As it is shown in Table 2, Bakırköy İdo Pier parking area has maximum turnover rates. Also, Pendik İdo and Kadıköy İski parking areas have large turnover rates after Bakırköy İdo Pier. Although Kazlıçeşme Marmaray Large Parking has maximum capacity, this area has minimum turnover rates and minimum capacity utilization rates.

Kazlıçeşme and Kadıköy PnR facilities, which are sited beside the terminal stations of Marmaray, Old Salı Bazaar and Levent Metro station, are analyzed in details. Then, average turnover rates for these PnR facilities are shown in Figure 7 as of weekdays and weekends for 2015.
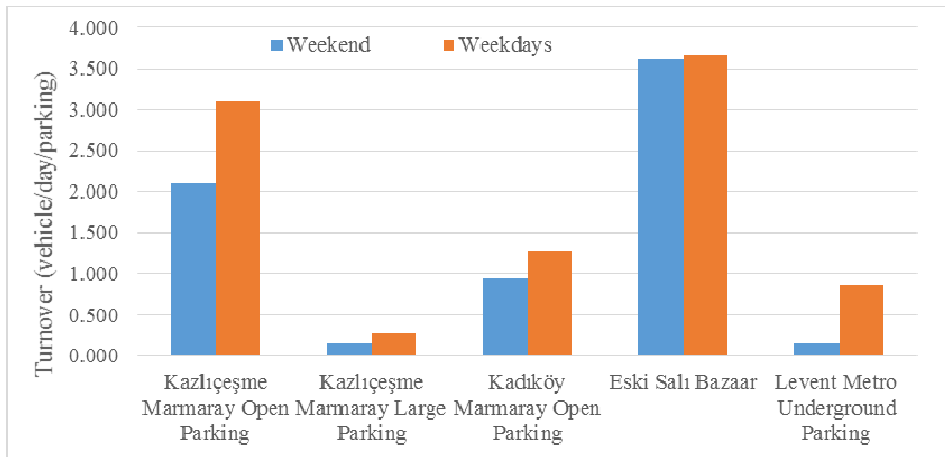

Figure 7. Turnover rates of selected PnR facilities for weekdays and weekends in 2015

Average turnover rates of Kazlıçeşme and Kadıköy parking lots, which are located in terminal stations of Marmaray, are shown as monthly for weekday and weekends in Figure 8 and Figure 9 respectively for 2014. As can be seen in the figures, after the opening of the Yenikapı metro connection, which is a transfer point for Marmaray railway line to Taksim-Hacıosman (M2) metro line in 3rd month of 2014, average turnover rates practically doubled for Kazlıçeşme Marmaray open parking lots. Opening of the Yenikapı metro connection has encouraged the private car users to use the M2 metro line with PnR facility. So, Kazlıçeşme Marmaray open parking area has been a good example for the use of a PnR facility. Also, average turnover rates of Kadıköy Marmaray open parking area, opened in 3rd month of 2014, has increased. However, Kazlıçeşme Marmaray large parking area, opened 6th month of 2014 to satisfy the increasing demand, has not been demanded because of its far location from the metro station. On the other hand, average turnover rates have decreased for weekend in summer.

Table 2. Daily turnover rates for weekdays and weekends

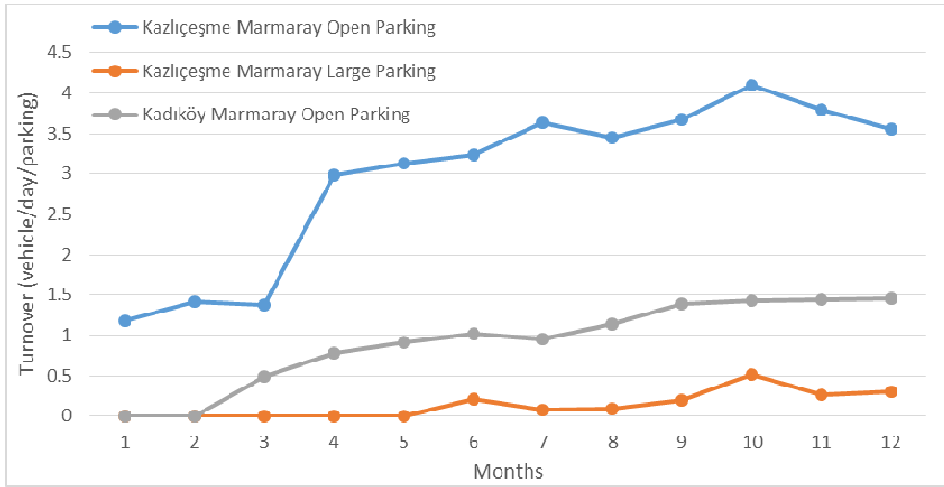| Parking Lots	Weekends			Weekdays		
	2013	2014	2015	2013	2014	2015
Old Salı Bazaar	2,993	3,624	3,621	2,737	3,843	3,663
Kartal 1 – İdo	1,445	1,777	1,982	1,419	1,605	1,759
Bostancı Open Parking	0,989	1,458	1,543	1,151	1,735	1,637
Pendik İdo	3,628	5,187	5,533	2,606	4,093	4,138
Yenikapı İdo Open Parking	1,816	2,581		1,687	2,249	
Menekşe Beach	1,763	2,893	2,425	1,096	1,710	1,239
Güneş Beach 1	1,877	2,191	3,125	0,572	0,844	1,050
Güneş Beach 2	2,543	3,308	4,127	1,360	1,850	1,812
Kabataş Pier	2,162	2,226	2,562	2,356	2,261	2,724
Samatya Seaside	0,961	0,957	1,007	0,521	0,638	0,644
Avcılar İdo	1,125	1,384	2,154	0,553	0,728	0,933
Kadiköy İski	2,370	4,146	4,286	2,043	3,445	3,400
Zeytinburnu Metro Station – Çırpıcı	0,989	1,342	1,424	1,352	1,793	1,852
Bakırköy İdo Pier	5,671	7,527	6,982	5,389	6,929	5,834
Tuzla İdo Pier	0,894	1,910	4,255	0,641	1,204	2,203
Acıbadem P+R Open Parking	0,771	0,752	0,903	0,984	0,975	1,120
Tatlıcı Kuleleri	0,277	0,233	0,191	1,169	1,109	0,966
Kadıköy Marriage Department	1,556	2,335		1,929	3,338	
Maslak P+R	0,526	0,835	0,846	1,333	2,425	2,242
Cemal Kamacı Open Parking	2,235	0,953	1,161	1,805	0,972	0,981
Levent Metro Underground Parking	0,152	0,116	0,139	0,450	0,601	0,851
Atatürk Airport Street	0,670	1,098	1,236	1,546	1,331	1,356
Darüşşafaka Underground Parking	0,528	0,501	0,924	1,018	1,138	1,547
Çengelköy Open Parking	0,963	1,977	2,393	0,663	1,281	1,470
Hacıosman Metro Underground Parking	0,750	1,325	1,345	1,805	3,064	2,931
Sabiha Gökçen P+R	0,177	0,399	0,465	0,202	0,540	0,701
Ataköy Metro Station P+R	1,084	1,226	1,299	1,503	1,597	1,472
Gülsuyu Metro Underground Parking	0,100	0,404	0,534	0,172	0,925	1,286
Tüyap P+R	0,283	0,440	0,604	0,604	0,874	1,090
Maltepe Küçükyalı P+R	0,578	1,132	1,167	1,094	1,553	1,712
Old İETT Garage – 2	0,154	0,304	0,266	0,593	0,703	0,792
Bağcılar Meydan Mosque	1,346	1,761	1,944	1,171	1,655	1,783
Bağcılar Meydan Hospital	1,045	1,421	1,789	1,282	1,778	1,992
Kazlıçeşme Marmaray Open Parking	0,632	1,642	2,098	0,627	2,403	3,099
Kirazlı Metro Station	0,273	0,253	0,438	0,337	0,325	0,574
Esenler Menderes Metro Station		0,963	0,967		0,852	0,913
Üsküdar Ünalan Open Parking		0,433	0,467		0,770	0,710
Soğanlık Metro Open Parking		0,465	0,539		0,734	0,770
Kadıköy Marmaray Open Parking		0,774	0,936		0,988	1,274
Kazlıçeşme Marmaray Large Parking		0,107	0,150		0,149	0,280
Yenikapı Marmaray Small Parking		1,160	2,166		1,861	2,717
Yenikapı Marmaray Large Parking		0,825	1,531		1,234	2,350

Figure 8. Monthly turnover rates of selected parking lots for weekdays in 2014
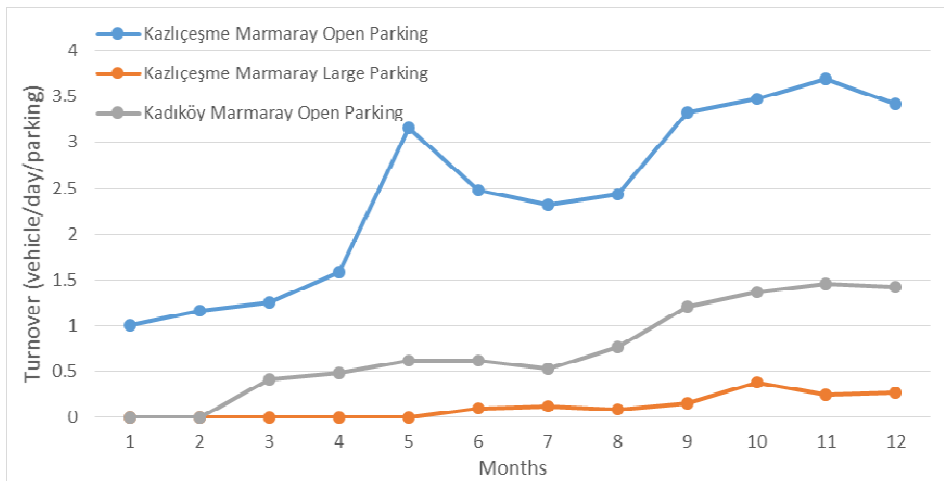

Figure 9. Monthly turnover rates of selected parking lots for weekend in 2014

6. CONCLUSION

In this study, relationship between PnR facilities and transportation network are analyzed by using GIS tool for Istanbul. Obtained results are listed below.

- Average turnover rates are higher for parking lots, which are located close to railway lines and also away from the commercial activities in weekdays.
- Average turnover rates are almost the same in parking lots, which are located in mixed land use or have different activities like commercial, shopping and cultural.
- Walking distance between parking lots and the station has a major effect on the turnover rates like the case of Kazlıçeşme Marmaray large parking lots.
- When monthly change in turnover rates is analyzed, the highest turnover rates are

observed in September, October, November and December.

- While the estimation of demand for PnR facility is done, relationship between parking lots and public transportation systems should be considered as well as the land use.
- Facilitating access to the central business district with transfer of metro lines, has increased the use of PnR facilities at these locations.
- Parking areas that are located close to the central business district have large average turnover rates.
- When PnR options is compared according to turnover rates, PnR facilities that have "PnR with ferry" opportunity (such as Bakırköy İdo Pier, Pendik İdo) has greater turnover rates.

As a result, transit ridership would be increased by some consideration, such as; facilitating access from PnR facilities to transfer points, providing use of PnR facilities within only their purposes and correspondingly implementing a discount in transfer fee, promoting access to the central business district with transfer of metro lines and also introducing PnR facilities in proper location.

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