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ENHANCING URBAN SUSTAINABLE MOBILITY: A BINARY LOGISTIC REGRESSION APPROACH TO MODELLING CYCLISTS' BEHAVIOUR

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Abstract

Urban mobility is a critical aspect of modern city life, and the integration of sustainable transportation modes, such as cycling, has gained prominence. However, in Izmir, a vibrant city in Turkey, there are limited cycling routes, which poses a challenge for cyclists. This study aims to model the behaviour of individuals who choose to cycle in İzmir despite the lack of proper infrastructure, particularly focusing on their interaction with public transportation. To achieve this, we employ binary logistic regression to analyse the factors influencing individuals' decision to combine cycling with public transportation. Variables considered include travel distance, travel purpose, bike use frequency, socioeconomic factors, and the availability of alternative transportation options. The dataset is derived from surveys conducted among cyclists in İzmir, capturing their preferences, challenges faced, and motivations for choosing this unconventional mode of transportation. 539 (27%) out of 1982 survey data were found to use bicycles and public transportation together. Despite the absence of dedicated bicycle lanes, a significant number of individuals prefer cycling in conjunction with public transportation, suggesting a latent demand for improved cycling infrastructure. In the preliminary findings, it has been determined that the purpose of travel has a significant impact on the co-use of cycling and public transportation. Individuals using bicycles to commute to work or school are more likely to combine cycling with public transportation compared to those using bicycles for leisure or shopping. The frequency of bicycle use also has a notable effect on the co-use of cycling and public transportation. Individuals who regularly use bicycles have a higher likelihood of combining cycling with public transportation compared to those who rarely use bicycles. This research provides a foundation for evidence-based urban planning, aiming to enhance the overall quality of life and contribute to the development of cyclist-friendly cities.

Keywords: bicycle, bike users, intermodality, public transportation and bike, sustainable transportation systems

1 Introduction

Sustainable transportation is a system where accessibility and quality are prioritized, multimodality is emphasized, intermodal integration is achieved, all costs are considered in planning, more realistic and visionary plans are made, and transportation demand is effectively managed. Bicycles are an integral component of sustainable transportation systems. As an environmentally friendly and energy-efficient mode of transportation, bicycles offer numerous advantages. Firstly, due to their reliance on human power, bicycles eliminate dependence on fossil fuels, thereby contributing to a reduction in greenhouse gas emissions.

This environmental benefit contributes to improved air quality and aids in the fight against climate change [1]. According to [2] well-designed transportation systems should meet the needs of mobility and individuals while also providing safe and environmentally friendly transportation options. Therefore, the design, integration, and accessibility of transportation systems are of great importance [2]. When a transportation system is properly planned and managed, it can enhance a community's productivity and quality of life while also stimulating the development of transportation demand. Environmental protection requirements already implemented by local authorities also encourage improvements in existing systems [3].

The use of bicycles has steadily increased in recent years, which is a positive development due to its promotion of a healthy lifestyle, environmental friendliness, and reduction of traffic congestion. However, enhancing bicycle safety is of great importance for further promoting the widespread use of bicycles. Bicycle usage is typically designed for short-distance trips with an average intended travel length of 15 - 25 minutes or approximately 5 km. Bicycle systems are designed to fill the gap in urban transportation networks between walking and public transportation/car travel, where distances are too far to walk but also not worth waiting for public transportation systems or bearing the cost of a car journey. Shared bicycle journeys exceeding 10 kilometers are becoming more common in conjunction with public transportation [4].

When bicycle systems are widespread and more accessible in urban areas, it has been found to have a positive effect on mode shift between private vehicles, public transportation, and bicycles. [5] have suggested that the proliferation of shared bicycle systems in cities leads passengers to move away from crowded buses during peak hours [5].

The integration of bicycle systems with public transportation systems plays a pivotal role in fostering sustainable urban mobility. By providing seamless connectivity between these two modes of transportation, cities can offer commuters greater flexibility and accessibility in their journeys. This integration facilitates first-mile and last-mile connections, enabling commuters to conveniently access public transportation hubs from their starting point and reach their final destination from the public transportation stop (Figure 1). Moreover, it encourages a modal shift away from private car usage, thereby reducing traffic congestion, greenhouse gas emissions, and air pollution.

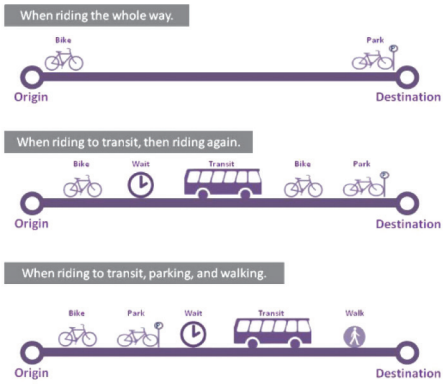

Figure 1 Bicycle systems integrated with public transportation systems

Urban mobility serves as a fundamental aspect of contemporary urban life, where sustainable transportation modes occupy a central position in efforts to promote eco-friendly and efficient commuting practices. Nonetheless, Izmir, Turkey, a dynamic urban centre, faces a distinct challenge characterized by a scarcity of designated cycling infrastructure, thereby presenting a significant obstacle for cyclists navigating its bustling streets.

This study undertakes an examination of the intriguing behavioural patterns observed among individuals who opt for cycling in Izmir despite the conspicuous absence of adequate infrastructure. Of particular interest is the intricate interplay between cyclists and public transportation systems, aiming to unravel the underlying dynamics propelling this unconventional mode choice. Ultimately, this research endeavours to establish a foundation for evidence-based urban planning initiatives poised to enhance the overall quality of life and contribute tangibly to the development of cities that actively accommodate and promote cycling within their urban fabric.

2 Methodology

Izmir is one of the cities located in the Aegean Region of Turkey. It is the third most populous city in the country. It is one of the leading cities economically, historically, and socio-culturally. Its population is 4,462,056 people as of 2022 [6].
As of 2020, there are approximately 55 km of designated bicycle lanes throughout Izmir city under the Izmir Metropolitan Municipality. Bicycle parking areas are an integral part of the bicycle transportation network. There are 127 bicycle parking areas located at various points in Izmir city, with a total capacity of 1,664 bicycle parking spots [7]. Currently, the designated bicycle lanes are limited to the coastline. In the city, there are 103 km of bicycle lanes planned in the short term and 248 km planned in the long term (Figure 2).
Existing cycling routes start from the north of the city and extend southwards along the coastline. Apart from the city centre, there are also bicycle lanes in suburban areas. The bicycle lanes in these districts are not continuous and do not cover the entire district. Bicycle lanes do not connect to activity centres such as transfer centres, hospitals, stadiums, terminals, universities, bazaars, shopping centres and city centres.

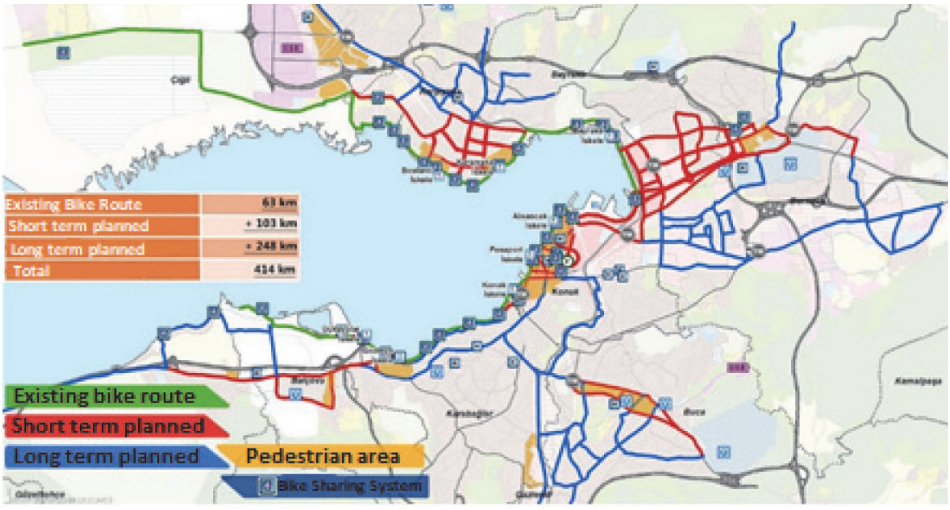

Figure 2 Map of Existing and Planned Bicycle Lanes in Izmir City [7]

Among the defined bicycle routes throughout the city, the length of bicycle lanes and curb-raised bicycle lanes is higher than other road types. Divided bicycle lanes with Barrier, bicycle crossings, bicycle bridges, which are shared by bicycles and pedestrians, are concentrated in Alsancak Harbour, Bayrakli, Turan and Karsiyaka regions, and their approximate length is 6 km (Table 1).

In the city of Izmir, bicycle user surveys were conducted in two periods, namely the summer and autumn seasons, between 2018 and 2019. It was assumed that the number of bicycle users could vary seasonally, and thus, two separate studies were conducted for periods when schools were open and closed. A total of 1982 surveys were conducted. The survey data from bicycle users consists of demographic and socioeconomic information. In face-to-face interviews with users, in addition to socioeconomic and demographic characteristics such as age, gender, occupation, education level, and vehicle ownership, information regarding the purpose of the journey, frequency of bicycle use, whether public transportation was used during the journey, journey distance, and reasons for choosing the bicycle were also obtained.

Table 1 Bicycle Road Types and Lengths in Izmir [7]

Road type	Lengths [km]
Separated Bicycle Lane with Separator	4,5
Divided Bicycle Lane with Barrier	3,3
Bicycle Crossing	1,3
Bicycle Bridge	1,8
Bicycle Lane	29,9
Curb Raised Bicycle Lanes	14,1
Total	55

The users are analysed in terms of gender; most of them are male (%75). Women are mostly between the ages of 20-30, male users are mostly over the age of 45 (Figure 3). The vehicle ownership rate is 65%.
Among bicycle users, the income distribution is as follows: below minimum wage constitutes (8%), 17,000 (minimum wage) - 30,000 TL (Turkish Liras) constitutes (30%), 30,000-50,000 TL constitutes (45%), 50,000-100,000 TL constitutes (14%), and over 100,000 TL constitutes (%3) (Figure 3).
The occupational distribution of bicycle users is as follows: 39% are from the private sector, 36% are students, 14% are retired, 8% are public sector employees, and 3% are unemployed. Users trip for recreational purposes at a rate of 51%, for work purposes at a rate of 27%, for school purposes at a rate of 16%, and for other purposes at a rate of 6%. The daily usage rate of bicycles is 33%, while the usage rate of 4-5 times a week is 19%, 2-3 times a week is 36%, 1-2 times a month is 9%, and 1-2 times a year is 3% (Figure 4).

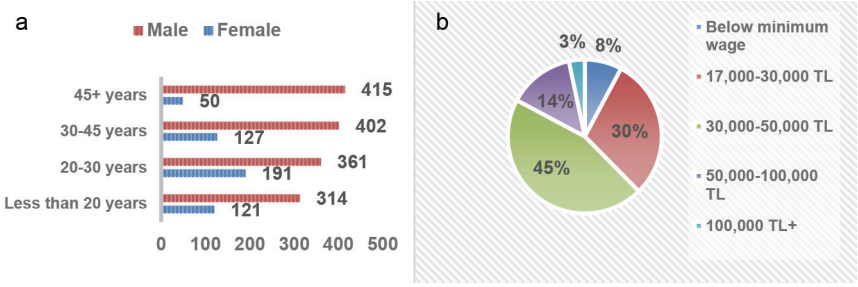

Figure 3 Gender-Age (a) and Income (b) Distribution

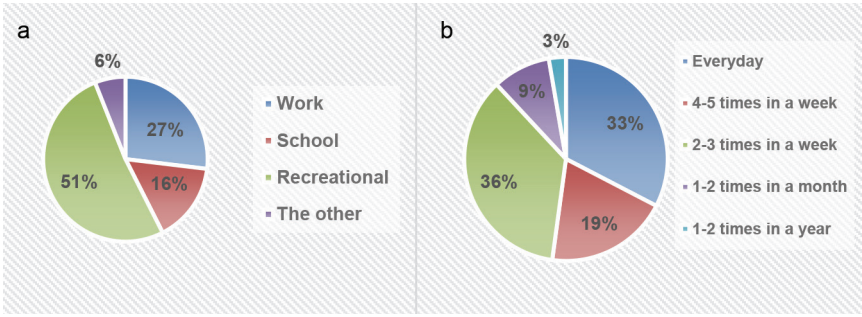

Figure 4 Travel Purpose (a) and Bike Use Frequency (b) Distribution

2.1 Binary logistic regression

In the Binary Logit model, the categorical dependent variable is dichotomous, representing two outcomes: the occurrence of an event (y = 1) and its non-occurrence (y = 0), displaying a special case of the binomial distribution for n = 1 known as the Bernoulli distribution. In the Bernoulli distribution, the probability of the event occurring is expressed as P (y = 1) = n, and the probability of non-occurrence is expressed as P (y = 0) = 1 - n [8].

The advantage of binary choices is that they enable the development of practical models that are more suitable for complex choice scenarios [9]. In this study, the binary logit model has been established using the NLOGIT program. In the binary logit model, the dependent variable is the use of public transportation systems during bicycle journeys, while the independent variables include age, gender, car ownership, purpose of the journey, frequency of bicycle use, and income (See Table 2).

Dependent variable	**Public Transportation Use**
Log-likelihood function	– 919.49198
Restricted log-likelihood	– 1159.83922
Chi-squared [11 d.f.]	– 480.69448
Significance level	– 0.00000

McFadden Pseudo R-squared = 0.2172246
Estimation based on N = 1982, K = 12
Inf.Cr.AIC = 1863.0 AIC/N = 0.940
Hosmer-Lemeshow chi-squared = 16.40987
P-value = 0.03688 with deg.fr. = 8

The results of the binary logistic model are presented in Table 2. According to the findings, gender, age, car ownership, certain occupational groups, specific travel purposes, and one of the income levels significantly influence the combined use of cycling and public transportation.

Table 2 Binary logistic regression result

Dependent Variable: public transportation use	Coefficient	Standard error	z	|z|>Z	95% Confidence	
Gender	-0.33673*	0.13682	-2.46	0.0139	-0.60489	-0.06856
Age	01603***	0.00597	2.69	0.0072	0.00433	0.02773
Car Ownership	-1.54118***	0.17025	-9.05	0.0000	-1.87486	-1.2075
Occupation						
Student	-0.88106***	0.24198	-3.64	0.0003	-1.35534	-0.40678
Private Sector	-0.60048***	0.18681	-3.21	0.0013	-0.96661	-0.23435
Retired	1.00473***	0.31827	3.16	0.0016	0.38093	1.62854
Bike Usage						
Everyday	-0.35583**	0.14162	-2.51	0.0120	-0.63340	-0.07826
4-5 Times a Week	-0.27469*	0.16033	-1.71	0.0867	-0.58893	0.03956
Trip Purpose						
Work Trip	1.41035***	0.23572	5.98	0.0000	0.94835	1.87235
School Trip	1.17864***	0.28500	4.14	0.0000	0.62006	1.73723
Recreational Trip	-1.43692***	0.21711	-6.62	0.0000	-1.86245	-1.0113
Income						
Below Minimum Wage Income	0.50810*	0.20676	2.46	0.0140	0.10286	0.91335

3 Findings

Based on the survey results of bicycle users conducted in Izmir, bicycle users who utilize public transportation with their bicycles have been modeled. According to the model results, it has been found that the probability of men using bicycles in conjunction with public transportation is higher than that of women.

When examining the age variable, it is observed that the rate of using public transportation with bicycles significantly increases as age progresses (p-value = 0.0072). Moreover, vehicle ownership has a negative effect the usage bicycle with public transportation. As vehicle ownership increases, bicycle usage with public transportation decrease (p-value = 0.000). Additionally, a significant increase in using bicycles with public transportation is detected among individuals earning at or below minimum wage (p-value = 0.0140).

In Izmir, bicycle paths are limited to the coastal area, and these paths do not provide continuous access to all parts of the city. Therefore, as mentioned in the methodology section, the purpose of bicycle usage primarily revolves around recreational activities. When examining the use of public transportation systems with bicycles among different occupational groups, it is observed that both students and private sector employees have a negative influence on this usage. However, for these users, when traveling for work (p-value = 0.000) or school purposes (p-value = 0.000) rather than recreation, a positive significant relationship between public transportation and bicycle usage is identified. Conversely, it is found that bicycle usage alongside public transportation decreases when users travel for recreational purposes (p-value = 0.000).

When users are retired, a significant increase in the rate of using public transportation with bicycles has been identified. On the other hand, it has been found that individuals who cycle daily or 4-5 times a week exhibit a significantly negative correlation with using bicycles with public transportation.

4 Conclusion

In conclusion, the findings from the analysis of bicycle user survey data in Izmir highlight the significant role of sustainable transportation solutions, particularly the integration of cycling with public transportation. The results demonstrate that factors such as gender, age, car ownership, income level, occupation, and travel purpose influence the likelihood of individuals using cycling alongside public transportation. Notably, out of 1982 bicycle journeys surveyed, 539 were undertaken in conjunction with public transportation.

The study underscores the importance of promoting cycling as a mode of transportation and enhancing its integration with public transportation. Encouraging this combined usage can lead to several benefits, including reduced traffic congestion, decreased environmental impact, improved public health, and enhanced urban mobility.

To realize these benefits, the integration of cycling and public transportation should prioritize the development of cycling infrastructure, including dedicated bike lanes and bike-sharing programs, while also improving access to public transportation hubs for cyclists. Additionally, efforts should be made to address barriers such as car ownership and promote cycling as a viable alternative for daily commuting and other travel purposes.

Overall, the findings contribute to the growing body of evidence supporting the importance of sustainable transportation solutions in addressing urban mobility challenges and creating more livable cities. By promoting cycling and integrating it with public transportation, cities like Izmir can work towards achieving their sustainability goals while enhancing the quality of life for their residents.

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