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MODELING THE FACTORS INFLUENCING METRO & BIKE-SHARING INTEGRATION: A CASE STUDY FROM İZMIR

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Abstract

This study investigates the key determinants influencing the integration of metro systems and bike-sharing services in İzmir, Turkey, based on data collected from 489 participants across nine stations. A face-to-face survey was conducted to capture users' socio-demographic characteristics, travel patterns, cycling experience, and perceptions of metro–bike-sharing integration. Descriptive statistics were first employed to identify general behavioral trends, followed by a binary logistic regression model to determine the statistically significant factors affecting the likelihood of choosing an integrated metro–bike-sharing trip. The results indicate that cycling experience, bike ownership, and prior use of bike-sharing systems significantly increase the probability of preferring integration, while motor vehicle ownership and longer access distances reduce this likelihood. Younger individuals, students, and frequent commuters demonstrate stronger adoption potential. Perceived barriers such as safety concerns and inadequate cycling infrastructure also negatively affect willingness to integrate. Overall, the findings highlight the role of metro–bike-sharing integration in addressing first- and last-mile challenges and supporting sustainable urban mobility, offering policy-relevant insights for strengthening multimodal transport systems.

Keywords: bike-sharing systems, metro integration, multimodal transportation, regression analyses

1 Introduction

While bicycle use is widespread for recreational purposes today, it has yet to reach the expected level as a primary mode of transport. Defined as a non-motorized vehicle under the Highway Traffic Law, the bicycle is one of the cornerstones of sustainable urban mobility. One of the most fundamental challenges encountered in the public transport systems of modern cities is that transit stops are often beyond walking distance from the users' final destinations. This situation, defined in the literature as the "last-mile problem", directs users toward motorized vehicles such as taxis or additional transfers, leading to inefficiency and unnecessary congestion within public transportation networks.
At this juncture, Bicycle Sharing Systems (BSS) offer a complementary, alternative, and sustainable solution to public transportation. The ability of users to reach their final destinations from transit hubs via BSS highlights the critical importance of intermodal integration. The integration of green transport systems not only mitigates carbon emissions but also significantly contributes to the enhancement of urban liveability. The global evolution of BSS, which originated in 1965 with Amsterdam's "white bicycles", has progressed into its fourth generation, characterized by smart card integration and dockless mobile applications.

In Turkey, systems such as İSBİKE (Istanbul), ANTBİS (Antalya), KOBİS (Kocaeli), and BİSİM (Izmir) serve as local benchmarks for this developmental trajectory.
Within the scope of this study, it is aimed to determine the factors affecting the spatial and fare integration of metro systems and shared bicycle systems in İzmir. As part of the research, face-to-face surveys were conducted with 489 participants across 9 distinct locations (9 metro stations) throughout İzmir. The data obtained were analyzed using descriptive statistical analysis and a binary logistic regression model developed in the SPSS environment. The key variables influencing integration were identified, and proposals for a sustainable integration model were developed.

2 Literature review

Public transport and bicycle integration, a cornerstone of sustainable urban mobility, is extensively documented in the literature. This section examines the factors influencing such integration (specifically the first and last-mile problem, socio-demographic determinants, land use, and infrastructural characteristics). The efficiency of public transport systems is directly correlated with the capacity of users to access stations and reach their final destinations. Sogbe et al. [1] define the 'first mile' problem as the challenge of accessing from one's residence to the station, while the 'last mile' refers to the journey from the station to the destination. Lack of connectivity within the public transportation network causes individuals to rely on private vehicles, which leads to increased traffic congestion and environmental degradation. In this context, BSS provide complementary solutions to rail and bus networks [2]. Studies conducted by Martin and Shaheen [3] in Washington and Minneapolis demonstrate that BSS play a 'complementary' role to public transport in small and medium-sized cities, whereas in large and dense metropolitan areas, they alleviate system strain by substituting for public transit on high-demand routes. The literature provides evidence that BSS usage exhibits significant disparities across different user profiles. Research conducted by Ji et al. [4] and Liu et al. [5] in Nanjing indicates that younger people (specifically those aged 18-35) use BSS-metro integration more frequently due to their technological proficiency. Conversely, older populations and individuals in lower-income groups have been observed to face significant barriers to accessing the system. From a gender perspective, it has been observed that women tend to prefer taxis or private bicycles over BSS, primarily due to safety concerns and the limited carrying capacity of shared bikes [6]. Furthermore, a study conducted in Dublin revealed that the utilization of BSS for accessing rail systems is more prevalent among higher-income passengers [4].
The success of integration is directly correlated with the physical environment and distances surrounding the stations. In the cases of Beijing and Singapore, it was found that high population density in city centers increases BSS usage; however, this trend is reversed in suburban areas [7]. The literature clearly shows that distance thresholds are one of the most critical factors in determining the use of bike-sharing systems. For example, a study in Xiamen, China, found that preference for bike-sharing systems (BSS) decreases at distances less than 800 m or greater than 2 km [8]. Conversely, peak usage in Beijing was found to occur within the 1–5 km range [9]. Similarly, research from Seoul, South Korea, indicates that the most dominant and efficient range for metro integration lies between 0.8 and 1.5 km [10]. In terms of land use types, while there is a consensus regarding the positive impact of commercial and business districts on BSS usage, the influence of residential areas varies depending on the city under study [11]. Furthermore, the availability of cycling lanes, the density of docking stations, and the multiplicity of intersection points across metro lines constitute the fundamental infrastructural components that enhance the likelihood of integration.

BSS usage patterns exhibit distinct variations between weekdays and weekends. Cases from Seoul and Tianjin demonstrate that during weekdays, BSS is predominantly utilized for 'commuting' purposes during morning and evening peak hours, whereas on weekends, 'leisure and shopping' trips become more prominent [10] Furthermore, functional differences exist between station-based and free-floating systems, with the former primarily serving regular work-related commutes [12]. Considering these findings, this study aims to evaluate the contribution of public transport–bicycle integration to sustainable transport planning, with a specific focus on Izmir. The results of the reviewed literature emphasize the importance of an integrated approach to urban transport planning that considers behavioral, spatial, and infrastructural factors simultaneously.

3 Method

This study is designed within the framework of a quantitative research methodology to identify user tendencies toward the integration of rail systems and bike-sharing systems in the city of Izmir, as well as the key factors influencing such integration. The research process comprises literature review, survey design, field data collection, descriptive statistical analysis, and binary logistic regression modelling. The research was conducted at eight metro stations and one IZBAN (Izmir suburban system) station, where access to the rail network is concentrated across the city of Izmir. The stations where the survey was conducted are illustrated in figure 1.

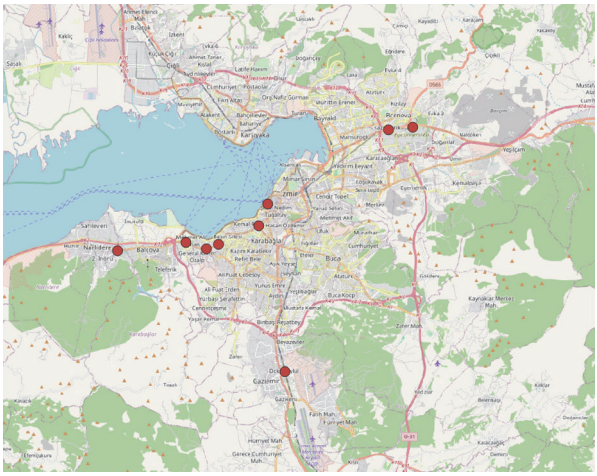

Figure 1 Survey locations across the city

These stations were selected to represent regions with diverse socio-economic characteristics and land-use patterns. Thus, the study aims to ensure the comparability of perspectives on integration among various user profiles located in the city center, sub-centers, and university vicinities. Data were collected through face-to-face surveys, and a total of 489 valid responses were included in the evaluation. The sample size was determined based on the number of observations needed to ensure statistically significant results in subsequent analyses.

3.1 Survey design and data collection process

The survey instrument was developed by considering the factors identified in the literature as influencing bicycle-public transport integration. The questionnaire consists of four primary sections:

- demographic characteristics: gender, age, educational level, occupation, income level, driver's license, and vehicle ownership
- travel habits: primary trip purpose, trip frequency, transfer status, frequency of metro usage, and preferred transport modes
- cycling and bike-sharing experience: cycling proficiency, bicycle ownership, usage frequency, experience with bike-sharing systems, and satisfaction levels
- attitudes toward integration: tendency to opt for integrated systems (spatial and fare integration), and evaluations of factors such as traffic density around stations, proximity to arterial roads, and bus service intensity.

The surveys were conducted on different days and time slots to ensure the representativeness of user tendencies during both peak and off-peak periods. Initially, the collected data were imported into Microsoft Excel, where descriptive statistical analyses were conducted. Within this scope, frequency distributions, percentages, and cross-tabulations were generated to reveal the overall profile of the participants and their tendencies toward integration. In the second stage, the data were imported into SPSS (Statistical Package for the Social Sciences) software, and a binary logistic regression model was constructed to determine the factors influencing integration preferences.

3.2 Binary logistic regression model

The dependent variable in the model was defined in a binary (0–1) format based on the responses to the statement, 'I would prefer to use a bicycle if rail systems and bike-sharing systems were integrated.' The response 'I would prefer' was coded as 1, while the negative response was coded as 0. The independent variables were selected from demographic characteristics, travel habits, cycling experience, and perceptual variables regarding integration. When incorporating categorical variables into the model, they were appropriately converted into dummy variables. The model is expressed by the following equation:

$$P_n(i) = \Pr\left(U_{in} \geq U_{jn}\right) = \frac{1}{1 + e^{-\mu(Vin - Vjn)}} = \frac{e^{\mu Vin}}{e^{\mu Vin} + e^{\mu Vjn}} \quad (1)$$

In this equation, P represents the probability of choosing a bicycle in the event of integration. The statistical significance of the model coefficients was evaluated using the Wald test, while the overall goodness-of-fit was examined via the -2 Log Likelihood and coefficients of determination (Cox & Snell R^2 and Nagelkerke R^2). Additionally, the classification performance of the model was analyzed based on the overall accuracy rate. By means of this method, the variables that play a significant and decisive role in integration preferences were identified.

4 Results

4.1 Descriptive results

The results of the analysis of the 489 valid surveys obtained indicate that the potential for metro-bike sharing integration in Izmir is particularly high among young people and students. A significant portion of the participants falls within the 18–29 age group, suggesting that integration policies could be proliferated through this specific younger user segment. Most participants do not own a motorized vehicle. This finding presents a significant opportunity for a shift toward alternative and sustainable modes of transport. In contrast, the proportion of those actively utilizing bike-sharing systems remains limited.

Factors such as safety concerns, infrastructural deficiencies, traffic congestion, and established habits emerge as the primary reasons for non-usage. Upon examining the responses to the statement, "I would prefer to use a bicycle if rail and bike-sharing systems were integrated, " it was observed that a significant portion of participants view integration favorably. This indicates that despite the current low usage rates, integration holds the potential to stimulate demand. Notably, the increased inclination to choose cycling as bus congestion around metro stations rises demonstrates that bike-sharing systems can complement public transportation. However, the location of stations on major roads has been identified as a discouraging factor for some users.

4.2 Binary logistic regression model results

The constructed binary logistic regression model significantly explains the probability of choosing metro–bike-sharing integration. According to the model results, several variables exert a statistically significant influence on the preference for integration; the results of the model are presented in table 1.

Table 1 Binary logistic model results

Variables	Coefficient	Standard Error	Wald Value	Significance	Odds Ratio
Age	-0.019	0.009	4.165	0.041	0.981
Bike Ownership	0.525	0.235	4.994	0.025	1.691
Income	0.014	0.006	5.301	0.021	1.014
Preference for BSS in case of bus stop congestion	2.221	0.232	90.499	0.000	9.125
Non-avoidance of BSS use near arterial roads	0.537	0.25	4.625	0.032	1.711
Perceived suitability of stop-to-home distance for walking	-0.54	0.227	5.675	0.017	0.583
Perceived comfort of public transport transfers relative to BSS use	-0.497	0.29	2.939	0.086	0.608

The coefficients of determination indicate that the model explains a significant portion of the variance in integration preferences. The model findings reveal the following key results:

- Age: This variable has a negative impact on the preference for integration. As age increases, the probability of choosing integration with bike-sharing decreases, indicating that younger users are more receptive to these systems.
- Motorized vehicle ownership: This factor negatively affects the integration preference. Individuals who own a private vehicle are less likely to opt for the bike-sharing–metro integration.
- Cycling and bike-sharing experience: Both cycling proficiency and previous experience with bike-sharing systems significantly and positively influence the preference for integration. Individuals with prior experience are found to be more inclined toward integrated use.

- Perception of bus congestion: This is a crucial factor that increases the preference for integration. As the perceived congestion at bus stops near metro stations rises, the tendency to choose bicycles increases. This finding demonstrates that bike-sharing systems can play a strong complementary role, particularly as a 'last-mile' solution.
- Arterial road location and traffic perception: These factors create a deterrent effect for certain user groups. Perception of safety emerges as a critical determinant in the overall success of integration.

5 Conclusion

This study examined the integration potential of rail systems and bike-sharing systems in Izmir from a user perspective and revealed the determinants of integration preferences. The findings demonstrate that bike-sharing systems can generate stronger demand when planned in an integrated manner with rail systems, rather than as standalone systems. The age variable emerged as a significant determinant, with younger users showing a greater openness to integration. While motorized vehicle ownership reduces integration preferences, previous cycling experience and usage habits increase this preference. Furthermore, the findings regarding income levels indicate that the system has the potential to appeal not only to low-income groups but also to a diverse range of socio-economic segments. The fact that the perception of bus congestion increases the preference for integration supports the potential use of bike-sharing systems as a 'last-mile' transport solution. Conversely, the perception of heavy traffic on arterial roads and related safety concerns can act as deterrents for certain user groups. Therefore, physical proximity alone is insufficient; a safe and comfortable cycling infrastructure must also be provided. Overall, the results indicate that while integration potential exists, safety, infrastructure, and behavioral factors must be addressed collectively; furthermore, younger users play a critical role in this transformation process. The integration of bike-sharing and rail systems serves as a strategic tool that can contribute to the sustainable transport transition for short-distance urban trips. The study area is restricted to the city of İzmir and nine stations, and this may not allow the study to be generalized to other cities. In addition, data collection is done in particular time slots, and no consideration is given to how weather and seasonality may affect cycling behavior. Survey data used in the study may not give accurate information because they are based on users' perceptions and preferences.

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