Modelling Shared Bicycle Demand Using Artificial Neural Networks

Selim Dündar[1[0000-0003-4433-1998]],Pelin Alcan Gezginci[2[0000-0001-7155-7621]], Gürkan Günay[3[0000-0003-0597-1511]], Elçin Mert[4[0000-0002-7539-6666]] and Ersoy Soyer[5[0000-0002-6299-5846]]

[1] Istanbul Okan University, Civil Engineering Department, Istanbul, Türkiye, selim.dundar@okan.edu.tr
[2] Istanbul Okan University, Industrial Engineering Department, Istanbul, Türkiye, pelin.alcan@okan.edu.tr
[3] Istanbul Bilgi University, Civil Engineering Department, Istanbul, Türkiye, gurkan.gunay@bilgi.edu.tr
[4] Yapıdrom Technology, Istanbul, Türkiye, elcin.mert@yapidrom.com.tr
[5] Yapıdrom Technology, Istanbul, Türkiye, ersoy.soyer@yapidrom.com.tr

Abstract. Since bicycles are based entirely on muscle power, they are the transportation vehicles with the lowest negative impact on the environment. In addition, since they are an active mode of transportation, they are also named among the leading modes in terms of sustainability. They are also the leading vehicles types among the micromobility systems, which can be considered as small-sized and individual transportation modes, in terms of their historical background as well as purchasing and operating costs. Today, bicycle ridership rates are increasing thanks to the bike-sharing or rental services provided by both local governments and companies in the private sector. Traveling by bicycle, rather than using a motor vehicle, has a positive effect on the natural environment as it does not cause pollutant gas emissions and effects the traffic jams minimally. It is crucial to investigate the periodic changes in the use of shared bicycle systems, especially in order to define the factors that affect this modal shift and to predict the demand for bicycle use in the future. Within the scope of the developed study, the changes in bicycle use and various factors affecting it were investigated in 4 of the cities in which one of Turkey's leading companies in micromobility provides bicycle sharing services. The values regarding bicycle use were then modelled using artificial neural networks. Thanks to the developed model, it will be possible to predict the number of future trips in the cities where bike sharing service is provided and the periodic changes of these trips, as well as to make estimations about the passenger demand that will arise in a city where the new service will be provided.

Keywords: Bicycle, Micromobility, Traffic demand, Artificial Neural Networks.

1 Introduction

The concept of micromobility, which refers to small-sized and individual transportation, which is generally operated at speeds of less than 25 km/h, is a popular concept that has emerged in recent years. Especially with the effect of the COVID-19 pandemic, people tried to avoid using public transportation and this has led to an increase in the use of micromobility systems such as bicycles and e-scooters. Although micromobility is a new concept, some micromobility vehicles, especially bicycles, have actually existed in our lives for many years as a mode of transportation. The modern form of the bicycle, whose very primitive models were seen in 12th century China, was developed by Conte de Sivac in France in 1791 [1]. Since then, the bicycle, which has been developed in different models, has maintained its popularity and has become an important mode of transportation.

Since bicycles are a type of transportation based entirely on muscle power, they are the means of transportation with the lowest negative impact on the environment. Unlike vehicles with internal combustion engines, they do not emit any polluting gases during their use. Unlike electrically powered vehicles, they do not have a battery containing chemicals. However, nowadays, electric bicycles (e-bikes) have also started to be used in order to eliminate the factors that may create adverse conditions during bicycle use, such as high gradients. Fully muscle-powered bicycles, which can be defined as classic bicycles, are among the leading transportation modes in terms of sustainability, as they are an active mode of transportation. Among the micromobility systems, which can be considered as small-sized and individual transportation, bicycle is the leading transportation vehicle due to both its historical background and its purchasing and operating costs. On the other hand, it is not possible to claim that they don't have any negative impact on the environment due to the various metal alloys, plastic parts and processes used in its production. However, since it is the transportation mode that has the least damage to the environment after walking, it is preferred especially by the young people with higher environmental awareness.

Today, it is aimed to increase the rate of bicycle usage thanks to the vehicle sharing or rental services provided by both local governments and companies in the private sector. The increase in the use of bicycles shows that the journeys made with different transportation modes cause a shift towards the use of bicycles. From which transportation modes do this modal shift occur is among the subjects that researchers are currently working on. According to a study e-scooter and e-bike vehicles have the opportunity to replace other types on journeys less than 8 km [2]. These mentioned trips in the EU, USA and China have a share of approximately 50-60% of the total trips. For bicycle sharing systems, an online survey was conducted on bicycle and public transport integration within the scope of the study carried out in Montreal, Canada in the summer of 2010 [3]. The questionnaire consists of six parts: general travel habits, public transport questions, cycling/transfer questions, priorities for improving cycling and its integration with public transport, general demographics and comments section. In the study, 1432 questionnaires were collected and a binary logit model was developed to determine the factors that encourage the use of the bike sharing system called BIXI (bike taxi). The dependent variable is whether BIXI was used before (yes-

no). A linear regression was then applied to a subsample of BIXI users to identify factors affecting the frequency of use of shared bikes. The dependent variable in this second model is the number of BIXI uses for 2010. The first model tests various variables (age, gender, income level) based on the results of previous studies examining the motivation to cycle in general or the use of shared bicycle systems. As a result of the research, the factors that motivate the use of BIXI are using BIXI for transfer (bus-train), proximity to the station, living close to the city center, low security of personal bicycles in Montreal (bicycle theft is high), users not paying for the first half hour in BIXI, no need for maintenance and popularity of BIXI. The factors that reduce usage are having a driver's license and riding a bicycle for recreational purposes only. The variable with the strongest effect was found to be the presence of a BIXI station less than 500 m from the house, in which case individuals were 3 times more likely to use a shared bicycle. It was stated that the proximity of a BIXI station to the route that the participant regularly travels will increase the probability of using BIXI. Recreational cyclists and women were less likely to use BIXI, while integrating bicycle and public transport for trips and holding a driver's license increased a person's likelihood of using BIXI.

Traveling by bicycle, rather than using a motor vehicle, has a positive impact on the natural environment as it does not cause pollutant gas emissions and does not contribute to traffic jams. With the increase in environmental awareness recently, the demand for the use of micromobility systems, especially bicycles and e-scooters, has increased, particularly among young people. Another reason for the increase in demand for micromobility systems is that it is used as a complementary mode to public transportation, especially in trips defined as the last kilometer.

It is necessary to examine the periodic changes in the use of shared bicycle systems, in order to examine the factors that affect the modal shift from other modes of transportation to bicycles, and to predict the demand for bicycle use in the future. Within the scope of the developed study, the number of periodic bicycle use and various factors affecting this in 4 of the cities where Yapıdrom Technology JSC, one of Turkey's leading organizations in the field of micromobility provides bicycle sharing services, were examined and modeled by artificial neural networks (ANN) method.

2 Methodology

Yapıdrom Technology JSC, which was founded by Yavuz Salih Şahin in 2012, while the subject of micromobility is not talked about much in the world, is Turkey's first micromobility company. The infrastructures established for shared bicycles operating in dozens of cities and districts of Turkey today serve the transportation of more than five million people using electric bicycles and scooters in the cities. Thanks to this system initiated by Yapıdrom, environmental awareness has provided great benefits in reducing carbon emissions and developing alternative transportation systems in the Turkey today.

While the “Baksi” brand within Yapıdrom refers to sustainable smart bike sharing systems; mainly in Istanbul (Isbike), Izmir (Bisim), Antalya (Antbis), Bursa (Nilespit)

etc. continues to serve the public together with public institutions in nearly thirty cities. In 2019, Yapıdrom launched their first e-scooter operation, the “Tazı” brand. In addition, in 2022, they launched Turkey's first e-bike operation with Jant-i e-bikes in Bursa. Tazı, which aims to provide access to alternative transportation systems in Turkey, especially in Anatolian provinces, offers a safe and enjoyable transportation service for everyone with electric bicycles and e-scooters in eight provinces.

Within the scope of the study, first of all, bicycle usage data of Yapıdrom were obtained for four cities with different characteristics, where bicycle rental services are provided by the company. These four cities are Çanakkale and Nilüfer District of Bursa in the Marmara Region, Çorum in the Central Black Sea Region and Marmaris District of Muğla in the Mediterranean Region.

2.1 Çanakkale

Çanakkale, located in the Marmara Region in the northwest of Turkey, has a population of 559,383 people [4]. The city, which is divided into two by the Dardanelles Strait, is one of our two cities with lands in both Europe and Asia, together with Istanbul. Since the city hosts Çanakkale Onsekiz Mart University, it also attracts a significant number of students from different cities. Yapıdrom started shared bicycle services in Çanakkale in August 2016. Shared bicycle services still continue in Çanakkale.

2.2 Bursa-Nilüfer Municipality

Bursa, located in the Marmara Region in the northwest of Turkey, is the fourth most populous city with a population of 3,194,720 people. The population of Nilüfer Municipality is 536,365 [4]. The city hosts Bursa Uludağ University, Bursa Technical University an, Mudanya University. Bursa Orhangazi University, which was opened in 2011, was closed in 2016. As hosting three different universities, the city also has a significant student population. Yapıdrom started shared bicycle services in Nilüfer Municipality of Bursa in April 2016. Shared bicycle services still continue within the borders of Nilüfer Municipality.

2.3 Çorum

Located in the Inner Central Black Sea Region of northern Turkey, Çorum has a population of 524,130 [4]. Hittit University, founded in 2006, is located in the city. Yapıdrom started shared bicycle services in Çorum in August 2020. Shared bicycle services still continue in Çorum.

2.4 Muğla-Marmaris Municipality

Muğla, which is located in the Aegean Region in the west of Turkey and the Mediterranean Region in the south, has a population of 1,048,185 people. The population of Marmaris Municipality, located in the Mediterranean Region, is 97,818 [4]. However, since Marmaris is one of important summer tourism centers, it attracts a significant number of tourists between May and October. Due to Muğla Sıtkı Koçman

University, it also has a significant student population. Yapıdrom started sharing bicycle services in Çorum in April 2019. Shared bicycle services still continue in Marmaris.

2.5 Data Collection

In order to examine the demand for shared bicycle use, first of all, for each of the four cities, the total rental numbers, total usage times and average usage times of bicycles were obtained on a monthly basis from the date Yapıdrom started to serve in the city until the end of 2021. Then, the factors that may affect the usage were investigated and for each city, the total population, female and male population [4], gross domestic product (GDP) in TL and USD, population between 16-35 years of age [5], population with university students (compiled from the websites of universities), length of the urban road network [6], average air temperatures on a monthly basis, average number of rainy days [7], whether it is COVID-19 pandemic period, whether full closure was implemented, and how long shared bicycle service was provided in that city were collected. While all the collected data had real values, only the pandemic and closure variables were shown with a dummy variable of 0 when they were applied and 1 when they were not. Since 2022 GDP values were not disclosed during the research, all data were obtained for the time intervals until the end of 2021.

2.6 Artificial Neural Networks Model

Artificial Neural Networks (ANN) is a machine learning method developed based on the basic working principles of the human brain such as learning, generalizing, remembering and memorizing. It is called a black box modeling technique because it aims to produce appropriate output values from the input values, rather than creating a mathematical relationship between them.

Within the scope of this study, using the collected data, ANNs have been developed that try to predict the shared bike usage demand. First of all, for each city, 3 different models were developed that estimate the total number of rentals, the total usage time in minutes and the average usage time in minutes. Finally, by evaluating the data collected for all cities together, 3 different models have been developed that can be used to predict output values for any city. Thus, a total of 15 different ANN models were created. An example of the models created is shown in Figure 1.

The hyperparameters of each ANN model were determined by trial-and-error method proposed by [8], due to its simplicity. For the rapid convergence of the ANN model, all input and output values are normalized to the range of 0 and 1 as seen in Equation 1.

$$x_{normalized} = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (1)$$

Here, xnormalized, xi, xmin, xmax represent the normalized value of the input or output, the actual value, the smallest and largest value that variable can take, respectively. The sigmoid function was chosen as the activation function in the hidden layer, and the linear function in the output layer. Levenberg Marquardt (LM) algorithm

was preferred in ANN training because it converges rapidly and requires less iteration. MATLAB®'s default values are used for the parameters of the LM algorithm; where initial mu is 0.001, mu reduction factor is 0.1, mu increase factor is 10, and maximum mu is 100000000000. 70%, 15%, and 15% of the data is selected randomly as training, test, and validation sets, respectively. The output values of the developed ANN model are denormalized by using Equation 2.

$$x_i = x_{normalized} \times (x_{max} - x_{min}) + x_{min} \quad (2)$$

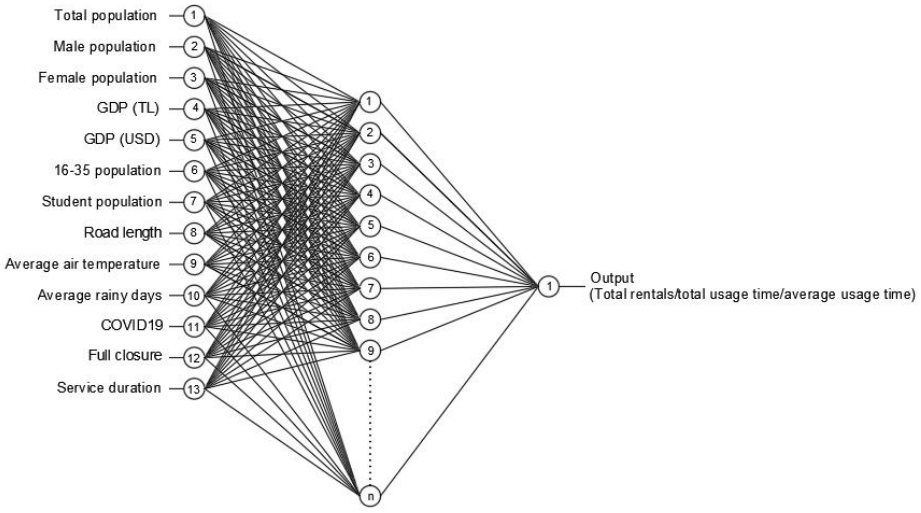
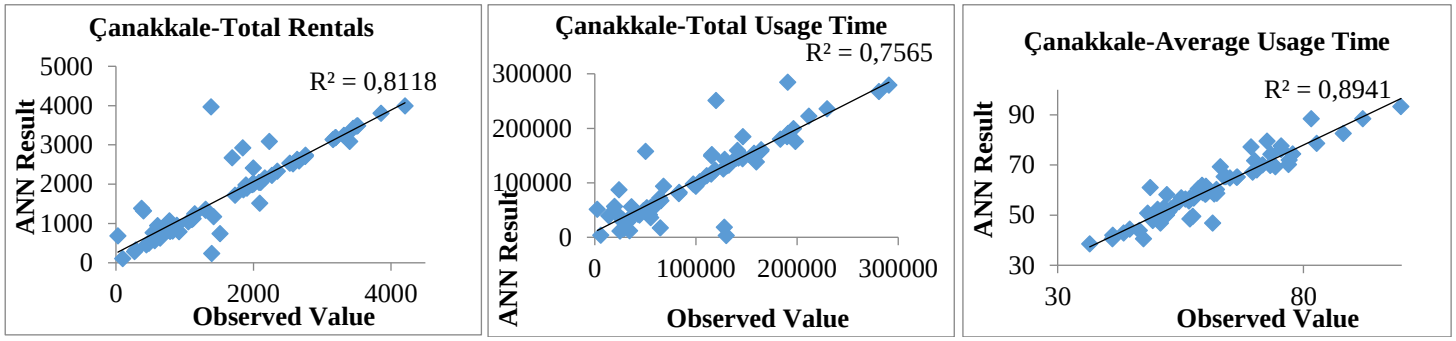


Fig. 1. Developed ANN model.

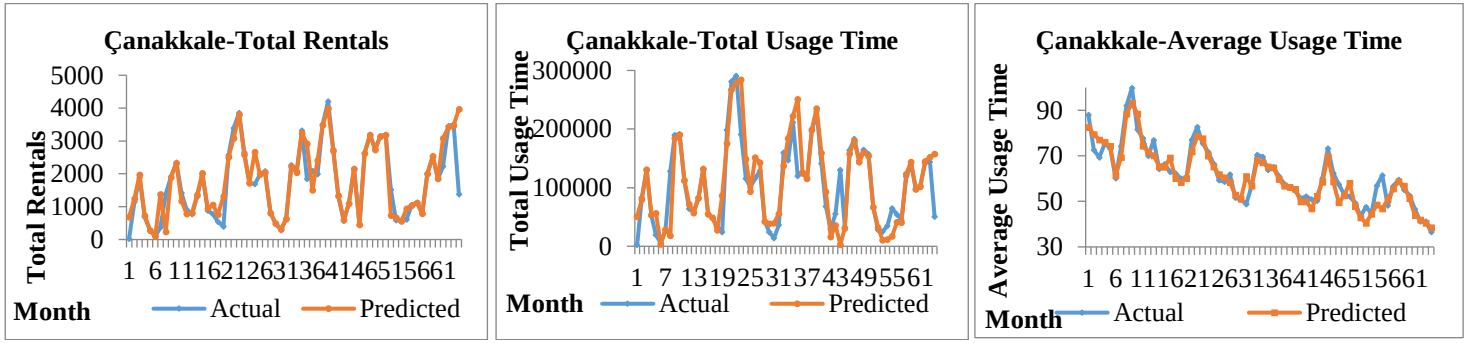
3 Results

In order to evaluate the success of the developed ANN models, a scatter diagram was drawn between the measured values and the model result, and the coefficient of determination, r^2 was measured. In addition, observed and modeled values are plotted as time series. The scatter diagrams and the time series drawn for Çanakkale are given in Figure 2 and 3, respectively. The scatter diagrams and the time series drawn for all the cities are evaluated together are given in Figure 4 and 5, respectively. The r^2 coefficients of ANN models developed for each city are shown in Table 1.



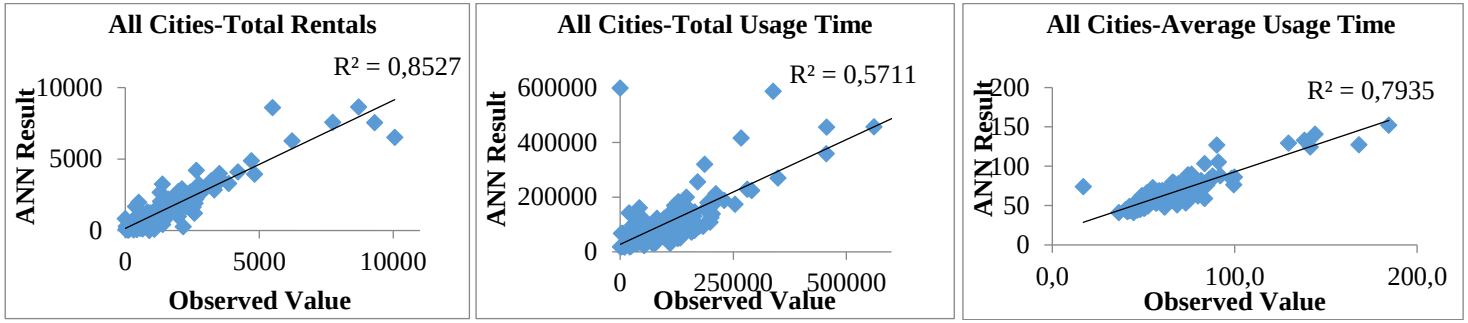
(a) (b) (c)

Fig. 2. Scatter plot for Çanakkale (a) total rentals, (b) total usage time, (c) average usage time



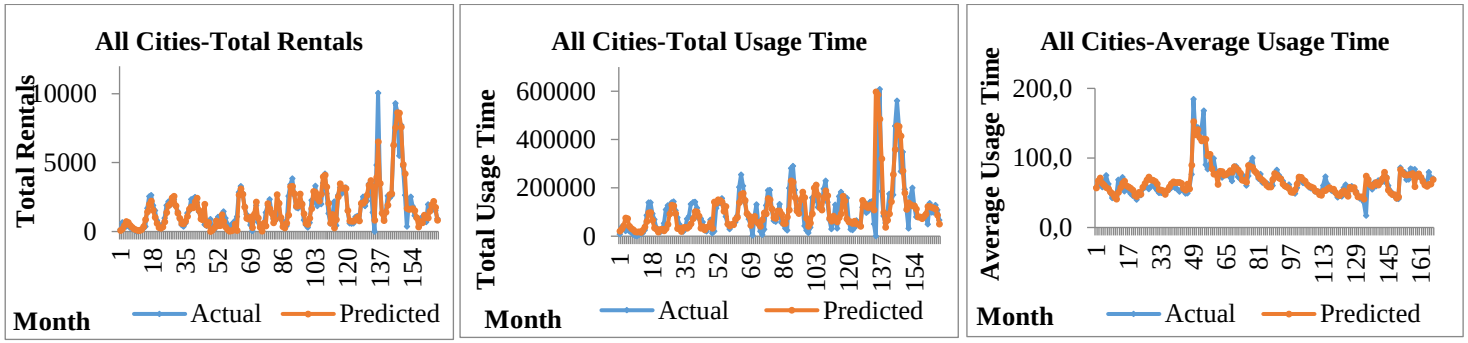
(a) (b) (c)

Fig. 3. Time series for Çanakkale (a) total rentals, (b) total usage time, (c) average usage time



(a) **(b)** **(c)**

Fig. 4. Scatter plot for all cities evaluated together (a) total rentals, (b) total usage time, (c) average usage time



(a) **(b)** **(c)**

Fig. 5. Time series for all cities evaluated together (a) total rentals, (b) total usage time, (c) average usage time

Table 1. Performance of ANN models.

City/r^2	Total rentals	Total usage time (min)	Average usage time (min)
Çanakkale	0,8118	0,7565	0,8941
Nilüfer	0,9038	0,8624	0,6557
Çorum	0,4354	0,1512	0,8671
Marmaris	0,6364	0,1621	0,3722
All	0,8527	0,5711	0,7935

4 Discussions

The performance of the ANN models developed for Çanakkale and Nilüfer Municipality, two cities where Yapıdrom has been serving for a longer period of time, are higher than Çorum and Marmaris, which have been in service for a shorter period of time and therefore have less data. With the acquisition of new data, more successful ANN models can be obtained for these two cities. The model, in which data for all cities were evaluated together, was more successful in estimating changes in bicycle usage demand than the models developed for Çorum and Marmaris, which had less data. It was more successful in estimating the total number of rentals for Çanakkale and the average usage time for Nilüfer Municipality, with more data obtained. This shows that when enough data is obtained and a separate model is established for each city, higher performance will be achieved. On the other hand, when a single model can be developed for all cities, it can be used to predict the demand, or in other words, the number and usage time for a completely different city. This can be a guide for investments to be made in a new city.

When the time series obtained from the results of the ANN models are examined, it is seen that the models generally catch the trend of increase or decrease in the number or duration of use. Thus, it can be said that it can be usefully used in the prediction of future change trends. For this reason, it can be used as a useful method in making decisions regarding maintenance/repair needs that may arise especially for vehicles and/or infrastructure and, if necessary, expansion or contraction of the vehicle fleet.

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