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A Comprehensive Analysis of Shared E-scooter Usage Patterns in Urban Mobility

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Abstract: Shared transportation systems are increasingly playing a pivotal role in urban mobility. Micro-mobility solutions, in particular, have become essential as people seek fast, convenient ways to travel during their daily routines, avoid the hassle of parking their personal vehicles, and face challenges accessing public transportation at their preferred times or locations. Among the emerging shared transportation options, station-less electric scooters (e-scooters) have gained global popularity due to their ease of parking, environmental benefits, cost savings, and ability to alleviate traffic congestion. As a potential solution to first- and last-mile problems, academic studies on e-scooter technology are expanding. This study analyzes data from a shared station-less e-scooter service operating in Türkiye to explore how weather parameters influence user behavior. Additionally, it offers an innovative perspective on geographic and regional variations in user behavior by comparing findings with studies from different cities and countries. This research also provides valuable insights for city planners and mobility service providers seeking to optimize shared transportation systems.

Keywords: Shared e-scooter, log records, micromobility, user behavior, trip patterns

I. Introduction

The proportion of the global population residing in cities has risen significantly, from 30% in 1950 to 21% in 2018. According to the United Nations Habitat World Cities Report 2022, this figure is projected to reach 68% by 2050. The transportation sector accounts for approximately one-quarter of global greenhouse gas emissions, with reliance on fossil fuels exacerbating environmental issues such as air pollution, acid rain, and climate change[1]. Eco-friendly transportation solutions such as electric vehicles, hybrid vehicles, bicycles, walking, public transport, and micro-mobility options help mitigate the environmental impacts of the transportation sector. However, rapid urbanization has led to challenges like traffic congestion and environmental pollution, exposing the limitations of traditional transportation methods. For decades, individual vehicles, taxis, and public transportation have been the primary options, but technological advancements have introduced innovative alternatives to address these growing urban demands [2].

Advancements in smart city solutions and the proliferation of IoT devices have introduced innovative solutions into our daily lives [3]. Environmentally friendly, lightweight, and practical transportation options, such as micro-mobility vehicles, are gaining increasing significance. Shared e-scooters were first introduced in the United States in 2017. Companies like Bird, Lime, and Spin, which initially launched in San Francisco, quickly gained popularity in many American cities. Within less than a decade, shared e-scooters have become a common feature in metropolitan areas worldwide [4].

In Türkiye's rapidly urbanizing and densely populated metropolitan cities, where traffic congestion is a significant issue, shared e-scooter systems emerge as a viable alternative transportation solution, similar to their adoption worldwide. By examining the dynamics of micro-mobility in Türkiye, this study offers original and practical insights for urban planners and mobility service providers within the local context.

Shared transportation systems operate on a similar logic, regardless of the type of vehicle used. These systems typically include a mobile application that allows users to view vehicle locations. There are two main types: station-based systems, which share station locations, and stationless/free-floating/dockless systems, which provide real-time vehicle locations. The app also facilitates rentals and payments. Users start by downloading the application, registering, and logging into the system. The app then displays nearby vehicles on a map, enabling users to rent the one close to their locations. Figure 1 illustrates the usage steps common to all shared transportation systems, regardless of vehicle type.



Figure 1. Steps performed by users before riding

II. Literature

Many studies in the literature have examined the usage statistics of shared vehicles and analyzed the patterns they exhibit under different conditions. Noland analyzed one year of data on shared transport vehicles with different modes (dockless e-scooters, free-floating e-bikes, and docked bicycles) in Austin, Texas. The study correlated usage characteristics (number of rides, duration, and distance) with various weather parameters (temperature, relative humidity, precipitation, and wind speed). The weather parameters analyzed in this study were found to impact all three modes of transport. Specifically for e-bikes, both riding distance and riding time decreased in low temperatures, and windy, or rainy weather. However, in some cases, bad weather conditions showed a positive correlation with utilization, possibly due to traffic congestion. It is suggested that more detailed studies be conducted to better understand this relationship [5].

Campbell et al. enhanced their study by incorporating environmental impacts, such as air quality, which had not been previously examined, as well as various types of characterized data, such as surveys, regarding the choice to use shared bicycle and e-bike systems. By analyzing user concern patterns specific to China, they found that socio-demographic characteristics were not significant factors, whereas air quality exhibited an inverse relationship with the usage of the studied system [6].

Younes et al. analyzed stationless e-scooter and docked bike-sharing systems, examining environmental and economic variables such as petrol prices, local events or disturbances, day of the week, and time of the day, alongside weather parameters. They studied six months of usage data from six different companies in the USA and categorized users into three groups. The findings indicated that fluctuations in gas prices influence the riding behavior of all user groups [7].

Chen et al. analyzed several new parameters across four different modes of shared transport, including vehicle charging status, vehicle density, price, time of day, distance traveled, and altitude differences during rides. Their findings indicated that users in Zurich adjust their mode of transport based on the time of day (particularly during commuting hours) and the distance traveled. Additionally, they observed a fundamental relationship between fleet density and utilization; however, once density exceeds a certain threshold, a plateau effect emerges [8].

Aboulela et al. investigated spatiotemporal hourly and daily usage patterns in five North American cities (Austin, TX; Calgary, AB; Chicago, IL; Louisville, KY; Minneapolis, MN) and observed that demand patterns tend to be consistent across cities. By analyzing riding characteristics such as speed, duration, and distance, they identified empirical consistency among the five cities, although these characteristics varied temporally within each city. This variation was attributed to exogenous weather factors, including temperature, wind speed, precipitation, and snow; infrastructure elements such as cycle lanes, pavements, and shared cycle stations; and sociodemographic variables, including gender, age, and income. [9].

Gebhart and Noland investigated the influence of weather on the usage patterns of the Washington DC bike-sharing system. Their study established correlations between hourly usage statistics and weather variables, including temperature, precipitation, snow, wind, fog, and humidity levels. The findings informed statistical models that estimated the reciprocal effects of user numbers and usage duration. Furthermore, they examined the characteristics of trips originating from locations within walking distance of metro stations during hours of metro operation. Notably, the research explored whether the metro served as an alternative to cycling during unfavorable weather conditions [10].

Hasan and Sisiopiku examined the travel patterns of shared e-scooter users in Birmingham, Alabama. Their analysis revealed that peak hourly rides occurred between 21:00 and 22:00, with daily rides peaking on Saturdays. Furthermore, the findings indicated that the highest usage rates were observed in densely populated areas with educated and high-income residents. This case study

offers valuable insights into the transportation preferences of Birmingham's residents and provides critical information for city planners in Birmingham and other medium-sized cities to optimize micro-mobility options [11].

Mathew et al. conducted a six-month study on e-scooter usage in Indianapolis to investigate the impact of weather. By analyzing surface temperature, precipitation, snow, and wind speed, the researchers discovered that although the number of rides declined by over 80% during the winter months, the average trip distance and duration showed minimal reduction, contrary to expectations. Additionally, the findings revealed that user riding behavior was more influenced by sub-freezing temperatures and snowfall compared to rainfall [12].

This study is among the few that examine the use of shared e-scooters in Türkiye. Unlike existing literature, it provides a comprehensive analysis by incorporating additional insights and presenting detailed graphs of various parameters.

III. Data and Method

In most shared transportation systems, data is collected from mobile phones and IoT devices installed on the transportation vehicles, including information such as location (via GPS), speed, distance, and duration [13] [14]. To ensure consistent analysis and efficient fleet operations, these two data sources are utilized. For instance, real-time location data from GPS and vehicle performance metrics are cross-referenced to verify accuracy and optimize route planning. The data used in this study includes both ride-related information—such as start and end times, locations, total duration, distance, average speed, and costs—and user-submitted data collected through the rental mobile application, including location and time telemetry. Location telemetry also referred to as log records, is captured usually every 10 seconds, recording data from the moment users launch the mobile application until the ride is completed. The data for this study was provided by a shared e-scooter service operating in various cities and towns across Türkiye [15] and consists of trip data and user location telemetry collected between August 2022 and December 2023.

The weather parameters incorporated into the data were obtained from the Meteorological Data Information System (MEVBIS) provided by the Turkish General Directorate of Meteorology (MGM). As the most authorized and reliable public institution for national meteorological data collection and monitoring, MGM offers high-quality data on temperature, humidity, wind speed, and precipitation. Multiple sensors within each region enable validation of meteorological data, ensuring accuracy even when data from the nearest station is incomplete or inaccurate. In summary, MGM's status as a state institution, coupled with its rigorous standards and frequent data collection, makes its meteorological data an ideal source for scientific studies [16].

To safeguard both company secrets and user data, the raw data from the database underwent a comprehensive anonymization process to protect users' personal information. Data anonymization and privacy practices are fundamental to the ethical and scientific standards of this study. During this process, direct personal identifiers (e.g., first name, last name, phone number) were entirely removed from the dataset. Additionally, user identifier numbers were replaced with system-assigned IDs, ensuring privacy while maintaining data traceability. The figures presented in this article were generated using Python's Matplotlib and Seaborn libraries.

IV. Result

According to records from the shared e-scooter company, 46% of registered users did not take any rides, indicating a significant proportion of inactive accounts. This may be because users downloaded the application to familiarize themselves with the system and registration process but decided against using it, potentially due to dissatisfaction with the system or vehicles. Among the 54% of users who completed at least one ride, the average number of rides was 12.78, the average number of log records was 748.05 minutes, and the median distance traveled was 1.4 kilometers. Additionally, Table 1 provides the standard deviation, skewness, and median values for the number of rides, log records, and logs per trip.

Table 1. Summarized data details

Property	Mean	Standard Deviation	Skewness	Median
Trip Count (ZAMAN)	12.78	32.16	9.40	3
Log Count (ZAMAN?)	748.05	1977.24	14.42	242
Log Per Trip	97.37	193.87	36.37	54.33
Distance Per Trip	1.4 km	222.43	205.48	1.34
Duration Per Trip	5 min	10.34	10.71	5

Table 2 presents the percentage distribution of trips by duration. It indicates that 36% of trips last between 0-1 minute (e.g., rides that end within a minute of starting). The remaining trips are distributed as follows: 27% last 2-3 minutes, 28% last 4-9 minutes,

and 9% exceed 10 minutes. Notably, 53% of users tend to take shorter trips (0-3 minutes) on average. As trip duration increases, the frequency of longer trips declines.

Table 2. Trip rental time groups and percentages

Trip Duration (min)	Ride Count Percentage (%)
0-1	36
2-3	27
4-9	28
10+	9

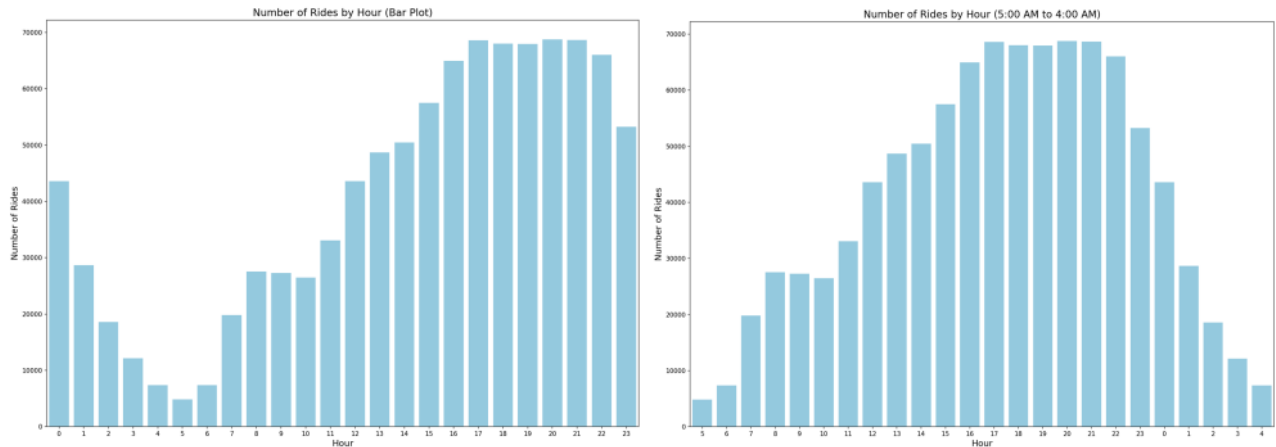


Figure 2. Ride counts by hour (0 to 23 on the left and 5 to 4 on the right)

Figure 2 illustrates the number of rides by hour. In the classic hour-based display on the left, the data is shown for the 0-23 hour range, as is common in the literature. On the right, the graph has been adjusted to display data from 5 am to 23 pm to better represent the actual distribution. Ride counts begin to increase around 4-5 am, rise steadily until 5 pm, stabilize at their peak between 5 pm and 10 pm, and then sharply decline until 4 am.

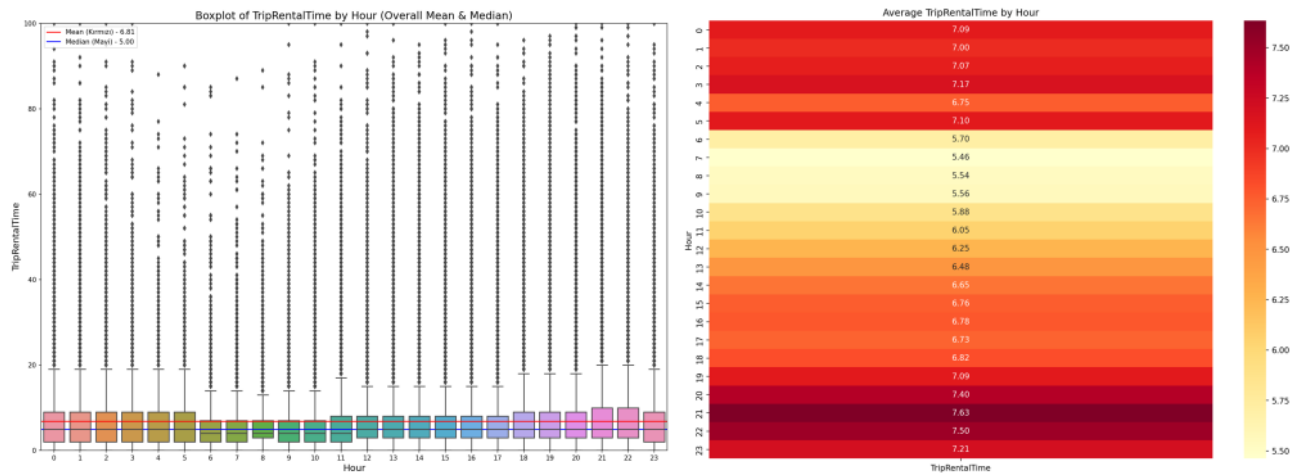


Figure 3. Trip rental time by hour, a. boxplot, and b. heatmap

Figure 3 provides two different visualizations of trip rental duration by hour. The box plot illustrates the number of trip rentals for each hour of the day and presents the average and median rental durations (6.81 and 5 minutes, respectively). It also highlights the presence of outliers, indicating that rider behaviors vary significantly throughout the day. Conversely, the heat map shows changes

in rental duration preferences, revealing that riders tend to take shorter trips between 6 am and 10 am. After 10 am, however, rental durations gradually increase.

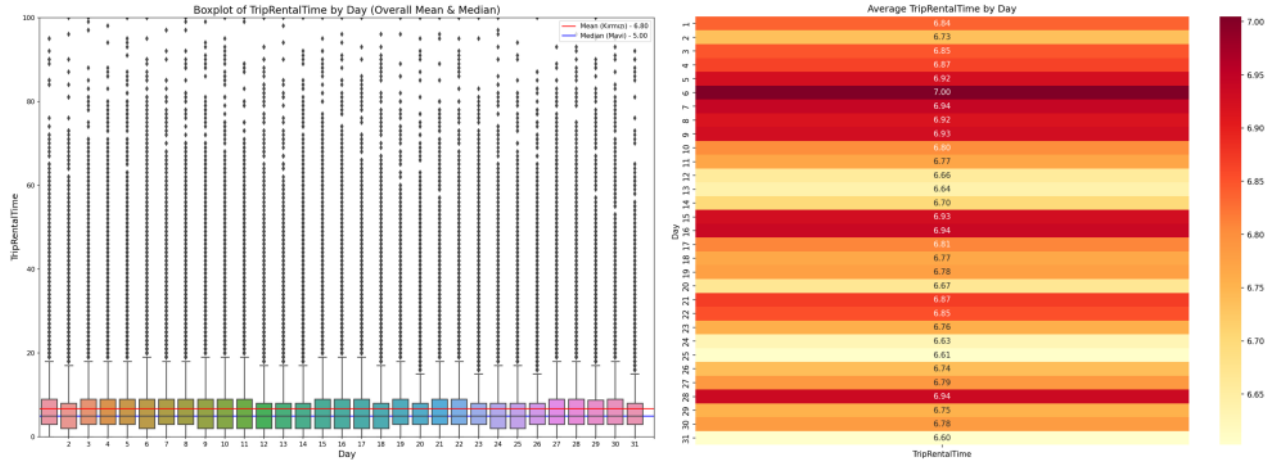


Figure 4. Trip rental time by day, a. boxplot, b. heatmap

Figure 4 illustrates the average rental duration of scooters by the days of the month. The box plot reveals a high number of outliers concerning mean rental duration. The first 10 days of the month, excluding the second day, see a noticeable increase in longer rental durations. This trend is also observed around the middle of the month and on the 20th-21st and 28th days. This pattern likely correlates with salary payments, as private sector employees in Türkiye typically receive their wages at the beginning of the month, while public sector employees are paid mid-month.

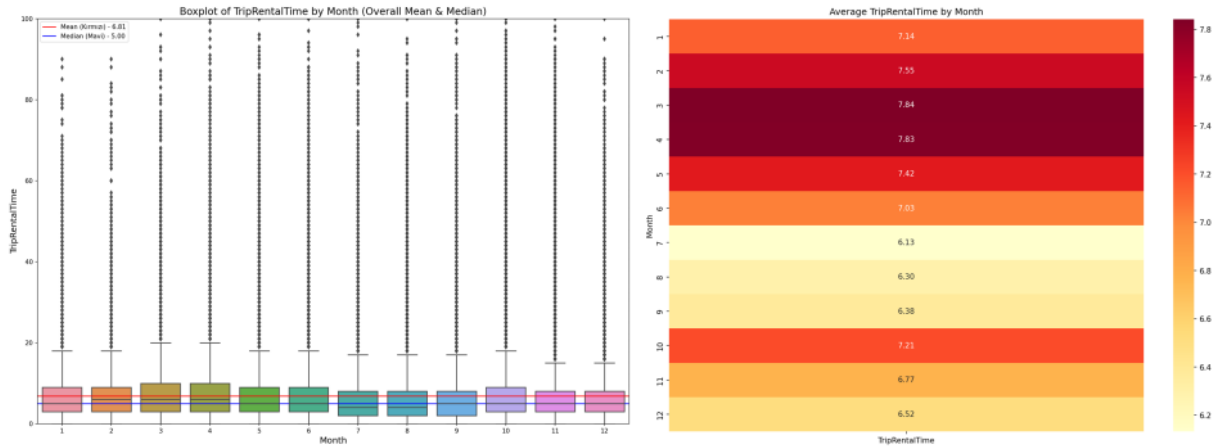


Figure 5. Trip rental time by month, a. boxplot and b. heatmap

Figure 5 illustrates rental durations by month. The box plot highlights fluctuations in monthly rental durations and reveals a significant number of outliers. Notably, substantial variability exists in rental durations across different months. The heat map identifies the months with the highest rental durations, showing that the first half of the year tends to have longer rental times compared to the latter half, except for October. This suggests that rental durations are shorter during hotter months compared to relatively cooler ones.

Figure 6 displays rental durations by season. Spring has the highest average trip rental duration at 7.64 minutes, while Summer records the lowest at 6.45 minutes. Fall and Winter exhibit moderate average durations of 6.81 and 6.78 minutes, respectively.

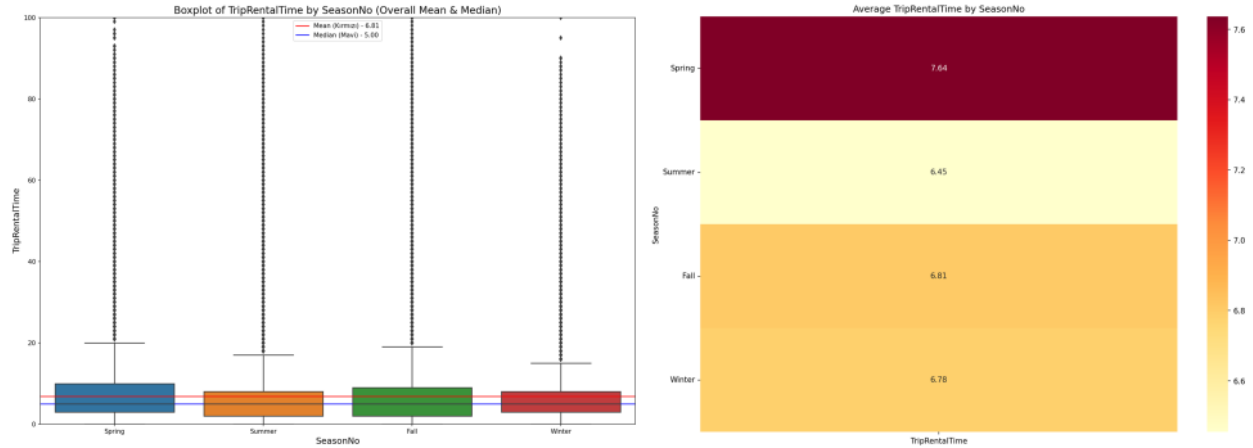


Figure 6. Trip rental time by season, a. boxplot, and b. heatmap

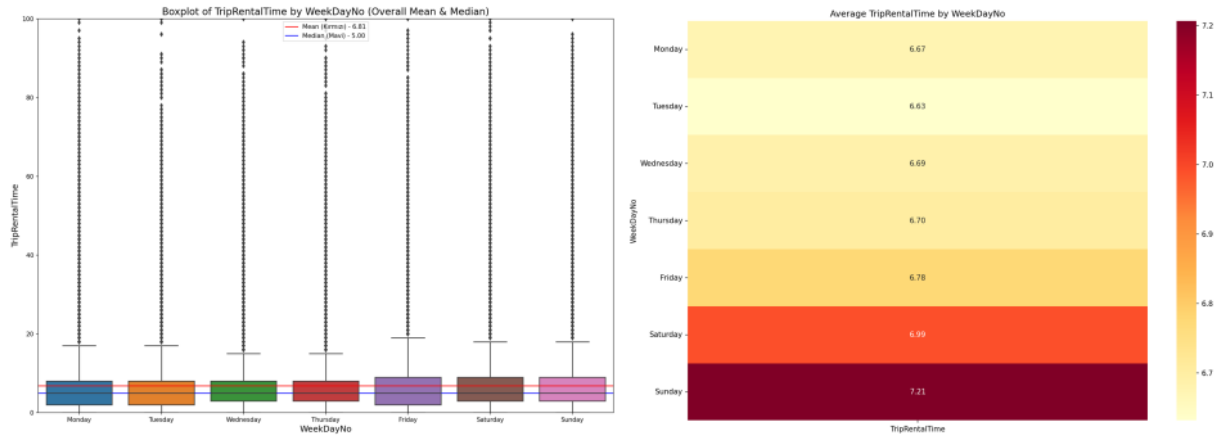


Figure 7. Trip rental time by weekday, a. boxplot, and b. heatmap

Figure 7 illustrates trip rental durations by weekday. Monday through Thursday exhibit similar patterns, likely associated with commuting to work or school. In contrast, a sharp increase in rental durations is observed on Friday, Saturday, and Sunday, with Sundays showing the longest rental times.

Weather conditions are expected to influence rental durations. Figure 8 examines precipitation and wind speed in relation to rental time across the entire dataset. The data indicates that most trips last less than 20 minutes, regardless of wind speed. However, as wind speed increases, the number of trips decreases, suggesting that higher wind speeds deter users from taking longer rides. Similarly, low levels of precipitation have minimal impact on rental durations, but as precipitation increases, a sharp decline in rental trip durations is observed.

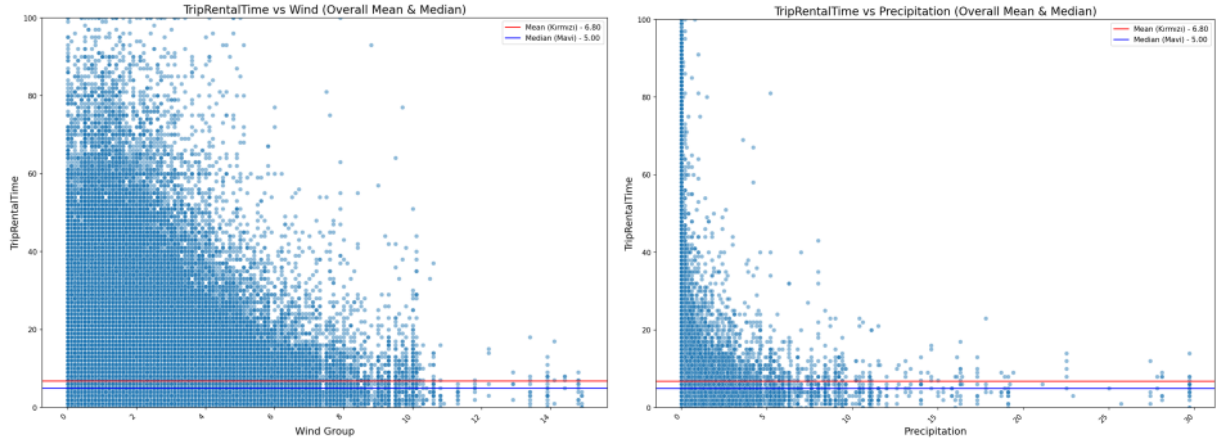


Figure 8. Trip rental time by weather, a. wind, and b. precipitation

The scatter plot in Figure 9 examines the relationship between temperature and humidity. Most trip durations are concentrated between 0 and 20 minutes across all temperature groups, with a dense cluster of data points forming a roughly normal distribution. The dataset contains outliers, indicating that some riders take longer trips under adverse conditions. However, the highest number of rentals occurs in mid-temperature ranges, suggesting that temperature has a limited overall impact on rental durations, though this may not be fully evident in the graph due to the dataset's scale. Conversely, colder temperatures tend to reduce rental durations. It is evident that moderate temperatures encourage rentals more than extreme low or high temperatures.

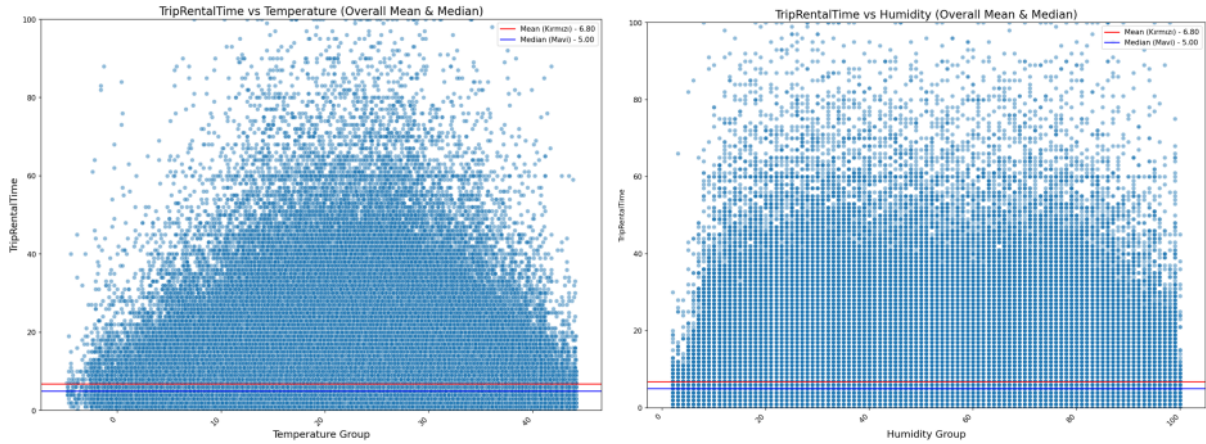


Figure 9. Trip rental time by weather, a. temperature, and b. humidity

V. Conclusion and Future Work

Shared vehicles, despite being a relatively recent addition to urban transportation, have quickly filled a significant gap. They play a crucial role in connecting various modes of transportation within urban infrastructure. Additionally, these vehicles—particularly shared e-scooters—are often used for recreational and tourism purposes. These diverse travel purposes have resulted in varying usage behaviors, requiring operator companies to adopt more informed and conscious decision-making processes.

A detailed descriptive analysis of e-scooter usage data provides valuable strategic insights for companies. It highlights the need to consider external factors such as wind, precipitation, and temperature, alongside rental durations, which are influenced by time of day, day of the week, month, season, and their interactions with external conditions. Understanding user behavior trends is essential for enhancing service quality, improving operational efficiency, and meeting customer expectations.

Although a significant portion of users are either inactive or engage only occasionally, targeted campaigns can attract these potential users, increase retention, and promote more consistent usage. Notably, 15% of users constitute a loyal core group, which can be further engaged through rewards or incentives to maintain loyalty, boost ride frequency, and extend rental durations.

In conclusion, compared to existing studies in the literature, shared e-scooter usage in Türkiye aligns with some universal trends while exhibiting unique local dynamics. Weather conditions (e.g., wind speed and precipitation) and temporal parameters (e.g., time of day and day of the week) significantly influence users' riding times. Increased wind speeds lead to noticeable decreases in riding times. While very long rides can occur in rainy weather, riding times are generally shorter under such conditions.

Contrary to findings in the literature, user behavior in Türkiye does not exhibit a linear relationship with temperature. Riding times tend to be relatively longer at optimal temperatures between 20-25°C, whereas colder or warmer conditions result in shorter rides. No clear relationship was identified for humidity.

Analyzing time-of-day effects reveals that the highest number of trips occurs between 17:00 and 21:00. However, riding times are relatively shorter during early morning hours (6:00-10:00) and working hours (until 18:00). Regarding the day of the month, a noticeable increase in rides is observed around common salary payment days in Türkiye, although unexpected variations, such as on the 28th, also occur.

Monthly and seasonal analyses show that average riding times differ in March and April and during the Spring season, consistent with temperature trends. Finally, weekday and weekend riding behaviors differ, with weekends showing longer rides on average compared to weekdays.

The findings offer valuable insights into the usage patterns of the shared e-scooter service, helping operators optimize deployment strategies, rebalancing efforts, and enhancing user experience by analyzing trip durations and counts across different time intervals. For example, strategies could be implemented to encourage longer ride durations, particularly those exceeding 10 minutes, which currently account for only 9% of the dataset. Such initiatives could expand the service's usage range and promote adoption for diverse commuting needs.

In the future, users' walking behaviors can be further analyzed by integrating riding and location telemetry datasets to identify patterns leading to riding spots. Additionally, the influence of external factors such as weather and altitude on walking patterns can be examined to better understand how these factors determine walking behaviors.

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Conflicts of Interest: None

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