**Shared E-scooter Service Use Pattern According to City Layout Cluster**

*(Work in Process)*

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**ABSTRACT**

To find out the role of e-scooter (electronic scooter) in the metropolitan city, we combine the data of city layout components that have an effect on the urban transportation system, with city infrastructure, transportation, residential, and floating population information. After clustering the autonomous districts in Seoul, Korea, we analyze E-scooter usage patterns according to clustering groups resulting from city layout components cluster. Analyzing the data by the time unit, our study found the pattern of weekdays and weekends is different depending on the district cluster, and we expect a distinguished role for E-scooter in each cluster.

*Keywords*: E-scooter, micro-mobility, city layout, district cluster, Seoul

**INTRODUCTION**

With the development of technology, the speed of urban development is accelerating, and transportation is being raised an important part of urban areas (McKenzie, 2019) especially, where the population is concentrated. Thereby traffic is changing rapidly in line with the pace at which the city develops. Cities like Seoul have a population of about 12 million which is more than one-fifth of a country, so the role of each autonomous district becomes important. That is why metropolitan transportation plans are made according to the city characteristics of each district. Within this environment, micro-mobility is in the spotlight that challenges the urban transport system (Chang et al., 2019; Kopplin et al., 2021). As the role of micro-transportation in cities is important, a lot of research on emerging transportation has been conducted.

Micro-mobility is an innovative urban transport solution aimed at providing short-distance travel options including first and last-kilometer trips (Abduljabbar et al., 2021). E-scooters best reveal characteristics such as dockless and small devices, single-user, and electric vehicles (Eccarius & Lu, 2020) which leads to the economic feasibility of micro-mobility. According to the Seoul Metropolitan Statistical Office, the number of shared e-scooters in Seoul, which was only 150 in 2018, surged to about 35,850 in 2020, and 55,499 shared e-scooters were in operation as of June 2021(Lee at al., 2022). Electric scooters have surged in popularity not only in Seoul but also in large cities around the world. Accordingly, many studies on e-scooters are being conducted actively (Bai & Jiao, 2020; Eccarius & Lu, 2020; Huo et al., 2021). Our study aims to analyze the usability of electric scooters according to the characteristics of each autonomous district of the city based on clustering the data of a representative electric scooter company in Korea, KickGoing.

We focused on which the characteristics of the city layout in each ‘gu’ are different from each other and the elements that make up each district also appear differently. Therefore, with a total of 4 clusters, this study explores the different use patterns of shared e-scooter per district ‘gu’ unit according to the time. Through hourly and monthly analysis, a cluster with many office workers and a large floating population shows superior usage of e-scooter service. For the analysis between weekends and weekdays, cluster1 showed a significant difference. Furthermore, the ultimate research question for this study is “What are the city layout components that determine the role of shared E-scooter service?” giving contributions to e-scooter companies where to place kickboards and how to manage the usage efficiently.

**LITERATURE REVIEW**

**E-scooter as Micro-mobility**

Micro-mobility is a concept that originated in Sheller’s (2011) study on the new mobilities paradigm, and later was re-discussed by other researchers (Eccarius and Lu 2020). Micro-mobility is an innovative urban transport solution aimed at providing short-distance travel options including first and last-kilometer trips (Abduljabbar et al., 2021). Micro-mobility has several characteristics like light and small devices, single-user, and electric vehicles (Eccarius & Lu, 2020; Shaheen et al., 2020). Overall, micro-mobility relates to shorter distance trips for personal transport which provides cost-effective, flexible, and sustainable. A representative product that encompasses the above characteristics is an electric scooter. E-scooters in metropolises, especially large cities in the United States have seen extensive growth (NACTO, 2020) and become increasingly popular in many cities worldwide (Caspi et al., 2020; Li et al., 2022) like Seoul, the largest city in South Korea.

In Seoul, the domestic e-scooter sharing service market was first opened in September 2018 when Olulo launched a service called “Kick-Going”. Since then, domestic latecomers such as "Sing-Sing" and "Swing" have entered the market, and global companies such as "Lime" and "Beam" have continued to enter Korea. According to the Seoul Metropolitan Statistical Office, the number of shared micro-mobility in Seoul, which was only 150 in 2018, surged to about 35,850 in 2020, and 55,499 shared e-scooters were in operation as of June 2021(Lee at al., 2022). As mentioned, micro-mobility mainly relates to short-distance trips. This characteristic makes benefits like time-saving, and economical use which leads e-scooter to become alternative transportation. To find out how e-scooters generate trips and improve mobility accessibility Chang et al. (2019) analyzed e-scooter sharing trips in Austin, TX, Louisville, KT, Minneapolis, MN, and Washington DC. It showed that 63% of e-scooter trips are under one mile in distance.

Smith and Schwieterman (2018) investigated the benefits of e-scooter in Chicago, Illinois. They predicted the potential use of an e-scooter as a short-distance purpose vehicle. Eccarius and Lu (2020) conducted a study to find out the factors that influence university students’ intention of using e-scooter sharing services. According to the model, Walk Score and Bike Score influenced E-Scooter trip density positively which can replace walking and biking within short-trip. Gössling (2020) mentioned that e-scooters are specifically suitable to cover short distances and suggest that e-scooters are highly attractive as urban transport modes. Caspi et al. (2020) analyzed trip patterns and spatial regression techniques to examine how the built environment, land use, and demographics affect the e-scooter trip. They found that low-income area with students shows positive relation with high e-scooter trips more than low-income area (Li et al., 2022).

**The role of the Micro-mobility in Urban Transportation System**

The various components in a city affect the urban transportation system. Zhou and Gao (2020) study show how the big city's transportation is structured and utilized through a case analysis of Tokyo, the capital of Japan, using a large set of data on economic factors, population, land use policies, and urban traffic modes. They showed that a substantial increase in traffic demand is usually due to the fundamental cause of urbanization and the increasing trend of the urban population (Zhou & Gao, 2020). In another context, Lee (2021) conducted an empirical effect analysis of transportation infrastructure on regional development. It suggests that a policy for transport projects be implemented to maximize their cost effectiveness and ensure that agglomeration is promoted in the area where they are developed (Lee, 2021). Also, with the continuous development of large cities, building a tuneful urban transportation system to ease traffic pressure is a common problem faced by many countries in the process of the urban development process (Zhou & Gao, 2020). Rather than establishing new transportation facilities, investment methods that can make the most of existing facilities are promoted. When constructing roads, it promotes public transportation and sharing with pedestrians rather than vehicles, and expands high-tech public transportation facilities that can be replaced (Lee at al., 2022).

E-scooter has been used often recently in transport literature as an essential component of high-tech urban transportation. As urban transport welcomed e-scooter, there were clear pros and cons to accepting e-scooter as alternative urban transportation. Gössling (2020) collected data to assess the challenges that 10 cities confronted when they set up e-scooters. Through the study, he suggested that city transport planners should set detailed regulations such as speed limits, and design dedicated parking areas to integrate e-scooters into urban transportation. Smith and Schwieterman (2018) also find out that e-scooters are strong alternatives to private mobility through their research. They randomly selected 30,000 e-scooter trips in Chicago and Illinois using network-based analysis. However, it was notable that the benefit of e-scooters varies from one area to another. A typical purpose of using public transportation in the city is to commute. Various studies on this are also being conducted, but opinions are still divided. Hardt and Bogenberger (2019) found that about 86% of commuting trips can be replaced by e-scooters with a pilot study of e-scooter users in Munich, Germany. However, there are a few more studies that have discovered that e-scooters are not used for commuting (Caspi et al., 2020; Mathew et al., 2019; McKenzie, 2020).

Mathew et al. (2019) focused to investigate the spatio-temporal usage patterns of e-scooter. They collected data for more than three months in Indianapolis and analyzed the temporal pattern of e-scooter usage. It was found that the peak usage was between 4:00-9:00 on weekdays, which indicates in Indianapolis citizens seldomly use e-scooter for morning commute (Bai & Jiao, 2020). Another study in Austin, Texas, reported descriptive data suggesting that commuting is not the main trip purpose for users in Austin. The hourly weekday trip distribution does not show a two-peak pattern, during morning and evening commuting times and the average daily usage was shown higher on weekends and holidays (Caspi et al., 2020). The work by McKenzie (2019) identified spatial and temporal usage patterns by data from Washington, D.C. and compare two representative share mobility, bike, and e-scooter. They find out that while bike-share in Washington is predominantly used by those commuting to and from work, e-scooter trips don’t indicate commuting as a purpose of using.

**E-scooter usage patterns in city**

As mentioned earlier, E-scooter was noted as an alternative means of transportation based on analysis reflecting usage patterns and characteristics. However, as a means of transportation, some studies have found out that the usage behavior of e-scooter is different for each region; and the need for future studies on how to efficiently use e-scooter by city or in what place. To find out e-scooter usage patterns and their association with urban environments, Bai and Jiao (2020) compared two cities, Austin and Minneapolis. They showed the heaviest usage in downtown areas and universities in both cities but found out the temporal characteristics of the two cities’ e-scooter usage patterns are varied largely. To understand the spatial-temporal heterogeneity of micro-mobility services Zhu et al. (2020) conducted a comparative analysis between bike-sharing and scooter-sharing activities in Singapore. By exploring two different districts in Singapore, the similarities and differences between the two sharing services were discovered (Li et al., 2022).

Huo et al. (2021) collected the e-scooter trip data of five cities in the United States to fill the research gap which only a few studies have considered multiple cities to obtain generalizable results. They find out the temporal distribution of e-scooter trips in different cities is similar and the ridership characteristics are positively correlated with population density, employment density, bus stop, etc. (Huo et al., 2021). Li et al. (2022) conducts a study to find out a comprehensive comparison of e-scooter in different cities. They collected and analyzed the data from 30 different Europe cities during COVID-19, and get four different perspective results, temporal trip patterns, statistical characteristics, utilization efficiency, and wasted electricity during idle time, to compare the similarity and differences between 30 cities.

Studies so far have not distinguished the characteristics of the region within the city, but have compared the city as a whole or centered on large cities in each country. However, a large city is a space where a large population works and lives. Generally huge cities can be divided into district by living characteristic like residential district, business district etc. For instance, there are Manhattan in New York, Los Angeles in California, are central business district and have difference place like Queens in New York and Bakersfield in California. Seoul is a huge city which one of the South Korea population lives. The purpose of this study is to divide a city into more details according to the city layout components, in Seoul, distinguished to autonomous district called as “-gu”, combine each space into clusters with common characteristics, and analyze the usage pattern of electric kickboards.

***Research Question*** *: What are the city layout components that determine the pattern of shared E-scooter service?*

**DATA**

**Determinants of district cluster**

In Korea, Seoul is home to about 20% of the Korean population and is the first place where shared e-scooters were introduced. There are 25 districts, which are called ‘gu’. And the characteristics of the city layout in each ‘gu’ are different from each other and the elements that make up each district also appear differently. For example, Gangnam-gu has a large number of business people and has an active public transportation system, but Nowon-gu has a similar transportation infrastructure as the number of bus stops and shared bicycle installations are similar to those of Gangnam-gu (table2). So, we compare the different use pattern of shared e-scooter per district ‘gu’ unit and make clusters according to the characteristics in each district. To make a cluster, we gather data from two sides for city layout and e-scooter usage in Seoul, Korea. Currently, 17 shared e-scooter companies are active, and the cumulative usage is estimated to have exceeded 1 million as of June 2020. In addition, compared to other cities, various types of land use exist at the same time, and each autonomous district has strong characteristics. To define district clusters, transportation, floating population, resident population, and infrastructure information are collected.

***Transportation***

An important role in city layout is the public transportation that composes the area. The number of buses and subways frequently used by people is identified from public data and included as a factor to distinguish clusters. We use the number of bus stops and subway stops located in each district, and calculate the number of subways by adding up the number of subway lines passing through each station. For example, if three lines pass through one subway station, this is because traffic is more active than at a subway station where only one line passes. In addition, since the existing shared bicycle and shared car stops will play an important role in distinguishing the traffic environment, they are also added as cluster variables.

***Floating population***

As it is expected that the use of electric scooters will increase in places with a large floating population, variables that determine the floating population are added. The number of offices and employees in each district is included, and the number of universities is also included to reflect the number of people in their 20s, who are known as major customers of electric scooters. In addition, it is expected that the use of an e-scooter will appear frequently in places where the walking distance is long and walking space is wide. So the area of the park that creates a walking environment is included, and the area of the road that can be walked within the park is also combined.

***Resident population***

Not only the floating population but also the residential population is expected to have an impact on the use of kickboards. We include basic demographic indicators such as the number of people in each region, the number of cars, and the gender ratio. The number of single-person households that can reflect the demographic characteristics of each region and information on whether single-person households are young or elderly is also considered and reflected. In order to consider the number of family generations that make up the area, the number of nearby elementary schools is also included.

***Infrastructure***

Variables are also included to determine how the surrounding commercial district is formed and how developed the city is. To reflect the degree of public facility development, the number of public libraries and post offices is reflected. In addition, the surrounding cultural infrastructure and commercial district indicators such as department stores and shopping malls are also reflected.

Table 1 : Description of City Layout Components of 25 districts

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Type of variables** | **Description of variables** | **average** | **min** | **max** | **sd** |
| Transportation | The number of Subway stations (T1) | 12.28 | 2 | 27 | 6.655 |
| The number of bus stations (T2) | 428.16 | 178 | 607 | 106.756 |
| The number of sharing bicycle stations (T3) | 1263.88 | 649 | 2444 | 466.053 |
| The number of sharing car stations (T4) | 74.8 | 37 | 146 | 26.435 |
| Floating population | The ratio of traffic generation per population (F1) | 0.642 | .33 | 2.33 | .45879 |
| The number of enterprises in a district (F2) | 32944.96 | 18628 | 71027 | 13218.163 |
| The number of workers in a district(F3) | 209079.88 | 72939 | 698840 | 146782.482 |
| The number of universities (F4) | 7.96 | 5 | 9 | 1.57 |
| Total area of park (F5) | 6625.84 | 1219 | 15073 | 4573.486 |
| Total area of walking route in park (F6) | 2177.72 | 563 | 4357 | 1003.399 |
| Resident population | The number of owned auto-mobiles (R1) | 127211.96 | 50832 | 248750 | 50318.607 |
| The number of total resident populations (R2) | 396443.52 | 134635 | 673926 | 126718.527 |
| The average age of resident populations (R3) | 43.948 | 41.9 | 46.9 | 1.3383 |
| The average gross regional product (R4) | 17437088.6 | 3283572 | 71852681 | 17234094.938 |
| The average ratio of gender (R5) | 94.08 | 88 | 103 | 3.390 |
| The number of elementary schools (R6) | 24.28 | 12 | 42 | 7.786 |
| The number of one-person households (R7) | 55628.04 | 22818 | 129233 | 21245.607 |
| The number of young single-person households (R8) | 21843.20 | 6964 | 74026 | 13508.904 |
| The number of elderly single-person households (R9) | 10389.32 | 4526 | 17738 | 3250.827 |
| Infrastructure | The number of public libraries (I1) | 7.52 | 4 | 14 | 2.859 |
| The number of complex cultural spaces (I2) | 31.20 | 8 | 172 | 33.721 |
| The number of post offices (I3) | 16.28 | 6 | 36 | 6.580 |
| The number of large supermarkets (I4) | 2.28 | 0 | 6 | 1.487 |
| The number of department stores (I5) | 1.24 | 0 | 6 | 1.332 |
| The number of complex shopping malls (I6) | 2.04 | 0 | 8 | 2.245 |
| The number of other large stores (I7) | 12.16 | 1 | 38 | 7.261 |

Table 2 : City Layout Variables in Districts

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Districts**  **(unit : gu)** | **T1** | **T2** | **T3** | **T4** | **F1** | **F2** | **F3** | **F4** | **F5** | **F6** | **R1** | **R2** |
| Dobong-gu | 3 | 362 | 775 | 37 | 0.38 | 18,628 | 72,939 | 5 | 10160 | 1121 | 95,573 | 327,361 |
| Dongdaemun-gu | 5 | 306 | 1,019 | 59 | 0.48 | 31,324 | 138,400 | 9 | 1219 | 1049 | 98,574 | 357,014 |
| Dongjak-gu | 13 | 439 | 916 | 82 | 0.47 | 19,793 | 106,159 | 9 | 4329 | 2311 | 106,263 | 401,572 |
| Eunpyeong-gu | 11 | 499 | 1,052 | 87 | 0.39 | 24,681 | 93,631 | 9 | 14366 | 2201 | 133,291 | 484,043 |
| Gangbuk-gu | 3 | 411 | 649 | 43 | 0.49 | 19,014 | 73,904 | 5 | 14425 | 1956 | 75,148 | 311,569 |
| Gangdong-gu | 13 | 366 | 1,527 | 84 | 0.35 | 29,080 | 141,770 | 6 | 3362 | 2100 | 151,875 | 463,998 |
| Gangnam-gu | 22 | 506 | 1,761 | 146 | 0.87 | 71,027 | 698,840 | 9 | 7769 | 3628 | 240,480 | 544,055 |
| Gangseo-gu | 18 | 567 | 2,352 | 111 | 0.41 | 39,458 | 257,494 | 6 | 4512 | 3520 | 206,352 | 585,901 |
| Geumcheon-gu | 1 | 345 | 856 | 57 | 0.47 | 33,814 | 242,686 | 6 | 2774 | 563 | 90,508 | 247,835 |
| Guro-gu | 7 | 496 | 1,264 | 81 | 0.45 | 38,756 | 225,668 | 9 | 3641 | 1533 | 146,040 | 432,488 |
| Gwanak-gu | 4 | 468 | 901 | 90 | 0.53 | 25,505 | 115,329 | 9 | 12431 | 1910 | 118,148 | 509,803 |
| Gwangjin-gu | 9 | 272 | 1,128 | 55 | 0.59 | 24,445 | 126,305 | 9 | 3451 | 1351 | 99,126 | 360,109 |
| Jongno-gu | 12 | 350 | 1,201 | 44 | 1.79 | 39,679 | 260,446 | 9 | 11403 | 3024 | 50,832 | 158,996 |
| Jung-gu | 14 | 178 | 1,002 | 64 | 2.33 | 60,127 | 392,568 | 9 | 3164 | 1345 | 60,081 | 134,635 |
| Jungnang-gu | 8 | 424 | 986 | 50 | 0.35 | 28,228 | 103,345 | 6 | 4,990 | 1,669 | 114,961 | 399,562 |
| Mapo-gu | 14 | 567 | 1,437 | 130 | 0.71 | 37,290 | 247,276 | 9 | 4565 | 4338 | 121,250 | 381,858 |
| Nowon-gu | 11 | 517 | 1,476 | 67 | 0.38 | 26,618 | 116,684 | 9 | 14742 | 1884 | 152,305 | 527,032 |
| Seocho-gu | 13 | 600 | 1,804 | 95 | 0.87 | 46,940 | 438,985 | 9 | 15073 | 2148 | 176,639 | 429,025 |
| Seodaemun-gu | 4 | 460 | 1,004 | 74 | 0.53 | 20,095 | 113,819 | 9 | 5082 | 1123 | 89,435 | 322,952 |
| Seongbuk-gu | 9 | 607 | 936 | 60 | 0.45 | 23,617 | 111,005 | 6 | 8507 | 1640 | 122,016 | 447,056 |
| Seongdong-gu | 13 | 437 | 1,001 | 54 | 0.62 | 28,343 | 178,243 | 9 | 3074 | 2896 | 106,035 | 300,505 |
| Songpa-gu | 22 | 416 | 2,444 | 94 | 0.45 | 48,644 | 341,201 | 9 | 4771 | 4357 | 248,750 | 673,926 |
| Yangcheon-gu | 6 | 323 | 1,269 | 77 | 0.33 | 25,894 | 121,582 | 6 | 3050 | 2206 | 151,251 | 457,781 |
| Yeongdeungpo-gu | 13 | 465 | 1,838 | 66 | 0.72 | 42,370 | 373,478 | 9 | 3009 | 2957 | 145,946 | 407,367 |
| Yongsan-gu | 9 | 323 | 999 | 63 | 0.64 | 20,254 | 135,240 | 9 | 1777 | 1613 | 79,420 | 244,645 |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Districts (unit : gu)** | **R3** | **R4** | **R5** | **R6** | **R7** | **R8** | **R9** | **I1** | **I2** | **I3** | **I4** | **I5** | **I6** | **I7** |
| Dobong-gu | 46.3 | 3,404,872 | 94 | 23 | 34,884 | 6,964 | 10,706 | 7 | 15 | 13 | 2 | - | - | 6 |
| Dongdaemun-gu | 44.3 | 7,555,543 | 96 | 21 | 60,925 | 27,207 | 11,072 | 6 | 26 | 14 | 2 | 1 | - | 15 |
| Dongjak-gu | 43.6 | 6,527,100 | 93 | 21 | 64,101 | 31,876 | 9,923 | 6 | 19 | 12 | - | 1 | - | 4 |
| Eunpyeong-gu | 44.8 | 4,919,715 | 92 | 30 | 57,853 | 17,164 | 14,020 | 8 | 22 | 12 | 2 | - | 5 | 10 |
| Gangbuk-gu | 46.9 | 3,283,572 | 93 | 14 | 45,685 | 11,626 | 12,704 | 7 | 18 | 8 | 1 | 1 | 2 | 8 |
| Gangdong-gu | 43.2 | 9,348,668 | 96 | 29 | 50,316 | 15,085 | 10,831 | 9 | 15 | 14 | 3 | 1 | - | 8 |
| Gangnam-gu | 42.0 | 71,852,681 | 91 | 33 | 68,999 | 26,845 | 10,335 | 14 | 67 | 36 | 1 | 6 | 4 | 21 |
| Gangseo-gu | 43.2 | 17,458,926 | 93 | 35 | 86,172 | 33,262 | 16,294 | 9 | 14 | 17 | 3 | 1 | 1 | 10 |
| Geumcheon-gu | 44.9 | 17,614,623 | 103 | 18 | 42,334 | 15,524 | 7,619 | 4 | 20 | 6 | 3 | - | 7 | 5 |
| Guro-gu | 44.4 | 14,090,156 | 98 | 26 | 50,971 | 16,953 | 10,819 | 11 | 22 | 16 | 3 | 2 | 1 | 17 |
| Gwanak-gu | 43.0 | 5,963,769 | 99 | 22 | 129,233 | 74,026 | 13,676 | 5 | 14 | 16 | 1 | 1 | 4 | 15 |
| Gwangjin-gu | 43.0 | 6,587,069 | 93 | 22 | 62,301 | 29,523 | 8,200 | 5 | 18 | 14 | 2 | 1 | - | 16 |
| Jongno-gu | 45.5 | 33,780,610 | 93 | 13 | 25,983 | 10,365 | 4,897 | 7 | 172 | 20 | - | - | 4 | 11 |
| Jung-gu | 45.9 | 53,823,217 | 93 | 12 | 22,818 | 8,180 | 4,526 | 6 | 65 | 13 | 2 | 3 | 8 | 38 |
| Jungnang-gu | 45.4 | 4,741,739 | 97 | 23 | 56,605 | 14,778 | 13,280 | 5 | 8 | 9 | 6 | - | 1 | 7 |
| Mapo-gu | 42.3 | 19,943,128 | 88 | 22 | 63,172 | 30,285 | 8,569 | 6 | 35 | 19 | 3 | - | 1 | 11 |
| Nowon-gu | 44.0 | 6,620,672 | 93 | 42 | 56,438 | 14,658 | 17,738 | 11 | 20 | 24 | 2 | 2 | 1 | 9 |
| Seocho-gu | 41.9 | 35,570,338 | 91 | 24 | 43,942 | 16,631 | 6,891 | 8 | 32 | 25 | 4 | 2 | - | 18 |
| Seodaemun-gu | 44.0 | 8,652,191 | 88 | 19 | 49,863 | 23,347 | 8,899 | 4 | 15 | 16 | - | 1 | - | 8 |
| Seongbuk-gu | 43.7 | 6,141,921 | 92 | 29 | 61,510 | 26,630 | 11,771 | 13 | 24 | 15 | 3 | 1 | 1 | 16 |
| Seongdong-gu | 43.5 | 12,167,850 | 95 | 21 | 42,585 | 16,910 | 7,361 | 7 | 14 | 10 | 2 | - | 1 | 9 |
| Songpa-gu | 42.3 | 29,962,528 | 93 | 40 | 73,694 | 27,000 | 12,324 | 12 | 28 | 26 | 4 | 2 | 3 | 11 |
| Yangcheon-gu | 42.9 | 7,125,314 | 96 | 30 | 39,436 | 9,268 | 10,847 | 9 | 15 | 13 | 1 | 1 | 1 | 17 |
| Yeongdeungpo-gu | 43.3 | 36,095,497 | 99 | 23 | 64,000 | 28,114 | 10,036 | 5 | 15 | 23 | 5 | 3 | 3 | 13 |
| Yongsan-gu | 44.4 | 12,695,516 | 93 | 15 | 36,881 | 13,859 | 6,395 | 4 | 67 | 16 | 2 | 1 | 3 | 1 |

**Shared E-scooter use data**

To measure the actual shared e-scooter service, the data of the biggest company in Korea is used. The company currently has the most e-scooter usage and customers in Seoul, Korea. It launched the service in 2018 and exceeded 1.2 million customers as of 2021. Also, among the 25 districts in Seoul, 18 are providing services. The data for all rental records for a total of one year, from January to December 2021, is used. Each customer was given a unique ID, and a record of each usage is also accumulated. So, through the data, we can know the departure and arrival location of each user, the time, and the amount of use. The fee for using an e-scooter is a method in which the basic fee is paid when renting for the first time, and then additional payment is made according to the distance traveled. So, the amount paid can be considered proportional to the distance traveled.

**RESULT**

**Clustering analysis**

In comparing total 26 variables of city layout, we divide 25 districts into clusters with K-means clustering algorithm, which groups districts according to their characteristics. When the K, meaning the number of clusters, is gradually increased, it is confirmed that cluster classification was stabilized when K was 4 (figure1). As classified into a total of 4 clusters, the districts are classified in table3. So, it means that all regions are properly distributed when divided into four clusters.

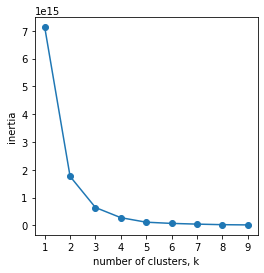


Figure 1 : Number of Clusters

Table 3 : Result of District Clustering

|  |  |  |  |
| --- | --- | --- | --- |
| **Cluster1** | **Clsuter2** | **Cluster3** | **Cluster4** |
| Gangnam-gu | Seocho-gu | Gangseo-gu | Gangdong-gu |
| Jung-gu | Songpa-gu | Guro-gu | Gangbuk-gu |
|  | Yeongdeungpo-gu | Geumcheon-gu | Gwanak-gu |
|  | Jongno-gu | Mapo-gu | Gwangjin-gu |
|  |  | Seongdong-gu | Nowon-gu |
|  |  | Yongsan-gu | Dobong-gu |
|  |  |  | Dongdaemun-gu |
|  |  |  | Dongjak-gu |
|  |  |  | Seodaemun-gu |
|  |  |  | Seongbuk-gu |
|  |  |  | Yangcheon-gu |
|  |  |  | Eunpyeong-gu |
|  |  |  | Jungnang-gu |

Table 4 : City Layout Variables in Cluster

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  | **Cluster1** | **Cluster2** | **Cluster3** | **Cluster4** |
| **Transportation** | Average of Subway stations | 22 | 19.5 | 12 | 9 |
| Average of bus stations | 342 | 458 | 456 | 420 |
| Average of sharing bicycle stations | 1,382 | 1,822 | 1,318 | 1,049 |
| Average of sharing car stations | 105 | 75 | 83 | 67 |
| **Floating population** | Average ratio of traffic generation per population | 1.6 | 0.96 | 0.55 | 0.44 |
| Average of enterprises in a district | 65,577 | 44,408 | 32,986 | 24,379 |
| Average of workers in a district | 545,704 | 353,528 | 214,435 | 110,375 |
| Average of universities | 9 | 9 | 8 | 7 |
| Average area of park | 5,466 | 8,564 | 3,391 | 7,701 |
| Average area of walking route in park | 2,486 | 3,122 | 2,410 | 1,732 |
| **Resident population** | Average of owned auto-mobiles | 150,281 | 155,542 | 124,934 | 115,997 |
| Average of total resident populations | 339,345 | 417,329 | 365,539 | 413,066 |
| Average age of resident populations | 44.0 | 43.3 | 43.8 | 44.2 |
| Average gross regional product | 62,837,949 | 33,852,243 | 15,661,700 | 6,220,934 |
| Average ratio of gender | 92 | 94 | 95 | 94 |
| Average of elementary schools | 23 | 25 | 23 | 25 |
| Average of one-person households | 45,909 | 51,905 | 53,686 | 59,165 |
| Average of young single-person households | 17,513 | 20,528 | 21,132 | 23,242 |
| Average of elderly single-person households | 7,431 | 8,537 | 9,510 | 11,821 |
| **Infrastructure** | Average of public libraries | 10 | 8 | 7 | 7 |
| Average of complex cultural spaces | 66 | 62 | 29 | 18 |
| Average of post offices | 25 | 24 | 14 | 14 |
| Average of large supermarkets | 2 | 4 | 3 | 2 |
| Average of department stores | 5 | 3 | 1 | 1 |
| Average of complex shopping malls | 6 | 3 | 2 | 2 |
| Average of other large stores | 30 | 13 | 9 | 11 |

When comparing the total usage according to time for each cluster, the usage patterns of all clusters are similar. It can be seen that the usage increases rapidly in the morning and evening hours. In particular, it can be seen that among cluster 1, where there are many commuting users, the increase in morning and evening usage is larger than in other clusters (figure2). And it can be seen that the usage of cluster1 is significantly higher in all time zones. This shows that usage is high in clusters with a large floating population and many workplaces.

Also, depending on the time, the distance used may vary. Since the e-scooter is charged according to the distance used, the average usage fee per hour was analyzed, and as a result, the average usage fee per hour of all clusters showed a similar pattern (figure3). This shows that the distances used by people at different times are similar, irrespective of the characteristics of the region. In the early morning, when public transportation is not in operation, the average fee is high because users travel a relatively long distance. In the morning, there are many users who use short distances, so the average usage fee is generally low, and it can be seen that the travel distance gradually increases in the evening.

Since the usage of users may increase depending on the season and weather, the monthly usage of each cluster was compared. As a result, seasonal usage shows similar patterns in all clusters (figure4). The usage increases in March and April, when the weather is warm, and a slight increase was also observed in the hot summer. As the weather gradually got colder, the same pattern was found in autumn and winter with a decrease in usage. And like the hourly analysis, it can be seen that the usage of cluster 1 regions is significantly higher than that of other clusters. Through hourly and monthly analysis, it can be seen that a cluster with many office workers and a large floating population shows superior usage of e-scooter service.

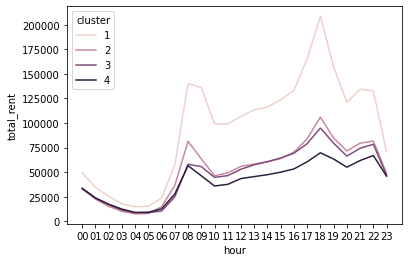


Figure 2 : Hourly Analysis of Rental Volume

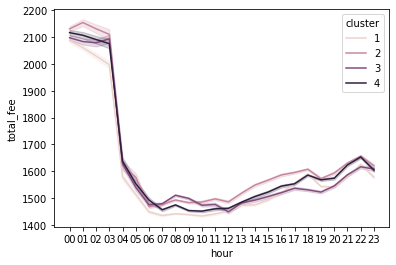


Figure 3 : Hourly Analysis of Average Rental Fee

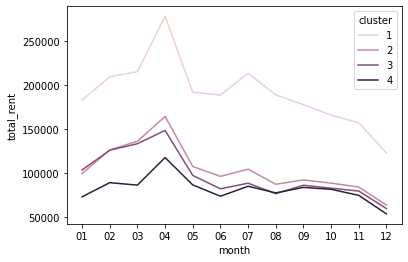


Figure 4 : Monthly Analysis of Rental Volume

**Weekdays vs Weekends**

Through cluster analysis, it is confirmed that the use of e-scooter increases significantly in places with a large number of commuters and floating populations, and through this result, the difference in usage between weekdays and weekends is confirmed to check whether office workers have a large impact on the use of kickboards. Weekend and weekday hours are compared for each cluster with rental data of 2021. When the difference between the weekday group and the weekend group is compared through the T-test, there is a significant difference in cluster1. Although there is a difference in usage between weekends and weekdays in other clusters 2, 3, and 4, the difference in usage is not significantly different in other clusters. Through this, we confirm that the use of kickboards is large in clusters with many office workers, and that the effect on the increase in the use of kickboards is greater than that of the floating population.

Table 5 : Result of Weekdays and Weekends Analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Cluster** | **District (gu)** | **t** | **df** | **P** | **95% CI** | |
| **ULCI** | **LLCI** |
| Cluster1 | Gangnam-gu | 5.23 | 82 | 0.000 | 7601779 | 16935274 |
|  | Jung-gu | 1.955 | 82 | 0.054 | -12480.15 | 1440843.5 |
| Cluster2 | Seocho-gu | 2.457 | 82 | 0.016 | 310408.04 | 2951777 |
|  | Songpa-gu | 0.732 | 82 | 0.466 | -786768.3 | 1703598.3 |
|  | Yeongdeungpo-gu | 0.219 | 82 | 0.827 | -377656.8 | 471015.12 |
|  | Jongno-gu | 0.889 | 82 | 0.377 | -421639.6 | 1102797.9 |
| Cluster3 | Gangseo-gu | - | - | - | - | - |
|  | Guro-gu | 2.252 | 82 | 0.027 | 40421.927 | 653646.41 |
|  | Geumcheon-gu | - | - | - | - | - |
|  | Mapo-gu | 0.217 | 82 | 0.829 | -2125944 | 2646930.7 |
|  | Seongdong-gu | 1.554 | 82 | 0.124 | -186959.4 | 1519867.7 |
|  | Yongsan-gu | -0.957 | 82 | 0.341 | -433285.6 | 151850.62 |
| Cluster4 | Gangdong-gu | - | - | - | - | - |
|  | Gangbuk-gu | - | - | - | - | - |
|  | Gwanak-gu | -0.498 | 82 | 0.62 | -686627.1 | 411752.08 |
|  | Gwangjin-gu | 0.546 | 82 | 0.587 | -482392.6 | 847217.63 |
|  | Nowon-gu | 0.162 | 77 | 0.872 | -288227.1 | 339241.16 |
|  | Dobong-gu | - | - | - | - | - |
|  | Dongdaemun-gu | 1 | 82 | 0.32 | -315672.5 | 954232.52 |
|  | Dongjak-gu | -0.598 | 82 | 0.551 | -81424.12 | 43777.45 |
|  | Seodaemun-gu | 0.562 | 82 | 0.576 | -308547.5 | 551530.8 |
|  | Seongbuk-gu | - | - | - | - | - |
|  | Yangcheon-gu | - | - | - | - | - |
|  | Eunpyeong-gu | -0.026 | 82 | 0.979 | -415608.1 | 404961.45 |
|  | Jungnang-gu | - | - | - | - | - |

**CONCLUSION**

**Discussions**

In order to solve the problem that the urban characteristics of each region were not reflected in confirming the purpose of using the e-scooter in the previous study, regions were clustered according to the city layout. When cities were clustered by reflecting factors such as residential population, infrastructure, transportation system, and floating population, the clusters were grouped based on factors related to the office environment. This implies that the characteristics of each region vary according to the floating population and office-related factors.

Accordingly, the region was clustered into a total of four clusters based on the city layout components, and the use of electric kickboards within each cluster was analyzed. Several similar usage patterns appeared in all clusters. Overall, the distance used at dawn was longer, and there was a difference in the amount of use depending on the season. However, there was also a difference, and the morning and evening hours of usage were significantly higher in the dense office environment, and there was a big difference between the weekend and weekday usage. In other regions, high usage was observed during commuting time, but we confirmed that e-scooters were used for commuting purposes by showing the highest usage in places with dense offices.

**Implications**

Various studies have been conducted on whether or not kickboards are used for commuting purposes in prior studies, and what role they play among substitutes and complements in cities. However, depending on which city is analyzed, the role of the electronic scooter service appears to be different, even contradictory. To solve this problem, our study clustered based on the characteristics of each district within the city. The usage of E-scooters service was analyzed based on common characteristics within the district, and as a result, the role of E-scooter used for commuting within the city was revealed. In addition, further analysis will reveal that kickboards can play a different role depending on each regional cluster. This study suggests that even within the same city, the role of a kickboard may differ depending on the characteristics of each region, and it is suggested that the role of micro-mobility should be clustered according to city layout components.

**Future research**

In district clusters with a large number of floating population and office workers, the role of E-scooter is likely to be commuting. For additional checks about that supposed role, we plan to conduct additional analysis to determine whether the number of people who use e-scooter for commuting is significantly higher in weekly analysis. Also, to find an additional role in other districts, a time analysis is planned. We would find which time zone has the highest usage according to the clusters and it is expected that the time series analysis makes the role of the e-scooter defined.

**REFERENCES**

Abduljabbar, R. L., Liyanage, S., & Dia, H. (2021). The role of micro-mobility in shaping sustainable cities: A systematic literature review. *Transportation research part D: transport and environment*, *92*, 102734. <https://doi.org/10.1016/j.trd.2021.102734>

Bai, S., & Jiao, J. (2020). Dockless E-scooter usage patterns and urban built Environments: A comparison study of Austin, TX, and Minneapolis, MN. *Travel behaviour and society*, *20*, 264-272. <https://doi.org/10.1016/j.tbs.2020.04.005>

Caspi, O., Smart, M. J., & Noland, R. B. (2020). Spatial associations of dockless shared e-scooter usage. *Transportation research part D: transport and environment*, *86*, 102396. <https://doi.org/10.1016/j.trd.2020.102396>

Chang, A., Miranda-Moreno, L., Clewlow, R., & Sun, L. (2019). Trend or fad. *Deciphering the Enablers of Micromobility in the US*.

Eccarius, T., & Lu, C.-C. (2020). Adoption intentions for micro-mobility–Insights from electric scooter sharing in Taiwan. *Transportation research part D: transport and environment*, *84*, 102327. <https://doi.org/10.1016/j.trd.2020.102327>

Gössling, S. (2020). Integrating e-scooters in urban transportation: Problems, policies, and the prospect of system change. *Transportation research part D: transport and environment*, *79*, 102230. <https://doi.org/10.1016/j.trd.2020.102230>

Hardt, C., & Bogenberger, K. (2019). Usage of e-scooters in urban environments. *Transportation research procedia*, *37*, 155-162. <https://doi.org/10.1016/j.trpro.2018.12.178>

Huo, J., Yang, H., Li, C., Zheng, R., Yang, L., & Wen, Y. (2021). Influence of the built environment on E-scooter sharing ridership: a tale of five cities. *Journal of transport geography*, *93*, 103084. <https://doi.org/10.1016/j.jtrangeo.2021.103084>

Kopplin, C. S., Brand, B. M., & Reichenberger, Y. (2021). Consumer acceptance of shared e-scooters for urban and short-distance mobility. *Transportation research part D: transport and environment*, *91*, 102680. <https://doi.org/10.1016/j.trd.2020.102680>

Lee, J. K. (2021). Transport infrastructure investment, accessibility change and firm productivity: Evidence from the Seoul region. *Journal of transport geography*, *96*, 103182. <https://doi.org/10.1016/j.jtrangeo.2021.103182>

Lee, Y., Koo, J., & Choo, S. (2022). Analyzing Intention to Use Shared E-scooters Considering Individual Travel Attitudes: The Case of Seoul Metropolitan Areas. The Journal of The Korea Institute of Intelligent Transport Systems, 21(1), 1-16. <https://doi.org/10.12815/kits.2022.21.1.1>

Li, A., Zhao, P., Liu, X., Mansourian, A., Axhausen, K. W., & Qu, X. (2022). Comprehensive comparison of e-scooter sharing mobility: Evidence from 30 European cities. *Transportation research part D: transport and environment*, *105*, 103229. <https://doi.org/10.1016/j.trd.2022.103229>

Mathew, J. K., Liu, M., Seeder, S., Li, H., & Bullock, D. M. (2019). Analysis of E-Scooter Trips and Their Temporal Usage Patterns. *ITE Journal*, *89*(6).

McKenzie, G. (2019). Spatiotemporal comparative analysis of scooter-share and bike-share usage patterns in Washington, DC. *Journal of transport geography*, *78*, 19-28. <https://doi.org/10.1016/j.jtrangeo.2019.05.007>

McKenzie, G. (2020). Urban mobility in the sharing economy: A spatiotemporal comparison of shared mobility services. *Computers, Environment and Urban Systems*, *79*, 101418. <https://doi.org/10.1016/j.compenvurbsys.2019.101418>

NACTO, 2020. Shared Micromobility in the U.S.: 2019. <https://nacto.org/shared-micromobility-2019/>

Shaheen, S., Cohen, A., Chan, N., & Bansal, A. (2020). Sharing strategies: carsharing, shared micromobility (bikesharing and scooter sharing), transportation network companies, microtransit, and other innovative mobility modes. In *Transportation, land use, and environmental planning* (pp. 237-262). Elsevier. <https://doi.org/10.1016/B978-0-12-815167-9.00013-X>

Sheller, M. (2011). Sustainable Mobility and Mobility Justice. Mobilities: New perspectives on transport and society, 289.

Smith, C. S., & Schwieterman, J. P. (2018). E-scooter scenarios: evaluating the potential mobility benefits of shared dockless scooters in Chicago.

Zhou, H., & Gao, H. (2020). The impact of urban morphology on urban transportation mode: A case study of Tokyo. *Case Studies on Transport Policy*, *8*(1), 197-205. <https://doi.org/10.1016/j.cstp.2018.07.005>

Zhu, R., Zhang, X., Kondor, D., Santi, P., & Ratti, C. (2020). Understanding spatio-temporal heterogeneity of bike-sharing and scooter-sharing mobility. *Computers, Environment and Urban Systems*, *81*, 101483. <https://doi.org/10.1016/j.compenvurbsys.2020.101483>