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An Effect of Land Use Characteristics and Policy Changes on Shared Personal Mobility Use*

Lee, Jae-Wook** · Jang, Seongman***

Abstract

There are many studies on factors that affect transportation. According to previous studies, land use and policies are among such factors. However, studies related to personal mobility vehicles, which are increasingly attracting attention as a new means of transportation, are still relatively insufficient. In this study, we comprehensively analyzed how land-use characteristics and personal mobility vehicle-related regulation-strengthening policies affect shared personal mobility. For independent variables, we considered land-use characteristics and access to public transportation. We set the amount of shared personal mobility usage in the morning, afternoon, and evening as dependent variables, and performed regression analysis. We set the time frame of this study at 45 days before and 45 days after the strengthening of the regulation. In addition, we analyzed the spatial range in Gangseo and Yangcheon districts, Seoul, and Goyang, Gyeonggi Province. We found that land-use characteristics had a significant effect on shared personal mobility users according to the time of day. In addition, we identified different influencing factors on shared personal mobility before and after the regulation. Our analysis is expected to provide basic data necessary to examine the correlation between transportation, policy, and land use.

Keywords Personal Mobility, Traffic, Land Use, Public Transport Accessibility, Policy
주제어 퍼스널 모빌리티, 교통, 토지이용, 대중교통 접근성, 정책

Ⅰ. Introduction

With the growing interest in sustainable development, green transportation for sustainable development is on everyone's lips in the transportation sector. Since a long time ago, many studies investigated the factors that affect transportation. Previous studies reported that land use and policy are the factors having significant impact on transportation (Seong et al., 2008; Wegener, 2004; Lee et al., 2011). Some of these studies analyzed the factors affecting various modes of transportation.

However, there are only a few studies on personal mobility (PM), that is garnering a lot of attention as a new green transportation, due to limited data. Moreover, the Ministry of the Interior and Safety (MOIS) tightened the PM related regulations on May 13, 2021 in an effort to establish a safe operation environment of PM. However, no study has examined the effect of enforced regulatory policies of PM on shared PM.

Therefore, this study aims to analyze the effects of land

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** Bachelor, Department of Urban and Regional Development, Mokpo National University (First Author: ljaewook97@naver.com)
*** Assistant Professor, Department of Urban and Regional Development, Mokpo National University (Corresponding Author: sjang@mnu.ac.kr)
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use characteristics and access to public transport on shared PM use by time period, focusing on the boarding and alighting points of shared PM users. Furthermore, the study investigated the comprehensive impact of the land use characteristics, access to public transport, and stricter regulations of PM on the use of shared PM.

Ⅱ. Previous Research

1. Previous research on the relation between land use and transport

There are a number of previous studies that analyzed the relation between land use and transportation. Seong et al. (2008) intended to examine the effects of land use characteristics such as density and diversity, the key elements comprising Transit-Oriented Development (TOD), and urban design characteristics such as street network and building formation on the use of public transport. As a result, the study concluded that there was a correlation between transport and land use. Mixed use of office and commercial areas with high-density land and the concentration of narrow street networks positively affect the use of public transport. Seong et al. (2008) also argued that residential-oriented land use and the formation of large-scale building groups centered on urban freeways negatively affect the public transport use.

Jeong et al. (2016) aimed to analyze energy consumption in the transportation sector by classifying the administrative dongs in Seoul into origin and destination depending on the purpose of travel. As a result, the study concluded that differentiated policies should be implemented in which the functions of the destination is incorporated at the origin while residential-oriented land use policies, one of the functions of origin, are put in place at the destination by distinguishing the origin and destination in an effort to reduce energy consumption in the transportation sector.

Lee et al. (2015) investigated the close relationship between the land use and the subway ridership in station area. As a result, it was concluded that the demand during the peak and off-peak hours by type of station area should be balanced to enhance the efficiency of public transport use.

Lee and Kim (2018) analyzed the population distribution of urban areas which varies with the time of the day and the day of a week, focusing on Seoul that has abundant information on land use and transit ridership. The study argued that the transit ridership or population distribution should be analyzed in conjunction with land use, and the spatio-temporal variations of population distribution must be taken into account according to land use.

Koh and Lee (2010) reported that the land use in urban areas referred to the spatial distribution or geographic pattern of urban functions. For instance, land use indicates an area where residential, industrial, and commercial areas are located, and the developed land use is categorized by functional activity. The study argued that the supply of transportation facilities gives functionality to the interaction amongst land use activities, and that the capacity or operation level of transportation facilities is measured based on the combination of travel time and costs.

Meyer and Miller (1984) found that the land use and transport system affect one another with each activity to establish a new system, which is repeated until an equilibrium state is maintained. The study also reported that urban space is a product of a long cycle where the land use and transport systems endlessly are linked and interacting with one another (Wegener 2004; Lee et al., 2011).

Based on the previous studies, the correlation between land use and transport can be examined. Although land use was confirmed to be one of the factors affecting various means of transport and the traffic flow of city dwellers, no study was conducted to investigate factors affecting PM, a new means of transport. Therefore, this study examined the relations between land use and PM, a new mode of green transport.

2. Previous research on the use of bicycles and PM

Before conducting this study, previous studies on shared bicycles that share similar similar characteristics with PM were reviewed. Bieliński and Ważna (2020) performed comparative analysis on the differences and characteristics of the users of shared electric bikes and shared PM. As a result, it was revealed that shared electric bikes were used for commuting while shared PM was used more for leisure. As for user characteristics, the users of shared PM were found to be younger than the users of shared electric bicycles.

Jang et al. (2016) studied Ttareungi, the shared bicycle in

Seoul, particularly in the districts of Yeouido and Sangam. The study found that the shared bicycle in Seoul can be used as a first and last mile transport for short-distance travel.

Li et al. (2017) focused on the ways to optimize Mobility as a Service (Maas) in New York. As a result, it was concluded that the use of shared bicycles will continue to increase and that it takes on the characteristics of the first-and-last-mile as a means of connecting public transport.

Sa and Lee (2018) examined the effect of surrounding environment on public bicycle rental and return, focusing on public bicycle rental stations, and found that the higher the slope of the surrounding area, the more negative effect it had. As a result, the level of preference between bicycles and shared PM was determined in terms of the slope of the surrounding area.

After that, previous studies on PM at global level was reviewed. Smith and Schwieterman (2018) reported that PM is effective in the areas with limited parking space. According to the study, PM can be an effective alternative to passenger car for a distance of 0.5 to 2 miles, and be used as a means of first-last mile mobility. PM also has the potential to increase the number of households without cars in Chicago, the target area of the study.

Shaheen and Chan (2016) found that shared mobility is not only an innovative means of transport that enhances urban mobility, but also a potential solution to the issues of First-and-Last-Mile with public transport. Furthermore, it also reported that shared mobility can expand the catchment area of public transport and potentially play a pivotal role in narrowing the gap in the existing traffic network.

Baek et al. (2021) used a mixed logit model to investigate how the shared PM is different from other last-mile transport means. As a result, it was found that shared PM is a competitive mode of transportation in the case of last mile, compared to other modes of transportation.

Hardt and Bogenberger (2019) argued that PM can help alleviate problems in urban areas such as traffic congestion, air pollution, noise and limited parking spaces. As a result of identifying the types and purposes of PM users, a majority of participants of the experiment used PM for commuting and leisure. Prior to conducting the study, previous studies on PM use and ways of vitalization were reviewed.

The results of the studies on shared bicycles and PM overseas had implications that shared bicycles and PM are first-last mile mobility. Moreover, the purpose and type of PM users were identified, and the differences between shared bicycles and shared PM were determined.After that, previous studies in Korea were reviewed in terms of PM.

Choi and Jeong (2020) aimed to formulate the measures to improve access to urban railroads by using the PM sharing service considering the growth of PM. As a result, the PM sharing service was preferred more with lower fare, higher age and income level, greater distance of travel, and higher level of average slope. Accordingly, the study argued that PM sharing service would be required as a means of transport connected to the urban railroad.

Kim and Kim (2018) developed ways to vitalize PM based on overseas operation cases. As a result, it argued that an accurate and concrete investigation and analysis of the domestic users' characteristics is required, and as for revision of law, experts should pay attention to seeking ways of improvement by putting more weight on the safety of users rather than political elements.

Park and Lee (2021) analyzed the safety and engagement of PM. The results of the study found that a policy that puts safety first is needed and the maintenance of facilities and operation is urgent to ensure safe use of new modes of transport for citizens.

Lim et al. (2015) performed simulations by density in order to examine the congestion relief effect following PM operation in a congestion condition. As a result, the average travel speed was found to rise with increasing PM rate.However, the PM used in the study was set as a new-concept vehicle equipped with a cutting-edge automotive technology enabling ultra-compact and ultra-light compared to existing ones and that drives on electricity as a source of power, which is different from the PM defined in this stud

Park (2019) carried out its research considering the necessity of effective urban transportation by introducing smart mobility as small and medium-sized cities have a very high modal share of passenger cars compared to large cities. The study concluded that shared bicycles and shared PM were adequate as complementary means to the existing modes of transport for the original and the new city center.

Choi et al. (2021) intended to investigate the elements to consider in introducing shared PM and appropriate PM operation plan. As a result of multilevel binomial logistic regression analysis, the likelihood of using shared PM was found to increase with longer travel time.

Through previous studies in Korea, the factors affecting the use of PM, measures to vitalize, and the necessity of PM were identified. However, no previous studies examined the effect of land use on PM.Further, there were no studies on the enforced regulation of PM on May 13 while the regulatory change of PM on December 10, 2020 was mentioned. Accordingly, this study aimed to investigate the effect of strengthened regulatory policies of PM on shared PM.

Ⅲ. Scope and Data Collection

1. Scope of research

This study examined how land use, access to public transport, and policy changes affect the use of shared PM. Table 1 shows 19 PM sharing service operators and the number of PM in operation in 2019. As of the end of 2019, there are 19 operators of shared PM, with a total of 21,410 units in operation. This figure is assumed to be higher as of 2021 following the expansion of the service area.

Table 1. PM share service operating companies

No.	Company name	Brand	Operation quantity
1	MasS Asia	Go Go Sing	5,000
2	Olulo	Kickgoing	4,300
3	PUMP	xing xing	3,540
4	Hyundai Motor Car	Zet	2,300
5	Gbility	Gcooter	1,500
6	Beam Mobility Korea	Beam	1,000
7	Lime Korea	Lime	1,000
8	Kakao	T-bike	1,000
9	The Swing	Swing	700
10	Nine2one	Elecle	150
11	EVPASS	EV-Pass	150
12	Alpaca	Alpaca	100
13	Dart sharing	Dart	100
14	Launchers	RYDE	100
15	Flying	Flower Road	100
16	BPM	Boosty	100
17	Wind Mobility Korea	Wind	100
18	Urban Band	Moovit	100
19	Deer corporation	Deer	20

The spatial scope of the study was defined based on the available shared PM data. The shared PM data was analyzed using the data of "Gcooter" that provides nationwide service. Gcooter operates the PM sharing service in Yangcheon-gu, Gangseo-gu, Yeongdeungpo-gu in Seoul, Goyang-si, and Ansan-si in Gyeonggi-do. Thus, the spatial scope of the study was set to include 29 legal dongs in Yangcheon-gu, Gangseo-gu, and Goyang-si, Seoul, which were considered to show the representative patterns of shared PM users due to the high usage of shared PM.

The temporal scope of this study was set based on the strengthened PM regulation on May 13, 2021 to identify the policy effect on the use of shared PM. Hence, the time span of this study is from March 29, 2021 to June 27, 2021 including 45 days before and after the regulation enforcement. The target area of this study is shown in Figure 1.

2. Data Collection

Kim and Yeo (2019) elucidated the importance of population distribution at the grid level of 200×200 across the nation. Therefore, the target area of this study was divided into hexagons with the side length of 200 m to subdivide the 29 legal dongs. Then, only hexagons with buildings were extracted and analyzed to examine the land use of each hexagon. Figure 2 shows the result of extracting hexagons with buildings.

The process of the study is illustrated in Figure 3. To determine how land use and access to public transport affect the shared PM by time period, the shared PM usage by time

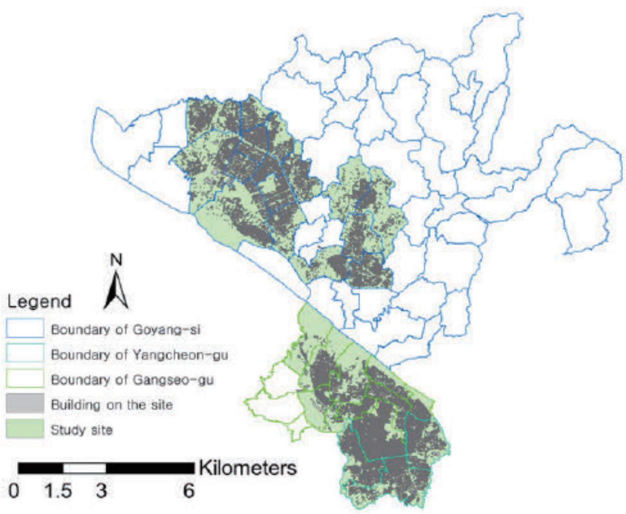

Figure 1. Study site

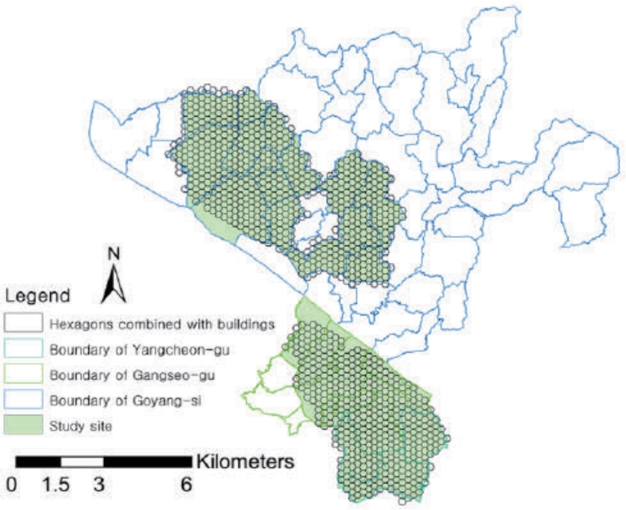

Figure 2. Hexagon extraction including buildings

period was set as the dependent variable. To determine how land use and access to public transport affect the use of shared PM by time period, the land use characteristics and public transport accessibility were set as independent variables for the analysis. Additionally, the shared PM usage was analyzed for the separate period of before and after strengthening the regulations to identify the effect of the strengthened PM regulations on the use of shared PM. The regression analysis was performed after setting the variables to examine the comprehensive effects of strengthened PM policy, land use characteristics, and public transport accessibility

First, the usage of shared PM by time period was set as the dependent variable. The shared PM usage was categorized into morning (7-9am, 12.10%), afternoon (5-7pm, 21.33%), and night (8-10pm, 20.25%), the time periods with the most usage, and the usage of shared PM for boarding and alighting within a hexagon was identified. Then, the usage of shared PM before and after the regulation enforcement was analyzed to investigate the comprehensive effects of policy and land use on the shared PM.The variables and sources of data are as shown in Table 2.

Among the independent variables, land use characteristics were analyzed for residential, commercial, office facilities, and other facilities based on building data. Other facilities include warehouse, religious, and educational facilities without residential, office, and commercial facilities. Also, the other type 1 neighborhood facilities were considered as commercial facilities due to the highest share of commercial facilities. The other type 2 neighborhood facilities were considered as office facilities due to the highest share of office facilities. Table 3 shows the facility classification standards of land use.

After that, the total floor area for each facility was obtained

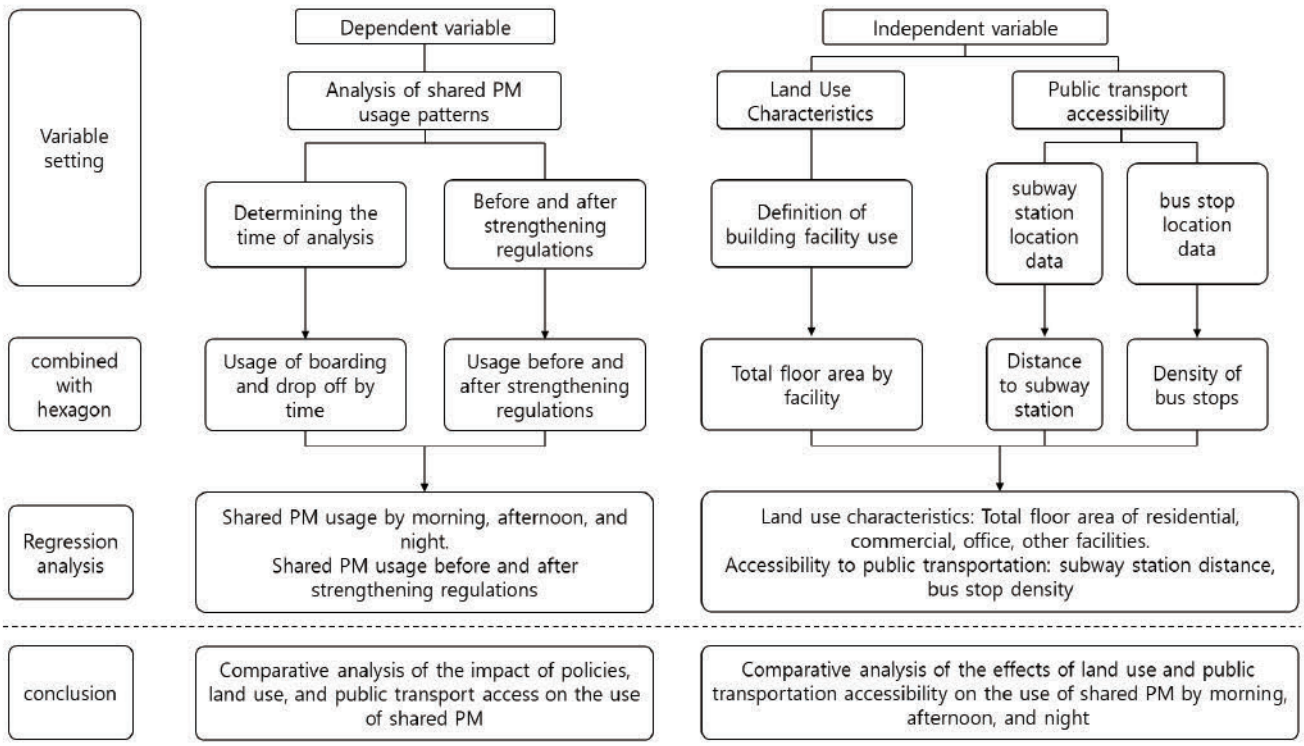

Figure 3. Process of research

Table 2. Variables and sources

Variable			Source
Dependent variable	Shared PM usage	Morning (7~9)	Gcooter data (2021)
		Afternoon (17~19)	
		Night (20~22)	
		Before strengthening regulations	
		After strengthening regulations	
Independent variable	Land Use Characteristics	Total floor area of residential facilities (km^2)	Road name address data (2021)
		Total floor area of commercial facilities (km^2)	
		Total floor area of office facilities (km^2)	
		Total floor area of other facilities (km^2)	
	Public transport accessibility	Distance to subway station (km)	KTDB (2021)
		Density of bus stops	Public data Portal (2021)

Table 3. Facility classification standards

Classification	Facility
Residential facilities	Detached house, apartment house
Commercial facilities	Retail stores, restaurants, shops, Other Type 1 Neighborhood Facilities, etc.
Office facilities	District office, police station, office, Other Type 2 Neighborhood Facilities, etc.
Other facilities	Warehouse facilities excluding residential, commercial, and business facilities, religious facilities, animal and plant related facilities, etc.

and set as an independent variable. The total floor area was calculated by the formula, (ground floor+basement floor)×building area, based on the building data. The building area was obtained using the calculate geometry tool of Arcmap 10.5. In the process of the total floor area calculation, since many of the ground floor data were missing, the average number of floors of the building was used to estimate the ground floor data. Then, the total floor area of residential, commercial, office facilities, and other facilities for each hexagon were set as the independent variables for the analysis.

The independent variables for the public transport accessibility were determined considering subway stations and bus stops. The distance between the hexagon and the nearest subway station was measured and used as the distance to subway station in this study. Since the number of bus stops outnumbered the number of subway stations, the obtained value was considered insignificant. Therefore, the density of the bus stop was estimated through the point density analysis of Arcmap. The bus stop density was calculated using 100×100 raster data, and the affected area was set as a radius of 500 m. Through the density analysis, the average density of each hexagon was obtained and analyzed. Figure 4 shows the results of bus stop density analysis.

Lee (2016) studied the factors affecting the integration of industrial activities using a spatial metric model as an empirical analysis. For empirical analysis of factors affecting the use of shared PM, an appropriate analytical model should be applied depending on the presence of spatial autocorrelation of variables. A Spatial Lag Model (SLM) or a Spatial Error Model (SEM) that considers spatial autocorrelation can be used for empirical analysis. If a variable has spatial autocorrelation, the selection process of optimal model between SLM and SEM is as follows. First, if the Lagrange Multiplier (LM) statistics of the SLM and SEM are not significant through LM diagnosis as a result of general regression analysis, the general regression model is considered to be the most appropriate. Second, if only one of the LM statistics is

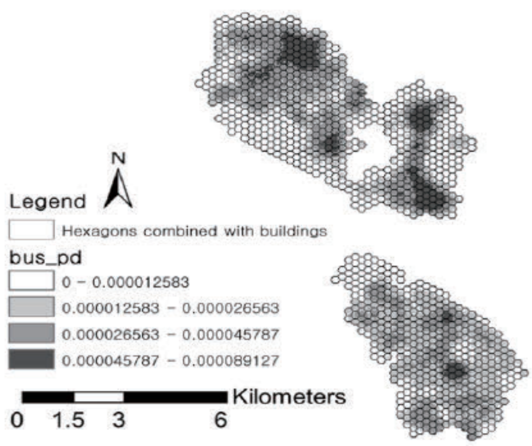

Figure 4. Density of bus stops

significant, select the corresponding model as the final model. Third, if the LM statistic of both models are significant, select the more significant model as the final model based on the Robust LM statistics resulting from Robust LM diagnosis.

As a result of the analysis, the Robust LM Lag model was found to be a significant variable for the shared PM boarding and alighting in the morning. For the remaining variables, the Robust LM Error model was found to be more significant. Table 4 shows the results of statistical analysis.

Ⅳ. Analysis Results

1. Explanatory Power of the Model

When there is an interaction between the variables, regression analysis was performed which is advantageous in estimating the magnitude and direction of the interaction. Furthermore, the variance inflation factor (VIF) was used to verify the multicollinearity of the independent variables. The VIFs of the all final variables were found to be below 3, indicating there was no problem of multicollinearity

Table 4. Results of basic statistical analysis

Classification				Value	p-value
Shared PM boarding point	Morning	Lagrange multiplier	Lag***	458.3619	0.00000
			Error***	441.2468	0.00000
		Robust LM	Lag***	17.1941	0.00003
			Error	0.0789	0.77875
	Afternoon	Lagrange multiplier	Lag***	558.3395	0.00000
			Error	564.9380	0.00000
		Robust LM	Lag***	16.2333	0.00006
			Error***	22.8318	0.00000
	Night	Lagrange multiplier	Lag***	472.0300	0.00000
			Error***	505.6374	0.00000
		Robust LM	Lag**	4.3445	0.03713
			Error***	37.9519	0.00000
Shared PM drop off point	Morning	Lagrange multiplier	Lag***	848.7891	0.00000
			Error***	816.9053	0.00000
		Robust LM	Lag***	45.4060	0.00000
			Error***	13.5221	0.00024
	Afternoon	Lagrange multiplier	Lag***	548.5312	0.00000
			Error***	571.0944	0.00000
		Robust LM	Lag***	8.3999	0.00375
			Error***	30.9631	0.00000
	Night	Lagrange multiplier	Lag***	802.1720	0.00000
			Error***	855.0989	0.00000
		Robust LM	Lag*	3.4540	0.06310
			Error***	56.3809	0.00000
Before strengthening regulations	Shared PM boarding point	Lagrange multiplier	Lag***	590.4859	0.00000
			Error***	613.3454	0.00000
		Robust LM	Lag***	9.8807	0.00167
			Error***	32.7401	0.00000
	Shared PM drop off point	Lagrange multiplier	Lag***	766.3819	0.00000
			Error***	805.8683	0.00000
		Robust LM	Lag***	10.6739	0.00109
			Error***	50.1603	0.00000

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Classification				Value	p-value
After strengthening regulations	Shared PM boarding point	Lagrange multiplier	Lag***	664.3421	0.00000
			Error***	686.0973	0.00000
		Robust LM	Lag***	10.6672	0.00109
			Error***	32.4225	0.00000
	Shared PM drop off point	Lagrange multiplier	Lag***	914.9435	0.00000
			Error***	951.6067	0.00000
		Robust LM	Lag***	13.3749	0.00026
			Error***	50.0381	0.00000
Women's	Shared PM get off	Lagrange multiplier	Lag***	785.6718	0.00000
			Error***	827.5055	0.00000
		Robust LM	Lag***	10.3268	0.00131
			Error***	52.1605	0.00000
Men's	Shared PM get off	Lagrange multiplier	Lag***	831.7906	0.00000
			Error***	868.2033	0.00000
		Robust LM	Lag***	12.2564	0.00046
			Error***	48.6691	0.00000

p-value of 0.1(*), 0.05(**), 0.01(***)

between the independent variables set in this study. As a result of the analysis, the R-square that represents the explanatory power of the variables was found to be 0.155 for the shared PM boarding in the morning, a low explanatory power. However, the remaining variables were found to show rather high explanatory power of 0.27 or more. In addition, the independent variables with significance probabilities of 0.1(*), 0.05(**), and 0.01(***) or less were regarded to be significant variables for the analysis. Then, the significant effects of the land use characteristics and strengthening of PM regulations on the boarding and alighting points of shared PM were investigated. Table 5 shows the VIF result of the independent variables and Table 6 is a list of R-square of the variables.

The results of basic statistical analysis of 1,144 variables of hexagons in the target area are shown in Table 7. It was confirmed that the standard deviation of the dependent variables was large but showed rather great variance by hexagon. However, the standard deviation of the independent variables excluding the bus stop density was found be as low as 1 or below. It indicates that most of the independent variables are evenly distributed for each hexagon.

Table 5. VIF of the independent variable

Independent	VIF
Total floor area of residential facilities	1.217
Total floor area of commercial facilities	1.081
Total floor and of office facilities	1.172
Total floor and of other facilities	1.092
Distance to subway station	1.347
Density of bus stops	1.263

Table 6. R-square

Dependent variable	R-square	
	Boarding point	Drop off point
Morning	0.155	0.270
Afternoon	0.285	0.276
Night	0.286	0.284
Before regulation	0.297	0.313
After regulation	0.268	0.285
Female		0.277
Male		0.281

2. Effects of land use characteristics and public transport accessibility on the boarding and alighting of shared PM

The variables with significant effects on the shared PM boarding were identified as the distance to subway station, bus stop density, and the total floor area of residential, commercial, office facilities, and other facilities. As a result, the absolute value of the non-standardization coefficient revealed that the total floor area of commercial, office facili-

Table 7. Statistical analysis result

Classification			Min		Max		Mean		Standard deviation	
			Boarding point	Drop off point	Boarding point	Drop off point	Boarding point	Drop off point	Boarding point	Drop off point
Dependent variable	Shared PM usage	Morning	0.0	0.0	559	334	8.2	8.0	30.0	33.2
		Afternoon	0.0	0.0	887	840	14.4	14.3	57.8	55.6
		Night	0.0	0.0	928	458	13.6	13.5	55.8	42.0
		Before strengthening regulations	0.0	0.0	2,069	987	43.2	24.0	152.0	83.6
		After strengthening regulations	0.0	0.0	1,237	981	24.1	23.9	90.1	83.4
		Female	-	0.0	-	250	-	6.0	-	21.8
		Male	-	0.0	-	731	-	17.9	-	62.2
Independent variable	Land use characteristics	Total floor area of residential facilities		0.0		0.7		0.1		0.1
		Total floor area of commercial facilities		0.0		0.5		0.0		0.0
		Total floor area of office facilities		0.0		0.5		0.0		0.0
		Total floor area of other facilities		0.0		0.9		0.0		0.1
	Public transport accessibility	Distance to subway station		0.0		2.8		0.7		0.6
		Density of bus stops		6.6		19.4		12.3		3.3

ties, and other facilities had the most positive effect in the night time. The distance to subway station and density of bus stops were identified as the variables with the most positive impact in the afternoon. Further, the total floor area of residential facilities was identified to be the significant variable only in the morning. The results of statistical analysis is shown in Table 8.

Table 9 shows the results of analysis based on the alighting point of the shared PM. The variables with significant effects on the shared PM alighting were identified as the distance to subway station, density of bus stops, and the total floor area of residential, commercial, office facilities, and other facilities.In particular, variables such as the total floor area of commercial facilities and the distance to subway stations were found to be significant variables in the afternoon and at night except for the morning. As a result of identifying the absolute value of the non-standardization coefficient, it was revealed that the distance to subway stations, the total floor area of commercial, office, and other facilities had the most positive impact in the afternoon. The total floor area of residential facilities and the density of bus stops were identified as the variables that had the most positive impact at night.

3. Gender-based Shared PM User Patterns

The user patterns of alighting the shared PM were analyzed by gender based on the alighting points of the shared PM where the users intend to alight. The variables with significant effects on the shared PM alighting by gender were identified as the distance to subway station, density of bus stops, and the total floor area of commercial, office facilities, and other facilities. As a result of identifying the absolute value of the non-standardization coefficient, it was revealed that the distance to subway stations and the total floor area

Table 8. Result of analysis based on shared PM boarding point

Dependent variable	Independent variable	Coefficient	Significance probability
Morning	Total floor area of residential facilities*	11.44694	0.16550
	Total floor area of commercial facilities	12.44607	0.49668
	Total floor and of office facilities***	104.0237	0.00000
	Total floor and of other facilities	1.248318	0.90974
	Distance to subway station**	-0.815898	0.55578
	Density of bus stops***	0.560784	0.01700
Afternoon	Total floor area of residential facilities	-6.096301	0.72923
	Total floor area of commercial facilities***	107.9244	0.00416
	Total floor and of office facilities***	443.3532	0.00000
	Total floor and of other facilities	-16.63020	0.47998
	Distance to subway station**	-11.00907	0.04748
	Density of bus stops**	2.557226	0.02388
Night	Total floor area of residential facilities	-4.864243	0.77733
	Total floor area of commercial facilities***	110.3193	0.00271
	Total floor and of office facilities***	478.8884	0.00000
	Total floor and of other facilities***	-56.21760	0.01447
	Distance to subway station*	-9.268710	0.08558
	Density of bus stops**	2.492061	0.02288

Significance Probabilty of 0.1(*), 0.05(**), 0.01(***)

Table 9. Result of analysis based on shared PM drop off point

Dependent variable	Independent variable	Coefficient	Significance probability
Morning	Total floor area of residential facilities**	-16.53867	0.02136
	Total floor area of commercial facilities	18.65283	0.24294
	Total floor and of office facilities***	148.9524	0.00000
	Total floor and of other facilities**	19.59572	0.04317
	Distance to subway station	-1.020626	0.39792
	Density of bus stops*	0.357730	0.07777
Afternoon	Total floor area of residential facilities	5.657732	0.73839
	Total floor area of commercial facilities***	100.0905	0.00573
	Total floor and of office facilities***	444.5109	0.00000
	Total floor and of other facilities**	-45.90004	0.04285
	Distance to subway station*	-9.141794	0.09450
	Density of bus stops**	2.570049	0.02272
Night	Total floor area of residential facilities***	29.45891	0.01194
	Total floor area of commercial facilities***	82.37537	0.00101
	Total floor and of office facilities***	312.7903	0.00000
	Total floor and of other facilities***	-37.57716	0.01695
	Distance to subway station*	-5.942917	0.15672
	Density of bus stops***	2.682605	0.00368

Significance Probabilty of 0.1(*), 0.05(**), 0.01(***)

of commercial, office, and other facilities had the greater impact on female users. On the other hand, the density of bus stops had a greater effect on male users. Table 10 shows the results of analysis based on the alighting point of the shared PM for different gender.

Table 10. Effect of shared PM on gender users

Dependent variable	Independent variable	Coefficient	Significance probability
Female	Total floor area of residential facilities	2.042099	0.36976
	Total floor area of commercial facilities***	16.12975	0.00093
	Total floor and of office facilities***	65.11807	0.00000
	Total floor and of other facilities***	-7.199529	0.01860
	Distance to subway station**	-1.728958	0.03668
	Density of bus stops**	0.434436	0.01829
Male	Total floor area of residential facilities	1.949263	0.38225
	Total floor area of commercial facilities***	15.67792	0.00102
	Total floor and of office facilities***	61.64071	0.00000
	Total floor and of other facilities**	-5.697531	0.05755
	Distance to subway station**	-1.625201	0.05026
	Density of bus stops***	0.459719	0.01446

Significance Probabilty of 0.1(*), 0.05(**), 0.01(***)

4. Effects of strengthening regulatory policy on boarding and alighting of shared PM

As a result of analyzing the effect of the strengthened PM policy on the use of shared PM, the usage decreased from 49,722 before strengthening the regulations to 27,640 after the regulations were strengthened. Average usage time also reduced from from 7 minutes 29 seconds before tightening the regulations to 6 minutes 36 seconds after the regulations became stricter. The above analysis results are shown in Figures 5 and 6.

As for the comprehensive effects of policy and land use on shared PM boarding and alighting, the variables including the total floor area of commercial, office facilities, and other facilities, distance to subway station distances, and density of bus stops brought about significant results. In particular, it was confirmed that the absolute value of the non-standardization coefficient for the variables before tightening the regulations were higher. Table 11 and Table 12 show the analysis results based on the boarding and alight points of shared PM.

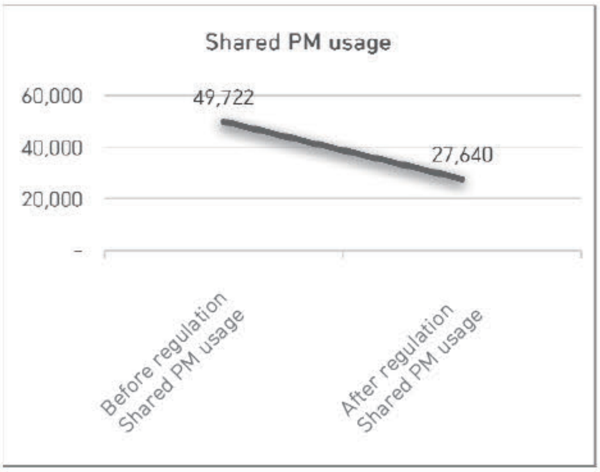

Figure 5. Shared PM usage before strengthening regulations

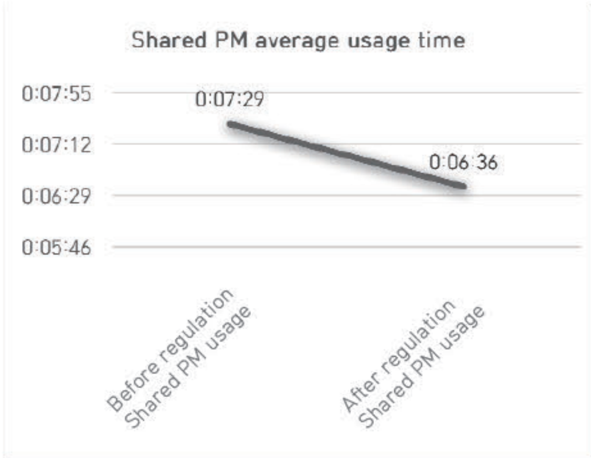

Figure 6. Shared PM usage after strengthening regulations

V. Conclusion

This study used the shared PM usage by time period as a dependent variable based on the 2021 Gcooter data.The independent variables were set considering land use characteristics and access to public transport.Furthermore, this study analyzed how policy, land use, and public transport

Table 11. Analysis results before and after strengthening regulations based on shared PM boarding point

Dependent variable	Independent variable	Coefficient	Significance probability
Before regulation shared PM usage	Total floor area of residential facilities	13.94019	0.75841
	Total floor area of commercial facilities***	309.8604	0.00139
	Total floor and of office facilities***	1168.577	0.00000
	Total floor and of other facilities*	-80.13827	0.18627
	Distance to subway station**	-28.76863	0.04840
	Density of bus stops***	8.444827	0.00490
After regulation shared PM usage	Total floor area of residential facilities	16.05328	0.54917
	Total floor area of commercial facilities***	154.5183	0.00701
	Total floor and of office facilities***	681.0359	0.00000
	Total floor and of other facilities**	-69.79465	0.05186
	Distance to subway station*	-16.73541	0.06083
	Density of bus stops**	4.281463	0.02244

Significance Probabilty of 0.1(*), 0.05(**), 0.01(***)

Table 12. Analysis results before and after strengthening regulations based on shared PM drop off point

Dependent variable	Independent variable	Coefficient	Significance probability
Before regulation shared PM usage	Total floor area of residential facilities	30.3341	0.44148
	Total floor area of commercial facilities***	301.8531	0.00034
	Total floor and of office facilities***	1102.861	0.00000
	Total floor and of other facilities**	-91.17745	0.08501
	Distance to subway station**	-28.59368	0.04406
	Density of bus stops***	8.24885	0.00861
After regulation shared PM usage	Total floor area of residential facilities	24.28089	0.27518
	Total floor area of commercial facilities***	133.442	0.00508
	Total floor and of office facilities***	625.4196	0.00000
	Total floor and of other facilities***	-77.58804	0.00961
	Distance to subway station**	-16.76632	0.05110
	Density of bus stops**	4.26538	0.03353

Significance Probabilty of 0.1(*), 0.05(**), 0.01(***)

accessibility comprehensively affect transportation. Furthermore, this study analyzed how policy, land use, and public transport accessibility comprehensively affect transportation.

The effect of land use on shared PM boarding and alighting can be boiled down to four key points. First, the total floor area of office facilities, distance to subway stations, and density of bus stops had a positive effect in all time periods of shared PM boarding and alighting. The total floor area of office facilities, in particular, always showed the highest non-standardization coefficient, which is believed to have a certain impact. The total floor area of office facilities, in particular, always showed the highest non-standardization coefficient, which is believed to have a certain impact. This finding is consistent with the study results that most shared PM users use it for commuting and that if PM is used for commuting to work, the intention to use shared PM increased by 1.941 times (Hardt and Bogenberger, 2019; Choi and Jung, 2020). The total floor area of residential facilities found to have a significant effect on shared PM boarding and alighting in the morning and night time, but no significant effect was found in other boarding and alighting times. Kim and Shin (2007) analyzed the correlation between the network of pedestrian spaces and the pedestrian traffic in terms of land use patterns. The study also discovered the effect of spatial network as a factor affecting the pedestrian environment. As a result of the analysis, however, the pedestrian characteristics of the residential area were found to be insignificant which is consistent with the results of this study. This was believed to be because the pedestrian patterns are formed largely by learning and experience rather than a spatial network in residential areas.

Second, the total floor area of commercial facilities was found to have a significant effect only for the night and afternoon boarding and alighting of shared PM. It is assumed that users ride shared PM after doing activities in commercial facilities in the afternoon and at night. However, the shared PM boarding and alighting was found as not significant in commercial facilities in the morning.

Third, the variables such as the distance to subway station and bus stop density had a significant effect on shared PM boarding in all time periods. This suggests that shared PM is a last-mile mobility that is used from the boarding and alighting stations of public transport to get to the destination.

Fourth, as a result of identifying the shared PM alighting point, the bus stop density had a significant effect in all time periods while the distance to subway station had a significant effect in the afternoon and night time. It is believed to be affected by the time of returning from school and work. These results verified that the shared PM is a means of transport with the characteristics of first mile mobility that goes from the departure point to the boarding and alighting stations of public transport.

As a result of examining the effect of land use on shared PM boarding and alighting, the total floor area of the office area played as the most influential variable in all time periods because most of the users use shared PM for commuting (Hardt and Bogenberger, 2019).The significance of the public transport accessibility as a variable suggests that shared PM is more competitive as a first-mile and last-mile transport than other modes of transport (Shaheen and Chan, 2016; Baek et al., 2021; Choi et al., 2021).

Although there was some difference in the degree of user patterns of shared PM by gender, most of them showed similar patterns. For women, the total floor area of commercial, office, and other facilities, and the distance to subway stations had a greater effect. For men, however, the density of bus stops was found to had a greater effect.

The effect of strengthened PM policies on the use of shared PM can be summarized into three key points. The effect of strengthened PM policies on the use of shared PM can be summarized into three key points. First, the usage of shared PM decreased from 49,722 to 27,640 after the regulations were tightened. Average usage time also reduced from from 7 minutes 29 seconds to 6 minutes 36 seconds after the regulations became stricter. It appears that meaningful values were obtained for these results as the strengthening regulations affected transportation. It is considered that existing users have changed their patterns to use the shared PM for moving only a short distance for a shorter time after strengthening the regulations. PM that travels only such short distances, could be a mode of transport that replaces automobiles that cause air pollution (Smith and Schwieterman, 2018).

Second, as a result of identifying the comprehensive impact of independent variable on the dependent variables, the total floor area of commercial, office, and other facilities, the density of bus stops, and the distance to the subway station were found as the variables that had a positive effect both before and after strengthening PM regulation. This finding is consistent with the study that most users of shared PM use it for commuting and leisure (Hardt and Bogenberger, 2019).

Third, the absolute value of the non-standardization coefficient for all independent variables was found to be higher before tightening the regulations. It is thought to be because land use had a greater impact before tightening the regulations. As a result of the analysis, the strengthened PM policy, land use, and public transport accessibility found to had a comprehensive effect on the use of shared PM.

The future direction of this study will focus on the research scope and data to be used. First, the scope of the study was focused 29 legal dongs in Gangseo-gu, Yangcheon-gu, Seoul, and Goyang-si, Gyeonggi-do. Although the analysis was focused on the metropolitan area with high usage of PM, the regional characteristics could lead to distorted results. Second, the missing information on the ground floor among the building data was calculated with the average floor by application. This shows a limitation in that the explanatory power of the total floor area for each application is rather weak. In the future, more accurate study is required using more specific data. Third, the reason for the reduction of shared PM usage for "Gcooter", one of the shared PM service operators, was explained only in terms of strengthening PM regulations in this study. However, this explanation was given without considering external effects such as increased usage of other shared PM operators. Moreover, this study only considered land use conditions, access to public transport, and regulatory policies of PM as the factors affecting the use of shared PM. However, various other factors such as operating costs of shared PM, meteorological factors including temperature and precipitations, economic capacity of local residents, and the slope of the terrain also have an effect. In a follow-up study, it is considered to be necessary to take various variables into account which affect the use of shared PM. Fourth, there is a limitation in comparing the impact before and after tightening the regulations. Accordingly, further research is required by using difference-in-difference approach or extending the investigation period. Nevertheless, this study is significantin that it analyzed the shared PM, a promising green transport, in terms of land use characteristics, public transport accessibility, and policy. This analysis results will be used as basic data to examine the correlation amongst transport, policy, and land use.

Through this study, more effective ways to manage urban space in the future can be offered and the implications on the characteristics of PM, an emerging mode of transport can be provided. Further, this study result will be used as basic data to understand the characteristics of shared PM and formulate related policies.

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