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Environmental Impact of Personal Mobility in Road Managements

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Recently, the interest and operation of personal mobility (PM) have been actively conducted in Seoul. The PM penetration rate in Seoul is increasing by more than 30 % every year, and the number of PM-shared lenders is increasing every year. PM enables faster and greener movement in complex downtown Seoul. The survey showed that PM is 1.8 times faster than regular cars within 5 km of short-distance traffic in Seoul, and PM is eco-friendly because it does not emit smoke or exhaust gas compared to cars. PM, which has become a sustainable means of transportation, can now be easily seen throughout Seoul and can be used anytime and anywhere. If a PM collides with a car of comparable speed and size while driving on a road dedicated to cars, the risk of accidents is very high, and there is also a risk of a PM colliding with a pedestrian while driving on pedestrian roads. The government decided to investigate the effects of reducing the first two-way road by reorganizing the existing car road and establishing a new PM road. The Gangnam area, which has the highest traffic volume in Seoul, was set as an empirical research area, and its effectiveness was analysed. Many benefits, such as environmental benefits and reduced travel time, are expected if transportation is converted from cars to PM for short-distance transportation. It was analysed that the construction of PM-only roads resulted in environmental benefits of 6.6 x 10^9 KRW/y. Environmental benefits could also lead to active reviews of various roads that could trigger public transportation.

1. Current status of Personal Mobility in Seoul

Personal mobility (PM) means a single-person or two-person short-distance low-speed transport powered by electrical energy. The demand for personal mobility (PM) in Seoul has increased. In Seoul, more people are interested in using PM because of a study that showed that PM is faster than cars and public transportation within a short distance. People say that demand for use explodes because they feel that their lives are improving through improved PM (Nakajima, 2017). According to a survey conducted by the Seoul Metropolitan Government, the number nearly doubled from 35,850 shared PMs in 2020 to 68,025 in 2021. In the past three years, demand for PM has increased by approximately 345 %. The Seoul Metropolitan Government is experiencing a heightened sense of crisis over air environment issues, such as deepening fine dust and increasing greenhouse gas emissions, and citizens' social attention and demands for improvement are increasing. Ku et al. (2020) presented a review of the low-carbon zone setting for Europe, suggesting the importance of carbon reduction. Kim et al. (2020) analysed the cost of economic analysis of eco-friendly transportation and presented savings benefits for eco-friendly transportation. Ku et al. (2021) investigated the health benefits of constructing bike lanes in Seoul, as well as the diversity of benefits. Zeng et al. (2018) used the PSO-SA mixed algorithm model to examine the impact of electric cars on microgrid in terms of carbon dioxide emissions, and the microgrid energy unit scheme examined electric cars as a means of high economic efficiency. By presenting a model of user-aware assessment of environmental impacts from public transportation operations, vehicle safety and pollutant emissions had a significant impact on users' perception, but did not contribute to positive user satisfaction (Sellitto et al., 2013). Wang et al. (2019) found the form of land as one of the most important influential factors in the formation and distribution of air pollution, and examined the relationship between topography and air pollution. Fan et al. (2018) conducted a study in Rotterdam to identify greenhouse gases and air pollutants from the cargo transport group and found that the gross weight of the

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loaded transport affected air pollutants. Hanpattanakit et al. (2018) calculated carbon dioxide emissions from tourist traffic on Thailand's islands using the bottom-up approach, and the Intergovernmental Panel on Climate Change critic calculated transportation energy consumption. PM is as eco-friendly as electric vehicles because it is powered by electric motors, and it is in the spotlight as an alternative means of transportation in downtown Seoul, where traffic is high.

There is a lot of PM thinking around the world, the only problem is of colliding with pedestrians and cars. A PM has a smaller body and is as dangerous as a motorcycle, so the damage is greater if an accident occurs. South Korea recently enacted a law related to PM, making it no longer possible to ride PM on footpaths. It is urgent to implement PM-only roads because coexistence of PM and cars is expected to cause more damage. Alternatively, many positive effects are expected to occur if PM-only roads are constructed. Because of the high speed within the short range, switching to the PM can be performed. It is hoped that if the travel time is shortened because of PM-only roads, conversion can be achieved within a short distance. If the means are switched to PM, various benefits will be incurred. It is expected that there will be various positive effects, such as travel time-saving benefits, environmental benefits, and health benefits. This effect will be analysed by converting roads in the Gangnam district of Seoul, which has the most PM traffic, into PM-only roads. When installing PM-only roads in Gangnam, the aim is to explain the effects of PM-only roads by analysing automobiles, public transportation, PM conversion volume, and benefit effects.

2. Research methodology

2.1 Selection and operation of PM priority road in Seoul

Several localization methodologies have been applied to create PM priority roads. First bus transfer stops and subways that can be linked to public transportation are selected. PM use was higher when PM and public transportation were linked (Park and Lee, 2021) than when riding PM alone. Second, the highest use rate in the first section was analysed. Most PM users use mobile applications. Mobile Index is a professional analyst of application usage and published "Smart Transportation, Electric Kickboard Sharing Service User Status" in May 2020. Various PM usage status in Seoul was analysed. According to MobileINDEX.inc, a mobile application analysis company, the PM use rate in downtown Seoul was analysed, and the highest use section is presented in Figure 1, and PM only roads in Seoul are planned accordingly. According to the analysis of the PM use rate, the highest shared PM use rate is in Gangnam-gu. This was followed by Songpa-gu and Seocho-gu, which belong to the Gangnam area. Gangnam is a busy area with many people passing through it daily because it consists of a commercial and a business area. For these reasons, implementing PM-only roads in the Gangnam area, will result in more efficient PM road operation.

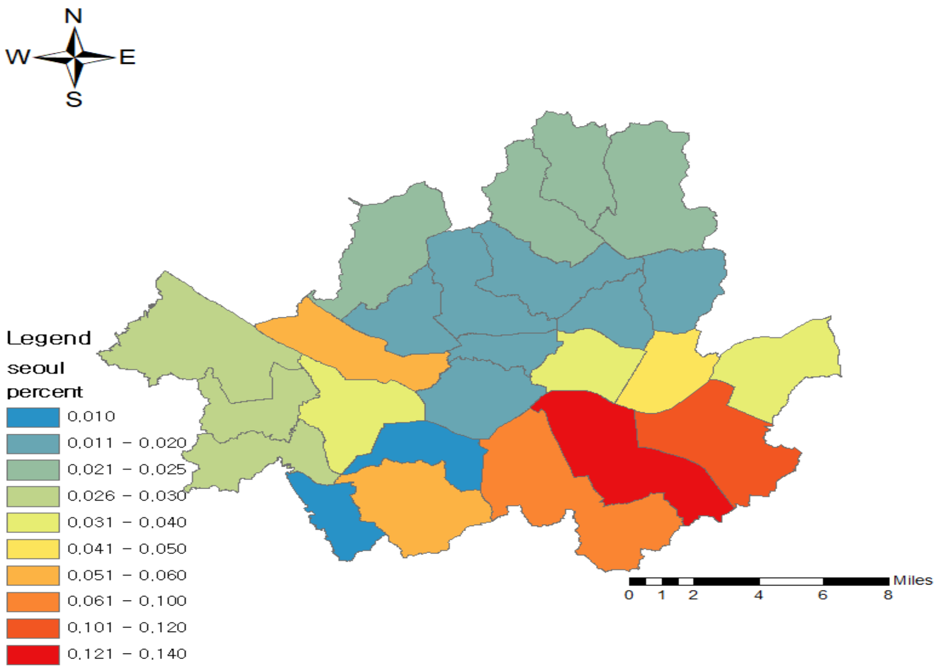

Figure 1: PM utilization rate in Seoul

Figure 2a shows a picture of the location of PM-only roads in the Gangnam area. A representative road was set up in Gangnam-gu as a demonstration area. It has seven roads and a length of 9 km. Gangnam operates in bus-only lanes. Bus-only lanes operate on the leftmost lane of all lanes and coexist with existing roads. It is desirable to set PM-only roads in the outermost lane to avoid affecting existing roads as much as possible (Hong and Park, 2020).

(a) (b)

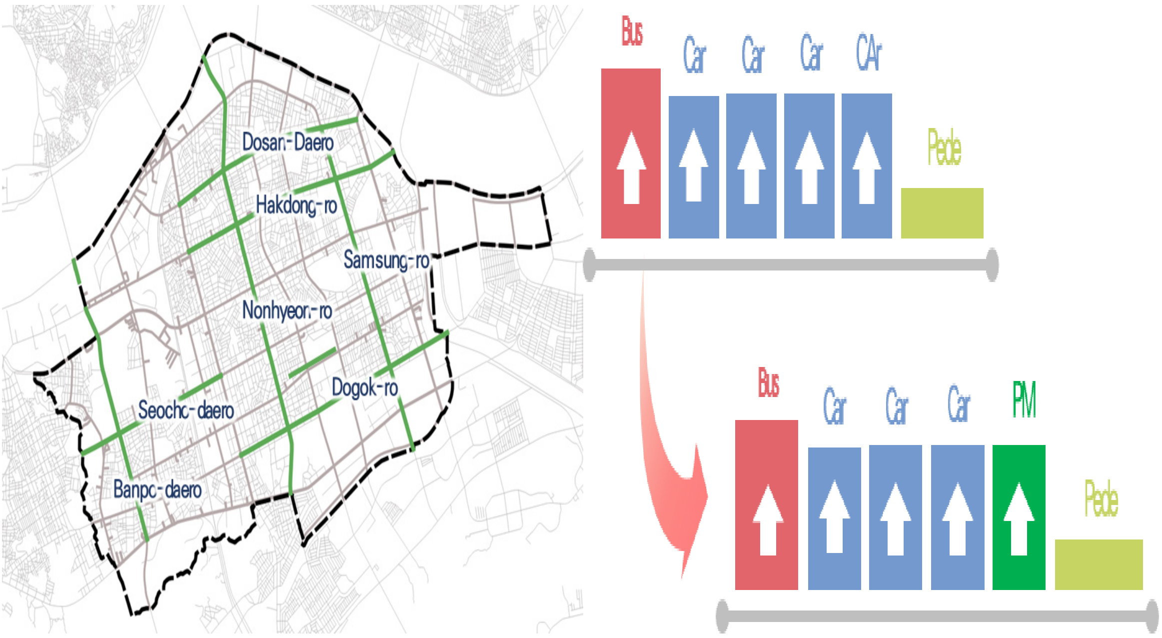

Figure 2: (a) PM-Only Roads in Seoul (b) PM-only roads operation way

2.2 Mode transition calculation methodology

Estimation is conducted using a four-step model when estimating traffic demand, and this estimated traffic demand is used as the main data for policy-making and alternative evaluation of transportation investment projects, such as improving and expanding transportation facilities. The method estimates traffic demand sequentially around the traffic zone and is divided into four stages: traffic generation, traffic distribution, selection, and traffic allocation (Figure 3). To secure the public confidence and accuracy of the traffic demand estimation results, the Korea Transport DataBase(KTDB) builds and distributes annual Origin and Destination(O/D) matrices and networks, and because the already established O/D matrix is at the end of the process of traffic generation and distribution, it is conducted only through means selection and traffic distribution (Lee and Park, 2019). If traffic supply patterns change significantly, such as new construction of railway lines or the level of provision of road facility services, a means-sharing model is used to calculate the rate of means conversion according to policy enforcement. In the case of this study, the calculation of means conversion volume was also conducted because the existing and road facility service levels were significantly different when PM roads were newly established. In the means-sharing model, the logit model is applied to individual traffic models that predict the means sharing rate by identifying the characteristics of the passers-by's individual traffic behaviour. The transition model to out-of-service traffic uses an incremental logit. The utility function is calculated using the total travel time, travel cost, etc., and for utility function parameters, the utility function and the modification factor of the method selection and passage allocation model (modification) analysed by the Gyeonggi Research Institute of Korea will be applied. Recent studies have derived measures to enhance access to urban railways and public transportation using shared PM services (Choi and Jung, 2020). According to the study by Choi and Jung (2020), 74.1 % of public transportation users are willing to use public transportation along with PM-sharing services. In this analysis, the mean conversion volume was used to estimate approximately 74 % of potential PM users, and the resulting benefit calculation was performed.

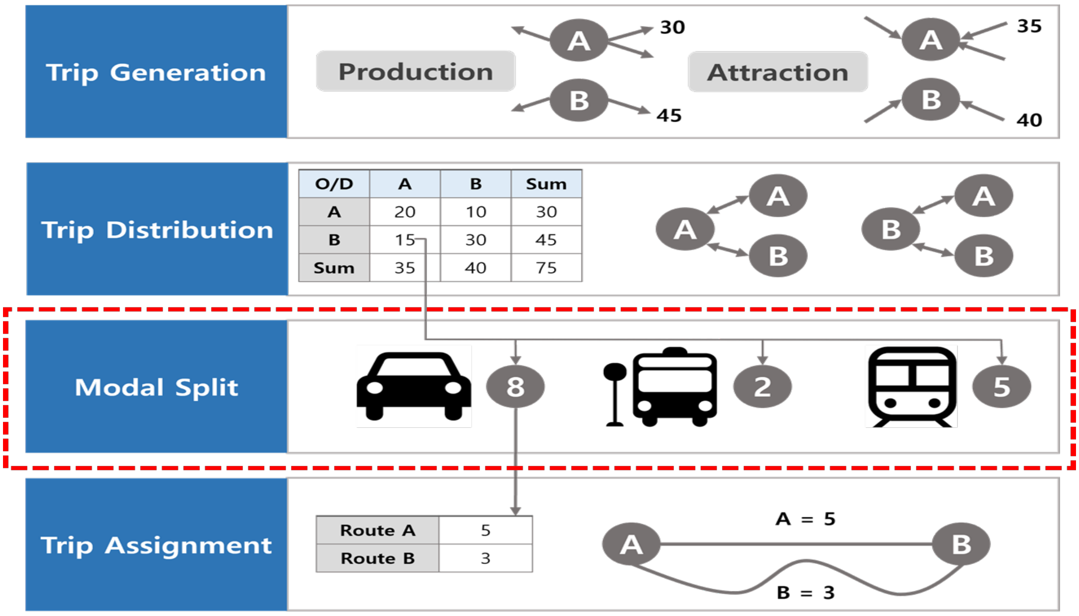

Figure 3: Traffic demand estimation step 4 flow

2.3 Green effect benefit methodology

This methodology analyses the impact of traffic on the environment to select the effect indicators of traffic reduction as environmental benefits (Lee et al., 2020). Traffic volume and environmental benefits were calculated through a transportation demand analysis program, and benefits were calculated by setting the area of influence of analysis to administrative buildings adjacent to the PM-only road area. The calculation of the benefits of reducing air pollution is calculated in three stages: air pollution costs incurred by implementing transportation facility projects (Lee et al., 2020). First, the calculation of the emission coefficient for each pollutant generated by driving a car. Second, it calculates the cost of air pollution by pollutants. Third, the calculation of the changes in pollutant emissions by source and pollutant because of the implementation of the project, then multiplying the unit of fabric for air pollution costs by the pollutant to get the monetary value.
Eq(1) shows that environmental benefits arise from differences in environmental costs under the unimplementative and implementative conditions. Eq(2) is the formula used to calculate environmental costs. In Eq(2), D_{lk} is Unit-km by link (l) by vehicle type (k). VT_k is Air pollution cost per km of relevant link speed by vehicle type (k).

$$VOPCS = VOPC_{Unimplemented} - VOPC_{Implemented} \qquad (1)$$

$$VOPC_{road} \sum_{l} \quad \sum_{k=1}^{3} \quad (D_{lk} \times VT_k \times 365) \qquad (2)$$

3. Result

3.1 PM traffic change analysis and PM traffic forecast in Gangnam

For a total of seven 9 km-long roads in Gangnam, one lane was reduced to form PM-only roads to install PM-only roads. A simulation of the section was performed using a traffic-planning program. The traffic allocation was calculated by converting taxis, buses, and lorries into passenger cars and calculating the value as the number of cars converted into passenger cars. Traffic volume on PM-only roads decreased while traffic volume on roads surrounding PM-only roads increased (see Figure 4). Because of reducing one lane, the total traffic volume in Gangnam decreased by 107,306 from 1,810,632 to 1,703,326, which is approximately 5.93 %. The main road in Gangnam was reduced from 124,832 to 102,369 when it was not implemented, and traffic was converted to an axis that did not reduce the road. At this time, approximately 24,584 traffic was converted to public transportation, and 18,217 traffic, or 74.1 % of the traffic, used PM during the transition.

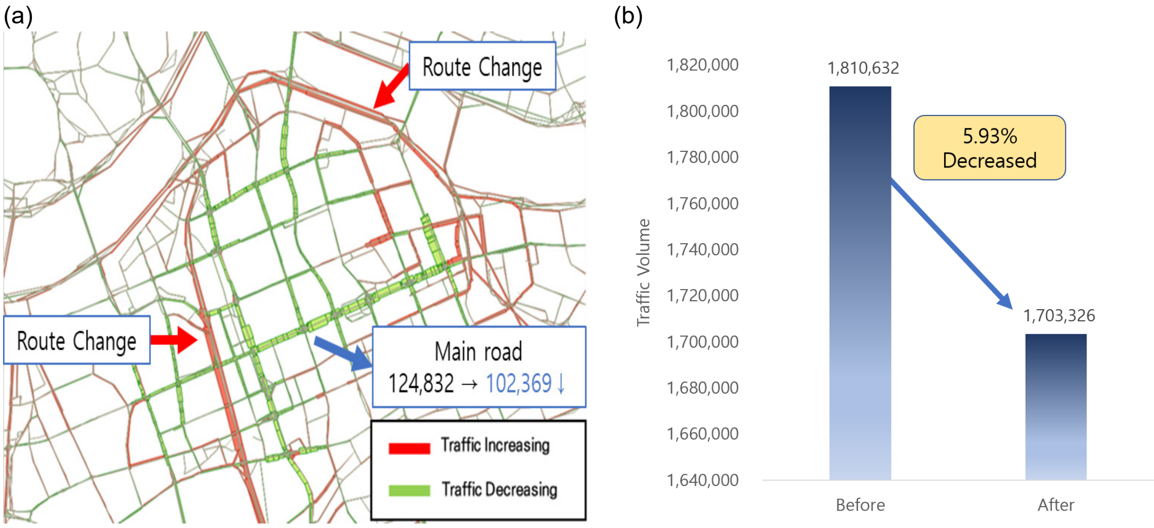

Figure 4: (a) Visualisation of traffic volume change (b)Traffic volume comparison in Gangnam

3.2 Environmental benefits of PM only roads

The construction of the PM-only road in Gangnam reduced overall traffic volume while increasing public transportation-sharing rate by 24,584. Environmental benefits can be expected from reduced vehicle traffic, and the environmental benefits are calculated using the appropriate formula. Each Vehicle Kilometers Travelled (VKT) was calculated both during non-execution and during implementation. VKT calculates the distance travelled by the vehicle by multiplying traffic by distance. It was found that 8,5285,484 km were not implemented while 8,341,877 km were constructed for PM only. Figure 5 shows the pollutant emissions factor according to the speed of the car. Second, because the Gangnam area has a speed limit of 60 km/h, the emission coefficient of pollutants in the section was calculated according to Table 3. As a result, it was calculated annually that air pollution savings benefits from the construction of PM-only roads totalled 0.66 x 10^9 KRW, with 30.164 x 10^9 KRW/y for non-executive cities and 29.504 x 10^9 KRW/y for PM-only roads (Table 4).

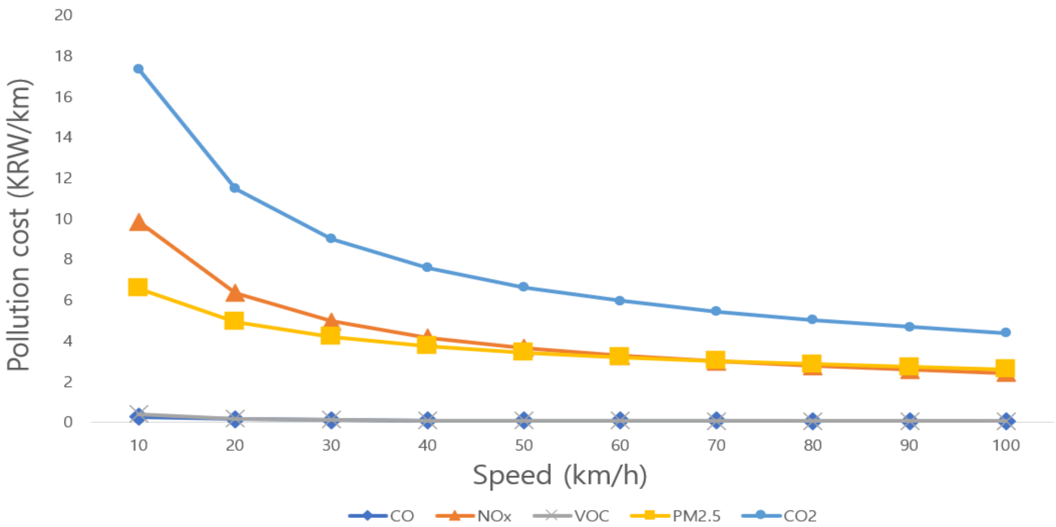

Figure 5: Pollutant emission factor by car speed

Table 3: Car air pollution cost factor

	CO	NOx	VOC	PM2.5	CO_2	Sum
Car	0.0 KRW/km	3.25 KRW/km	0.05 KRW/km	3.17 KRW/km	3.17 KRW/km	9.69 KRW/km

Table 4: Air pollution cost difference

	VKT	Car Air Pollution Cost Factor	Cost	Difference
Before	8,528,484		30.164 x 10^9 KRW/y	
After	8,341,877	9.69 KRW/km	29.504 x 10^9 KRW/y	0.66 x 10^9 KRW/y

4. Conclusion

With the rapid increase in demand now, PM has now become a means of constructing urban transportation along with bicycles. PM-related accidents are also increasing, so there is an urgent need for PM to coexist in urban transportation. In order for PM to coexist, the first way is to create an environment where PM can ride it. No matter how good transportation is, it will not be an environment to ride and if there is no place, it will not be easy to use, which will result in a decrease in utilization. In the meantime, the PM is only allowed to ride on the road under Korean law. However, most of the time PM is now using the walkway because of its dangers when travelling with cars. In Seoul, there is no dedicated road for PM to travel in Seoul. In response, the effect of installing PM-only roads was to be analysed. Installing PM-only roads can prevent collisions with cars, bicycles, and pedestrians, which can increase safety when using PM. Most PM users use public transportation which may also result in an increase in public transportation usage. The study found that 24,584 traffic increased when constructing PM-only roads, of which 18,217 traffic, or 74.1 % of which, could use public transportation with PM. Thirdly, if the use of public transportation increases due to the installation of PM-only roads, the use of cars can be reduced, which can also be expected to have an eco-friendly effect. Reducing car use can reduce air pollution emissions, which can also come as an environmental benefit. It is analysed that about 0.66 x 10^9 KRW in environmental benefits are caused by the construction of PM-only roads every year. This study predicts PM utilization when PM-only roads are created and calculates benefits. In future studies, PM utilization can be predicted on general roads or pedestrian roads, and the study will be conducted by applying various methodologies such as calculation of benefits reflecting the accident rate caused by PM.

Acknowledgments

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