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Impact Assessment on Cycle Super Highway Schemes

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Recently, Seoul has been pushing for eco-friendly transportation policies to reduce emission and improve environment, including restrictions on the use of cars and the introduction of shared bicycles. The government introduced the shared bicycles, of which the demand has been steadily increasing. The government is planning to introduce Cycling Rapid Transit (CRT) for the enhancement of the shared bicycle program. However, by applying the standard feasibility assessment, it is difficult to secure the feasibility of many eco-friendly measures, such as CRT. This research intends to promote the eco-friendly transportation by reflecting other benefit indicators represented by the wider impact parameters, such as health benefits. Based on the Origin/Destination data of the shared bicycles users, this study conducted a demand forecast estimation for various scenario considering the conversion of existing means to short-distance traffic, and analysed the benefits reflecting the wider impact. The study considered cycling's health benefits, which are estimated by the HEAT (Health Economic Assessment Tool) and the SART (The Sickness Absence Reduction Tool) used by WHO. The CRT introduction analysis was conducted on three sites, and the analysis showed that if human life value is not reflected, B/C is found to be at a minimum of 0.47 and the feasibility of the project cannot be secured with the existing methodology. When wider impact was applied, B/C was shown up to 3.29. Through this study, an efficient and more adequate feasibility methodology for evaluating the eco-friendly transportation policies was suggested, as the research intended to present the development direction for the analysis of health benefits suitable for domestic analysis and the selection of reference values.

1. Introduction

Transportation is shown to have a lot of influence on air pollution, nevertheless, the demand continues to increase (Fan et al., 2018). As a result, the interest to solve transportation environmental problems has been risen in various cities, as result they have adopted Traffic Demand Management (TDM) policies, such as Low Emissions Zone (LEZ), which has being implemented in Europe (Ku et al., 2020). In addition, many efforts have been made to introduce an eco-friendly transportation in various regions, but there is no clear and efficient methodology to evaluate the feasibility of the project. Especially that the bicycle-related costs are not estimated separately in bicycle-related projects (Weigand et al., 2013). Researchers are conducting various investigations that permit to consider the impacts of pedestrian and bicycle-related benefits (Kim et al., 2020). The OECD also analyses the benefits of projects in policy, social and macroeconomic aspects, reflecting the benefits of passers-by and environmental benefits. WebTAG also includes noise, air quality, urban landscape, physical health and reliability as a wider impact. The World Health Organization (WHO) applies HEAT (Health Economic Assessment Tool) and the Transport for London (TfL) applies SART (The Sickness Absence Reduction Tool) to measure the health benefits. HEAT is the calculation of economic benefits by converting the value of human life resulting from reduced mortality due to the increased physical activity (Kahlmeier et al., 2017). SART measures the value of productivity growth based on the number reduced days in absenteeism, which due to the increased physical activity (Transport for London, 2015). In this study, in order to promote eco-friendly transportation, the purpose of this study is to present a more effective methodology for evaluating the feasibility of eco-friendly transportation policies by improving the existing feasibility assessment methods. The analysis was based on focusing on health benefits among the wider impacts, different from other studies. The results of this study are expected to support promote eco-friendly transportation policies.

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2. Methodology

2.1 Estimation of CRT demand using big data for shared bicycles

The world recognizes walking and cycling as a major means of transportation for urban transport. They are examining the effects of investment by utilizing various economic models. Various investment assessment cases are shown in Table 1.

Table 1: A Case Study on the Investment Evaluation of Pedestrian and Bicycle

A Case Study	Summary	Utility / Application	Result
Vermont Agency of Transportation: Economic Impact of Bicycling and Walking, 2012	- Industry-linked model - Consider employment rates, GDP, consumption, relative costs, compensation, jobs	- Allow multi-layered spatial coverage analysis - Time-intensive - Cost: Depends on the scale of the analysis	- B/C
North Carolina Department of Transportation: "Economic Impact of Bicycle Facilities," 2004	- To measure the cumulative impact of the economy in whole or in certain parts	- Provides various results applicable to bicycle and pedestrian projects - Static: No change over time - Cost: Depends on the application of software or data	- Secondary impact on sales, tax revenues, occupations, and industrial suppliers - Effects of generation change
Virginia Department of Transportation: Multi-modal Transportation Plans	- Web-based dynamic analysis - Consider economic analysis, cost-benefit analysis, and public/private financial analysis for all means of transportation	-	- Impact on the economy - Return on investment - Cash Flow - Demographics - Performance measurement - Social benefits
Federal Highway Administration/Volpe Center: Report to Congress on the Outcomes of the NTPP, 2012; and NTPP 2014 Report	- Estimate economic benefits by utilizing reduced mortality from physical activity	- Useful for evaluating the benefits of bicycle riding - No correction has been made for reduced economic costs due to reduced mortality from increased walking - Analyze specific time or time series data	- Maximum annual benefits - Average annual benefits - The present value of annual benefits
Europe	- Attention is paid to the phenomenon that causes delays between means of transportation in limited road space	- Traffic analysis model of macro or micro should be pre-built	- B/C - Multi-standard analysis and weighted benefit analysis

In this research, the network of Seoul was established to analyse the effect of introducing the CRT, by estimating the demand through the O/D data by mean of transportation. Based on the records of rental and return of shared bicycles operated in Seoul, the research estimated the O/D data for bicycle mode. And for the shared bicycle data, since the traffic volume was calculated based on the rental office, the study could estimate the O/D data by zones. In addition, passenger O/D data by means of transportation was used to analyse the amount of other passenger switching to biking. The prediction of bicycle demand was based on the premise that the future demand for newly supplied bicycle roads will be converted to the same level as the existing bicycle user's use function.

2.2 Method for calculating benefit by applying wider impact

The benefits indicators of eco-friendly transportation are summarized in the table below, through a comprehensive investigation of different existing Korean and international literature, including papers, reports, and guidelines, related to walking and cycling. Among these benefits, the focus was on the health benefits, and through an exhaustive review of the applicability of such data for analysis in Korean context. The benefits covered by existing studies and guidelines related to walking or cycling are presented in Table 2.

Table 2: Benefit indicators in the literature related to the benefit calculation case

	Author (year)	Reducing travel time	Reducing driving cost	Reducing environmental cost	Reducing greenhouse gases	Reducing noise	Reducing traffic accident	Health promotion	Reducing parking cost
Walking and Bicycle	Litman (2018, 2011)	○	○	○	○		○	○	○
	WHO (2017, 2014)			○	○		○	○	
	Zulkifli (2010)			○			○	○	
	FHWA (2015)			○				○	
Walking	Kahlmeier (2010)							○	
	DfT (2014)							○	
	Litman (2003)							○	○
	Belter (2016)	○	○	○		○	○	○	○
Bicycle	Deenihan (2014)							○	
	Li and Faghri (2014)	○		○		○		○	○
	Kuster (2013)	○		○	○	○		○	
	Murphy (2013)		○	○				○	○

The benefits of promoting physical health were divided into two categories: social benefits and reducing disease benefit. The social benefits are considered a consequence of the reduction of the number of absenteeism days and sickness days. The average number of absenteeism days for people who use physical energy such as walking and bicycles is about 6 % less than those who do not (WHO, 2003). As the number of absent days has decreased, the time available for productive activities has increased. On the other hand, the benefit of disease reduction is calculated based on the distance of traffic instead of the travel time of pedestrian, due to the difficulty in measuring pedestrian's travel time. Then, the social benefits resulting from this are calculated according to the equation Eq(1).

$$\text{Social Benefit} = A \times \rho_A \times 8 \times P^{w} \times Q_w \quad (1)$$

Where A is average number of absence days from work, ρ_A is rate of reduction in the number of absence days (%), 8 is average daily working hour, P^{w} is time value of business trip (USD/h), Q_w is the number of pedestrians and cyclists.

Next, the benefits of reducing disease are measured through the effect of reducing mortality, due to the increase in the amount of physical activities (walking and cycling). In most studies, the health value of biking is either equal to or a half of the health value of walking. The PWC (2011) rated the health value of the bicycle the highest at 1.283 USD/km. While New Zealand ranked the highest value of walking at 2.387 USD/km. The results of the reviewed studies on the health benefits of walking and cycling are shown in Table 3.

Table 3: Health benefit in references

	Cycling (USD/km)	Walking (USD/km)
AECOM (2010)	0.071	-
Marsden Jacob Associates (2009)	0.431	0.431
WHO (HEAT tool) (2012)	0.939	2.267
New Zealand Transport Authority (2010)	1.193	2.387
PWC (2011)	1.283	1.924
Australia (NSW, 2018)	1.190	1.790

since there are no similar studies in Korea, the basic unit used in Britain and Denmark has been applied to measure the reduce mortality due to walking. According to the results of a study conducted in Copenhagen (Andersen et al., 2000), the total distance of travel was 0.173/1,000 person-km to calculate the benefits of disease reduction according to the formula(refer to Eq(2), (3)) below.

$$VMCS = VMC_{Before} - VMC_{After} \quad (2)$$

$$VMC = D_w \times \rho_M \times P^M \quad (3)$$

Where VMCS is the benefits of disease reduction (USD), D_w is total travel distance of pedestrians and cyclists (person-km), M is mortality rate (%), ρ_M is basic unit of mortality rate, P^M is social cost of mortality (USD).

3. Result and discussions

3.1 Scenario settings

The existing benefit calculation method could be maintained in order to maintain consistency in the case of the same type as those covered by the current guidelines, which identified specific benefits indicator of eco-friendly transportation. In addition, a scenario-by-case analysis was performed, assuming that the demand for short-distance travel was changed following the implementation of the project in order to reflect the ratio of switching between transportation modes, while considering cycling. The conversion volume of demand was assumed to be 30 % based, and scenarios were divided step by step. The setting by scenario is shown in Table 4.

Table 4: Project effectiveness settings by scenario

	Basic Plan	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Project effectiveness	30 % short-distance travel switching	10 % short-distance travel switching	20 % short-distance travel switching	40 % short-distance travel switching	50 % short-distance travel switching

3.2 Estimation of demand using big data for shared bicycles

The future demand was estimated using the established network and O/D data. Based on the basic plan, the estimated future demand for each project is shown in Table 5

Table 5: Results of demand estimates by scenario

	2020	2025	2030	2035	2040	2045
Cheonggye Stream street	4,988	5,013	5,270	4,897	4,596	4,594
Mapo main street	4,859	4,939	4,978	4,855	4,696	4,558
Han river main street	5,364	5,452	5,495	5,359	5,184	5,031

As a result of the analysis of changes in traffic patterns following the implementation of the project, it was found that not only the project route but also the surrounding bicycle routes' traffic has increased in case of the basic plan, in which 30 % of short-distance traffic within 4 km of Cheonggye Stream street is converted. The mentioned change in traffic patterns is shown in Figure 1.

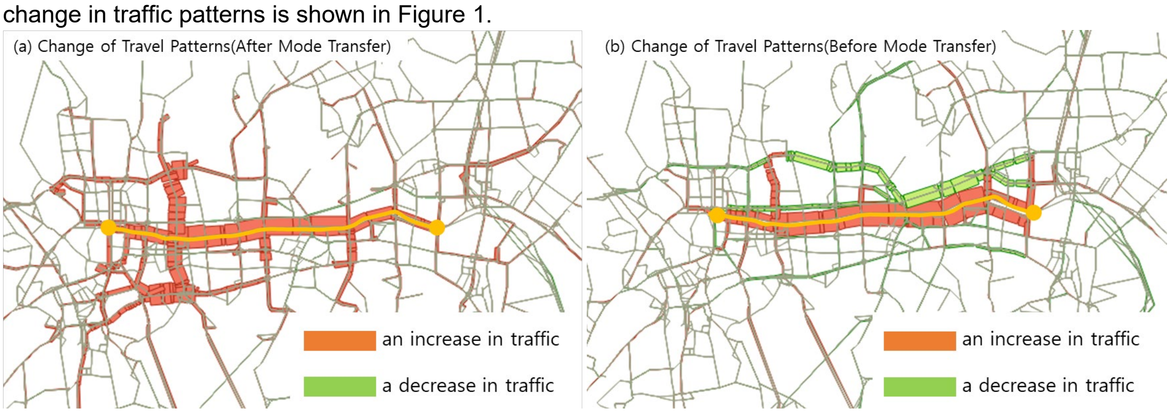

Figure 1: Results of Traffic Pattern Change Analysis of (a) after mode transfer, (b) before mode transfer

3.3 Estimating the benefits applying wider impact

In order to calculate the benefits, an area where the changes in traffic patterns directly occur, due to the implementation of the project, was selected and designated as an area of influence. The benefits consist of the benefits of reducing travel time, operating time, traffic accidents, environmental costs, and parking costs, while improving physical health. In the case of the basic plan of the project, the benefits estimated for each project are as shown in Table 6.

Table 6: Results of benefit estimates (Basic plan in 2020) (Unit: 1,000 USD)

Benefits	Travel time	Driving cost	Traffic accidents	Environmental costs	Parking costs	Physical health	Total
Cheonggye Stream street	213.0	98.3	23.4	19.7	17.9	263.8	636.2
Mapo main street	48.8	44.3	10.5	8.8	22.8	252.2	387.3
Han river main street	37.7	40.5	9.6	8.1	22.2	277.8	395.8

Benefit/Cost Ratio (B/C) was used as an economic analysis technique (refer to Eq(4)), and it is considered economical if the benefit/cost ratio is greater than or equal to 1, as the ratio of the total benefit and total cost. The analysis period was applied for 30 y of operation, and the social discount rate was 4.5 % depending on the domestic situation.

$$B/C\ Ratio = \sum_{t=0}^{n} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} \quad (4)$$

where B_t is the benefit during year t, C_t is the cost during year t, r is the social discounted rate and n is the analysis period.
In the case of existing methodologies without wider impact, the value of B/C in the three projects did not exceed 1, making it difficult to ensure the feasibility of the project. as a result of applying the HEAT and SART measures, adding health benefits among wider impact, other projects, other than Cheonggye Stream street, showed B/C values of 1 or higher, which then ensure the feasibility of the project. The results of the analysis are shown in Table 7 and Figure 2.

Table 7: Results of economic analysis (Basic plan)

Street	B/C Ratio	
	Before applying wider impact	After applying wider impact
Cheonggye Stream street	1.93	3.29
Mapo main street	0.47	1.35
Han river main street	0.73	2.45

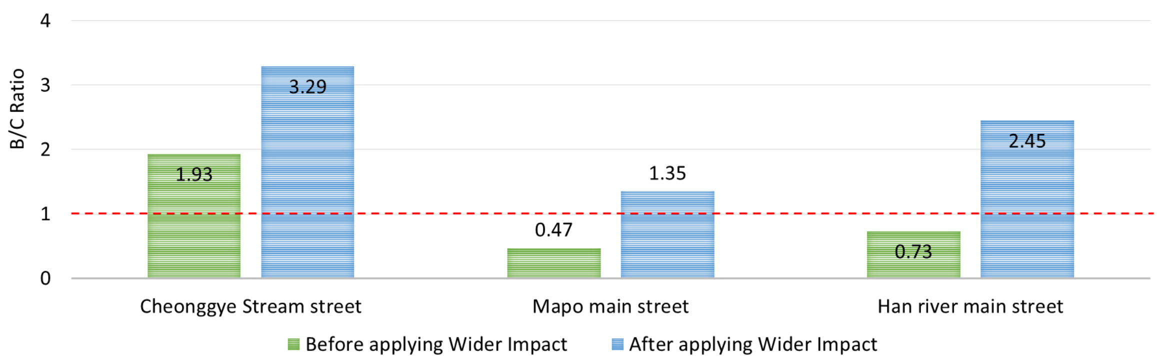

Figure 2: Comparison of B/C values, before and after applying wider impact

In the case of Cheonggye Stream street, government can build a bicycle road without reducing the number of lanes. Under these circumstances, the project can be implemented without reflecting the wider impact, such as health benefits. However, other projects other than Cheonggye Stream street need to reduce the number of existing roads, which requires a detailed analysis of the effects on public roads and bicycle paths. In such cases, it is necessary to specifically estimate the effects of bicycle paths by reflecting the wider impact, such as health benefits. In addition, the results of conducting the sensitivity analysis are shown in Table 8.

Table 8: The Result of sensitivity analysis (B/C ratio, basic plan)

	Cost		Benefit	
	+30 %	-30 %	+30 %	-30 %
Cheonggye Stream street	2.53	4.70	4.28	2.30
Mapo main street	1.04	1.93	1.75	0.94
Han river main street	1.89	3.50	3.19	1.72

4. Conclusions

Currently, various countries are focusing on solving urban traffic and environmental problems through the introduction of eco-friendly transportation modes. However, the current Korean method of estimating benefits alone lacks in terms of sufficient logic to consider the introduction of eco-friendly transportation. In this study, health benefits were introduced among wider impact as a methodology for promoting eco-friendly transportation. As a result, if wider impact was not reflected, B/C was lower than 1, but by reflecting it, the B/C was found to be a higher than 1, which guarantee the feasibility of the project. Through this study, the goal was to raise the issue of existing Korean feasibility evaluation methods, and to suggest a better and effective methodology for evaluating the feasibility of eco-friendly transportation policies. The study developed an application method of Wider Impact suitable for Korean conditions and the direction of development of the selection of standard values.

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