CHEMICAL ENGINEERING TRANSACTIONS
VOL. 78, 2020
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Jiří Jaromír Klemeš

ISBN 978-88-95608-76-1; **ISSN** 2283-9216
DOI: 10.3303/CET2078042

Cost Estimation Methods in Feasibility Studies on Eco-Friendly Transportation Facilities

Seunghyun Kim[a], Yejin Na[b], Sungyong Na[a], Donggyun Ku[a], Seungjae Lee[a,*]

[a]163, Seoulsiripdae-ro, Dongdaemun-gu, Seoul, Republic of Koreaniversity of Seoul, Korea South.
[b]Smartmobility co. Ltd., 56, Mangu-ro 12-gil, Dongdaemun-gu, Seoul, Republic of Korea
sjlee@uos.ac.kr

Rapid evaluation processes are required especially for government funded eco-friendly projects, which aim to create eco-friendly transport facilities for cyclists and pedestrians. These projects should be constructed massively and timely to increase the use of bicycle and pedestrian facilities. Because the global warming issues are increasingly threatening, the infrastructures should be developed to be more environment-friendly, in order to cope with natural disasters occurred due to these global warming issues. Therefore, evaluation methods should consider the effectiveness of both walking and biking benefits, including the complement of limitations caused by local differences such as traffic culture and environment. This study investigated and analysed studies and business cases related to cost estimations of environment-friendly transportation means in Korea and foreign countries. It decided on the items of cost estimation methods and suggested an estimation methodology for each item. As a result of this study, coded and standardized estimation methods for feasibility studies of pedestrian and bicycle-related transportation facilities are suggested and these lead to use and shorten the cost estimation processes in the feasibility studies for eco-friendly transport facilities.

1. Introduction

As environmental problems, such as fine dust and greenhouse gases, are increasing in recent years, various efforts have been made to raise the awareness of sustainability in diverse fields: environment, energy, and economy. Therefore, concerning sustainable transportation systems, a transition to green transportation, an eco-friendly means of transportation, has been tried to enhance the sustainability of cities in the transportation sector. Notwithstanding this importance, it is difficult to apply a general evaluation method that has been used for the investment projects in the transportation sector, to non-motorized transportation means using human body activities, such as walking and cycling. With a worldwide-expanding trend in the investment projects to increase uses of walking and cycling, such as pedestrian facilities and public bicycles, an objective evaluation system is required for these projects, where central and local government funds will be invested. It is necessary to study the beneficial effects of walking and cycling, using an investment evaluation system, and establish an evaluation plan considering various limitations and supplementations due to locality such as traffic culture and environment (Zohreh et al.,2014). The purpose of this study is to establish a scientific evaluation method for the investment of pedestrian and bicycle-related transportation facilities so that it can be used as basic data for investment priority and efficient allocation of government resources.

2. Research methodologies

Climate change, which is driven by man-made greenhouse emission gases (GHGs), such as CO_2, is now a major environment issue. This study analysed and investigated studies and business cases related to the cost estimation of environment-friendly transportation systems. Figure 1 shows the 8 policies used in transportation economics, which are mainly about the analysis of data, methodology of transportation studies and transport Engineering. These estimation methods are used to evaluate transportation policies

Paper Received: 15/04/2019; Revised: 04/09/2019; Accepted: 19/11/2019
Please cite this article as: Kim S., Na Y., Na S., Ku D., Lee S., 2020, Cost Estimation Methods in Feasibility Studies on Eco-Friendly Transportation Facilities, Chemical Engineering Transactions, 78, 247-252 DOI:10.3303/CET2078042

Evaluation of Policies in Transport Economics	
Make Comedy of Commons of Tragedy of Commons	Impact Analysis
Transport Planning Methodology	Data Analysis based on Statistics and Survey
Transport Engineering Methodology	Feasibility Studies (Economic and Financial, Value for Money)
Expert Judgment, Political Economy	Business Related

Figure 1: Evaluation of policies in Transportation Economics

3. Review of relevant studies

After reviewing Korean and overseas cases, it was found that a review of relevant materials had not been done in full scale, due to the limitation of pedestrian and bicycle facilities. A report on Cost Analysis of Bicycle Facilities by Lynn et al. (2013) highlighted the following problems:

- Biking projects often occur as part of larger multi-modal roadway projects, and bicycle-related costs are not tracked separately.
- The facility costs may reside in several departments or agencies, commonly planning and engineering, and not always aggregated at the end of the project.

According to major studies, the cost mainly includes construction cost, land compensation cost, and maintenance cost. It was found that the average unit cost of each pedestrian and bicycle facility was mainly applied to estimate the construction cost. A research conducted by the Seoul Institute estimated the costs by pedestrian facility project (Yonghoon and Segu, 2014). However, this study had limitations, since the pedestrian facility projects were not specific

As a result of analysing both domestic and overseas cases, it was found that the total project costs of environment-friendly transportation were estimated through the following procedures. In Figure 2a, project cycle (HM Treasury, 2018) shows that monitoring part is an implementation stage. In Figure 2b the performance of link between transport and economic performance (Rod, 2006) is indicated with 3 parts, which are users part, direct impact part, and wider impact part.

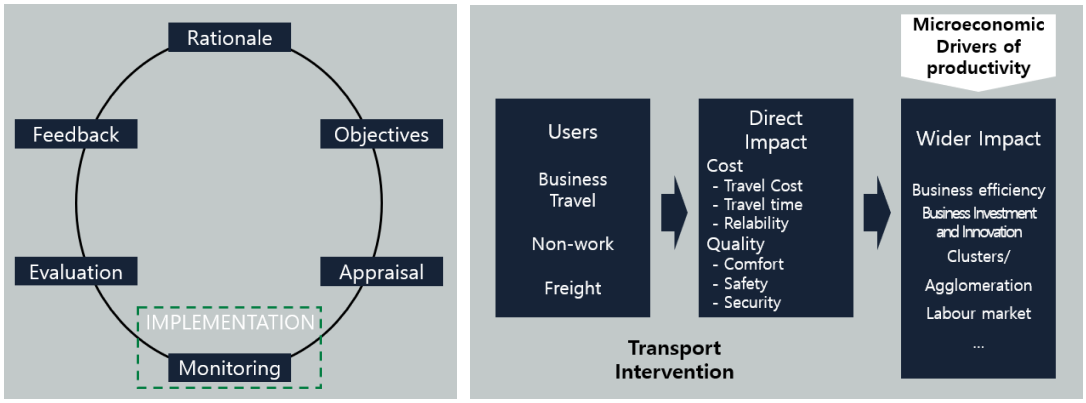

Figure 2: (a) The project cycle of HM Treasury Green Book (HM Treasury, 2018) and (b) Eddington's Transport study (Rod, 2006)

3.1 Appraisal Process

The transport appraisal process is about: option generation, development, and evaluation of intervention impacts (Department of Transport, 2019). Each country is using different appraisal guidance, for example, United Kingdom uses the Web-based transport analysis guidance (WebTAG), Australia uses Australian transport assessment and planning, and New Zealand uses economic evaluation manual (EEM). WebTAG was formulated in 2013 as a result of Cost-benefit analysis (CBA). The CBA was neither considering the impacts of cycling and walking, nor quantifying the reliability improvements, nor incorporating the latest forecast. Figure 3 shows the relationship between the appraisal process and the decision-making process. This process is a cycle considered with decision-making process part and monitoring and evaluation part.

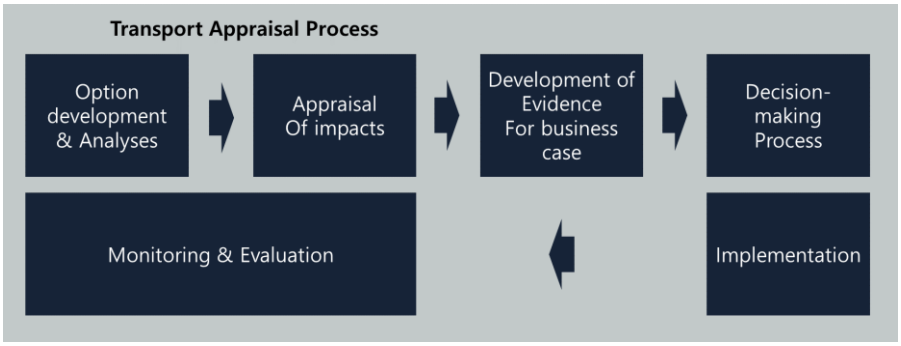

Figure 3: Relationship between appraisal process and the decision-making process

Figure 4 is a appraisal process and methodology of ATAP. ATAP appraisal process undergoes three stages that are presented in the form of filters. The three stages are strategic merit test, rapid appraisal, and detailed appraisal. And they are representing a benefit-cost analysis (BCA), an optimal test known as adjusted BCA, and an appraisal summary table concept.

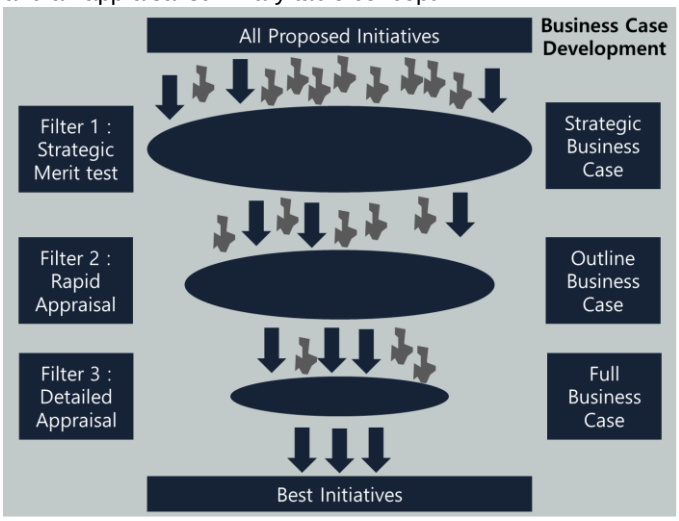

Figure 4: ATAP Appraisal Process and Methodology

4. Proposal of cost estimation methodology

Analysing the estimation methods of constructions, related to pedestrian and bicycle, in Korean and overseas, has shown that the cost estimation method based on unit cost per facility was the largest used one. The Seoul Institute (2014) classified pedestrian projects by types, but the system seems to be weak. Reviewing the total project cost of the main projects in pedestrian and biking sectors, revealed a big gap in projects' costs, ranging from 34 USD to 15,883 USD (see Table 1). Furthermore, comparing to other projects, especially related to roads and railways, the size and cost of pedestrian and biking projects are relatively small. Therefore, this study suggests the implementation of the cost estimation method based on unit load by project, for all large-scale projects (more than 170 USD). As for the small and medium-sized projects (less than 200 million KRM), the cost estimation method based on unit cost by facility is recommended.

In the cost estimation method according to unit load by project, construction costs are estimated based on the cases of pedestrian and biking related projects by type in Korea. Then, it calculates the average unit load by size/distance. The obtained average unit load is applied to the estimation of total construction cost.

In the cost estimation method based on unit cost by facility, pedestrian and biking facilities are classified by type according to relevant laws. The construction costs are estimated by applying unit costs used in the Korean construction code for each facility. As for the small and medium-sized projects of less than 170 USD, it would be advantageous to apply the cost estimation method according to unit cost by facility, because it is easy to perceive an accurate number of individual facilities and calculate the unit cost. For large-scale projects of more than 200 million KRM, it might be difficult to estimate an accurate number of individual facilities and their unit cost, thus, this study uses the cost estimation method according to unit load by project.

Table 1: Construction cost by project related to pedestrian and bicycle sectors

Project name	Location	Construction cost (x10^3 USD)	Area/length	Unit
Children's safety zone improvement project (Article 12 of the Road Traffic Act)	Dongho Elementary School	100	830	m
	Soongshin Elementary School	38	200	
Designation and management of protection zone for elderly people (Article 12 of the Road Traffic Act)	Oguem Elderly Hall	58	300	m
	Yeoksam Elderly Welfare Center	33	250	
	Daehan Association of Elderly Welfare	42	280	
	Seongsam Elderly Hall	3,000	230	
Pedestrian-oriented zone (Article 3 of the Pedestrian Safety and Convenience Enhancement Act)	Guil-ro 10-gil	483	0.43	km
	Cheongyesan-ro	1,417	2.1	
	Choansan-ro	833	0.7	
Pedestrian environment improvement zone (Articles 9 ~ 10 of the Pedestrian Safety and Convenience Enhancement Act)	World Food Culture Street	100	22	km^2
	Yongmasan-ro	725	28	
	Seoae University Culture Street	17,000	128	
Safety facility improvement project for the disabled	21 places	150	-	sites
Urban improvement project for pedestrians (Removal of obstacles on pathway)	Dasan-ro	917	2.6	km
Pedestrian-friendly road	Macheon-ro 61Ba-gil	60	180	m
	Donsomun-ro 20Ga-gil	99	300	

※ Source: Refer to the master plans and detailed drawings by project and various media articles.

4.1 Construction cost estimation by project related to pedestrian and bicycle

For the large-scale transportation facility projects, the costs will be estimated based on unit load by project as shown in the table above. In the event, there is no identical project in that classification, a unit load of a similar project in terms of size, area, and business purpose can be applied. Otherwise, three cases of similar projects in terms of size, area, and business purpose will be suggested. In that case, the average unit load of the three projects will be applied.

4.2 Construction cost estimation by pedestrian and bicycle-related facility

As for the small and medium-sized transportation facilities (less than 170 USD), the following cost estimation method is used according to unit cost by facility in pedestrian and biking sectors.

Table 2: Average unit construction cost of pedestrian & bicycle-related facilities (Data source: PPSK, 2019)

Relevant laws	Items	Unit cost
Act on Promotion of the Transportation Convenience of Mobility Disadvantaged Persons	Sidewalk	107 USD/m^2
	Speed reduction facility	8,056 USD/unit
	Crossing facility	16,886 USD/place
	Traffic information facilities	1,834 USD/unit
	Other facilities	96,231 USD/car
Promotion of the Use of Bicycles Act (Installation and Management Guidelines for Bicycle Use Facilities)	Bicycle lanes	78 USD /m^2
	Bicycle racks	1,528 USD/bike
	Electric bicycle charging station	5,000 USD/station
	Bicycle crossing	24,574 /unit

4.3 Land compensation cost estimation

For transportation projects related to pedestrian and biking sectors, the project size is relatively small compared to other projects, such as road, railways, port, and logistics. Also, land compensation is not big in these projects. Hence, it is required to simplify the system considering the project size, while following the system recommended by Jiwon (2009), and which was done in Korea.

This study used both estimation methods according to direct appraisal and official land prices in a complementary way. The most accurate estimation method is to follow the direct appraisal, as suggested in

previous studies, which is not available in the event, thus, the official land price is used instead. Although estimation applying standard compensation rate based on official land prices was regarded as a method with low accuracy in the past, recently its accuracy and reality are quite improved, owing to actualization and adjustment of official land prices and provision of more detailed information.
The estimation by direct appraisal is considered the most accurate estimation method. The land compensation cost's appraisal is directly included in the entire land cost of the project site. It is a method to do random sampling on representative types (about 5 %), in consideration of the traits of each item, such as purpose and usage of the land, and the structures thereon in the project site, and conduct an appraisal directly to estimate entire land compensation cost. It is the most realistic estimation method for land compensation costs.
Moreover, the application of standard compensation rate, according to official land price, is a method to estimate land compensation cost by applying a standard official land price presented in each public organization to which the area of land to compensate belongs (e.g. see the official land price announced in Ministry of Land, Infrastructure and Transport in Korea). In that case, compensations for the structures that have to be added to land acquisition costs, will be about 10~20 % of the land acquisition costs, which is adjustable according to project conditions.

4.4 Maintenance cost estimation

In Korea, one of the best studies that estimated the maintenance costs for pedestrian and biking facilities is 'Economic Analysis on Pedestrian Facility by Type for Evaluation of Investment Projects of Seoul City' conducted by the Seoul Institute (2014). This study suggested the maintenance and repair period for pedestrian projects, but it lacked a specification of the cost estimation method.

Table 3: Maintenance and repair period for pedestrian projects suggested in economic analysis techniques by type of pedestrian facilities

Project type		Description
Pedestrian facility	Sidewalks (exclusive pedestrian facility)	30 y for the facility (15 y is available in case of expansion and improvement project)
	Bicycle lanes	
	Dual-purpose walkways for bicycles and pedestrians	
	Crossing facility	30 y
Other	Creation of walkways in ecological system and park	30 y for structural project (10~15 y for other cases)
Specially created street	Creation of a Historical Culture Street	30 y for new establishment (15 y in case of expansion and improvement project)

Therefore, the most reasonable estimation method is the one suggested in a study in USA (Bethlehem, 2010), where the estimation items for maintenance cost in a pedestrian and biking facilities are as follows:

- Maintaining pavement quality through spot repairs, regular overlays and longer-term repaving.
- Maintaining trail up to ADA standards.
- Sweeping and removal of litter on a regular basis (daily or weekly).
- Vegetation trimming to provide clear access (Spring / Fall).
- Restriping paths as needed (usually annually).
- Landscaping maintenance (weekly / monthly), including irrigation costs.
- Lighting feature maintenance, including electricity costs.
- Repair of damage due to storms, floods, collisions and other unforeseen events.
- Repair and replacement of wayfinding or other signage.

The maintenance cost by facility is suggested by period. The maintenance cost for multi-purpose pathways is diverse and ranging between 396 and 3,125 USD/m annually depending on the landscape, economics, and material. In estimating maintenance costs for pedestrian and biking related facilities, proper maintenance costs should be obtained through trial tests and case studies on each one of these facilities.

5. Conclusions

This study selected cost estimation items through a comprehensive review of relevant cases in Korea and overseas, regarding the feasibility evaluation of pedestrian and biking related transportation facilities. Based

on that, this study additionally reviewed the estimation methods of construction and maintenance costs and elicited other necessary matters in that regard. The construction costs include construction work and land compensation cost estimation items. For the construction cost estimation, methods were suggested for both large-scale and small-scale investment projects. First, for large-scale investment projects of more than 170 USD of total project costs in transportation facilities for pedestrian and bicycle sectors, the unit load by project is used as a cost estimation method. As for the small and medium-sized projects of less than 170 USD of total project costs in transportation facilities for pedestrian and bicycle sectors, the unit cost by facility is applied for estimation.

As for land compensation costs, and since the land compensation is not big and these projects' sizes are relatively small compared to other projects such as road, railways, port, and logistics, the used method follows the system suggested in cost computation guideline in Korea. A simplification of the system is required in consideration of the size of the entire project. This study suggested the following two as simplified methods. A direct appraisal on the entire land has to be included in the project site and the structures thereon, and if the above method is not available, land compensation cost is estimated by applying standard official land price presented by the Ministry of Land, Infrastructure, and Transport in Korea. Finally, concerning the estimation of the maintenance cost for pedestrian and biking related facilities, estimation through trial tests and case studies on each facility was suggested to obtain proper maintenance estimation costs.

Further studies are required for better analysis and accuracy. For example, in the case of estimating unit load by project for large-scale investment projects of more than 170 USD, the project scope should be extended national wide in each country to obtain the construction cost by project. However, in case of estimating the maintenance cost by facility, estimation through trial tests and case studies on each pedestrian and biking facility is suggested to obtain proper maintenance costs.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2017R1D1A1B06032857).

References

Angie L.-C., Philip J.-T., Billy F., Steven J.-M., Shannon V.-S., Franz G., Marianne F., 2009, Factors Associated with Federal Transportation Funding for Local Pedestrian and Bicycle Programming and Facilities, Journal of Public Health Policy, 30, 38-72.

Atkins M.J., Neale J.R., Wu Y.-H., Walmsley M.R.W., 2018, Regional and National Greenhouse Gas Emissions Reduction Planning, Chemical Engineering Transactions, 70, 19-24.

Bethlehem, 2010, Bicycle and Pedestrian Annual Operations Budget Recommendations, New York, USA.

Cormos A.-M., Dragan S., Petrescu L., Chisalita D.-A., Szima S., Sandu V.-C., Cormos C.-C., 2019, Reducing Carbon Footprint of Energy-Intensive Applications by CO2 Capture Technologies: An Integrated Technical and Environmental Assessment, Chemical Engineering Transactions, 76, 1033-1038.

Damian A., Arvin P., Gayle B., Tom S., 2015, Pedestrian and bicycle facility design guidance, Region of Peel, Canada.

HM Treasury, 2018, The Green Book: Central Government Guidance on Appraisal and Evaluation, HM Treasury, London, UK.

Jaeyong L., 2009, A Study on Feasibility Analysis Method of Investment in Bicycle Facilities, Daejeon Sejong Research institute, South Korea.

Jiwon W., 2009, A Study of maintenance cost estimation in the road sector to perform a preliminary feasibility study, Korea Development Institute, South Korea.

Lynn W., Nathan M., Jennifer D., 2013, Cost Analysis of Bicycle Facilities: Case from cities in the Portland, OR region, Portland State University, Portland, USA.

Rod E., 2006, The Eddington Transport Study The case for action: Sir Rod Eddington's advice to Government, Manchester City, UK.

PPSK, 2019, Public Procurement Service in Korea, <http://shopping.g2b.go.kr> accessed 05.03.2019.

Tan R.R., Foo D.C.Y., 2018, Process Integration and Climate Change: From Carbon Emissions Pinch Analysis to Carbon Management Networks, Chemical Engineering Transactions, 70, 1-6.

Transportation Research Board, 2005, NCHRP Report 522(A Review of DOT Compliance with GASB 34 Requirements), Transportation Research Board of the National Academies, USA.

Yonghoon G., Segu L., 2014, A Study on Economic Feasibility Analysis for Various Pedestrian Project in Seoul, The Seoul Institute, Seoul, South Korea.

Zohreh A.-S., Mehdi M., Muhammad Z.-S., 2014, A pedestrian level of service method for evaluating and promoting walking facilities on campus streets, Land Use Policy, 38, 175-193.