A Study to Assess the Economic Effect of the Project to Improve High-risk Sections on National Roads

Wonchul KIM [a], Dong Wook IM [b], Jin-Tae KIM [c]

[a] *Dept. of Regional & Urban Research, Chungnam Development Institute, Gongju-si , 314-140, Korea; E-mail: iwonchul@cdi.re.kr*
[b] *Safety Assessment Office, Korea Transportation Satety Authority, Ansan-si , 425-801, Korea; E-mail: idw0709@ts2020.kr*
[c] *Graduate School of Transportation, Korea National University of Transportation, Uiwang-si, 437-763, Korea; E-mail: jtkim@ut.ac.kr*

Abstract: The road improvement project requires a huge budget for construction and compensation costs, and repair and maintenance costs. This study conducted an assessment on the economic effect of the improvement of high-risk sections on the road improvement projects (four phases) that were implemented in 2008-2012. The results show B/C ratio 1.02, NPV 2.93 billion won and IRR 5.69%, demonstrating that the project was highly economical.

Keywords: Assessment, Economic Effect, High-risk Section, Traffic Safety

1. INTRODUCTION

The onset of industrialization in the 1970s led to a high proliferation of vehicles, which was followed by the quantitative expansion of traffic facilities and roads. But due to a lack of consideration in qualitative terms, factors such as poor maintenance and management came to threaten traffic safety.

In response, the government established a series of five-year basic plans to improve high-risk national roads since 1989 and is continuously improving potential accident-prone spots caused by poor road structures, such as passing through settlements, narrow roads and sharp curves. The road improvement project mainly focuses on improving road alignments and road facilities, installing safety facilities and speed management. Such improvement projects require a huge budget for construction and compensation costs, and repair and maintenance costs. This is why an effective assessment must be carried out for the validity and continuation of such projects. Assessments on projects to improve high-risk roads, however, are limited to assessments focused on reducing traffic accidents, and there are almost no comprehensive assessments that also take into consideration effects other than the reduction of traffic accidents, such as vehicle operation costs, travel time and the reduction of air pollution.

In this respect, this study conducted an assessment on the economic effect of the improvement of high-risk sections on the road improvement projects (four phases) that were implemented in 2008-2012.

2. ECONOMIC ANALYSIS METHODOLOGY

2.1 Analysis Criteria

Among a number of economic analysis methods, the cost-benefit analysis method was used since this is method allows little room for any intervention of the evaluator's subjective ideas and permits comparison on a uniform scale (monetary value). An accurate computation of project costs and benefits needs to be undertaken for the economic analysis to be sufficiently reliable. Thus, criteria were set up based on the following three analysis premises:

1) Base point and base price of analysis: The base point of the prices of different variables applicable to economic analysis is January 1 of the year of the analysis considering factors such as the possibility of acquiring multiple data. The beginning of the construction period is based on January 1 and the completion of the construction period, December 31. Future costs and benefits were estimated at constant prices at the price base point, and the base year and base price of the analysis was set at 2011 constant prices.
2) Period of analysis: The period of analysis was set at 30 years, and the operation period in which costs and benefits incur in the design and construction period was also set at 30 years; the two adding up to constitute the total analysis period.
3) Discount rate: The discount rate of the opportunity cost of capital in the economic analysis of traffic facility construction projects was applied as the determinant parameter in converting the costs and benefits of the project to present value. High social discount rates signify that anticipated costs and benefits will have a relatively low present value due to a high growth rate of the overall society and high interest rates. This study was conducted based on the principle that the social discount rate of 5.5% would be utilized in the economic analysis.

2.2 Assessment Items

In order to reflect the direct effects and indirect effects or social benefits of the improvement projects, this study incorporated building costs, including construction and compensation costs, in terms of costs, and benefits of reducing vehicle operation costs due to faster driving speed, benefits of reducing travel time, benefits of reducing traffic accidents and environmental benefits of reducing air and noise pollution, in terms of benefits.

Table 1. Qualification method and applicability of assessment items

Category	Assessment Items		Quantification Method	Conversion to Monetary Value	Applicability
Costs	Project costs	Construction cost	Building construction costs	Construction cost	◎
		Compensation costs	Compensation value	Compensation cost	◎
	Repair and maintenance		Labor cost and repair/management cost	Labor cost and material cost	×
Direct benefits	Benefits of reducing travel time		Time converted to monetary value	Conversion to monetary value	◎
	Benefits of reducing vehicle operation costs		Operation cost	Operation cost	◎
	Benefits of reducing traffic accidents		Property damage cost and compensation cost	Conversion to monetary value	◎
	Benefits of reducing air pollution costs		Air pollution cost	Conversion to monetary value	◎
Indirect benefits	Regional development effect		Increase of land prices and income	N/A	×
	Expansion of market		Increase of land prices	N/A	×
	Restructuring of regional industry structure		Increase of land prices and income	N/A	×

2.2.1 Benefits of reducing travel time

Benefits of reducing travel time was a quantification of positive (+) benefits and negative (-) benefits in travel time costs that could incur if the travel demand and travel speed changed as a result of the implementation of the improvement project. The traffic volume and travel time are computed through the traffic demand analysis. As for time value, it is categorized into work/non-work travel according to the purpose of travel, and only the time value (work) of truck drivers has been considered for cargo. Provided, however, bus drivers have been regarded as work travelers.

The value of time per vehicle is needed to calculate the benefits of reducing travel time, which is determined by the number of persons in the vehicle and the ratio of work and non-work travel. The basic data on traffic demand analysis provided by KTDB(Korea Transportation Database) is based on nationwide, metropolitan areas and five regional zones, and the number of persons in the vehicle and the ratio of work and non-work travel by vehicle differ by region. Therefore, the time value per vehicle of each region computed based on the characteristics of each data must be applied.

Table 2. Value of time per vehicle in nationwide

Category	Passenger car		Bus			Truck
	work	non-work	driver	work	Non-work	work
Auto occupancy(person)	0.44	1.11	1	1.35	7.63	1.00
Travel rate(%)	28	72	-	15	85	-
Value of time per person(won/person•hour)	21,578	7,035	16,102	21,578	2,999	15,612
Value of time(won/vehicle•hour)	9,494	7,808	16,102	29,131	22,885	15,612
Average value of time	17,303		68118			15,612

The total travel time for roads was computed by multiplying the travel time of the links within the direct influence areas calculated as a result of traffic assignment and traffic volume by vehicle type. The total travel time cost by vehicle type was calculated for both cases: if the project was implemented or not. The difference between the two can be calculated as the benefit of reducing travel time.

$$VOTS = VOT_{non-implemented} - VOT_{implemented} \quad (1)$$

where,

$$VOT = \sum_{l} \sum_{k=1}^{3} (T_{kl} \times P_k \times Q_{kl}) \times 365$$

T_{kl} : travel time of vehicle type on link l,

P_k : value of time of vehicle type

Q_{kl} : volume of vehicle type on link l,and

k : vehicle type (1: passenger car, 2: bus, 3, truck).

2.2.2 Benefits of reducing vehicle operation cost

Vehicle operation cost is calculated by first computing the traffic volume over capacity (V/C) according to the traffic volume in the link. The link and average operation speed by vehicle type is determined by the curves of the traffic volume and speed. The vehicle operation cost by vehicle type according to speed is then calculated. The sum of these values constitute vehicle operation cost. Reductions in vehicle operation costs for work routes have been computed by comparing the total vehicle operation costs based on previous networks. In general, benefits of reducing vehicle operation costs mainly include oil, engine oil, tire, repair and maintenance, and depreciation costs. These benefits, however, depend on road and traffic conditions, and therefore the real vehicle operation cost must be calculated to befit both road and traffic conditions. The won unit by speed in the vehicle operation cost according to speed was calculated based on vehicle operation cost computation results by vehicle type and speed proposed in the Guidelines on Investment and Assessment of Traffic Facilities by the Ministry of Land, Transport and Maritime Affairs (2011). As for the vehicle operation cost by driving speed, the minimum vehicle operation cost for passenger cars and small buses were 100km/h and trucks, 70-80km/h.

It is impossible to calculate the different variables included in the generating function of each item, thus total vehicle operation cost will be calculated for each 10km/h, and the total operation cost at middle speed computed using the regression equation.

Additionally, link driving speeds differ by vehicle type in reality, but this cannot be reflected in the current traffic assignment model. Therefore, in calculating the benefits of reducing vehicle operation cost, the analysis hypothesizes that there is no difference in speed among different vehicle types.

$$VOCS = VOC_{non-implemented} - VOC_{implemented} \quad (2)$$

where,

$$VOC = \sum_{l} \sum_{k=1}^{3} (D \times VT_k) \times 365$$

D_{kl} : vehicle•km of vehicle type on link l,

VT_k : operating cost of vehicle type according to driving speed, and

k : vehicle type (1: passenger car, 2: bus, 3, truck).

2.2.3 Benefits of reducing traffic accidents

Benefit of reducing traffic accidents is the quantification of traffic accident costs that may be reduced by the implementation of a certain project. This occupies a large proportion in road investment assessments, and in case of the UK and Japan, it accounts for about 20% of total benefits. Road improvement results in reducing accidents, which is why it should be calculated as a benefit. This study also quantified the effect of the reduction in traffic accidents and calculated it as a benefit.

Road traffic accident costs can be categorized into physical costs and psychological costs, according to the Korea Transport Institute (KOTI) (research on estimation of traffic accident costs by year). The physical cost is broken down into costs of human damage, material damage and social institutions according to the estimation and assessment of road traffic accident costs (Road Traffic Authority, by year). Here, human damage costs are produced by excluding compensation, which is equal to psychological costs.

Expressway links, national road links and rural road links are defined by utilizing link traffic assignment results for existing road networks. The benefit of reducing traffic accident is calculated as the difference between hundreds of millions of km for cases if the project is implemented or not. The computation formula for the benefits of reducing traffic accidents for each year of the analysis is as follows:

$$VICS = VIC_{non-implemented} - VIC_{implemented} \tag{3}$$

where,

$$VIC = \sum_{t=1}^{3}\left[\sum_{s=1}^{2}(A_{ts} \times P_s \times VT_t)\right]$$

P_s : traffic accident cost by accident type,

VT_t : one hundred million•km by annual road type,

A_{ts} : number of injury by one hundred million•km and road type•accident type,

t : road type (1: express way, 2: national highway, 3: local road), and

s : accident type (1: fatality, 2: injury).

Table 3. Basic unit of traffic accident cost

Category			Human damage cost	Material damage cost	Social institution cost
Human damage accident (psychological cost)	Fatality (PGS)	Number(won)	-	1170000	-
		Person(won)	479,630,000 (124,330,000)	-	1,760,000
	Injury (PGS)	Number(won)	-	1170000	-
		Person(won)	3,800,000 (14,510,000)	-	1,350,000
Material damage accident	Vehicle damage	Number(won)	-	1,050,000	140,000
	Human damage	Number(won)	-	1,230,000	140,000

2.2.4 Benefits of reducing air pollution and green house gas emissions

Benefits of reducing air pollution and green house gas emissions are largely computed by calculating the pollutant and green house gas emissions coefficient, environmental damage cost per pollutant and green house gas units, and changes in pollutant and green house gas emissions if the project is implemented or not. As for air pollution cost, it must consider the damage costs of carbon monoxide (CO), hydrocarbon (HC), nitrogen oxide (NOX) and particulate matter (PM), but it must be calculated by multiplying the emissions coefficient by pollutant and the won unit of social costs. The emissions coefficient of air pollutants CO, HC, NOX and PM was acquired by utilizing the calculation formula for pollutant emissions coefficient by vehicle type suggested by the Manual to Calculate Emissions of Air Pollutants by the National Institute of Environmental Research (NIER) (2007). In case of green house gases, there are carbon dioxide (CO2), methane (CH4), nitrus oxide (N20), hydrofluorocarbons (HFCS), perfluorocarbons (PFCS) and sulphur hexafluouride (SF6). Since only CO2 is related to the use of transportation, only CO2 was reflected, and the results of vehicle performance tests were utilized, given it is a substance generating green house gases.

Table 4. Basic unit of air pollution and green house gas emissions

CO (won/kg)	HC(VOC) (won/kg)	NOX (won/kg)	PM(won/kg)		CO2 (won/kg)
			urban	rural	
10,426	12,117	12,546	842,436	77,789	161.4

Benefits of reducing air pollution and green house gas emissions were calculated as below by utilizing the won unit of air pollution costs and green house gases and the air pollution and green house gas emissions coefficient by vehicle type and speed:

$$VOPCS = VOPC_{non-implemented} - VOPC_{implemented} \quad (4)$$

where,

$$VOPC = \sum_{l} \sum_{k=1}^{3} (D_{kl} \times VT_k \times 365)$$

D_{kl} : vehicle•km by link and vehicle type,

VT_k : cost of air pollution and green house gas by km, and

k : vehicle type (1: passenger car, 2: bus, 3, truck).

3. AVAILABLE DATA

A total of 230 sections were subject to the four phase project to improve high-risk sections in national roads (2008-2012). Of those sections, projects that began prior to 2007 and are currently underway and projects that began after 2011 have been excluded due to a lack of traffic accident data. Consequently, a total of 106 sections, for which data was available, have been selected for the analysis.

Table 5. Collected data to assess the economic effect of the project

Category	Total (section number)	Seoul	Pusan	Insan	Daejeon	Wonju
traffic safety improvement project of high-risk sections	230	10	62	59	37	62
Analysis sample	106	9	29	21	20	27

Table 6. Overview of traffic accident safety improvement project of high-risk sections

Category	Non-implemented (Before)			Implemented (After)			Construction duration
	Length (m)	Volume (number/day)	Radius (m)	Length (m)	Volume (number/day)	Radius (m)	
Sections 1	1,120	11,356	29	1,100	12,543	107	08.11~09.11
Sections 2	1,010	11,356	76	1,000	12,543	140	08.11~09.11
Sections 3	320	7,887	90	320	8,266	140	08.10~09.12
Sections 4	300	2,141	17	300	2,181	60	08.08~09.01
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Sections 106	600	4,829	90	580	5,069	280	09.02~09.11

4. ANALYSIS RESULTS

4.1 Calculation of Costs

Project costs incurred due to the improvement of high-risk roads have been divided into construction costs and compensation costs. Construction periods are defined as the period from when the construction first begins to when it ends. Land acquisition costs are incurred over two years at 30% and 70% during the initial stage of the project. The basic costs and final design costs have been hypothesized to be paid in advance prior to the input of construction costs. Meanwhile, repair and maintenance costs have not been applied under the hypothesis, given that the project is the improvement of high-risk sections in already existing roads and not the installation of new roads, the repair and maintenance costs incurred previously on existing roads would also be applicable identically to the roads after they have been improved. The total costs of the project were estimated at 134.1 billion won, including 120.5 billion won as construction costs and 13.6 billion won as compensation costs.

4.2 Computation of Benefits

4.2.1 Basic premise

In case of changes in future traffic volumes, difficulty is expected in the acquisition of regional development plans and management plans across the nation as the subject sections are distributed nationwide and also in conducting micro-traffic demand estimations for each route. Furthermore, change in average future traffic volume by year is estimated to be merely 0.1% according to the 2010 National Traffic DB Project by the KOTI (2012). Therefore, the study hypothesized as there being no changes in future traffic volume.

The different types of vehicles has been applied accordingly by using the 2011 traffic volume by vehicle type for national roads in the Road Traffic Volume Statistics Year Book (passenger cars 69.6%, buses 2.7%, small trucks 21.4%, middle-size trucks 5.0%, large trucks 1.3%).

Shortening of road elongations for the benefit analysis showed that the subject routes were to be lengthened by a total of 61.9km but were shortened by 2.2km (3.6%) to 59.7km. As for improvements in speed as a result of the high-risk road improvement project, similar points for each radius of curvature were selected during field investigations. A study of speed by each radius of curvature was conducted and the results utilized. The speed study was conducted by utilizing driving method of the test vehicle at a minimum of five times for each radius of curvature. The improvement of speed in 106 subject sections according to differences in radius of curvature was estimated by utilizing the results of the study on average driving speed by radius of curvature before and after the improvement project.

4.2.2 Benefits of reducing travel time

The benefits of reducing travel time according to the shortening of road elongations and improved vehicle driving speeds due to the improvement of road curves have been calculated. The time value per vehicle was estimated at 18,213 won after taking into account and adjusting for consumer price index and ratio of vehicle types. The reduction of travel time as a result of road elongations and speed improvements was estimated at a total of 471.6 hours a day, resulting in the generation of benefits of 3.13 billion won annually.

4.2.3 Benefits of reducing vehicle operation costs

The benefits of reducing vehicle operation costs according to the shortening of road elongations and improved vehicle driving speeds due to improvement of road curves have been computed. The reduction in vehicle operation costs by speed was calculated by taking into account and adjusting for consumer price index and ratio of vehicle types. As a result, benefits of reducing vehicle operation costs have been analyzed to generate benefits of 1.26 billion won every year at the total elongated section of 59.7km.

4.2.4 Benefits of reducing traffic accidents

The benefits of reducing traffic accidents as a result of the improvement of high-risk roads have been calculated. The total number of traffic accidents in the subject sections, as compared to one year before the beginning of the project, fell by 61% from 59 cases to 23 cases, the number of deaths declined by 87.5% from eight persons to one person, and the number of injuries fell by 60% from 90 persons to 36 persons. The benefits of reducing traffic accidents were estimated at 5.3 billion won per year according to the application and adjustment of consumer price index against the won unit of traffic accident costs.

4.2.5 Benefits of reducing environmental costs

The benefits of reducing environmental costs as a result of the improvement of high-risk roads have been computed. The reduction in environmental costs by speed or the benefits of a reduction in environmental costs was estimated to generate 200 million won of benefits every year.

4.2.6 Results of calculating comprehensive benefits

Aggregating the results of the computation of benefits showed that a total of 9.89 billion won of benefits were generated every year: annual benefits of reducing travel time at 3.07 billion won, benefits of reducing vehicle operation costs at 1.26 billion won, benefits of reducing traffic accidents at 5.30 billion won and benefits of reducing environmental costs at 0.2 billion won. The results of having conducted an economic analysis based on the above were B/C ratio 1.02, NPV 2.93 billion won and IRR 5.69%, demonstrating that the project was highly economical.

Table 7. Analysis results of the economic effect of the project

Year	Cost (one hundred million won)			Benefit (one hundred million won)					Net cash flow
	Construction	Compensation	Sub total	Travel time	Operation	Traffic accident	environment	Sub total	
2008	427	91	518	0	0	0	0	0	(518)
2009	521	45	566	0	0	0	0	0	(566)
2010	257	0	257	0	0	0	0	0	(257)
2011	0	0	0	31	13	53	2	99	99
2012	0	0	0	31	13	53	2	99	99
2013	0	0	0	31	13	53	2	99	99
2014	0	0	0	31	13	53	2	99	99
2015	0	0	0	31	13	53	2	99	99
2016	0	0	0	31	13	53	2	99	99
2017	0	0	0	31	13	53	2	99	99
2018	0	0	0	31	13	53	2	99	99
2019	0	0	0	31	13	53	2	99	99
2020	0	0	0	31	13	53	2	99	99
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2038	0	0	0	31	13	53	2	99	99
2039	0	0	0	31	13	53	2	99	99
2040	0	(136)	(136)	31	13	53	2	99	235
Total	1,205	0	1,205	940	378	1,590	60	2,969	1,763

5. CONCLUSION AND FUTURE STUDY

This study conducted an economic analysis on the project to improve high-risk roads (four phases) implemented in 2008-2012. The project was analyzed to reduce 61% of traffic accidents, 87.5% of deaths and 60% of injured persons, suggesting that improvement of high-risk roads were highly effective in reducing traffic accidents. Additionally, the comprehensive economic analysis showed that the project was highly economical (B/C Ratio 1.02, NPV 2.93 billion won, IRR 5.69%), implying that the project was not only effective in reducing traffic accidents, but it was also a valid project in economic terms as a policy which generated benefits to citizens who used the roads from a national perspective.

Before now, analysis on projects to improve high-risk roads was largely inclined to focus on accident-based qualitative effects rather than quantitative analysis based on objective analysis by experts or data. There is also a lack of pre- and post- project assessment data after the completion of a project. An assessment methodology which can constantly monitor the project in detail and a data base must be established. This study applied and suggested a comprehensive assessment method in an attempt to overcome such a limit.

In order to improve the methodology to assess the effect of improvement projects, the development of representative objective items for the economic analysis is imperative. Furthermore, high-risk road projects incur large project costs as they are mainly road curve improvement projects. This leads to an under evaluation of the effects of the project, creating problems in equity compared to other projects. In order to resolve this problem, a model and criteria that can incorporate citizen happiness indices, such as driving convenience and resolution of civil complaints, according to improved road curves must be developed.

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