A STUDY OF MEASURING THE EFFECTIVENESS FOR ROAD SAFETY FEATURE IMPROVEMENTS

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Abstract: The Korean government has recognized the serious situation and tried to reduce the traffic accidents with various countermeasures. However, the resources for the safety improvement projects are limited. In order to allocate the limited resources efficiently, the priority list should be established based upon economic efficiency. The current evaluation criteria seem to have deficiencies. One is the estimation of accident reduction rate for each safety treatment. The other is the estimation of overall effect when several safety treatments are applied simultaneously at the same spot. In this study, accident reduction rates for each safety treatment are re-estimated considering related domestic and foreign data. Also, a new methodology to estimate the overall effectiveness of countermeasures at the same location is proposed. The methodology presented in this study is a tentative one. In order to enhance the results presented in this study, more comprehensive study should be performed in the near future.

Key Words: Road Safety Treatment, Effectiveness of Accident Reduction, Accident Reduction Rate, Overall Effectiveness for Safety Countermeasures

1. INTRODUCTION

1.1 Background and Purposes

The number of road traffic accidents has increased as the number of vehicle has increased in Korea. The total road traffic accidents cost in 1997 reached at 11 trillion won. Not only the economic losses by the road traffic accidents, the road traffic accidents cause personal damages. The Korean government has recognized the serious situation and tried to reduce the traffic accidents with various countermeasures. Among them, the most popular one is the safety improvement projects at black spots on the roads which have been put in a practice since 1989.

In 1999, the government spent 28.8 million won on the national highway system, and it reached 4.8% of national highway maintenance budget of Ministry of Construction and Transportation. For the proper allocation of the budget, the setting up of the priority list has been progressing, but it should be studied further in setting up the accident reduction factor and duplication effect for various countermeasures.

The purpose of this study is to introduce the detail of accident reduction rates for each safety treatment and the estimation of overall effects when several safety treatments are applied simultaneously at the same spot in order to set up the prior investment at black spot.

1.2 Methodology

In order to allocate the limited resources efficiently, the priority list should be established based upon the economic efficiency. In this study, the accident reduction rates for each safety treatment are re-evaluated considering related domestic and foreign data and figure out the proper alternative to apply in field test site in national highway 17. Especially, the computation of accident reduction rate for each safety treatment and duplication effect shall be studied.

The traffic accident reduction rate by the same safety improvement treatment may be different based on the characteristics of traffics and passengers of the corresponding highways. However, it is necessary the standard reduction rate of each safety improvement feature. The value of reduction rate of each safety feature plays an important role to calculate the benefit of the safety feature. That is why the determination of reduction rate of safety feature properly is so important. The estimation of accident reduction rate for various safety features was performed in this study by domestic and foreign studies.

In case that several alternatives are applied on the same spot, the duplicate effect shall be estimated. In this study, the methodology to find out the real accident reduction rate in the case that several alternatives are applied simultaneously on the same spot will be presented.

2. ACCIDENT REDUCTION RATE OF SAFETY COUNTERMEASURE IN KOREA

The Ministry of Construction and Transportation(MOCT) has set up the accident reduction rate for each safety feature in order to set up the priority list for the safety improvement projects at black spots. And the Road Traffic Safety Authority(RTSA) evaluates the effectiveness of black spot improvement projects. However, it does not provide the accident reduction rate for each safety feature. Therefore, in this study, the results from the Ministry of Construction and Transportation safety evaluation case studies have been carefully examined.

2.1 Current Methodology to Set up the Priority List

"National Comprehensive Transportation Safety Improvement Plan" was initiated to improve the level of safety in transportation area by the Office of Prime Minister in 1987. It also includes the improvement projects at black spots and they have been executed from 1989, and positively promoted in 1996. It had been executed in 1,042 spots, budget of 23.9million won before 1996, and shall be executed in 1,750 spots, budget of 213.1 million won during 1997 to 2001. In order to allocate the limited budget, there should be a decision process of setting up the priority list and the accident reduction factor of the countermeasure is applied to estimate benefits.

First, the accident costs are applied to the number of accident reduction by the countermeasures. In this way, benefit is estimated in monetary terms. The following equation shows how to calculate the reduced number of accidents.

$$\text{The reduced number of accidents} = N \times AR \times \frac{ADT\ after}{ADT\ before} \tag{1}$$

where,
N : the average number of accidents before improvement
AR : accident reduction factor
ADT : average daily traffic (vehicles/day)

In the case that multi countermeasures are applied at the same spot, the duplicate effect is estimated by equation 2.

$$AR_m = AR_1 + (1-AR_1)AR_2 + (1-AR_1)(1-AR_2)AR_3 + \cdots + (1-AR_1)(1-AR_2)\cdots AR_m \quad (2)$$

where,
AR_m : accident reduction factor when multi countermeasures are applied in the same spot
i : the number of countermeasures at one spot

2.2 Problems Associated with the Current Methodology

The investment priority list shall be established based upon the benefit and cost ratio of the improvement projects. The accident reduction factor is applied to estimate the number of accidents reduced by the countermeasures in order to calculate benefit.

In the decision of investment priority list at black spots, the accident reduction factor is currently applied as the same value as the Kentucky State University in U.S. presented. At that time, the prime goal of the study was to execute the safety improvement project at black spot and establish the methodology of investment priority list. In this study, in the process of estimating accident reduction factor for each countermeasure, time and effort were very limited. However, this is the time to estimate own accident reduction factor that reflects our own road and passenger's characteristics for the feasibility study and decision of the investment priority list.

Besides the accident reduction factor, the estimation of duplicated effect for multi countermeasures should be improved. Because the current methodology (equation 2.) has the limit not to consider the characteristics of each accident spot, it is necessary to develop a new methodology to estimate real effect of countermeasures considering traffic characteristics of the spots.

3. ACCIDENT REDUCTION RATE OF SAFETY COUNTERMEASURE IN FORIGN COUNTRIES

Several studies in estimating accident reduction factor had been performed. Ogden (1996) presents accident reduction factors in type of road, countermeasures and accidents. The road type is divided into normal express section, normal low-speed section, express intersection, and low-speed intersection. The improvement methods include all traffic safety improvement countermeasures such as channelization, median barrier, lighting, re-pavement, and re-paint.

Lasek (1990) presents the countermeasures to reduce severity of accidents between vehicles and shows the effects of countermeasures. Countermeasures such as median barrier, strengthening guardrail, improving sight distance, and channelization were presented.

Louick (1990) performed effect of each countermeasure and estimated the benefit/cost ratio of coutermeasures. Improving sight distance, signs, markings, lighting, and removing obstacles were suggested as countermeasures.

The Civil Engineering Research Institute in Japan presents accident reduction factors by each safety treatment. The accidents were divided into accident types, day/night, parties of accidents, speed of vehicles, and road surface condition. Also the accident types are divided to injury accident, vehicle accident, and single vehicle accident. Road surface condition is divided to dry, wet, freeze, snow, and obscurity.

Table 1. Accident Reduction Rate for Various Studies (%)

		OGDEN	LASEK	LOUICK	KENTUKY	FHWA	JAPAN	DEVIATION
Signs		10-40	-	8	10	23	-	32
Installed traffic signal		30-80	-	-	32	18	-	62
Improved traffic signal operation		30-80	21	21	10	18	-	70
Red light camera		20-30	-	-	-	-	-	10
Repainting		20-40	-	-	-	13	-	27
Guardrail		30-40	10	10	-	13	82.1	72.1
Cat's eye		-	-	-	2.5	-	-	-
Skid resistant pavement		40-60	-	-	-	48	-	20
Delineation		20-30	-	3	10	-	58.6	55.6
Acceleration and deceleration lane		50-80	25	-	5	23	S-	75
Left-turn bay		50-60	25	-	15	23	-	45
Bus bay		-	-	-	-	-	34.0	-
Median barrier	Fatalities	54	9	27	60	91	48.7	82
	Injuries	54	9	27	10	6	-	48

Table 1. shows the results of the previously mentioned foreign studies about the results of the accident reduction factor by the safety countermeasures. The data of Ogden presents normal express section's results and data of Japan shows accident reduction rate of injury accidents.

The item which shows the biggest deviation was median barriers, its accident reduction rate was 9%~91%, and systemically providing transitional lanes, guardrail, and traffic signal operation improvement followed. The reason there were big differences in the accident reduction rate even at the same countermeasures is due to not only the characteristics of the accident but also the differences of the survey and classification methods.

4. ESTIMATION OF ACCIDENT REDUCTION FACTOR FOR SINGLE AND MULTIPLE COUNTERMEASURES

4.1 Estimation of Accident Reduction Factor for Each Countermeasure

For calculating benefit, accident reduction factor of each countermeasure should be estimated. The accident reduction factor of each countermeasure is presented in various ways and the accident reduction factor by the Kentucky, U.S is currently applied in Korea. However, applying the accident reduction factor does not reflect the transportation characteristics in Korea. Therefore, in this study, the accident reduction factor is re-evaluated considering related domestic and foreign data.

For domestic, data of 272 spots, which executed the safety improvement project of black spots, were analyzed. These data may not be reliable because accident data used in this evaluation contains only one year data before and after the improvement project. The domestic data was used only for the purpose of comparing with the foreign data.

Table 2 Accident Reduction Factor for Different Countermeasures in Korea

	No. of traffic accidents			No. of fatality			No. of injury		
	Before	After	Reduction rate (%)	Before	After	Reduction rate (%)	Before	After	Reduction rate (%)
Installed Traffic Signal	1,360	1,062	21.91	56	34	39.29	1,198	984	17.86
Improved Traffic Signal Operation	79	123	-55.70	1	1	0.00	59	102	-72.88
Delineation	49	29	40.82	3	3	0.00	43	26	39.53
Guardrail	174	120	31.03	12	12	0.00	161	125	22.36
Cat's Eye	952	817	14.18	57	36	36.84	821	744	9.38
Skid Resistant Pavement	1,199	817	31.86	80	51	36.25	1,132	803	29.06
Pedestrian Crossing	279	275	1.43	13	7	46.15	281	250	11.03
Left-Turn Bay	120	134	-11.67	7	2	71.43	100	123	-23.00
Bus Bay	365	221	39.45	14	3	78.57	350	214	38.86
Median Barrier	63	74	-17.46	2	2	0.00	67	78	-16.42

The result of analysis shows that the traffic signal operation improvement, providing the life-turn bay, installing median barriers turned out to be negative effect. The reason is that in traffic safety improvement project, it may need 3 to 5 years of collecting and analyzing period to evaluate of real effect of the project, but in this case, the abnormal result may come out because the time period was the 1-year after the project. The accident reduction factors such as providing bus bay, delineation, and guardrail show high accident reduction rates. The accident reduction factors of countermeasures in Korea are followed in Table 2.

After analyzing results from foreign studies including the Kentucky State data, the domestic results were accepted in case they were similar to the foreign ones. In the case that the domestic results are far different from the foreign ones, the foreign ones were bench marked, because the results of the study in Korea based on relatively short time period. The final results are followed in Table 3.

Table 3. Proposed Accident Reduction Factor (%)

		Accident Reduction Factor
Signs		16.5
Installed traffic signal		47.44
Improved traffic signal operation		25
Red light camera	**Speed**	28
	Signal	25
Repainting		21.5
Guardrail		31.03
Cat's eye		14.18
Skid resistant pavement		42.11
Delineation		19.71
Acceleration and deceleration lane		29.5
Left-turn bay		29.5
Bus bay		39.45
Median barrier	**Fatalities**	48.2
	Injuries	21.2

4.2 Estimation of Accident Reduction Factor for Multiple Countermeasures

It is necessary to estimate the overall effectiveness for the case that several countermeasures are applied to the same location. In Korea, the equation 2 has been used to estimate this. However, because this equation is applied to every type of accident with equal weight, it is impossible to estimate net effectiveness of each countermeasure. For example, in case of installing the median barrier, guardrail, and overpass, each countermeasure contributes to reduce accidents to different type of accidents. However, according to the current methodology, accident reduction factor to all types of accident is equal. This is the main problem of the current procedure.

In this study, a new methodology is proposed in order to solve the main problem associated with the current methodology. The new methodology considers the net impact of a countermeasure to certain type of accidents. For example, when a overpass for pedestrian is installed on a spot in order to reduce accidents associated with jaywalking, the accident reduction factor for overpass is applied to the accidents with jaywalking on that spot. In this way, every accident reduction factor of countermeasures can be applied to the designated types of accidents and overall net effectiveness can be estimated.

4.3 Estimation of Benefit When Multiple Countermeasures Are Applied

Equation 3 shows the procedure to estimate the annual benefit (B_i) from countermeasures. In this case, the benefit is accident reductions.

$$B_i = \sum_{j=1}^{n} [(D_{ij} \times AC_d + W_{ij} \times AC_w + S_{ij} \times AC_s) \times IE_j] \qquad (3)$$

where

D_{ij} : Reduced maximum number of fatalities by countermeasure " j " on spot " i "

W_{ij} : Reduced maximum number of severe injuries by countermeasure " j " on spot " i "

S_{ij} : Reduced maximum number of minor injuries by countermeasure " j " on spot " i "

AC_d : Accident costs for fatality

AC_w : Accident costs for severe injury

AC_s : Accident costs for minor injury

IE_j : Accident reduction factor for countermeasure " j "

j : Countermeasure

In Equation 3, reduced number of accidents by certain countermeasure is estimated based upon accident data at the locations where countermeasures are implemented. In order to classify the reduced number of accident to each countermeasure, the real purpose of each countermeasure should be identified. In other words, each countermeasure is intended to prevent certain types of accidents. Based upon this idea, accident data have been classified in order to estimate the real effect of each countermeasure. Also, accident data more than 3 years after countermeasure is implemented should be collected. In this way, accident reduction factor for certain countermeasure can be established.

In order to estimate benefit in monetary term, accident costs is widely used. In safety improvement projects, benefit is mainly accident reduction. However, accident reduction in numbers does not provide absolute degree of the improvements. Also, in the process of economic analysis and priority setting of improvement projects, accident costs are commonly used as benefit estimation. Accident cost savings due to accident reduction consider both the number and severity of accidents.

In Korea, the Korea Transport Institute (KOTI) published the accident costs for each accident severity annually. Table 4 shows the results of accident costs per accident and person for different severity of accidents in 1997. Originally, accident costs include loss of output, vehicle repair costs, medical costs, administration costs, and PGS (Pain, Grief & Suffering). However, the procedure to estimate the PGS costs has not been concrete yet. Therefore, in this study, PGS costs are not applied.

Table 4 Accident Costs for Each Severity Level (10,000 won)

	Fatality	Injury		PDO (Property Damage Only)
		Severe	Minor	
Per person	22,074	1,814	608	-
Per accident	25,042	2,424	805	130

Source: Determinants and Trends of Road Accident Costs in Korea, The Korea Transport Institute, 1997

5. CASE STUDUY

In this study, the case study has been performed at 5 different spots on the section of the national highway 17 form Chunju to Namwon where represents higher accident rates than national average. In this case study, the suggested accident reduction factors have been used. The main purpose of this case study is to compare the current methodology and proposed methodology to evaluate the overall benefit/cost ration when multiple countermeasures are applied at the same spot.

Table 5 shows the overall benefits due to accident reductions at 5 different spots with current and proposed methodology. The results of the current methodology show 2-7 times bigger than the results of proposed methodology. It means that the current methodology easily overestimate the benefit.

Table 6 shows the results of benefit/cost ratio and investment priority list at five different spots. The results show that the benefit/cost ratio by the current methodology is much higher values than those by the proposed methodology. Also, priority lists of both methodologies show different results.

Table 5 Comparison of Benefit of Accident Reductions for Current & Proposed Methodologies (Unit: 10,000 won)

Spot Number	Proposed Methodology (A)	Current Methodology (B)	B/A
Spot #1	4,546,086	10,167,840	2.24
Spot #2	2,227,009	13,341,247	5.99
Spot #3	2,421,893	16,812,740	6.94
Spot #4	1,173,785	6,071,652	5.17
Spot #5	1,560,352	10,104,630	6.48

Table 6 The Results of Economic Analysis

Spot number	Construction costs (10,000 won)	B/C		Priority list	
		Current	Proposed	Current	Proposed
Spot #1	14,091	7.22	3.23	5	4
Spot #2	3,406	39.17	6.54	1	1
Spot #3	17,218	9.44	1.36	4	5
Spot #4	2,751	22.07	4.27	2	2
Spot #5	5,315	19.01	2.94	3	3

6. CONCLUSIONS

The purpose of this study is to re-evaluate the current procedure to estimate the effectiveness of road safety improvement projects in Korea and to propose a new methodology. Especially, the accident reduction factors for countermeasures and the overall accident reduction effect for multiple countermeasures used in the same spot are presented.

In Korea, the road safety is one of the most important issues. However, the allocation procedure of the limited budget of road safety improvements has not been properly studied. Accident reduction rate for each countermeasure will be different from road environment and traffic conditions. Also, when multiple countermeasures are implemented at the same spot, the overall effectiveness will be different from the summation of the effectiveness of each countermeasure.

In this study, the current accident reduction factor for each countermeasure has been carefully investigated with real accident data and compared with foreign studies. And adjusted values for accident reduction factors for countermeasures are proposed. Also, the procedure of estimating overall accident reduction effect when multiple countermeasures are applied in the same spot is proposed. A case study is performed to compare the existing and proposed methodology. The result shows that the overall effectiveness of accident reduction by the current methodology for multiple countermeasures at the same spot is 2-7 times higher than the overall effectiveness by the proposed one. It shows that the current methodology overestimates the accident reduction effect. Also, the results from the current methodology are able to direct a false allocation of the limited budget for road safety improvements. With the proposed methodology, it is possible to estimate the real overall effectiveness of the safety improvement projects and to allocate the limited budget efficiently.

In this study, in order to estimate accident reduction factor for each countermeasure, the results from foreign studies are referenced. With this reason, the results from this study might not consider the real situation. In order to solve this limitation, vast and long accident data collection and analysis should be performed in the near future.

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