

COST BENEFIT ANALYSIS OF SPEED LIMIT REGULATION FOR HIGHWAYS IN JAPAN

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Abstract: In Japan, the evaluation procedure for infrastructure investment projects have been developed well in past ten years, while the evaluations of regulatory provisions are yet to be implemented in spite of OECD recommendation for applying cost benefit analysis (CBA) to regulations. One of the candidate regulations for applying CBA is speed limit regulation since speed limit is set by police agencies without any objective analysis, and the ongoing reform process in road sector is considering relaxation of speed limit in general trunk roads as an alternative policy option. This paper proposes an analytical framework based on CBA and make an attempt to apply the framework to objectively evaluate the resulting costs and benefits due to relaxation of regulated speed in one expressway route in Japan. The result of analysis demonstrates that a net positive benefit can be achieved by upgrading regulated speed.

Key Words: Speed Limit, Evaluation of Regulation, CBA, and Accident Analysis

1. INTRODUCTION

In the past 10 years a significant progress has been made in improving evaluation process for public works in Japan. In the beginning, conventional cost-benefit analysis (CBA) was introduced as the key project appraisal tool. However, the increasing concerns of environmental impacts and other social aspects of public works demanded a more comprehensive CBA, which could also include cost and benefit items corresponding to environmental and social impacts of the public works. As a result, the scope CBA has been gradually expanded in Japan to deal with many “soft” issues related to public works. In fact, the newly discovered strength of CBA to handle many soft aspects of decision-making in public sector has brought about new thinking in the domain of public policy. Recently, OECD (1997) recommended all member governments to adopt framework of CBA not only for public work projects but also for regulations. This is understandable since all regulatory policies, in one or other ways, incur costs and bring benefits for the society, and CBA could be useful tool to evaluate regulatory policy objectively.

Among the countries of the East Asian region, the above mentioned trends- the evolution of comprehensive CBA for project appraisal and use of CBA to evaluate regulations- are of significant policy relevance. As the developing countries in the region are expecting a huge investment in public works, effective methods of public investment appraisal are imperative to ensure efficient use of scarce investment resources. On the other hand, public works sector in developed countries like Japan is expected to undergo a drastic reform process, which may require a comprehensive framework to evaluate regulatory policies.

In Japan, project level comprehensive CBA has already been introduced in transport sector, such as in road projects. However, Japan has yet to make progress in applying CBA for regulatory policies. OECD (1999) pointed out that Japan is lagging behind other OECD members in regards with subjecting regulatory policy to CBA. In fact, the introduction of CBA to evaluate regulatory provisions is very timely in Japan in the context of the ongoing reform process in public work sectors.

The privatization process of Japan Highway Corporation initiated in recent years has triggered discussions over range of issues related to road investment and infrastructure management, which in turn has opened discussion on various alternative options. In the face of increasing financial constraint for new investment, some of the strategic options currently under consideration are; (1) reduce the construction cost of new expressway project by scaling-down design standard and (2) relax the speed limits (scale-up operation) for general trunk roads.

The proposal of relaxing speed limits of general trunk road seems to be logical, since the decision to set up speed-limit regulation for highway is made by prefecture level police agencies usually in an ad-hoc way. In spite of the design standards of highway for higher traffic speed, the police agencies have a tendency to set a lower speed limit without any economic analysis. As the prefectural police agencies can set the speed limit independently, there are cases that a single highway route is subjected to different speed limits in different sections of highways (even if the design speed is same), which are under the jurisdiction of different police agencies. This has caused a significant inefficiency in the use of highway infrastructure. However, the speed limit should not be relaxed just by intuitive reasoning, as there are also associated costs (related to safety and environment). Hence, the question of whether the speed limit should be relaxed or not makes a perfect case of applying CBA as recommended by OECD.

With this background this paper makes an attempt to apply the framework of CBA to objectively assess the effects of relaxing speed limit. As the first step, the application in this paper is limited to cases of speed relaxation for an expressway route. A brief review of relevant literature is presented in the Chapter 2. This is followed by a discussion on relationship among design speed, regulated speed and actual speed in Chapter 3. Chapter 4 deals with the impacts of actual speed on safety and environment. Finally, a case study is presented applying the CBA to evaluate effects of speed relaxation regulation in Chapter 5, which is followed by conclusion.

2. LITERATURE REVIEW

A standard CBA manual has been developed and officially adopted to carry out CBA for expressway projects in Japan (Committee on Evaluation of Road Investment Projects 1998,

Ministry of Land, Infrastructure and Transport, 2003). The manual prescribes standards parameters to compute various cost and benefits items. Most important benefit item in case of expressway projects is the time saving due to high-speed travel. The Japanese CBA manual prescribes that the time saving benefit should be computed using actual speed, which is estimated with the help of link specific volume-speed (Q-V) curve. The manual also recommends standard formula to estimate vehicle operating cost (VOC), environmental cost and accident cost, though the environmental cost is rarely considered for CBA.

Even though the manual prescribes actual speed to be used for CBA, the actual driving speed might be different when the regulated speed is changed. However, there are so limited studies that examined relationship among design speed, regulated speed and actual driving speed. Most research studies on road accident are limited to examining relationship between accident rate and road design parameters (related to road geometry) along with design speed. Hence, relations of regulated speed and actual speed with the accident rate are not known well (Expressway Research Foundation of Japan, 2000). For this paper, it is therefore necessary to establish a relationship among design speed, regulated speed and actual speed first in order to evaluate the effect of relaxation of speed limits on various costs and benefits items.

3. RELATIONSHIP AMONG DESIGN, REGULATED AND ACTUAL SPEEDS

3.1 Relationship between design speed and regulated speed

In Japan, three categories of design speeds for expressways are in existence, namely 80 km/hr, 100 km/hr and 120 km/hr. Basically the design speed is determined taking several relevant factors into account. These include expected traffic volume, land-use (urban or rural) and topography (flat or mountainous) around the road alignment and other constraints to road geometry. In fact, it might be possible to overcome most of such physical constraints technically, such as by constructing appropriate structure. However, consideration on the cost side demands that a compromise should be made between design standard and the cost of construction. For example, if road alignment passes through a mountainous area, keeping a high design speed requires very costly construction (such as tunnels and bridges). The constraints of right of way and environmental concern are most common in urbanized areas. Likewise, high traffic volume justifies higher design speed as this yield relatively higher time saving benefits. In fact, it is possible to take all these factors into account through the framework of CBA and then arrive at appropriate design speed to obtain higher benefit cost ratio.

Even though the design speed is chosen on the basis of CBA, regulated speed is decided by police agencies in ad-hoc ways. In most cases, for a section with 80 km/hr design speed, the regulated speed is also 80 km/hr except for the sections passing through special urban areas where 60-70 km/hr speed limit is sometimes imposed mainly due to noise problem. In case of sections with design speed of 100 km/hr and 120 km/hr, the regulated speed most commonly adopted 100 km/hr. Under some severe climatic conditions, the regulated speeds are lowered temporarily, sometimes as low as 50 km/hr. These represent basic considerations used while setting regulated speed. In practice, keeping these basic factors and other factors in view, the regulated speed is set on case-by-case basis without any objective analysis. However, if we intend to apply some analytical method to decide on regulated speed, we need to use actual driving speed.

3.2 Relationship between design speed, regulated speed and actual speed

As mentioned before, in the CBA manual, the actual speed is calculated by using link specific volume-speed (Q-V) curves. The Q-V curve for each road link is drawn taking several link specific factors into account. These factors include the category of road (expressway or general road), land use condition around the road alignment (DID, other urbanized areas, rural areas), topographical condition (plain or mountainous area), the type of median treatment (divided or undivided with a physical median separating two direction of flow), and number of intersections (for general roads). In each Q-V curve, the speed corresponding to maximum traffic volume is set same as the regulated speed.

As the central element of this research is about changing the regulated speed, the actual speed is computed using an alternative model, in which actual speed is specified as a function of regulated speed, design speed, physical characteristics of road (curvature, gradient and number of lanes) and traffic volume. The model parameters are estimated using actual data of the year 2003 obtained from the highway traffic counter for samples of expressway routes. The routes in the sample include, Kanetsu, Joban, Tohoku, Higashi Kanto and Chuo expressway. The data is averaged over each expressway section. Upper panel of Figure 1 shows how actual speed varies with design and regulated speed and road curvature. The figure confirms the fact that actual speed is higher if regulated speed is higher. It also shows that actual speed is higher for a section with higher design speed even if the regulated speed is the same as illustrated by the curves for design speed of 120km/hr. It is also evident that curvature of the road has strong influence on actual speed when the radius of curvature is less than 1000 meters.

Likewise, lower panel of Figure 1 shows relationship between actual speed and road gradients for roads with different design and regulated speeds. Regarding relationship between actual speed and design and regulated speed, this figure shows same patterns as that of earlier figure. It can be seen that down slopes cause higher actual speed while upward slopes cause relatively lower actual speed.

Table-1 shows the estimation result of the model set for computing actual speed. The explanatory variables include radius of road curvature, gradient, traffic volume and regulation

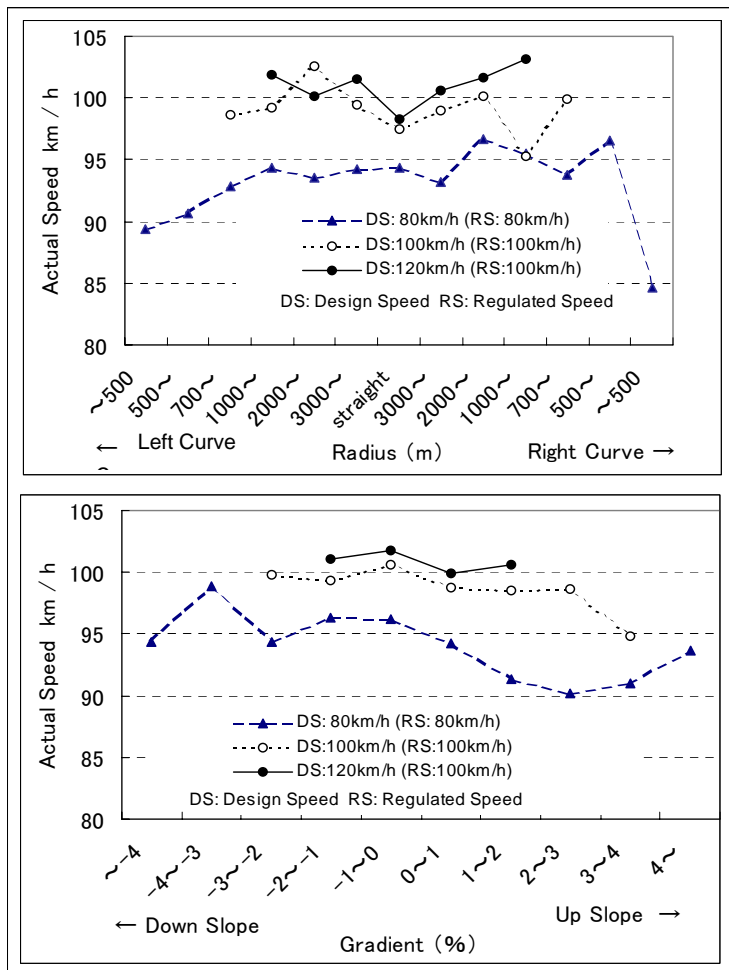


Figure 1: Actual speed and road geometry

speed. All explanatory variables are classified into different categories and regression is conducted over categorical variables (dummy variables). As shown in the table, all the parameters have expected signs and R^2 value is 0.42.

Table 1: Estimation results for model to compute actual speed (km/hr)

Explanatory variables	Category	No. of Samples	Parameters	Range	Partial correlation coefficient
Radius of road curvature (m)	~500	4	-6.28	6.42	0.153
	500~1500	50	-0.26		
	1500~	265	0.14		
Gradient (%)	~-3	13	1.85	5.82	0.290
	-3~0	150	1.23		
	0~3	148	-1.20		
	3~	8	-3.97		
Traffic Volume/Lane (1000 Vehicle)	~10	139	1.71	4.20	0.325
	10~15	141	-1.00		
	15~	39	-2.49		
Regulated Speed (km/h)	80	136	-3.55	6.19	0.549
	100	183	2.64		
	120 ¹	—	8.83		
Constant		319	97.82		
R	0.64		R^2	0.42	

Note1: Since the regulated Speed of 120km/h is not in practice Japan, the coefficient for this speed is extrapolated using coefficients for 80 and 100 km/h..

4. ACTUAL SPEED AND IMPACT ON SAFETY AND ENVIRONMENT

4.1 Relationship between speed and accident ratio

There exist research studies, which conducted accident analysis using actual data from expressway routes (Expressway Research Foundation of Japan, 1999). The accident ratio is assumed to be dependent on factors like road geometry (curvature and gradient), number of road lanes and design speed. It is found that relatively sharp curve (with smaller radius) and downward gradient cause more accidents.

Charts in Figure 2 plots accident ratio data obtained from five different routes of expressway in Japan (Tomei, Kanetsu, Joban, Tohoku, and Higashi Kanto). The data is annual average covering years from 1995 to 1998. The charts show relationship of accident ratio and road geometry (curvature and gradient) for different design and regulated speeds. The

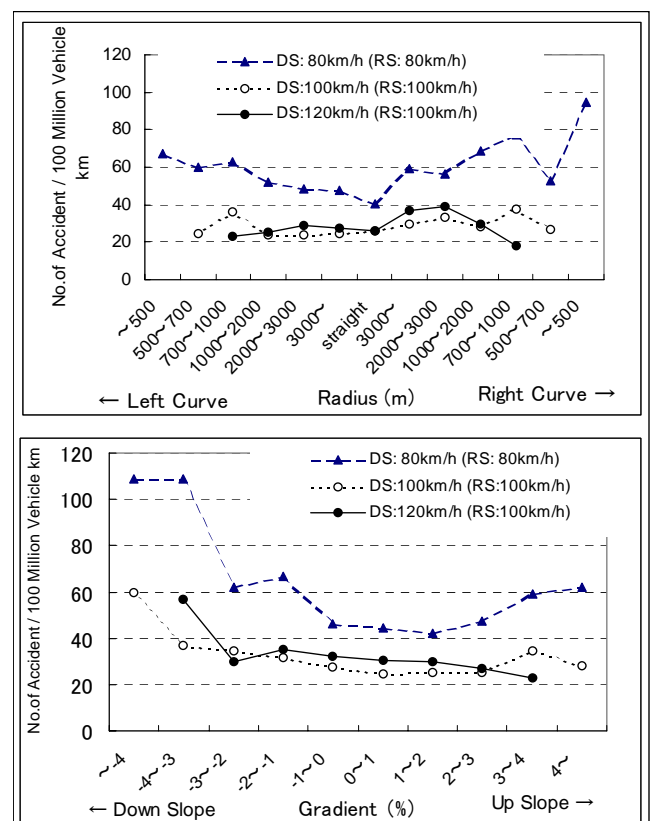


Figure 2: Accident ratio and road geometry

patterns confirm the results of other researches as mentioned above. The charts show that accident ratio for routes with design and regulated speed of 80 km/hr is higher than that for routes with higher design and regulated speeds. These patterns should not be interpreted as the lower speed causing more accidents; rather there might be other factors at works. In fact, lower design speed indicates lower design standard and the fact that in expressway routes with 80 km/hr design speed, actual speed significantly exceeds the design speed (as illustrated in Figure 1) indicates the possibility of higher accident rates in these routes. The curves for higher design speeds (100 km/hr and 120 km/hr) show that for normal road geometry, setting regulated speed below design speed contributes to the reduction of accident ratio.

Equation (1) shows a model for computing accident ratio, which is estimated using 10 years annual data (1995 to 2004) from Joban Expressway in Japan. The data is averaged for every 1 km section of the Expressway. Though the explanatory power of the model is not so high ($R^2 = 0.152$), it can be considered as an improvement over the formula given in the CBA manual, which simply uses average value of accident coefficient. Using this model, accident ratio for upgraded regulated speed can be calculated.

$$AR = -0.3095^{**} (DV - RV) + 9.732Q_3^{**} - 14.180Q_1^{**} + 36.764^{**} \quad (1)$$

(* significant at 5 % ; ** significant at 1 %; Adjusted $R^2 = 0.152$)

AR : Accident ratio (number of accidents per 100 million vehicle-km)

RV : Regulated speed (km/h)

DV : Design speed (km/h)

Q_1 : The dummy variable for traffic volume (under 10,000/one direction)

Q_3 : The dummy variable for traffic volume (over 30,000/one direction)

4.2 Relationship between speed and environmental impacts

The CBA manual for road sector in Japan recommends formula to estimate different components of environment impacts such as emission of pollutants and greenhouse gases and noise pollution. However, the manual includes for road speed of only up to 80 km/hr. As we intend to deal with road speed beyond 80 km/hr, additional formula (for 100 km/hr and 120 km/hr) are derived through linear extrapolation of parameters for the speed ranges includes in the manual as shown in Table 2.

Table 2: Expressions to compute environmental impacts

Speed (km/h)	Magnitude of various environmental impacts (γ)		
	Air pollution	Greenhouse gases	Noise
	NO_x (g/km/day)	CO_2 (g-c/km/day)	Noise level (dB(A))
60	$(0.23a_1 + 1.90a_2) Q$	$(40a_1 + 122a_2) Q$	$41 + A$
70	$(0.25a_1 + 2.10a_2) Q$	$(39a_1 + 123a_2) Q$	$42 + A$
80	$(0.27a_1 + 2.29a_2) Q$	$(40a_1 + 129a_2) Q$	$42 + A$
100	$(0.31a_1 + 2.67a_2) Q$	$(42a_1 + 141a_2) Q$	$43 + A$
120	$(0.35a_1 + 3.05a_2) Q$	$(44a_1 + 153a_2) Q$	$44 + A$

Source: Guidelines for Evaluation of Road Investment Projects (1998)

Where,

- $A: 10 \times \log(a_1 + 4.4a_2) + 10 \times \log(Q / 24)$
 a_1 : Ratio of small vehicles
 a_2 : Ratio of large vehicles
 Q : Traffic volume (vehicles/day)

From the above table, we find impact load for each type environmental effect for given speed, traffic volume and composition of small and large vehicle. However, we need to convert these impact loads into money term so that they could be included in CBA. The CBA manual gives unit cost for each of these impacts as shown in Table 3.

Table 3: Unit costs of different environmental effects

Type of impacts	Coefficients for converting environmental impact into money-term δ			
	Densely urbanized areas	Other urbanized areas	Rural areas (Flat land)	Rural areas (Mountainous)
Air pollutants (1000 yen/ton)	2920	580	200	10
Noise (1000 yen/dB(A)/year)	2400	475.2	165.6	7.2
Greenhouse gases (1000 yen/ton)	2.3			

Source: Guidelines for Evaluation of Road Investment Projects (1998)

5. CASE STUDY

5.1 Setting up cases

Utilizing the models and analytical frameworks discussed above, the method of CBA is applied to evaluate the impact of relaxing regulated speeds. Two cases are considered for the purpose:

Case-1: Regulated speed same as the maximum speed (100km/h) allowed by Japanese law

Case-2: Regulated speed same as the design speed

For both cases, an expressway route in Japan, named Joban Expressway is considered, primarily due to data availability and variation in design speeds and regulated speed for different section of the route. The basic characteristics of the chosen expressway route are presented in Table 4.

As we are dealing with the case of upgrading regulated speed, we need to estimate actual speed using the model presented in Table 1 (since there is no observed data).

In both cases, traffic demand generation and increase in modal share due to relaxation of speed limits are neglected. That is, while calculating the benefits on the routes under consideration, traffic volume is assumed to be same as before relaxing the speed limit. Though the change (increase) in traffic volume can be computed, neglecting this part seems to be reasonable as this contributes to an underestimation of benefits resulting from relaxation of

speed limit. Because the relative benefit from total travel time saving is likely to be higher than the costs of environmental impact and accident. Such conservative estimation places the estimation of benefits on a safer side.

Table 4: Characteristics of expressway route under analysis

Sections	Length (km)	Design speed (km/h)	Regulated speed (km/h)	Number of lanes per direction	Road classification			Traffic in most congested section ¹ (veh/day)
					Type	Class	Service level	
Ichikawa JCT~ Chibakita IC	4.0	80	80	3	1	3	B	104,000
Chibakita IC~ Narita IC	6.8	120	80	3	1	1	A	98,000
Narita IC~ Sawara IC	71.2	120	100	3	1	1	A	82,000
Sawara IC ~ Itako IC	23.3	120	100	2	1	1	A	41,000
Hitachiminamiota IC~ Hitachikita IC	19.0	80	80	2	1	3	A	29,000
Hitachikita IC~ Iwakinakoso IC	30.2	100	100	2	1	2	B	26,000

Note 1

1. The average traffic volume per year from 1995 to 2004

Average traffic composition in the chosen route includes 57.0 % of passenger cars, 1.3 % of buses, 26.5% of standard size trucks and 15.2 % of small trucks.

5.2 Computation of benefits or costs due to change in regulated speed

Change in regulated speed, which in turn changes actual driving speed, cause changes in the cost of travel-time, vehicle operation, accident and environmental impacts. Total of all these items represents total transport cost (user cost and external costs). In order to evaluate the net benefit or cost resulting from upgrading regulated speed, we need to compare the total transport cost before upgrading with the one after upgrading. Cost corresponding to each individual item is calculated for existing case (before upgrading regulated speed) and new case (after upgrading regulated speed). Existing case cost minus new case cost for each item represents net benefits (if positive) or net cost (if negative) caused by upgrading the regulated speed in regard with the given item. It is expected that relaxation of speed limit reduce travel time (benefits) while it might increase environmental and accident costs. The formulations for computing benefits or costs (for each section of the route) due to change in regulated speed for each items are presented in the following paragraphs where the subscript “o” represents “before upgrading case” and the subscript “w” represents “after upgrading case”.

(1) Computation of change in travel time cost:

This is the principal item. As the upgrading regulated speed increases actual driving speed, it brings benefits in terms of reducing costs due to travel time. Expression given in the manual is used to calculate the change in travel time cost for each section of the route:

$$\text{Change in travel-time cost (yen/year)} \Delta BT = BT_0 - BT_w \quad (2)$$

$$\text{Total travel-time cost (yen/year)} BT_i = \sum_j \sum_l (Q_{jl} \times T_{ijl} \times \alpha_j) \times 365 \quad (3)$$

BT_i : Total travel time cost for a given section for case i (yen/year)

Q_{jl} : Traffic volume of the vehicles type j on the link l vehicle/day

T_{ijl} : The travel time of the type of vehicles j on the link l case i (minute)

α_j : Money cost of time for vehicles type j (yen/ minute \cdot vehicle)

i : o (before upgrading), w (after upgrading)

j : Index for vehicle types

l : Index for links within a given section

The travel time for each link is obtained from the actual driving speed (to be computed from the model presented in Table 1) and link length. The money cost of time for each vehicle type (α_j) is given in the CBA manual as shown in Table 5.

Table 5: Money value of time for type of vehicles (α_j)

	Car	Bus	Small truck	Truck
Yen/minute-vehicle	62.86	519.74	56.81	87.44

Source: Cost Benefit Analysis manual (2003)

Now the change in travel time cost for each section of the route can be computed using equation (3) and (2).

(2) Computation of change in vehicle operation cost (VOC)

$$\text{Change in vehicle operation cost (yen/year), } \Delta BR = BR_o - BR_w \quad (4)$$

$$\text{Total vehicle operation cost (yen/year), } BR_i = \sum_j \sum_l (Q_{jl} \times L_l \times \beta_j) \times 365 \quad (5)$$

BR_i : Total vehicle operation costs for a given section for case i (yen/year)

β_j : The unit cost of vehicle operation for vehicle type j (yen/ vehicle \cdot km)

L_l : Length of link l (km)

i : o (before upgrading), w (after upgrading)

j : Index for vehicle types

l : Index for links within a given section

The coefficient for unit operating cost of different type of vehicle (up to speed of 90 km/hr) is given in the CBA manual as shown in Table 6. Coefficients for higher speed not included in the manual are linearly extrapolated.

Table 6: Unit operating cost for different vehicle types (β_j)

speed (km/h)	Car	Bus	Small truck	Truck
80	6.50	28.58	13.81	21.59
85	6.65	29.09	13.97	22.36
90	6.85	29.74	14.18	23.36
100	7.25	31.04	14.60	25.36
120	8.05	33.64	15.44	29.36

Source: Cost Benefit Analysis manual (2003)

Values of β_j corresponding to speed as obtained from model given in Table 1 (actual speed) are picked up and total change in vehicle operation cost is obtained using above equations.

(3) Computation of change in accident costs

In Japanese CBA manual for road sector, the cost of accident for expressways is given by a simple expression as,

$$\text{Accident cost (thousand yen /year), } AA = 270QL \quad (6)$$

Q: Traffic volume (thousand vehicles/day)

L: Length of road link (km)

The above expression simply uses average accident coefficient for vehicle-km per day and remains same for all sections of expressway irrespective of other relevant factors. However, in this research the accident impact of speed is important and need to be taken into account. For this purpose, we utilize the model of accident ratio presented in Chapter 4, and improve the above expression as follows,

$$\text{Accident cost for a given link } l, AA_{il} = 270Q_l L_l \left[1 + \frac{AR_i - AR_o}{AR_o} \right] \quad (7)$$

$i : o$ (before upgrading), w (after upgrading)

Equation (7), in effect, adjusts the accident cost prescribed by the manual in the proportion of change in accident ratio as a result of upgrading regulated speed.

AR (Accident ratio) is given by equation (1) as,

$$AR = -0.3095^{**} (DV - RV) + 9.732Q_3^{**} - 14.180Q_1^{**} + 36.764^{**} \quad (8)$$

$$\text{Total accident cost for a given section (thousand yen/year), } BA_i = \sum_l (AA_{il}) \quad (9)$$

$$\text{The change in accident cost (thousand yen/year), } \Delta BA = BA_o - BA_w \quad (10)$$

(4) Computation of change in environmental costs

$$\text{Change in total environmental cost (yen/year) } \Delta BE = BE_o - BE_w \quad (11)$$

$$\text{Total environmental cost for a given section, } BE_i = \sum_p \sum_l (\gamma_{pli} \times \delta_{pl} \times L_l) \times 365 \quad (12)$$

γ_{pli} : Impact load of environmental effect type p on link l for case I (Table 2)

δ_{pl} : Unit cost of environmental effect type p on link l (Table 3)

L_l : Length of link l (km)

Using the expression and coefficient given in Table 2 and Table 3 of Chapter 4, equation (12) and (11) gives change in total environmental cost due to upgrading of the regulated speed.

5.3 Computed benefits

The computed benefits or costs (change in each cost item) for each section of the expressway routes under Case-1 and Case-2 are shown in the Table 7.

Table 7: Change in various cost items due to upgrading of regulated speed

Expressway sections	Total transport cost ¹ mil/year	Change in benefits ² due to upgrading Regulated Speed (mil yen/year)				Net benefits(mil yen/year) ②+③+④+⑤	Net benefits (%) ⑥/①
		Travel time	Vehicle operation	Accident	Env. impacts		
	①	②	③	④	⑤	⑥	⑥/①
	Case-1: Regulated speed same as the maximum speed(100km/h) allowed by Japanese law						
Ichikawa JCT～Chibakita IC	10,037	291	-86	-15	-24	165	1.6
Chibakita IC～Narita IC	16,406	291	-33	-33	-9	216	1.3
Narita IC～Sawara IC	—	—	—	—	—	—	—
Sawara IC ～Itako IC	—	—	—	—	—	—	—
Hitachiminamiota IC～Hitachikita IC	11,719	293	-52	-24	-0.5	217	1.8
Hitachikita IC～Iwakinakoso IC	—	—	—	—	—	—	—
Total	38,162	874	-171	-72	-34	598	1.6
	Case-2: Regulated speed same as the design speed						
Ichikawa JCT～Chibakita IC	—	—	—	—	—	—	—
Chibakita IC～Narita IC	16,406	856	-140	-67	-39	609	3.7
Narita IC～Sawara IC	92,439	5,539	-1,086	-207	-73	4,174	4.5
Sawara IC ～Itako IC	20,074	1,452	-283	-49	-8	1,112	5.5
Hitachiminamiota IC～Hitachikita IC	—	—	—	—	—	—	—
Hitachikita IC～Iwakinakoso IC	—	—	—	—	—	—	—
Total	128,919	7,847	-1,509	-323	-120	5,895	4.6

Note 1 ~ 4

- Existing total transport cost includes costs for travel time, vehicle operation, environmental impact and accident
- Positive figures imply benefits while negative figures imply increase in costs due to upgrading Regulated Speed.

For Case-1 in which regulated speed is increased to the level of allowable speed by Japanese law (100 km/h), the relaxation in speed limit resulted in an additional net total benefit equivalent to 598 million yen per year, which is 1.6 % of total transport cost before upgrading regulated speed. Likewise, for Case-2, in which regulated speed is increased to the level of design speed, the net benefit as result of this change is equivalent to 5.9 billion yen per year which is 9.1 % of total transport cost. In both case, for some sections, there is no change in regulated speed (since the present speed is same as max allowable speed by the Law or regulated speed). The sections for which there is no change in regulated speed are not included in the calculation of percentage benefit.

From these results, we can see that upgrading of regulated speed may bring significant time saving benefits while the costs due to negative impacts on vehicle operation cost, traffic accident and environment are relatively small. That means, upgrading of regulated speed is recommendable through CBA. As shown in Table 7, the net benefit in Case-2 is higher than the net benefit in Case-1. That is, to maximize the benefit, the regulated speed need to be relaxed to make it same as the design speed. However, there is a legal barrier to increase regulated speed beyond the legal limit (100 km/h). For this reason, as the first step, the regulated speed can be relaxed up to the legal limit, and then initiative can be taken to change the legal limit too depending upon on the practical results.

6. CONCLUSION

In Japan, the Ministry of Land, Infrastructure and Transport (MLIT) decides the design speed of expressways and regulated speed is decided by police agencies. While deciding the design standards and corresponding design speed for each route of expressways network, framework of CBA is utilized for objective assessment of associated costs and benefits. However, regulated speed is set up without using any established analytical method, which indicates possibility of some degree of inefficiency. To examine the impacts of upgrading regulated speed objectively, we made an attempt to set up an evaluation framework and computed costs and benefits through case studies. The results of case studies showed that a remarkable increase in benefits could be achieved by upgrading regulated speeds. This also indicates that it is necessary to follow analytical procedure to decide on regulated speed. To make more effective use of existing road infrastructure, the procedure proposed in this paper can also be applied to general roads.

As mentioned before, in Japan, the evaluation procedure for infrastructure investment have been developed well in past ten years, while the evaluations of regulatory policies are yet implemented in spite of OECD recommendation. Though the scope of this paper is limited to regulatory speed of expressways, the result of analysis demonstrate that there is possibility and practical usefulness of applying CBA framework for evaluating regulatory policies.

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