A Life Cycle Assessment of the Existing Highway Bridge

Soichi SANO*, Hajime OHUCHI**, Hiroaki KITOH*** and Hisao TSUNOKAKE****

(Received September 30, 2009)

Synopsis

Life cycle assessment has been carried out for the existing highway bridge in urban area. Environmental impacts from material production, construction, operation, dismantlement, abandonment and recycling stages, are analyzed by cost evaluation technique. Focusing points are a comparison of the amounts of the influence between stages and a comparison of the influences between environmental aspect and also between environmental elements especially from construction related aspect.

KYE WORDS: Life Cycle Assessment, LIME, Inventory Analysis, Primary Unit, Integration Coefficient

1. Introduction

From the view point of global environmental concern, it is necessary to consider infrastructure imposed environmental impacts during its life cycle through plan, design, construction, operation, maintenance abandonment and recycling stages. When focusing on roadway bridge, there have been some studies focusing on material production impact for types of super structure and also impacts during maintenance and operation stages. However, only a few studies have been conducted on environmental impacts through life cycle of the typical infrastructure such as road way bridges, significant facility in urban area of Japan. In these backgrounds, the present study investigates economical value based life cycle assessment of highway bridges in the urban area from material production up to recycling stages.

2. Evaluation Method

LIME(Lifecycle Impact Assessment Method based on Endpoint Modeling), the life cycle environmental assessment method developed as a national project of Japan, is employed to quantitatively evaluate the environmental impact.

Life cycle assessment is carried out as the integration of environmental impact provided by each inventory material. Inventory analysis can be carried out by eq. (1) as the economic value.

* Student, Master Course of Department of Civil Engineering

** Professor, Department of Civil Engineering

*** Associate Professor, Department of Civil Engineering

**** Research Associate, Department of Civil Engineering

$$BE = \sum AiBi \qquad (1)$$

Where, Ai : Inventory (Amount of environmental influence material unit : kg)

Bi : Integration coefficient (unit : ¥/kg)

The representing values of the inventory (turning on and emission matter) to these influence regions and the integration coefficients are shown in Table 1 here.

It is necessary to calculate the amount of influence during the life cycle for integration. It becomes possible by employing the primary unit value for each item that influences the inventory data at each stage. Table 2 shows the primary unit value of environmental impact material such as carbon dioxide included in the typical fuel.

Table 1 Integration coefficients

inventory		influence region	integration coefficient
Nonmetal resource		resource consumption	1.02E-01
iron			1.12E+00
coal			2.10E+00
oil			3.55E+00
debris		waste	7.10E-01
scrap metal			6.39E-01
cover soil			7.10E-01
CO_2		global warming	1.62E+00
SOx		air pollution	1.01E+03
NOx	point source		1.41E+02
	radiation source		1.97E+02
SPM	point source		2.45E+03
	radiation source		1.11E+04

Table 3 represents primary unit for a typical constituent material. It is used for the environmental impact assessment by the constituent material during construction and maintenance stages. The primary unit for concrete casting is shown in Table 4 as an example. Similarly, the primary unit for dismantlement, abandonment and recycling is respectively shown in Table 5 and Table 6.

Table 2 Primary unit for a typical fuel

sort	unit(*)	oil conversion	CO_2(kg/*)		SOX(kg/*)		NOX(kg/*)			SPM(kg/*)	
		kg/*	digging	transfer constructing machine	digging	transfer constructing machine	digging	transfer	constructing machine	transfer	constructing machine
coal	kg	0.02	0.06	2.36	0.76		1.17				
gasoline	ℓ	0.17	0.36	2.31	1.72	0.59	1.29	17.15		0.64	
diesel	ℓ	0.08	0.18	2.64	1.55	2.04	1.15	19.77	39.61	1.66	2.01

Table 3 Primary unit for a typical constituent material

large classification	small classification	unit(*)	oil conversion	CO_2	SO_X	NO_X	SPM
			kg/*	kg/*	kg/*	kg/*	kg/*
cement	portland cement	t	1.62E+01	7.67E+02	1.22E-01	1.55E+00	3.58E-02
	eco cement		1.09E+02	7.84E+02	1.52E-01	3.19E-01	6.52E-03
aggregate	natural fine aggregate		3.70E-01	2.90E+00	6.07E-03	4.15E-03	1.41E-03
	natural coarse aggregate		3.70E-01	3.70E+00	8.60E-03	5.86E-03	1.99E-03
	low-grade recycled aggregate		2.10E-01	3.10E+00	1.27E-03	1.08E-02	6.55E-04
	high-grade recycled aggregate		4.90E-01	1.77E+01	6.28E-03	2.89E-02	2.18E-03
reinforcing steel	Electric steel		3.60E+00	7.67E+02	1.34E-01	1.24E-01	1.91E-02
	Blast furnaces haped steel		7.29E+00	1.26E+03	1.18E+00	1.80E+00	7.18E-03
	Blast furnace bar steel			1.21E+03	1.18E+00	1.80E+00	7.59E-03

Table 4 Primary unit for concrete casting

large classification	small classification	unit(*)	oil conversion	CO2	SOX	NOX	SPM
			kg/*	kg/*	kg/*	kg/*	kg/*
fresh concrete	cement mixer	m^3	-	6.20E-01	1.99E-04	2.44E-04	4.58E-05
concrete work	mobile concrete pump	m^3	1.10E-01	3.30E-01	2.54E-04	4.94E-03	2.50E-04
	agitator track	h	1.10E+01	3.38E+01	2.60E-02	2.53E-01	2.12E-02
Construction machine	backhoe ($0.6m^3$)		1.68E+01	5.17E+01	3.98E-02	7.74E-01	3.93E-02
	crawler crane		6.92E+00	2.13E+01	1.64E-02	3.20E-01	1.62E-02
	crawler crane(16t)		5.36E+00	1.65E+01	1.27E-02	1.24E-01	1.04E-02
	crawler crane(over 22t)		5.53E+00	1.71E+01	1.31E-02	1.27E-01	1.07E-02
	bulldozer		1.10E+01	3.22E+01	2.49E-02	4.83E-01	2.45E-02
	benoto machine		5.50E+00	1.61E+01	1.24E-02	2.42E-01	1.23E-02
	welding machine		1.50E+01	4.41E+01	3.41E-02	6.61E-01	3.36E-02
	vibratory hammer		2.59E+00	1.13E+01	3.97E-03	4.88E-03	9.15E-04
	tire roller		5.76E+00	1.78E+01	1.37E-02	2.66E-01	1.56E-02
	grouting pump		1.22E+01	3.56E+01	2.75E-02	5.35E-01	2.71E-02
	asphalt finisher		9.64E+00	2.82E+01	2.18E-02	4.24E-01	2.15E-02
	tampa		7.20E-01	2.10E+00	4.51E-07	1.32E-05	4.89E-07

Table 5 Primary unit for dismantlement

large classification	small classification	unit(*)	oil conversion	CO2	SOX	NOX	SPM
			kg/*	kg/*	kg/*	kg/*	kg/*
PC・RC	Dismantlement from rooftop	m^3	3.34E+00	1.03E+01	7.94E-03	1.54E-01	7.83E-03
	Dismantlement of underground portion		6.17E+00	1.90E+01	1.47E-02	2.85E-01	1.45E-02
pavement	concrete pavement		2.91E+00	9.00E+00	6.92E-03	1.35E-01	6.83E-03
Reinforced steel cutting	welding machine		2.50E-01	7.00E-01	0.00E+00	0.00E+00	0.00E+00
Concrete accumulation	backhoe	m^3	2.57E+00	7.90E+00	6.11E-03	1.19E-01	6.02E-03
Heavy weight breaker	Oil pressure type (1300kg)	h	1.68E+01	5.17E+01	3.98E-02	7.74E-01	3.93E-02

Table 6 Primary unit for abandonment and recycling

large classification	small classification	unit(*)	oil conversion	CO2	SOX	NOX	SPM
			kg/*	kg/*	kg/*	kg/*	kg/*
Repository site	High processing	t	1.70E-01	6.19	2.20E-03	1.01E-02	7.63E-04
	Stability type		5.30E-01	1.64	1.26E-03	2.46E-02	1.24E-03
Recycling	aggregate		1.20E-01	1.45E+01	-8.70E-04	2.40E-02	5.22E-04
	reinforcing steel		-3.69E+00	-445.6	-1.05E+00	-1.68E+00	1.12E-03

3. Life Cycle Assessment of the Existing Highway Bridge

3.1 Objective Structure

The objective structure is shown below. Figure 1 shows the superstructure elevation view. Figure 2 shows the substructure with foundation. The superstructure cross section is shown in Figure 3 respectively.

(1)Superstructure: Prestress Concrete Girder (I shape section))

(2)Substructure: Reinforced Concrete Pier(φ2.4m×H11.7m)

(3)Underground : pile foundation (φ1.0m×L22.5m cast-in-place pile－9)

(4)Roadway width: Four lanes in one side 7.0m (two lanes)

(5)Superstructure Span : 24.0m

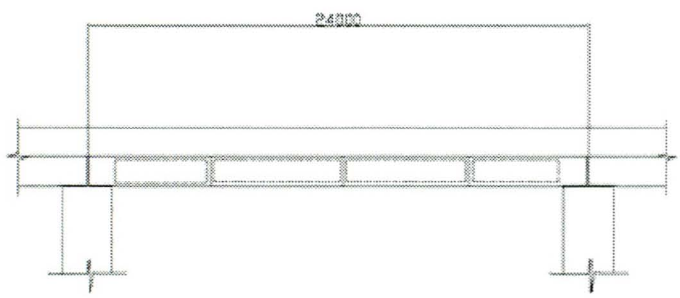

Figure 1 Elevation of superstructure

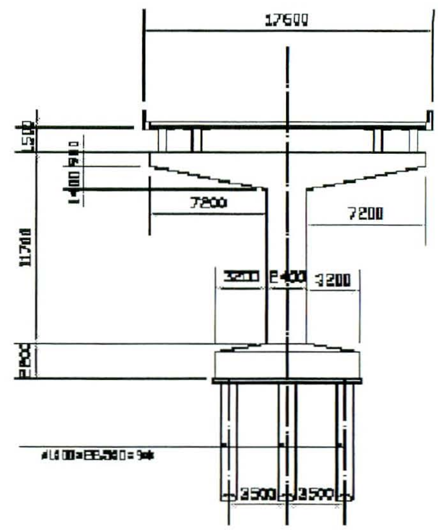

Figure 2 Substructure with Foundation

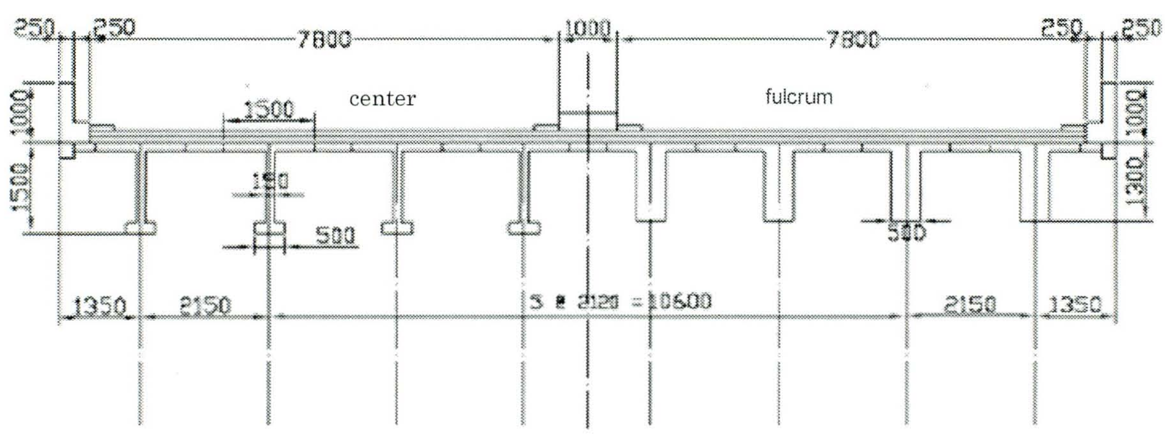

Figure 3 Cross Section of Superstructure

3.2 Life Cycle Assessment

3.2.1 Evaluation Object

(1)Environmental aspect and influence material

Figure 4 shows the environmental aspect and the environmental influence material considered by this case. Four sides of resource and energy (oil and coal), waste (reinforced concrete and surplus soil), and global warming (CO_2) and air pollutions (SO_X,NO_X,SPM) are considered about the environmental aspect.

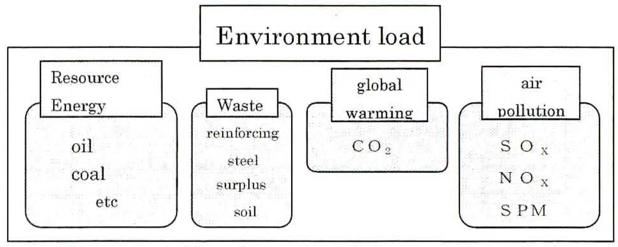

Figure 4 Environmental aspect and the environmental influence material

(2) Life cycle and stages

The negative environmental impact that reaches the materials, construction, dismantlement, and abandonment and recycling the life cycle generally as shown in Figure 5 is studied. Cement, aggregate, and formwork that is a constituent material of concrete, a steel material become objects at the materials production stage. At the construction stage, the transportation related to operation and operation of the construction machine that is related to the concrete production, placing, and the underground, the substructure, and the superstructure becomes a major target. The future clause 3.2.2～3.2.6, analysis of one base, Substructure, and 1 superstructure span are done as one unit, and the concreteness of the evaluation method is shown. At the use stage after construction, the environmental impact by the car traffic use is considered. The heavy equipment operation and the transportation related to dismantlement and crushing the building frame are considered in dismantlement and the recycling of the aggregate and the reinforced concrete and the steel material is considered in abandonment and recycling.

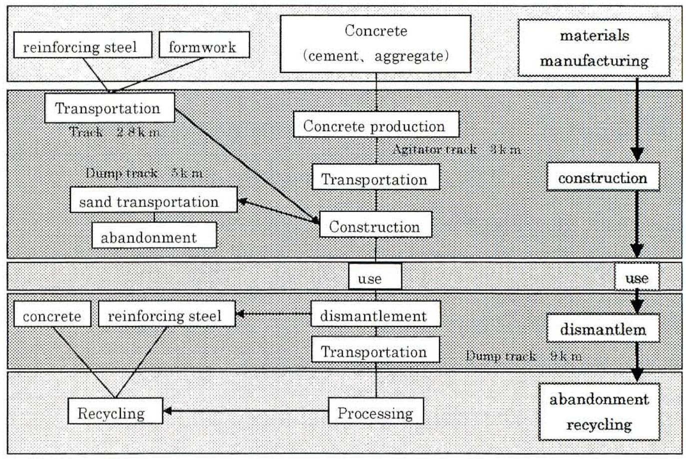

Figure 5 Considered stage during Life Cycle

3.2.2 Materials Production stage

Table 7 Amount of materials(1 span)

	Reinforcing steel (t)	Prestressed concrete steel (t)	Concrete (m^3)	Frame (m^2)
superstructure worker	27.3	16.1	217.8	154.0
Substructure work	31.0		273.9	243.2
Base	17.8		162.5	

Table 7 shows the amount of materials used by the top and bottom part worker and the base. As for the environmental impact generated at the materials production stage, economic value can be evaluated by multiplying the integration coefficient described and the primary unit and the amount of each material. Concrete is mixing shown in Table 8, and it evaluates it separately for cement, the fine aggregate (nature), and the coarse aggregate (nature).The evaluation is calculated by expression 2. The primary unit for the concreting material, the reinforced concrete, and the steel material uses Table 4.The value indicated in Table 9 is used about the primary unit for the formwork[1).

$$Q_i = \sum[\text{Amount of each material} \times \text{primary unit of each material (kg/t)}] \quad (2)$$

Table 8 Concrete mixing

	Design strength	W/C	air	water	cement	fine aggregate	coarse aggregate	additive
	N/mm^2	(%)	(%)	(kg/m^3)				
superstructure worker	24	61	5	161	264	812	1034	0.68
Substructure work	35	47	5	165	351	714	1028	0.88

Table 9 Primary unit for the formwork

	unit(*)	CO2 (kg/*)	SOX (kg/*)	NOX (kg/*)	SPM (kg/*)
Frame	t	755.3	1.34E-01	1.24E-01	1.01E-02

3.2.3 Construction stage

Figure 6 shows the process of construction. It consists of a base, a Substructure, and an superstructure greatly. Figure 7 shows the list of the construction machine along with the operation number used. Table 10 shows the operation day, the number of each process separately for the transport machinery and the construction machine. A utilization rate was considered about the construction machine that had to evaluate it every time. Moreover, a concreting practice was not evaluated by operation time of the machine (agitator track, mobile concrete pump, and cement mixer), and was evaluated by a concrete volume. Then, it is possible to calculate as follows by taking the impact amount sum total of each machine of environmental impact material i that pays attention.

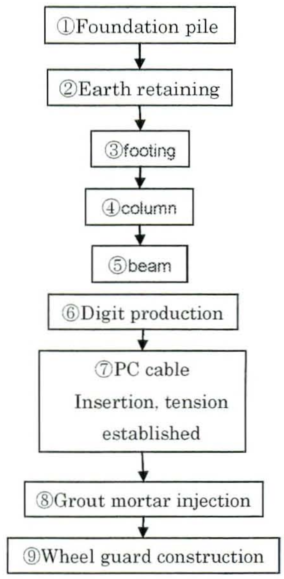

Figure 6 Process of construction

Mobile concrete pump	②~⑥⑨
Agitator track	
Soil compaction vibrator	②~⑥⑨
Cement mixer	②~⑥⑨
Raw concrete plant	
Backhoe	①②④
Crawler crane	①②
Truck-mounted crane	①③~⑦⑨
Bulldozer	①④
Benoto machine	①
Welding machine	①②④
Vibratory hammer	②
Tire roller	①④
Grouting pump	
Asphalt finisher	⑨
Tampa	①②④

Figure 7 Construction machine

(1)Environmental impact dose when transported

For the dump track, the trailer, and the track

$$Q_i = \sum[\text{haul distance} \times (\text{Weight of transportation material} + \text{deadweight})] \times \text{Emission factor according to environmental impact material i (g/t} \cdot \text{km)}^{1)2)} \quad (3)$$

For the agitator track

$$Q_i = \sum[\text{haul distance} \times (\text{Capacity of transportation material})] \times \text{Emission factor according to environmental impact material i (g/m}^3 \cdot \text{km)}^{1)} \quad (4)$$

The haul distance of the dump track for the earth and sand transportation assumes the distance 5km from the construction site to disposal site. The haul distance of trailer and track chiefly for construction machine transportation assumed the distance 15km from the construction site to the construction machine leasing company. The distance 3km to the raw concrete factory was assumed about the agitator track. The transportation of the reinforcing steel assumed the distance 2.8km to the reinforcing steel processing company.

(2) Impact during construction

For the agitator track, the mobile concrete pump, and the cement mixer

$Q_i = \sum$[Amount of construction of machine (m^3/day)×primary unit for environmental impact material i (g/m^3)] [1)2)] (5)

For the construction machines other than the above-mentioned

$Q_i = \sum$[Operating time a day (hr/day)×Operation day×the number of machine×Utilization rates (ℓ/hr)×primary unit for environmental impact material i (g/m^3) (g/ℓ) [2)] (6)

Table 10 Operation day, the number of each process formwork

Base and substructure work

unit: Operation day × the number of machine

	Machine	Foundation pile	Earth retaining	Earthwork	Paving average	Footing	Back-filling	Column	Earth retaining removal	Beam	Sum	Utilization rates (h/day)
Transport machinery	Agitator track										※1 436	
	Dump truck	27		9			6				42	
	Trailer	4	4						4		12	
	Truck(2～4t)	4				6		6		22	38	
	Truck(10t)	13	7	2			2		9		33	
Construction machine	Mobile concrete pump				1	1		2		1	5	
	Agitator track										5	
	Soil compaction vibrator					1		2		1	4	
	Cement mixer										※1 436	
	Backhoe	29		13	2		6	1			51	5.6
	Crawler crane	31	9	4			4		9		57	6
	Truck-mounted crane(15t)	3				6		6		18	33	6
	Bulldozer	29					6	1			36	6.3
	Benoto machine	27									27	6.3
	Welding machine	3	9	4			4		9		29	7
	Vibratory hammer		9						9		18	7.5
	Tire roller	1						1			2	5.7
	Tampa	1			2		6				9	7

Superstructure worker

unit: Operation day × the number of machine

	Machine	Digit production	bridge seat installation PC Digit construction	Work stand installation	Horizontal digit ･stuff part construction	PC cable	Concrete average	Road asphalt	Work stand dismantlement	Sum	Utilization rates (h/day)
Transport machinery	Agitator track										
	track	56		5	5	5			3	74	
Construction machine	Mobile concrete pump	8			1		1			10	
	Agitator track									8	
	Soil compaction vibrator	8			1		1			10	
	Cement mixer									※1 218	
	Truck-mounted crane(100t)	8	8							16	6
	Truck-mounted crane(15t)	70		5	5	5			3	88	6
	Tire roller							1		1	5.7
	Grouting pump	16				5				21	
	Asphalt finisher							1		1	6.1

※1 Amount of construction a span(m^3)

3.2.4 Use stage

Table 11 shows the traffic data on the weekday and holiday according to the model obtained by the road traffic census (2005) [3)].

(1) Energy consumption

Energy consumed each day E is given by the following expressions 7[4)].

Table 11 Traffic data

	weekday		holiday	
auto	34,654	53,407	34,824	40,822
bus	213		190	
Small freight	12,805		4,427	
normal freight	5,735		1,381	
large car	5,948		1,571	
Travel speed (crowded).	56.1km/h		58.1km/h	

$$E = E_G + E_D \tag{7}$$

where

$E_G = \sum[P_{Gi} \times R_G \times S_i \times K_G] = \sum[P_{Gi} \times R_G \times S_i \times (1 - K_D)]$ (fuel consumption of gasoline car, kcal/day)

$E_D = \sum[P_{Di} \times R_D \times S_i \times K_D]$ (fuel consumption of diesel car,kcal/day)

G is index shows gasoline and D is index shows the diesel and $\sum$ show the sum total to all models.

P_{Gi}, P_{Di} : It is a fuel input rating per km of the gasoline car and each diesel-powered vehicle to model i. It is given as a reciprocal of the fuel efficiency of Table 12 (ℓ/km) .

R_G : Calorie per amount of gasoline 1ℓ (8.27×10^3kcal/ℓ)

R_D : Calorie per amount of diesel 1ℓ (9.13×10^3kcal/ℓ)

S_i : Traffic of model i (number/day)

K_D : Rate of making to diesel shown in Table 15 remarks

(2) Amount of CO2 emission

Amount QCO2 of the CO2 exhaust is calculated by the following expressions by the use of the emission factor shown in Table 13[4].

$$Q_{CO2}=E_G\times U^G{}_{CO2}+E_D\times U^D{}_{CO2} \tag{8}$$

where $U^G{}_{CO2}$: Emission factor of gasoline

$U^D{}_{CO2}$: Emission factor of diesel

Table 12 Utilization rates

car type	fuel consumption(km/ℓ)	
	Diesel	Gasoline
auto	9.1	8.3
bus	4.6	3.5
Small freight	11.7	9.0
normal freight	6.8	5.2
large car	6.8	5.2

Table 13 Emission factor (U_{CO2},U_{SOX})

fuel type	CO_2 ($t/10^7kcal$)	SO_X ($kg/10^7kcal$)
Diesel	0.790	0.710
Gasoline	0.761	2.230

(3) Amount of SO_X emission

Amount Q_{SOX} of the SO_X exhaust is calculated by the following expressions by the use of the emission factor shown in Table 13[4].

$$Q_{SOX}=E_G\times U^G{}_{SOX}+E_D\times U^D{}_{SOX}{}^{3)} \tag{9}$$

Where $U^G{}_{SOX}$:Emission factor of gasoline

$U^D{}_{SOX}$: Emission factor of diesel

(4) Amount of NO_X emission

Amount Q_{NOX} of the NO_X exhaust is calculated by the following expressions by the use of the emission factor shown in Table 14[4].In general, the emission factor used the one when it was crowded though were given according to the speed.

$$Q_{NOX}=\sum S_i\times K_G\times U^G{}_{NOX}+\sum S_i\times K_D\times U^D{}_{NOX}$$
$$=\sum S_i\times(1-K_D)\times U^G{}_{NOX}+\sum S_i\times K_D\times U^D{}_{NOX}{}^{3)} \tag{10}$$

Where $U^G{}_{NOX}$: Emission factor of gasoline

$U^D{}_{NOX}$: Emission factor of diesel

Clause 1 shows the sum total to the gasoline car. Clause 2 shows the sum total to the diesel-powered vehicle.

Table 14 Emission factor (U_{NOX},U_{SPM})

car type	NOX(g/km)		SPM(g/km)			remark
	Diesel※	Gasoline※	Diesel※	Gasoline	tire wear-out	(Rate of diesel)
auto	0.25	0.14	0.016	0.010	0.02	0.037
bus	4.55	4.49	0.494	0.085	0.1	0.950
Small freight	1.39	1.09	0.017	0.063	0.02	0.610
normal freight	3.01	2.72	0.443	0.077	0.2	
large car	3.01	2.72	0.443	0.077	0.2	0.717

※Speed region(40～60km/h)

(5) Amount of SPM emission

The amount of the SPM exhaust considers the exhaust from the car and the exhaust by the tire wear-out.It calculates by the following expressions by the use of the emission factor shown in Table 14[4].

$$Q_{SPM}=Q^1{}_{SPM}+Q^2{}_{SPM} \tag{11}$$

the exhaust from the car : $Q^1{}_{SPM}=\sum S_i\times(1-K_D)\times U^G{}_{SPM}+\sum S_i\times K_D\times U^D{}_{SPM}$

exhaust by the tire wear-out : $Q^2{}_{SPM}=\sum S_i\times U^T{}_{SPM}$

$U^G{}_{SPM}$ and $U^D{}_{SPM}$ are the emission factors to the gasoline car and each diesel-powered vehicle and $U^T{}_{SPM}$ are the emission factors by the tire wear-out.

3.2.5 dismantlement

The primary unit for the environmental impact by the dismantlement act of each dismantlement part uses Table 6.The welding machine, the backhoe, and the heavy weight breaker are used for the dismantlement machine. The dump track was assumed the transportation of the dismantlement thing, and it calculated by the method similar to clause 3.2.3 from the skeleton volume. The main dismantlement thing is a concrete mass, a reinforced concrete, and a steel material. These do the recycling use as shown by the following clause.9km is assumed as a haul distance to the recycling factory.

3.2.6 abandonment and recycling

The effect of recycling of the environmental impact decrease is considered After it dismantles it, the aggregate is recycled as a high-grade recycled aggregate. The reinforcing steel and the iron frame are recycled as electric steel. The amount of the environmental impact of each material is calculated as a negative value. The sum with the environmental impact by the abandonment act is assumed to be a environmental impact of abandonment and recycling. The primary unit for the environmental impact related to abandonment and the recycling disposal uses Table 7 for here. The primary unit for the recycling material and the field material uses Table 4.

Amount of aggregate environmental impact=Recycling weight×
(primary unit of high-grade recycled aggregate－primary unit of nature aggregate (12)
Reinforcing steel and amount of iron frame environmental impact=
Recycling weight×(primary unit of Electric steel－primary unit of Blast furnace steel (13)

3.3 Evaluation result

The result of evaluating economic value by integration is shown as follows. It shows as a value converted into expressway unit route length (km) hit that explains the preceding clause based on the result of assuming one base, Substructure, and 1 superstructure span to be one unit.

(1) Secular change of environmental impact

The amount of the environmental impact (environmental influence cost) linear changes between to calculate every year at the age, and shows the result in Figure 8.

Unit:100 million yen/km

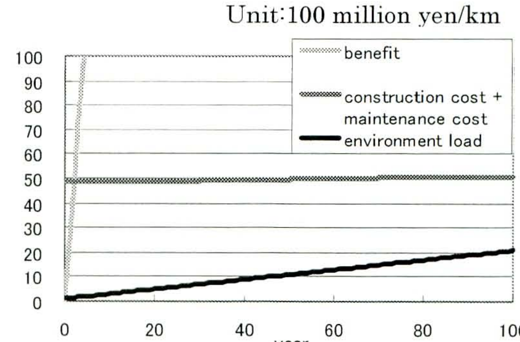

Figure 8 Environmental influence cost changes

The land purchase cost, the road pavement is repaired at ten cycles of year, is included in the initial cost of construction. The administrative and maintenance expense set the road pavement repair expense at ten cycles of year referring to document (5). Moreover, it shows in figure referring to benefit(sum of benefit of shortening the running time and the running expenditure decrease benefit) change in the cost benefit analysis. In this case, benefit of shortening the running time that became a point was calculated according to the difference when the travel speed (It was crowded) in the travel speed shown in Table 12 referring to the road traffic census[3] and the adjoining public highway was made holiday 21.2(km/h) on weekday 17.5(km/h).The number of use was assumed to be constant. The amount of the environmental impact (environmental influence cost) reaches about 1/5 for actual expenses (cost of construction + administrative and maintenance expense) for 50 years at the use stage and about 1/3 for actual expenses for 100 years at the use stage. The benefit shown in the reference here exceeds amount in which the environmental influence cost for actual expenses was unified in about two years after it begins to use it because the benefit of shortening traffic and the running time is large.

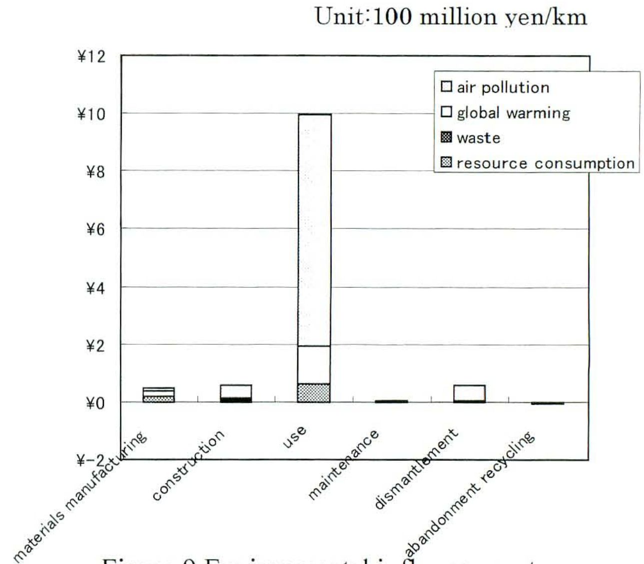

Figure 9 Environmental influence cost (50 years use)

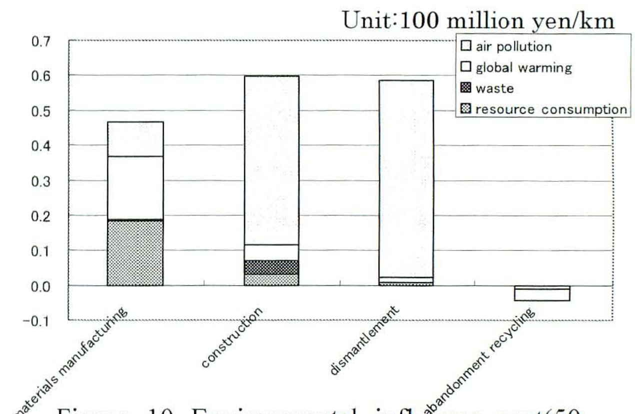

Figure 10 Environmental influence cost(50 years use)

(2) environmental impact according to stage

Figure 9 as one example, the result of comparing the environmental influence cost until 50 years after it begins to use it according to the stage is shown. It is understood that the use stage accounts from figure for 80% or more of the whole. Moreover, it is understood that the air pollution effect is large when seeing from the viewpoint of the environmental aspect. Because the influence of the emission matter such as NOX and SOX according to the fuel firing of the car is large, the importance of measures against these can be recognized again.

Figure 10 shows the one except the use stage of Figures 9.Environmental of recycling and abandonment is displayed on a negative side because it catches as a negative environmental impact. Therefore, the value that the value of a negative side was subtracted from the value of a positive side becomes the amount of a whole impact. The materials production, construction, and the dismantlement stage are large. The air pollution effect is large as the

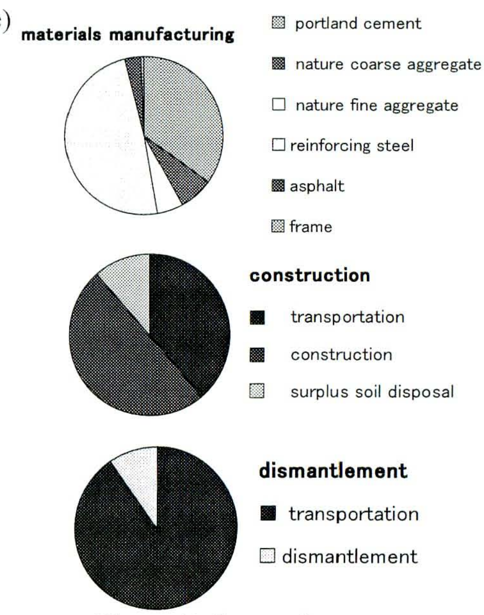

Figure 11 Comparison in materials each stage

environmental aspect.

It entrusts measures against the car exhaust material to the industrial world. It pays attention to the materials production, construction, dismantlement, and abandonment and recycling that the construction industry is deeply related in following (3)~(5) and it be analyzed.

(3) Environmental influence item at each stage

The comparison in materials production, construction, and dismantlement stage is comparatively shown in Figure 11 about the influence item. It classifies it into cement, the aggregate, the reinforced concrete, the iron frame, and the formwork that is the composition materials at the materials in manufacturing stage. The construction stage is classified into three items like construction in the site and transportation and the surplus soil disposal, though is used various construction machines. Moreover, the dismantlement stage is similarly classified into the dismantlement construction in the site and the transportation of the dismantlement thing.

At the materials production stage, the environmental impact of the proportion of cement and the reinforced concrete and the iron frame with complex the manufacturing process is larger than that of a natural aggregate and the formwork that it is easy to produce. At the construction stage, the environmental impact of construction on the site exceeds the environmental impact by the transportation of the machine parts and constituent material a little. The environmental impact by transportation of the machine parts and constituent material and the demolition waste greatly exceeds the on environmental impact by dismantlement in dismantlement stage.

(4) Environmental impact impact according to inventory

Next, the result of analyzing the environmental influence material according to the inventory is shown in Figure 13.The environmental influence with a large influence is SOX, is SPM, CO2, and, NOXSOX reaches about 40% of the whole, and SPM is 22%, CO2 is 14% and NOX is 5%. Moreover, the environmental impact of SOX in the dismantlement and construction stage are large. This depends on being large the ratio that transportation occupies as shown in Figure 12.

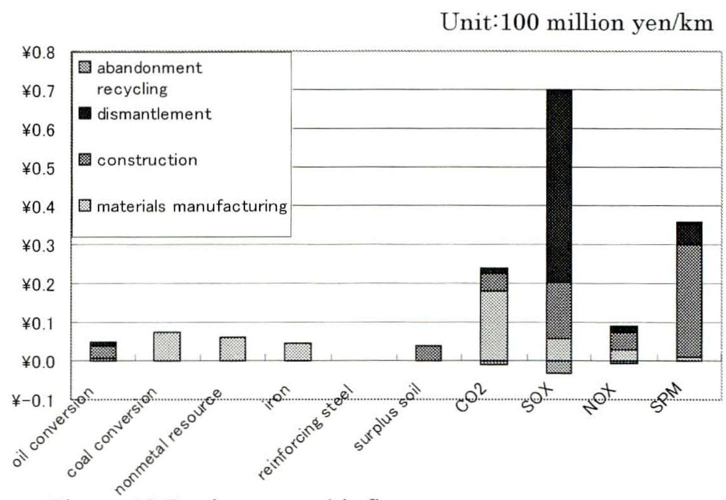

Figure 12 Environmental influence material according to the inventory (50 years use)

4. Concluding Remarks

Based on the present study, followings are concluded.

(1) Significant impact during operation

70% or more of the entire environment impact is due to operation stage for 50 years service period, ecological fuel and effective performance are needed for vehicles.

(2) Comparison between stages

60% or more of construction industry based environmental impact is due to production.

(3) Comparison between environmental aspect

The impact of air pollution provides six times that of global warming, the main cause is due to impact carriage for construction material and carriage.

(4) Comparison between inventories

The influence of particle material and waste soil accounts for 90% or more. The operation of the heavy machine and load vehicle are major causes.

【Reference】

1) Japan Society of Civil Engineers: Environmental performance check indicator of concrete structure (tentative plan) and 125 in concrete library,(2005) (in Japanese)

2) Japanese construction machinery making society: Hire calculation table of construction machineries ,(2000) (in Japanese)

3) The Ministry of Land, Infrastructure ,Transport Kinki Regional Development Bureau
HP : http://www.kkr.mlit.go.jp/osaka/mobile_info/siryo_mb/cen_h17/a/_27000501a.htm(in Japanese)

4) National Institute for Environmental Studies: Embodied Energy Emission Intensity Data for Japan Using Input-Output Tables (3EID),(2002) (in Japanese)

5) K.Amano, K.Makita : Construction of paving, lode environment impact according to maintenance mending, and evaluation at life cycle of cost, Journals of Japan Society of Civil EngineersVol.657、No.7-16、pp.57－64,(2000)(in Japanese)