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A Study on Analyzing the Factors Affecting Environmental Loads in the Planning Stage of Korean National Highway Projects

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Abstract: ***Carbon emission calculation guidelines provided by the Korean Ministry of Land, Infrastructure and Transportation (MOLIT) and existing environmental load assessment studies have suggested a method for estimating based on the volume determined after the design development. Therefore they are not being helpful in the decision making of the environmental economics of road facilities in the planning stage in which specific information on construction output volume is lacking. Based on literature analysis of existing studies and consultation from a group of construction environmental professionals, 12 types of property information considered to be related to environmental load were selected from an inventory of information that will be available in the road planning stage. In addition, multiple regression analysis was performed based on the environmental load computed through the life cycle assessment (LCA) of 40 national highway project cases of Korea to deduce five impact factors of environmental load in the road facilities planning stage.***

Keywords: national highway, environmental load, planning stage, impact factors

I. INTRODUCTION

Construction industry is a field with a high level of resource and energy consumption and its greenhouse gas emission amount is nearly about 40% of the emission amount of all domestic industries [6]. Particularly, roads being constructed as infrastructure generate a high level of environment load by using large amounts of construction materials and equipment [4].

It is necessary to use eco-friendly construction method, material and equipment to reduce such environmental load occurring from construction project. It is also necessary to review environmental economics in the planning stage of project. Although it is necessary to identify the volume of resources used, namely construction output volume to assess environmental load in the planning stage of road facilities, there are not enough property information through which construction output volume that affects environmental load in this stage can be directly identified [5]

In this study, environmental load impact factors will be deduced to present a foundation for assessing environmental economics in the planning stage of road facilities based on the correlation analysis between the environmental load computed through the life cycle assessment(LCA) of national highway project cases and the available information in the planning stage.

II. METHODOLOGY AND SCOPE

The scope of this study will be limited only to earthwork zone by excluding bridge and tunnel with different characteristics of work and resources used. In addition, the planning stage of road assumed in this study refers to the stage in which road height can be estimated through digital map after overall route has been determined.

To deduce the environmental load impact factors in the planning stage of road facilities, construction statements and bill of quantity of 40 national highway construction project cases in Korea will be analyzed to identify resource volume (material, equipment) used through which environmental load will be computed based on life cycle assessment(LCA).

Road property information available in the planning stage will be collected through literature review of existing studies on the planning stage of road facilities, and correlation analysis will be conducted regarding environmental load after finalizing the list of available information in the road planning stage through qualitative assessment by a group of construction environmental professionals. Lastly, environmental load impact factors in the road planning stage will be deduced by conducting multiple regression analysis with environmental load as dependent variable and the inventory of available information in the planning stage as independent variable based on the correlation analysis.

III. AVAILABLE INFORMATION

According to Korean Ministry of Land, Transport and

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Maritime Affairs (MLTMA), the inventory of available information in the planning stage of road facilities includes project owner, project type, number of lanes, road width, lane width, length of road, road division, design speed, administrative district, regional characteristics, geographical feature, etc [3]. It was revised through addition or exclusion according to this study.

Since the scope of this study is limited to earthwork zone by excluding bridge and tunnel of road facilities, length of road in which bridge or tunnel is included in the research findings of the MLTMA was excluded from the inventory of available information in the planning stage. It was substituted with length of earthwork that excludes the length of bridge and tunnel from length of road. In addition, area of earthwork computed to simultaneously consider the length and width of earthwork by the product of these values was newly added to the inventory of available information.

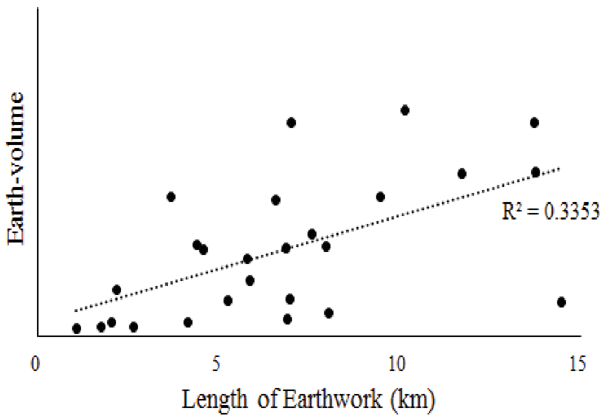

Fig.1 CORRELATION BETWEEN LENGTH OF EARTHWORK AND EARTH-VOLUME

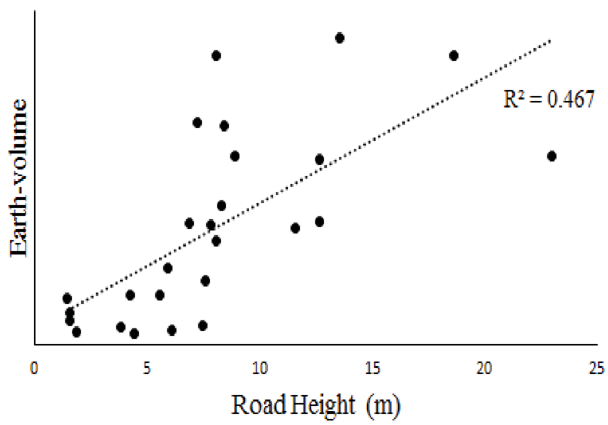

Fig.2 CORRELATION BETWEEN ROAD HEIGHT AND EARTH-VOLUME

It was found that road earthwork such as banking consumes over 90% of the total energy consumption during construction [2], fluctuation in the earthwork volume is expected to significantly affect environmental load. The result of correlation analysis between earth-volume and available information in the road planning stage estimated to be related to earth-volume revealed that, as shown in Fig. 1, in the length of earthwork coefficient of determination (R^2) in the correlation analysis with earth-volume was approximately 0.34. As for road height, as shown in Fig. 2, coefficient of determination (R^2) was approximately 0.47, thereby being approximately 28% larger. Namely, correlation between road height and earth-volume affecting the fluctuation of environmental load was found to be high. The road height was added to the inventory of available information. Pavement work was considered and in terms of representative information of pavement work in the road facilities planning stage, thickness of pavement and material of pavement were selected and included in the inventory of available information.

Qualitative assessment was conducted on the correlation with environmental load based on the consultation from construction environmental professionals to ensure objectivity. Items of relatively low correlation with environmental load and items that can be substituted with other information were excluded from the inventory. Among the inventory of candidates of available information, project owner showed similar characteristics as administrative district and has the advantage of allow more specific classification when its property information is expressed as administrative district. In terms of regional characteristics, it can be classified as an information item showing similar characteristics as geographical feature. They were excluded from the inventory of available information, as shown in Table 1. The lane width having a similar range of 3.2-3.5m in most national highways was also excluded from the inventory of available information. The final inventory of 12 available information in the road planning stage was selected

TABLE 1
AVAILABLE INFORMATION IN THE PLANNING STAGE

Selected Items	Excluded Items
Project Type Number of Lane Road Width Length of Earth work Road Division Design Speed Administrative District Geographical Feature Area of Earth work Material of Pavement Thickness of Pavement Road Height	Project Owner Lane Width Regional Characteristics

IV. ENVIRONMENTAL LOAD

To compute the environmental load to be used for correlation analysis with available information in the planning stage of road facilities earthwork zone, 40 cases of national highway construction projects implemented in Korea were collected. The environmental load of the database of national highway construction project cases was computed through LCA. This method of quantifying environmental load in the life cycle of a product or function from energy and raw material acquisition to disposal. It is an analytical method with a characteristic of considering every process of raw material from extraction, assembly and transportation to usage, maintenance, recycling and disposal [1]. As shown in Fig. 3, LCA consists of 4 stages - Goal and Scope Definition, Inventory Analysis, Impact Assessment and Interpretation.

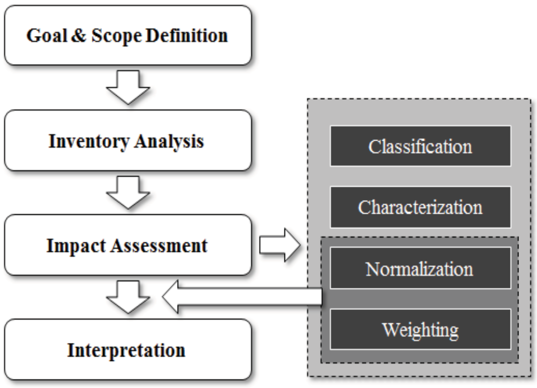

Fig.3 LCA COMPONENT

For the LCA of road facilities, it is necessary to review entire life cycle of planning - construction - maintenance - dismantling. Since it is difficult to obtain data on the resources used in the maintenance and dismantling stages, however, LCA was performed based on the construction statement and bill of quantity used in the construction stage. Table 2 shows basic unit output table of main resources used in the national highway construction earthwork used in this study.

TABLE 2
BASIC UNIT ENVIRONMENTAL LOAD

Division	Unit	Environmental Load
Portland Cement	/kg	9.10E−05
Ready Mixed Concrete	/m^3	5.32E−02
Deformed Bar	/kg	4.55E−05
Electricity	/kWh	4.52E−05
Light Fuel Oil	/kg	2.48E−04
Gasoline	/kg	2.51E−04
Asphalt Concrete	/kg	4.19E−06
Asphalt	/kg	3.57E−05
Sand	/m^3	4.24E−04

It is necessary to identify resource input volume of each specific work to compute the environmental load of national highway construction earthwork. The resources used to earthwork were mainly divided into materials and equipment. The basic unit of Table 2 was applied to main materials used in road earthwork such as concrete, asphalt concrete, cement and deformed bar. Resources used for equipment are mainly fossil fuel (gasoline and diesel fuel). Total fossil fuel input volume of construction equipment based on the unit price statement for work and equipment. Then, it is multiplied by the basic unit environmental load of diesel fuel or gasoline in Table 2 to compute the environmental load of equipment used for each specific work.

Table 3 shows the environmental load output result through LCA of 40 national highway projects used as case data of this paper. It is necessary to revise the differences of environmental load occurring from different length of earthwork in each case to review the changes in environmental load from impact factors under the same condition. Accordingly, environmental load per unit area was computed by dividing the environmental load obtained for each case by earthwork area. The values were used for the correlation analysis with the available information in the planning stage.

TABLE 3
ENVIRONMENTAL LOAD COMPUTATION RESULTS

PJT No.	Environmental Load		PJT No.	Environmental Load	
	Total	/m^2		Total	/m^2
1	1.29E+03	1.73E-02	21	2.75E+03	1.13E-02
2	3.63E+03	2.65E-02	22	7.33E+03	4.83E-02
3	3.20E+03	3.04E-02	23	5.16E+03	5.26E-02
4	9.93E+02	7.25E-03	24	4.96E+03	6.74E-02
5	5.89E+03	4.17E-02	25	9.18E+02	1.39E-02
6	7.52E+02	1.73E-02	26	4.82E+03	3.19E-02
7	1.48E+03	1.85E-02	27	1.45E+03	1.47E-02
8	3.66E+03	3.13E-02	28	1.59E+03	7.60E-03
9	1.10E+03	3.79E-03	29	5.68E+02	2.80E-02
10	8.80E+03	4.65E-02	30	2.01E+02	1.97E-03
11	2.22E+03	1.91E-02	31	1.62E+03	1.85E-02
12	7.31E+03	3.86E-02	32	2.84E+02	1.68E-03
13	2.16E+04	1.74E-01	33	8.16E+03	2.53E-02
14	2.40E+03	2.63E-02	34	1.62E+03	1.63E-02
15	1.53E+03	1.11E-02	35	7.17E+02	3.06E-02
16	3.70E+03	2.76E-02	36	5.13E+03	3.90E-02
17	3.80E+03	1.62E-02	37	1.40E+03	6.23E-03
18	6.28E+03	5.03E-02	38	3.56E+03	2.55E-02
19	7.68E+03	3.79E-02	39	1.14E+03	4.62E-02
20	4.41E+03	1.60E-02	40	4.21E+02	1.97E-02

V. IMPACT FACTORS OF ENVIRONMENTAL LOAD

A. Correlation Analysis

For the correlation analysis, Microsoft Excel program was used and the results were showed in Table 4. The analysis result showed that the correlation coefficient (R) of administrative district was 0.596, thereby showing that it is an item with the highest correlation with environmental load. In the qualitative assessment of environmental load by the construction environmental professional group, it was assessed that the degree of impact of administrative district will be small, but it was found to be an item with the biggest impact in the correlation analysis. It is thought that the administrative district-specific geographical features in the database of cases are affecting the changes of earth-volume and the fluctuation of environmental load. Fig. 4 shows the changes in earth-volume of each administrative district. In the database of national highway construction cases used in this study, it can be seen that the unit earth-volume of Chungbuk, Gyeongnam and Gyeongbuk with many mountainous areas is larger than that of other areas. In the case of Gyeonggi region with significant changes in earth-volume compared to other administrative districts, the collected cases were implemented in North-Gyeonggi region and near Chungbuk region with relatively many mountainous areas. Meanwhile, Gangwon that showed relatively smaller earth-volume changes despite its geographical feature of mountainous area had only two cases collected, thereby not having representative nature. Namely, it is necessary to increase the reliability of the correlation result of administrative district item through additional multiple database analyses.

TABLE 4
CORRELATION ANALYSIS RESULTS

Dependent Variable	Independent Variable	Coefficient of Correlation(R)
Environmental Load	Administrative District	0.596
	Road Height	0.490
	Road Division	0.316
	Project Type	0.226
	Geographical Feature	0.209
	Length of Earth work	0.165
	Area of Earth work	0.146
	Design Speed	0.136
	Thickness of Pavement	0.068
	Number of Lane	0.027
	Road Width	0.015
	Material of Pavement	0.012

Next to administrative district, road height showed correlation coefficient (R) of 0.49, thereby showing that it is relatively highly correlated with environmental load compared to other information that can be used in the planning stage. The number of lane, thickness of pavement and length of earthwork estimated to be most highly correlated with environmental load was respectively 0.027, 0.068 and 0.165, thereby showing that they are not very correlated with environmental load. This shows that number of lane and length of earthwork indicate the increase in volume of horizontal earthwork, which does not lead to increase in environmental load. Namely, increase of earth-volume affecting environmental load indicates the increase in vertical volume. Administrative district and road height with the largest correlation coefficient (R) become the representative available information in the planning stage.

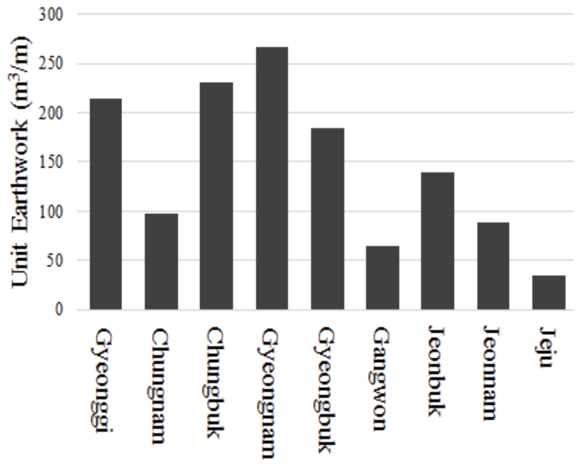

Fig.4 UNIT EARTHWORK OF ADMINISTRATIVE DISTRICT

B. *Impact Factors*

To deduce factors affecting environmental load among the inventory of available information in the planning stage based on the correlation analysis result, multiple regression analysis was performed with environmental load as dependent variable and the inventory of available information as independent variable. For the multiple regression analysis, a commercially available statistical application SPSS (Statistical Package for Social Science) was used. As for the reliability, it was set as 95% that is commonly used in regression analysis. The inventories of available information in planning stage were combined and applied to multiple regression analysis. Five items, namely administrative district, road height, road division, design speed and geographical feature found to have the largest coefficient of determination (R^2), as shown in Table 5, with below 5% of statistical level of significance (F) were deduced as the environmental load impact factors in the road planning stage.

TABLE 5
ENVIRONMENTAL LOAD IMPACT FACTORS

Factors Influencing	R	R^2	F
Administrative District Road Height Road Division Design Speed Geographical Feature	0.737	0.544	0.048

VI. CONCLUSION

A summary of the findings in this study is as follows.

First, it was found that project type, number of lane, road width, length of earthwork, road division, design speed, administrative district, geographical feature, area of earthwork, material of pavement, thickness of pavement and road height were available information in the road planning stage that could affect environmental load.

Second, environmental load of road earthwork zone was found to be affected by the fluctuation of earth-volume such as banking. In addition, it was found that information items affecting vertical volume increase such as administrative district and road height instead of items affecting horizontal volume increase such as number of lane and length of earthwork are highly correlated.

Third, the result of multiple regression analysis of environmental load and inventory of available information in the planning stage showed that administrative district, road height, road division, design speed and geographical feature were found to be factors significantly affecting environmental load in the planning stage of road facilities.

The scope of this study is limited only to earthwork zone of national highway projects implemented in Korea by excluding bridges and tunnel, and the number of national highway construction cases used in this study is 40. The finding of this study can be utilized as useful data in assessing environmental economics through accurate estimation of environmental load in the planning stage of road facilities upon increasing the reliability of the findings by obtaining and analyzing a large quantity of case data.

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