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Spatial Analysis of the Impact of Urban Forms to Road-traffic Noise in a Highly Populated City

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ABSTRACT

Road traffic noise is widely distributed in the cities and is more closely related to the urban resident people than other noise sources. To understand the relationship between road-traffic noise level and urban form indicators such as ground space index, floor space index, road density, road length, traffic volume and so on, spatial analysis was performed on highly populated city in South Korea. A system of 125m X 125m grid cells is placed on the city. And the urban forms and noise levels were calculated in each grid. Noise levels were calculated as energetical averages on each grid based on the noise map. Finally, it was simulated for changes in road-traffic noise levels due to urban forms change situations such as land development, road construction, and land use change. This study can be a policy tool to consider residents' noise exposure or area exceeding noise standard in the design process such as the redevelopment of highly populated urban city or the policy decision making process for urban planning.

Keywords: Road-traffic noise, Urban form, Noise mapping, Ordinary least square,

1. INTRODUCTION

Urban noise is due to human activity. Human activities generate noise by driving cars, running factories, using trains. In the case of highly populated cities there are relatively more human activities. Especially, road-traffic noise is closely related to urban residential population compared to other noise.

Much research has been done to understand the noise of the city accurately. The equation for predicting noise is summarized. Since then, the computation power has been able to perform complex calculations, and this equation has been applied to the entire city to produce a noise map that predicts noise. However, for more complicated cities, there are more and more times to build and compute 3D models for producing noise maps. Therefore, in this study, we devised a method to predict more concise and quick results by using city components such as floor space index, population density, road length, road area, road density, and traffic volume.

In this study, the relationship between urban form and road-traffic noise level was derived from the highly populated city of Korea (Gwangju metropolitan city) and the OLS(Ordinary Least square) model was created. The results were compared with the noise map results.

2. LITERATURE REVIEW

In a recent study, Salomons et al.(1) analyzed the changes in noise level due to urban form and urban density in Amsterdam and Rotterdam. In this study, As the GSI, FSI and population density

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increase the noise level decreases and as the road density and traffic density increase, the noise level increases. Silva et al.(2) analyzed the effect of the urban model on noise propagation. Analyzing 10 types of urban and 3 traffic scenarios. This study shows that noise levels increase as urban structures become denser and open. Also, it is shown that the noise level is decreased when the urban form is complicated. Aguilera et al. (3) analyzed the relationship between urban form and road traffic noise in three European cities (Basel, Girona and Grenoble) through the Land Use Regression(LUR) model. The model using only GIS(GIS-only model) showed coefficient of determination for 0.66 ~ 0.87. The model with actual collection data of urban form(Best model) had coefficient of determination for 0.7~0.89

In this study, the OLS model, which is the most basic form of multiple regression analysis, is used to show the correlation between noise and Urban form. The OLS model is the simplest and computation time is short, but it can be difficult to estimate complex relationships.

For more accurate prediction, the influence range of the noise source(road) was expanded considering the characteristic of the noise source. This is because noise affects not only the neighborhood but also the wider range. In a complex city, the factors related to the building that insulated the noise are sufficient to analyze only the target area, but in the case of the noise source, it is necessary to expand the scope to the surrounding area.

3. Materials and Methods

3.1 Materials

The Gwangju metropolitan city, located in the south-west part of the Republic of Korea, is selected for this study. As of 2016, the total population of Gwangju metropolitan city was 1.517 million, the total length of roads was 27,022 km and the total city area for this study was 501.2 km^2. The data for this study were obtained from the National Geographic Information Institute, the Gwangju Metropolitan Police Agency, the Gwangju Metropolitan City Office, and the Korean National Statistical Office. Table 1 shows the types and parameters of the data used.

Table 1 – Summary of input data for this research

Type	Parameter	Provider	Production year
Topography	Terrain elevation	National Geographic Information Institute	2106
Road	Network	National Geographic Information Institute	2016
Vehicle	Volume Speed Type	Gwangju Metropolitan Police Agency	2016
Building	Footprint	Gwangju Metropolitan City Office	2016
Population	Population for '-dong' district	Korean National Statistical Office	2016

3.2 Methods

Noise maps were produced for this study. Noise maps were produced with 3-Dimension using the data presented in Section 3.1. As a result of the noise map, a façade noise map was derived. The results were classified into 125m × 125m grid and the energetical average noise level in each grid was selected as the representative noise level of each grid. Urban form was also classified by the same grid.

Figure 1 shows the roads, buildings and sphere boundaries of Gwangju Metropolitan City. The red box is a detailed representation of some areas. The red box is an enlarged view of some areas, and the solid black line represents the 125m × 125m grid used in this study. Also, considering the propagation characteristics of the roadside, a buffer area is set at the center of the grid. The road length index, road area index, and traffic speed of each buffer area are additionally used. The size of the buffer area is set to 500m and 1,000m when the noise level is 1.5dB (A) and 1dB (A), respectively, when the receiver is located 100m interval vertically on the road. Figure 2 shows the difference in noise level between the receiver and the next receiver in 100m interval.

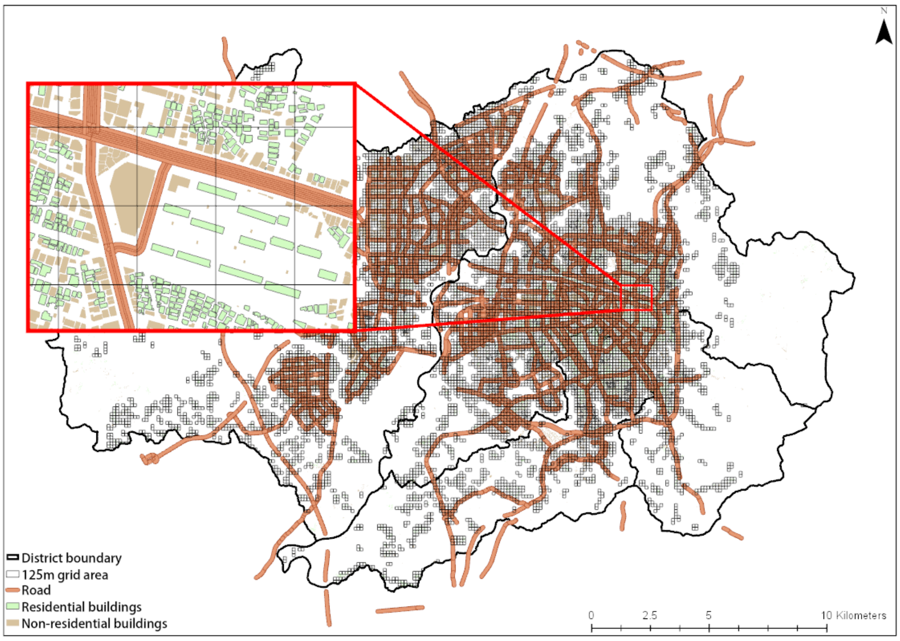

Figure 1 – Square grid cells overlaid over the Gwangju metropolitan city.

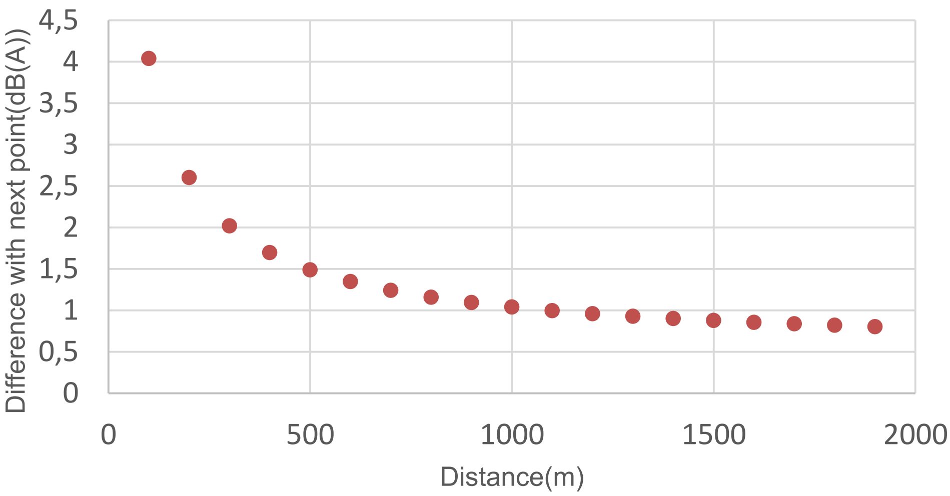

Figure 2 – Noise difference with next point in 100m interval

The variables considered in this study are shown in Table 2. L_d was set as a dependent variable, and the remaining variables were set as independent variables. The variables were excluded from the final model when the variable was not significant or the variance inflation factor (VIF)> 7.5. In addition, when the buffer area of 500 m and 1,000 m is set, a buffer area having a high coefficient of determination of the model is selected even if the variables of both buffer areas are significant

Table 2 – Explanation and unit for each variable of the initial statistical model

Variable	Explanation	Unit
L_d	Energetic average of noise levels during daytime	dB(A)
P	Population density	Person/m^2
GSI*	Ground space index	m^2/m^2
FSI	Floor space index	m^2/m^2
Q	Traffic volume during daytime	Vehicle/h
PH	Percentage of heavy vehicles during daytime	%
D*	Traffic density	Vehicle/km
R_a	Road area index	m^2/m^2
R_l	Road length index	m/m
$R_{a,500}$*	Road area in 500m buffer area	m^2
$R_{l,500}$	Road length in 500m buffer area	m^2
S_{500}	Traffic speed during daytime in 500m buffer area	km/h
$R_{a,1,000}$	Road area in 1,000m buffer area	m^2
$R_{l,1,000}$	Road length in 1,000m buffer area	m^2
$S_{1,000}$	Traffic speed during daytime in 1,000m buffer area	km/h

Note: * is the selected variables in the OLS model

4. Results

GSI, traffic density, and road area in 500m buffer area were found to be statistically significant. In addition, the coefficients of determination in the 500m buffer area (R^2 = 0.473, adjusted R^2 = 0.473) were higher than those of the 1,000m buffer area (R^2 = 0.458, adjusted R^2 = 0.457). The created OLS model is shown in Table 3 below, and is summarized as Equation (1).

Table 3 – Results for ordinary least squares model

Variable	Estimated	t-Value
Constant	43.8114***	349.557295
GSI*	-3.392992***	-6.708942
D*	0.550123***	46.471753
Ra,500*	0.000145***	71.453010

Note: *** indicates a statistically significant p-value($p < 0.01$)

$$L_d = -3.392992 \times GSI + 0.550123 \times D + 0.000145 \times R_{a,500} \quad (1)$$

Based on the estimated model, a noise map was created and compared with the existing noise map results. The two results are shown in Figure 3 below. A scatter plot of the result is shown in Figure 4. Comparing Figure 3- (A) and (B), the overall noise figure distribution is similar. In detail, the absolute mean for the difference between the two noises is 5.88 and the skewness for the two noise differences (OLS model estimates - noisemap results) is 1.12. The noise map result is higher than the OLS model estimate. Noise map results are higher than OLS model estimates. The difference in noise (OLS model estimation - Noise Diagnosis) among a total of 11,822 observations has a negative value of 6,349 and a positive value of 5,473. The coefficient of decision(R^2) for the two noises in Figure 4 is 0.4735. The solid line in the figure is the case where the two noise levels are the same, and the dotted line is the trend line for the correlation of the two noise levels.

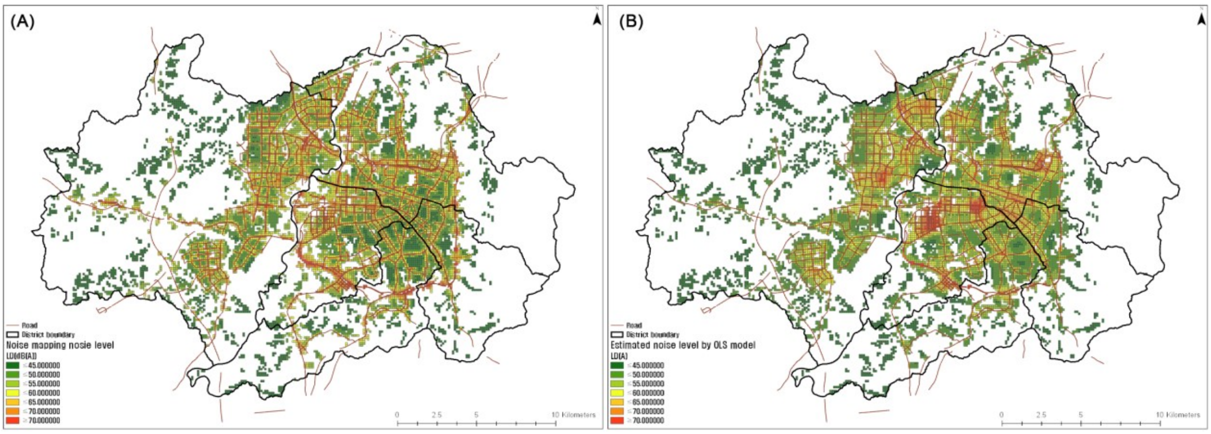

Figure 3 – Comparison of noisemap results(A) with OLS model estimates(B)

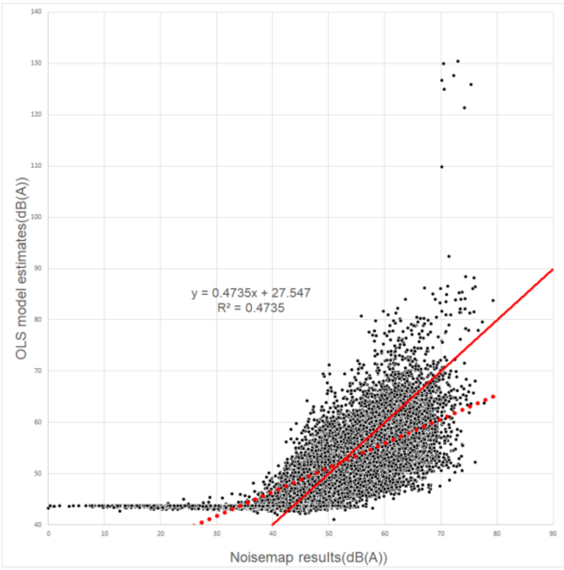

Figure 4 – Scatter plot of the noise map results and the results of the OLS model estimates

5. CONCLUSIONS

This study deals with the method of estimating the noise level using the urban form as an alternative method in a situation where the complexity of the city is increased and the noise map is difficult to make due to the increase of the population. Numerous studies have been conducted on this method, and there are many methods for improving the accuracy. In this study, we used OLS model, which is the simplest model, and extended the influence range of road by setting buffer area at prediction point. As a result, the coefficient of determination was 0.473. This decision coefficient was improved compared with 0.44 proposed by Ryu et al. (4). Also, as the results of Salomons et al.(1) and Ryu et al.(4) suggested, the tendency of the noise level to decrease with increasing GSI was confirmed.

The statistical noise estimation method using the Urban form can be a good way to find out the distribution of urban noise easily and quickly. This methodology can be useful for decision-making by enabling efficient information transmission without complicated simulations in preparation of projects such as planning or redevelopment of complex cities with many populations.

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