Potential of Novelty Noise Evaluation by Using Road Traffic Noise Maps in Japan

Yasuhiro HIRAGURI

1 National Institute of Technology, Tokuyama College, Japan

ABSTRACT
Noise evaluation using the noise maps becomes popular in the European countries owing to the Environmental Noise Directive. However it is unfamiliar and is started to discuss recently in Japan. In this research, a lough road traffic noise map in Shunan City, Japan is tried to be illustrated with quite attributive calculation condition. And then the novelty noise evaluations in Japan by using noise map and some geographic information data were discussed by analyzing with the GIS focusing on three points: the property of buildings, the exposure population and the relationship between noise level and land price. As a consequence, the usefulness of the noise map was objectively become clear by some spatial analysis and it was found. Although this field in Japan has a late start compared with in other countries, we have to quickly establish the methodology of estimating noise maps.

Keywords: Road traffic noise, Noise mapping, Evaluation techniques, Geographic information systems

I-INCE Classification of Subjects Number(s): 52.3, 68.3, 68.7

1. INTRODUCTION
Some large projects such as Harmonoise/Imagine (1) and CNOSSOS-EU (2) in connection with the Environmental Noise Directive (hereinafter referred to as END) (3) have been conducted with energy by EU countries. Implementation of a noise assessment by using seamless noise mapping in whole Europe area is studied at the most recent project CNOSSOS-EU. In those projects, a new concept of noise assessment that the subject to evaluate is not only buildings but also human who lives in the buildings, has been introduced. The trend of noise assessment by using noise mapping spreads to Asia (4 - 7).

The noise maps are sometimes illustrated in the case of conducting aircraft noise assessment, industrial noise assessment or construction noise assessment in Japan. However, the mapping areas in the case of Japanese noise assessment are quite smaller than those in the case of EU. New ideas those are “estimating noise level” and “wide-area evaluation” had been introduced into the Japanese Environmental Quality Standard for Noise (hereinafter referred to as EQSN) (8) in 1998. The noise level shall be evaluated by the following method in the EQSN.

- Noise levels to which the respective buildings are exposed shall be evaluated. Noise levels at the sides of residential buildings most affected by noise shall be evaluated.
- Noise shall be evaluated by the equivalent continuous A-weighted sound pressure levels, in principle, throughout the hours of the respective time categories (daytime period: 6 a.m. to 10 p.m., nighttime period: 10 p.m. to 6 a.m.).
- Evaluation shall be conducted by selecting a day or days showing the average conditions of noise throughout the year.
- In case noise cannot be measured for the required period, its level can be estimated from conditions such as the volume of road traffic instead of the actual measurement.

And the area-wide evaluation of the achievement of the EQSN shall be made at areas facing roads (generally less than 50 meter from the side of roads) and other than those by using the following methods.

- For areas facing roads, achievement shall in principle be evaluated by obtaining numbers and rates of the houses at which noise levels exceed the standard value of EQSN stipulated for the respective areas.
- For areas other than those, achievement shall in principle be evaluated by choosing points considered to represent the noise of the respective concerned areas.

1 hiraguri@tokuyama.ac.jp
In the methods, there are some problems for appropriate noise assessment that it has never been focused on the population in the buildings, usually only one day as the average conditions of noise throughout the year is selected to evaluate noise, the area-wide evaluation of the achievement at the area only less than 50 meter from the side of roads is conducted, or the numbers and rates of exceeding the standard value are obtained and publicly available (Fig. 1). The ministry’s noise evaluation may not be enough to say the Noise Mapping.

Figure 1 – Results of noise assessment (noise level and achievement rate) by Environmental Quality Standard for Noise in Japan.

In an effort to the implementation of appropriate noise assessment in Japan, the road traffic noise map in the whole area of Shunan city is illustrated with attributive calculation condition and some problematic points for calculating noise levels at a huge number of receiving points will be clarified. Thereafter, spatial analyses are experimented with open geographic information data by using geographic information system (GIS). The Japanese potential of novelty road traffic noise evaluation by using noise map and some geographic information database such as hospital, school and population is discussed.

2. ROAD TRAFFIC NOISE MAP IN SHUNAN CITY

Noise map is illustrated at whole area of Shunan City (area: 656 km², population: 140,000 people), Yamaguchi Prefecture, Japan. Noise levels that is the equivalent continuous A-weighted sound pressure levels during 24 hours \( L_{\text{Aeq, 24h}} \) at every receiving point are estimated using ASJ RTN-Model 2013 (hereinafter referred to as ASJ Model) (9). The road traffic conditions such as the volume of road traffic and the running speed of vehicles are referred to a result of road traffic census survey in 2010 (hereinafter referred to as Road Census 2010) by the Ministry of Land, Infrastructure, Transport and Tourism (hereinafter referred to as MLIT) (black heavy lines in Fig. 2).

2.1 Process of noise mapping

The road traffic noise map in this study is illustrated by the following process.

- The discrete noise source points are generated by traffic flow diagram of the Road Census (Fig. 3) by using GIS (ArcGIS by ESRI Co., LTD. is used in this study). The traffic volumes and the running speeds of vehicle at each discrete noise source points are linked to the diagram of the Road Census 2010 that is available from the Ministry or the local authorities. In the case of Yamaguchi Prefecture, the prefectural government reports it on the web site by dividing into 21 districts. In this study, assuming single lane road for all roads, the discrete noise source points are generated at 10 m intervals along the black heavy line in Fig. 2. The total number of discrete noise source points is 45,343 points. Then, the traffic volumes consisted of two category (light vehicles and heavy vehicles) and averaged...
running speed during 24 hours are linked to each discrete noise source points assuming that traffic flow is steady running condition.

- In order to estimate the noise levels at whole area of Shunan City, predicted points are placed 100-meter intervals in a grid pattern. The number of predicted points is 65,625 points.

Figure 2 – Roads as noise sources (black heavy lines) and points under constant observation of noise level (black dots).

Figure 3 – An example of the traffic flow diagram of the Road Census 2010 in Yamaguchi Prefecture.

- The discrete noise source points located in arbitrary range from the predicted point affect to the noise level by reason that the noise propagation model of ASJ Model is a point-to-point model. In this study, a 500-meter buffer is generated at every predicted point.
- The effect of road gradient, sound radiation directivity, ground absorption, atmosphere absorption,
meteorological, buildings and noise barriers are ignored to estimate noise propagation. Only distance attenuation and diffraction attenuation by undulation of ground is considered for rapidly estimation. Digital elevation model database with five meter mesh size available from the MLIT is used for judgement of the diffraction attenuation by undulation of ground. If the discrete noise source point was visible from the predicted point, across-the-board attenuating 5 dB is considered as the effect of diffraction attenuation.

- As a background noise effect, 35 dB is added to the estimated $L_{A_{eq, 24h}}$ at every receiving point.
- Finally, the $L_{A_{eq, 24h}}$ at every receiving point are interpolated to 10 meter interval data in a grid pattern as a raster image (road traffic noise map). Natural Neighbor method is adopted as the interpolating method in this study.

As described above, the noise map is illustrated with attributive calculation condition in this study. Therefore, there is really no meaning about the evaluated noise levels.

2.2 Result of noise mapping

Figure 3 shows the road traffic noise map at whole area of Shunan City calculated by above calculating process. The noise levels at the receiving points located within one or two meter from edge of some busy roads are almost 90 dB. If the discrete noise source point does not lie in the 500-meter buffer, the noise levels are 35 dB as the back ground noise level. The noise levels at area facing express way like Sanyo Express Way or Chugoku Express Way, or a national road like Route 2 are louder than those located other areas. There is no validity for the noise levels because of the attributive calculation condition, but the noise map qualitatively looks the part. Here, Fig. 4 is enlarged noise contour of an area enclosed by black broken lines in Fig. 3 and the relationship between the noise level and the color map is the same as Fig.3. Due to the spatially rough estimation of noise levels with the predicted points placing 100-meter intervals in a grid pattern, the noise contour is patchy pattern especially around the areas facing road with discrete noise source points.

![Figure 4 – Road traffic noise map in Shunan City.](image-url)
In order to confirm the trend of accuracy of noise contour depend on the distance of interval, noise levels at the receiving points placed one meter intervals in a grid pattern are recalculated. The estimating areas are four squares 200 meter on a side respectively that illustrated in Fig. 2 (Point 1 to 4). These points are the constant monitored point of road traffic noise level out of 11 points in Shunan City. Figure 5 shows the noise contour with 100 meter intervals receiving points at upper stand and the results of recalculating of noise levels at lower stand. In the figure, the black dots means the location of the discrete noise source points and the black crossed lines at the upper stand means the location of the receiving points when the interval of receiving points is 100 meter. The relationship between the noise level and the color map is the same as Fig.3.

In any of these points, the receiving point interval of 100 meter is not enough to estimate proper noise levels. For example, noise maps around the point 1 and 2 when the intervals of receiving points are 100 meter get island shape, because the noise level at the receiving point closest with the discrete noise source points is the highest. On the other hands, due to the area around the point 1 and 2 consists overall of flat terrain, the noise level attenuates parallel along the line of the discrete noise source points under normal condition in accordance with the distance decay like the figures in the case of one meter interval. In addition, there is effect of diffraction attenuation around the point 4 in the case of one meter intervals, but there is not such effect in the case of 100 meter intervals.
Figure 6 – Variation of noise maps between intervals of receiving points. Noise maps in the case of 100 m intervals are shown at upper stand, of 1 m intervals are shown at lower stand. Black dots means location of discrete noise source points and black crossed line means location of receiving points in the case of 100 m intervals.

2.3 Problems and solutions for estimating road traffic noise map in Japan

Problems brought to light by actual estimating road traffic noise maps on a regional scale in Japan are organized and probabilities of solutions to bring about the realization of estimating noise maps are discussed here.

- In the case of estimating road traffic noise maps, method of predicting propagation of noise is close to completion as ASJ Model. However, almost database for predicting noise like location of every traffic lane, location and shape of noise barrier, height of buildings, land cover for ground absorption and other relevant geographic information are not prepared.
- In order to difficulty of completing all database for estimating noise level, it is necessary to bring out the relationship between will or choice of the correction of noise estimation and accuracy of estimation.
- It takes 72 hours to calculate noise levels at 65,625 receiving points with personal computer (CPU of Intel’s 5th-generation Core). If the intervals of receiving points are one meter, it will take 80 years to calculate whole area in Shunan City. It is necessary to increase the speed of calculation by streamlining of calculating programs or by using parallel computation like GPGPU.

3. POTENTIAL OF NOVELTY NOISE EVALUATION USING NOISE MAPS IN JAPAN

Geographic information data in digital format about many types of facilities is available by Geospatial Information Authority (hereinafter referred to as GSI), MLIT in Japan. Novelty noise evaluations by using noise maps and such geographic information data are discussed in the following paragraph by analyzing with the GIS. In order to low accuracy of estimated noise levels, however, obtained results will have no meaning.

3.1 Noise evaluation focused on property of buildings

The EQSN provide the standard values for each area type like AA, A, B or C which mean areas where
quietness is specially required, such as those where convalescent facilities and welfare institutions are concentrated, areas used exclusively for residences, areas used mainly for residences or areas used for commerce and industry as well as for a significant number of residences, respectively. Three types of facilities designated as the area category AA shown in Fig. 7 are available by National Land Numerical Information download service (10). These data are overlaid with obtained road traffic noise map. At the results, noise exposures to each type of facility in Shunan City are obtained as shown in Fig. 8.

Figure 7 – Locations of three types of facilities that especially require silence in Shunan City.

Figure 8 – Noise exposure to each type of facility in Shunan City.
3.2 Noise evaluation focused on exposure population

In order to a priority of the noise policy is lower than other environmental policies in Japan; it is difficult to calculate the number of noise exposure population. Because, number of people lived in each residences is not able to be obtained easily for the general public due to the personal information protection. Currently, a methodology of estimating the number of residents in each building has been developed using a lot of open geographic information data. If the method is completed, the noise exposure population will be obtained in Japan.

3.3 Relationship between noise level and land price

Land price [JPY/m²] is investigated at standard places throughout Japan by the Land Price Publication Act and is available at GSI web site. Figure 9 a) illustrates the distribution of the posted land price in Shunan City. In order to a number of factors have effect on the land price, analyzing only with noise level and land price is not enough to obtain the effect of noise. Therefore, at first, the land price data is classified into types of land use zones in the following Table 1 on a GIS. The land use zones are areas that are regulated by City Planning Act and designate the possible usage of land and properties in each type of area. Figure 9 b) illustrates the location of land use zones in Shunan City. As a consequence, the relationships between the $L_{A_{eq}, 24h}$ and the land price at each land use zones in Shunan City are obtained as following Fig. 10. The trends are divided roughly into the following two categories. The land price tends to come up at the commercial area and the industrial area as the noise level becomes louder (distance from road becomes shorter). On the other hands, there is no correlation between the land price and the noise level at the areas related to the residential zones. There is potential to obtain the effect of noise levels on the land price by improving the accuracy of noise map.

![Figure 9: Current state of the Posted Land Price and the Land Use Zones in Shunan City published by the Ministry of Land, Infrastructure and Transport Japan.](image)

4. CONCLUSIONS

In this paper, the road traffic noise map at the whole areas in Shunan City, Yamaguchi Prefecture, Japan was tried to estimate, and the problems brought to light by actual estimation of the road traffic noise map on a regional scale in Japan were organized and probabilities of solutions to bring about the realization of estimating noise maps were discussed. Finally, the novelty noise evaluations in Japan by using noise map and some geographic information data were discussed by analyzing with the GIS focusing on three points: the property of buildings, the exposure population and the relationship between noise level and land price. As a consequence, the usefulness of the noise map was objectively become clear by some spatial analysis and it was found. Although this field in Japan has a late start compared with in other countries, we have to quickly establish the methodology of estimating noise maps.
ACKNOWLEDGEMENTS
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REFERENCES
Table 1 – Twelve categories of Land Use Zones which are allocated according to a future vision of land-use pattern in Japan

<table>
<thead>
<tr>
<th>Types of Land Use Zone</th>
<th>Summary</th>
</tr>
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<tbody>
<tr>
<td>Category I exclusively low-rise residential zone</td>
<td>This zone is designated for low rise residential buildings. The permitted buildings include residential buildings which are also used as small shops or offices and elementary/junior high school buildings.</td>
</tr>
<tr>
<td>Category II exclusively low-rise residential zone</td>
<td>This zone is mainly designated for low rise residential buildings. In addition to elementary/junior high school buildings, certain types of shop buildings with a floor area of up to 150m² are permitted.</td>
</tr>
<tr>
<td>Category I mid/high-rise oriented residential zone</td>
<td>This zone is designated for medium to high residential buildings. In addition to hospital and university buildings, the permitted buildings include certain shops and office buildings with a floor area of up to 1,500m² to provide conveniences for the local community.</td>
</tr>
<tr>
<td>Category II mid/high-rise oriented residential zone</td>
<td>This zone is mainly designated for medium to high rise residential buildings. In addition to hospital and university buildings, the permitted buildings include certain shops and office buildings with a floor area of up to 500m².</td>
</tr>
<tr>
<td>Category I residential zone</td>
<td>This zone is designated to protect the residential environment. The permitted buildings include shops, offices and hotel buildings with a floor area of up to 3,000m².</td>
</tr>
<tr>
<td>Category II residential zone</td>
<td>This zone is designated to mainly protect the residential environment. The permitted buildings include shops, offices and hotel buildings as well as buildings with karaoke box.</td>
</tr>
<tr>
<td>Quasi-residential zone</td>
<td>This zone is designated to allow the introduction of vehicle-related facilities along roads while protecting the residential environment in harmony with such facilities.</td>
</tr>
<tr>
<td>Neighborhood commercial zone</td>
<td>This zone is designated to provide daily shopping facilities for the neighborhood residents. In addition to residential and shop buildings, small factory buildings are permitted.</td>
</tr>
<tr>
<td>Commercial zone</td>
<td>Banks, cinemas, restaurants and department stores are constructed in this zone. Residential buildings and small factory buildings are also permitted.</td>
</tr>
<tr>
<td>Quasi-industrial zone</td>
<td>This zone is mainly occupied by light industrial facilities and service facilities. Almost all types of factories are permitted excepting those which are considered to considerably worsen the environment.</td>
</tr>
<tr>
<td>Industrial zone</td>
<td>Any type of factory can be built in this zone. While residential and shop buildings can be constructed, school, hospital and hotel buildings are not permitted.</td>
</tr>
<tr>
<td>Exclusively industrial zone</td>
<td>This zone is designated for factories. While all types of factory buildings are permitted, residential, school, hospital and hotel buildings cannot be constructed.</td>
</tr>
</tbody>
</table>

Figure 10 – Relationship between the $L_{Aeq}$ and posted land price at each land use zone in Shunan City.