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GENERAL VIEW OF ROAD TRAFFIC NOISE PROBLEM

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Abstract
Road traffic noise is one of the typical community noise problems all over the world. To mitigate this environmental problem, noise reduction technologies for motor vehicles, tires, road surfaces, road structures, and sound insulation of roadside buildings are essential conditions and at the same time legislative and administrative systems for this noise problem need to be well established. In this paper, the present situations of these factors are reviewed by giving examples mainly in Japan.

Keywords: Road traffic noise, motor vehicle, tire/road noise, noise regulation, noise barrier

1 Introduction

Road transportation is essential to our everyday life and goods transportation, and the number of motor vehicles is constantly increasing in the world as shown in Figure 1. Figure 2 shows the number of the registered motor vehicles and its increase ratio in sixteen countries. Although we receive a great deal of benefit from road vehicles, as its negative aspect road traffic noise is a serious environmental problem together with aircraft noise and railway noise in almost all countries. According to Reference 1, one third of the European population is exposed to noise levels that are considered annoying and ten percent of the population is subjected to levels that carry serious health risks. To see the contents of the complaints about environmental problems brought to the Japan Highway Public Corporation, about 60 % of the complaints are related to road traffic noise.
In this paper, the current situation of road traffic noise and the ways to mitigate the problem is reviewed mainly base on Japanese data. This problem in European countries is discussed in References 1 and 2.

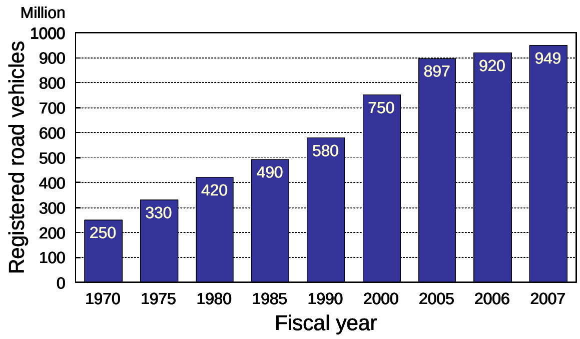


Figure 1 – Total number of motor vehicles in the world (JAMA)

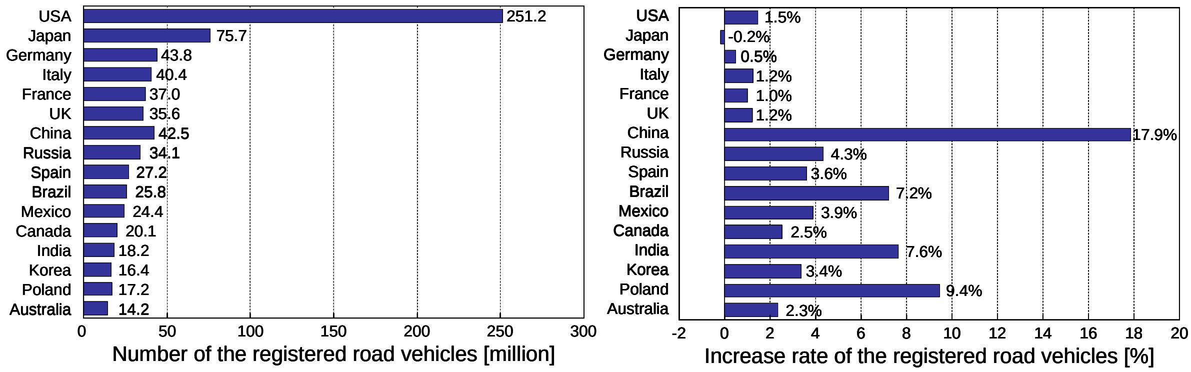


Figure 2 - Number of the registered motor vehicles and its increase ratio in sixteen countries (JAMA)

2 Holistic view of road traffic noise problem

Generally, environmental noise problems can be divided into noise source (emission side), propagation process and noise reception (immission side). Figure 3 shows such a flow for road traffic noise problem. Noise mitigation measures should be considered for motor vehicles including tire/road interaction, road structures, propagation process and roadside buildings, respectively. Besides such technical treatments, legislative/administrative measures are also essential to cope with the problem.

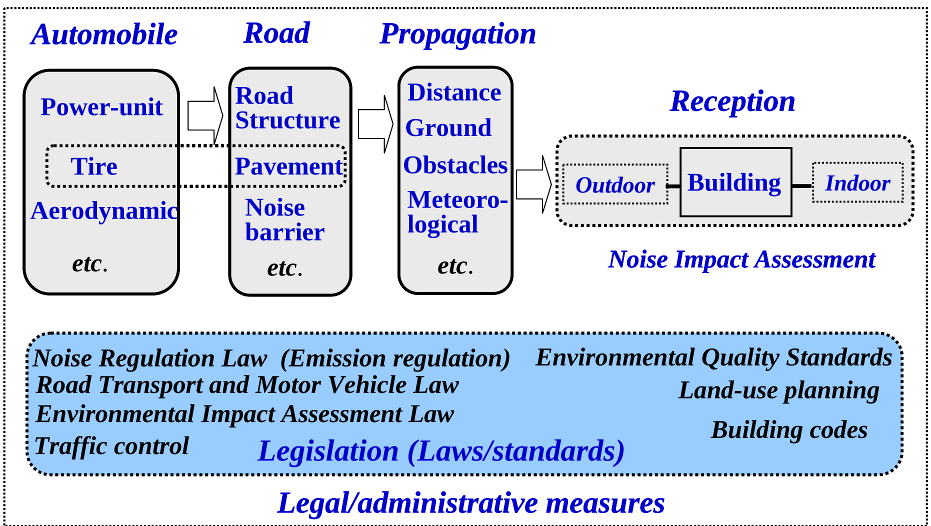


Figure 3 – Composition of road traffic noise problem

3 Legislative/administrative measures

The legislative/administrative measures for environmental noise problems are classified into two categories: emission regulation and immission control. The former measures will be mentioned later on.

In order to preserve the acoustical condition in living environment, the criteria of sound levels indoor and/or outdoor due to road traffic are specified in each country [3]. As the noise descriptor in these specifications, energy-base quantities like time-averaged, A-weighted sound level for a specified reference time interval ($L_{\mathrm{Aeq},T}$) is widely used. However, specification of the reference time intervals (daytime, evening, nighttime, *etc*.) varies in each country. Among the EU Member States, day-evening-night time-weighted L_{Aeq} (L_{den}) and nighttime L_{Aeq} (L_{night}) is uniformly used. In the U.S. and some other countries, day-night time-weighted L_{Aeq} (L_{dn}) is used. In Japan and some other countries, L_{Aeq} value is specified for daytime and nighttime, separately. The noise limit is different in each country not only due to the difference of noise descriptor but also due to the differences of the category of legislative documents (law, decree, act, regulation, recommendation, guidelines, or legal standard) and the assessment positions, *etc*. [3].

In Japan, the new "Environmental Quality Standards (EQS) for Noise" is enacted in 1999, which specify the noise levels in general environments including roadside areas (see Table 1). The EQS are specified as the administrative targets for maintaining the desirable living environment. To realize the targets, "Noise Regulation Law" is enacted, in which noise emission limits are prescribed for motor vehicles as mandatory regulation.

Table 1 – "Environmental Quality Standards for Noise" in Japan (enacted in 1999)

I. Standard values for general areas in L_{Aeq}

Type of area	Daytime (06:00 - 22:00)	Nighttime (22:00 - 06:00)
AA	50 dB or less	40 dB or less
A and **B**	55 dB or less	45 dB or less
C	60 dB or less	50 dB or less

Notes:
AA: areas where quietness is specially required, such as those where convalescent facilities and welfare institutions are concentrated.
A: areas used exclusively for residences.
B: areas used mainly for residences.
C: areas used for commerce and industry as well as for a significant number of residences.

II. Standard values for areas facing to roads in L_{Aeq}

Area category	Daytime (06:00 - 22:00)	Nighttime (22:00 - 06:00)
Area **A** facing roads with two or more lanes	60 dB or less	55 dB or less
Area **B** facing roads with two or more lanes, and area **C** facing a road with one or more lanes	65 dB or less	60 dB or less

For the space adjacent to a road carrying arterial traffic:

Daytime (06:00 - 22:00)	Nighttime (22:00 - 06:00)
70 dB or less	65 dB or less

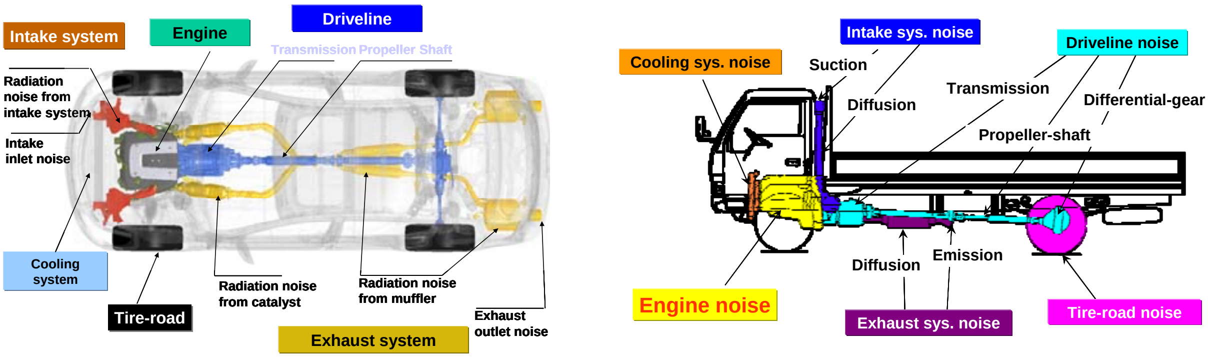
Note:
Standards for indoor noise transmitted from the outside (45 dB or less for daytime, and 40 dB or less for nighttime) can be applied for the respective residences whose windows are judged as usually closed on the sides most affected by noise.

4 Measures for noise emission

In general noise problems, control at the source is most effective. In the case of road traffic noise problem, the measures to reduce noise emission by motor vehicles are essential. However, motor vehicles are multiple noise sources including noise generation by tire/road interaction as mentioned below.

4.1 Motor vehicles

The noise generated by motor vehicles can be classified into two categories, propulsion noise and rolling noise and the major components are as shown in Figure 4. The contribution of each of these components to total noise has been examined under various running conditions and noise reduction measures have been investigated, respectively.



(a) Passenger car (b) Heavy duty track

Figure 4 – Main noise sources in motor vehicles [4]

In order to control noise emission by motor vehicles, noise regulation system is legislated in each country, but the test methods and limit values are not unified internationally at present. In Japan, the permissible limits for accelerated running noise, steady running noise and exhaust proximity noise are stipulated and the measurement methods for these noises are specified, respectively, in TRIAS (Japanese Automobile Type Approval Test Standard) 20. Figure 5 shows the process of noise emission regulation for motor vehicles in Japan. The limit values have been lowered stepwise and automobile manufacturers have been made great effort to comply with these regulations in the type approval test. The similar emission regulation is legislated in many other countries [5], but the limit values can not be simply compared because the certification test methods in each country are somewhat different. Figure 6 shows the process of noise reduction for passenger cars and heavy trucks according to the change of the noise emission regulation in Japan.

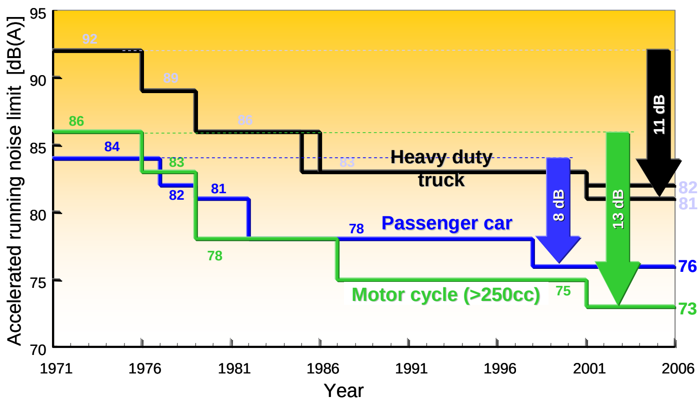


Figure 5 – Transition of noise limits for motor vehicles in Japan (accelerated running noise)

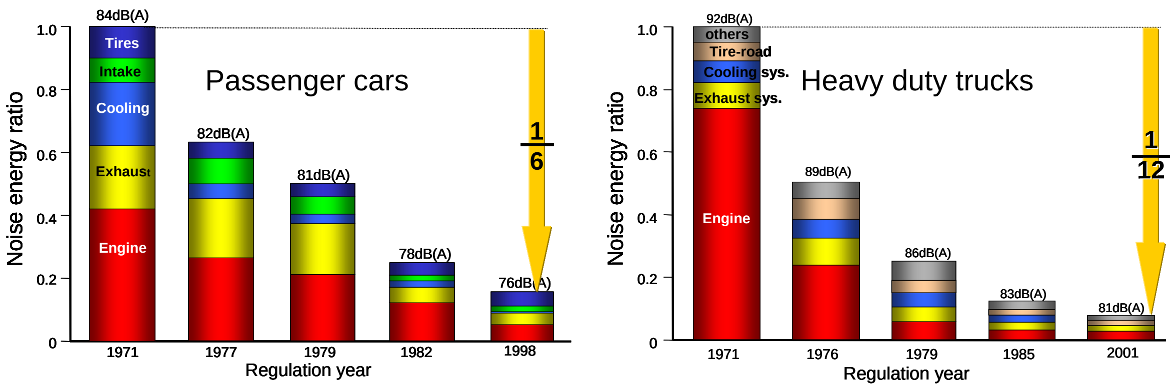


Figure 6 – Nose emission reduction of motor vehicles (accelerated running noise) [4]

"**Illegal muffler problem**": In spite of these noise emission regulations and the technical development of quiet automobiles, it is a big problem that the standard exhaust mufflers of passenger cars and motorbikes are replaced by illegal mufflers. These are modified ones to make big sound for sport and fashion. In the results of our experimental study, a car equipped with an illegal muffler was noisier by 20 dB(A) or more than that with standard muffler during accelerated running condition [6]. To cope with this problem, the Japanese Ministry of Land, Infrastructure and Transport (MLIT) set up a technical committee and the Muffler Certification System (type designation for mufflers) has been in effect from December 2008. In this system, the same measurement method (TRIAS 20) for accelerated running noise for type approval test are applied to all mufflers on the market.

"**Quiet car problem**" : In recent years, hybrid and electric cars are becoming popular and the number of production is rapidly increasing being pushed by the recent green policy. Due to the electric drives, their propulsion noise is much lower than the gasoline engine cars especially at low speeds. This is a splendid success from a technical viewpoint of noise reduction, but it is bringing about another problem; that is, such quiet cars are dangerous when they approach to pedestrians, especially blind and visually impaired people, at low speeds. To examine this problem, a comparison test was performed by the Japan Automobile Research Institute in which the running noise of a hybrid car and two types of gasoline-engine cars were measured at a point 2 m apart from the running path. Figure 7 shows the measurement result and it is seen that the hybrid car is much quieter than the gasoline-engine cars especially in the speed range below 15 km/h.

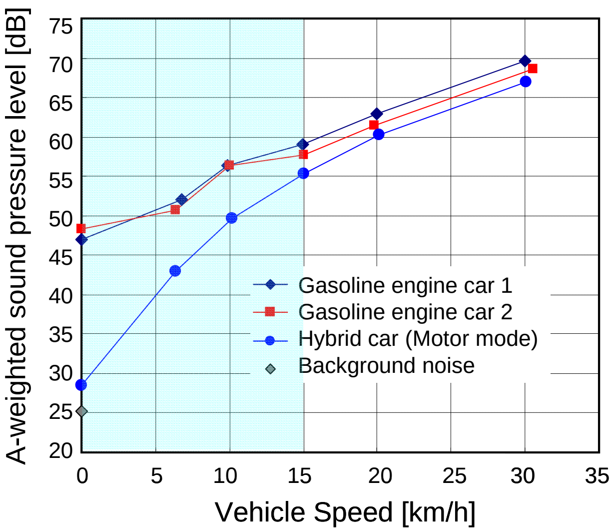


Figure 7 – Comparisons of exterior noise between gasoline-engine cars and a hybrid car

As a measure to cope with this problem, the MLIT set up a technical committee and recently published a guideline, in which it is recommended to add some sound ("sound associating vehicle") to hybrid and electric cars as an artificial warning sound device [7].
This new problem has various aspects not only acoustical but also physiological, psychological and sociological and can not be discussed further in this paper, but there must be many difficult problems; that is, what kind of sound should be added, how to set the level of the alarm sound, which can be a new noise source in quiet areas [8].

4.2 Tires

In the process of starting and acceleration the propulsion noise dominates, whereas in the steady running condition at high speeds, the contribution of the tire/road noise becomes overwhelming for passenger cars and more than 50 % for heavy trucks. Therefore, various contrivances to reduce noise emission have been made for the construction, material and tread-pattern of tires (see Table 2). However, priority must be given to such tire performances as safety, handling, mileage, and rolling resistance rather than quietness which are often conflicting conditions.

Table 2 – Tread-patterns of tires and comparison of features

Tread pattern category			Features
Rib		Circumferential grooves	Drive-ability; good Noise; good Traction; poor
Lug		Lateral blocked grooves	Traction & Braking; good Noise; poor High speed driving; poor
Rib-Lug		Rib and Lug pattern	Drive-ability; good Traction & Braking; good Noise; poor
Block		Separated blocks, “rubber islands”, by grooves	Traction & Braking; good Skid performance; good Noise; poor

Reference JATMA “TYRE/ROAD NOISE”

As an example of noise reduction by improving tread-pattern, Figure 8 shows the visualization of the difference of noise emission from the rear wheels of a heavy track when changing the tires.

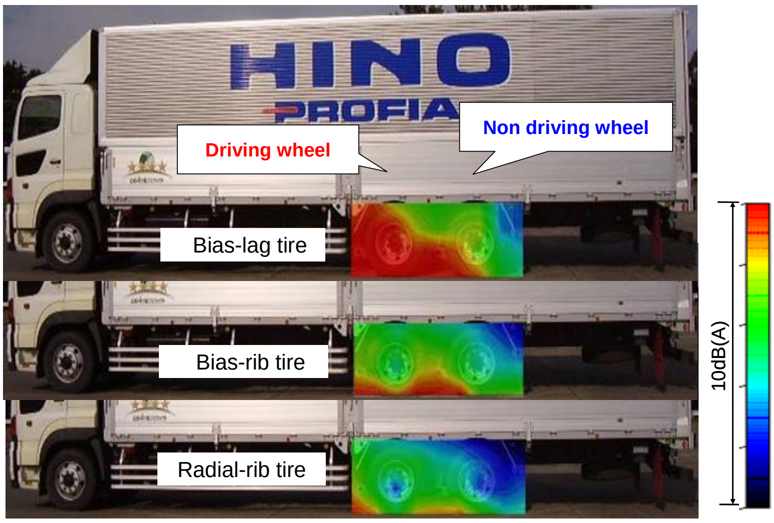


Figure 8 – Change of noise emission by the difference of tire [4]
(A heavy truck of gross vehicle weight 25 ton ran at a speed of 50 km/h.)

The EU has a certification system with limit values (ECE R117) which is the first legislation on tire noise in the world. In Japan, there is no such a legislation but the test method for steady running noise is specified and tire/road noise can be tested practically.

4.3 Road surfaces

Porous asphalt concrete pavement which was developed originally for drainage has also acoustical effects to reduce tire/road noise with its sound absorption performance and by suppressing the air-pumping effect and horn effect. This type of pavement has become being widely used as an effective measure to reduce tire/road noise. Recently, double-layer type consisting of two layers with different maximum chipping sizes has been developed. This types of pavements have a potential to provide noise reduction of 7 to 9 dB for passenger cars and up to 6 dB for heavy trucks when compared to standard dense asphalt concrete pavement [2]. We also performed an experimental study to examine the noise reduction effect by double-layer porous asphalt pavement [6]. As a result, it has been found that 10 dB or more noise reduction can be expected by combining the latest noise reduction technologies for motor vehicles, tires and road pavements.

Although these porous asphalt pavements have an excellent noise reduction effect initially, the problem is that the acoustical performance deteriorates by clogging. To prevent this deterioration, the way of cleaning the pavement surface is now investigated.

As another type of road surface, porous-elastic pavement made of rubber chips is under development. It has a very high performance of reduction of tire/road noise but the remaining problems are the cost and the construction technique.

5 Road structures

Following the measures taken at the source, the measures for road structures and propagation process are also important. In Japan, it is general case that residential areas are very close to expressways and highways because of the incompletion of land-use policy. To prevent the influence of road traffic noise in such areas, various types of noise barriers are equipped. To improve their sound insulation performance, various contrivances including active control are made for the edge parts of the barriers [see Figure 9]. However, noise barriers are apt to destroy the scenery and sometimes cause sunlight disturbance.

Figure 9 – Various types of noise barriers used in Japan

As another measure to prevent road traffic noise, depressed or semi-underground road is sometimes constructed (see Figure 10).

Figure 11 shows an example of FDTD numerical study on the sound propagation from a semi-underground road, in which the effect of noise barrier and sound absorption treatment to the sidewalls were examined [9].

For general roads which have to be connected to access roads, noise barrier can not be applied. In these cases, urban design including buffer zone or buffer buildings should be planned.

Figure 10 – Semi-underground road (Joban expressway, Japan)

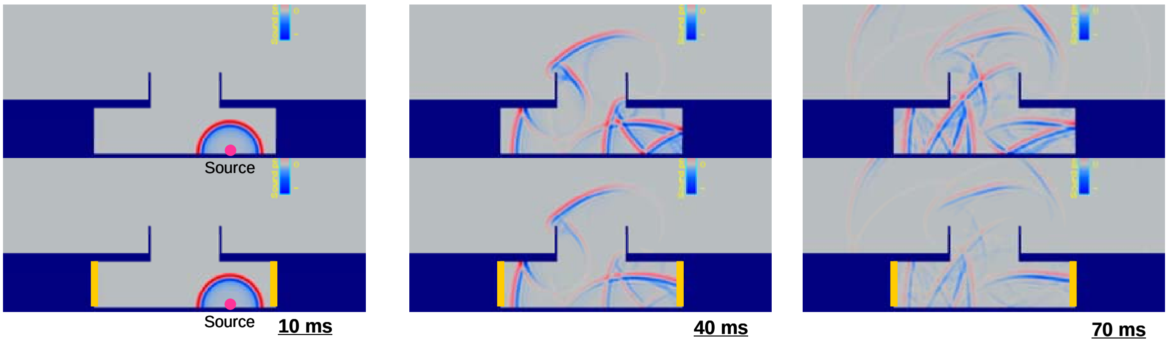


Figure 11 – FDTD calculation of noise propagation from a semi-underground road [9]

6 Roadside buildings (immission side)

In principle, road traffic noise should be reduced at the road side, but it is almost impossible to make sufficiently quiet in the areas just adjacent to roads. Therefore, buildings built in these areas should be provided with proper sound insulation performance. In the Japanese EQS for noise, the standard values for indoor noise for residential buildings facing to arterial roads are specified for the present, but regrettably any legal control or sound insulation certification system has not yet been enacted.

7 Noise monitoring

In the EU Member States, noise mapping is being made enthusiastically to set the action plan for the mitigation of community noises according to the EU Directive (2002/49/EC). In Japan, we have not such a systematic program at present but noise monitoring has been performed every year by the local governments according to the Noise Regulation Law. The measurement results are collected by the Ministry of the Environment and the statistical data regarding road traffic noise are published every year. Figure 12 shows an example of the data of 2008, which indicates the achievement rate of the EQS for various types of roads in Japan. In this result, it is seen that to achieve the EQS is relatively easy in the case of expressways but it is rather difficult in the case of general national roads because such measures as noise barriers is difficult to be applied to this kinds of roads.

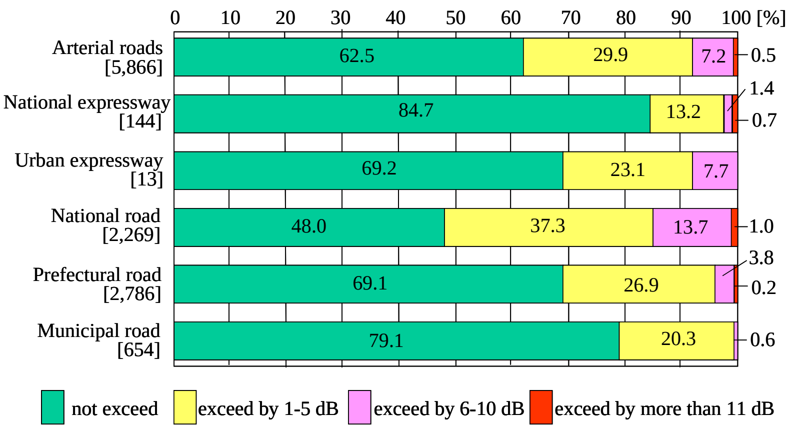
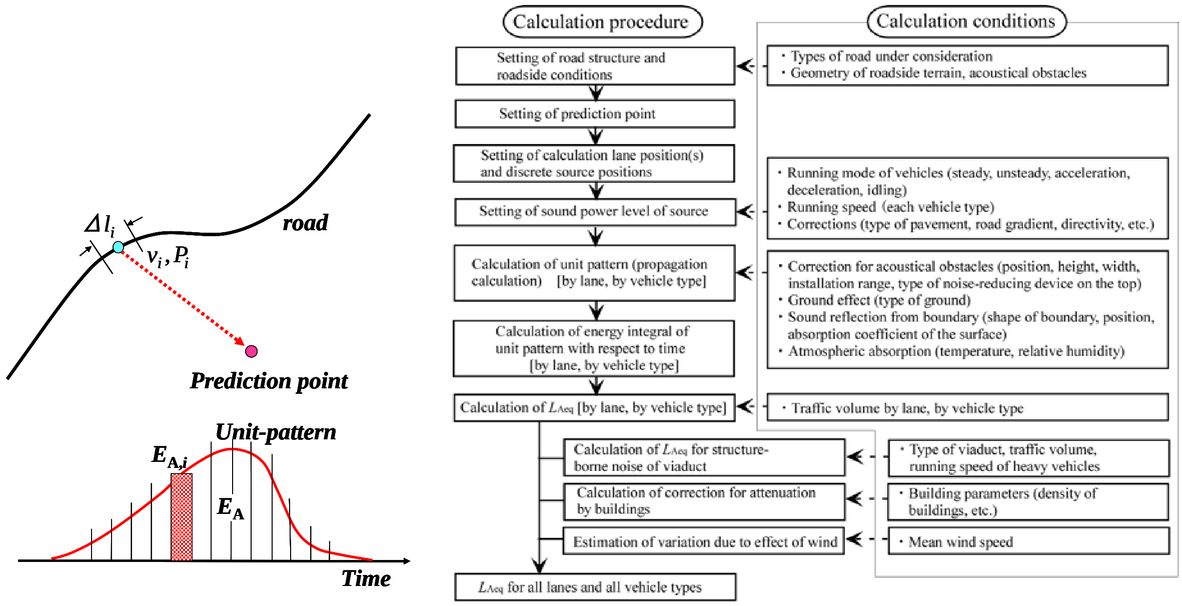


Figure 12 - Nighttime L_{Aeq} in the space adjacent to arterial roads, compared with the EQS value (65 dB) [2008 annual report from the Ministry of the Environment, Japan]

8 Noise impact assessment

To prevent serious influence on environment by large-scale developments, environmental impact assessment system is enacted in many countries. Also in Japan, the Environmental Impact Assessment Law was enacted in 1997 and when constructing expressways and highways with 4 lanes and length of more than 10 km, environmental impact assessment is mandatory. In this process, the EQS values shown in Table 1 are used as the noise criteria.
As the noise prediction model of traffic noises, the soft programs named “HARMONOISE” (2001-2995) and “IMAGINE” (2003-2006) have been developed according to EU Environmental Noise Directive and are being widely used in European countries. In Japan, the Acoustical Society of Japan has been developing a noise prediction model for road traffic noise from 1974 and the latest one “ASJ RTN-Model 2008” was published last year [10]. The principle of this model is very simple; the sound propagation from the discrete source points set on the hypothetical road under consideration to the prediction point is calculated by considering attenuation in distance, reflection, diffraction, ground effect and meteorological effects, and the unit-pattern of sound pressure is obtained (see Figure 13 (a)). By integrating it, the single event sound exposure level L_{AE} is calculated. From this result, the time averaged sound level L_{Aeq} is obtained by considering the traffic conditions, traffic volume and vehicle category ratio. The practical calculation flow is as shown in Figure 13 (b).



(a) Basic idea of calculation (b) Flow of the prediction calculation

Figure 13 – Road traffic noise prediction model “ASJ RTN-Model 2008” [10]

9 Conclusions

In this paper, the current situation of road traffic noise problem and technical and legislative measures against the problem have been reviewed. In order to further improve the noise situation, the following points should be considered in the future.
(1) Reduction of noise emission by motor vehicles and tires: A great deal of technical endeavor has been made to reduce the noise emission from motor vehicles and tires and it seems to be rather difficult to expect any innovative development in the future. Even hybrid and electric vehicles radiate high level of tire/road noise when running at high speeds. When

considering further noise reduction at the source, the basic performances of motor vehicles should be re-considered. Is it necessary that all motor vehicles have to have such a high performance of top speed of 250 km/h or more? If the top speed could be down to 130 km/h or so, the constraints in designing motor vehicles and tires would be much lessened and potential of noise reduction would much increase [2]. It may be consistent with traffic safety and the global climate change issue.

(2) Road pavements: Road pavement is one of the most important factors of road traffic noise emission together with motor vehicles and tires and “quiet pavements” have been being developed. The future problems regarding this matter are maintenance and sustainability of low-noise performance of porous asphalt pavement and further development of new types of quiet pavements like porous-elastic pavement.

(3) In-use vehicle problem: In spite of tightening emission regulations for motor vehicles and tires, the actual road traffic noise situation does not seem to be properly improved. This may be because old model vehicles and those equipped with various after-market products are still be in use. To resolve this problem, subsequent inspection of motor vehicles including tires should be institutionalized.

(4) Holistic scheme for the problem: To mitigate the road traffic noise problem, noise reduction at the source is essential, but measures in the noise propagation process, sound insulation of roadside buildings, land-use planning, and traffic flow management are also needed.

(5) Deepening general public’s awareness of quiet environment: Besides the technical developments, the drivers’ attitude is also very important. Recently, the word “echo-driving” has become popular according to the rise of global climate change issue and energy-saving, but the sense of preserving quiet environment seems to be rather weak in this slogan. It is very important to make people be conscious that motor vehicle is a very social tool and it can become antisocial to drive just for sport and fashion.

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