Impact Assessment of Motorway Traffic Noise Using Visualized Noise Mapping Technique

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Abstract: - The objective of this study is to analyze and assess the impact of traffic noise from newly expanded Bangkok-Chonburi Motorway, which links Bangkok-the capital of Thailand to Pattaya-the famous beach resort in the eastern seaboard of the country, with the utilization of visualized noise mapping technique in plan view and cross-section of this motorway. The newly expansion of main roadways of this motorway is to serve the higher demand of traffic flow on this highway section due to opening of the new Suvarnabhumi International Airport nearby this motorway. The high speed and higher volume on this motorway creates the higher traffic noise impact to the vicinity area around this motorway. Traffic noise data are collected on several locations along the side of motorway together with traffic characteristics in simultaneous basis. The physical dimensions of motorway are also measured. Motorway traffic noise model is then applied with all of the measured parameters in order to provide prediction results of traffic noise levels from this motorway, which shows a highly significant in the prediction results against the measured ones. This model is then used to estimate noise levels on the uniform grid platform around the study area for both in the plan view (horizontal plane) and cross-section (vertical plane) of the vicinity area around the motorway. From the analysis result, this newly expanded motorway create traffic noise level in Leq(1hr) index higher than the FHWA's standard level of 72 dBA and 67 dBA for office building and residential housing respectively at the location of right-of-way of this motorway. In order to build the office buildings or residential houses without any barrier and window protection, the safe building line should be located at about 75 m or 190 m respectively from the right-of-way of this motorway.

Key-Words: - Motorway, Visualized noise mapping, Traffic noise, Plan view, Cross-section, Noise prediction, Motorway noise model, Traffic noise on building, Noise impact.

1 Introduction

1.1 Background

Bangkok-Chonburi motorway was built to link Bangkok - the capital city to Pattaya - the famous beach resort on the eastern seaboard of Thailand.[12] Due to the opening of new Suvarnabhumi International Airport that locates nearby this motorway, the expansion of this motorway has been done in order to provide the service to the increasing in traffic demand on this highway section to and from this new airport. The high speed and the presently higher traffic volume on this motorway create a higher traffic noise impact to vicinity area around the corridor of this motorway.[4,8,12]

1.2 Objective

This study, therefore, aims at the investigation and assessment of traffic noise impact from this newly expanded motorway. Visualized noise mapping technique is developed in this study and used in the visual investigation of noise impact. This noise impact analysis is applied to both plan view and cross-section investigations of the expanded motorway section. The final analysis result of this study together with the conclusion remarks of the study work are presented in this paper.

1.3 Review of Related Works

Highway generally causes the traffic noise impact to the surrounding area.[4,8] So that highway that has the higher traffic volume and higher speed such as motorway creates even higher environmental noise impact to the vicinity area.[11,12,16] Several studies have been done in order to investigate the impact of this highway and road noise.[6,10,17,23] Some types of road traffic noise model and modeling technique are also suggested and presented.[14,15,16,18,21] Environmental noise study and investigation are used in many sustainable city planning for environmental friendly city and urban area.[3,7,22,24] Mapping technique is also used in some environmental qualities analysis and assessment.[1,9] Visualization technique has been applied to environmental issues and to aesthetic analysis with utilization of GIS and 3D virtual display.[2,13,25] Several environmental impacts to buildings are also investigated in many countries.[5,13]

2 Scope of the Study

2.1 Study Area

The newly expanded section of this motorway is used as a study site. The total length of this expanded motorway section is about 78.5 km starting from Srinakarin Road passing the new airport to end at km 78+525 in Ban Bung area of Chonburi province. The site of this expanded motorway section is shown in the area map as presented in **Figure 1**.

2.2 Data Collection

Traffic noise data are randomly collected along the side of this motorway. These data consist of traffic noise level, traffic characteristics, and physical condition of motorway. All of these data are collected in the simultaneous basis.

2.2.1 Traffic Noise data

Traffic noise is measured in Leq(1hr)-equivalent sound level in 1 hour period which is the average energy mean emission of noise in the measuring period of 1 hour. This traffic noise data are collected using precision sound level meters set on tri-pod with the height of 1.20 m from ground surface. These sound level meters are located randomly at the distances ≥ 1m further from the edge of near side frontage road. The noise data are also randomly collected based on time of the day basis in order to provide fully random data sets for this study.

2.2.2 Traffic Characteristics

Traffic characteristics in terms of volume with vehicular classification and average spot speed of each vehicle class are collected in the simultaneous basic with traffic noise collection.

2.2.3 Physical Dimension of Motorway

The physical dimensions of this motorway are measured in terms of number of lane, lane width, medium width, shoulder width and right-of-way width.[12,19]

The total of 200 data sets is collected in this study. All of these data are further used as the input parameters into traffic noise modal validation and analysis. The cross-sections of previous motorway and the motorway with newly expanded main roads are presented in **Figure 2** and **Figure 3** respectively.

3 Traffic Noise Prediction Modal of Motorway

The previously built and tested motorway traffic noise prediction modal which has been built and tested by Tansatcha, Pamanikabud, Brown and Affum is used for this study.[21] This model is mathematically descripted as the followings.

$$L_{eq}(1h),i = L_{eq}(10s),i + 10\log\left[\frac{D_0}{D}\right]^{1+\beta_{eff}} + 10\log N_i - 25.563 \quad (1)$$

and

$$\beta_{eff} = \frac{(\%Soft \times 0.5)}{100} \quad (2)$$

where $L_{eq}(1h),i$ is equivalent sound level of vehicle class i in 1 hour (dBA); $L_{eq}(10s),i$ is basic noise level of vehicle class i in equivalent sound level in 10 seconds (dBA)(as shown in **Table 1**); N_i is number of vehicles per hour in class i (veh); D is perpendicular distance from observer to the center line of the traffic lane (m); D_0 is reference distance at which the emission levels are measured (15 m); β_{eff} is ground effect adjustment; and i is classes of vehicle (1-8) (automobile, light truck, medium truck, heavy truck, full trailer, semi trailer, bus, and motorcycle).

Table 1 Basic Noise Model for Each Vehicle Type in $L_{eq}(10s)$

Vehicle	Basic Noise Model	Sample Size
Automobile	y = 4.158 log(x) + 61.460	315
Light Truck	y = 11.228 log(x) + 48.213	305
Medium Truck	y = 6.735 log(x) + 60.689	312
Heavy Truck	y = 8.061 log(x) + 59.818	311
Full Trailer	y = 2.959 log(x) + 69.981	300
Semi Trailer	y = 6.846 log(x) + 62.015	301
Bus	y = 10.204 log(x) + 54.973	300
Motorcycle	y = 7.691 log(x) + 60.294	300

where: y = noise level in L_{eq} in 10 sec time period-$L_{eq}(10s)$(dBA)
x = speed (km/h)

The noise levels generated by all types of vehicle i are then combined for each roadway. Then, the total hourly of traffic noise level from this motorway section that is perceived at each noise meter position are combined from the four roadways of this motorway which consists of two main roads and two frontage roads. This total hourly of traffic noise from the whole motorway section can be mathematical by described as follow.

$$L_{eq}(1h), total = 10 \log \left(\sum_{j=1}^{4} 10^{\frac{L_{eq}(1h), j}{10}} \right) \qquad (3)$$

where $L_{eq}(1h)$,total is total equivalent sound level in 1 hour of motorway at noise meter (dBA); $L_{eq}(1h)$,j is equivalent sound level in 1 hour for j^{th} roadway (dBA); and j is number of roadway on cross section of motorway (1-4)(near side frontage roadway-FN, near side main roadway-MN, far side main roadway-MF and far side frontage roadway-FF) as shown in the motorway cross-section.

This traffic noise modal was previously built from this motorway when it was firstly opened for traffic with the four lane divided main roadways.[12] At present, it is expanded into eight lane divided main roadways.[19] Therefore, the validation of this motorway noise modal with data collected from the newly expanded section is done in order to check the accuracy of this modal. The total of 193 data sets from the original 200 field observation data are used in the validation process. This is due to errors in some data sets that make them to be screened out and do not use for the final analysis.[19]

Paired t-test is used in this validation test of motorway traffic noise model.[11,12,14,16] The result from this test as presented in **Table 2** shows that this motorway noise modal can provide a highly significant in predicting traffic noise from this newly expanded motorway by giving the t-Stat value of 1.7867 that is within the t-Critical two-tail of ±1.9724 with the significant level $\propto$ = 0.05.[19] This motorway traffic noise modal is then used for further analysis of traffic noise on this newly expanded motorway section.

Table 2 Paired t-Test Results for Validation of Motorway Traffic Noise Model

	Measured	*Predicted*
Mean	82.7834	82.7197
Variance	1.1346	0.9678
Observations	193	193
Pearson Correlation	0.8860	
Mean Difference	0.0637	
Hypothesized Mean Difference	0	
df	192	
t Stat	1.7867	
P(T<=t) two-tail	0.0756	
t Critical two-tail	±1.9724	

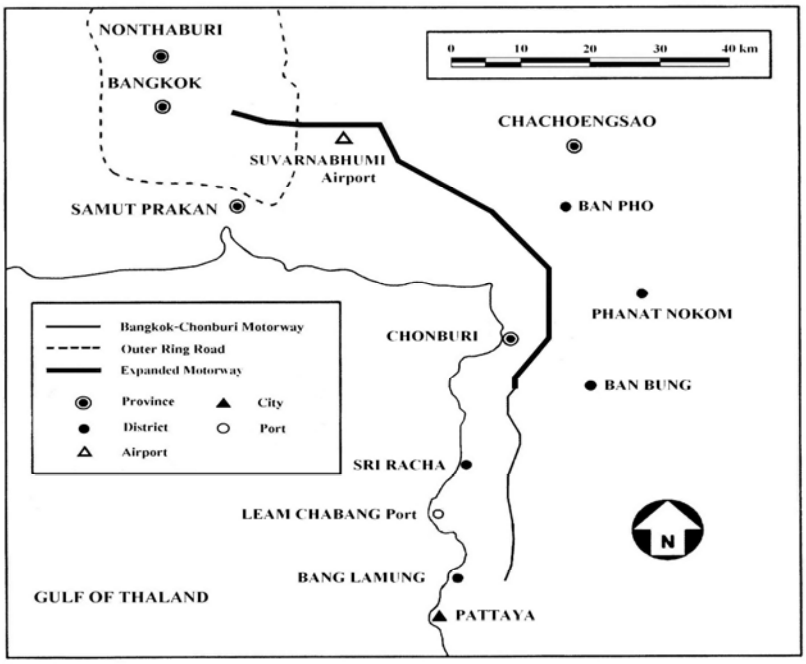

Fig. 1 Site of Newly Expanded Bangkok-Chonburi Motorway Section

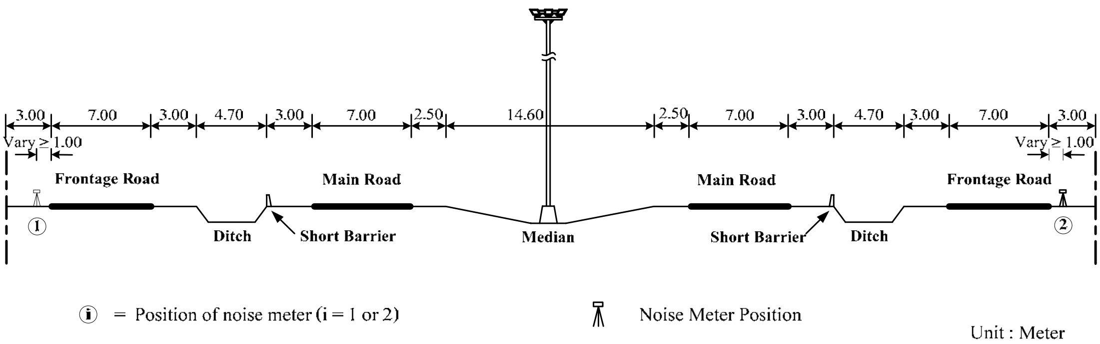

Fig. 2 Previous Bangkok-Chonburi Motorway Cross-sections

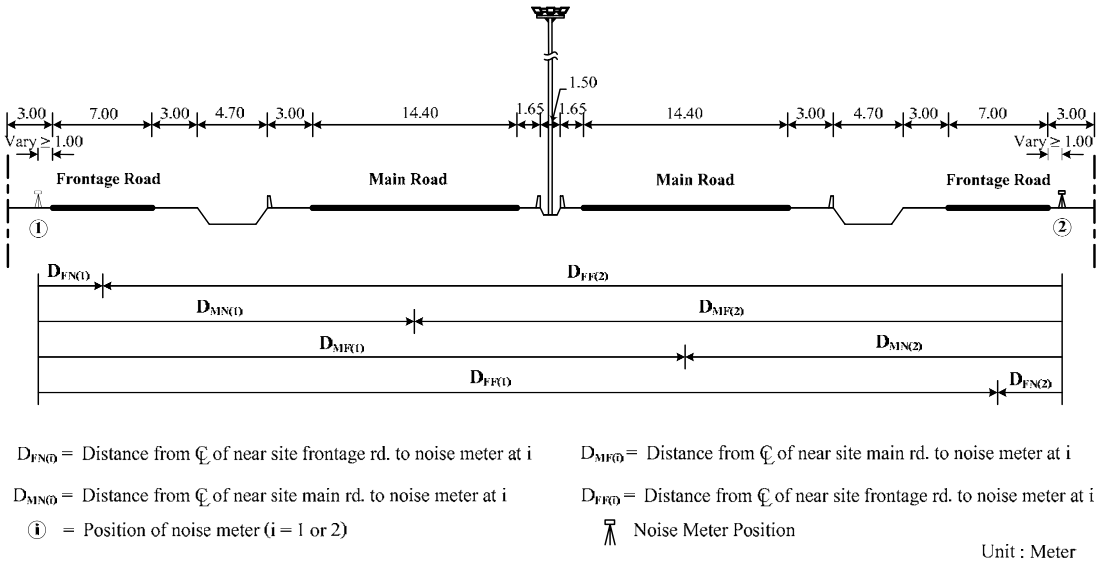

Fig. 3 New Bangkok-Chonburi Motorway Cross-sections with Newly Expanded Main Roadways

4 Plan View and Cross-sectional Analysis of Motorway Noise with Visualized Noise Mapping

4.1 Mapping of Area in Between Right-of-Way

Traffic noise levels are calculated by using the validated motorway traffic noise modal for perceived locations in the uniform grid system of 2m x 2m in the vicinity around the motorway for both plan view (horizontal plane) and the cross-section (vertical plane). The noise mapping by visualization of traffic noise with noise contour in order to transform the invisible traffic noise into the visible one is then performed.[13]

The noise data that have been analyzed in the uniform grid system are input into the QuikGrid program.[20] Traffic noise mapping in the form of noise contours are then plotted on the studied area based on these input data. Color shades based on noise level can also be applied to enhance this noise contour mapping.

This visualized traffic noise mapping analysis is applied to both the plan view and cross-section of the motorway. In this study, the morning peak hour period (8:00 am - 9:00 am) is used in the investigation due to the highest noise level generated by its highest hourly volume.

The visualized noise mapping in plan view for the morning peaks hour is shown in **Figure 4**. The cross-section noise mapping of the same peak hour period is also presented in **Figure 5**.

4.2 Mapping of Vicinity Area Further from Right-of-Way

In order to investigate impact of traffic noise into the vicinity area further from the R-O-W of motorway, noise mapping analysis done to cover the analytical distance of about 360 m far from the R-O-W in both directions. Traffic noises from this motorway are calculated on the uniform grid base.

This data base is then input into the QuikGrid program in order to plot the traffic noise contour map with color enhancement of the vicinity area. This analysis is done for both on the plan view and cross-section of motorway. Traffic characteristics during the morning peak hour period (8:00 am - 9:00 am) of this motorway section which create the highest noise level are used for this analysis.

The result of this visualized noise mapping on plan view for one side of the motorway that has the maximum traffic volume in the morning peak hour period is shown in **Figure 6**, and the visualized noise mapping in the cross-section for the same time period is shown in **Figure 7**.

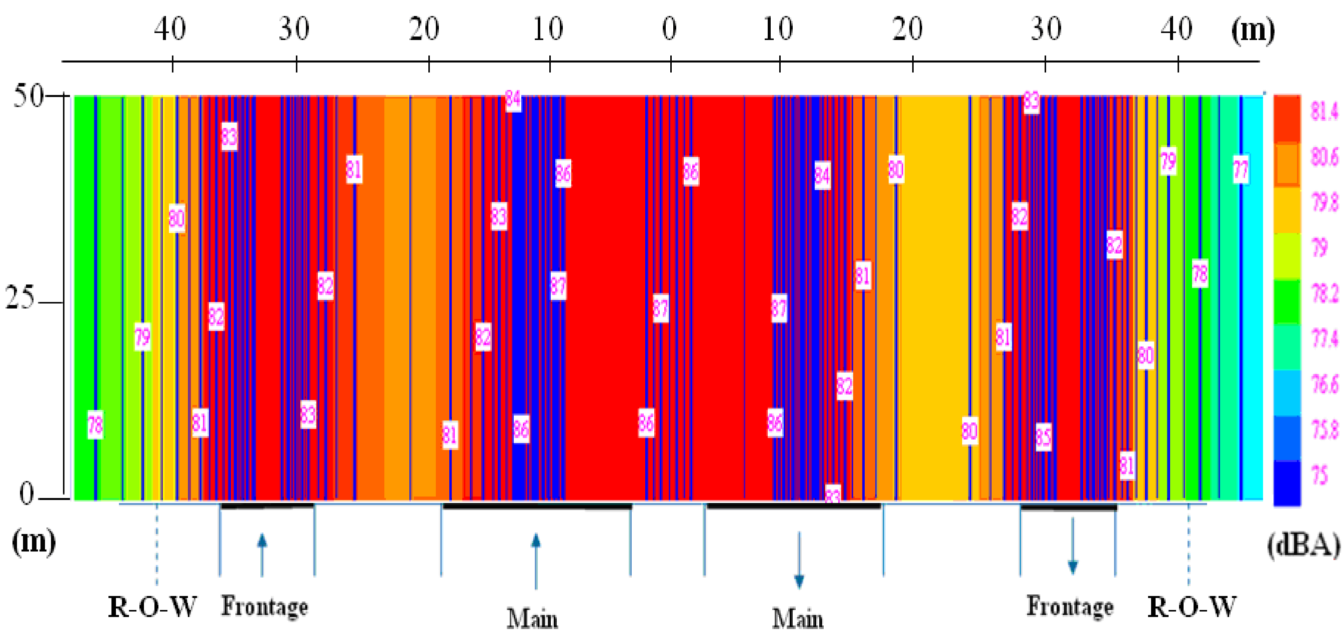

Fig. 4 Visualized Noise Mappings in Plan View of Motorway for Morning Peak Hour in Area between R-O-W

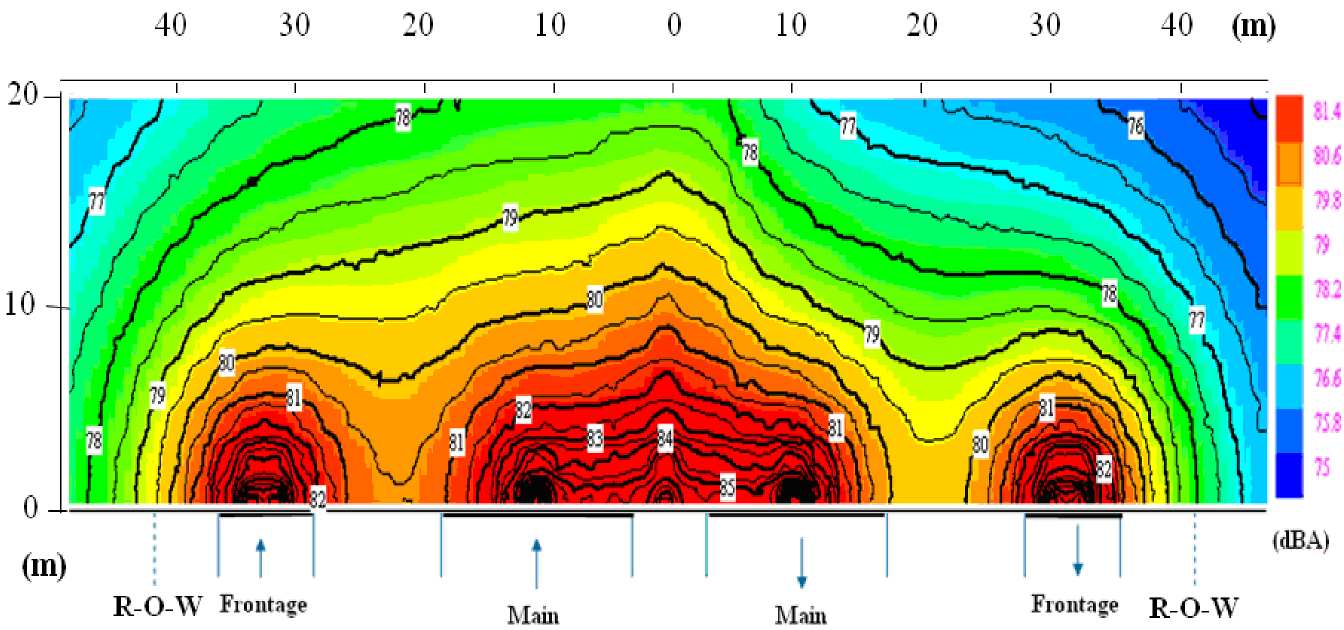

Fig. 5 Visualized Noise Mappings in Cross-section of Motorway for Morning Peak Hour in Area between R-O-W

5. Impact Analysis of Traffic Noise

Impact from traffic noise of this motorway is investigated from of these plan view and cross-section noise mappings by based on the maximum noise levels that occur in the interested locations in the vicinity area around this motorway.

5.1 Traffic Noise Impact at Location of R-O-W

From the noise mappings in **Figure 4** and **Figure 5**, the maximum traffic noise levels at the location of right-of-way of motorway are 79.5 dBA. This noise level is higher than the Federal Highway Administration (FHWA) of USA for highway noise standard of Leq(1hr) of 67 dBA and 72 dBA for land use in the category of residential housing and office building respectively.

This means that the motorway traffic noise is harmful to the health of people to live or stay in either residential houses or office buildings at this location without any traffic noise protection to their houses or office buildings. The FHWA highway noise standard that is used for this study is shown in **Table 3**.[24]

5.2 Traffic Noise Impact further from the R-O-W

Investigation is also given to see how far that traffic noise can create an impact to the vicinity area further from the R-O-W of this motorway. For residential housing and office building to be built by the side of this motorway without any noise barrier wall along the side of this motorway or any other noise protection on the windows and doors of houses and buildings, the safe building line should be located at the distances of about 190 m for residential house and 75 m for office building far from the R-O-W of this motorway, as the result analyzed from the visualized noise mapping in **Figure 6** and **Figure 7** respectively.

5.3 Traffic Noise Impact on High Rise Building

In order to use the height of building as a mitigation measure for traffic noise control or prevention, such as the case of constructing a high rise building at a set back distance of 10 m from the R-O-W without noise barrier along the motorway and without any other window protection on this building.

Traffic noise can create an impact from ground level up to the heights of about 99 m, if this building is going to be built for the office building. If this building is going to be used for residential building, this height is estimated to be about 192 m from ground surface. So that it is not practical and improper to utilize the building height for traffic noise control from this very noisy motorway.

5.4 Mitigation Measures

Therefore, in order to provide a harmonized living of people around this Bangkok-Chonburi motorway, the proper noise barrier of certain designs are supposed to be built along the side of this motorway to protect people who live on low level houses or office building near the motorway.

At the same time, providing some types of window protection such as glass window or double glazing window on the high rise buildings by basing on the proper type of proposed future land uses zoning in the vicinity area along this motorway.

Table 3 FHWA Highway Noise Standard

Noise Abatement Criteria (NAC)
Hourly A-Weighted Sound Level - decibels (dBA)*

Activity Category	Leq(1h)	L_{10}(1h)	Description of Activity Category
A	57 (Exterior)	60 (Exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (Exterior)	70 (Exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	72 (Exterior)	75 (Exterior)	Developed lands, properties, or activities not included in Categories A or B above.
D	--	--	Undeveloped lands.
E	52 (Interior)	55 (Interior)	Residences, motels, hotels, public meeting rooms, schools, churches, libraries, hospitals, and auditoriums.

*** Either Leq(1h) or L_{10}(1h) (but not both) may be used on a project**

Leq(1h) is Equivalent Sound Pressure Level in 1 hour measuring time period (or average energy mean emission level in the measuring period)

L_{10}(1h) is noise level that exceeds 10% of time in 1 hour measuring time period (or peak noise level in the measuring period)

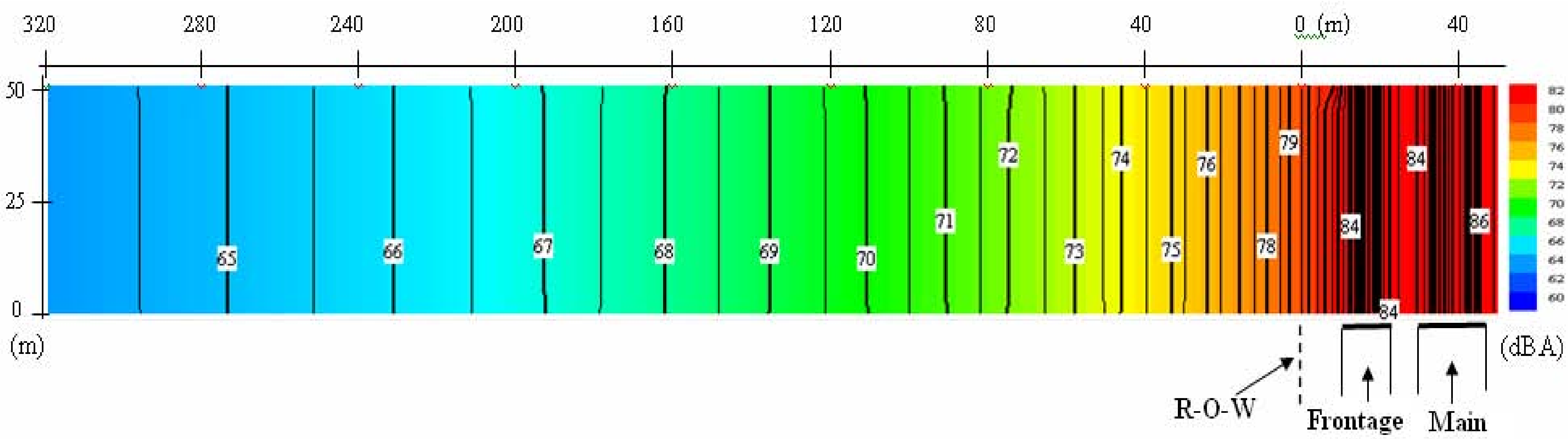

Fig. 6 Visualized Noise Mappings in Plan View of Motorway for Morning Peak Hour in Vicinity Area Further from R-O-W

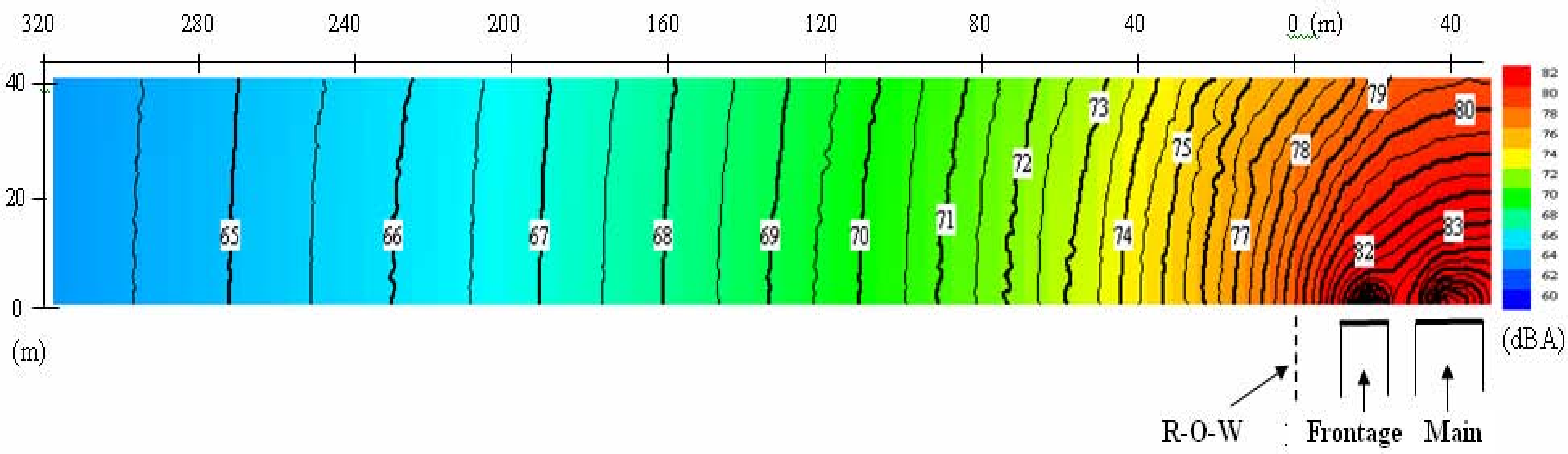

Fig. 7 Visualized Noise Mappings in Cross-section of Motorway for Morning Peak Hour in Vicinity Area Further from R-O-W

6. Conclusion

Several conclusion remarks can be drawn from this study as the followings.

This study shows that the newly expanded Bangkok-Chonburi motorway causes a highly traffic noise impact to the vicinity area around this motorway.

Visualized traffic noise mapping analysis on both plan view and cross-section of this motorway identified that noise level at the R-O-W location is 79.5 dBA in Leq(1hr) and it is higher than the FHWA's standard highway noise of 72 dBA and 67 dBA for office building and residential housing respectively.

Without noise barrier or window protection, the health safety building line for office building and residential housing can be located only at the distance of 75 m and 190 m further from the R-O-W of this motorway. The result from this study also shows that height of building is un-practical and improper to be used for noise control from this motorway.

In order to provide the health safety for people to live in harmony by the side of this motorway, some types of noise barrier wall are expected to be built along this motorway section together with certain types of window protections should be proposed for high rise building along the side of this motorway basing on the proper land use zoning to be proposed in the future for the vicinity area of this motorway corridor.

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