Buffer distances for surface roads and elevated highways correlated with pre-existing ambient noise

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ABSTRACT
The guidelines for environmental impact assessment (EIA) in China prescribe a buffer zone - consisting in reserved land or compatible uses -on both sides of noisy roads. However, many EIA reports typically only include predictions and assessment of the traffic noise levels due to the concerned road only. The pre-existing ambient environmental noise levels are then overlooked which may result in under-estimating the resulting noise levels and in buffer distances that are too short. Moreover, in the specific case of viaducts or elevated roads, consideration should be given to extend the concept in the vertical direction as well as the horizontal direction. Based on 3D mathematical modeling by means of proprietary software and typical input traffic data, several road situations are assessed and discussed here. These include surface urban road (e.g. arterial and access roads) and elevated highways passing through different land uses with specific pre-existing noise environments. These examples are used to determine and review the distribution of buffer zones and their boundaries. Results from this review can apply to EIA for road projects and their optimization.

Keywords: Highway vehicles:13.2;Road traffic noise:52.3;Ordinances, including zoning requirements:85Background or ambient noise (baseline):68.1;Noise control planning; sitting issues and zoning:68.7.

1. INTRODUCTION

The guidelines for environmental impact assessment (EIA) in China (1) prescribe a buffer zone - consisting in reserved land or compatible uses -on both sides of noisy roads. However, many EIA reports typically only include predictions and assessment of the traffic noise levels due to the concerned road only. The pre-existing ambient environmental noise levels are then overlooked which may result in under-estimating the resulting noise levels and in buffer distances that are too short. Moreover, in the specific case of viaducts or elevated roads, consideration should be given to extend the concept in the vertical direction as well as the horizontal direction.

3D noise modeling was conducted for twelve case studies for typical road types (six national or provincial highways and six urban roads). This exercise provided an insight into the noise emissions in the horizontal and the vertical plane, and the resulting noise levels when the pre-existing background noise is taking into account. A critical distance was then determined as the minimum distance for which compliance to a nighttime noise criterion is achieved. The influence of the pre-existing noise levels and of noise shielding by noise barriers or building along the road was also investigated.

After recalling the road nomenclature in China and introducing the twelve case studies, the results of the modeling exercise are presented in the form of cross-sectional noise maps. The practicability of establishing buffer zones is then discussed.

While this concept is not new, the authors consider that it is important to emphasize the opportunities adequate planning can provide to address traffic noise for typical situations, relevant to the road network in China.

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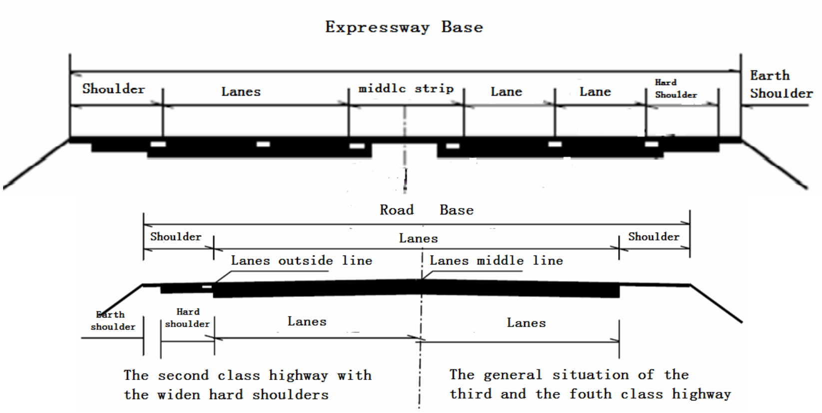
2. CROSSSECTIONS OF HIGHWAYS AND URBAN ROADS IN CHINA

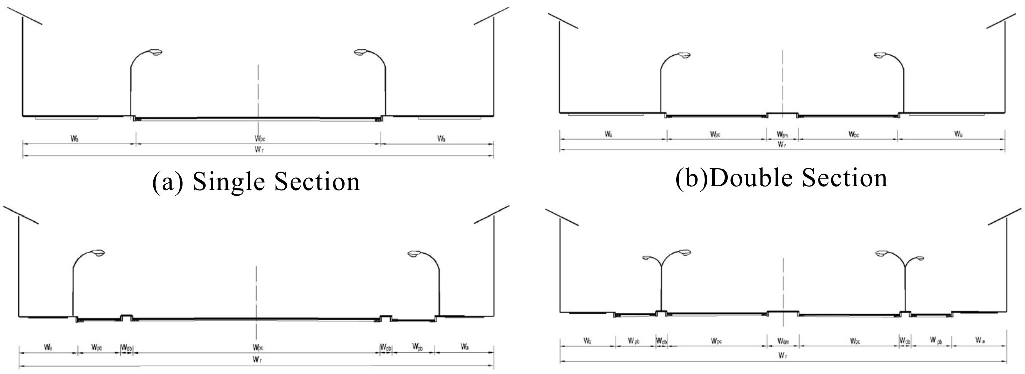
The nomenclature applicable to most roads in China is detailed in Table 1 (2, 3). The two main groups are Highways freeways and urban roads. Highways include expressways and national or provincial highways ranked in four classes (Class 1~4). Typical cross-sections are given in Figure 1. Sub-groups for urban roads include freeways/elevated freeways, arterial roads, collectors and local roads. Different cross-sections applicable to urban roads are shown in Figure 2.



Typical cross section for Expressway and Class 1 highway

Typical cross section for Class 2 to Class 4 Highway

Figure 1 -Expressway and Highway cross sections (2)



(a) Single Section (b)Double Section

(c) Triple Section (d) Quadruple Section

Figure 2-Cross section of urban roads (3)

3. CASE STUDIES FOR BUFFER DISTANCE

3.1 Case studies

Several typical scenarios, based on actual road projects, were selected to investigate the distribution of noise levels in the vertical and in the horizontal plane. The case studies included the following highway types: a typical surface expressway, an elevated expressway over a surface expressway, three instances of national or provincial highways (Class 1~3). Urban roads selected included an urban freeway, an elevated freeway over an arterial road, a collector and two local roads. For all cases, consideration was given to the pre-existing noise environment and to potential shielding by noise barriers or by a first row of buildings. Details of these case studies are given in Table 2.

3.2 Noise modeling

Cross sectional noise contour maps were generated for each road investigated. The distribution of noise levels predicted using proprietary software Cadna A in the horizontal and vertical plane are given in Table 2. An assessment was also conducted to determine a *critical distance* defined as the minimum distance from the road to comply to the criterion of 50 dB L_{night} ($L_{Aeq-night}$) for a noise sensitive receptor located at height 4 m above the ground, representative of the second floor of a residential building.

The inputs to the 3D noise model are detailed in Table 2, abbreviations P, M and H in the description of traffic volumes stand out for Passenger cars, Medium trucks and Heavy trucks, respectively. Safety barriers on viaducts were modeled with a height of 0.9 m, and all noise barriers were assumed to have a height of 3.5m.

The noise contour maps are shown in Table 3. This table also reports the critical distance determined based on the noise emissions from the road only, on the combination of road traffic noise and pre-existing background noise and on the noise levels resulting from the combination of background noise level and mitigated traffic noise levels when noise barriers or buildings are located along the road.

4. RESULTS

4.1 Expressways (Cases H.1 & H.2)

With high traffic volumes and an important proportion of trucks in the traffic composition, high noise levels and large critical distances were observed for expressways. For the surface expressway (Case H.1), the 50 dB L_{night} criterion was found to be met 348 m away from the expressway when only the noise from this road is considered. When combined to the pre-existing background noise (43.4 dB), this distance increased to 385 m. There was some benefit in mitigating road traffic noise by means of noise barriers, resulting in a critical distance of 215 m. With such large distance the practicability of establishing a buffer zone to address road traffic noise is obviously disputable.

The situation for two superimposed expressways, investigated in Case H.2 was even more severe, with critical distance exceeding 500 m even when noise barriers were considered for the elevated freeway.

4.2 National or provincial Highways (Cases H.3 to H.6)

With lower traffic volumes, noise levels from Class 1 to Class 3 highways investigated in Cases H.3 to H.6 were significantly lower than those due to expressways. However, a greater sensitivity to the pre-existing background noise levels resulted from these lower traffic noise level. This was particularly noticeable for Case H.3 (Class 1 Highway) and Case H.5 (Class 2 Highway) for which the critical distance increased by 37 m and 80 m respectively for pre-existing background noise levels in the range 44~47 dB. High background noise levels also resulted in a lower effectiveness of noise barriers to reduce the depth of buffer zones: despite the introduction of noise barriers for Case H.3, the critical distance still remained 100 m. (Noise barriers were not investigated for Case H.5 since it is a typical case of an open boulevard type road for which the installation of noise barrier is not a practical noise mitigation measure)

In comparison, the increase in critical distance was only 10 m for Case H.4 (Class 1 Highway) for which the pre-existing background noise level was 38 dB. For this case, roadside noise barriers allowed to achieve compliance to the 50 dB criterion at a distance of 15 m only.

With low traffic volumes and speed, the noise emissions of the Class 3 Highway in Case H.6 were lower than for the other highways investigated, resulting in a relatively short critical distance, in despite of the selection of a noisy road surface (cement concrete). With a pre-existing background noise level of 42 dB the critical distance was found to be 39 m. Establishing a buffer zone to address road traffic noise can be practical in such case.

4.3 Urban freeways (Cases U.1 & U.2)

With high traffic volumes, the noise impact from these roads is comparable to that from highways or even expressways. As discussed in 4.1, the erection of noise barriers would have limited effectiveness in reducing the critical distance. Nevertheless, the investigations for Cases U.1 and U.2 showed that in the presence along the road of a row of (non-noise sensitive) buildings of some height (three or more storey, U.1 only buildings and U2 with buildings and Wall both), this distance could be reduced to 30 m.

4.4 Arterial roads (Case U.3)

This common type of urban road carries high traffic volumes, resulting in high noise emissions and large buffer distances. Moreover, their urban sitting results in high pre-existing ambient noise levels, which limits the opportunities in making use of buffer zones (346 m was determined for the road in Case U.3). A first row of non-noise sensitive buildings along the road is again of significant benefit and can allow compliance to the 50 dB L_{night} criterion. Such arrangement used to be common in Chinese cities in the past, but is becoming rare since newer cities are designed to accommodate dense populations as well as an increasing number of private cars.

4.5 Collectors (Case U.4)

Collectors are similar to arterials roads, but carry somewhat lower traffic volumes, which results in lower noise emissions. This also results in a higher sensitivity to pre-existing background noise. For Case U.4, the critical distance increased from 102 m to 159 m when a background noise level of 42 dB was taken into account. A first row of non-noise sensitive building along the road would again allow for compliance to the criterion.

4.6 Local roads (Cases U.5 & U.6)

Traffic volumes are typically limited on these roads which are essentially used for local trips. This results in a relatively moderate noise impact. The introduction of buffer zones can be a practicable measure to address road traffic noise. Nevertheless, careful consideration should be given to the pre-existing background noise levels.

5. DISCUSSIONS

Cross-sectional noise contour maps were established for a number of typical road configurations in China. For each case study, the noise impact was investigated taking the pre-existing background noise level into account. Additionally the benefits introduced by noise barriers or by a first row of building was also given consideration.

For roads with high traffic volumes (expressways, freeways, arterial roads), a nighttime noise criterion of 50 dB L_{night} would only be achieved at distances in the order of several hundred meters away from the road. The establishment of a noise buffer zone would then not be a practical solution to address road traffic noise. Alternative measures, such as architectural sound insulation (e.g. window retrofitting) or relocation of noise-sensitive buildings, are usually preferred. A relatively short buffer zone could nevertheless be considered when effective noise barriers are erected, or when a first row of non-noise sensitive buildings provides shielding to sensitive uses located behind. As a matter of fact, land reservation and arrangement of compatible uses are planning tools that can effectively influence the size of buffer zones. Adequate planning is instrumental to the mitigation of road traffic noise impacts. A particularly interesting illustration of the effective establishment of a buffer zone along a high traffic volume road is given in reference (5).

For roads with lower traffic volumes (Class 3 highways, local roads), compliance to noise criteria can generally be achieved at a relatively short distance from the road, providing the opportunity to establish a buffer zone.

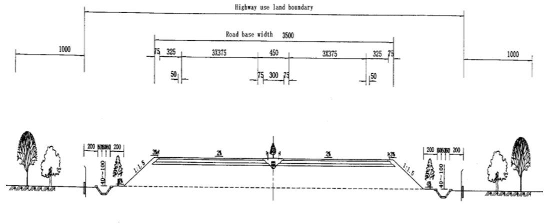
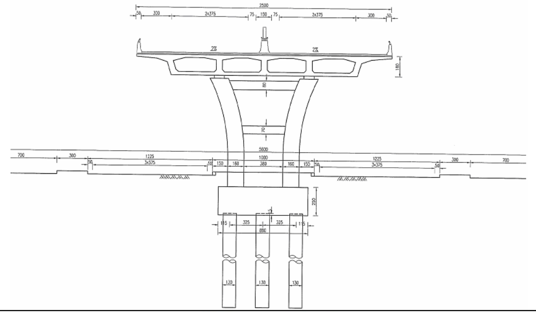
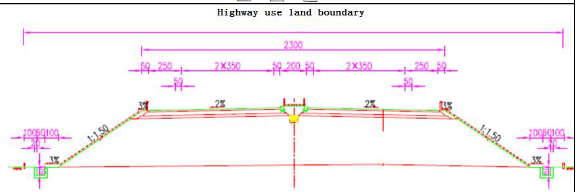
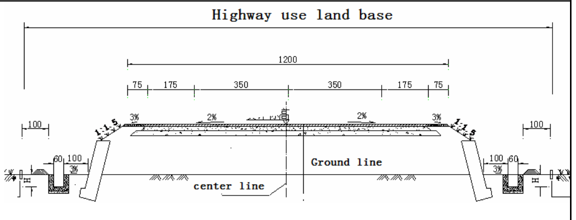
Table 1 - Road nomenclature in China

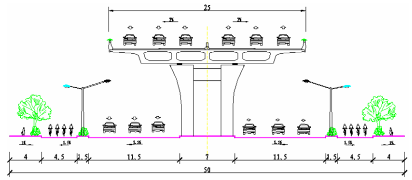
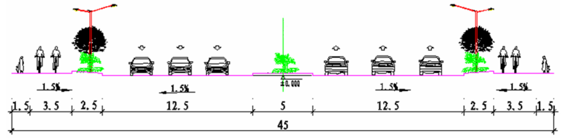
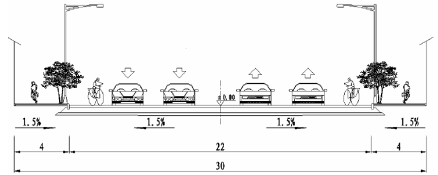
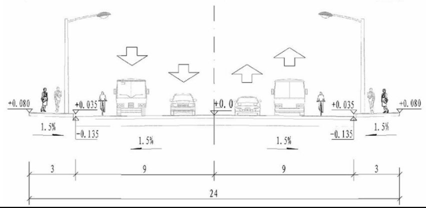
Ref. Standard	Road type	Lanes	Design life (yr)	Speed km/h	Annual average daily traffic, pcu/d	basic/design traffic volume , pcu/h/ln	Single lane width, in m	Center Lane separator/Left curb/middle trip width, in m	Right hard shoulder/earth shoulder width, in m	Total width of road bed, m	Road* pavement
JTG B01(1): High -way	Express -way	4	20	120	40000~55000	2200/1600	3.75	3/0.75/4.5	3.5/0.75	28	①、②
				100	35000~50000	2100/1400	3.75	2/0.75/3.5	3/0.75	26	
				80	25000~45000	2000/1200	3.75	2/0.5/3.5	2.5/0.75	24.5	
		6	20	120	55000~80000	2200/1600	3.75	3/0.75/4.5	3.5/0.75	34.5	
				100	50000~70000	2100/1400	3.75	2/0.75/3.5	3/0.75	33.5	
				80	45000~60000	2000/1200	3.75	2/0.5/3.5	2.5/0.75	32	
		8	20	120	80000~100000	2200/1600	3.75	3/0.75/4.5	3.5/0.75	45	
				100	70000~90000	2100/1400	3.75	2/0.75/3.5	3/0.75	44	
				80	60000~80000	2000/1200	3.75	2/0.5/3.5	2.5/0.75	--	
	Class 1 Highway	4	15	100	27000~30000	1400/850~1000	3.75	2/0.75/3.5	3/0.75	26	
				80	20000~27000	1200/700~900	3.75	2/0.5/3	2.5/0.75	24.5	
				60	15000~25000	900/550~700	3.5	2/0.5/3	2.5/0.5	23	
		6	15	100	30000~55000	1400/850~1000	3.75	2/0.75/3.5	3/0.75	33.5	
				80	27000~45000	1200/700~900	3.75	2/0.5/3	2.5/0.75	32	
				60	25000~35000	900/550~700	3.5	2/0.5/3	2.5/0.5	--	
	Class 2 Highway	2	15	80	5000~15000	2500/550~1600	3.75	--	1.5/0.75	12	
				60	5000~15000	1400/550~1600	3.5	--	0.75/0.75	10	
	Class 3 Highway	2	15	40	2000~6000	1300/400~700	3.5	--	--/0.75	8.5	
				30	2000~6000	1200/400~700	3.25	--	--/0.5	7.5	①、②、③
	Class 4 Highway	2	-	20	<2000	<1200/<400	3.0	--	-/0.25	6.5	①、②、③、④
		1	-	20	<2000	<1200/<400	3.5	--	--/0.5	4.5	
CJJ37–2012(2): Urban Road	Transit Freeway	4	15/30	100	40000~80 000	2200/2000	3.5~3.75	2/ /3	1.5/ /2.5		①、②
		6	15/30	100	60000~120 000	2200/2000	3.5~3.75	2/ /3	1.5/ /2.5		
		8	15/30	100	100000~160 000	2200/2000	3.5~3.75	2/ /3	1.5/ /2.5		
			15/30	80	102 000	2100/1280~1750	3.5~3.75	2/ /3	1.5/ /2.5		
		4	15/30	60	39 600	1800/990~1400	3.25~3.5	2/ /3	1.5/ /2.5		
		6	15/30	60	59400	1800/990~1400	3.25~3.5	2/ /3	1.5/ /2.5		
	Elevated freeway	6~8	15/30	80~100	120000~160000	2100/1280~1750	3.5~3.75				
		4~6	15/30	60~80	40000~120000	1800/990~1400	3.25~3.5				
		1~2	15/30	40~50	1300/400~700	1300/400~700					
	Arterial road	2~6	15/30	60		1800/1400	3.25~3.5	2/ /3	1.5/ /2.5		
			15/30	50		1700/1350	3.25~3.5	1.5/ /2	1.5/ /2		
			15/30	40		1650/1300	3.25~3.5	1.5/ /2	1.5/ /2		
	Collector road	2~4	10/20	50		1700/1350	3.25~3.5	1.5/ /2	1.5/ /2		
				40		1650/1300	3.25~3.5	1.5/ /2	1.5/ /2		
				30		1600/1300	3.25~3.5	1.5/ /2	1.5/ /2		
	Local road	1~2	8~10/15	40		1650/1300	3.25~3.5	1.5/ /2	1.5/ /2		①、②、③、④
				30		1600/1300	3.25~3.5	1.5/ /2	1.5/ /2		
				20		1400/1100	3.25~3.5	1.5/ /2	1.5/ /2		

*Highway surface pavement types:① asphalt concrete；② cement concrete；③ stone mastic asphalt, exposed aggregate/drag treated surfaces; ④ gravel pavement.

**Urban road pavement structure：①asphalt concrete; ②cement concrete；③stone mastic asphalt and slurry seals；④concrete blocks.

Table 2 - Case studies for noise modeling

Case	Type	Original project	Engineering parameters						Pre-existing noise levels L_{day} / L_{night}	Cross section drawings
			Lanes	Design life	Speed, km/h	Average Annual Traffic，v/h	Width, m	Height, m		
H.1	Express way	A generic across-province expressway	6	2008 ~ 2030	120	2015:38374pcu/d 25081v/h (67%P+24%M+9%H) Ratio Day/night=85%	35/	4	49.0/ 43.4	
H.2		Elevated expressway over a surface expressway	Elevated 4	2015 ~ 2034	100	Elevated; 2025: 38998pcu/d Day:1498v/h (1052P+210M+236H) Night: 510v/h (234P+74M+202H)	25	8.5~10 average 9	44.1/ 42.1	
			Surface 6		80	Surface; 2025 Day: 1378 v/h (968P+193M+217H) Night: 469v/h (215P+68M+186H)	34.5	0		
H.3	Class 1 High -way	Highway in a highway net	4	2011 ~ 2024	60 (P\M:48 H:39)	2017: Day:602v/h (372P+174M+56H) Night:173v/h (95P+64M+15H)	23	4	56.3/ 43.8	
H.4		Provincial level highway	4	2014 ~ 2033	80km/h	2020: Day:803 v/h (85%P+10%M+5%H), Night178 v/h(86%P+8%M+6%H)	24.5	2	49.0/ 38.4	Road base 24.5m=Vehicle lanes 2×2×3.75m+left & right road sides 2×0.5m+center strip2.0m+hard shoulders 2×2.5m+earth shouldes2×0.75m
H.5	Class 2 High -way	A highway connecting two expressway s	2	2014 ~ 2028	60	2020:7956pcu/d: Day: 209P+22M+86H Night: 84P+9M+34H	12	3.5	51.1/ 47.1	

Case	Type	Original project	Engineering parameters						Pre-existing noise levels L_{day} / L_{night}	Cross section drawings
			Lanes	Design life	Speed, km/h	Average Annual Traffic，v/h	Width, m	Height, m		
H.6	Class 3 High-way	An highway alteration	2	2015 ~ 2029	30	2021:2543pcu/d Day: 119v/h (88P+22M+8H) Night: 42v/h (31P+8M+3H)	7.5、6.5	0	48.7/ 41.9	road base 7.5m and vehicle lanes 6.5m with cement concrete pavement
U.1	Urban free-way	An urban ring road	8	2006 ~ 2021	80	2012:day:1654 v/h (90%P+10%(H+M)) Night:584 v/h (80%P+10%(M+H))	80/ (2×16）4	0	49.2/ 42.5	80.0 m=5.0 m (walker lane) +6.0m (non-vehicle lane) +8.0 m (green strip) +16.0 m (vehicle lane) +10.0 m (middle strip) +16.0 m (vehicle lane) +8.0 m (green strip) +6.0 m (non-vehicle lane) +5.0 (walker lane)
U.2	Elevat -ed free -way	Elevated freeway over an arterial road	Freeway 6	2015 ~ 2029	Freeway 80	Freeway : 2021 : Day 2859v/h(100%P) Night 715v/h (100%P)	Freeway 25	15	53.7/ 46.6	
			Arterial 6		Arterial 50	Arterial : 2021 ; Day 1610 (73%P+12%M+15%H) Night : 402 (72%P+20%M+8%H)	Arterial 50	0		
U.3	Arterial road	Arterial road	6	2014 ~ 2020	50~60	2020: Day:1370v/h (1050P+300M+20H) Night:710v/h (500P+200M+10H)	45/30	0	55.5/ 48.3	
U.4	Collect -or road	Collector road	2~4	2012 ~ 2027	40	2019 17653pcu Day:938v/h (65%P+25%M+10%H), Night: 331v/h (80%P+15%M+5%H)	30/22	0	53/ 41.6	
U.5	Local road	Local road	2	2014 ~ 2026	30	2023 1036pcu/d: Day:67v/h (100%P) Night:7 v/h (100%P)	7/12	0	52/ 49.1	12m=2.5m（pedestrian）+7m（vehicle lane）+2.5m（pedestrian）
U.6	Local road	Urban branch road	2~4	2016 ~ 2030	30	202 2447pcu/d Day:138v/h Night:31v/h P95%、M5%、H0%	18/24	0	52.9/ 46.3	

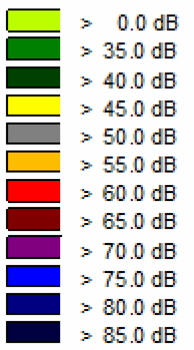
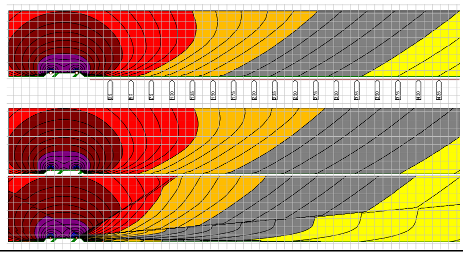
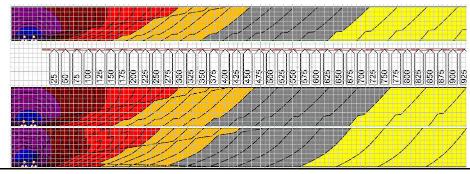
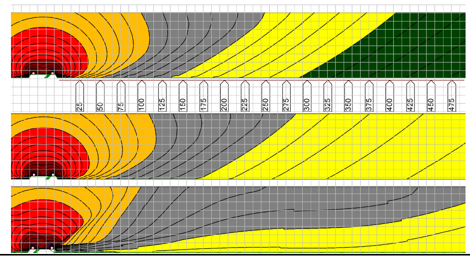
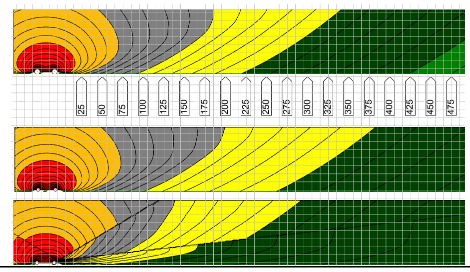
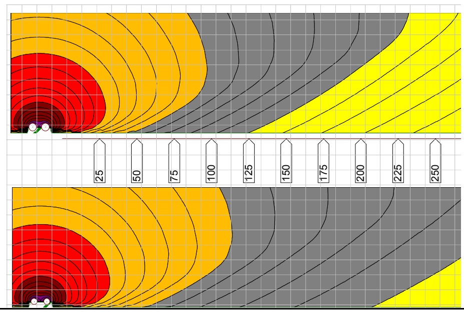
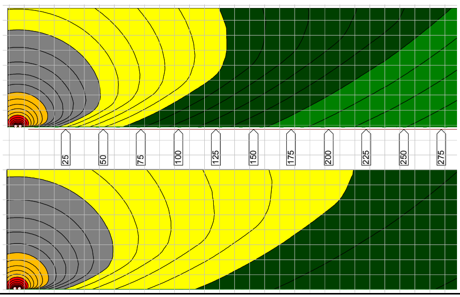
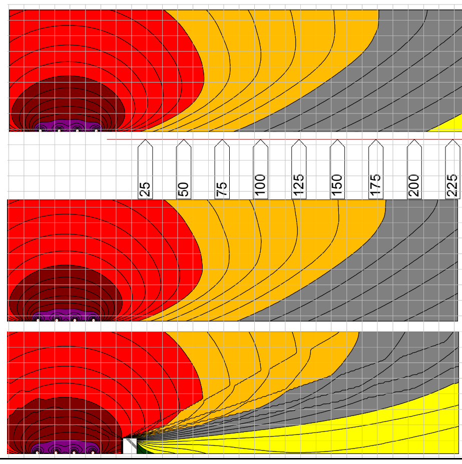
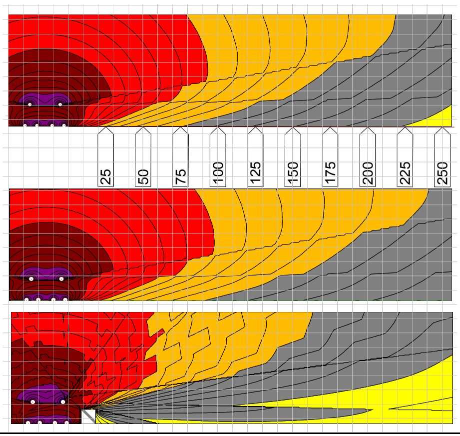
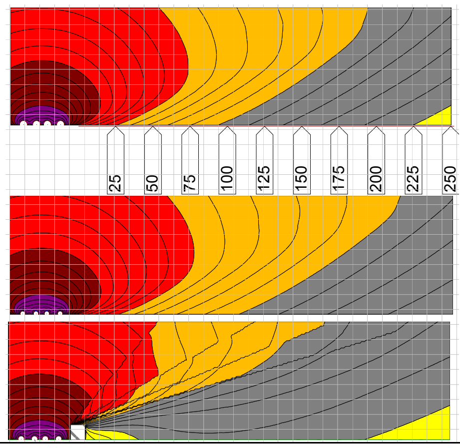
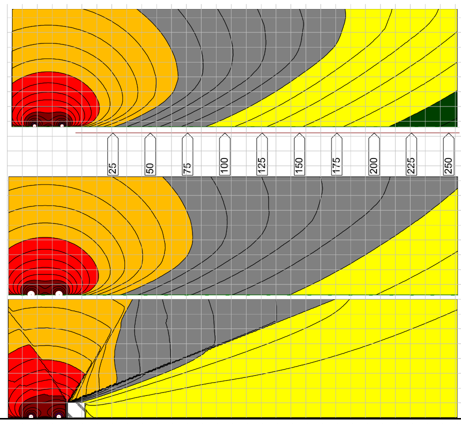
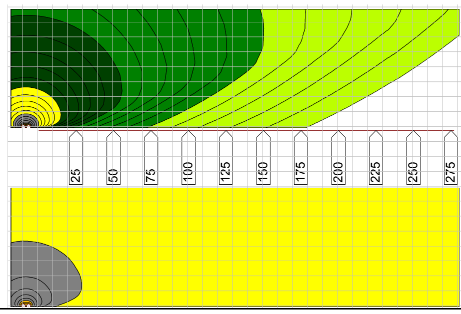
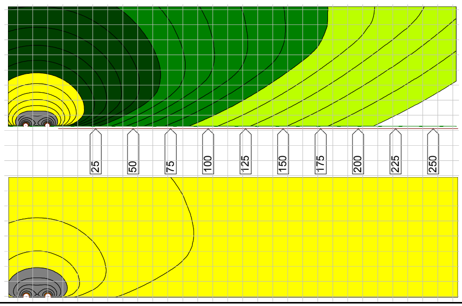


Figure 3 - Color scale for the noise contour maps of Table 3

Table 3 - Cross-sectional noise contour maps and critical distance for the case studies

Case study	Road type	Background Noise level L_{night} (dB(A))	Noise barrier	Critical distance, m	Cross-sectional noise contour maps (10m × 10m grid, 1dBA contour interval)
H.1	Expressway	0	-	348	
		43.4	-	385	
		43.4	Wall	215	
H.2	Expressway	0	-	642	
		42.1	-	686	
		42.1	Wall	584	
H.3	Class 1 highway	0	-	159	
		43.8	-	186	
		43.8	Wall	101	
H.4	Class 1 highway	0	-	106	
		38.4	-	116	
		38.4	Wall	15	
H.5	Class 2 highway	0	-	141	
		47.1	-	221	

Case study	Road type	Background Noise level L_{night} (dB(A))	Noise barrier	Critical distance, m	Cross-sectional noise contour maps (10m × 10m grid, 1dBA contour interval)
H.6	Class 3 highway	0	-	34	
		41.9	-	39	
U.1	Urban freeway	0	-	222	
		42.5	-	254	
		42.5	Row of build-ings	30	
U.2	Elevated Freeway	0	-	235	
		46.6	-	340	
		46.6	Wall & Row of build -ings Both	30	
U.3	Arterial road	0	-	251	
		48.3	-	346	
		48.3	Row of build -ings	30	

Case study	Road type	Background Noise level L_{night} (dB(A))	Noise barrier	Critical distance, m	Cross-sectional noise contour maps (10m × 10m grid, 1dBA contour interval)
U.4	Collector road	0	-	102	
		41.6	-	159	
		41.6	Row of buildings	14	
U.5	Local road	0	-	6	
		49.1	-	27	
U.6	Local road	0	-	5	
		46.3	-	11	

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