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Method to calculate L_{AFmax} noise map from L_{Aeq} noise maps, for roads and railways

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ABSTRACT

This paper presents the simple theoretical relations between L_{AFmax} and L_{Aeq}, for roads (simulation each vehicle as a moving point source) and railways (simulation of each vehicle/train as a moving line source with length *l*). From these relations – more valid for close proximity to the source – and knowing the typical values of L_{Aeq} for roads and railways, according with the standard methods available, the associated calculation of typical values of L_{AFmax} was performed. Knowing – by this way or another – the L_{AFmAx} close to the roads or railways, the typical noise source, on typical software, must be divided into small parts, with 1 m length each. After that, one of these small parts must be converted on a line source with a sound power that give, 1 m distance, an L_{Aeq} equal to the L_{AFMax} we want (the spectrum must be adjusted accordingly). All the other small parts, related, must be converted on a line source with the same sound power level. An independent noise map must be calculated for each small line source. For each noise receiver the L_{AFmax}, from a pass-by, is the greater value of all line source independent noise maps. This procedure can consume too much time, depending on the number of small line sources we have. Fortunately, some available software – for example the Cadna A – permits the calculation of L_{AFmax} noise maps from different line sources. To do that, Cadna A needs the introduction of the difference value between L_{AFMax} and L_{Aeq} for each small line source, so that must be calculated. At major distances to the road or railway, this L_{AFMax} noise map gives smaller values than the regular L_{Aeq} noise map, so, by definition, the global L_{AFMax} noise map must have the greater value, in each receiver point, from these two noise maps.

Keywords: Lmax Noise Map, road, railway
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1. INTRODUCTION

The great majority of the commercial software to produce outside noise environmental maps, can just produce, typically for roads and railways, L_{Aeq} noise maps, not L_{AFmax} noise maps (definitions of L_{Aeq} and L_{AFmax} in ISO 1996-1 [1]). The main reason is the fact that the standard methods used were developed for L_{Aeq} values not for L_{AFmax} values.

In some cases can be important to know not just the L_{Aeq} values but also the L_{AFmax} values.

This paper attempts to define a way to obtain L_{AFmax} values based on L_{Aeq} values.

2. THEORETICAL RELATIONS

For a passing light car, or for a passing truck, at constant speed v [m/s], we can simulate this situation as a point source, with a specific Noise Power Level L_{Aw}, and the instantaneous Noise Levels $L_{Aeq}(t)$ (t in seconds), on a receiver point at a perpendicular distance $d_\perp$ [m], can be written, by simplicity and applicability, as (Annex A1.1 of [2] or [3]):

$$L_{Aeq}(t) = L_{Aw} - 11 - 20\log\left(\sqrt{(d_\perp)^2 + (vt)^2}\right) \quad (1)$$

The L_{AFmax} of this variation occurs at $t = 0$ (the equation (1) is written in a way that the time before the pass-by is negative and the time after positive):

$$L_{AFmax} = L_{Aw} - 11 - 20\log(d_\perp) \quad (2)$$

The integration of $L_{Aeq}(t)$ during the pass-by can be written as $L_{Aeq,T}$ (where T is the duration of the pass-by). For a typical time of 1h (½ hour before and ½ hour after the pass-by) the relation of $L_{Aeq,1\mathrm{h}}$ with L_{AFmax} can be written as (Annex A1.1 of [2]):

$$L_{Aeq,1\mathrm{h}} \approx L_{AFmax} - 25 + 10\log(d_\perp) - 10\log(v_{\mathrm{km/h}}) \quad (3)$$

or:

$$L_{AFmax} \approx L_{Aeq,1\mathrm{h}} + 25 - 10\log(d_\perp) + 10\log(v_{\mathrm{km/h}}) \quad (4)$$

where $v_{\mathrm{km/h}}$ is the speed of the car, or of the truck, in km/h.

For a train, with length l [m], the previous point source approximation cannot be used anymore. Using now a linear source of length l the equations (3) and (4) can be rewritten as (Annex A1.2 of [2]), taking into account $L_{AE} = L_{Aeq} + 10\log(T)$):

$$L_{Aeq,1\mathrm{h}} \approx L_{AFmax} - 28 - 10\log(\mathrm{tg}^{-1}\left(\frac{l}{2d_\perp}\right)) + 10\log(\left(\frac{l}{v\mathrm{km/h}}\right)) \quad (5)$$

$$L_{AFmax} \approx L_{Aeq,1\mathrm{h}} + 28 + 10\log(\mathrm{tg}^{-1}\left(\frac{l}{2d_\perp}\right)) - 10\log(\left(\frac{l}{v\mathrm{km/h}}\right)) \quad (6)$$

The equations (4) and (6) are the main equations for obtain L_{AFmax} when we know the L_{Aeq} of a pass-by car, truck or train.

Since the global $L_{Aeq,global}$ of a road or a railway depends also on the number n of vehicles passing by, this value can be written as:

$$L_{Aeq,global} = L_{Aeq,1vehicle} + 10\log(n) \quad (7)$$

Once the $L_{AFmax,1vehicke}$ of 1 vehicle do not depends on the quantity of vehicles, there is a quantity n, for a given distance $d_\perp$to the road or railway, and for a given speed $v_{\mathrm{km/h}}$ of the vehicles, where $L_{Aeq,global}$ is equal to $L_{AFmax,1vehicle}$. Above this quantity $L_{Aeq,global}$ is higher than $L_{AFmax,1vehicle}$ and, by definition, $L_{AFmax,global}$ becomes equal to $L_{Aeq,global}$.

In Table 1 (roads) and Table 2 (railways) is showed the values of $L_{AFmax} - L_{Aeq,1\mathrm{h}}$, according to equations (4) and (6), for different values of $d_\perp$ and $v_{\mathrm{km/h}}$. For railways is assumed, by simplicity and applicability, $l = 50$ m.

In Table 3 (roads) and Table 4 (railways) is showed the values of n that makes $10\log(n)$ equal to, respectively, the values of Table 1 and 2. So, above this quantity – for the associated $d_\perp$ and $v_{\mathrm{km/h}}$ values – $L_{AFmax,global}$ becomes equal to $L_{Aeq,global}$.

Of course, these relations assume that the equations (4) and (6) are valid for all the distances, but in reality, for bigger distances, there are, normally, other kind of sound attenuations, like atmospheric, ground and obstacles attenuations, that makes the equations (4) and (6) not anymore right valid, so the relations presented are just indicative.

The equations (4) and (6) are just valid fore close distances to the road or railway.

For the NMPB'96 (the interim European noise method for roads [4]), SRMII (the interim noise method for railways [4]) and for CNOSSOS (the new harmonized European method for road, railways and other noise sources [5]) we have calculated the L_{Aeq} value of one pass-by, and we have obtained the values showed on Table 5 (roads) and Table 6 (railways). For Railways we just used the SRM II, because, so far, just for these we have, in Portugal, relations between the Standard Trains and the Portuguese reality [6].

Table 1: Differences between $L_{AFmax,1vehicle}$ and $L_{Aeq,1vehicle}$ (roads)

Distances $d_{\perp}$ [m]	$L_{AFmax,1vehicle} - L_{Aeq,1vehicle}$ [equation (4)] [dB(A)]				
	Speed				
	30 km/h	**50 km/h**	**70 km/h**	**90 km/h**	**120 km/h**
1	40	42	43	45	46
7.5	31	33	35	36	37
15	28	30	32	33	34
30	25	27	29	30	31
60	22	24	26	27	28
120	19	21	23	24	25
240	16	18	20	21	22
480	13	15	17	18	19

Table 2: Differences between $L_{AFmax,1vehicle}$ and $L_{Aeq,1vehicle}$ (railways)

Distances $d_{\perp}$ [m]	$L_{AFmax,1vehicle} - L_{Aeq,1vehicle}$ [equation (6); l = 50 m] [dB(A)]				
	Speed				
	30 km/h	**50 km/h**	**70 km/h**	**90 km/h**	**120 km/h**
1	28	30	31	32	34
7.5	27	29	31	32	33
15	26	28	30	31	32
30	24	26	28	29	30
60	22	24	25	27	28
120	19	21	23	24	25
240	16	18	20	21	22
480	13	15	17	18	19

Table 3: Values of n that make 10log(n) equal to the value of Table 1 (roads)

Distances $d_{\perp}$ [m]	Values of n/hour				
	Speed				
	30 km/h	**50 km/h**	**70 km/h**	**90 km/h**	**120 km/h**
1	10000	15849	19953	31623	39811
7.5	1259	1995	3162	3981	5012
15	631	1000	1585	1995	2512
30	316	501	794	1000	1259
60	158	251	398	501	631
120	79	126	200	251	316
240	40	63	100	126	158
480	20	32	50	63	79

Table 4: Values of n that make 10log(n) equal to the value of Table 2 (railways)

Distances $d_\perp$ [m]	Values of *n* *n*/hour				
	Speed				
	30 km/h	50 km/h	70 km/h	90 km/h	120 km/h
1	631	1000	1259	1585	2512
7.5	501	794	1259	1585	1995
15	398	631	1000	1259	1585
30	251	398	631	794	1000
60	158	251	316	501	631
120	79	126	200	251	316
240	40	63	100	126	158
480	20	32	50	63	79

Table 5: L_{Aeq} values (roads)

Vehicle	Distance to the road [m]	L_{Aeq} values at 1 and 7.5 m distance from road (pass-by off one vehicle/hour)				
		Speed				
		30 km/h	50 km/h	80 km/h	100 km/h	120 km/h
NMPB'96						
Light	1	45	46	51	53	54
Light	7.5	38	39	43	45	47
Trucks	1	61	58	59	61	61
Trucks	7.5	53	51	52	54	54
CNOSSOS						
Light	1	40	43	48	50	52
Light	7.5	34	37	41	44	46
Trucks (Cat.2)	1	49	49	51	52	54
Trucks (Cat.2)	7.5	42	43	45	46	47
Trucks (Cat.3)	1	52	52	54	55	56
Trucks (Cat.3)	7.5	45	46	47	49	50

Table 6: L_{Aeq} values for SRMII categories (railways)

Train	Distance to the railway [m]	L_{Aeq} values at 1 and 7.5 m distance from railway (pass-by off one vehicle/hour)				
		Speed				
		30 km/h	50 km/h	80 km/h	100 km/h	120 km/h
SRMII						
C02	1	54	56	59	61	63
C02	7.5	49	51	54	56	58
C03	1	48	50	53	55	56
C03	7.5	43	45	48	50	51
C03m	1	51	53	56	58	60
C03m	7.5	45	47	51	52	54
C05d	1	61	60	61	61	62
C05d	7.5	55	54	55	56	57
C08	1	51	53	55	56	58
C08	7.5	45	47	50	51	52
C09c	1	50	54	57	59	60
C09c	7.5	44	48	51	53	54

In Table 7 we have the L_{Aeq} values of the Portuguese Trains, taking into account its relationship with SRM II categories, according [6].

With the equations (4) and (6) we did the calculation of the associated values of L_{AFmax}, from the L_{Aeq} values, as presented in Table 8 and Table 9. So, these are the L_{AFmax} values that, theoretically, we can expect near to a road or a railway.

Table 7: L_{Aeq} values for Portuguese Trains [6]

Train	Relation to SRMI Category	Length [m]	Distance to the railway [m]	L_{Aeq} values at 1 and 7.5 m distance from railway (pass-by off one vehicle/hour) Speed [km/h]				
				30	**50**	**80**	**100**	**120**
SRMII – Portuguese Trains								
UQE 3150/3250	4.6×C02	79	1	61	63	66	68	70
UQE 3150/3250	4.6×C02	79	7.5	56	58	61	63	65
UQE 2X00+ UQE2X00	25×C02	192	1	68	70	73	75	77
UQE 2X00+ UQE2X00	25×C02	192	7.5	63	65	68	70	72
UQE 3500	14.6×C08	107	1	63	65	67	68	70
UQE 3500	14.6×C08	107	7.5	57	59	62	63	64
UTE 2240	3×C03	71	1	53	55	58	60	61
UTE 2240	3×C03	71	7.5	48	50	53	55	56
UDD 450	1×C05d	52/2= 26	1	61	60	61	61	62
UDD 450	1×C05d	52/2= 26	7.5	55	54	55	56	57
CPA 4000	2×C09r	159/3= 53	1	53	57	60	62	63
CPA 4000	2×C09r	159/3= 53	7.5	47	51	54	56	57
LOC5600/2600	1×C09m	19	1	51	53	56	58	60
LOC5600/2600	1×C09m	19	7.5	45	47	51	52	54
LOC1930/1960	1×C05d	20	1	61	60	61	61	62
LOC1930/1960	1×C05d	20	7.5	55	54	55	56	57

Table 8: L_{AFmax} values (roads)

Vehicle	Distance to the road [m]	L_{AFmax} values from L_{Aeq} values of Table 5 [equation (4)] [dB(A)] Speed				
		30 km/h	**50 km/h**	**80 km/h**	**100 km/h**	**120 km/h**
	NMPB'96					
Light	1	85	88o	94	98	100
Light	7.5	69	72	78	81	84
Trucks	1	101	100	102	106	107
Trucks	7.5	84	84	87	90	91
	CNOSSOS					
Light	1	80	85	91	95	98
Light	7.5	65	70	76	80	83
Trucks (Cat.2)	1	89	91	94	97	100
Trucks (Cat.2)	7.5	73	76	80	82	84
Trucks (Cat.3)	1	92	94	97	100	102
Trucks (Cat.3)	7.5	76	79	82	85	87

Table 9: L_{AFmax} values for Portuguese Trains

Train	Relation to SRMI Category	Length [m]	Distance to the railway [m]	L_{AFmax} values from L_{Aeq} values of Table 7 [equation (6)] [dB(A)]				
				Speed [km/h]				
				30	50	80	100	120
SRMII – Portuguese Trains								
UQE 3150/3250	4.6×C02	79	1	87	91	95	98	102
UQE 3150/3250	4.6×C02	79	7.5	81	85	90	93	96
UQE 2X00+ UQE2X00	25×C02	192	1	90	94	99	102	105
UQE 2X00+ UQE2X00	25×C02	192	7.5	85	89	93	96	100
UQE 3500	14.6×C08	107	1	87	92	95	97	100
UQE 3500	14.6×C08	107	7.5	81	85	90	92	94
UTE 2240	3×C03	71	1	79	83	88	91	93
UTE 2240	3×C03	71	7.5	74	78	82	85	88
UDD 450	1×C05d	52/2= 26	1	91	93	95	96	98
UDD 450	1×C05d	52/2= 26	7.5	84	85	88	90	92
CPA 4000	2×C09r	159/3= 53	1	80	87	91	94	96
CPA 4000	2×C09r	159/3= 53	7.5	74	80	84	87	90
LOC5600/2600	1×C09m	19	1	83	87	91	94	98
LOC5600/2600	1×C09m	19	7.5	75	79	84	86	90
LOC1930/1960	1×C05d	20	1	92	94	96	97	99
LOC1930/1960	1×C05d	20	7.5	84	86	88	90	92

3. SOME PRATICAL RESULTS

To have an idea of real values, to check the theoretically values presented in Table 8 and Table 9, we can appeal to values measured in reality.

For roads, there are some results related with the Statistical Pass-by Measurements, at a distance of 7.5 m to the road. For example, the refence [7] shows, on his Fig.1, L_{AFmax} for Cars at 80 km/h, from about 77 dB(A) to 86 dB(A), depending on the road surface. For trucks between about 87 dB(A) to 94 dB(A).

So, the values in Table 8, at 7.5 m, for 80 km/h, between 76 dB(A) and 78 dB(A), for cars, and between 80 dB(A) and 87 dB(A), for trucks, are similar to the reality values of reference [7].

We can compare also with the legal limits of the reference [8]. The legal limits are not exactly L_{AFmax} at 7.5 m from the road at 50 km/h, but can be compared, safely, like that (because the vehicle is tested accelerating). So, we have, in Annex III of refence [8], for 2016 and for "Vehicles used for the carriage of passengers", values between 72 dB(A) and 80 dB(A), and for "Vehicles used for the carriage of goods", values between 72 dB(A) and 82 dB(A). In Table 8, at 7.5 m distance and 50 km/h, we have, for Light vehicles, values between 70 dB(A) and 72 dB(A), and for trucks between 76 dB(A) and 84 dB(A), which are very similar values with the legal limits.

For railways, in the reference [9], at point 1 (about 7.5 m from the railways), we have about 95 dB(A) for L_{AFmax}, for UDD circulating about 80 km/h, and about 85 dB(A) for L_{AFmax}, for UTE circulating about 70 km/h, what are values similar but higher than the values calculate and presented in Table 9.

More information must be obtained for the L_{Aeq} and L_{AFmax} of trains. Must be highlighted that some L_{Aeq} values, during train pass-by, obtained on the reference [9], do not full feel the requirements of the reference [10].

4. NOISE MAPS

A typical software/method divides a road or a railway in small parts, each with some sound power level, in a way that, for the receiver points, the global L_{Aeq} values is the energetic sum of the contribution of each small part.

For example, the software Cadna A [11], permit the calculation of L_{AFmax}, for "industrial" sources (point, linear or area sources) if we know the difference between the L_{Aeq} of each small part and L_{AFmax}.

So, a way for the calculation of L_{AFmax} Noise Maps, for roads and railways, is to divide the road or the railway in small parts (for example 1 m each; "Break into pieces" tool of the software), and calculate the L_{Aeq} at 1m distance, for just one of the small parts, and convert this part to a line source and adjust the sound power level of this line source to give the same L_{Aeq} value on the receiver 1 m distance. We must create a line source spectrum accordingly with the spectrum of the pass-by we are considering.

Knowing the L_{AFmax} expected at this point (on the example 1m distance; so the values of Table 8 and Table 9 can be used, or others similar), for a certain pass-by of a certain vehicle, we calculate the difference between L_{AFmax} and L_{Aeq}. We must introduce this difference in the field "Res. PWL max" of the Line Source form (see Figure 1).

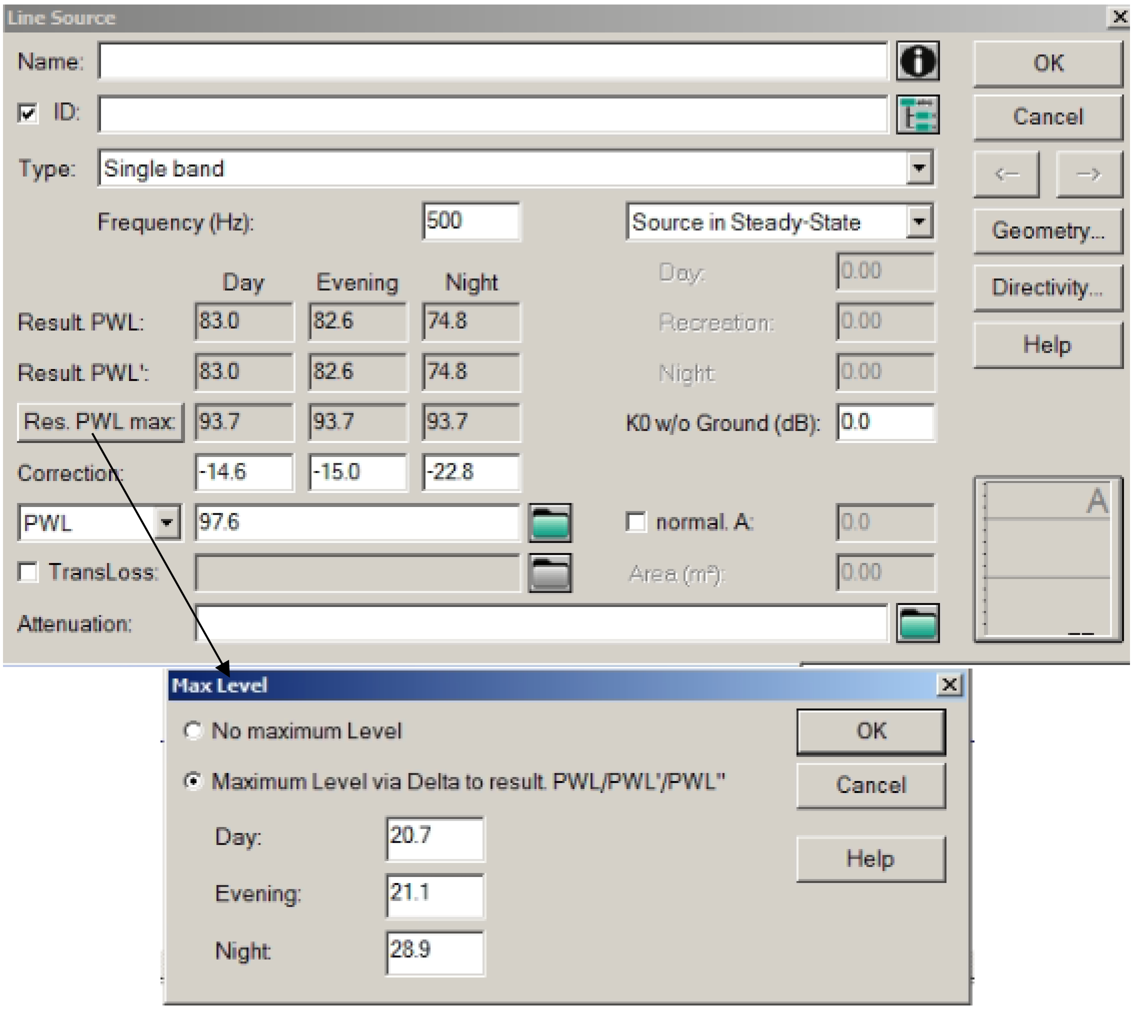

Figure 1: Example of L_{max} table of Cadna A

In Figure 2 we can see the L_{Aeq} noise map of some road. In the Figure 3 we can see de L_{AFmax} noise map of the same road, using the methodology described. As we can see, for some distances – as expected and explained on chapter 2 – the L_{Aeq} noise map give greater values than L_{AFmax}. So, the in fact L_{AFmax} global noise map must be the maximum values of the two maps.

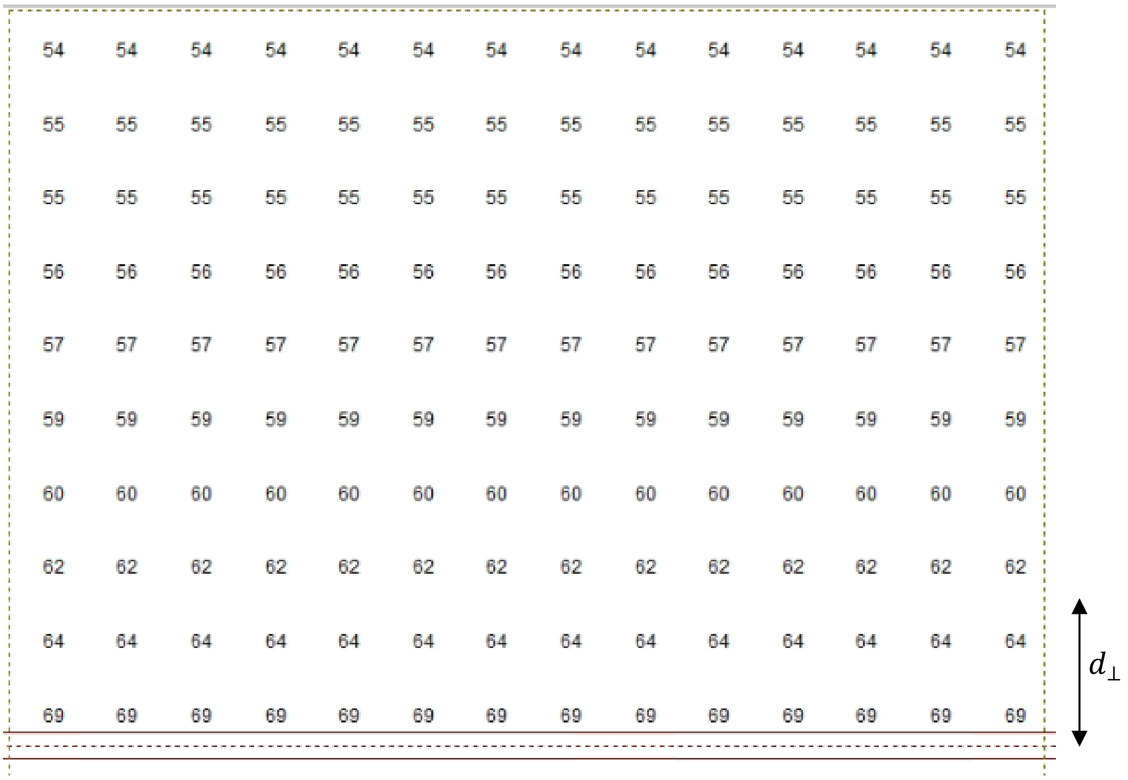

Figure 2: Example of L_{Aeq} Noise Map of a road

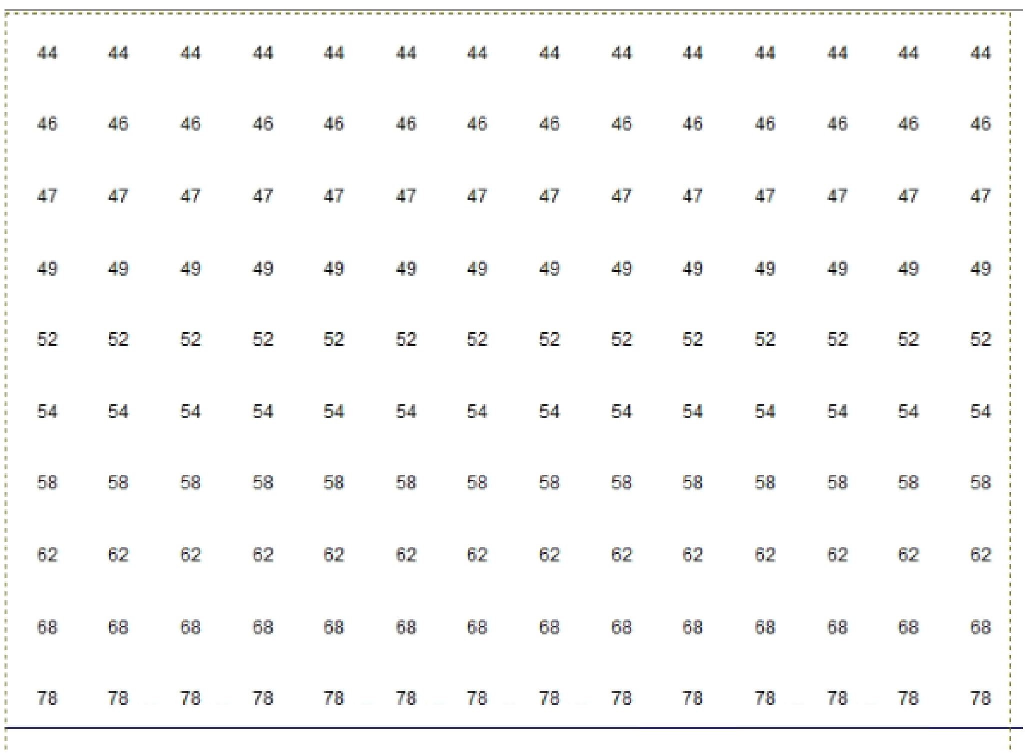

Figure 2: Example of the L_{AFmax} Noise Map of the same road

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