Statistical Method for an Assessment of Actions against Noise and Air Pollution in Order to compare the total Improvement in an Investigation Area

Frank-Christian Zacharias[1], Rainer Kunka[2], and Chris Hoar[3]

[1] Thüringer Landesanstalt für Umwelt und Geologie

Göschwitzerstraße 41, 07745 Jena, Germany

[2] Thüringer Landesanstalt für Umwelt und Geologie

Göschwitzerstraße 41, 07745 Jena, Germany

[3] NGIS China Ltd.

20/F, 359 & 261 Queen’s Road Central, Sheung Wan, HK

ABSTRACT

In accordance with the German regulation VBEB, LIMA provides intuitive methods for the evaluation of different planned actions. Noise and air pollution maps used alone are lacking in that they do not show any statistical evaluation of the quality of the actions. Actually, while the reduction of immissions is relevant, the reduction in numbers of exposed inhabitants after vs before any action is the most important evaluation criteria. In the following, we define the adapted statistical method for air pollution impact evaluation. All façades longer than 5m can be broken down into sub facades. For each part of the façade, a receiver point is calculated. LIMA determines the positions of the receiver points automatically. For noise mapping, we recommend 5 m or 10 m grid size, for air pollution mapping grid size can be fixed from 2 m up to 10 m. From the regular grid results, LIMA fetches by a sophisticated interpolation nicely fitted proper values to the necessary receiver points; this method is proved since years. The user is free to decide whether using the exact number of inhabitants for each building or using a statistical distribution of inhabitants proportional to volume of a building derived from the whole number of inhabitants in the investigation area.

Keywords: Noise, Air pollution, Action Planning

1. INTRODUCTION

In general, noise mapping and action planning take place separately from air pollution mapping and action planning. Although regulations mention to evaluate mutual effects of action planning against noise with action planning against air pollution one would never see an objective assessment in practice rather only verbal qualitative prose is provided in order to fulfil this demand. Such a kind of evaluation can’t really be proved by others; you have to believe it or you live on with doubts.

Even though noise and air pollution are very different topics devising a method for the evaluation of mutual effects is easy if one considers the common facts which yield to a common statistical method for an assessment of actions for both mediums. Here we will talk about common factors influencing air and noise pollution caused specifically by road traffic. Firstly, we have the same input data for the geometrical model, as buildings and roads for the same micro-scaling investigation area.

Secondly, we have almost the same quality of result resolution, in general between 2m and 10m grid size. Extraordinary cases might have other grid resolution, e.g. vertical cut might have a z-grid size of 1m for visualization and understanding more details. For noise mapping, we are accustomed to façade calculations in order to connect these results with the number of inhabitants in each building. For air pollution mapping it is not possible to compute only façade results, because of the necessary 3 dimensional computing space which is handled as a time depending FEM process over all grid boxes in x, y and z- direction, finally it is the wind field which causes propagation of any pollute. If we were to

[1] Frank.Zacharias@TLUG.Thueringen.de
[2] Rainer.Kunka@TLUG.Thueringen.de
[3] chris.hoar@ngis.com.hk

examine an air pollution mapping exercise, the second z layer looks similar to noise mapping using a grid calculation. In order to derive façade results all façades longer than 5 m are broken down into sub façades. For each part of the façade, a receiver point is calculated. LIMA determines the positions of the receiver points automatically and fetches interpolated values nicely fitted proper values to the necessary receiver points. With these values, the air pollution concentrations, the ordinary VBEB procedure provides the statistical evaluation of each building. Statistical classes in 5-microgram steps like for noise in 5 dB steps, and a summation over all buildings in the investigation area, will show the total result.

2. WORKFLOW

2.1 Calculation Area and Model Properties

The whole noise mapping is much larger than the investigation area for a statistical assessment. Noise mapping includes the whole city with its main roads. Depending on the state of expected quality, the noise mapping should contain more than the necessary minimum number of roads. Especially if the authorities want to distinguish calm areas it is important to take all roads into account over the whole city; a good example of this can be found in the very new fresh PhD work of Dr. Jäschke "Lärmkartierung und Ruhige Gebiete" www.ruhige-gebiete.de. Some times between narrow gaps, between buildings and in back yards the air pollution levels become very high or very small totally independent of nearby road category. Therefore try to get the best reachable quality with a minimum of effort. The state of art for city models is today very high and the road net has to be updated continuously improving the whole model between every mapping phase. Looking after data on the WS ODENSLEU is a duty that makes work easier and more efficient for every next mapping turn.

2.2 Investigation Area

Only the definition of the area of interest is important for the statistical assessment, which has to be fixed either once for all actions, for actions against noise or for against air pollution. It is of no use to investigate an empty area, our purpose is to protect people. Therefore residential areas are of interest where we know the number of inhabitants. Of course, if we have more than one hot spot several different investigation areas are to be defined. The investigation area or areas must be always the same for noise and air and for different actions. Otherwise, we would compare apples with pears. This is a basic for the assessment, and also allows for continuous evaluation if we want to compare older with new statistics. Of course, cities can be very large, several square kilometers. Actions normally are to be realized in so called hot spots which typically are not very huge areas. From our experience a 2km by 2km investigation area is more than enough, because too large an area masks the various influences of the actions. The influence range for noise effects is normally smaller than 2 km, for air pollution even smaller. Even a very long new bypass road around a city has only important effects at the junctions where it is again connected with the existing road net and these are again comparatively small hot spots. Not only a normal area can be evaluated, the user can as well define an investigation area for a single building if wanted. There is no rule how to define the investigation area but we can say the best shape and size of an investigation area would be where we expect the greatest variation of impacts connected with the greatest number of inhabitants.

Figure 1 – Calculation area with investigation area

2.3 Application of the Statistical Method for an Assessment of Actions

The statistical method has at least 4 statistics:

- Number of annoyed inhabitants before the action against noise
- Number of annoyed inhabitants after the action against noise
- Number of annoyed inhabitants before the action against air pollution
- Number of annoyed inhabitants after the action against air pollution

Of course not always we would plan actions against noise and air pollution at the same time, sometimes we'll find actions only against noise or vice versa only against air pollution. Important is to put all desired actions into the same statistic. Considering different result cases, we assume 4 cases:

- Both mediums, noise and air situation, become better
- Both mediums become worse
- One medium becomes better but the other worse
- One medium becomes better and the other stays neutral

The question is what is better and what is worse? In general better is a situation if the number of annoyed inhabitants will be reduced after actions. It is a strategic evaluation for policy. We are not dealing with absolute thresholds, especially not for air pollution, because the MISKAM software computes the additional concentration with very high quality but only caused by the road trafic.We are bothered about background concentration caused by other sources. In order to evaluate actions the background concentration are cancelled anyway. Only for this reason, this assessment is a kind of screening, but with clearly defined numerical results.

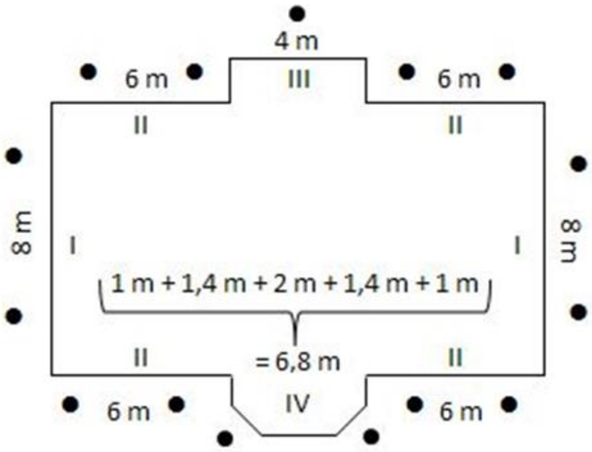

Figure 2 – Determining the position of the relevant receiver points

The number of inhabitants of a building is equally distributed automatically to each receptor point value. The distribution classes are 5 dB for LDEN and LNGT or 5 µg/m^3 for NO_2, NO_X, PM10 and PM2.5. The z level is the first floor, in 4 m height for noise and in 3 m height for air pollution. The reason for this difference of one meter is caused by the standard regulations for noise and air pollution mapping. For air pollution, we get three kinds of values:

- Mitw = Average weighted with the annual wind direction distribution frequency
- Maxw= Maximum over all wind directions
- Maxt = Total Maximum over all wind directions and all z- layers

The 3 different values are sometimes helpful because the statistical assessment might show another tendency for pollutants for each value. In other words we get 4 statistics for noise (LDEN, LNGT with and without action) and 18 statistics for air pollution (3 values for 3 pollutants with and without action). This seems to be confusing, but fortunately, the tendency for the 3 pollutants is almost always equal, we are dealing actually with 6 statistics (3 values with and without action).

We are talking about a kind of screening because up to now we do not have any regulation either for actions against noise nor against air pollution especially not for such an assessment for both combined evaluations. But this method should show the state of engineering, which might become a standard after practice acceptance in the future. Authorities want to have clear thresholds or limits otherwise they are in danger to make arbitrary decisions. There is no doubt about that local authorities have with this method a better access comparing with verbal discussions. Whom it may concern, perhaps experts in an ISO working group are predestined to fix limits instead of politicians?

3. EXAMPLES

3.1 Bypass Road as Action

Many cities with heavy traffic try to keep out traffic by the mean of building bypass roads. Larger cities have no chance to avoid any new annoyance totally. Policy is aware that abatement in one hot spot might increase on the other hand new annoyance somewhere else. The statistical assessment for noise and air pollution can show according point 2.3 whether the prognostic situation with this action would be successful or not.

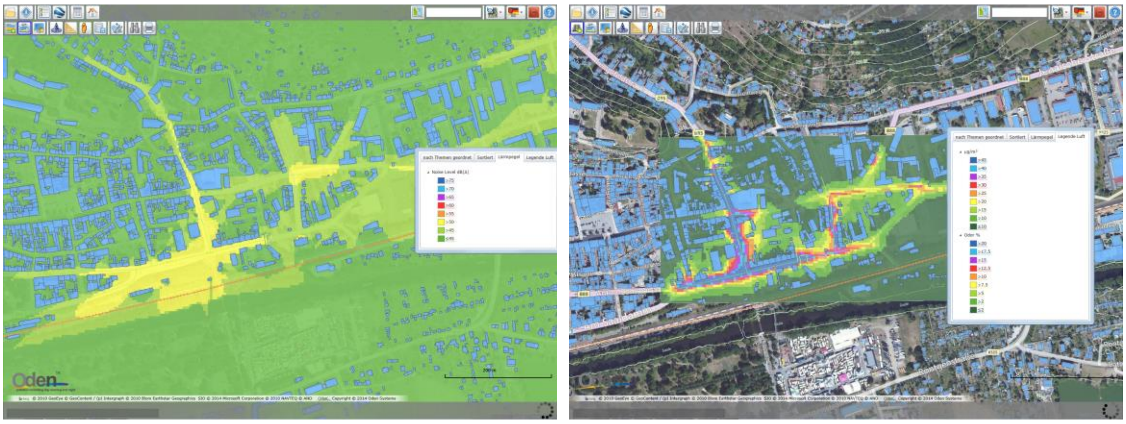

Figure 3 – Noise and Air pollution Map without Action[4]

[4]Noise calculation for full calculation area and air pollution is only computed for the investigation area

Even though the following table shows only small absolute values of noise annoyance, this was a real case with the political question to evaluate the use of a bypass. The reason for the low values was that the investigation considered only those roads, which show different traffic flow with or without action.

Table 1 – Noise statistics without action

Level	<35 (dB)	<40 (dB)	<45 (dB)	<50 (dB)	<55 (dB)
Annoyed inhabitants					
LDEN	431.7	160.6	143.7	101.7	48.3
LNGT	680.9	124.4	74.6	6.1	0
Annoyed inhabitants (%)					
LDEN	48.7	18.1	16.2	11.5	5.5

LNGT	76.9	14	8.4	0.7	0
Annoyed inhabitants (total):	886				

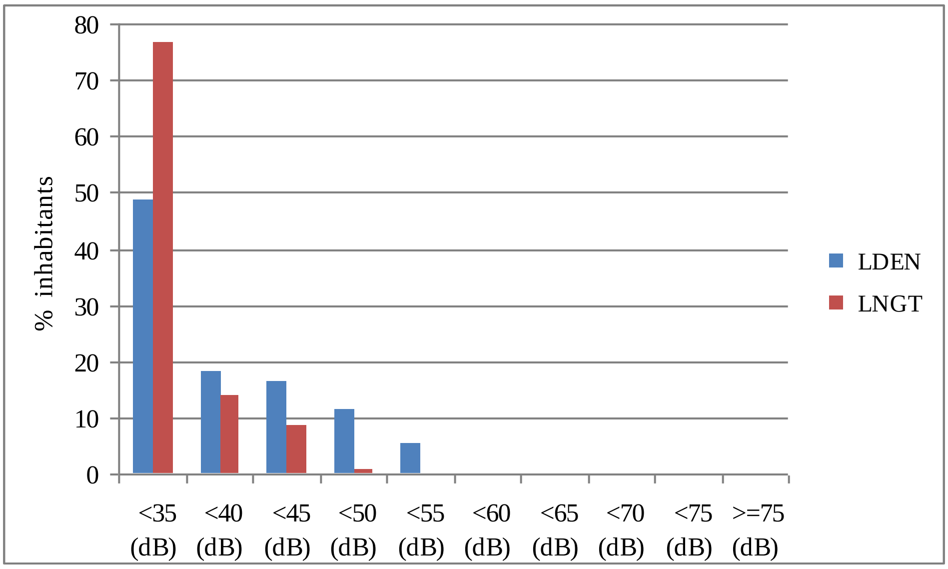

Figure 4 - % inhabitants in noise classes without action

Table 2 – Noise statistics with action

Annoyed inhabitants					
LDEN	366.8	224	124.9	93.1	72
LNGT	667.3	101.4	77.3	40	0
Annoyed inhabitants (%)					
LDEN	41.4	25.3	14.1	10.5	8.1
LNGT	75.3	11.4	8.7	4.5	0
Annoyed inhabitants (total):	886				

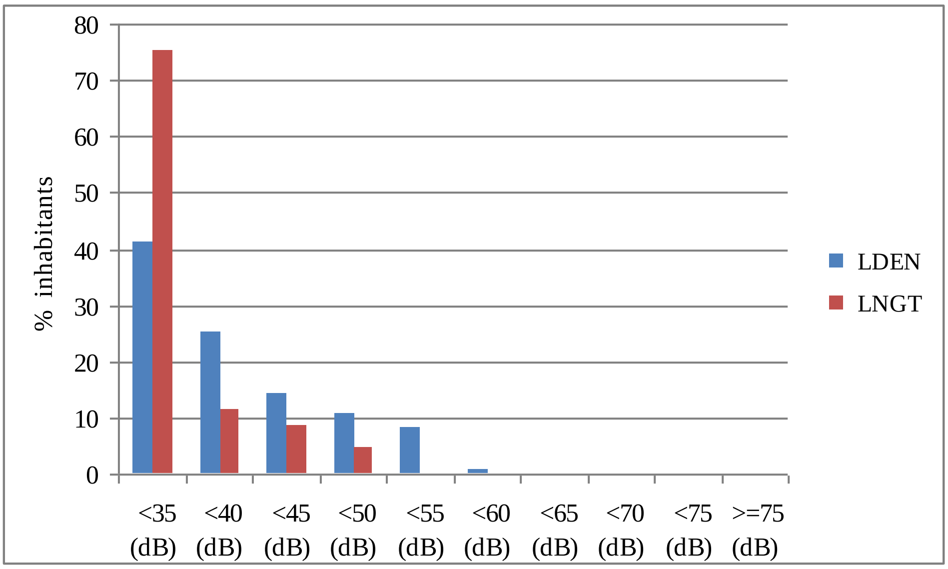

Figure 5 - % inhabitants in noise classes with action

Noise levels are in this case comparatively low. We recognize that the situation without action is not really different compared with action. It becomes even slightly worse or neutral.

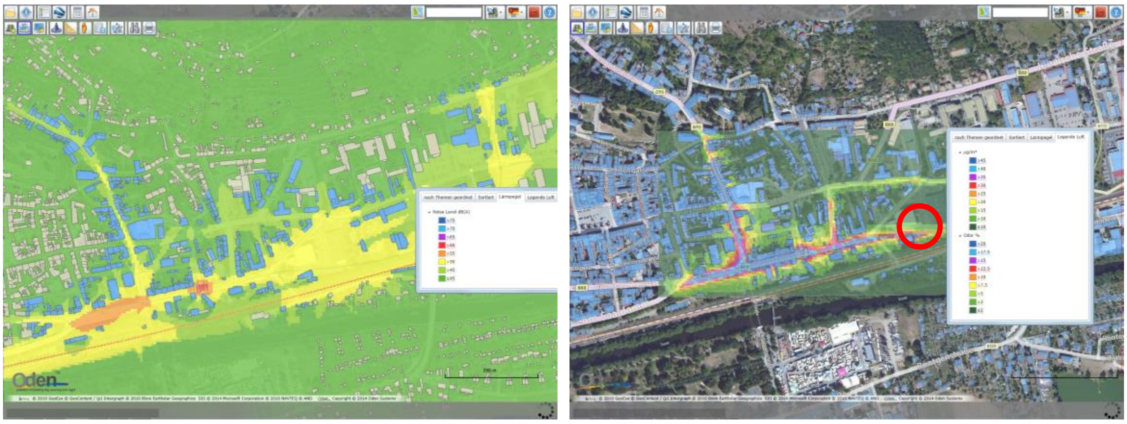

Figure 6 – Noise and Air pollution Map with Action, Bypass (red circle)

Table 4 – Air statistics NOX without action

Conzentration	<5 (µg/m3)	<10 µg/m3)	<15(µg/m	<20 µg/m3)	<25 µg/m3)	<30 µg/m3)	<35 µg/m3)	<40 µg/m3)	<45 µg/m3)	<50 µg/m3)	<55 µg/m3)	<60 µg/m3)	<65 µg/m3)	<70 µg/m3)	<75 µg/m3)	<80 µg/m3)	<85 µg/m3)	<90 µg/m3)	<95 µg/m3)	>=95 µg/m3)
Annoyed inhabitants																				
MITW	473,4	182,3	85,9	40	26,3	12,7	9,2	4,2	2,5	5,5	4,9	2,2	4,8	1,2	2,9	6,3	5,7	0,6	3,8	11,5
MAXW	239,7	66,4	152,7	119,8	75,6	22,4	29,3	25,3	20,1	9,4	8,4	17,6	12,8	7,6	6,4	5,5	3,4	4	4,3	55,3
MAXT	240,3	52,6	139	115,1	76,9	36,8	25,9	19,9	10,2	17	12,9	11,2	10,9	11,3	12,3	5,1	5,9	2,4	9,9	70,5
Annoyed inhabitants (%)																				
MITW	53,4	20,6	9,7	4,5	3	1,4	1	0,5	0,3	0,6	0,6	0,2	0,5	0,1	0,3	0,7	0,6	0,1	0,4	1,3
MAXW	27,1	7,5	17,2	13,5	8,5	2,5	3,3	2,9	2,3	1,1	0,9	2	1,4	0,9	0,7	0,6	0,4	0,5	0,5	6,2
MAXT	27,1	5,9	15,7	13	8,7	4,2	2,9	2,2	1,2	1,9	1,5	1,3	1,2	1,3	1,4	0,6	0,7	0,3	1,1	8

Annoyed inhabitants (total): 886

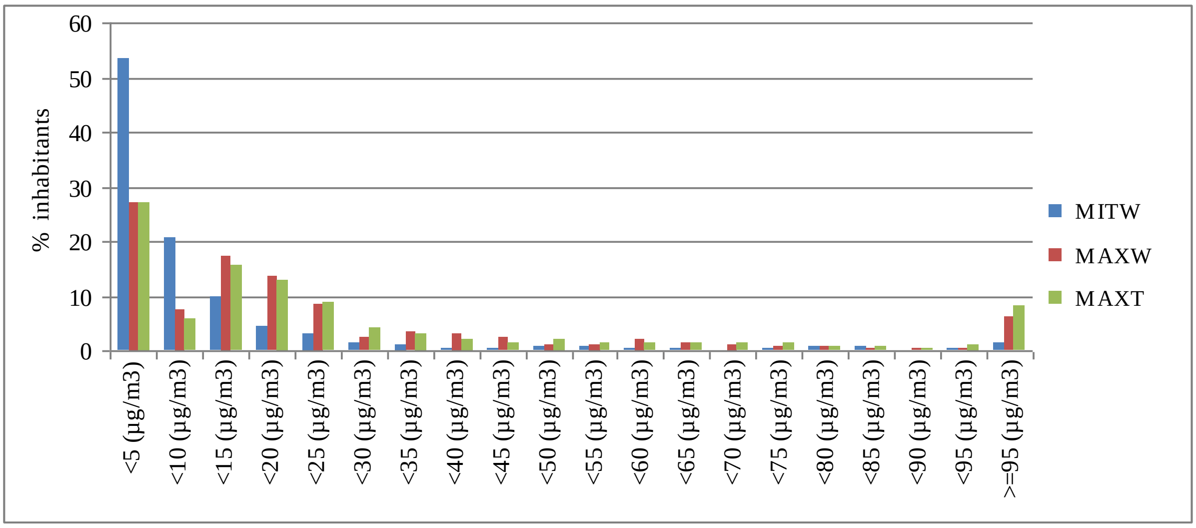

Figure 7 - % inhabitants, Air (Table 4)

Table 5 – Air statistics NOX with action

Conzentration	<5 (µg/m3)	<10 µg/m3)	<15(µg/m	<20 µg/m3)	<25 µg/m3)	<30 µg/m3)	<35 µg/m3)	<40 µg/m3)	<45 µg/m3)	<50 µg/m3)	<55 µg/m3)	<60 µg/m3)	<65 µg/m3)	<70 µg/m3)	<75 µg/m3)	<80 µg/m3)	<85 µg/m3)	<90 µg/m3)	<95 µg/m3)	>=95 µg/m3)
Annoyed inhabitants																				
MITW	527,2	191,6	51	37,5	15,5	18,6	4,4	1,7	0,4	1,8	3,9	2,4	1,4	1,9	5	2,5	0,3	0,2	0,6	18,1
MAXW	241,6	138,5	187	51,9	58,6	28,9	21,8	20,5	19,3	20,3	14,8	13	6,4	8,6	4,8	5,3	3,4	0,9	1,8	38,7

MAXT	240,8	121,7	177,6	58,1	56,7	37,1	18,5	17,8	16,9	9,4	15,2	12,7	14,1	16,6	6,2	6	5,2	3,7	3,4	48,4
Annoyed inhabitants (%)																				
MITW	59,5	21,6	5,8	4,2	1,7	2,1	0,5	0,2	0	0,2	0,4	0,3	0,2	0,2	0,6	0,3	0	0	0,1	2
MAXW	27,3	15,6	21,1	5,9	6,6	3,3	2,5	2,3	2,2	2,3	1,7	1,5	0,7	1	0,5	0,6	0,4	0,1	0,2	4,4
MAXT	27,2	13,7	20	6,6	6,4	4,2	2,1	2	1,9	1,1	1,7	1,4	1,6	1,9	0,7	0,7	0,6	0,4	0,4	5,5
Annoyed inhabitants (total):	886																			

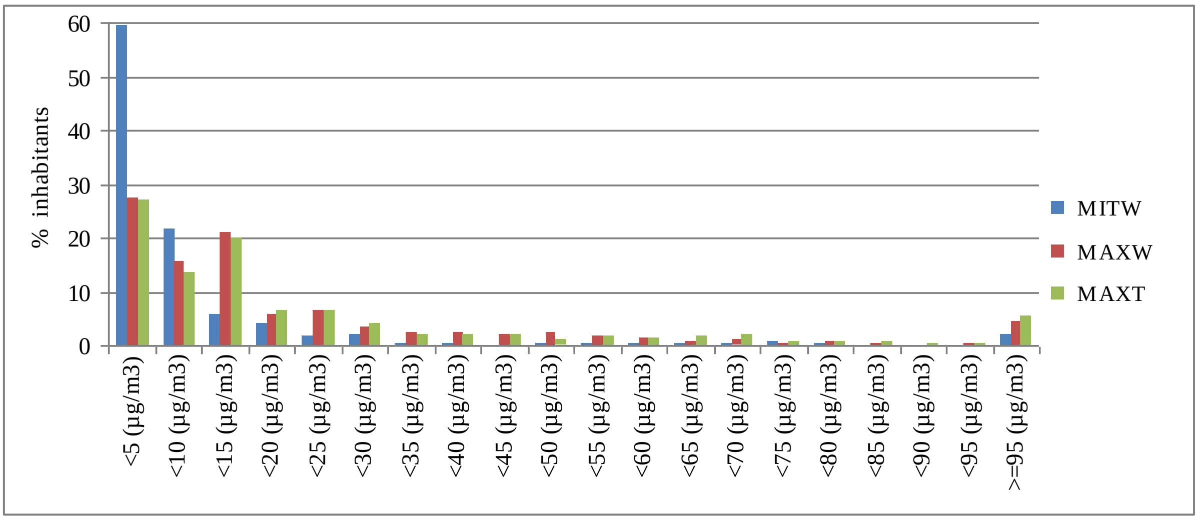

Figure 8 - % inhabitants, Air (Table 5)

Air pollution shows high and low levels. With action the situation becomes clearly better. The numbers of annoyed inhabitants are different for the three values MITW, MAXW and MAXT. For MITW the number of annoyed inhabitants increases a little but for both other values they decrease, that means the total evaluation shows that it would be a good action to build the bypass. The reason that the tendency for MITW is different depends on the weighted wind direction frequency distribution connect with the specific order of the building sites.

The high levels might be considered as still so bad that other new actions should be taken into account. According the German regulation 39. BImSchV a sector along a road should have at least 100 m length for which the height of concentration is representative. Fig. 6 shows that the sectors are always smaller/shorter than 100 m, they are treated as singularities; therefor other actions are not mandatory.

3.2 Speed Limit and No Entry for Heavy Trucks as Actions

One classically employed action measure is that of traffic control. This can be a complex road network control or even control over a single road, which has been identified as a single hot spot. In this case, and especially if the community runs short of money, simple cheap signs might help. In the following figure 13 the road with action measures in place is marked up with a blue buffer.

Figure 9 – No Entry and Speed Limit

Figure 13 in the right picture the blue zone shows the road with speed limit and no entry for heavy trucks. This area marks up the blue buildings which are dealt with the statistics, there are living the 229 annoyed inhabitants.

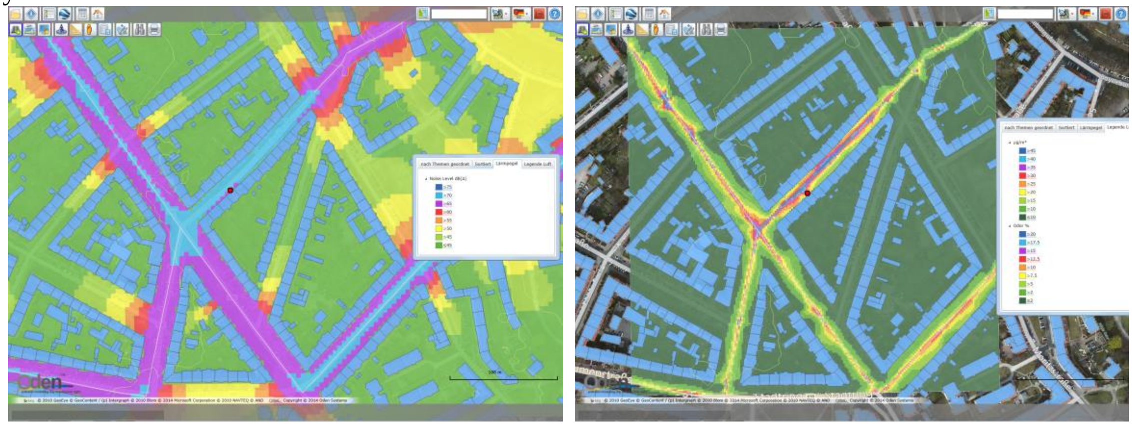

Figure 10 – Noise and Air pollution Map without Action

Table 6 – Noise statistics without action

Level	<35	<40	<45	<50	<55	<60	<65	<70	<75	>=75
Annoyed inhabitants										
LDEN	26.7	0.0	116.3	1.6	0.5	1.0	3.3	37.0	42.7	0.0
LNGT	142.9	1.0	1.0	1.0	3.3	38.8	40.9	0.0	0.0	0.0
Annoyed inhabitants (%)										
LDEN	11.7	0.0	50.8	0.7	0.2	0.4	1.4	16.2	18.6	0.0
LNGT	62.4	0.4	0.4	0.4	1.4	16.9	17.9	0.0	0.0	0.0
Annoyed inhabitants (total):			229							

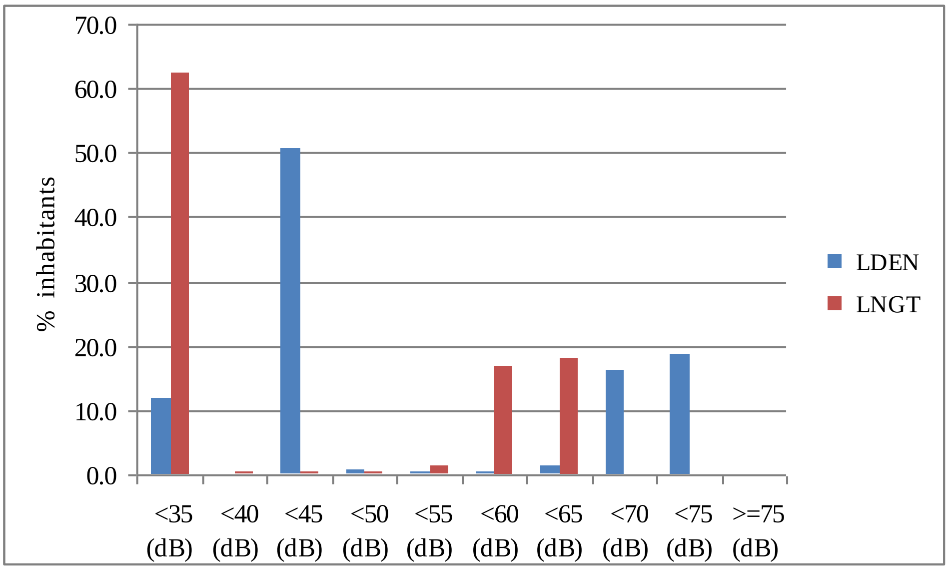

Figure 11 – % inhabitants, Noise (Table 6)

Table 7 – Noise statistics with action

Level	<35	<40	<45	<50	<55	<60	<65	<70	<75	>=75
Annoyed inhabitants										
LDEN	26.7	107.1	9.2	1.6	1.0	2.4	20.6	60.5	0.0	0.0
LNGT	142.9	1.0	1.0	2.4	18.9	62.7	0.0	0.0	0.0	0.0
Annoyed inhabitants (%)										
LDEN	11.7	46.8	4.0	0.7	0.4	1.0	9.0	26.4	0.0	0.0
LNGT	62.4	0.4	0.4	1.0	8.3	27.4	0.0	0.0	0.0	0.0
Annoyed inhabitants (total):			229							

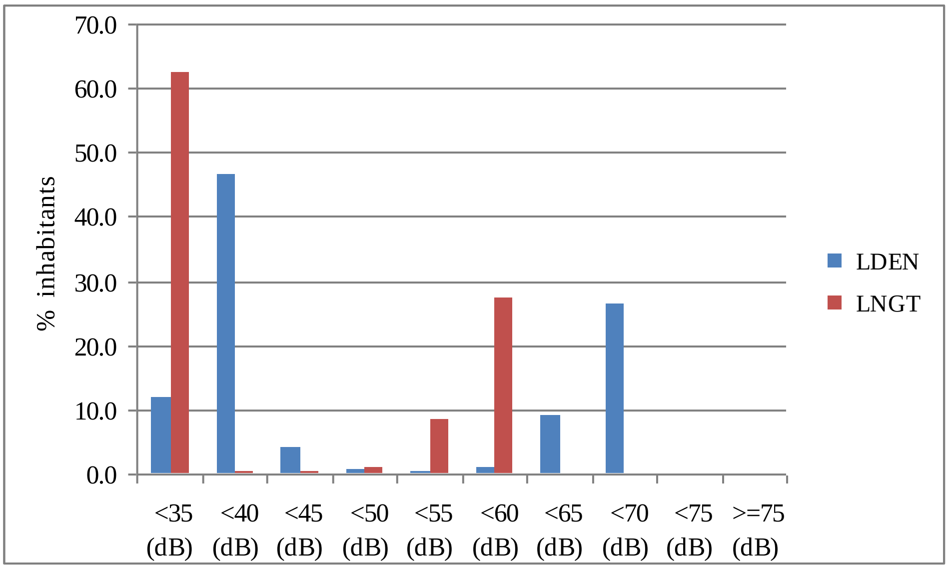

Figure 12 – % inhabitants, Noise (Table 7)

The noise statistics show, that the number of highly annoyed inhabitants will be reduced remarkable. 18, 6 % for LDEN and 17, 9 % for LNGT slipped into a lower class.

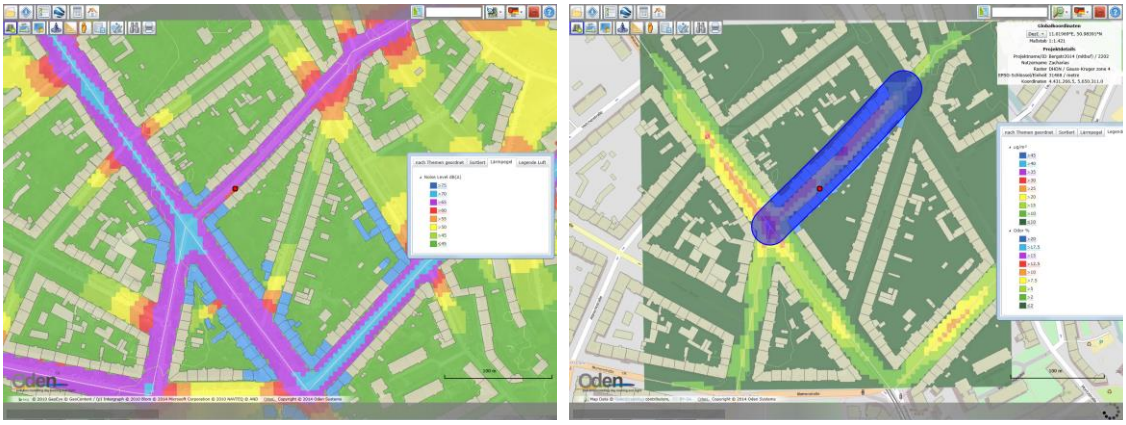

Figure 13 – Noise and Air pollution Map with Action

Table 8 – Air statistics NOX without action

Conzentration	<5 (µg/m3)	<10 µg/m3)	<15(µg/m	<20 µg/m3)	<25 µg/m3)	<30 µg/m3)	<35 µg/m3)	<40 µg/m3)	<45 µg/m3)	<50 µg/m3)	<55 µg/m3)	<60 µg/m3)	<65 µg/m3)	<70 µg/m3)	<75 µg/m3)	<80 µg/m3)	<85 µg/m3)	<90 µg/m3)	<95 µg/m3)	>=95 µg/m3)
Annoyed inhabitants																				
MITW	142.5	0.5	0.0	3.3	2.0	11.7	24.1	11.6	19.8	8.6	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAXW	81.6	59.9	1.0	0.0	0.5	0.0	1.6	1.2	1.1	6.3	6.7	18.0	9.7	11.5	10.7	4.4	3.6	4.4	2.9	3.9
MAXT	34.0	94.1	13.0	1.5	0.5	0.0	0.6	0.6	1.7	0.1	0.8	4.7	9.9	6.8	5.9	7.6	15.8	5.7	7.9	17.9
Annoyed inhabitants (%)																				
MITW	62.2	0.2	0	1.4	0.9	5.1	10.5	5.1	8.6	3.8	2.1	0	0	0	0	0	0	0	0	0
MAXW	35.6	26.2	0.4	0	0.2	0	0.7	0.5	0.5	2.8	2.9	7.9	4.2	5	4.7	1.9	1.6	1.9	1.3	1.7
MAXT	14.8	41.1	5.7	0.7	0.2	0	0.3	0.3	0.7	0	0.3	2.1	4.3	3	2.6	3.3	6.9	2.5	3.4	7.8

Annoyed inhabitants (total): 229

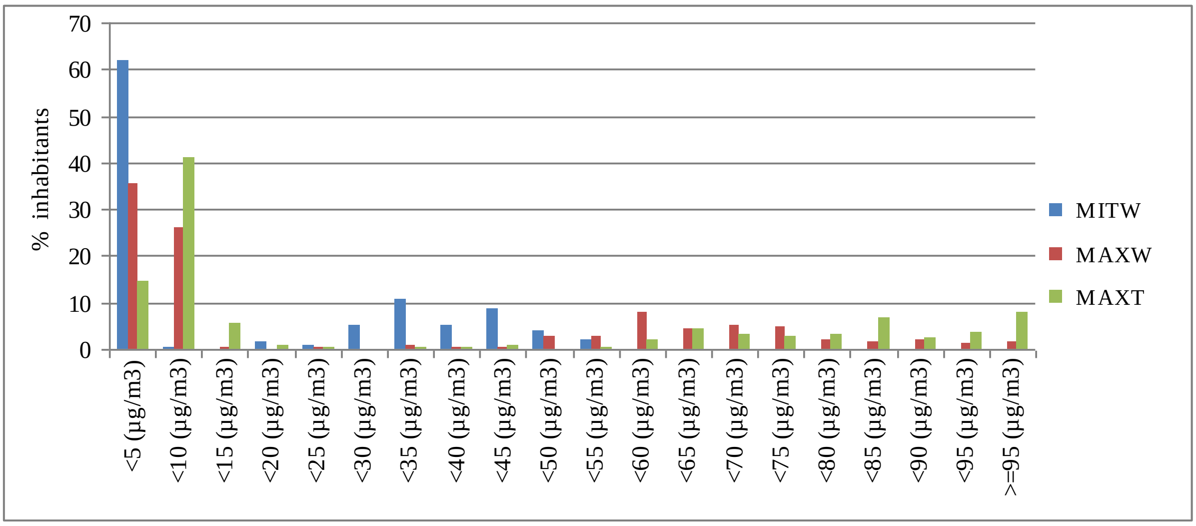

Figure 14 – % inhabitants, Air (Table 8)

Table 9 – Air statistics NOX with action

Annoyed inhabitants																				
MITW	142.5	0.5	3.4	32.1	25.3	21.9	3.1	0	0	0	0	0	0	0	0	0	0	0	0	0
MAXW	107.6	34.9	0.5	0.5	0.5	10.8	23.3	17.5	16.4	6.3	6.7	1.3	2.6	0	0	0	0	0	0	0

MAXT	104.7	35.9	2.5	0	0	0.6	9.1	13	12.1	23.8	9.6	7.7	2.9	0.9	3.6	2.1	0.5	0	0	0
Annoyed inhabitants (%)																				
MITW	62.2	0.2	1.5	14	11	9.6	1.4	0	0	0	0	0	0	0	0	0	0	0	0	0
MAXW	47	15.2	0.2	0.2	0.2	4.7	10.2	7.6	7.2	2.8	2.9	0.6	1.1	0	0	0	0	0	0	0
MAXT	45.7	15.7	1.1	0	0	0.3	4	5.7	5.3	10.4	4.2	3.4	1.3	0.4	1.6	0.9	0.2	0	0	0
Annoyed inhabitants (total):	229																			

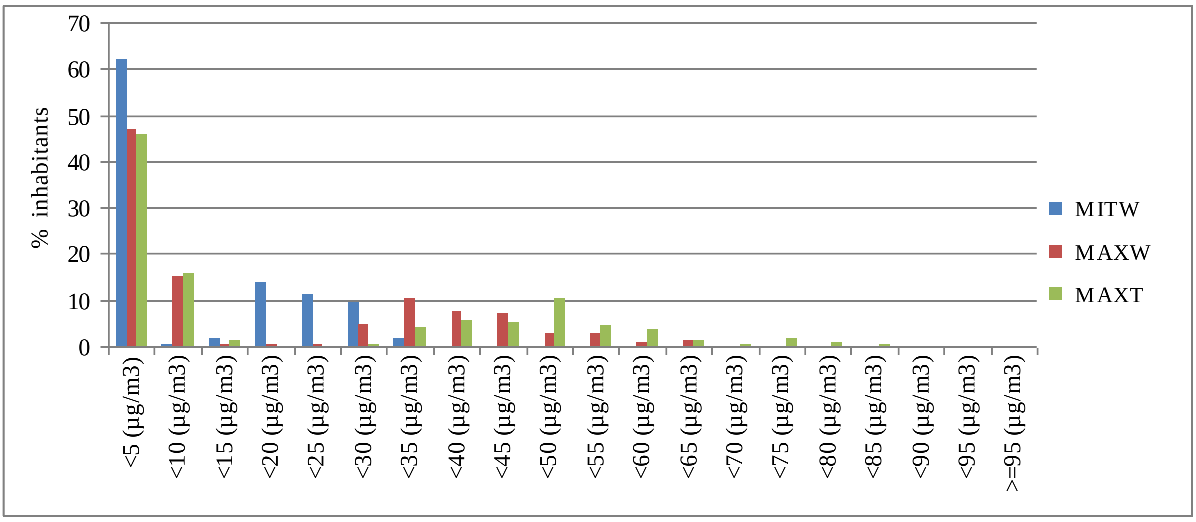

Figure 15 – % inhabitants, Air (Table 9)

The air statistics show, that the number of highly annoyed inhabitants will be reduced remarkably also. 19, 6 % for MITW, 18, 1 % for MAXW and 13, 7 % for MAXT slipped into a lower class.

The improvement for both mediums, noise and air, is about the same. With comparative small effort this action is considered to be recommended. The total values are not so important. The relative changes show much better that this action is very useful. Although it is possible to look at the absolute values in order to compare them with thresholds or limits, in this case we have to add the background concentrations which are caused by other sources.

4. CONCLUSIONS

The method presented is a contribution making decisions surer. Not only using the same data base but additionally using the same statistical method to evaluate actions the user can proof actions against noise vice versa actions against air pollution. If the statistics show insufficient results other actions might work as an iterative process until the planers and authorities are satisfied.

Because the WS ODENSLEU is modular system it is imaginable to put a third medium as special software in the background, such as cold air flow, to make the same evaluations.

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