Comparing models to predict the combined noise annoyance in Ho Chi Minh City and Hanoi

Q. Nguyenhuy[1], T.L. Nguyen[1], T. Yano[1], Y. Nishimura [2], S. Nishimura [2], T. Sato[3], T. Morihara[4] and Y. Hashimoto[5]

[1] Graduate School of Science and Technology, Kumamoto University, 2-39-1 Kurokami, 860-8555 Kumamoto, Japan, linh2lan@gmail.com, yano@gpo.kumamoto-u.ac.jp, nhuyquang@yahoo.com

[2] Kumamoto National College of Technology, 2659-2 Suya Koshi-shi, 861-1102 Kumamoto, Japan, nishimura@kumamoto-nct.ac.jp.

[3] Faculty of Engineering, Hokkai Gakuen University, Minami 26-Jo, Chuo-ku, 064-0926 Sapporo, Japan, sato@arc.hokkai-s-u.ac.jp

[4] Ishikawa National College of Technology, Kitachujo Ta-1, Tsubata, Kahoku, 929-0392 Ishikawa, Japan, morihara@ishikawa-nct.ac.jp

[5] Do Research, Nagai-Hikashi 4-13-20, Sumiyoshi-ku, 558-0004 Osaka, Japan, hashimoto@archi.ous.ac.jp

INTRODUCTION

Many residential communities especially in the urban areas of crowded and dense population city where the interference of many activities associated with the flow of variety of vehicles occurred are exposed by not only a single but also multiple sources. It means an environment composed of simultaneous occurrence of different noises, namely, combined noise source. The complex mechanism of the combined noise annoyance raises the need for efficient and simple prediction tools to evaluate its impact. Several previous studies regarding various models providing methods for predicting annoyance response to combined noise source have been published. Ollerhead's model named "Response and summation" was guided by the boundary condition that if one of the component sources masks all other sources the total annoyance must equal the response to that single source (Ollerhead 1978). A summation and inhibition model developed by Powell (1979) provides for the summation of the subjective magnitudes of annoyance due to the separate noise sources and for the inhibition of the subjective magnitudes of each source by the presence of the other noise sources.

This paper was inspired by the work of Taylor (1982), in which the powers of five models were compared for predicting annoyance reaction to mixed sources using data in the vicinity of Toronto International Airport. The result showed the energy difference model to be the most powerful predictor of mean total annoyance and the simple energy summation model to be the weakest. This finding confirmed the importance of absolute level differences between sources. Taylor also emphasized the need of further studies adding to the evidence provided by his analysis.

The socio-acoustic surveys conducted in the vicinity of the airports of the two largest cities in Vietnam where busy highways and roads concentrate. The residents are exposed to not only aircraft but also road traffic noise. Therefore, the impact of aircraft noise in Vietnam should be assessed in association with the impact of road traffic noise, in other words, as a combined noise of aircraft and road traffic. In the previous paper on these surveys, the dose-response curves for aircraft noise annoyance obtained in areas exposed to single noise showed to be different from that of areas exposed to combined noise source (Nguyen et al. 2009, 2010). In the survey in Hanoi, when the noise exposure level is lower than 55 dB, the two curves

are entirely parallel together with % highly annoyed difference of about 6 %. Above 55 dB aircraft noise annoyance in the combined noise survey steeply increases and the two curves are crossed each other at about 60 dB. This is opposite to the trend obtained in Ho Chi Minh Survey 2008. It is noteworthy that all the sites exposed to aircraft noise around main airports in Vietnam were also exposed to heavy road traffic noise. This shows the difference of characteristics of noise around the airports in Vietnam in comparison with Toronto Airport that was investigated in Taylor's paper. Hence, the social survey on combined noise of aircraft and road traffic noise in Vietnam can provide material to conduct more analysis to extent the discussion on the valid rating model for combined noise source. The final conclusion was still left open in Taylor's study.

In this paper, in addition to five models reviewed in the study of Taylor, two other models will also be taken into consideration. They are "Annoyance equivalents model" proposed by Miedema (2004) and "Dominant source model" developed by Rice and Izumi (Rice & Izumi 1984). Their research suggested the use of a dominant source model by which the total noise annoyance could be predicted by using the source specific annoyance of the most annoying of the noise sources.

The present study is expected to open for further analysis by using the data collected around the two largest airports in Vietnam before definitive conclusions can be drawn. The purpose of the present study is to find out the most powerful model in rating the annoyance caused by combined noise source determined by the traffic situation in Vietnam.

DATA COLLECTION

Site selection

The two cities chosen for the surveys are the busiest major metropolitan areas in Vietnam. In these cities, the effects of transportation noise on the health of the urban population continue to grow. The increase in transportation noise is due to rapidly increasing urbanization and industrialization. Tan Son Nhat Airport in Ho Chi Minh City and Noi Bai Airport in Hanoi are the two largest international airports in Vietnam. However, the handling capacity of Noi Bai Airport is only less than half of Tan Son Nhat Airport. Tan Son Nhat Airport is located inside a crowded residential area of Ho Chi Minh City with busy commercial streets. Noi Bai Airport is located among rural and scatted-populated areas far from downtown Hanoi and but right in the hub of many national arterial roads and industrial zones. Since the situations of the vicinity around the two airports were quite different, the validity of models will be examined separately for the data of the two airports.

Ten residential areas were selected around Tan Son Nhat Airport including eight sites under the landing and takeoff paths of aircraft and two other sites laying to the north and south of the runway. Nine sites were selected around Noi Bai airport including seven sites under the landing and takeoff paths of aircraft and two sites to the south of the runway. The site selection was intended to reflect the aircraft noise exposure covering locations at various distances from and directions relative to the airport. All houses selected in the combined noise areas at each site were facing the road with various traffic volumes in the vicinity of the airports.

Social surveys

Social surveys on community response to aircraft noise and combined noise from aircraft and road traffic were conducted around Tan Son Nhat Airport in Ho Chi Minh City from August to September 2008 and around Noi Bai Airport in Hanoi from August to September 2009. Community responses were obtained through an interview questionnaire presented as a social survey of the living environment. The responses to combined noise source were collected from residents of the houses facing the roads that were considered to be exposed to both aircraft and road traffic noise.

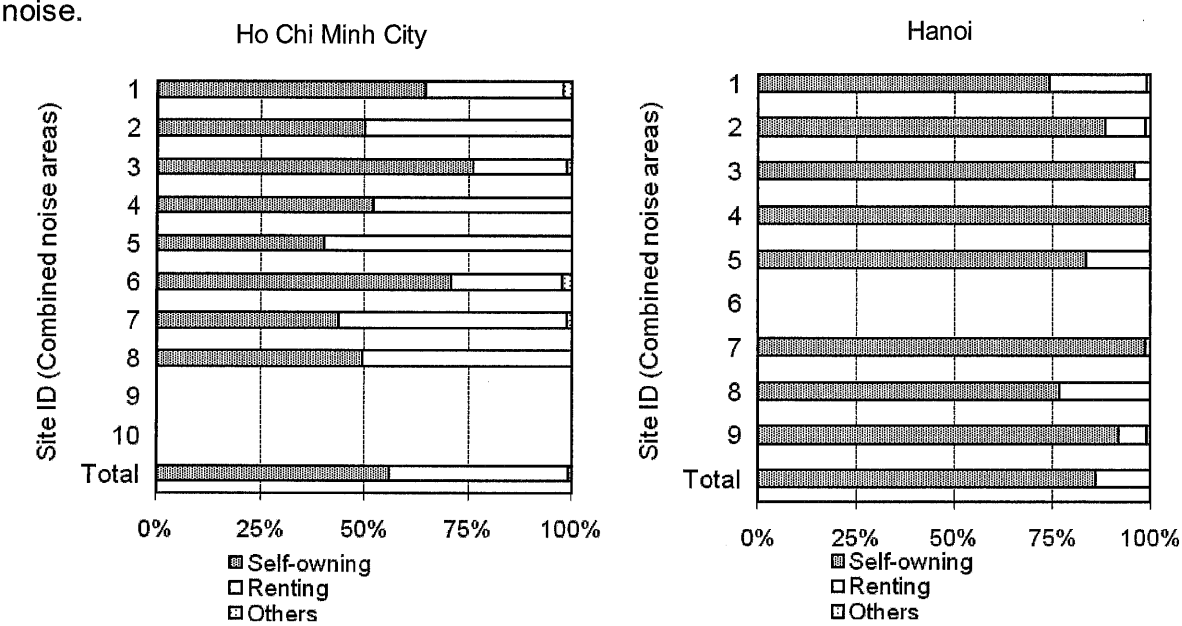

Figure 1: Component of the house's ownership types

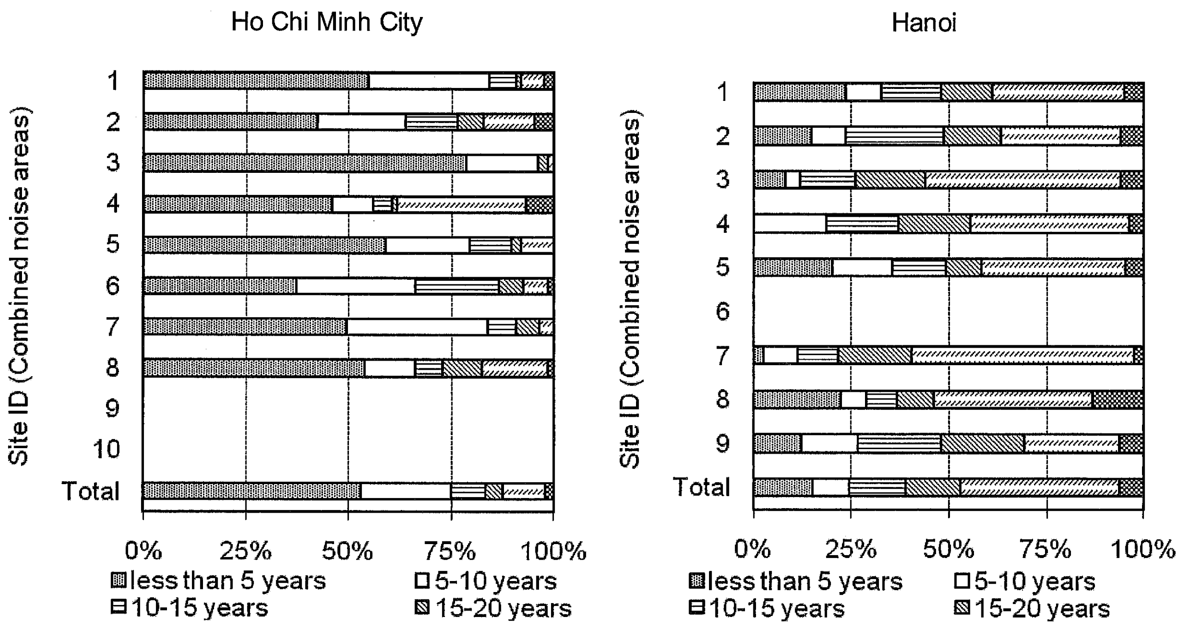

Figure 2: Length of residence

In the questionnaire, two scales — 5-point verbal and 11-point numeric — constructed according to the ICBEN (International Commission on Biological Effects of Noise) method were used to evaluate the respondents' noise annoyance (Yano & Ma 2004). The respondents were asked to evaluate their annoyance simultaneously to all three types of noise sources. They are aircraft, road traffic and combined noise of both. In this paper, the data from 11-point numeric question were used.

Ho Chi Minh City and Hanoi have different features with particular social and climate conditions. Figure 1 compares the respondents' house types obtained from the surveys in Ho Chi Minh City and Hanoi. The result reveals that the rate of respondents living in their own houses in Hanoi is higher than in Ho Chi Minh City. The rate of respondents that lived over 20 years in their houses in Hanoi is clearly higher than those in Ho Chi Minh City (Figure 2). Both cities are the major economic centers of Vietnam and attracting the huge number of migrants from the neighborhood areas. This result is consistent to the findings of Douglass et al. 2002 that presented migration rates of inter-provincial migrants are 23 percent and 8 percent for Ho Chi Minh City and Hanoi, respectively. Ho Chi Minh City has tropical climate with high and stable temperature, while Hanoi lies in the north with monsoonal climate with hot summer with high rainfall and cold winter, rare of rain. This might cause a different habituation of population in two cities.

Noise measurements

Noise measurements were performed in Ho Chi Minh City from September 22 to 29, 2008, and in Hanoi from September 10 to 17, 2009, by applying the same method in both cities. The combined noise of aircraft and road traffic was measured every 1 s for 24 h on the road shoulder. Aircraft noise exposure was measured every 1 s for seven successive days by using sound level meters (RION NL-21 and NL-22) at the same site but for the areas rather separate from the road which is supposed to be exposed to mainly aircraft noise. Road traffic noise metrics were calculated by energy subtraction of aircraft from combined noise metrics. The aircraft and combined noise exposures ranged from 53 to 71 dB and 73 to 83 dB L_{den} (from 49.4 to 65.8 dB and 69.4 to 76.9 $L_{Aeq, 24h}$) in Ho Chi Minh City and from 48 to 61 dB and 70 to 82 dB L_{den} (from 44.2 to 56.8 dB and 68.8 to 77.9 $L_{Aeq, 24h}$) in Hanoi, respectively.

RESULTS AND DISCUSSION

In this section, the data are used to examine the validity of combined noise models. The annoyance at each site was calculated by the unweighted mean of the individual annoyance score. The 24-hour average sound level $L_{Aeq, 24h}$ and average annoyance scores for aircraft, road traffic, and combined noise obtained from the surveys in Ho Chi Minh City and Hanoi are summarized in Tables 1 and 2, respectively. In Ho Chi Minh City, aircraft noise exposures ranged from 49.4 to 65.8 dB while road traffic noise exposure ranged from 69.3 to 76.9 dB at all sites. The average annoyance scores ranged from 0.5 to 7.7 for aircraft noise and from 3.8 to 8.9 for road traffic noise. In Hanoi, aircraft noise exposures ranged from 44.2 to 56.8 dB while road traffic noise exposure ranged from 65.7 to 77.9 dB at all sites. The average annoyance scores ranged from 1.6 to 7.9 for aircraft noise and from 4.7 to 8.4 for road traffic noise. It is clear to realize that in both Ho Chi Minh City and Hanoi, road traffic noise was shown to be not only physically but also psychologically dominant at all sites.

Table 1: Noise exposure and annoyance data in Ho Chi Minh City

Site ID	Noise level L_{Aeq} (dB)			Mean annoyance score			N
	Aircraft	Road	Combined	Aircraft	Road	Total	
1	54.2	71.1	71.2	3.2	4.3	4.4	59
2	49.4	76.9	76.9	0.5	8.9	8.9	57
3	49.4	69.3	69.4	7.7	3.8	5.9	54
4	52.0	70.7	70.7	2.7	4.1	3.5	88
5	65.8	75.1	75.6	7.0	7.8	8.2	87
6	59.0	74.3	74.5	5.4	6.6	5.7	84
7	59.8	73.8	74.0	6.3	4.2	4.9	85
8	56.8	71.8	71.9	5.9	7.1	7.0	85

N: Number of respondents

Table 2: Noise exposure and annoyance data in Hanoi

Site ID	Noise level L_{Aeq} (dB)			Mean annoyance score			N
	Aircraft	Road	Combined	Aircraft	Road	Total	
1	49.8	66.5	66.6	1.6	4.7	4.0	94
2	51.0	72.9	73.0	3.3	8.4	7.7	67
3	56.8	72.8	73.0	7.9	8.4	8.6	51
4	52.5	68.9	69.0	7.7	7.9	8.0	26
5	44.2	71.1	71.1	3.3	7.8	6.8	67
7	52.7	71.0	71.1	2.7	7.5	7.3	73
8	56.1	77.9	77.9	4.5	8.0	7.8	59
9	47.2	65.7	65.8	3.1	6.4	5.0	92

N: Number of respondents

The situation of surveyed sites in Taylor's study was quite different (Taylor 1982). The noise levels obtained in Taylor's study were from 55.6 to 71.1 dB for aircraft noise and from 52.2 to 69.9 dB for road traffic noise. The average annoyance scores were from 2.17 to 6.46 for aircraft noise and from 0.13 to 4.33 for road traffic noise. The aircraft and road traffic noise were quite comparable physically and aircraft noise was psychologically dominant. Such data indicates the different combination of aircraft and road traffic noise between two studies. Moreover, though 11 point numeric scale (0-10) was used in both surveys, the end point label was "extremely annoyed" in our study and "unbearably disturbed" in Taylor's.

In this part, linear regression analysis is applied to estimate the effects of aircraft and road traffic noise on annoyance. The individual annoyance scores and noise data are used to formulate the regression equations, in which the aircraft $L_{Aeq(24h)}$ (L_{AC}), the road traffic $L_{Aeq(24h)}$ (L_{RT}) and the cross production of L_{AC} and L_{RT} ($L_{AC}L_{RT}$) are used as independent variables for exploring the compositions of annoyance including total, aircraft and road traffic annoyance. The results are shown in Table 3. The aircraft $L_{Aeq(24h)}$ had significant effect at level $p<0.05$ and $p<0.01$ on total annoyance in Ho Chi Minh City and Hanoi, respectively. Total annoyance in Hanoi was significantly influenced at effective level $p<0.01$ by road traffic $L_{Aeq(24h)}$. The influence of aircraft and road traffic noise were opposite between the two cities that is negative for Ho Chi Minh City and positive for Hanoi. In contrast, interferences of slopes of two sources have positive effect on total annoyance in Ho Chi Minh City but negative for that in Hanoi. These findings emphasize different compositions of total annoyance between the two cities. It is noteworthy that while aircraft annoyance has the opposite mechanism, road traffic annoyance shows to be the same composition between the two cities. Moreover, no factor other than road traffic $L_{Aeq(24h)}$ significantly affects road traffic annoyance. In other word, this indicates an independence of road traffic annoyance from affecters. These findings imply the dominant role of road traffic noise in a mixed noise environment of all surveyed sites around Tan Son Nhat and Noi Bai Airport which are exposed to very heavy road traffic.

Table 3: Total, aircraft and road traffic annoyance as function of source L_{Aeq}

Equation													R^2	Std error
Ho Chi Minh														
A_T =	80.948	-	2.220	L_{AC}*	-	0.983	L_{RT}	+	0.030	$L_{AC}L_{RT}$*			0.200	2.465
A_{AC}=	301.464	-	5.106	L_{AC}**	-	4.231	L_{RT}**	+	0.073	$L_{AC}L_{RT}$**			0.351	2.294
A_{RT}=	-128.191	+	1.709	L_{AC}	+	1.81	L_{RT}*	-	0.023	L_{AC} L_{RT}			0.262	2.423
Hanoi														
A_T =	-160.129	+	2.851	L_{AC}**	+	2.296	L_{RT}**	-	0.039	L_{AC} L_{RT}**			0.280	2.191
A_{AC}=	-49.723	+	0.960	L_{AC}	+	0.583	L_{RT}	-	0.010	$L_{AC}L_{RT}$			0.134	2.729
A_{RT}=	-72.247	+	1.156	L_{AC}	+	1.152	L_{RT}*	-	0.017	$L_{AC}L_{RT}$			0.152	2.402

** $p<0.01$, * $p<0.05$

L_{AC} = Aircraft, $L_{Aeq(24h)}$ (dB), L_{RT} = Road traffic, $L_{Aeq(24h)}$ (dB),
A_T = Individual total annoyance score, A_{AC} = Individual aircraft annoyance score, A_{RT} = Individual road traffic annoyance score

In the next step, the multiple regression analysis was applied to compare how well seven models predict the observed data obtained in Ho Chi Minh City and Hanoi (Table 4). The regression equations are calculated by fitting a model to the data for which the sum of the squared differences between the line and the actual data points is minimized. The coefficient of determination R^2 indicates the percent that the model accounts for variability in the total noise annoyance. For example, in Table 4, R^2 is 0.474 in the energy summation model, indicating that the model accounts for 47.4 % of the variability in the overall annoyance. The standard error (Std error) of the estimate for regression measures the amount of variability in the points around the regression line.

The regression equations of seven combined noise models calculated for the data obtained in Ho Chi Minh City and Hanoi were shown in Table 4. The coefficient of determination R^2 of the regression equations for Ho Chi Minh City data indicated that the energy difference model estimated the total annoyance (R^2 = 0.49) better than energy summation, independent effects, response summation, summation and inhibition, and annoyance equivalents models (R^2 = 0.25–0.48). This result is consistent to Taylor's study at Toronto International Airport. The regression equations of seven models for Hanoi data show that the energy difference model (R^2 = 0.58) estimated the total annoyance slightly better than energy summation (R^2 = 0.53), independent effects (R^2 = 0.53) and annoyance equivalents models (R^2 = 0.54), but less effective than response summation (R^2 = 0.62) and summation and inhibition (R^2 = 0.62). This is partly different from Taylor's which can be explained by the differences in ranges of aircraft and road traffic noise exposures between two studies. These results confirm again the importance of absolute level differences between sources in their effects on a total annoyance.

Table 4: Regression equation for combined noise source models

Model						R^2	**Std error**
Ho Chi Minh City							
Energy summation	A_T =	-29.97	+	0.49	L_T	0.47	1.47
Independent effects	A_T =	-30.41	+	0.53	L_{RT} - 0.03 L_{AC}	0.47	1.61
Energy difference	A_T =	-30.48	+	0.49	L_T +0.05 L_{DIFF}	0.49	1.58
Response summation	A_T =	-28.53	+	0.47	$(L_T + 10.25 * 10^{(Lac - Lt/10)})$	0.48	1.60
Summation + inhibition	A_T =	-13.26	+	0.25	$L_{T(CORR)}$ (D=12)	0.25	1.75
Annoyance equivalents	A_T =	40.75	+	0.62	L	0.44	1.51
Dominant source	A_T =	-0.52	+	1.00	A_D	0.82	0.85
Hanoi							
Energy summation	A_T =	-14.30	+	0.30	L_T	0.53	1.17
Independent effects	A_T =	-14.65	+	0.23	L_{RT} + 0.098 L_{AC}	0.57	1.23
Energy difference	A_T =	-14.86	+	0.33	L_T - 0.095 L_{DIFF}	0.58	1.23
Response summation	A_T =	-18.88	+	0.35	$(L_T + 171.096 * 10^{(Lac - Lt/10)}$	0.62	1.17
Summation + inhibition	A_T =	-16.18	+	0.32	$L_{T(CORR)}$ (D=7)	0.62	1.06
Annoyance equivalents	A_T =	-14.77	+	0.31	L	0.54	1.17
Dominant source	A_T =	-1.99	+	1.20	A_D	0.90	0.53

However, the coefficient of determination R^2 is 0.82 and 0.90 for the dominant source models for the surveys in Ho Chi Minh City and Hanoi, respectively. They are also the highest value among all other models. The dominant source model implies that the overall annoyance is always equal to the highest single source annoyance. Though Miedema criticized the dominant source model in that it does not describe the empirical data correctly since the total annoyance increases if the annoyance level of non-dominant source approaches that of the dominant source (Miedema 2004), R^2 is highest for the dominant source models of both surveys in Ho Chi Minh City and Hanoi, suggesting that it is the most useful model in rating the total noise annoyance. This result can be explained by the case of the vicinity of the airports in Vietnam, where the difference in noise level between two sources is rather large (as shown in Table 1 and 2). This finding also confirms an early mention about a dominant role of road traffic noise in mixed noise environment around airports in Vietnam.

CONCLUSIONS

Since the dominant source model is to explain the total annoyance with the subjectively dominant source-specific annoyance and the other models are to explain with the objective noise levels, the superiority of the dominant source model could not be directly compared with the others. The much higher correlation coefficients of dominant source model in rating the total noise annoyance was confirmed in Vietnam where road traffic noise was more dominant than aircraft noise. This is convenient in such situation that dose-response curves are established separately for different noise sources.

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Noise and health in the greater Rotterdam area

H. Wolfert

DCMR Environmental Protection Agency, Centre for Environmental Expertise's, P.O. Box 843, Schiedam, The Netherlands, henk.wolfert@dcmr.nl

INTRODUCTION

As from 1994 the provincial and local authorities in the Rotterdam Metropolitan Area already realized that joint monitoring of the regional environmental situation was essential to an effective environmental policy. Since then, fifteen so called MSR reports on the Rotterdam region have been published. In the early years, the environmental quality appeared to improve visibly. More recently, however, on balance no further progress has been made. The explanation for this is that in the nineties, the 'easy' environmental problems could be solved through stringent source policies; the initiative at that time lay with the major polluters, mainly industries. As a consequence of this the difficult problems remained, which were mostly caused by diffuse sources. For example, noise nuisance is caused, among other things, by road and air traffic, and industry, while shipping traffic and road traffic are important sources of air pollution. Since there are usually a number of authorities responsible for tackling these diffuse sources, effective cooperation between these authorities is a prerequisite. Thus within MSR the most important authorities in the Rotterdam region environmental field are represented. By jointly sketching an integral picture of the environmental situation in the region, in MSR, these authorities can also jointly take those measures which are necessary in order to tackle the diffuse sources.

The goal of MSR is twofold. In the first place MSR aims at tracking the progress of environmental policy in the region and indicating new developments relating to environmental quality, free from value judgments. In this way MSR contributes to the policy cycles of the authorities who work together in MSR. Administrators and their staff thus obtain information which enables them to place, evaluate and, if necessary, adjust their policy in a broader context. Based on this information, they can also formulate new policy or speed up its implementation. Where no verifiable policy objectives are available, indicators in any case perform a warning function so that timely adjustments are still possible. In the second place, MSR informs residents and the business sector about the state of the environment in the Rotterdam region and its recent developments. In this way MSR fulfils the obligation that authorities have, in the framework of the Aarhus treaty, to supply environmental information to their residents. Furthermore, MSR responds to the societal need for transparent government.

The last MSR report was published mid-2010. During more than 15 years the monitoring program and report were elaborated. At first, only environmental themes as noise, air- and soil pollution were reported and developments on environmental permitting and enforcement of these permits. The very last report comprises indicators on energy, sustainable mobility, waste, water, air quality, noise, external safety, green and nature, space and also health. Environmental themes are cross border issues with other policy fields like economy, green, spatial- and urban planning, mobility et cetera. This is in particular true for noise. The number of noise indicators has increased during the past years. This paper mainly goes into the surveys that were done in 2008, the Environmental Perception Survey (Van Vliet et al. 2008) van con-