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Towards Livable Urban Environments by Addressing Health from a Spatial Perspective: Exploration by Mapping Environmental Noise and Air Pollution in the Northern Fringe of Brussels

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1 ABSTRACT

Although a growing societal awareness for the impact of the built environment on health and well-being urges spatial planners to take health aspirations into account, the issue is mostly addressed very late in the planning process.This results in a rather short term perspective of possible solutions and a mainly local focus on measures to mitigate environmental nuisance. The article starts from the existing gap between the requisite technical expertise concerning enviromnental nuisance and the daily spatial planning practice, preventing a substantial shift to incorporating public health concernsin spatial policy initiatives or interventions. Therefore opportunities to positively affect health and well-being through enhancing environmental liveabilty conditions are missed.

The article focuses on environmental noise and air pollution in relation to human health in the Northern Fringe of Brussels. Useful data sources are explored and selected indicators are processed by GISanalysis to establish a comprehensible mapping method for evidence informed spatial policy,showing spatial varation of environmental health issues in the area.

2 INTRODUCTION

Modern urban planning originated in the nineteenthcentury addressing the lack of sanitation, absence of potable water and the general poor quality of housing in the emerging industrial cities(Verbeek & Boelens, 2013). Despite of these strong historic ties spatial planning and health have lost connection in the last century(Levy, 2014).On the one hand alot of health criteria are converted in legislation, leaving the issue of enviromnental health to the environmental department, on the other public health today tends to be associated with individual human behavior rather than be affiliated with environmental conditions.Health however is not only associated with individual human behavior, but is also affected by environmental, social and economic conditions(de Hollander & Staatsen, 2003).Needless to point out that spatial planning practice plays an important role in shaping these conditions(Jackson, 2003).Furthermore a growing societal awareness for the impact of the built environment on health and well-being urges spatial practitioners and policy makers to take public health concerns into account. Consequently, the assurance of liveable urban environments as a precondition for spatial development in Flanders, is cited in the policy statement of the Minister of Environment(Flemish Government, 2014). The same policy goal is included in the Green Paper for the Spatial Policy Plan Flanders, whichaims to develop a diverse living environment with quality of life, health and identity as core values(Flemish Government, 2012).

The commitment to assure or maintain urban liveability when developing or transforming certain areas, or making spatial policy decisions, requires an insight in public health from a specific spatial perspective.Thisis not obvious sinceknowledge ofenvironmental nuisance and associated health impacts is fragmented over various fields of expertise. Moreover, spatial planning requires a generalist view, since it has to address a combination of very diverse challenges. Thus, even though mapping of nuisance indicators is more and more widely available, it is difficult to incorporate it in spatial planning practice because of thelack of expertise to comprehend, combine, interpret and use the evidence for spatial planning purposes.Therefore inplanning practice public health concerns are often considered very late in the planning process which results in a rather short term perspective of possible solutions and a mainly very local focus on measures to mitigate nuisance. Facing the issue earlier in the process and from a broader perspective could provide more sustainable and long term solutions for enhancing environmental liveabilty conditions. Indeed exposure can be achieved by a consistent proactive spatial planning strategy which transforms or adapts existing living environments or prevents the exposure to nuisance forfuture developments.Actions can be taken on a programmatic level by guiding social functions to less exposed areas or prohibitingcertain developments in overexposed environments, and can involve the evaluationof new locations of services for vulnerable social groups such as infants or senior citizens. Furthermore, spatial interventions or urban design can enhance liveabilty on a neighbourhood level by buffering emmission sources, providing greenery and parks to reduce exposure to certain pollutants or taking measurements to ensure sufficient flows of fresh air. But also at a building level measures can be taken in terms of insulation or alignment of windows.Our research hypothesis suggests that incorporation of health concernsin spatial policy initiatives or interventions is problematic due to the gap between the requisite technical expertise concerning nuisance and health topics and the spatial planning practice. The research aims to clarify and frame the existing technical evidence for spatial planning purposes, opening the pathway for more sustainable and long term solutions to profoundly enhance environmental liveabilty conditions.

The analysis is restricted to the environmental impacts of air pollution and noise. According torecent research issued by WHO, these form the first and third largest environmental burdens on health in Europe (with second hand smoke the second largest)(Hänninen et al., 2014). In Flanders, they are the two major environmental conditions affecting human health (Flemish Environmental Agency, 2013).For air pollution in general, residential exposure to high traffic has been related to asthma (e.g. Morgenstern et al., 2008), deficits in lung development (e.g. Gauderman et al., 2007) and allergy development (e.g. Nordling et al., 2008) in children; and a higher mortality risk (e.g. Finkelstein, Jerrett, & Sears, 2004) and coronary disease (e.g. Hoffman et al., 2007) for the whole population. For traffic-related noise exposure, conclusive associations have been found with sleep disturbance (e.g. Miedema & Vos, 2007), cognitive development of children (e.g. Stansfeld et al., 2005), (slightly) increased risk of hypertension (e.g. Babisch, 2006) and coronary heart disease (e.g. Gan, Davies, Koehoorn, & Brauer, 2012).

Following research questions are formulated: Which indicators concerning environmental noise and air pollution can provide insight in human health from a spatial perspective? Which thresholds are to be taken into account when evaluating or estimating the impact on human health? How can existing nuisance data be framed in order to establish comprehensible insights for spatial planning practice?

3 INDICATORS AND DATA FOR ENVIRONMENTAL NOISE AND AIR POLLUTION

3.1 Air Pollution

3.1.1 Indicators and standards

To assess air pollution several standard indicators are used. Depending on the aim of theanalysis other indicators come into view. For some indicators the WHO and the EU have respectively set guidelines or binding threshold values. A summary is given in Table 1.

- Fine dust, fine particles or particulate matter (PM): Two general indicators are in use, PM_{10} and $PM_{2,5}$, consisting of the concentration of particles with a diameter of 10/2,5 micrometer or less. They reflect all kinds of air pollution, both industrial, household and traffic-related air pollution. As such they donot give that much variation on a local scale and rather reflect urban background concentration. As indicator for traffic-related air pollution recent research proves that they are not very efficient (Berghmans et al., 2009; Fischer, Marra, Wesseling, & Cassee, 2007; Ibald-Mulli, Wichmann, Kreyling, & Peters, 2002; Zhu, Hinds, Seongheon, Shen, & Sioutas, 2002).
- Ultrafine particles (UFP): Because research increasingly suggests that the finest particles ($PM_{0,1}$: fraction of particles smaller than 0,1 micrometer) are most related with traffic and most harmful, there is a need for more monitoring, guidelines and policy concerning ultrafine particles. However, until today this does not exist. Only specific components like NO_2 and elementary carbon or soot (EC) are measured and monitored.
- NO_2:NO_2 is a gas that is produced for the biggest part by road traffic. Therefore it is a major indicator for traffic-related air pollution and has a lot of local spatial variation. It is not very likely that the reported health effects are caused by NO_2 in itself. Probably the presence of NO_2 is correlated with a specific mix of fine particles which is typical for traffic-related air pollution and the related health effects. NO_2 can thus be seen as a proxy indicator and therefore threshold values are set by WHO and EU.

- Elementary carbon (EC) or soot: EC is one of the fractions of particulate matter, and is a combination of carbon and carbon compounds. This fraction seems to cause the most environmental and public health damage. EC is especially emitted from the combustion of fossil fuels (e.g. diesel engines) and organic material. Both the WHO and the EU do not have threshold values. However, the indicator is often measured, modeled and monitored by government departments.

Indicator	WHO Air Quality Guidelines – Global Update 2005	EU Air Quality Standards (legally binding) (2008/50/EC)
PM_{10} annual mean level	20 µg/m³	40 µg/m³
PM_{10} 24-hour mean	50 µg/m³ (3 exceedences permitted/year)	50 µg/m³ (35 exceedences permitted/year)
$PM_{2,5}$ annual mean level	10 µg/m³	25 µg/m³
$PM_{2,5}$ 24-hour mean	25 µg/m³ (3 exceedences permitted/year)	-
UFP	-	-
NO_2 annual mean level	40 µg/m³	40 µg/m³
NO_2 mean daily one hour maximum	200 µg/m³ (18 exceedences permitted/year)	200 µg/m³
EC	-	-

Table 1: WHO Air Quality Guidelines and EU Air Quality Standards

3.1.2 Available data

To gain insight in the local variation in air pollution in Flanders and Brussels, there are two possibilities. On the one hand there are fixed monitoring stations, which measure specific indicators of air quality at fixed locations, on the other hand there is the RIO-IFDM model, which models several indicators of traffic-related air pollution.

Air quality monitoring stations

Both Flanders and Brusselsmaintain a telemetric monitoring network for air quality. The data is collected by IRCEL-CELINE (Belgian Interregional Environment Agency) for each measuring station (11 in the Brussels Capital Region and 75 in the Flemish Region) and can be retrieved at http://www.irceline.be. The stations monitor different kinds of pollutants (PM_{10}, $PM_{2,5}$, NO_2, O_3, EC), however not all pollutants are being measured in every station. The data can only give insights in air quality at a specific local level, which is notsufficientfor elaborate spatial analysis.

RIO-IDFM model

The RIO-IFDM model is used by ATMOSYS, an Environment Policy and Governance project co-financed by the European Commission, facilitating an air quality modeling system. On the project website (http://www.atmosys.eu) ‘annual air quality’ maps for traffic-related air pollution can be consulted by the public. On request also the rasterized source data can be retrieved. Maps are provided for several indicators (PM10, PM2,5, NO2, O3, EC), and different years.The model is conceived for Flanders but can be deployed in other regions aswell.

These maps are the result of the combination of two data sources: the spatial interpolation of air quality measurements and the calculation of air pollutant concentrations based on meteorological data and the emissions of air pollutants (Lefebvre et al., 2013). Although some validation tests gave reliable results, both data sources have limitations and uncertainties. Most importantly, the model does not take into account the effect of obstacles alongside roads (buildings, continuous urban fabric, trees, …) which can cause the so called street canyon effect. This means that in narrow inner city streets, with a lot of traffic, where the dispersion of polluted air goes slower, the model will probably underestimate the concentrations.

3.2 Environmental Noise

3.2.1 Indicators and standards

To assess environmental noise several standard harmonized indicators exist, that are also proposed in the European Union Environmental Noise Directive (EU2002/49/EC). The most used are L_{den} and L_{night}, in some situations also L_{day} and $L_{evening}$ can be useful.

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- L_{den} is the average long term sound level over a 24h period, with a penalty added for noise during the nighttime hours of 23:00 to 07:00. During the nighttime period 10 dB is added to reflect the impact of the noise.
- L_{night} is the average long term sound level during the night hours (23:00 to 07:00).
- L_{day} is the average long term sound level during the day hours (07:00 to 19:00).
- $L_{evening}$ is the average long term sound level during the evening hours (19:00 to 23:00).

In Flanders there are no fixed legal threshold values, which is in line with the European Enviromental Noise Directive that does not set binding limit values as well. However there are some guidelines issued by the World Health Organization. In 1999 they published Guidelines for Community noise (WHO, 1999), in which a threshold of 55 dB was determined for Lden, corresponding to serious annoyance. Further, they stated that moderate annoyance already occurs at 50 dB and that for new developments 40 dB should be the aim. For sleep disturbance at night (Lnight) they determined a threshold value of 45 dB.

For 24h noise exposure, their guidelines still are in force. For night noise the WHO published new guidelines in 2009 (WHO, 2009), in which they set an interim target for night noise (L_{night}) of 55 dB, and a guideline of 40 dB – which is the LOAEL or Lowest Observed Adverse Effect Level.

3.2.2 Available data

One of the binding decisions in the EU Environmental Noise Directive was the obligation of the member states to monitor the environmental problem of noise through the drawing up of ‘strategic noise maps’. This should be the base for drawing up ‘action plans’, developing a long-term EU strategy and informing and consulting the public. The ‘strategic noise maps’ had to be drawn up for all major roads, railways, airport and agglomerations, using the harmonized noise indicators of L_{den} and L_{night}. In Flanders these maps were drawn up in 2006, and updated in 2011, for airports, road traffic and railway traffic. For agglomerations with more than 250.000 inhabitants (Antwerp, Bruges, Brussels and Ghent), more detailed noise maps were created, including the noise effect of industrial plants.

These noise maps can be consulted as pdf on the websites of the Flemish Department of Environment, Nature and Energy (LNE - http://www.lne.be), and the Brussels Capital Region Department of Environment and Energy (BIM - http://www.leefmilieu.brussels.be). Disposing of the original high resolution, rasterized data however requires a lot of communicational effort.

4 PRESENTING DATA FOR EVIDENCE INFORMED SPATIAL POLICY

4.1 Selection of indicators for Air Pollution and Environmental Noise

For a comprehensible and relevant mapping two indicators were determined, one to assess air pollution and one to assess noise. For air pollution, the average yearly concentration of NO_2 (2013) was chosen, as it is known to be a good indicator of urban traffic generated pollution, showing more spatial variation than other modeled pollutants (Goodman, Wilkinson, Stafford, & Tonne, 2011). For noise, L_{den} (2006 for Brussels and 2011 for Flanders) is used as proxy variable for environmental noise. In Europe, it is the most standard harmonised noise indicator for assessing annoyance and sleep disturbance (cfr. EU Environmental Noise Directive).

4.2 Methods for aggregation or interpreting environmental pollution

In literature and planning policy or practice several methods to aggregate or interpret environmental pollution are used. To give inspiration, some are presented here.

DALY

The metric of DALY or Disabiliy Adjusted Life Year is the unity which is used by the WHO to define the environmental burden of disease of a certain environmental impact (Prüss-Ustün, Mathers, Corvalán, & Woodward, 2003). DALYs are a measure for the number of potentially lost healthy life years and were first described by Murray and Lopez (1996). Using DALYs, more or less serious diseases can be compared and weighed. The specific disability weight of a certain disease is determined by a team of medical experts. In general DALYs are the sum of the years of life lost (YLL) by premature mortality and the number of life years living with a serious disease or disability (Years Lived with Disability or YLD). DALY is a relative and not an absolute indicator for the disease burden. Several factors like lifestyle, smoking habits, diet, genetic predisposition can contribute to a disease. For Flanders as a whole DALYs were already calculated for environmental pollution (Torfs, 2003).

Partially because of its relative character, it is a good metric to estimate the environmental burden of disease for a region like Flanders, but it seems not to be the best way to translate local environmental pollution data to spatial planners. Chances are high that these DALYs do not meet the requirements of comprehensibility and easy data interpretation.

GES

A GES or Health Effect Screening (in Dutch: Gezondheidseffectscreening) is an instrument which gives insight in the different environmental factors that have on impact on the health of (future) residents (Fast, van den Hazel, & van de Weerdt, 2012). It can give an idea of the health related challenges and opportunities in urban development projects or other planning processes. A major advantage of the method is that also exposure below the legal thresholds is taken into account, leading to a nuanced view on the quality of planning towards environment and public health.

Concretely, the GES method considers the health effects of exposure to air pollution, noise, odour, external safety and electromagnetic fields. All relevant sources (industrial plants, roads, railways, shipping, air traffic and high tension lines) are included. Also land contamination is considered. Based on a dose-response relationship for each environmental factor the exposure is expressed in a GES-score which gives an idea of the environmental health quality. Scores vary from 0 (very good) to 8 (extremely insufficient). For each impact a score of 6 corresponds to the maximum acceptable risk. The different GES-scores are mapped per environmental impact, making use of the same colour scale. In a table or graph the number of inhabitants with a certain GES score for a specific impact is calculated. In this way planners and policymakers can have a comprehensible view on the public health effects of urban development plans and contribute to justified and evidence-based policy choices.

Kruize & Bouwman’s three approaches

In a study on environmental (in)equity in the Rijnmond region in the Netherlands, Kruize and Bouwman (2004) propose three different approaches to make environmental indicators operational and interpretable. In their study, this operationalization had to assess the socio-economic distribution of environmental quality. They think these disparities can be considered in several ways.

- A first approach starts from the basic ‘protection of general human rights’ and the equality of all citizens. Consequently, no disparities should exist between income categories in environmental quality. This leads to comparing the distributions, means or percentages of each socio-economic category with each other to see if there are differences.
- A second approach takes a minimum local environmental quality as a starting point. Environmental laws and standards may define this minimum quality. Levels above this standard could be defined as environmental ‘bad’. To analyse disparities, one might compare how often ‘bads’ are present for different socio-economic categories, i.e. how many households are exposed to pollution above a certain limit value.
- A third approach starts from the idea of a ‘nice and pleasant’ type of local environment, which is not only a guarantee for protection of health, but also a comfortable and liveable environment. For each impact target values can be decided on, based on expert judgment or on e.g. surveys on satisfaction or annoyance. Disparities could then be analysed by comparing how often the level of an environmental indicator is below the target value, or the amount of people being satisfied or not annoyed.

4.3 Case area and used methodology

4.3.1 Case area Northern Fringe of Brussels

The case studyfocuses on the Northern Fringe of Brussels, an area which is intersected by two of the most heavily used highways in Belgium, furthermore containing the international airport of Brussels, a major

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European aviation hub. It is self-evident that environmental health issues are to be expected in this area. Moreover recent forecasts predict a strong demographic growth (Schockaert, 2015) in the Northern fringe due to an influx of inhabitants from the capital to the adjacent municipalities (Schillebeeckx, De Decker, & Oosterlynck, 2015).

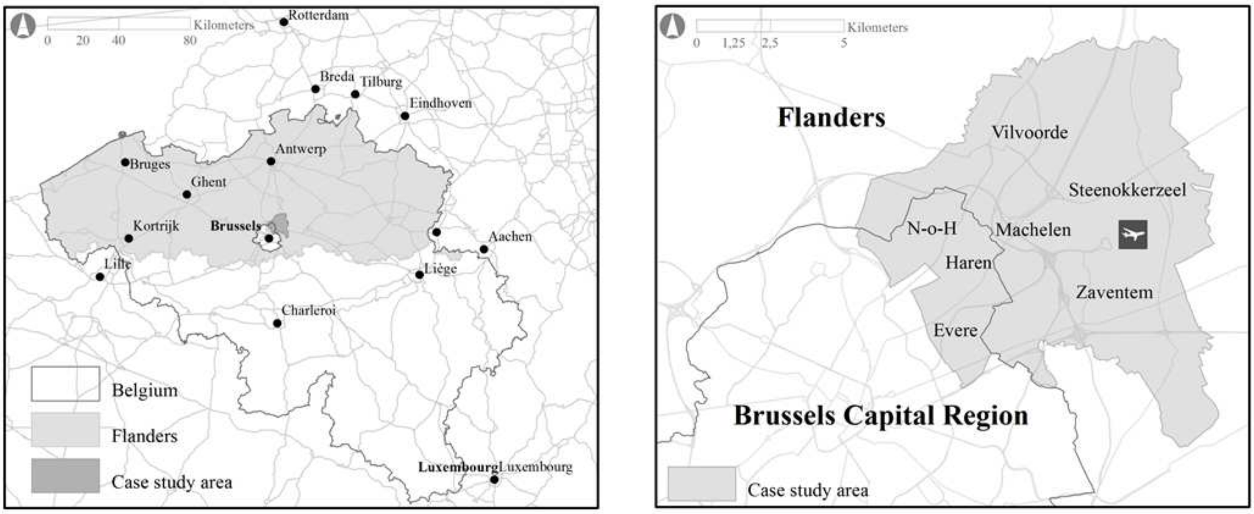


Figure1: Location ofthecasearea at the Northern fringeofBrussels, Belgium (source: ownmap)

This increase in the number of inhabitants will result in even more acute problems associated with urbanisation, including health issues, which are to be addressed by spatial planners in pursuit of a sustainable development of this area.Therefore, our research will specifically focus on current and future housing issues, although similar excersises could be performed regarding other socio-economic functions like attraction poles of employment, education or recreation.

Fortheextentof this research the study area consists of the municipalities of Vilvoorde, Zaventem, Steenokkerzeel and Machelen – which are situated in the Flemish region – and the municipalities of Evere, Haren andpartsofNeder-over-Heembeek -whichbelongtotheBrussels Capital region (figure 1). The areaispopulatedby approximately 147.000 inhabitants and is a central fragment of a mutual territorial development program, in which Flanders and the Brussels Capital region gather spatial partners to define and implement common goals for short and medium term development.Better knowledge about environmental health issues can help toclarifythechallengestobeaddressed in the program.

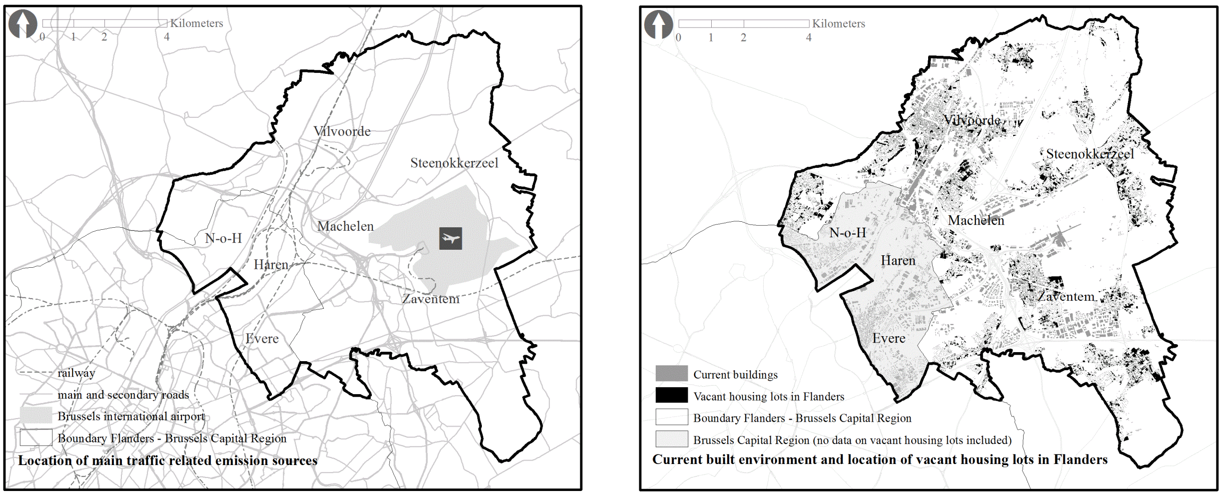


Figure2: left: Location oftrafficrelatedemissionsoures - (source: ownmap). right: Currentbuiltenvironmentandlocationofvacant lots in theFlemishpartofthecasearea(source: ownmap)

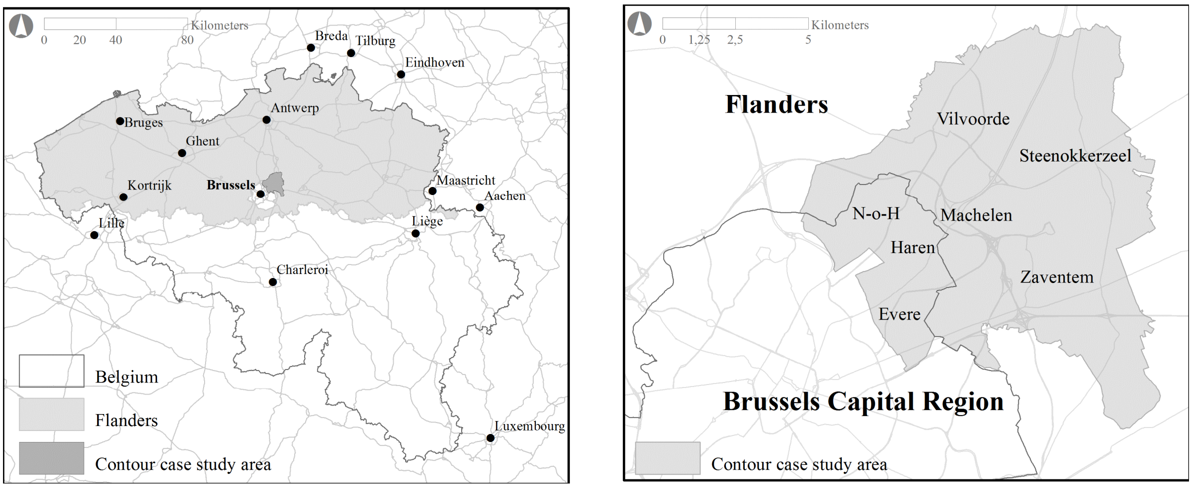
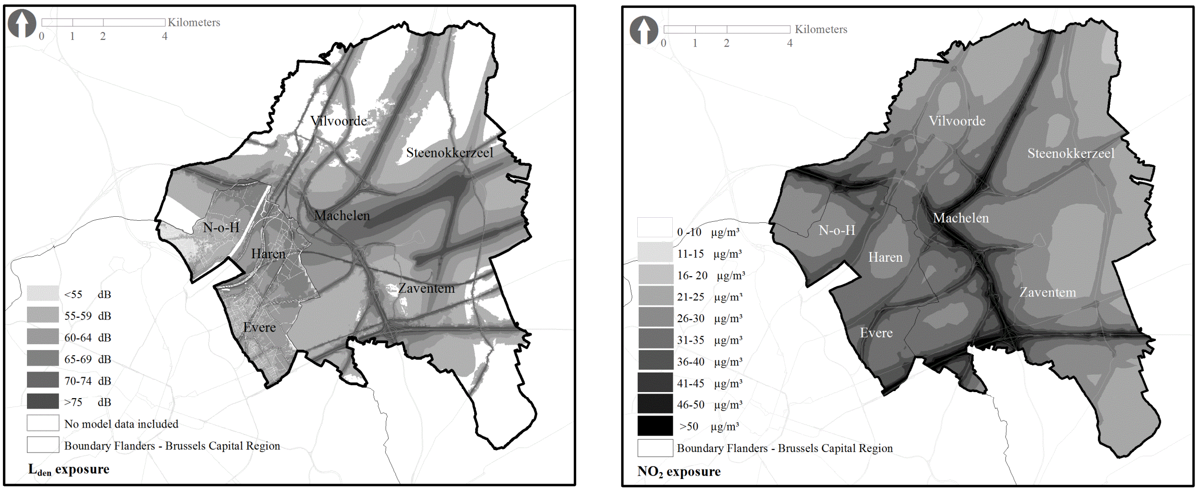


Figure3: left:ModdeledtrafficrelatedLdenexposure. ownprocessingasexplained in thearticle(source: noisemapsissuedby LNE 2013 Aand BIM 2006). right:ModdeledtrafficrelatedNO2exposure (source: RIO-IFDM data 2013 issuedbyIRCEL-CELINE)



4.3.2 Spatial scale of the output

In order to establish significant output it is presented on the level of statistical sectors, a subdivision of municipalities in Belgium, representing distinct neighborhoods, which is widely used for scientific research and collectionof statistical data. This subdivision ensures both the suitability of the produced data for possible further research and, being an intermediate spatial scale, provides appropriate evidence for spatial policy.

4.3.3 Methodology for mapping NO_2

The basis for the mapping of exposure to NO_2 in our research is a raster data set issued by IRCEL-CELINE (Belgian Interregional Environment Agency) which was produced by using the ATMOSYS RIO-IFDM-model for the year 2013. The dataset contains the modelled average yearly exposure of NO_2 in our case area, with a resolution of ten by ten meters. Two sets of maps were made; a first set giving insight in the current residential exposure, a second set clarifying the exposure of possible new housingdevelopments.

To map the current exposure per statistical sector firstly the exposure per person was calculated by IRCEL-CELINE making use of a recent data set (2008) containing population data per address. Theaverage exposure was calculated per statistical sector, giving insight in the general level of exposure within the sector. Also the percentage of inhabitants exposed to a yearly average NO_2 concentration exceeding 40µg/m³ was calculated, corresponding to the WHO and EU threshold.

To give insight in possible nuisance innew spatial developments the research firstly analysed the vacant lots for development. Because of data availability and limited time our mapping of this aspect only included the areas within the Flemish region. In Flanders every municipality is obliged by decree to set up and maintain a register containing information on vacant building lots as a useful instrument for local spatial policy. Due to a lack of recent data in the registers of the involved municipalities this data set couldnot be used for the extent of our research, necessitating a different approach. By making use of the Flemish register of zoning plans all possible lots legally allowed to be built on for housing were selected for the case area, all lots containing constructions according to the most recent dataset of the Belgian land register (2014) were deducted and all remaining lotswith a minor surface area to develop (a 150m² threshold was used) excluded. This methodology allowed to distinguish all vacant lots in the Flemish part of our case area but it did not exclude lotswith a morphology that prevents development (e.g. lots being too narrow)nor did it take possible spatial context avoiding development into account, as assessed in the municipal registers.The mapping of the exposure of available residential lots per statistical sector was done by assigning a level of exposure to every vacant lot using the centre of the lot as a reference. A weighted average was calculated per statistical sector by taking the areaof the exposed lots into account. In this way wider lots have a larger influence on the calculated average, since they allow more possible new development. In analogy to the mapping of existent exposure also a percentage of areaexposed to a yearly average amount of NO_2 exceeding 40µg/m³ was calculated per sector. Similar to the mapping of existent exposure two maps were established.

4.3.4 Methodologyfor mapping L_{den}

The basis for the mapping of exposure to L_{den} in our research are the mentioned noise maps for Brussels and the Flemish Region. Due to the different methodology, noise maps in both regions are difficult to compare and the calculation of averages per statistical sector would make no sense. Furthermore the data is not available as a raster data set making thesecalculations even impossible. For the extent of our research we made othermethodological choices to produce sensible maps for assessing exposure to L_{den} per statistical sector.

Firstly a combined noise map for the Flemish part of our research area was assembled by withholding only the highest levels of exposure when overlaying the different noise maps for aviation, roads and railways. Since there are no official standards for L_{den} exposure and the noise maps show an overall high exposure in the case area, an arbitrary threshold of 65dB was selected for assessing the variation in exposure betweenstatistical sectors. Clearly in less exposed areasa 55dB threshold as recommended by the WHO should be considered, but in our case this would not allow for enough spatial variation.Secondly, per statistical sector the percentage of inhabitants exposed to Lden exceeding 65dB was calculated by IRCEL-CELINE making use of the data set containing population data per address. To make sure exposure levels at the façade of buildings were taken into account a buffer of 10m was used in the calculation. The mapping of the exposure of available area for development per statistical sector was done similar to the mapping of NO_2 by calculating the area percentageof vacant lots being exposed to L_{den} exceeding 65dB.

5 RESULTS AND DISCUSSION

The research intended to establish a mapping method of environmental noise and air pollution useful for developing spatial planning policy and strategies that contribute to sustainable and long term solutions for the enhancement of environmental liveability conditions.Two (sets of) maps were created for both nuisances in the Northern Fringe of Brussels, gaining insight in the current level of exposure of inhabitants in the different districts onthe one hand and the level of exposure for potential housing development in those areason the other. Because of the focus on current and future housing, based on exposure at current addressess and the location of vacant building lots, the established maps will not give insights into exposure of other social functions (especially those which are spatially separated from housing like large poles of employment and industry). Additional mapping excercises can be performed to clarify health issues for other socio-economic functions, based on other parameters.

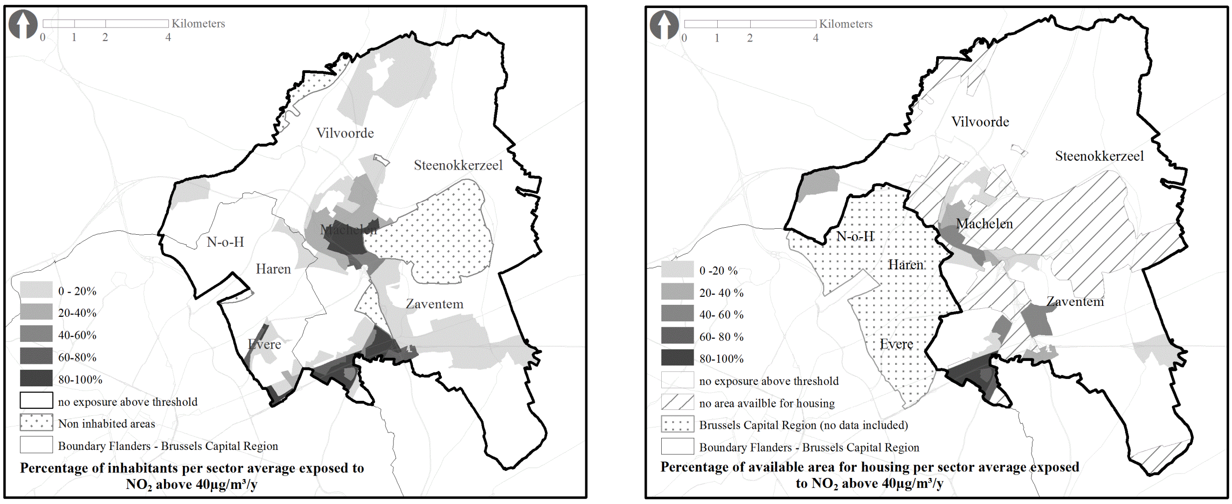


Figure4 : Currentand potentialexposureto NO_2> 40 µg/m³/year (source: ownmapbased on RIO-IFDM data 2013issuedby IRCEL)

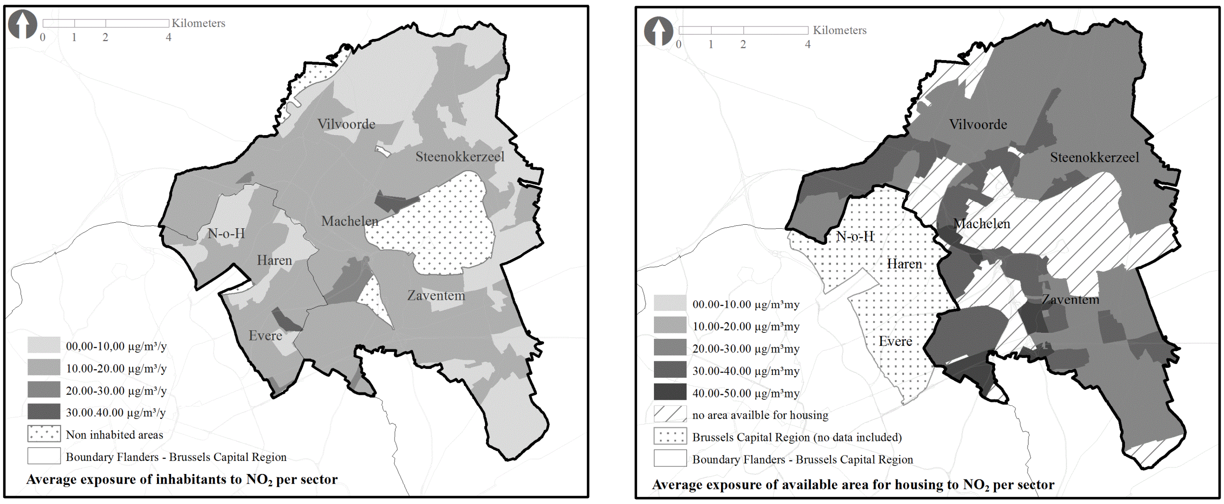


Figure5: Currentand potential average exposure to NO_2 per sector (source: own map based on RIO-IFDM data (2013) issued by IRCEL)

In our case study area the set of maps show no current average exposure above 40µg/m³/y per sector (figure 4, left map), although a large percentage of peope are in fact living in an overexposed area (figure 5, left map) especially in Machelen and around border of Evere and Zaventem. Observing the maps incating potential exposure for future development the percentage of potential new housingexposed above the 40µg/m³/y-threshold (figure 4, right map is generally lowerin comparison to the percentage of currently exposed inhabitants, except for some areas in Zaventem and southwest of Vilvoorde, but clearly the average percentage of vacant lots exposed to NO_2 is much higher (figure 5, right map). In Machelen and southwest of Zaventem even averages above the WHO and EU threshold are figured in available areas for housing development.

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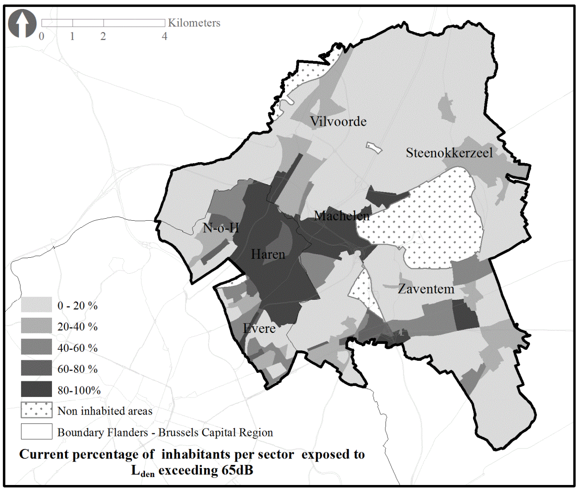

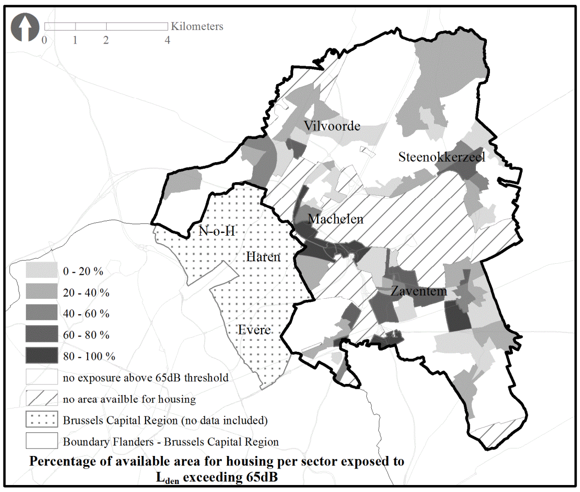

Figure6: Currentand potential exposure to Lden > 65dB (source: own map based on noise maps issued by LNE 2013 and BIM 2006)

As mentioned almost the entire case area is exposed to environmental noise above 55dB L_{den}, observing the established maps for exceendences of 65dB $L_{den}$the percentages of exposed inhabitants are high in Machelen and Haren and along the highway in Zaventem. (figure 6 – left map). Mapping of exposure for potential housing confirms high levels of exposure in Machelen, but also new areas like the Zaventem and Steenokkerzeel emerge (figure 6 – right map). The map for potential housing is clearly more fragmented. While some areas seem to manage staying under the threshold (figure 6 – right map), other areas have to deal with an increased relative exposure in comparison to the current situation. The latter is presumably a result of the relatively large acreages of available housinglotsclose to the sources of noise in those areas.

When comparing the maps for L_{den} and NO_2a more nuanced view emerges with indicated (potential) areas that have to deal witha variety of both nuisances, (potential) areas with a rather clear main nuisance and (potential) areas that are less exposed in general.High levels of environmental noise and airpollution areas expected revealed in Machelen en Haren, being close to the highway junctions and aviation routes, but still even there the mapping excersise shows local differences and spatial variation in levels of nuisance for (potential) inhabitants, moreover also variation regarding less exposed areas which might not had been noticed at first glance, is possible.

Being based on calculated data and long-term averages the maps are reliable for strategic planning purposes giving general information about the variation in exposure in a specific area, but less or not suitable as a basis for harsh local measures since the evidence does not include local or temporal peak exposures nor takes subjective annoyance into account. Furthermore mapping was based ononly one indicator for each nuisance.Including other indicators or a different mapping methodology could lead to different insights. The goal of the mapping exercise however was not to elaborate and extensively assess the environmental health conditions of an area, but rather to gain general insights as a basis for spatial policy which can positively affect health and well-being through enhancing environmental liveabilty conditions or to determine preconditions for future development. In that regard an important note is to be pointed out when using the (set of) maps for spatial planning purposes, since the calculated values for both NO_2 as for L_{den} are based on current traffic emissions. A differential spatial development, favourising certain areas, will inherently increase traffic intensity in those neighbourhoods thus influencing the spatial distribution of environmental health conditions. Regular updates of the modelling and mapping can overcome this issue.

The presentedmapping method combines the nuanced view of the GES-methodology, by mapping the average exposure in a district, with the attention for minimum local quality of the Kruize & Bouwman’s approaches, by expressing the percentage of exposure above acknowledged thresholds. Furthermore it is able to clarify possible differences in the current and possible future exposure. When using the resulting maps attention should be paid to possible large disparities in terms of population or vacant lots between districts, since the presented maps illustrate the percentage of exposure per total of the statistical sector, not per total of the entire case area. In our case for instance differences in population lie in the range of 1 to 3829 inhabitants per sector.

The research encountered several data issues to be tackled, some as a result of the difficulties obtaining data in original high resolution, other because of differences in modeling and presenting the calculated data at each side of the regional borders, but also the lack of recent data concerning vacant building lots was a burden.In that regard especially the unabilty to produce average noise maps is an unfortunate shortcoming of our results in terms of nuanced understanding.

In our opinion the presented mapping method frames the existing evidence in a comprehensible way for spatial planning practioners to be used in order to enhance environmental liveability conditions and to determine preconditions for future developments. To begin with, it is useful on aprogrammatic level in terms of general assessment for locating or relocating social functions.Furthermore, by indicating districts in need of more attention concerning air pollution and/or environmental noise, it is helpfulas a basis for further clarification and prioritisation of possible local spatial policy measures. Giving insight in the nature, level and distribution of the nuisance, the maps show different aspects of the evidence which are to be combined when assessing transformation or adaption strategies in existing living environments or avoiding the exposure to nuisance of future developments.

6 CONCLUSION

By presenting a methodology to establish a set of comprehensive maps concerning environmental noise and air pollution our research made an effort to bridge the gap between the requisite technical expertise concerning nuisance and health topics and the spatial planning practice. Accordingly it contributes to the more profound incorporation of public health concernsin spatial policy initiatives or interventions in order to establish enhanced environmental liveabilty conditions.

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