



When environmental indicators are not neutral: Assessing aircraft noise assessment in Europe

Frédéric Dobruszkes^{a,*}, Marina Efthymiou^b

^a Université libre de Bruxelles (ULB), Faculty of Sciences, DGES-IGEAT, Av. F. D. Roosevelt 50, box 130/03, 1050, Brussels, Belgium

^b Dublin City University Business School Glasnevin, Dublin, 9, Ireland

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ABSTRACT

This paper brings the lessons of critical thinking of environmental indicators to transport studies. To demonstrate the extent to which these indicators are not neutral, the case study focuses on airport noise indicators imposed by both the European Union and Flanders, Belgium, as they are applied to Brussels Airport's operations. Three directions have been considered. First, we unveil the spatial mismatch between protests and official noise contours that are supposed to reflect overall annoyance and sleep disturbance. Then we highlight the high sensitivity of the mandatory noise indicators (L_{den} , L_{night} and dose-effect function) to both their definition and the thresholds considered. Second, we review the legislative process at the time the EU and Flanders adopted their regulation on noise assessment. It appears both the nature of the indicators and thresholds have been the subject of debate by EU Ministers and MPs, while Flanders has imposed a dose-effect function that is arguably outdated and unusable in specific cases. Finally, we discuss the results through the lens of the authoritative power of official noise indicators and related maps, which many journalists and scholars take for granted. All this contributes to the construction of distorted knowledge of noise issues and calls for a re-evaluation of the EU's and Flanders' noise indicators.

1. Introduction

Aircraft noise in the vicinity of airports has become a commonplace environmental and health issue (Franssen et al., 2004; Basner et al., 2010; Kaltenbach et al., 2008; WHO, 2009; EEA, 2010). Exposure to aircraft noise results in cardiovascular disease, cognitive impairment, adverse birth outcomes, annoyance, sleep disturbance, and hearing impairment. It also affects quality of life, well-being and mental health (WHO, 2018). Traffic growth, expanding (sub)urbanisation, permissive land planning, increased sensitivity of residents to noise and higher legitimacy of environmental protests have made the conflicts increasingly visible, even though the specific noise level per aircraft has decreased (Bröer, 2007; Babisch et al., 2009; Daley, 2010; Rodríguez-Díaz et al., 2017). Conflicts between residents and the aviation industry, with public authorities in the middle, have forced the latter to react. In short, inhabitants are challenging a business activity that emits significant levels of daytime noise as well as overnight noise in many cases. On the other hand, the aviation industry (airlines, airports and aircraft/engine manufacturers) claims its business is an integral part of economic development, employment, trade, connectivity, leisure and

cultural experiences as well as social coherence. Public authorities are caught between these two conflicting views. While their representatives often agree air services bring social and economic benefits, they cannot ignore the negative externalities their voters bear. In this context, one way to sit on the fence without being disruptive is to conduct noise assessments and hold local community consultations.

Accordingly, various national and international public bodies have imposed regular assessments of noise around airports. In so doing, they have imposed standardised methods that specify how noise must be estimated and how the results have to be rendered. Typically, noise is estimated through models fed by traffic data, routes' profile, aircraft characteristics and weather conditions (see ECAC, 2016 and below). The results usually include average noise indicators that are mapped as noise contours. The number of noise events may be considered too, and all indicators tend to be required for various times during the day (e.g. day/night or day/evening/night).

Surprisingly, these noise indicators are rarely questioned (Pronello and Camusso, 2012). The fact that public authorities have coded noise indicators through legislation seems enough to legitimize them to policy makers and scholars. One notable exception is a qualitative study

* Corresponding author.

E-mail addresses: frederic.dobruszkes@ulb.ac.be (F. Dobruszkes), marina.efthymiou@dcu.ie (M. Efthymiou).

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conducted by [Cidell \(2008\)](#), who demonstrated that there are local residents living outside Minneapolis – St Paul International Airport's official noise contours (or within lower-level noise contours), who nevertheless have reported that they suffer from aircraft noise pollution. This suggests that official noise assessment does not sufficiently cover all aspects of noise pollution, such as the perceived annoyance induced by aviation operations.

In contrast to transportation studies, scholars in other fields, such as environmental sociology or politics, usually acknowledge that environmental indicators are everything but politically neutral ([Turnhout et al., 2007](#)). In the same vein, scholars engaged in critical cartography have helped to demonstrate maps are not more neutral ([Harley, 1988](#)). An increasing number of scholars and government statisticians have become aware that social, economic, environmental and health indicators are the result of political compromises that should be reviewed. Such a trend towards more critical governmental statistics does not seem to have reached transportation studies, in which the politics of official indicators remain significantly unexplored.

In this context, our paper aims to critically analyse aviation noise assessments and to demonstrate that existing methods in Europe lack neutrality and tend to lower the number of inhabitants affected by aircraft noise. In conducting this analysis, we bring to transportation studies the lessons resulting from a) the critical “politics of large numbers” ([Desrosières, 1998](#)), b) environmental socio-politics related to the science-vs.-policy dilemma of environmental indicators ([Turnhout et al., 2007](#)) and c) critical cartography ([Harley, 1988](#)). In this process, we will consider the case of the European Union's (EU) and Flanders' mandatory noise indicators applied to Brussels Airport (Belgium).

The remainder of this paper is as follows. Section 2 provides a literature review. Section 3 explains our research strategy. Section 4 introduces mandatory methods of airport noise assessment imposed by the EU and Flanders, as well as our Brussels Airport case study. The results can be found in Section 5, where three directions are proposed: the spatial mismatch between official noise contours and protests; the high sensitivity of noise contours to their definition; and the political nature of noise assessment. The last section discusses the results through the lens of the authoritative power of official noise indicators, and concludes with recommendations for future studies.

2. Literature review

Assessing noise assessment raises two key issues that are discussed in this section: the political production of environmental indicators and the authoritative power of these indicators as well as related maps.

2.1. Enacting environmental indicators

Environmental reporting is fundamental to environmental policy; thus, environmental indicators play a crucial role in achieving key policy objectives. In their study for the European Environmental Agency (EEA), [Smeets and Weterings \(1999\)](#) suggest indicators quantify information by aggregating multiple different data and provide unbiased information on environmental problems. Indicators are often used at the interface between science and policy ([Heink and Kowarik, 2010](#)). Indicators can be described as normative measures (e.g. [Burger, 2006](#)), variables (e.g. [Walz, 2000](#)), hybrid measures (e.g. [Ferris and Humphrey, 1999](#)) or components ([Heink and Kowarik, 2010](#)). The more specific literature on environmental indicators can be simplified to the following three layers: a) development of norms, b) use of indicators in policy and c) the authoritative power of norms that help create a reality. Norms are described as a form of expectations that prescribe or proscribe certain behaviour and explain social order and individual action ([Liebe and Dobers, 2019](#)).

[Rametsteiner et al. \(2011\)](#) discuss the different processes associated with the development of indicators and categorise them into two processes, *knowledge production* and *norm creation*. The knowledge

production framework reflects facts supported by scientists and experts, whereas the norm creation approach expresses the best possible reflection of societal values and interests where elected politicians, bureaucrats, stakeholders and citizens, all with usually different views, are the main actors. Scientific uncertainty is unavoidable ([Cimorelli and Stahl, 2005](#)) and different types of learning, such as social and political learning, occur ([Rametsteiner et al., 2011](#)).

[McCool and Stankey \(2004\)](#) cited in [Rametsteiner et al., 2011](#)) suggest a functional division of the roles of scientists and policy makers, whereas [Turnhout et al. \(2007\)](#) support the joint production of key information between policy makers and scientists. According to [Rametsteiner et al. \(2011\)](#), the diversity and independence of participating actors/groups from scientific disciplines and policy domains need to be acknowledged. Nonetheless, indicators are not as unbiased as might be imagined or expected.

[Rametsteiner et al. \(2011\)](#) question the involvement of various actors in the design and implementation of sustainability indicators and suggest that science-led and policy-led indicator development processes face different biases. In science-led processes, there is more bias towards knowledge production, but less inclusion of political dimensions than when policymakers were involved. [Rametsteiner et al. \(2011\)](#) propose that indicators are decided based on consensus, where participants may decide on indicators outside their expertise, and highlight the need for a properly designed indicator development process. Sustainability indicators are developed after political negotiation as a means of compiling knowledge, but also to express societal and political priorities.

According to [Rametsteiner et al. \(2011\)](#), sustainability indicators are developed in line with political-administrative rationales, needs and scientific knowledge, while [Stanners et al. \(2007\)](#) contend that environmental indicators should support policy development and be able to assess the effectiveness of policy responses. [Turnhout et al. \(2007\)](#) highlight the importance of the political context of indicators and their specific use in policy processes. The authors also state (2007: 220) that ‘policy makers are looking for the feasible in order to keep power’, whereas scientists seek the truth; these conflicting objectives may inevitably lead to the incorrect development and use of indicators.

Indicators can be a result of trans, regulatory, post-normal science or serviceable truth constructed in epistemic communities ([Turnhout et al., 2007](#)). [Bauler \(2012\)](#) discusses the instrumental, conceptual and political use of information. He suggests information is used to legitimize ex-post decisions and not necessarily to gain new knowledge. Contradictory interests may hide behind the use of indicators, and there is no consistency between the different political actors/groups that may have different views on the usability and quality of indicators.

Moreover, the potential of these indicators to bridge knowledge gaps is affected primarily by their proper configuration and by participants' consensus on their usability ([Bauler, 2012](#)). According to [Turnhout et al. \(2007\)](#), stakeholder participation, quality and acceptance play an important role in supporting the effective development and use of ecological indicators. [Cimorelli and Stahl \(2005\)](#) suggest that the way indicators are used in policy analysis influences problem definition, the generation of solutions and subsequent evaluation.

2.2. The authoritative power of environmental indicators and related maps

Whether or not environmental indicators are adopted based on scientific knowledge, they become authoritative once they are used to produce reports, graphs and maps that all are widely considered neutral. Indeed, few people realise that any statistical information built following political decisions is potentially affected, if not distorted, by political considerations. This pseudo-neutrality is arguably even reinforced once the indicators are mapped. Beyond the traditional critique of maps (restricted to accuracy issues and to well-known propaganda designs), the field of critical cartography has developed the idea that maps do

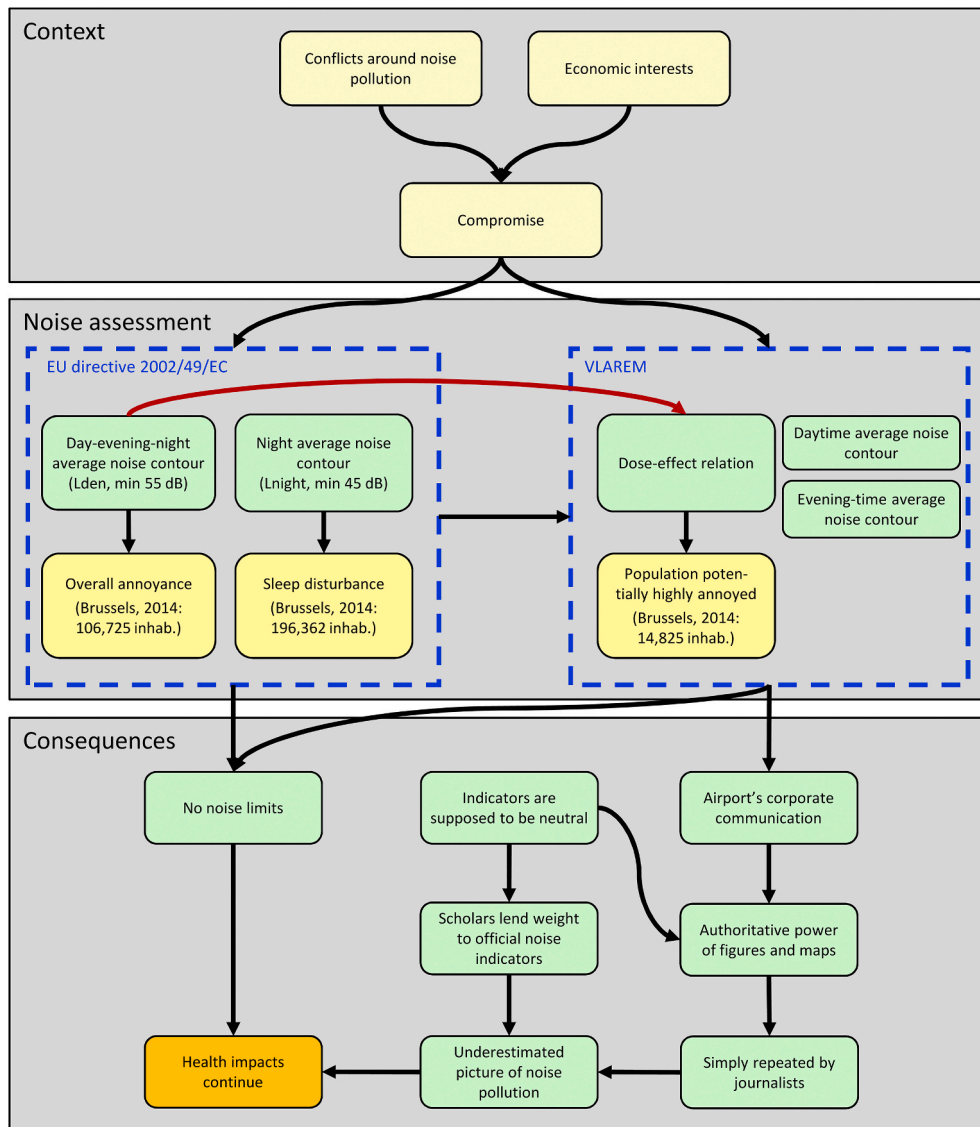


Fig. 1. Official noise assessment and its impacts.

much more than simply, and hopefully reliably, summarise phenomena embedded into spaces and places: maps, as social constructions expressing specific interests and values, serve as rhetorical devices that construct knowledge, produce the world, create a reality and, ultimately, exercise power (Crampton, 2001; Crampton and Krygier, 2006; Harley, 2001; Pickles, 2004; Wood, 1992; Wood and Fels, 2008) in the form of “authoritative images” (Harley, 2001). Simply said, most people trust maps.

McNeil and Culcasi (2015) provide a striking illustration of this through their investigations on the impact of maps on the debate over acid rain in the United States. Academics and their students drew the first related US maps. The indicator was the rain’s acidity (pH), and the maps were very simple. However, once in the hands of media with a wider audience, the maps were redrawn by graphic artists. One added colours to highlight temporal changes and sensitive areas. Another converted same-acidity lines into one single area and added the main areas acidity came from. This last map led to the idea that acid rain consisted of a transfer of pollution from far-off places to the densely populated East Coast. Then the electric power industry, which relied significantly on coal plants, drew its own map in view of a hearing at the Senate. Noticeably, this map (later published in Science) considered sulphate concentrations. While sulphates are precursors to acid rain, the

very word sounds less worrying for the public. And sulphates’ geography suggests that the apparent epicentre of pollution is not in the dense East Coast conurbation anymore, but in less-populated inner lands. In addition to well-known cartographic techniques that can help influence the final pattern depicted by a map (through a choice of colours, classes, projections etc.), McNeil and Culcasi’s research also highlights the extent to which indicator selection also affects the mapping of environmental indicators and, consequently, any related metric.

All this suggests that the development and utilisation of environmental indicators should be questioned and assessed, rather than taken for granted. The next sections will do so considering aircraft noise assessment around Brussels Airport.

3. Research strategy

Three directions have been followed to investigate the extent to which airport noise indicators are not neutral, considering official airport noise indicators applied to Brussels Airport (see Section 4). In a first step, we expanded Cidell (2008) finding according to which residents may complain about airport noise despite the fact that they live outside official noise contours. Cidell (2008) performed a qualitative analysis by examining the contents of public meetings. In this paper, we

conducted a quantitative analysis to compare official noise contours with the geography of protests. Brussels Airport's noise contours are published every year. Although raster noise maps are available online, Brussels Airport Company refused to pass us the related electronic files. As a result, we used a GIS to geolocate raster noise contours and to get them automatically redrawn as vector layers. Then the geography of protests has been investigated through two main sources. First, we considered complaints to the Federal ombudsman, who publishes an annual report with figures by postcode. Second, we considered the individuals who had signed the then main petition (initiated by an association called Pas Question [No Way in English]), also available by postcode. Protests were thus mapped and overlapped to the noise contours in our GIS.

Then, the sensitivity of noise contours to their definition was assessed by considering alternative thresholds, on the one hand, and alternative indicators, on the other hand. The information was retrieved from existing reports and from additional noise modelling performed by the Brussels Environment Agency and kindly passed on to us.

Finally, we moved to the political nature of noise indicators. The adoption of mandatory noise assessment methods by the EU is investigated through records that are made available to everyone by the European Parliament's Legislative Observatory website.¹ For each legislative process, a procedure file with all steps, summary of debates and links to detailed debates can be consulted. As for Flanders, we traced the origin of its mandatory dose-effect function and confronted its use with methodological restrictions highlighted by academics.

In addition, the authoritative nature of the apparently neutral official noise assessment is discussed through its misuse by the airport company within corporate communication and by information media in the aftermath.

4. Introducing the case study: EU and flanders' noise indicators and Brussels Airport

4.1. EU directive 2002/49/EC and flanders' environmental law

Aviation externalities have been characterised by international organisations such as the International Civil Aviation Organisation (ICAO) and the European Commission (EC) as a significant issue that needs to be corrected (Efthymiou and Papatheodorou, 2018, 2019; Camusso and Pronello, 2016). ICAO recognised that community exposure to aircraft noise constitutes the most adverse reaction to airport operation and expansion. ICAO Document 9829 provides guidance on a Balanced Approach to Aircraft Noise Management. It focuses on reducing noise at source, land use planning, noise abatement operational procedures and operating restrictions at airports but does not provide a single framework to assess noise.

In Europe, regulations on noise assessment actually come from the EU and national or sub-national authorities (Fig. 1). The EU Directive 2002/49/EC² on "the assessment and management of environmental noise" aims "to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise." This would be achieved through an EU-wide single noise assessment method, making results available to the public and adopting action plans for preventing and reducing noise pollution. The latter is implemented by Member States³, which, every five years, are obliged to prepare noise management action plans after consulting the concerned public. Clearly, the EU only set up a

Table 1

Main noise-related computations imposed by the EU, Flanders and Brussels Airport Company.

Indicators and time periods	EU Directive 2002/49/CE	Flanders and Brussels Airport Company
Day-evening-night average noise	Number of inhabitants living within L_{den} values of 55–59, 60–64, 65–69, 70–74, >75 dB	Noise contours based on L_{den} values of 55–59, 60–64, 65–69, 70–74, >75 dB
Daytime average noise	None	Noise contours based on L_{day} values of 55–59, 60–64, 65–69, 70–74, >75 dB (7:00–19:00) ^a
Evening-time average noise	None	Noise contours based on $L_{evening}$ values of 50–54, 55–59, 60–64, 65–69, >70 dB (19:00–23:00) ^a
Overnight average noise	Number of inhabitants living within L_{night} values of 45–49, 50–54, 55–59, 60–64, 65–69, >70 dB	Noise contours based on L_{night} values of 45–49, 50–54, 55–59, 60–64, 65–69, >70 dB (23:00–7:00)
Number of noise events	Optional	Frequency contours for at least 60 dB and 70 dB ^b
Number of daytime noise events	Optional	Frequency contours for at least 70 dB with frequencies of 5, 10, 20, 50 and 100 events a day (7:00–23:00) ^c
		Frequency contours for at least 60 dB with frequencies of 50, 100, 150 and 200 events a day (7:00–23:00) ^c
Number of overnight noise events	Optional	Frequency contours for at least 70 dB with frequencies of 1, 5, 10, 20 and 50 events a night (23:00–7:00) ^c
		Frequency contours for at least 60 dB with frequencies of 10, 15, 20 and 30 events a night (23:00–7:00) ^c
Noise mapping	Optional	At least L_{den} and L_{night} ^a
Harmful effects of noise	Optional dose-effect relations to compute the number of (highly) annoyed inhabitants	Dose-effect relation to compute the number of potentially highly annoyed inhabitants who live within the L_{den} and L_{night} contours ^a

Calculations are mandatory unless specified as optional. All noise levels are in dB (A).

^a Calculation imposed by Flanders' law (VLAREM).

^b Calculations imposed by the environmental permit.

^c Calculations imposed by Brussels Airport Company.

framework for assessments and action plans, but did not impose any noise limits. The directive especially targets noise emitted by transportation, outdoor and industrial equipment and mobile machinery. In terms of noise assessment methods, it stipulates that:

1. Member States have to use average noise indicators L_{den} to assess the "overall annoyance", and L_{night} to assess "sleep disturbance" (articles 3 and 5).
2. Supplementary noise indicators can also be considered under various circumstances, most of them matching airport operations (article 5).
3. Member States may assess the harmful effects of noise by means of dose-effect relations (article 6).

The L_{den} [day-evening-night] average noise indicator is an A-weighted, one-year round average measure of noise (in dB), which includes three specific time components aggregated through a weighted annual mean: a 12-h day period, a 4-h evening period with a five-dB penalty and finally an 8-h night period with a 10-dB penalty. Respective default values are 7:00–19:00, 19:00–23:00 and 23:00–7:00, but

¹ See <http://www.europarl.europa.eu>.

² Adopted by the European Parliament and the Council. Full text available at <https://eur-lex.europa.eu>.

³ When the EU writes "Member States", it also includes sub-national levels, subject to each country's distribution of competences among its specific administrative levels.

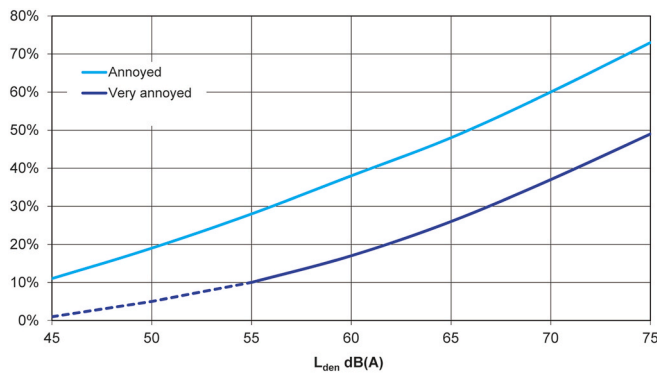


Fig. 2. Dose-effect functions proposed by the EC for aircraft noise. Source: EC (2002). The dark blue, continuous line is the one imposed by Flemish law.

Member States can adapt them subject to national and cultural specificities. The L_{night} indicator is the night-time component of the aforementioned L_{den} indicator. In practical terms, these indicators are computed through a noise model fed by the average 3D profile of departing/arrival routes, traffic on each route, aircraft types and weather/atmospheric conditions. The model utilised is often the so-called Integrated Noise Model (INM) developed by the US Federal Aviation Administration (FAA).

In contrast, the Directive does not officially define optional dose-effect relations at present. L_{den} and L_{night} indicators must be computed for urban agglomerations of more than 250,000 inhabitants and all “major airports”; that is, airports that accommodate more than 60,000 movements a year (a movement being either a landing or a take-off). The main mandatory and optional calculations are listed in Table 1.

These legal requirements have been transposed into Member States’ (sub)national laws. In this instance, competent authorities are free to add their own measures, provided they respect the EU legal corpus. Regarding Brussels Airport, which will be investigated further, Belgium’s Regions are in charge of environmental matters. As Brussels Airport is actually located in Flanders (one of the three Belgium’s Regions), we have to consider its specific environmental legislation, commonly called VLAREM⁴. In addition, Flanders also delivers the environmental permit needed to operate an airport. Finally, the airport’s owner, the Brussels Airport Company, which commissions experts in noise⁵, also adds its own requirements. Compared to EU Directive 2002/49/EC, both Flanders and the airport operator add several mandatory assessments, namely more average noise measures, frequency contours (number of noise events above given thresholds) and the use of a specific dose-effect function to estimate the number of inhabitants living within L_{den} contours and who are expected to be “highly annoyed” by noise (Table 1).

A dose-effect function (aka dose-response relationship or exposure-response relationship) is a mathematical function that is expected to estimate the impact of noise pollution on persons as a function of noise levels. Flanders opted for a dose-effect function suggested by the European Commission in a position paper (see below), which renders the share of “highly annoyed” inhabitants as a function of L_{den} , computed from 55 dB (Fig. 2). The share of “annoyed” residents has not been considered, although the function has also been suggested by the EC.

4.2. The Brussels Airport case

Brussels Airport is Belgium’s main airport. In 2019, the airport served as a portal for 25.7 million passengers and 543,493 tonnes of

cargo, involving 235,459 movements, of which 17,698 were night flights⁶. The airport is located in the north-eastern suburb, and comprises three runways – two main runways labelled 25L/07R and 25R/07L (25R being used for most take-offs), which are oriented towards the city, and one roughly north-south secondary runway labelled 01/19 (Fig. 3). This location, decided by the German army in WWII and later confirmed by the Belgian government (Van Humbeek, 2002), would clearly clash with the suburbanisation process in the decades to come. Because planes should avoid tailwinds and crosswinds above a threshold that is sometimes debated, and considering that in Belgium wind usually blows northeast, most take-offs occur towards the core city, at least during the day⁷. Then, the main debate is whether and how planes should turn left or right to avoid dense districts as much as possible, or fly directly over the core city.

Brussels Airport is located in Flanders but the Federal Government is in charge of aeronautical procedures for the whole country. There has been a long history of debates, conflicts and political decisions concerning air procedures at Brussels Airport (Nassaux, 2006; Oosterlynck and Swyngedouw, 2010; Dobruszkes et al., 2016). In contrast to Amsterdam Airport, for instance, the development of Brussels Airport has never been conducted by a united front combining relevant local and national authorities (Burghouwt and Dobruszkes, 2014). Moreover, local and regional authorities promoting the airport have not restricted the building of new homes in areas affected by aircraft noise, as recommended by the ICAO’s so-called balanced approach. At the same time, they have supported their citizens engaged in protests against Brussels Airport’s noise levels (Migeot and Coyette, 2017).

Due to the fall of the Federal Government, the aforementioned 2010 political agreement was implemented by the following coalition as a whole, through several phases known locally as the “Wathelet Plan” – unofficially named after the then Transport Secretary, which indicates the politicization of the issue. The most spectacular change in procedures started on February 6, 2014, when it appeared most planes departing toward the south-east were rerouted via (1) a new, enlarged left-turn route drawn via dense areas in the eastern part of the city (unofficially called the “Wathelet route”), and (2) also a variant of the pre-existing Canal route, which affects the capital’s densest districts (Fig. 4). The Canal route also received night flights rerouted from the northern suburb (these new procedures were cancelled in April 2015).⁸ The so-called Wathelet route replaced most of the 1972 left turn, with a much larger turn flying over much denser districts. A rough estimate suggests that the new, large left turn could affect up to 405,700 inhabitants, compared to 130,500 inhabitants for the shorter, pre-existing left turn, considering the population living along the routes up to 20 km from the airport (Dobruszkes et al., 2014).

5. Assessing the lack of neutrality of noise assessment

5.1. The spatial mismatch between official annoyance and protests

The new 2014 air procedures introduced above led to massive citizen protests from selected areas newly affected by noise, or which had become affected more than previously. The approach of the next Federal elections arguably motivated activists to make their action as broad and visible as possible. Since the new procedures started in early February 2014 (and were cancelled in April 2015), the 2014 annual assessment of

⁶ According to Belgium’s federal law, night-time is restricted to 23:00–5:59 only.

⁷ In Belgium, wind is usually weak overnight, so the government can select preferential runways more freely than during the day.

⁸ The Brussels-Capital Region went to court against the Federal State to cancel these changes that infringed regional aircraft noise limits. The court sentenced the Federal State in July 2014 and pre-existing procedures were then restored on April 2, 2015.

⁴ Vlaams Reglement betreffende de Milieuvergunning.

⁵ Formerly a KU Leuven-based team; today a UGent-based one.

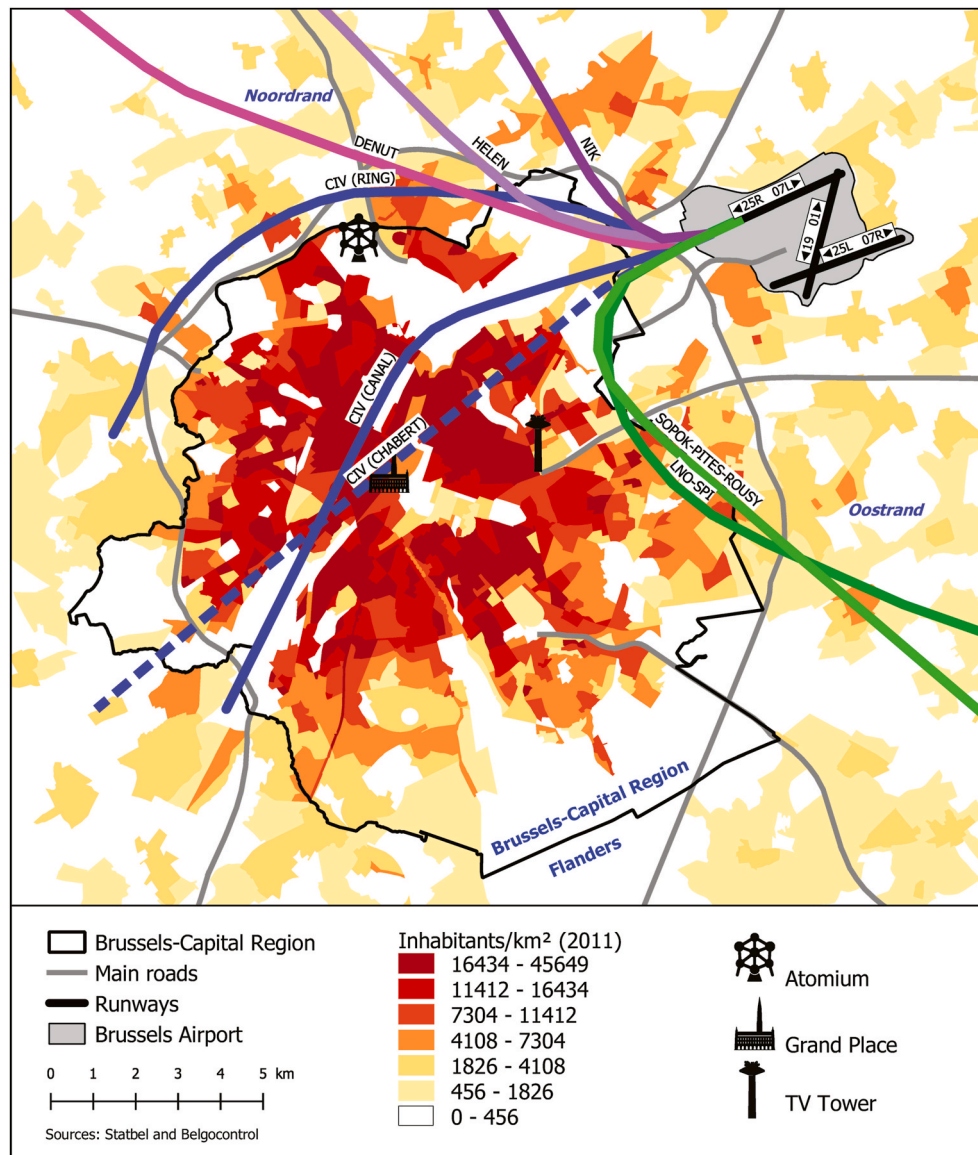


Fig. 3. Brussels Airport within its urban and administrative context and 2012 main departure routes from runway 25R. Routes are median axes computed from radar traces (see Dobruszkes and Peeters, 2017). The so-called Chabert route (dotted line) was moved to the Canal route in July 2012.

noise generated by Brussels Airport's operations largely fits with the new procedures. As a result, the 2014 change in procedures offers an opportunity to compare the official geography of noise (as derived from EU regulations) and the geography of protests.

Considering L_{den} is supposed to describe "overall annoyance" and L_{night} is expected to describe "sleep disturbance", it is thus expected protests would be included within the L_{den} or L_{night} contours. Of course, it could be that conversely, not all districts affected by noise would induce protests, since the geography of protests is also shaped by social attributes (Dobruszkes, 2008). Having said that, it is very clear from Fig. 5 that most of these protests come from districts located outside the official L_{den} and L_{night} noise contours.

Of course, residents may be in shock to suddenly be exposed to more flights overflying them than previously. It could be that protests would decrease over time. However, the geography of protests in older times (Dobruszkes, 2008; Denis, 2017) suggests that lots of complainants have lived outside the 55+ dB L_{den} contour for a long time.

5.2. The high sensitivity of noise assessment subject to noise indicators' definition

If the 55+ dB L_{den} and 45+ dB L_{night} indicators were not appropriate, two options could be considered. On the one hand, thresholds could simply be lowered to meet the last environmental noise guidelines made by the WHO as a "strong recommendation"⁹, namely reducing noise levels generated by planes below 45 dB L_{den} and below 40 dB L_{night} (WHO, 2018). By doing so, larger spaces would be included. Based on 2015 noise modelling, Fig. 6A and Table 2 show how much lowering the threshold by 5 and 10 dB dramatically extends the L_{den} surface and the related number of inhabitants. Alternatively, it could be argued that in any case, average noise indicators poorly reflect the annoyance of noise because the number of noise events would be more relevant. Indeed, by definition, an average indicator cuts the noise peaks that are arguably a key component of both the overall annoyance and health impacts due to

⁹ The WHO writes that a "strong recommendation can be adopted as policy in most situations" (WHO, 2018: XV).

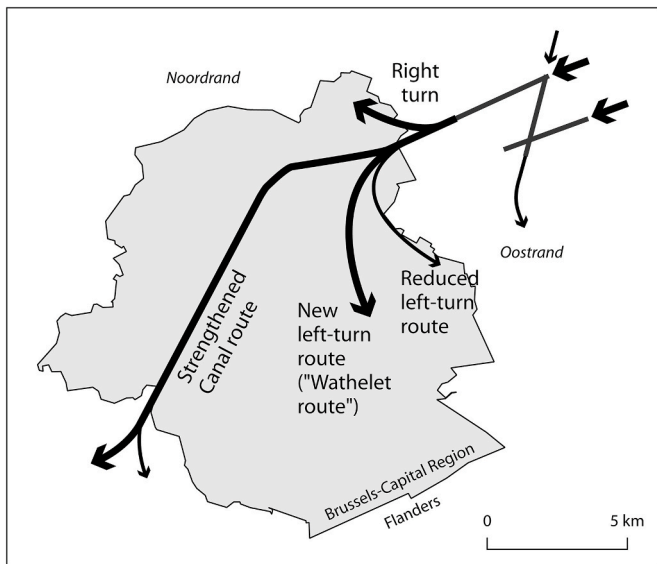


Fig. 4. Main runway use and main routes to/from Brussels Airport from February 6, 2014, to April 1, 2015. The thicker lines show the densest routes at the time.

aircraft operations. As an example, Fig. 6B compares the traditional L_{den} indicator (from 55 dB(A)) to noise events of at least 60 dB(A) that occur 50 times or more during daytime. It is very clear the spatial extent of the former is smaller than the one of the latter. And, unsurprisingly, the number of residents living in these areas varies significantly with indicators (Table 2).

In addition, the utilisation of the dose-effect function imposed by Flanders (see Fig. 2 above) suggests that only 14,825 inhabitants would be “potentially highly annoyed” in 2014, compared to 106,725 inhabitants that would face “annoyance”. This is an 86% drop.

It is thus clear that both the kind of measure (average vs. peaks) and the thresholds imposed by public authorities have a strong impact on the results of noise assessment that are supposed to inform the public and capture overall annoyance (L_{den}), sleep disturbance (L_{night}) and potential high annoyance (dose-effect function). The 55+ dB L_{den} seems comfortable for the industry and policy makers compared to lower thresholds or the number of noise events. And the dose-effect function dramatically reduces the apparent adverse impacts of aircraft noise.

5.3. The political nature of noise assessment methods

5.3.1. Debated before adoption, but then widely accepted: EU noise indicators

The above discussion raises a crucial question: Were noise indicators debated at the time legislative procedures were introduced? To address this, we have analysed all recorded debates around the adoption of Directive 2002/49/EC. The Directive was adopted under the so-called ‘codecision procedure’ (later renamed ‘ordinary legislative procedure’). Under this scheme, the European Commission (EC) has the monopoly to initiate a legislative procedure; to do so, it submits a legislative proposal to both the European Parliament (EP) and the Council of the European Union (hereafter the Council). The Parliament and Council then debate the proposal and need consensus to adopt the text eventually. Should they not reach consensus, the proposal cannot be adopted. In contrast with usual processes in democratic countries, the Parliament thus cannot start a legislative process or adopt a Directive against the Council. This is key to understanding the following steps, summarised by Fig. 7.

The initial proposal made by the EC was light in the sense it only included noise assessment. Neither noise limits nor measures to reduce noise emissions were included. Instead, the proposal stated that Member

States would have to adopt action plans to prevent and reduce exposure to noise where appropriate. In terms of noise assessment, the proposal only considered averaged noise indicators but let the door open to additional indicators without defining them. Within L_{den} and L_{night} noise areas, Member States were asked to compute the number of inhabitants and dwellings, and also schools/pupils and hospitals/patients. Finally, “Health effects shall be assessed with the dose-effect relations as defined in Annex II”, which actually did not supply any formula at the time.

The EC consulted the Economic and Social Committee and the Committee of the Regions (whose opinions are only consultative). The former was mostly in agreement with the proposal, but did not support the L_{den} indicator because no justification was supplied for adding 5 dB during the evening period and 10 dB overnight. The latter argued that aircraft noise calls for extra, specific indicators to be studied. It also asked for further scientific studies to improve knowledge about dose-effect relations.

The EP had a lively debate after its Committee on the Environment, Public Health and Consumer Policy proposed the addition of noise limits. At the end of the debates in the plenary session, the position of the EP was a call for noise limits, without deadline. The EP also stated that averaged noise indicators are not always the panacea, so it required that Member States would also have to consider extra indicators when relevant, including peak noise indicator LA_{max} . The EP also required not computing the number of pupils and patients within noise contours.

On its own, the Council also stated that peak indicators LA_{max} may be used. However, in contrast with the Parliament (which wanted to impose them when/where relevant), it proposed that Member States should be free to decide about their use. In addition, the Council considered that dose-effect functions should be optional and asked to remove all other counts than the number of inhabitants within the noise contours.

At the time of the second reading, the EP debated noise limits again. It was finally agreed that the EC would be required to propose noise limits within three years. Average indicators did not raise questions and the EP did not try to re-impose the mandatory use of peak noise indicators in certain circumstances. In addition, the dose-effect function was debated, and it was finally agreed it could be optional, as required by the Council. The EC had to comment and rejected the idea of later proposing noise limits. The time then came for the conciliation meeting between the Council and the EP. Without an agreement, the legislative process could only fail. Instead of noise limits, it was agreed that within four years, the EC would have to submit new legislation to mitigate noise.¹⁰ Additional noise indicators were accepted for specific cases that explicitly included aircraft noise and noise peaks-based indicators. Finally, the use of dose-effect functions remained optional, as the Council had requested. The EP accepted this overall compromise by the third reading, and thus the proposal forms part of the final act.

Beyond the nature of indicators (average vs. number of peaks), the European institutions also diverged in terms of noise ranges to be considered. As Table 3 shows, the Council tried to turn lower bounds up, which would play in favour of the airline industry since the related number of inhabitants could then only decrease. In reaction to this, or in view of the forthcoming conciliation meeting, the EP asked that the initial lower bound be turned down. In the end, the lower bounds the EC had initially proposed were set, except the wider, lower bounds that arguably do not help an understanding of noise issues. As for the upper bounds, the Council requested that the two highest ranges, which involve less detail for areas most exposed to noise, be merged. It succeeded in this way. All this confirms that thresholds are anything but neutral. Symptomatically, records show that neither Parliament nor the Council nor the European Commission cited academic literature to request changes.

¹⁰ The EC protested and argued that no one could force it to initiate a legislative process.

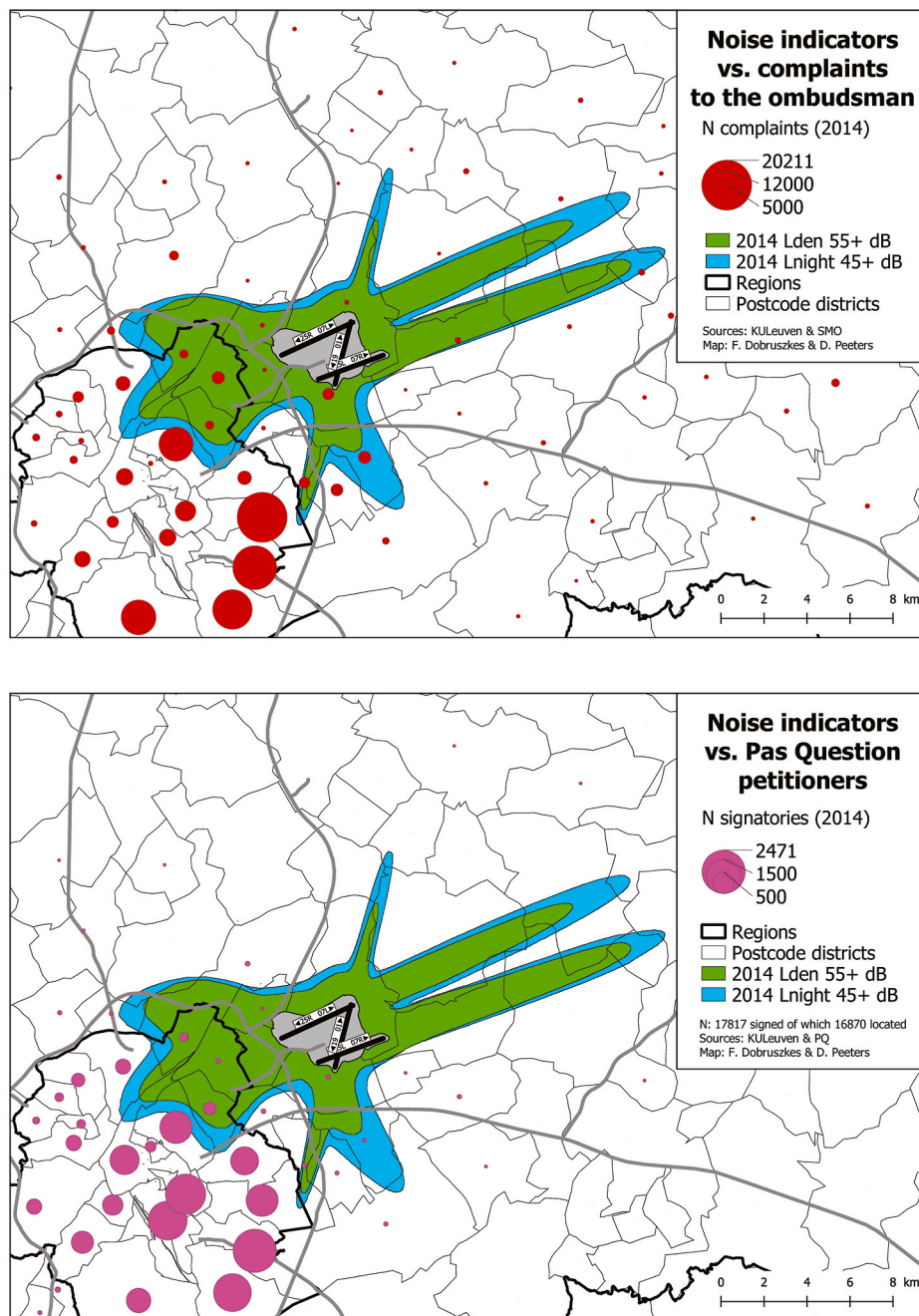


Fig. 5. Comparing official L_{den} and L_{night} noise contours to protests (2014). Circles are located at the centre of each related postcode, notwithstanding the more precise location of protesters.

To summarise, the Council (made up of each Member State's Minister of the Environment) tried to soften the scope of the directive in favour of the airline industry. The EP had vibrant debates and tried to get a "greener" directive than the initial proposal made by the EC. However, the EP could not convince the Council, and was eventually forced to accept most of the changes requested by the latter. A significant part of the lobbying was unofficial, and the debates took place nearly two decades ago. It is thus difficult, if not impossible, to accurately investigate this today. We could only find one piece of evidence, published by the airport lobby body (ACI, 2002), to support this contention. However, the member of the EP in charge of this case at the time confirmed to us that the airline industry had made significant efforts to influence public stakeholders.

5.3.2. Outdated and beyond the scope of their fathers: the EU dose-effect relations

Flanders' VLAREM imposes the use of a dose-effect relation, which is not mandatory under Directive 2002/49/EC. Having said that, the EU directive is somewhat unclear and ambiguous regarding the use of dose-effect relations. Article 6 states that "Harmful effects *may* be assessed by means of the dose-effect relations referred to in Annex III." However, Annex III states that "Dose-effect relations *should* be used to assess the effect of noise on populations." "May" suggests it is optional, while "should" implies a burden of responsibility to perform the task. Furthermore, the directive states that the rationale for such functions is about "harmful effects", which "shall mean negative effects on human health" (article 3). In such a perspective, one thus expects dose-effect relations to be based on epidemiological studies.

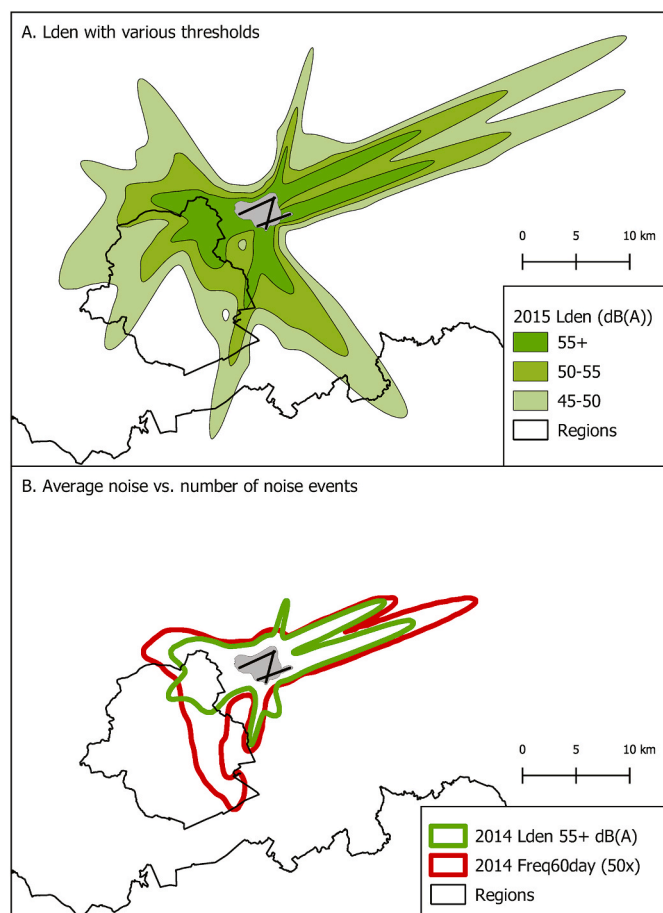


Fig. 6. Comparing the spatial extent of various noise indicators.
Sources: Rychtarikova et al. (2015) and Brussels Environment Agency

Table 2

The impact of noise indicators and thresholds on noise contours' surface area and on the related number of inhabitants.

Indicator	Area (km ²)	Inhabitants (2014)
2014 $L_{den} \geq 55$ dB	87.56	106,725
2014 $L_{night} \geq 45$ dB	125.83	196,362
Dose-effect function based on 2014 $L_{den} \geq 55$ dB	87.56	14,825
2014 Freq.60day, $\geq 50x$	153.57	357,461
2015 $L_{den} \geq 55$ dB	97.5	124,733
2015 $L_{den} \geq 50$ dB	255.9	519,009
2015 $L_{den} \geq 45$ dB	572.5	1,166,460

Sources: Rychtarikova et al. (2015) for 2014 and GIS-based own calculations following Brussels Environment Agency's noise contours for 2015.

The directive's Annex III actually does not provide dose-effect relations; they would be introduced later. However, it paves the way for a key contradiction, suggesting that future dose-effect relations will notably concern "the relation between annoyance and L_{den} ". This contradicts the idea of assessing the "harmful effects". Indeed, "annoyance" is based on declared statements made by surveyed residents. It is subjective in nature and depends not only on noise levels, but also on non-acoustical factors. The latter notably include personal attributes (e.g., subjective sensitivity to noise, neuroticism, both physical and psychological health status), social characteristics (e.g., gender, education

level, income and employment status), type of residential area (e.g., core, dense city vs. suburban detached houses) and relationships between residents and public/airport authorities (e.g., mutual trust, procedural fairness and information availability) (see Hede et al., 1979; Ohrstrom et al., 1988; Suau-Sanchez et al., 2011; Asensio et al., 2017; Denis, 2017). In contrast, "harmful effects" need to be assessed through proper epidemiologic studies to control impacts by other factors and to measure objective but unconscious impacts (Muzet, 2007; WHO, 2009). Annex III also plans relations "between sleep disturbance and L_{night} ". If sleep disturbance is properly assessed, it should not be simply self-reported because disturbance is not always realised.

Without waiting for further revision of the directive, the EC published an opinion paper about potential dose-effect functions (EC, 2002) based on a study it had commissioned. This document recommends a series of specific dose-effect relationships (such as those plotted in Fig. 2) to estimate the share of people "annoyed" or "highly annoyed" by road-, rail- and air transport-induced average noise. However, the EC bridges between the concept of "annoyance" and "health impacts", since it considers that these dose-effect relations "can be used in a target setting, in translating noise maps into overviews of numbers of persons annoyed (or highly annoyed, etc), in cost-benefit analysis and Environmental Health Impact Assessment. When used in Environmental Health Impact Assessment, they give insight in the situation that is expected in the long term."

To estimate their dose-effect functions, the experts performed a meta-analysis. The resulting equations included several limitations highlighted by the authors. The functions are valid for adults only, which means one does not know how to consider children. In addition, "substantial deviations from the predicted distribution of annoyance responses for limited groups at individual sites must be expected because random factors, individual and local circumstances, and study characteristics affect the noise annoyance." (Miedema and Oudshoorn, 2001). This is coherent with the aforementioned subjectivity in noise perception. The EC understood this, since its position paper highlights that dose-effect relations "are not applicable to local, complaint-type situations, or to the assessment of the short-term effects of a change of noise climate. The curves have been derived for adults." (EC, 2002). Another limitation is that the meta-analysis considered studies conducted between 1965 and 1993. At the time of publishing the EC's position paper, the more recent studies were at least nine years old, and up to 37. This casts doubt on their robustness today because several authors have found that people's sensitivity to noise has increased over time (Bröer, 2007; Babisch et al., 2009).

All this suggests that at the time, the Flanders' Government imposed the EC's dose-effect function in 2005 to assess the "harmful effects"¹¹ of noise around airports, it neglected that:

1. It was likely already outdated, and could only become increasingly ambiguous over time.
2. It should not be used locally. In other words, there is no evidence that global functions are valid for the Brussels' metropolitan area.
3. It will de facto be used to assess changes in procedures, which are frequent at Brussels Airport, instead of being restricted to "long-term stable situations" (EC, 2002).
4. The whole population will be considered, while functions are valid for adults only.

What is more, Flanders opted for the "highly annoyed" perspective only, rejecting the "annoyed" one that would have significantly increased the number of residents concerned. And of course, the confusion between "annoyance" and "harmful effects", including health, remains.

While both the nature and ranges of noise indicators have been the

¹¹ Same expression in VLAREM as in Directive 2002/49; our own translation from Dutch.

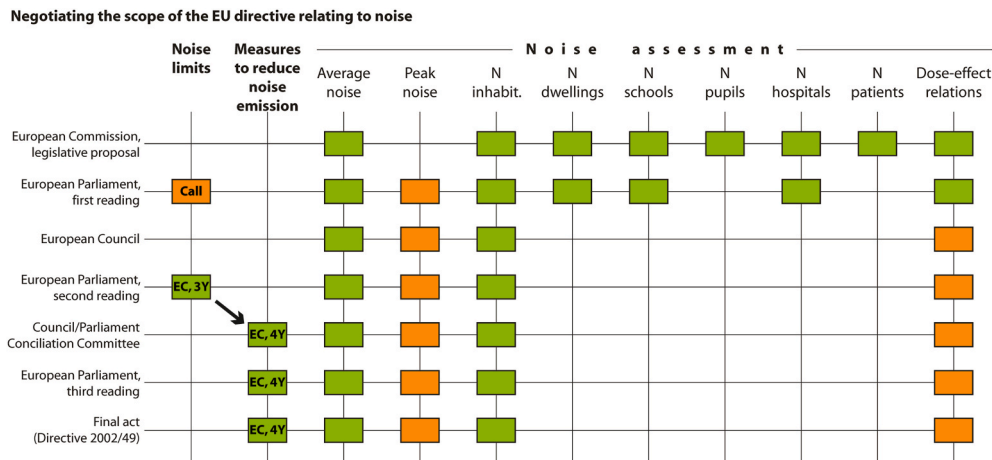


Fig. 7. Negotiating the scope of Directive 2002/49/EC Green boxes mean mandatory, orange means optional or call for.
Source: Own analysis based on EU's records.

Table 3

Negotiating noise ranges to be considered for reporting to the European Commission.

Step	Urban agglomerations ^a		Majors airports ^b	
	L _{den}	L _{night}	L _{den}	L _{night}
EC, legislative proposal	<55, 55–59, 60–64, 65–69, 70–74, 75–79, >79	<45, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, >74	55–59, 60–64, 65–69, 70–74, 75–79, >79	45–49, 50–54, 55–59, 60–64, 65–69, 70–74, >74
EP, first reading	Unchanged	Unchanged	Unchanged	Unchanged
European Council	55–59, 60–64, 65–69, 70–74, >74	50–54, 55–59, 60–64, 65–69, >70	55–59, 60–64, 65–69, 70–74, >75	50–54, 55–59, 60–64, 65–69, >70
EP, second reading	50–54, 55–59, 60–64, 65–69, 70–74, >75	40–44, 45–49, 50–54, 55–59, 60–64, 65–69, >70	55–59, 60–64, 65–69, 70–74, >75	45–49, 50–54, 55–59, 60–64, 65–69, >70
Conciliation Committee	55–59, 60–64, 65–69, 70–74, >75	50–54, 55–59, 60–64, 65–69, >70 45–49 by 18 July 2009 the latest	55–59, 60–64, 65–69, 70–74, >75	50–54, 55–59, 60–64, 65–69, >70 45–49 by 18 July 2009 the latest
EP, third reading	Unchanged	Unchanged	Unchanged	Unchanged
Final act (Directive, 2002/49/CE)	Unchanged	Unchanged	Unchanged	Unchanged

^a Separately for noise from each source listed, including air traffic.

^b For outside urban agglomeration areas.

subject of considerable debate during the legislative process, less attention has been paid to dose-effect relations. It is unclear why the Council wanted dose-effect relations optional only and why the EP supported their mandatory use at the time of their second reading. Considering that such relations lower the number of inhabitants eventually considered (compared to *all* the residents living within noise contours) and given other positions in the negotiation, one would rather have expected the Council to be in favour of dose-effect relations and the

EP against them. So, the opposite context may suggest that the confusion between genuine harmful impacts and declared annoyance worked well.

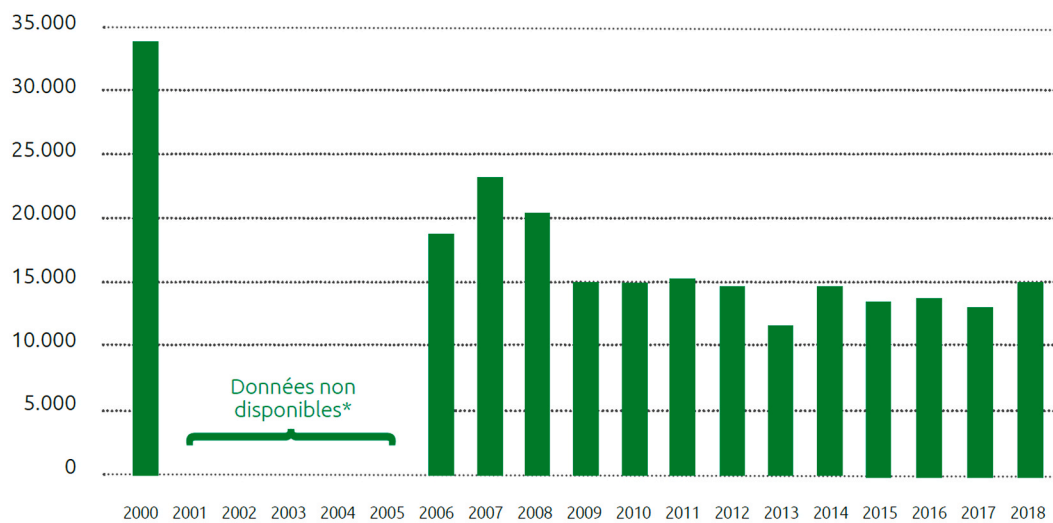
6. Discussion and conclusions

In a nutshell, the methods imposed by the EU and Flanders both lower the scale of noise issues around airports. First, the EU's conservative noise indicators tend to limit the spatial extent, and thus present a smaller number of inhabitants affected by aircraft noise (both "overall annoyance" and "sleep disturbance"). The spatial mismatch with protests (despite the fact that the latter is determined by social attributes) highlights the extent to which EU noise indicators are too conservative. Then, Flanders' decision to impose an absurd dose-effect function (that is outdated and not calibrated for local utilisation) helps to move attention to those inhabitants that would "potentially be highly annoyed", and this dramatically lowers the number of residents observers would eventually consider. In addition, the EU regulation suggests dose-effect functions should be used to capture "harmful effects", but then the EC proposes equations based on self-reporting instead of epidemiological studies.

It is beyond the scope of this paper to settle the extent to which these inappropriate indicators were maliciously imposed or whether MPs and governments are under-informed. However, an investigation of the EU legislative process has highlighted that noise indicators were indeed debated, both in terms of calculation (average noise vs. peaks) and of thresholds. The result was a mandatory compromise between the European Council and the European Parliament, so noise indicators can only be political.

It could be argued that all this is not really an issue and that environmental reports are of interest only to a small group of initiates and the EU bureaucracy. We do not think so. Indeed, the key impact of noise assessment is that related maps and figures become authoritative devices in the sense of critical cartography and of environmental sociology. Let us recall three key figures that were produced following the EU's and Flanders' regulation: 106,725 inhabitants would face "overall annoyance", 196,362 would face "sleep disturbance" and 14,825 would be "potentially highly annoyed" by Brussels Airport's operations (2014 figures). Unsurprisingly, only the last figure is considered by the airport's private operator, the Brussels Airport Company, in its corporate communication to media, residents and public authorities. Fig. 8 shows a typical example of this in the airport's gazette distributed to hundreds of thousands mail boxes around the airport. What is more, the graph is sourced from "an independent study" supervised by a "university professor", which can only give even more authority to these numbers. No one would of course recall that the academics hired by the airport

Evolution du nombre de personnes potentiellement très gênées dans le contour de bruit L_{den} de 55dB



Source : étude indépendante effectuée sous la direction de Dick Botteldooren, professeur d'Acoustique à l'université de Gand.

* Calcul effectué avec une autre version du modèle de calcul INM

Fig. 8. Typical corporate communication: Noise issues as introduced into Connect Brussels Airport's gazette delivered to residents (500,000 copies).

company do not freely decide the indicators they compute: they follow the law.

The same optimistic figures are constantly repeated by the media. In 2015, for example, Belgium's leading press agency, Belga, broadcasted a release following the publication of the Brussels Airport's 2014 noise assessment. The release copy-pastes a key sentence from the report, according to which "As for 2014, the total number of potentially highly annoyed residents comes to 14,825".¹² The other, less optimistic figures are not part of the release. These exact words are then duplicated by newspapers¹³, radio and TV channels and their websites¹⁴ without any further investigation. In the minds of observers and policymakers, the noise issue around Brussels Airport eventually affects less than 15,000 residents.

In addition to the deliberate utilisation of the most favourable figures, it is somewhat more surprising that several scholars (e.g. Thanos et al., 2011; Püschel and Evangelinos, 2012; Argyropoulos et al., 2016; Trojanek et al., 2017; Winke, 2017) have also considered official noise indicators without putting them into perspective and sometimes even explicitly assuming they make sense because they are in line with the EU regulation, and that a law would be neutral. The role of the media and, to some extent, of scholars, thus converges to reinforce the authoritative nature of numbers and of maps (see Fig. 1, last part).

In broader terms, our findings confirm the very political nature of environmental indicators. Like so many indicators imposed by public bodies, they are much more than neutral, technical tools, but are the result of political negotiations influenced by contradictory interests. As Desrosières (1998) stated, "Statistical information did not fall from the sky like some pure reflection of a preexisting 'reality'". Interestingly, the normative nature of environmental indicators decided by public authorities is twofold: it directly defines the contents of environmental reports and influences some scholars who lack a critical attitude. In conclusion, noise indicators do not simply summarise our world; they

also construct knowledge, produce the world, create a reality and, ultimately, exercise power. Accordingly, it is appropriate to think critically about them. In the meantime, noise assessment looks neutral and remains largely unquestioned, to the benefit of the airport business and to the detriment of public health.

Our findings also have policy implications. First of all, the EU should review its noise indicators and assess the rationale for both noise peaks-based measures and for alternative thresholds (extended ranges to lower bounds). In this regard, the European Environment Agency reviewed several scientific and political sources and concluded that "there seems to be a consensus that L_{den} around 50 dB (or the equivalent level in other units) would represent a good noise quality and $L_{night} < 55$ dB should be respected to protect the population from serious health effects" (EEA, 2010). This is soft, considering the same report states that annoyance/disturbance starts from L_{den} of 42 dB and that reported health and hypertension issues are problematic from L_{den} of 50 dB. Furthermore, the World Health Organization now recommends a night noise guideline of $L_{night} = 40$ dB to ensure health protection in Europe, instead of 45 dB under Directive 2002/49/EC.

In addition, Member States and regional/local authorities should be encouraged to think beyond regular EU indicators, and develop additional indicators subject to local specificities. Local authorities have the legislative power to regulate negative externalities for the benefit of the public's welfare as they deem appropriate.

CRedit authorship contribution statement

Frédéric Dobruszkes: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing - original draft, Writing - review & editing. **Marina Efthymiou:** Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing.

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¹² Our own translation.

¹³ For instance, La Libre Belgique, 8 May 2015.

¹⁴ RTBF.be, 8 May 2015.

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