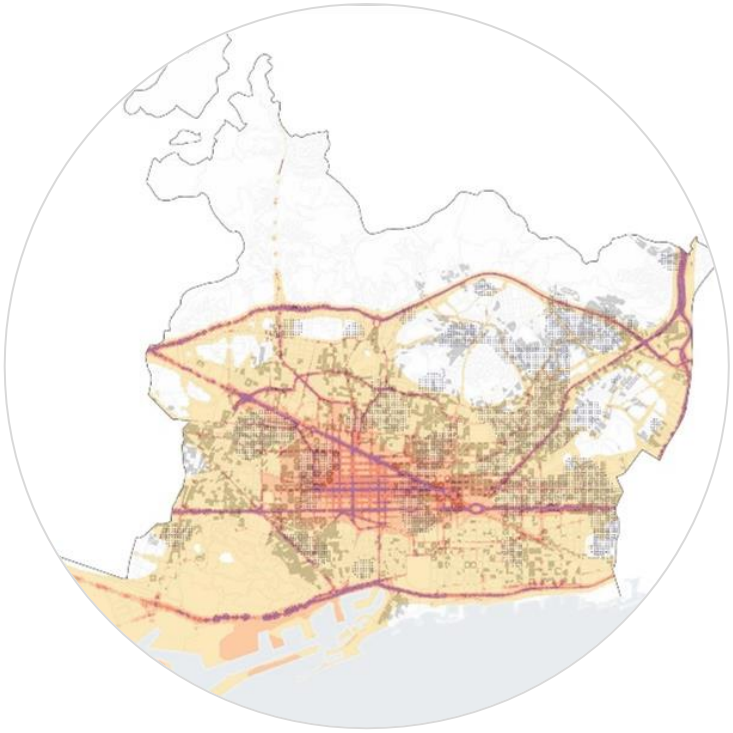
TERRITORIALISATION OF RISKS

RESILIENCE PLAN DIAGNOSIS



Where is the population most exposed to the impact of atmospheric pollution located?

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Urban Resilience
Department

Ajuntament de Barcelona

TEXT

Ajuntament de Barcelona
Department of Urban Resilience
Deputy Manager's Office for Mobility and Infrastructures
Urban Ecology

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Introduction

Global development trends are leading to populations being largely concentrated in urban areas. According to United Nations data, today more than 54% of the world's population is concentrated in cities, and this figure is expected to rise to 68%, or 6.3 billion people, by 2050. Consequently, cities play, and will increasingly play, a key role in human development, in fostering living conditions that guarantee protection, health, equality, equal opportunities and well-being for their inhabitants.

This is the context in which applying the concept of resilience to citizens and urban systems makes sense. Urban resilience is understood as the capacity of a city to prevent, or when faced with unavoidable situations, to minimise, the impact of the natural and anthropic risks it is exposed to, whether acute shocks or chronic stresses, and to recover in the shortest possible time in order to maintain essential functions.

The main shocks that Barcelona is exposed to derive from the effects that climate change may have on the city. On the other hand, most of the stresses that the city is exposed to come from the social, environmental and economic domains.

Thus, within the framework of the development of Barcelona's resilience plan, a study was carried out to identify and define the risks that could affect the city's public spaces.

First of all, with the aim of defining a list of the key risks that threaten Barcelona's public space, a working session was organised in March 2019 with around twenty municipal representatives from the different departments involved in the design, management and maintenance of public space, as well as professionals involved in ensuring peaceful coexistence and the provision of social services in the city. At the meeting, there was a general consensus regarding the concerns and risks that were deemed the most critically important: homelessness and atmospheric pollution. In second place came noise pollution, the heat island effect, a lack of green spaces, extremely heavy rainfall, drought, urban safety, tourism pressures and traffic congestion. Based on this classification, the next step was to restructure and refine the resulting table of risks by incorporating the comments received, and so identify a list of questions on how each risk might affect the city's public space.

Finally, based on the questions posed, and focusing the analysis on the most vulnerable groups, a risk assessment procedure was developed in order to map the points at which the places in the city with the highest levels of risk intersect with the areas that the section(s) of the population vulnerable to a particular risk are most likely to use or to live. For those risks that it was possible to map, the information used had in some cases already been studied in other contexts, meaning that it was only necessary to add the perspective of the impact on vulnerable

groups. In other cases, work also had to be done on data development to understand the impact of a particular risk.

This document is a compilation of the maps drawn up for the analysis stage of the Resilience Strategy with regard to risks affecting public space, with the aim of gaining a full overview of the city's vulnerabilities differentiated by location, thus allowing the identification of priority measures by area, in response to the identification of one particular risk, or the overlapping of several.

Each risk map is presented in the first part of this work together with the methodological details of the data used. The second section includes the conclusions reached, and explains the measures that the City Council is currently developing, or the possible lines of work to be pursued to reduce the risk and mitigate the impact.

1. What? The question

Where is the population most exposed to the impact of atmospheric pollution located?

2. Why? The reason

Barcelona, and 40 municipalities in the Barcelona conurbation, has been declared a Special Protection Area for the atmospheric environment, known as 'Àmbit 40' due to nitrogen dioxide (NO_2). NO_2 levels are above the limits established in Directive 2008/50/EC, and therefore pose a risk to human health and to the environment.

In ambient conditions, nitrogen dioxide behaves like a gas, reacting with sunlight in the atmosphere and increasing the proportion of NO and suspended particulate matter present, and favouring the appearance of ozone as a secondary pollutant. It is therefore an important contributor to the formation of photochemical smog, which is very common in urban areas. The main anthropogenic sources of emissions are transport, thermal power plants and fuel combustion (whether petrol, diesel, liquefied petroleum gases or natural gas), energy recovery plants, cement factories, glass factories and refineries.

Particulate pollution, especially fine particulate matter, can cause serious respiratory problems, such as irregular heart rhythms, the aggravation of asthma or breathing difficulties, and even premature death in people with heart or lung disease. On an environmental level, particulate matter serves as a catalyst for the formation of ozone and acid rain, as well as reducing visibility. Particulate matter (PM) not only stems from human activity, but also from natural sources such as dust from the Sahara desert, carried on the wind from thousands of miles away. Traffic,

stationary combustion sources (domestic heating, industry, incineration of industrial and municipal waste and fossil fuel power plants), construction, quarrying and mining, cement, ceramics, smelting and forest or agricultural fires are the main anthropogenic sources.

Emissions are defined as the quantity of a pollutant that ends up in the atmosphere from a particular source, e.g. the nitrogen oxides emitted by a discrete, mobile unit like a car, the sulphur dioxide released into the air by a chimney, or the particles emitted by a diffuse source such as wind blowing over a dry surface. On the other hand immissions are the concentration (or level) of a pollutant at each point in the territory, i.e. what a person would breathe in at that specific place.

The relationship between emission and immission is not a direct one. This means that for one specific emission, there can be a very different immission at a given location, as once the pollutant has been released into the atmosphere, it undergoes physical and chemical transformations (especially transport and dispersion, but also chemical reactions, deposition, aggregation, etc.) which depend on atmospheric conditions and that change over time.

The thresholds established by both the European Union and the WHO state that an annual average concentration level of 40 µg/m_3 for NO_2 should not be exceeded, and neither should the hourly average for NO_2 exceed 200 µg/m^3 more than 18 times a year. In the case of NO2 immission levels, the annual average for the city of Barcelona is currently below the threshold, and is therefore within the established limit. However, in 2018, two measuring stations (Eixample and Gràcia - Sant Gervasi) showed values that were above this limit.

Although notable efforts have been made at municipal level to understand levels of particulate pollutants in Barcelona, and measures have been implemented to reduce emissions which have led to improvements in the city's air quality, achieving a healthier urban environment remains an unfinished and urgent task.

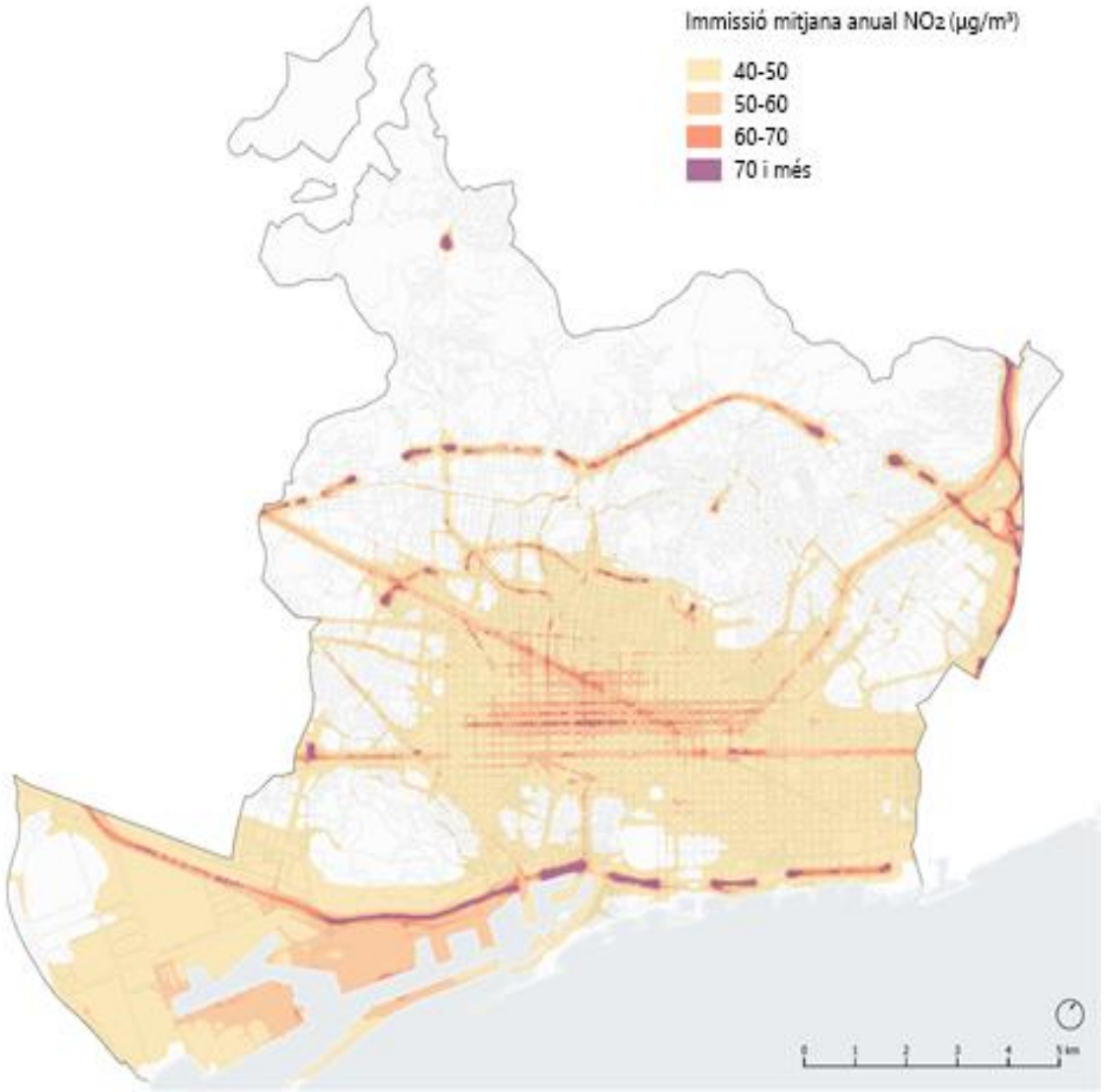
3. How? Data and methodology

In order to understand the areas where those most affected by $N0_2$ particles are located in the city of Barcelona, recent available data on air quality and population was used.

3.1 Average annual NO_2 concentration levels

In order to determine the degree of risk faced by the population, the current WHO guideline value was used, thus an average annual exposure of 40 µg/m^3 or higher was deemed to be harmful. Based on this value, four immission, or concentration, levels were established: 40 µg/m3 to 50 µg/m^3, from 50 µg/m^3 to 60 µg/m^3, 60 µg/m^3 to 70 µg/m^3, and 70 µg/m^3 and above.

Figure 1. *Average annual NO2 concentration levels. 2017 (see appendix 6.1)*



3.2 Population

There is no single answer to the question "Where are the most vulnerable sections of the population to be found?", because, according to the time of day, a person may be at home, at work or enjoying free time out and about. The population moves around, and therefore determining "where they are located" is something that cannot be resolved directly.

So in order to identify the areas with the highest concentration of population regardless of the time of day, we worked with two sets of data: **the 2018 municipal register of residents** at block level, which gave us a clearer idea of "where people live", and **the location of public facilities classified by type**, in order to understand where they might potentially spend part of their day.

By using the data from the municipal register, it was possible to define the areas with the highest density of residents, and the information on facilities allowed us to identify the areas of the city that are potentially those in most frequent use.

We know that a substantial number of people spend a significant number of hours a day at their places of work, or moving around the city in order to carry out job related tasks. This information, which could also help us to understand "where people are", unfortunately could not be included in this study, as the city does not have a reliable and comprehensive data matrix that would enable us to know how many people are in a given place for work purposes.

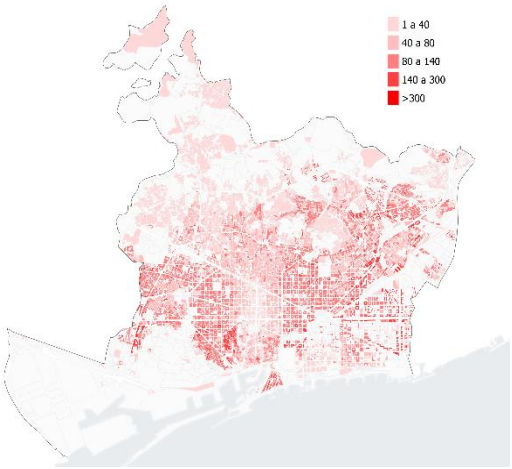
Another factor that needs to be taken into account when assessing vulnerability is the age of the population. As the data from the municipal register of residents is organised in five-year age bands, by subdividing we were able to determine the most vulnerable sections of the population. The same thing was done with the data on facilities, as classification by type allowed us to select those serving each age group. In this case, the age groups were the following: 0-4, 5-14, 15-34, 36-64, and 65+, and the most vulnerable age group is the sum of those aged 0-4 years old, and those aged 65 and above.

3.2.1 Delimitation of the most densely populated areas

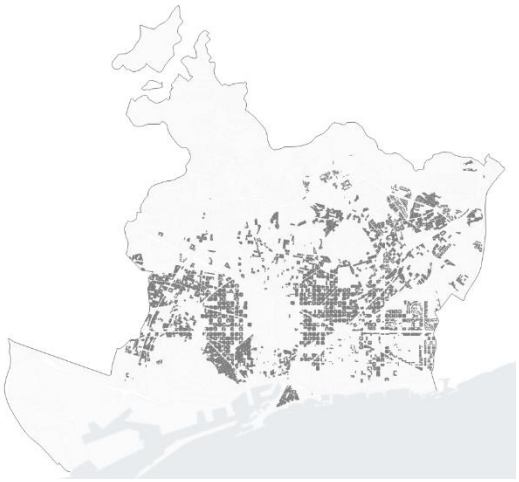
By using data from the municipal register, the aim was to obtain an overview of those areas of the city with the largest resident populations. Superimposing data on the risk factor in question on the map allowed the identification of critical points.

The process followed consisted of calculating population density for each age group, and selecting the areas with a population density above the average for the city. *Figure 2* shows the result after selection by population density.

Figure 2. *Selection process of areas with an above average population density. Population density is shown on the left, and the selection of areas above the threshold on the right.*



Map with calculation of population density. Inhabitants / km².

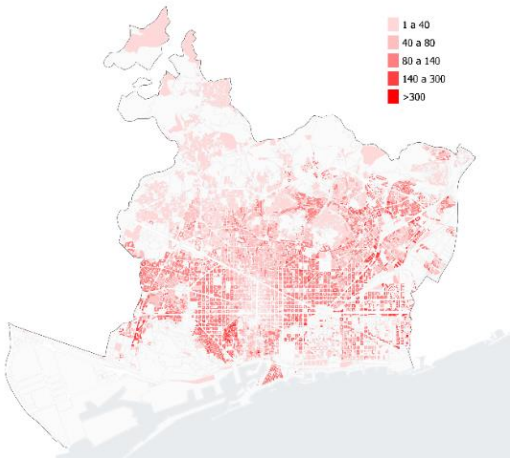


Result: Areas with an above average population density. Each age group has its own areas.

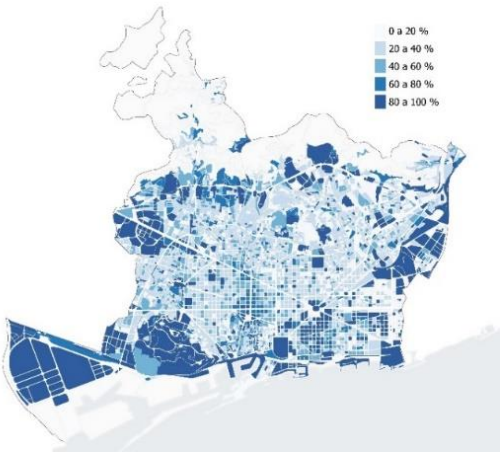
Looking at the result, it is striking that many areas of the city that we would expect to be densely populated in fact are not. This is the case of the area around Passeig de Gràcia and much of Ciutat Vella, to give two prominent examples. In these central areas of the city, a shift towards commercial uses as shops, offices or service providers has reduced the housing stock, and as a result we see a population density that is below the average for the city.

Figure 3 provides for a better understanding of the problem. A comparison of the population density map with the map of non-residential use of premises shows how the one behaves almost like a negative of the other.

Figure 3. *Map of population density contrasted with the map of the non-residential use of premises*



Population density by city block. Inhabitants / km²



Percentage of non-residential use of premises, by city block.

3.2.2 Delimitation of the most frequently used areas

In order to gain an idea of which areas of the city are potentially most used by the target population, the data on the location of the public and private facilities that provide services aimed at these groups has been used. The starting hypothesis was that the areas with the highest concentration of facilities are also those that will be subject to the greatest influx of these groups of people.

A first step in identifying these areas was to classify the facilities by age group, according to the type of service they provide. **Table 1** shows the complete list of types of facilities, and the age group at which they are targeted.

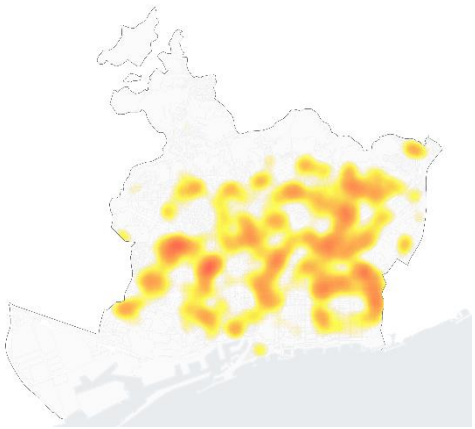
Table 1 – Facilities by type, and the age groups they cater to

Type of facility	From 0 to 4 years of age	From 5 to 14 years of age	From 15 to 34 years of age	From 35 to 64 years of age	> 65
Hostels and shelters for the homeless			X	X	X
Higher secondary education – Baccalaureate			X		
Children's libraries	X	X			
Children's activity centres	X	X			
Specialised day care centres			X	X	X
Winter reception centres			X	X	X
Women's refuges			X	X	
Family reception centres	X	X	X	X	
Reception centres for the elderly	X	X			
Reception centres for children and young people		X	X		
Day-care centres for the homeless			X	X	X
Day-care centres for senior citizens					
Mental health day centres			X	X	X
Mental health centres for children and teenagers	X	X			
Adult mental health centres			X	X	X
Municipal sports centres		X	X	X	
Open centres and pre-workshops for children and teenagers		X			
Occupational centres for people with disabilities			X	X	
Day nurseries	X				
Kindergartens	X				
Primary education		X			
Compulsory secondary education (ESO)		X			
University education			X	X	
Active ageing (elderly people)					X
Vocational training			X	X	
Assisted housing for the elderly					X
Hospitals for the chronically ill and the elderly					X
Prep schools		X			
Secondary boarding schools		X			
Supportive housing for people with disabilities			X	X	
Residential mental health centres					
Toy libraries	X	X			
Care homes for the elderly					X
Children's play area: 0 to 12 years of age	X	X			
Children's play area: 0 to 5 years of age	X				
Children's play area: 6 to 12 years of age		X			

From this classification, a heat map was generated for each age group to identify the areas of the city with the highest concentration of facilities.

Figure 4. *Processing of facility locations in order to obtain a heat map*

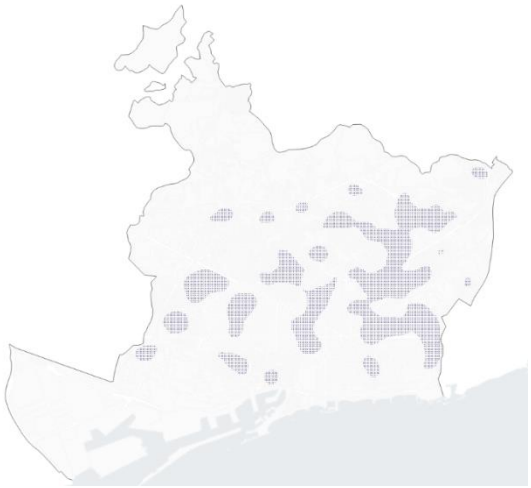
Map showing the locations of facilities targeting a specific age group



Heat map showing the areas with the highest concentration of facilities

The final layer was obtained using the selection of the areas in the heat map with a large number of facilities. The result can be seen in *Figure 5*.

Figure 5. *Final layer with areas with a high concentration of facilities. Each age group has its own areas.*



4. Vulnerability maps by age group

4.1 Vulnerability maps by age group

As a result of the territorialisation of risk, vulnerability maps have been created for the different data layers cross-referenced by age groups. The aim is to qualitatively highlight those areas that show an intersection of the highest risk-of-exposure values, cross-referenced with city blocks that have a higher than average density of registered city residents, and with areas that have a high concentration of facilities for the age group being studied.

It is important to remember that these maps require a broad interpretation, and that risks must be contextualised globally. They have been generated on a city-wide scale, and although a territorial degree of detail was sought, they are an interpretation based on approximations and will require a specific study on the selected areas of activity.

In this case the map shows population by age group exposed to NO_2 concentrations above the WHO recommended guideline levels (average annual NO_2 concentration of 40 µg/m_3). The correlation of each of the four NO_2 concentration levels defined in this study generates an eight-point vulnerability gradient.

Table 2. Levels of vulnerability, from the lowest to the highest

1P. An average annual concentration of 40 µg/m^3 to 50 µg/m^3, coinciding with population concentration
1PE. An average annual concentration of 40 µg/m^3 to 50 µg/m^3, coinciding with concentration of population and facilities
2P. An average annual concentration of 50µg/m^3 to 60µg/m^3, coinciding with population concentration
2PE. An average annual concentration of 50µg/m^3 to 60µg/m^3, coinciding with concentration of population and facilities
3P. An average annual concentration of 60µg/m^3 to 70µg/m^3, coinciding with population concentration
3PE. An average annual concentration of 60µg/m^3 to 70µg/m^3, coinciding with concentration of population and facilities
4P. An average annual concentration of 70 µg/m^3 or more, coinciding with population concentration
4PE. An average annual concentration of 70 µg/m^3 or more, coinciding with concentration of population and facilities

Estimates of above average population according to the municipal register and facilities located in critical areas were also obtained for each age group as part of data cross-checking.

4.2 Population most at risk

Chronic exposure to the typical levels of air pollution in Barcelona has a major impact on human health, and is estimated to be responsible for hundreds of premature deaths each year.

As can be seen from the map overlays by age group (see appendix) in Barcelona, average annual NO_2 concentration levels above 40 µg/m^3 are directly linked with the city's road network and, more specifically, with the link roads that connect to the Metropolitan area, such as the ring roads, Gran Via, Meridiana, Diagonal, Via Augusta and Aragó. The road network in the Eixample also registers high levels of atmospheric pollution.

People who go about their essential everyday work, shopping, play, study, leisure, etc. tasks on these heavily used roads are therefore more exposed to a higher concentration of particulate pollutants than those who go about their everyday tasks on less busy streets.

The sections of the population most at risk due to atmospheric pollution are babies and the elderly. On the one hand, children, especially those who are between 0 and 3 years old, are especially susceptible to atmospheric pollution because their immune system has not yet fully developed. On the other, elderly people are vulnerable due to the cumulative effects of atmospheric pollution, and the fact that their bodies are less able to eliminate noxious substances. It is estimated that nearly half of the population of all age groups registered in Barcelona live in these exposure areas. In terms of vulnerable people, approximately 35,000 are babies and 20,000 are over the age of 65.

With regard to facilities, around 10 schools and 5 playgrounds for children aged 0-4 were found to be exposed to NO_2 pollution levels above 60 µg/m^3, as were some 21 social care centres, and one active ageing space for the elderly.

On the vulnerability maps (see appendix 6.3), the degree of correlation of higher numbers of residents, more facilities, and undesirable levels of NO_2 reveals parts of the city that enable us in broad terms to identify the most critical points of risk. More specifically, those adjacent to the edge of the road. Neighbourhoods crossed or delimited by Metropolitan link roads, many of them highly developed, densely populated and located close to the city limits, contain blocks with high levels of exposure to risk. This is the case for the neighbourhoods of Hostafrancs, Font de la Guatlla, Poblenou, Besòs i el Maresme on Gran Via. Also the La Sagrera neighbourhood on Meridiana, and the neighbourhoods of La Prosperitat, Trinitat Nova, El Verdun and Les Roquetes, on the uncovered part of Ronda de Dalt. The concentration of facilities for children and adolescents in this section of La Ronda should be noted (see appendices 6.2.1 and 6.2.2).

Other neighbourhoods are located near the Ronda del Mig, where there is also a significant concentration of facilities, as there is in the La Salut, El Putxet i el Farró and Sarrià-Sant Gervasi

neighbourhoods. These are also critical areas of risk, especially for the elderly, due to the high concentration of facilities aimed at this age group located in these areas (see appendix 6.2.5).

Finally, we would highlight a group of blocks with a degree of vulnerability to average annual concentrations of between 50 µg/m3 and 60 µg/m3, which are mostly located in the more central districts of the city. The most notable examples are to be found in the neighbourhoods of Antiga Esquerra de l'Eixample and Nova Esquerra de l'Eixample on Carrer Urgell and Avinguda Roma, and also in the neighbourhoods of Dreta de l'Eixample on Diagonal and Aragó, Sagrada Familia on Valencia and Mallorca, and in the neighbourhoods of Camp d'en Grassot i Gràcia Nova, mainly on Passeig de Sant Joan. The centrality of many of these areas clearly coincides with facilities used by all age groups, which makes it difficult to identify the profile of the people most affected.

Although the two highest indicators of vulnerability were taken into account (average annual immission of 70 µg/m^3 and greater correlation with population and/or facilities), in line with the aim to understand the maximum risk to which residents and users of facilities may be exposed, almost none are identified by the map. However, attention is focused on the elderly in the area of the La Barceloneta neighbourhood where it borders Ronda Litoral. There is no significant concentration of facilities in this area for that age group, but there is a high density of resident population, and the people living there are exposed to those immission levels (see appendix 6.3.5).

5. Related initiatives

In conclusion, all measures that seek to reduce the number of vehicles circulating on the city's roads where traffic density is high will play a key role in reducing the population's risk of exposure to high immission levels. For a number of years now, Barcelona City Council has been working to ensure compliance with the limits established by the European Union and the WHO. Among the main measures recently implemented with a view to improving air quality are restrictions on the circulation of the most polluting vehicles, with a 95 km^2 area of the city being designated a Low Emission Zone. The LEZ, together with other measures for planning and managing mobility in Barcelona, such as regulating parking, promoting public transport and cycling, promoting the use of electric vehicles or changes in the city model, aim to establish a political agenda that includes structural measures that will have a positive impact on health and on the environment.

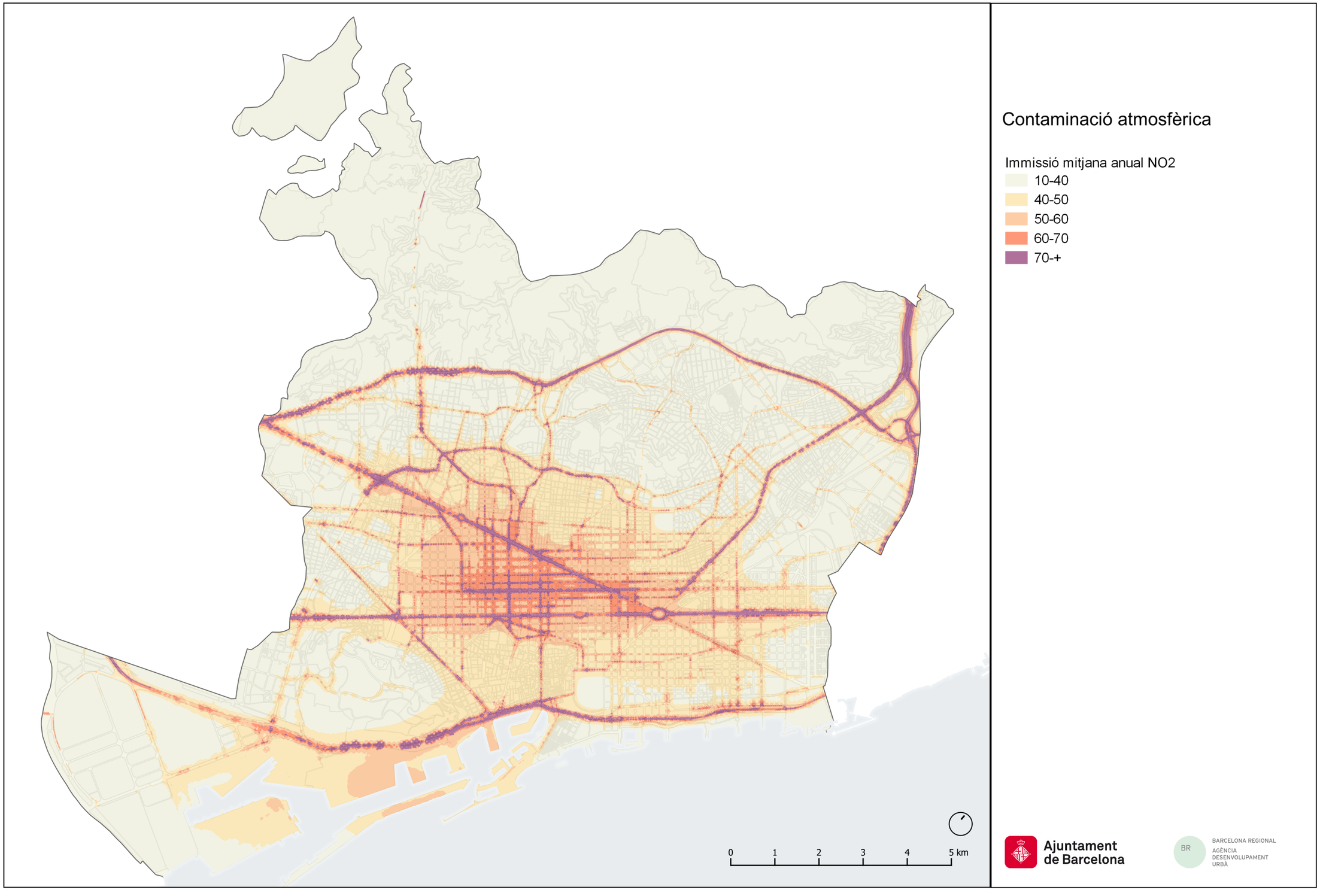
In addition, the new Urban Mobility Plan (2019-2024) which is currently being drafted, proposes a change in the mobility model in line with its predecessor, namely, to encourage walking, by creating safe and convenient spaces for pedestrians, and sustainable means of transport (bicycles and public transport). At the same time, the aim is to reduce the use and presence of

private motor transport (cars and motorbikes). The main focus of the plan is to achieve safe, healthy, sustainable, smart and equitable mobility.

Barcelona’s Resilience programme is a new opportunity to showcase the city’s current efforts to implement structural measures aimed at tackling current levels of atmospheric pollution. Measures to discourage the use of private vehicles, such as the introduction a 30 km/hour limit on an additional 200 kilometres of streets, the Walking Mobility Plan and improvements in road safety in areas around the city's school areas, stand out.

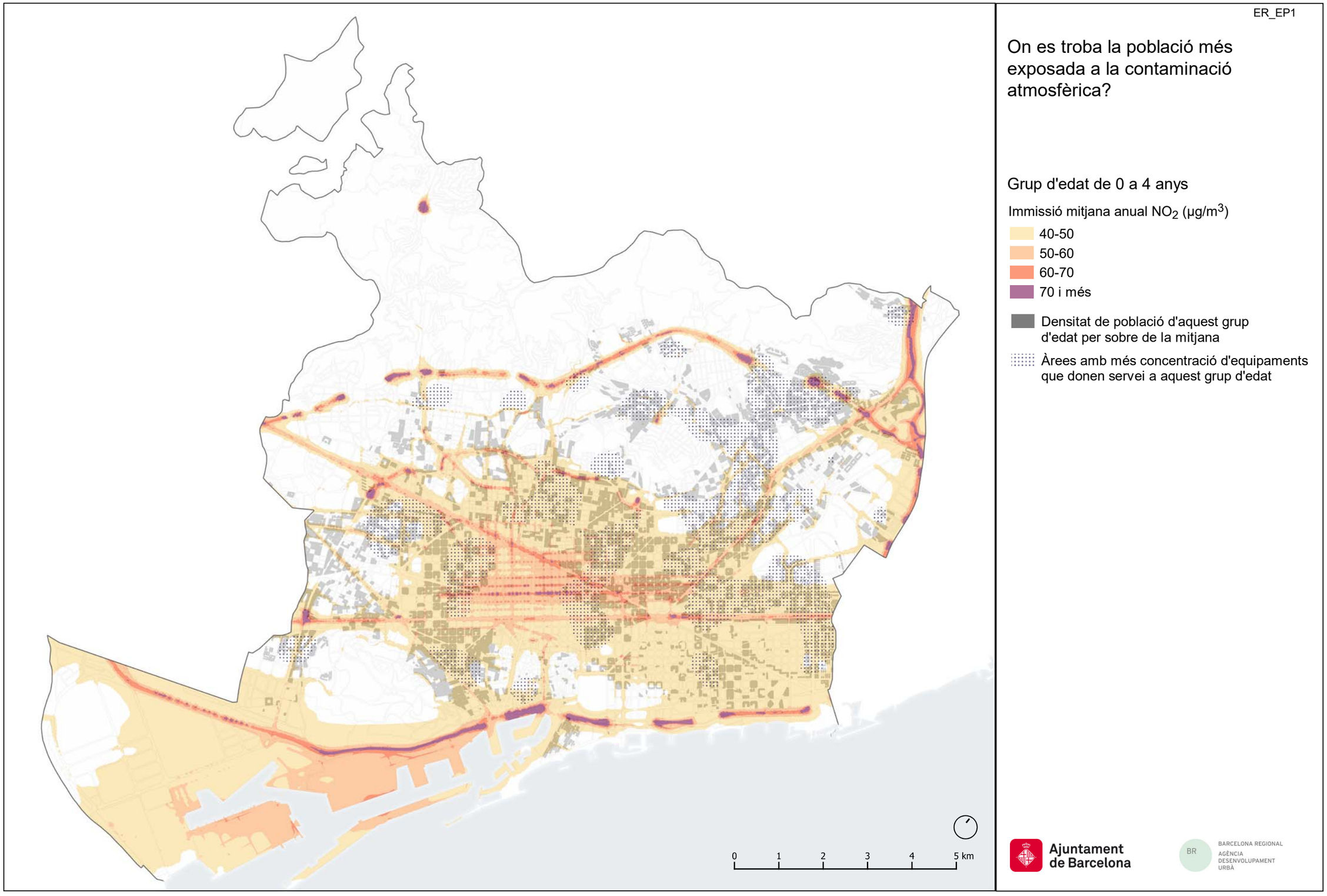
6. Appendices

6.1 Map of annual average NO2 concentration. 2017



6.2 Population by age group maps superimposed

6.2.1 Map 0 - 4 age group



6.2.2 Map 5 - 14 age group

ER_EP1

On es troba la població més exposada a la contaminació atmosfèrica?

Grup d'edat de 5 a 14 anys

Immissió mitjana anual NO_2 ($\mu g/m^3$)

- 40-50
- 50-60
- 60-70
- 70 i més

Densitat de població d'aquest grup d'edat per sobre de la mitjana

Àrees amb més concentració d'equipaments que donen servei a aquest grup d'edat

0 1 2 3 4 5 km

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ER_EP1

On es troba la població més exposada a la contaminació atmosfèrica?

Grup d'edat de 15 a 34 anys

Immissió mitjana anual NO_2 ($\mu g/m^3$)

- 40-50
- 50-60
- 60-70
- 70 i més

Densitat de població d'aquest grup d'edat per sobre de la mitjana

Àrees amb més concentració d'equipaments que donen servei a aquest grup d'edat

0 1 2 3 4 5 km

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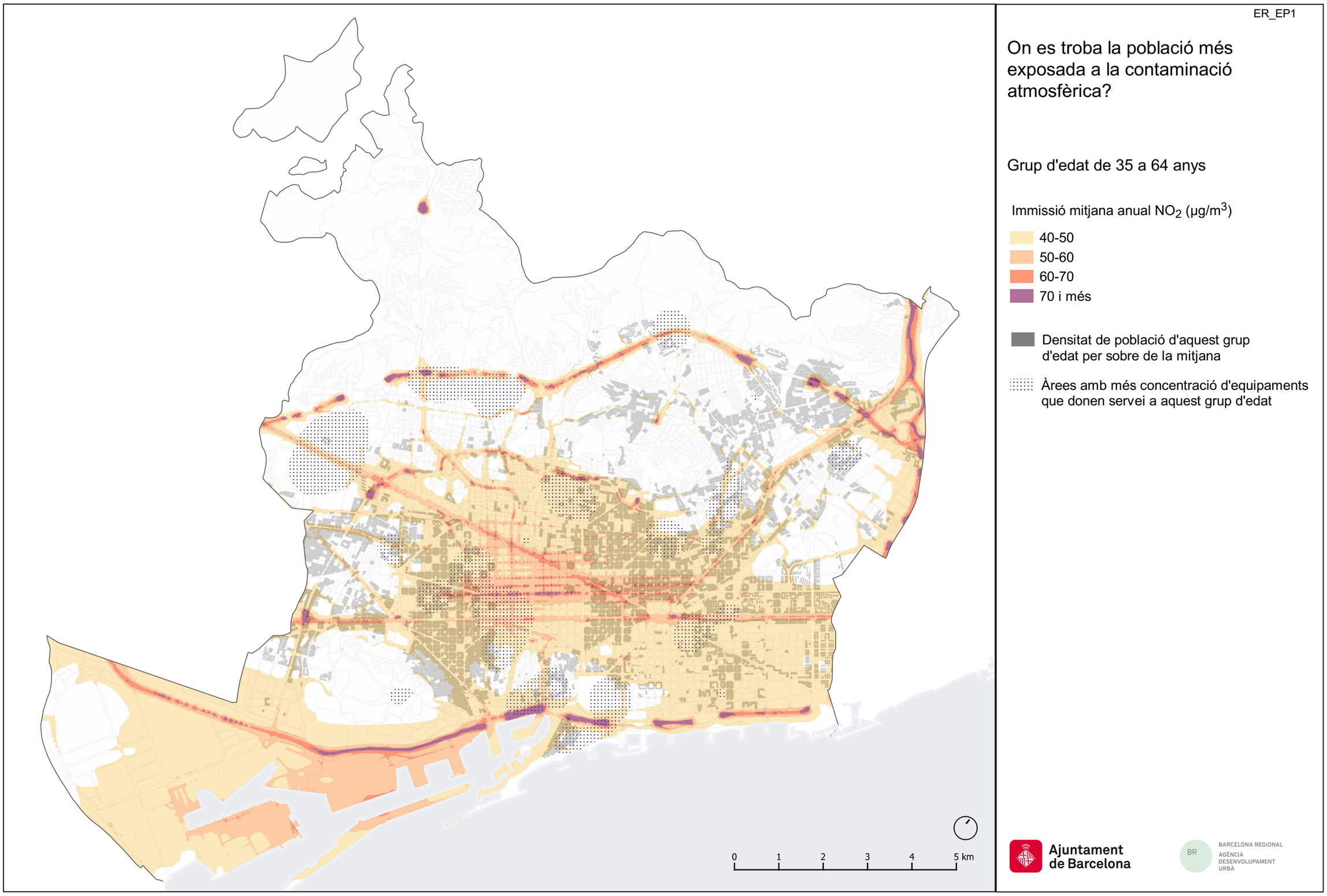
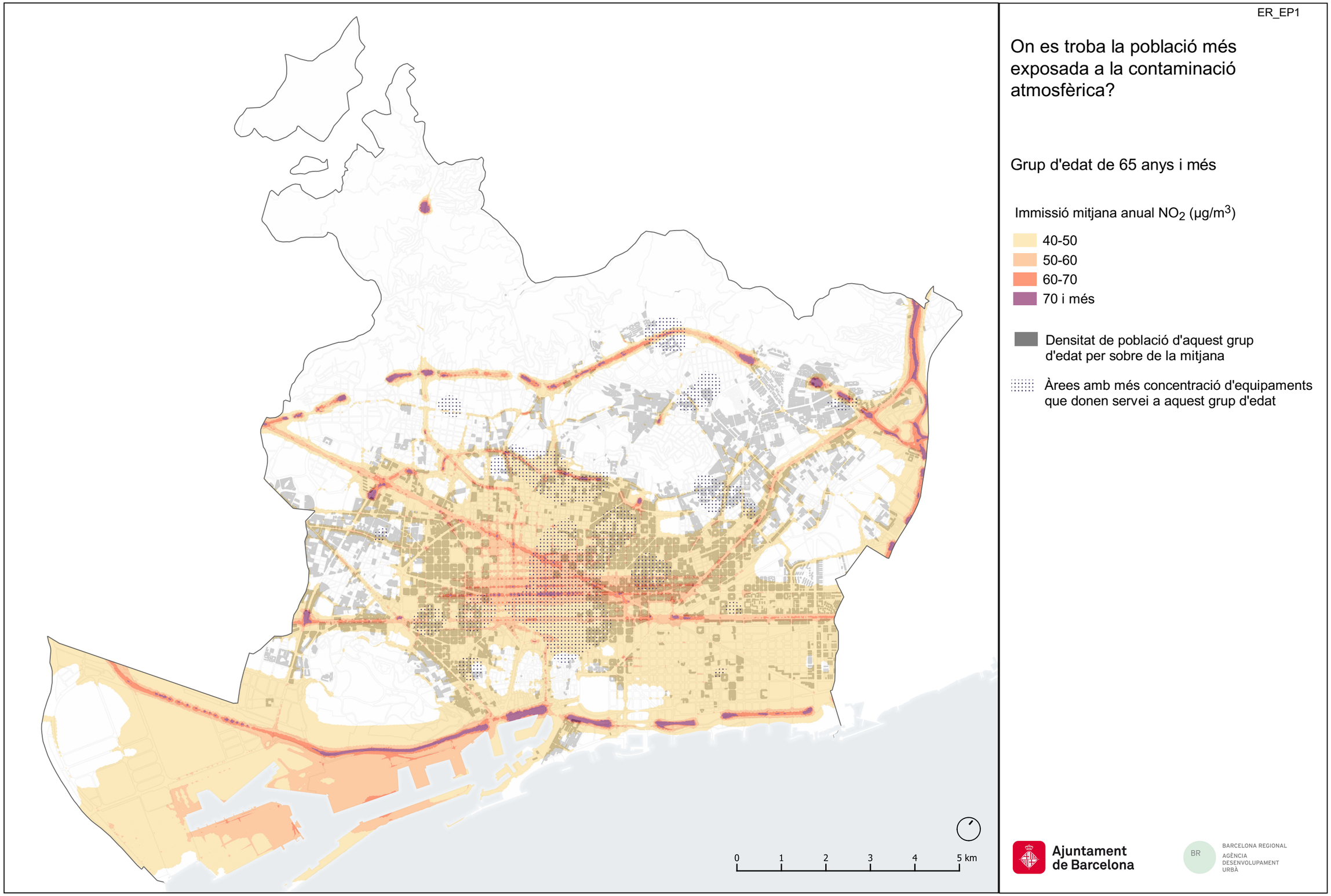
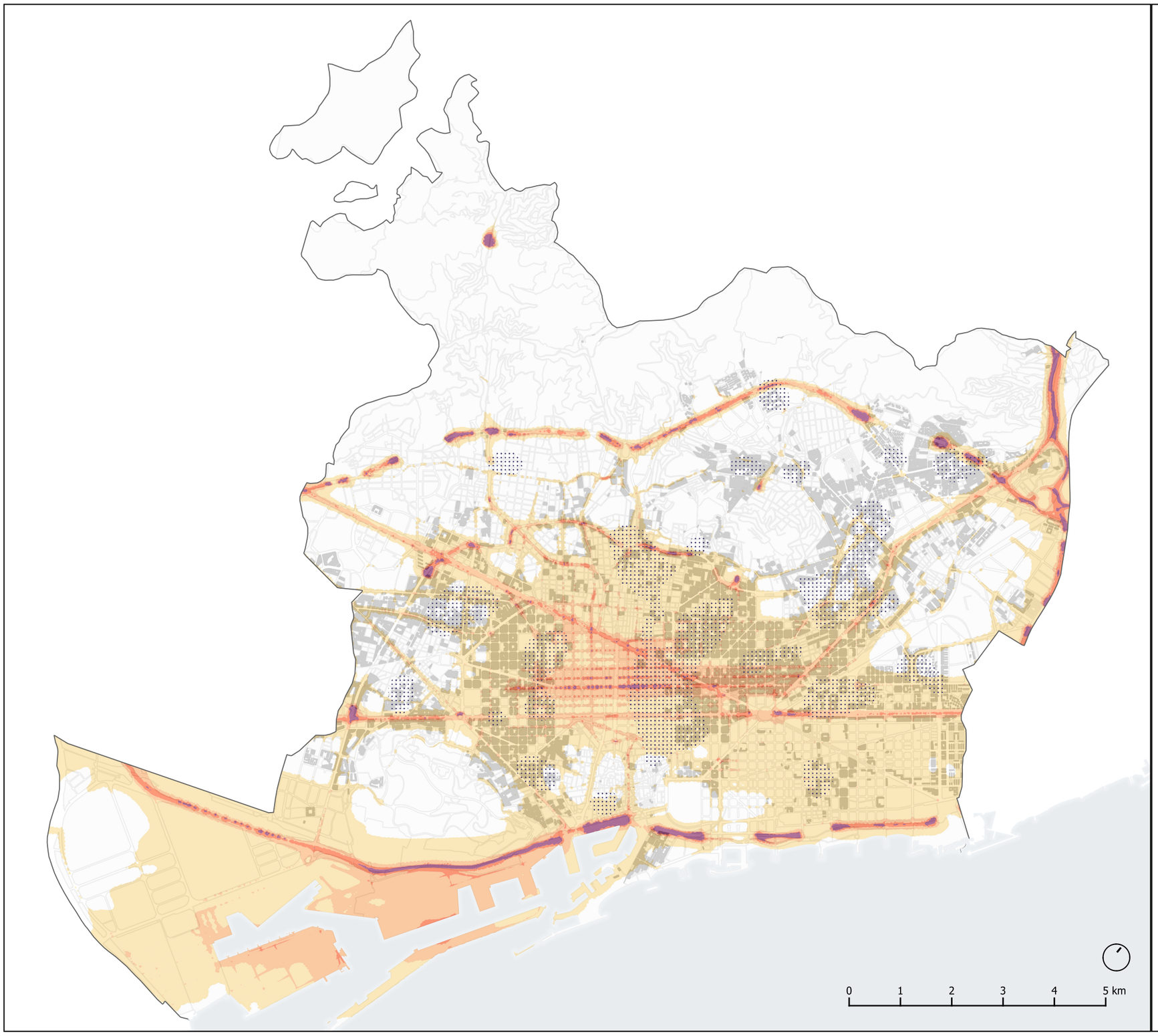
6.2.4 Map 35 - 64 age group



6.2.5 Map 65+ age group



6.2.6 Map for vulnerable age groups (0 - 4 and 65+ years of age)



ER_EP1

On es troba la població més exposada a la contaminació atmosfèrica?

Població vulnerable
(grups d'edat de 0 a 4 anys i de 65 anys i més)

Immissió mitjana anual NO_2 ($\mu g/m^3$)

- 40-50
- 50-60
- 60-70
- 70 i més

Densitat de població d'aquest grup d'edat per sobre de la mitjana

Àrees amb més concentració d'equipaments que donen servei a aquest grup d'edat

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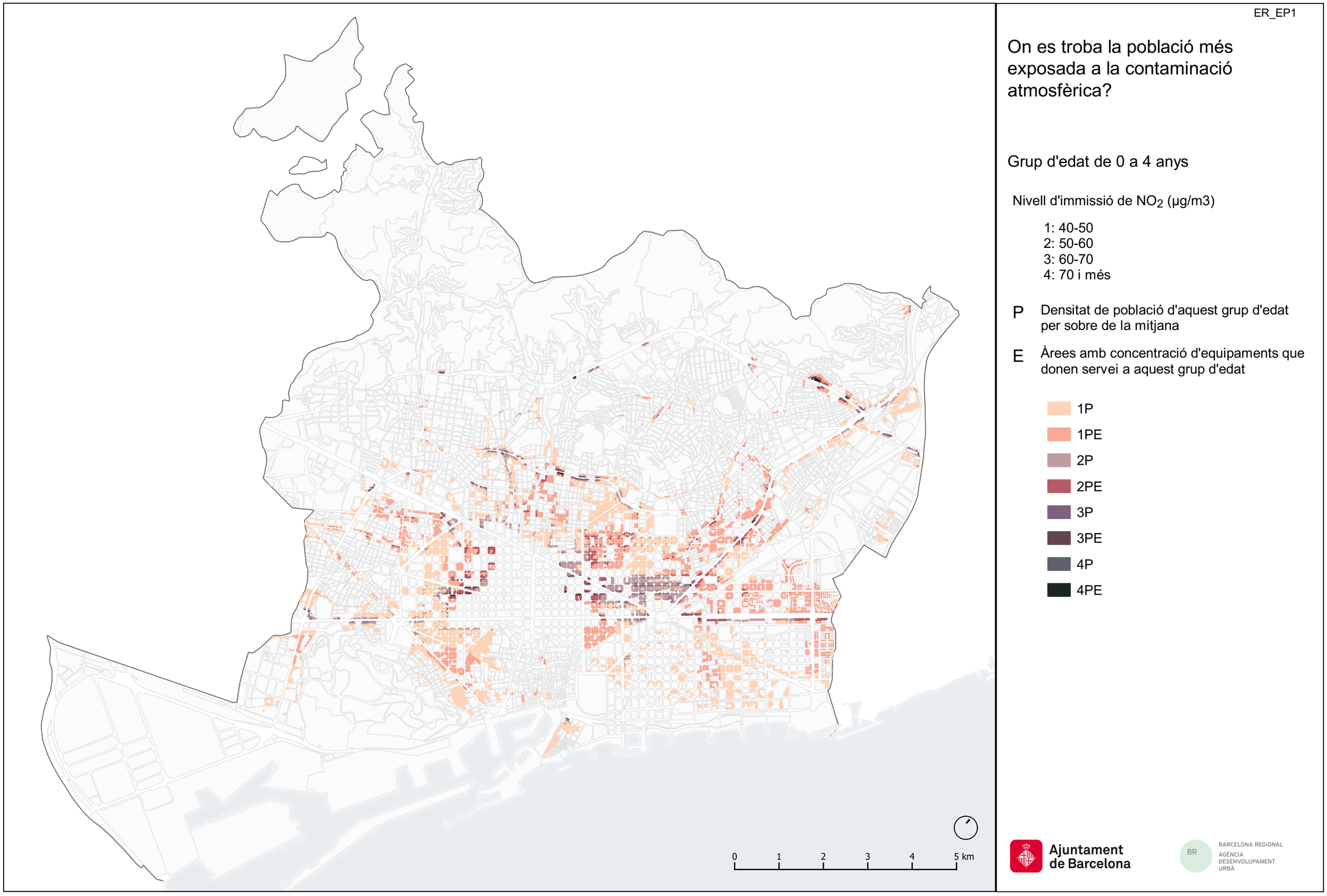
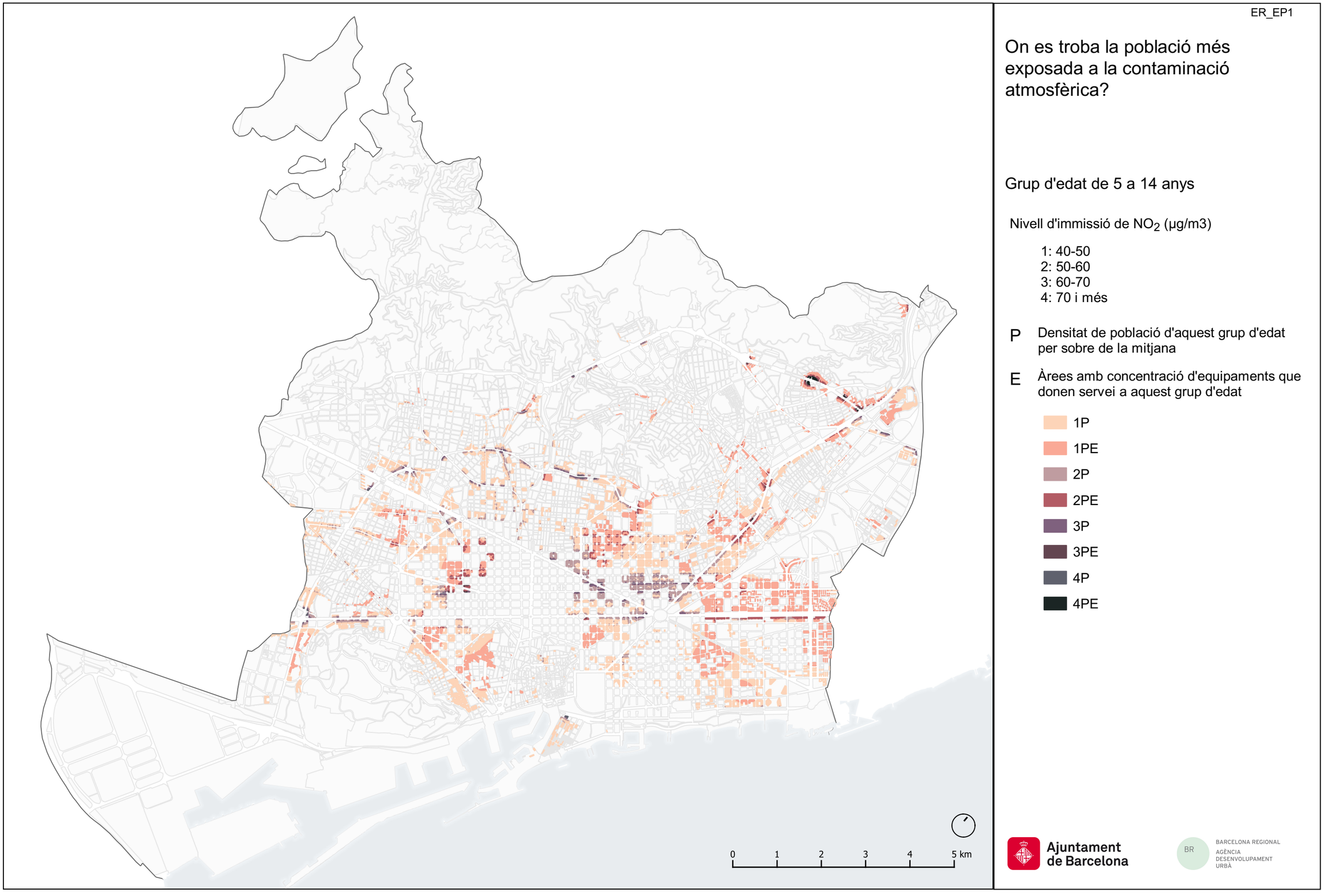
6.3 Vulnerability maps by age group

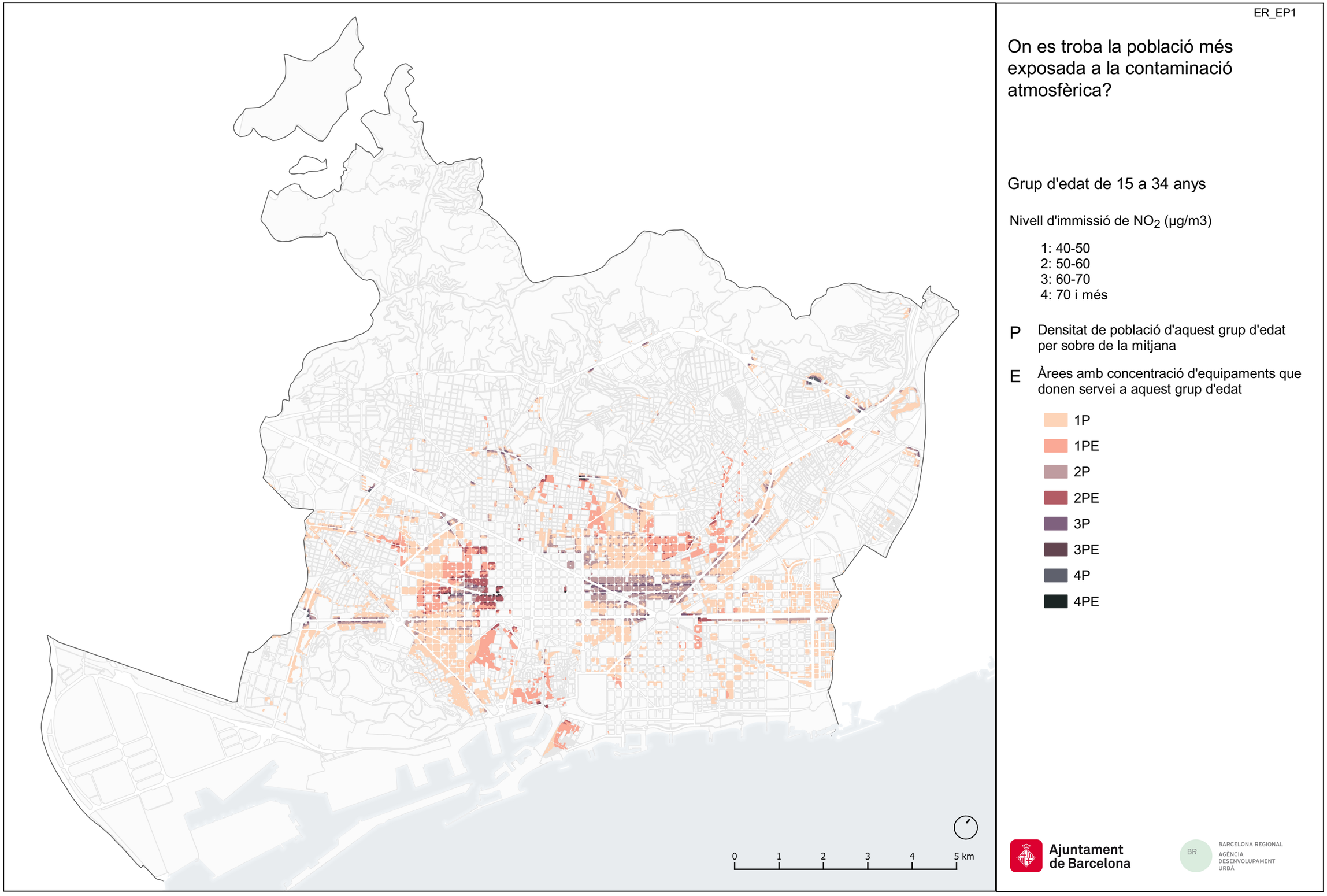
6.3.1 Vulnerability mapp 0- 4 age groups



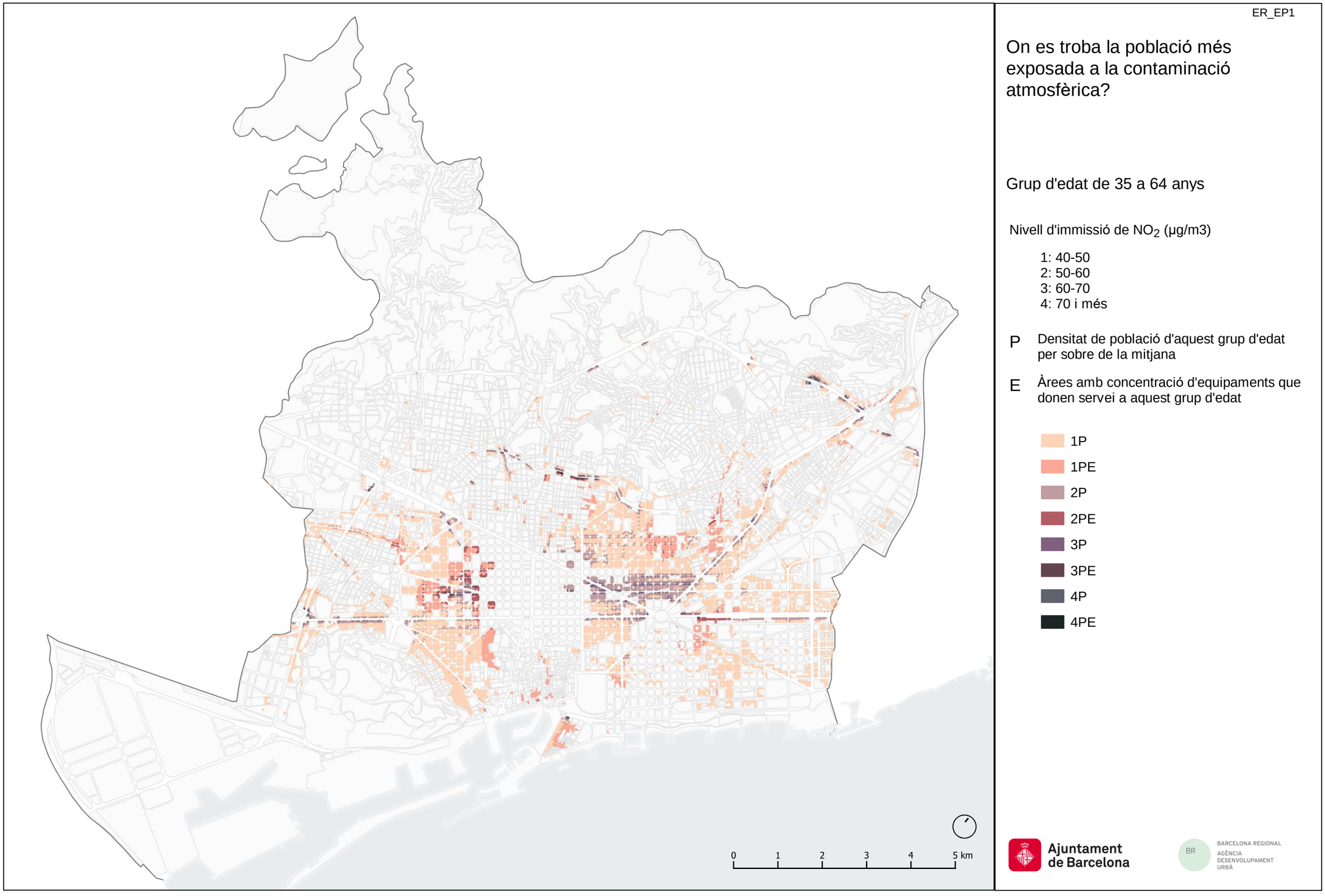
6.3.2 Vulnerability map 5 -14 age group



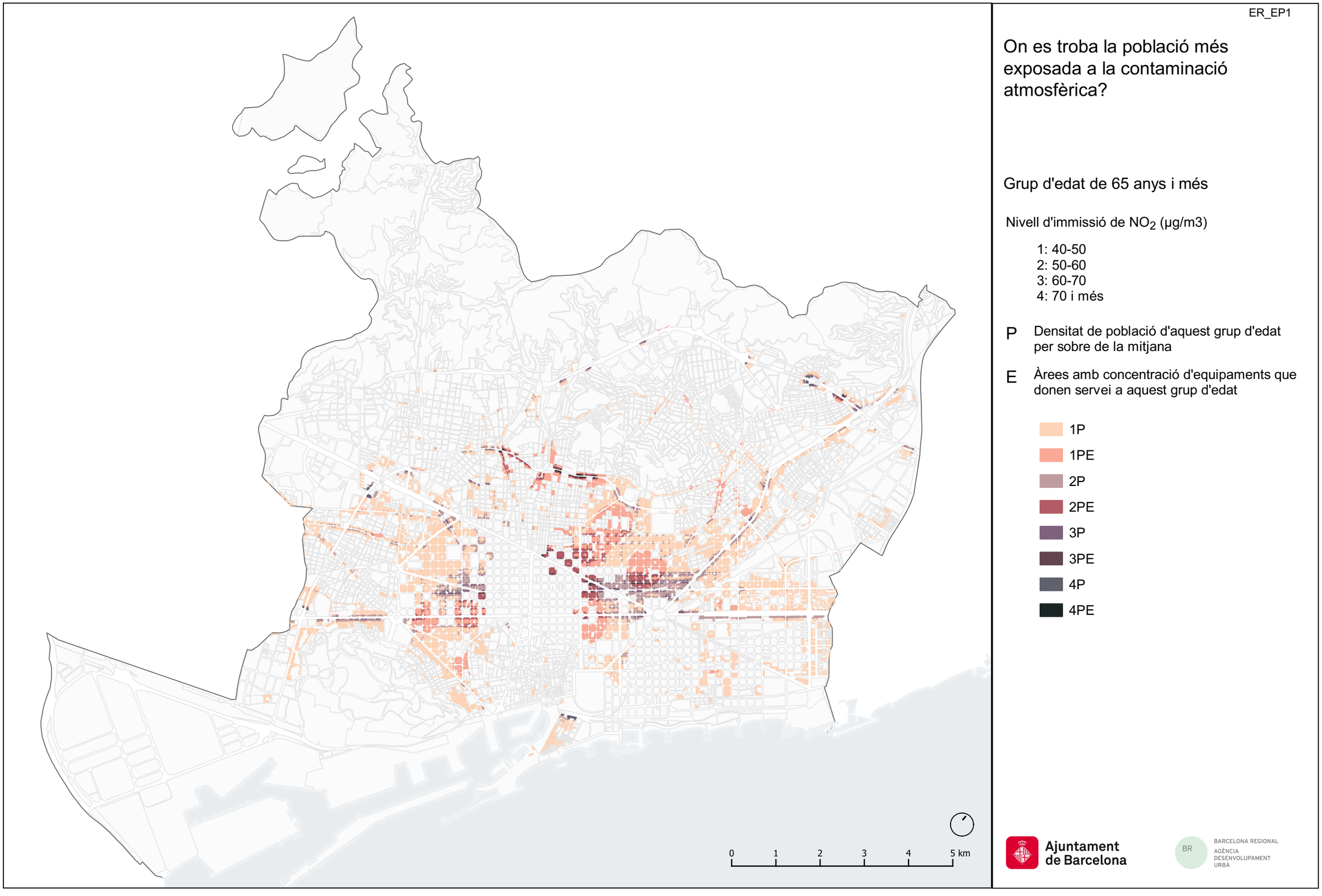
6.3.3 Vulnerability map 15 - 34 age group



6.3.4 Vulnerability map 35 - 64 age group



6.3.5 Vulnerability map 65+ age group



6.3.6 Vulnerability map 0 - 4 and 65+ age groups