A Spatial Analysis Related to the Soundscapes Within and Surrounding the Rotterdam Port Area

de Kruif, R.; Vassallo, Rodrigo; Asadollahi Asl Zarkhah, S.; Lugten, Martijn

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A **Spatial Analysis** related to the **Soundscapes** within and surrounding the **Rotterdam Port Area**

A study by **NOISELab** Rotterdam (2025)

TU Delft
Resilient Delta

Colophon

A **Spatial Analysis** related to the **Soundscapes** within and surrounding the **Rotterdam Port Area**

Rosa de Kruif — Researcher
Rodrigo Vassalo — Researcher
Sahar Asadollahi Asl Zarkhah — Researcher, Project Co-Organizer
Martijn Lugten — Project Coordinator

NOISELab Rotterdam

TU Delft
Resilient Delta

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Content

Introduction

Environmental noise is recognised as the second most significant environmental stressor on human health after air pollution (WHO, 2018). Defined as 'unwanted sound', noise exposure presents a growing public health concern, particularly in urban settings. It contributes not only to adverse physical and mental health outcomes but also to a marked reduction in quality of life (WHO, 2018; EEA, 2020).

It is estimated that 40% of the population in European Union member states is exposed to road traffic noise levels exceeding the WHO's recommended threshold of 55 dB Lden (Münzel et al., 2014). According to epidemiological data, environmental noise accounts for the loss of approximately one million Disability-Adjusted Life Years (DALYs) annually (EEA, 2020).

While road traffic is a major contributor, it is not the only source of environmental noise, particularly within and around the port area of Rotterdam. Internationally standardized noise maps, including those used for Rotterdam, distinguish several categories of environmental noise, such as road, rail, aircraft, and industrial sources. Notably, current measurements for industrial noise exclude activities taking place on water, despite their significant contribution to the port's acoustic environment (Witte, 2016; Port of Rotterdam Authority, 2022).

Given that many residential neighbourhoods lie in close proximity to port operations, and with further housing developments planned in these areas, it is necessary to assess the implications of these 'noise landscapes'. Existing noise maps are generally based on calculated average values, such as Lden and Lnight, which do not account for the variability in the perception of sound between individuals, as associated with non-acoustical factors. Yet perception plays a crucial role in how sound is experienced. It is influenced not only by individual sensitivity but also by contextual and spatial characteristics. As Herranz-Pascual et al. (2010) argue, the perception of sound is shaped both by its acoustic properties and by the spatial context in which it is heard.

With this in mind, the research presented in this report takes initial steps toward developing methods to predict soundscape typologies. By situating the study within the context of Rotterdam, it aims to provide deeper insight into how spatial configurations in and around the port area shape the quality of acoustic environments. This relationship will be explored across multiple scales: the city scale, by examining proximity to dominant noise sources; the (sub) neighbourhood scale, by analysing the functional distribution; the street scale, by analysing the street profiles; and the building scale, by analysing the influence of urban morphology.

This report presents the findings of an exploratory study into the relationship between soundscapes and the built environment, with Oud-Charlois serving as a pilot area. The goal is to lay the groundwork for future research directions and methodological approaches.

The first part consists of a theoretical investigation into the perception of sound and the various frameworks that describe the connection between soundscapes and spatial form, which is addressed through a literature review. The aim of this section is to establish a conceptual basis for identifying and interpreting soundscapes in relation to spatial characteristics.

The second part applies this theoretical framework to the empirical context of the Rotterdam port area, gradually zooming in through various spatial scales. This analysis draws on a range of data sources, including satellite imagery, GIS datasets, and noise complaint records provided by DCMR. Through this multi-scalar and data-integrated approach, the study aims to develop a more spatially nuanced understanding of soundscapes and their implications for further research.

Finally, the report reflects on the research conducted so far, identifying limitations and emerging questions, and outlines directions for future investigation.

Research structure

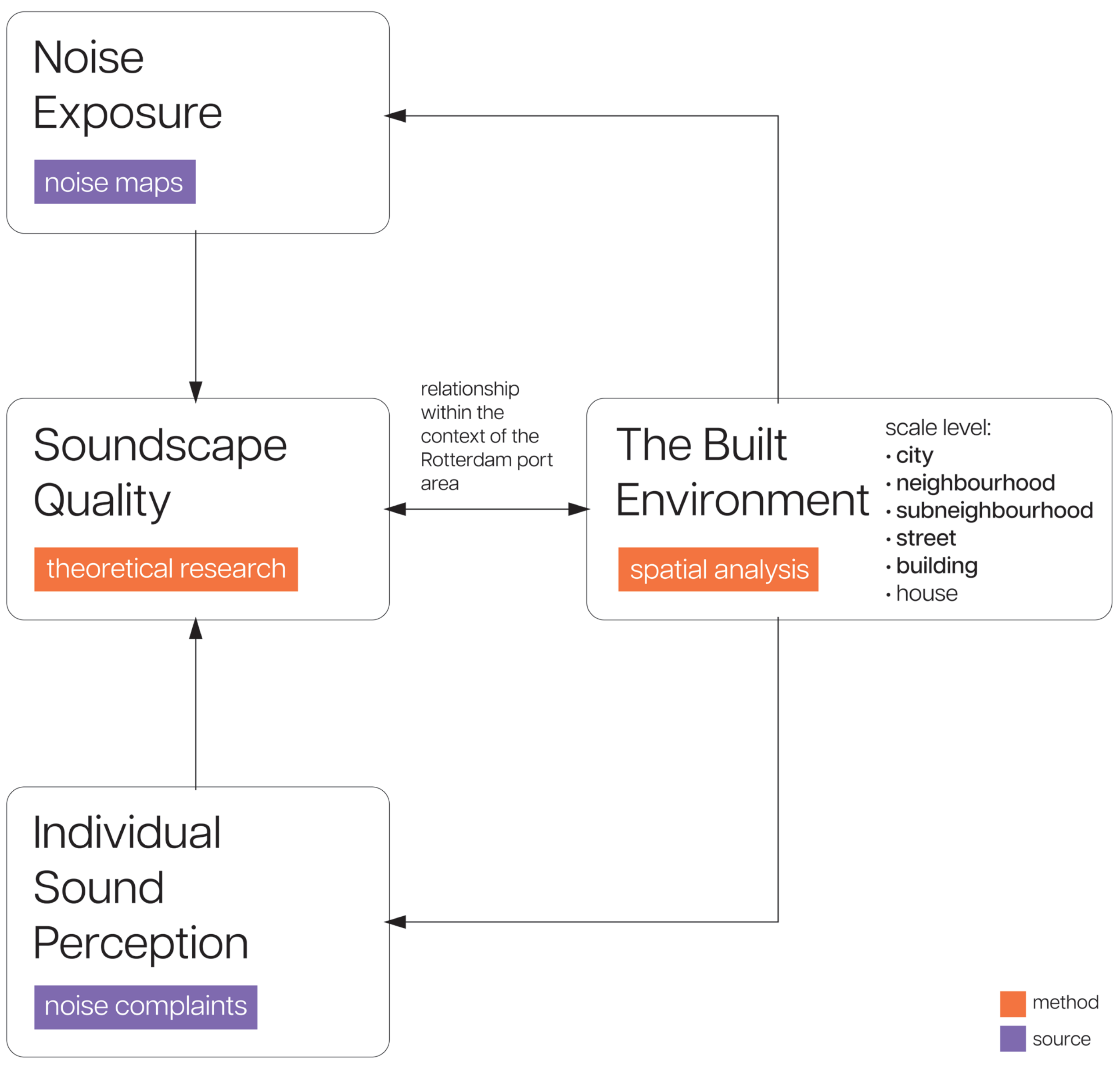


Fig. 1
Research framework
(authors, 2025)

Theories behind soundscapes

Several theories on the concept of soundscapes offer different explanations of the term. Since Schafer's seminal work (1977), the notion has carried ambiguity, sometimes referring to the physical sounds present in a place and sometimes to the way people perceive them. To address this, Grinfeder et al. (2022) distinguish three complementary categories: distal soundscapes (the spatial and temporal distribution of sounds shaped by propagation effects), proximal soundscapes (the collection of propagated sound signals at a specific location), and perceptual soundscapes (the subjective interpretation of a proximal soundscape). This report focuses on perceptual soundscapes and their underlying sources.

In order to analyse the soundscapes of the port area, it is first necessary to clarify the term and be able to link soundscape characteristics to specific spatial elements identified through spatial analysis. This approach makes it possible to pinpoint locations with high-quality soundscapes as well as areas where improvement is needed, which can then be explored in further research.

Sources of sound

A soundscape results from the combination of various overlapping sounds, which can be categorised into three components based on their source, being: geophonic, biophonic and anthrophonic (Krause, 2008). The physical dimension of the soundscape serves as an initial descriptive approach, offering a simplified and objective classification. This distinction is particularly valuable when investigating the relationship between soundscape patterns and landscape configurations (Farina, 2013).

Geophonic sounds

Geophony encompasses all sounds generated by non-biological natural agents, such as wind, flowing water, rain. These sounds form the sonic backdrop against which other sounds can overlap, blend, or be masked. Geophonic sounds are heavily influenced by the geomorphic characteristics of a region, such as orientation, steepness and the presence of features like valleys, canyons, ridges, and cliffs, which shape sound propagation and contribute to sonic degradation. Climatic conditions and local weather also play a significant role, with factors like breeze patterns, air humidity, and temperature affecting the way sound waves continue. In aquatic environments, additional factors such as water depth and temperature are key drivers of sonic developments (Farina, 2013).

Biophonic sounds

Biophonies are the sounds produced by nonhuman living organisms (Krause, 2012). Each biome in which these sounds occur is unique, with its own distinct biophonies. These biophonic compositions vary based on factors such as season, latitude, and time. For instance, frogs and birds often perform choruses at dusk and dawn, while birds are most acoustically active during the spring (Farina, 2013).
Study shows that biophonic sounds -such as bird sounds- are associated with restorative benefits (Uebel et al., 2022).

Anthrophonic sounds

Lastly, anthrophonic sounds are those generated by human-made devices, such as cars, trains, and industrial machinery. This component of the soundscape is becoming increasingly prominent in our globalised world, largely due to its strong association with urban development. Additionally, anthrophonic sounds are a major contributor to noise pollution, with its significant health consequences as a result. The soundscapes, shaped by anthrophonic sounds, vary according to the city's function, structure, and its economic and social context. A city's sonic gradient fixes the prices of the houses, since a higher noise exposure leads to a decreased economic value (Farina, 2013).

As can be seen in Fig. 3, anthrophonies increase in presence when moving towards urban areas, in which the most urbanised areas can be seen as industrial infrastructures (Farina, 2013). This means that in the area of the port of Rotterdam, this component of the soundscape is highly dominant.

Interrelated components

In a soundscape, the three components - geophonies, biophonies and anthrophonies - interact with each other. When comparing the these components, the geophonies are representing the variable being independent, influencing mainly the biophonies and indirectly also the anthrophonies (Fig. 2). As an example, heavy wind depresses most birdsongs. But also anthrophonies has a direct effect on biophonies, thinking of the example of an highway within a highly urbanised area, both depressing sounds of nonhuman species as being not a suitable environment for them to live in.

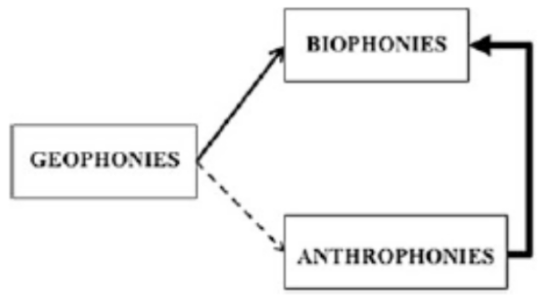
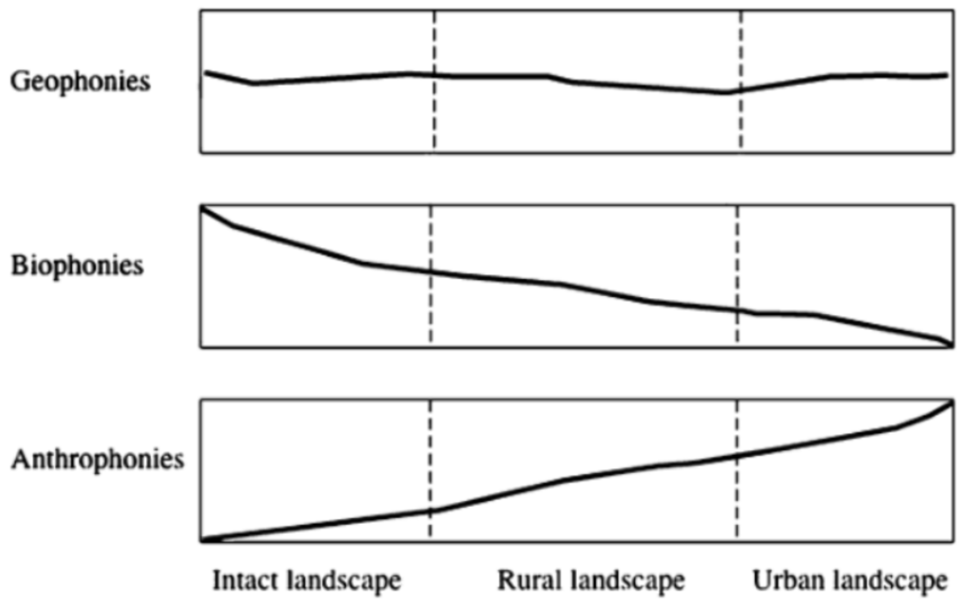


Fig. 2
Sound sources
(Farina, 2013)

Fig. 3
Sources through places
(Farina, 2013)



Perceptions of sound

The perceptions of sound refer again to the way people perceive the sound within the larger context of perception (Schafer, 1977). To understand the human perception of soundscapes, the concept of 'the core affect' gives valuable insights. Originally, core affect comes from emotion theory and is associated with mood (Russell, 2003). Unlike emotions, being oftenly short-lived, mood can always be described, so the definition of the core affect is essentially the way we feel at a certain point in time, which can be described by either pleasantness or activation (Van den Bosch, 2015).

Research by Axelsson, Nilsson, and Berglund (2010) demonstrated that individuals evaluate auditory environments primarily along the dimensions of pleasantness and eventfulness. Building on this, Erfanian et al. (2021) found that psychological well-being is positively associated with perceived pleasantness. In addition, demographic characteristics can shape how people perceive sounds, including gender (Xiao & Hilton, 2019), educational background (Zhang & Kang, 2007), and age (Zhang & Kang, 2007; Erfanian et al., 2021). It can thus be concluded that the way people describe their internal emotional state, mood, is connected to the way they perceive and describe the external world. Supporting this idea, research has shown a strong, reciprocal, and ongoing relationship between individual's moods and their appraisal of their surroundings (Kuppens et al, 2012; Andringa & Lanser, 2013).

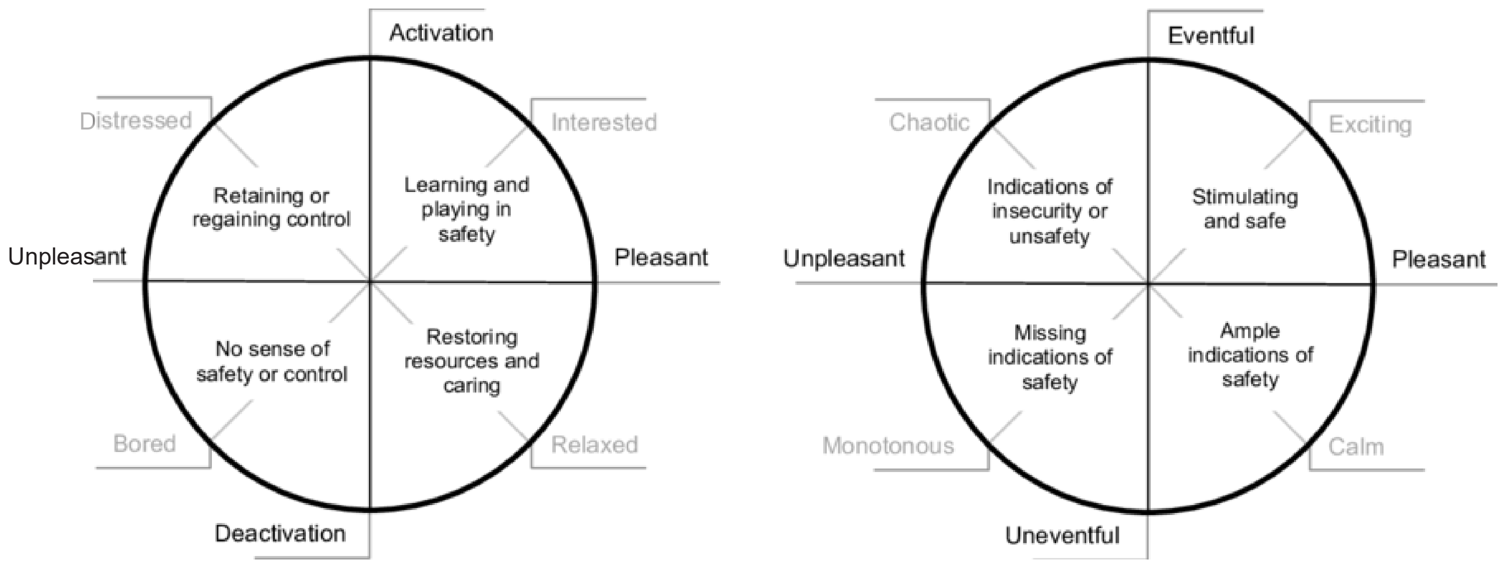


Fig. 4
Soundscape framework
(Andringa & Lanser, 2013)

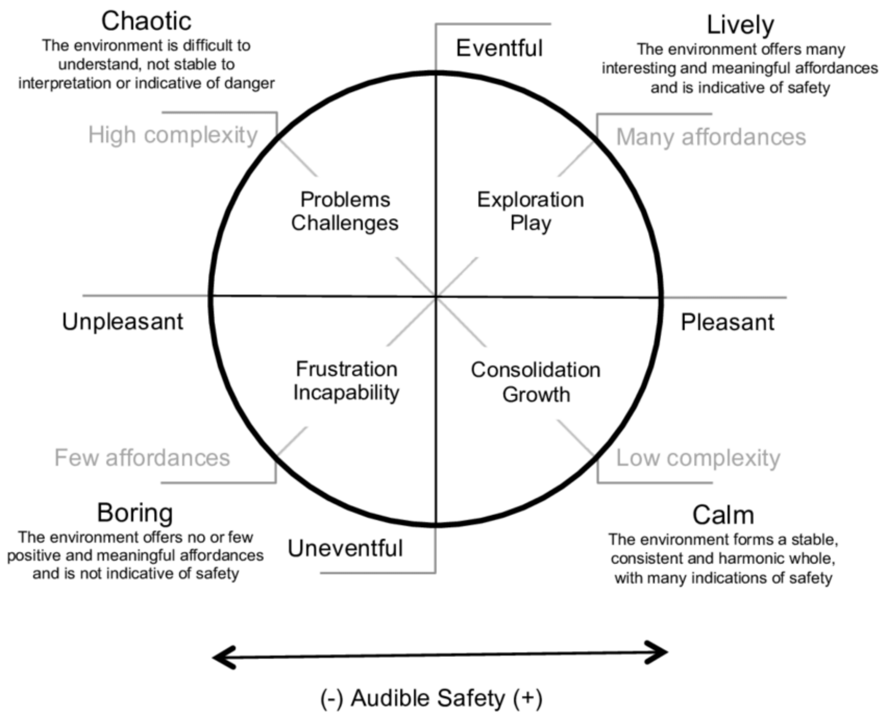


Fig. 5
Soundscape framework
(Andringa, Van den Bosch & Vlaskamp, 2013)

However, beyond individual-dependent factors, contextual characteristics of the spatial environment across different scales also shape perceived soundscapes. A systematic review by Zhang et al. (2025) highlights that spatial-physical attributes operate at three levels: the macroscale (landscape patterns such as shapes, diversity, and area types), the mesoscale (landscape elements including water, greenery, roads, and buildings), and the microscale (multisensory factors such as humidity, temperature, and colour).

Zhang et al. (2025) emphasize the reciprocal relationship between context and soundscapes, whereby context shapes perception, while soundscape experiences can, in turn, modify context. The study highlights the importance of systematically integrating contextual factors into future soundscape research and practice.

Soundscape framework

The framework, originally developed by Axelsson and Nilsson (2010), evolving from the perceptions of sounds, shows four main quadrants; boring, chaotic, lively, and calm (Fig. 5). An extra element of this model shows two diagonal axes, representing increasing complexity and affordances, in which the complexity reflects how challenging it is to determine the appropriate behaviors in a given situation within that environment and affordances refer to the degree to which an environment provides opportunities for self-directed actions and choices (Van den Bosch, 2015).

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Chaotic

Characterized by an overload of sounds or signals of potential danger, often featuring loud and unpleasant foreground noises. These soundscapes make it difficult for individuals to remain calm and can trigger stress or alert behaviours (Van den Bosch, 2015).

Boring

Defined by monotonous, unpleasant background noise and a lack of safety cues, leading to environments where people feel neither secure nor in control. Such settings promote passive, self-protective, or stereotypical behaviors due to the absence of engaging or meaningful stimuli (Van den Bosch, 2015).

Lively

Composed of pleasant, stimulating foreground sounds and a diversity of affordances that capture attention. Lively soundscapes create safe, engaging environments that encourage exploration, curiosity, active interaction, and deeper connection with the surroundings (Van den Bosch, 2015).

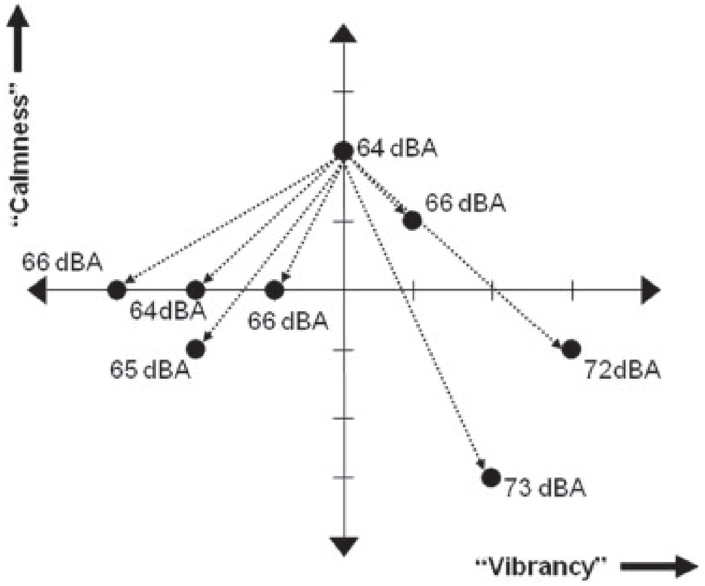
Calm

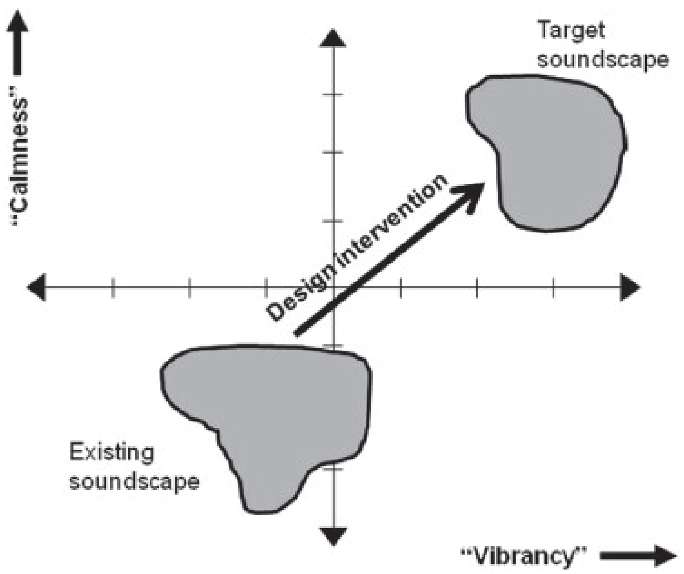
Featuring soothing background sounds—often from natural sources—with minimal intrusive foreground noise, calm soundscapes foster relaxation, stress recovery, and well-being. They provide restorative spaces where individuals, including those with profound intellectual or multiple disabilities, can feel comfort and enjoyment (Van den Bosch, 2015).

Designing with soundscapes

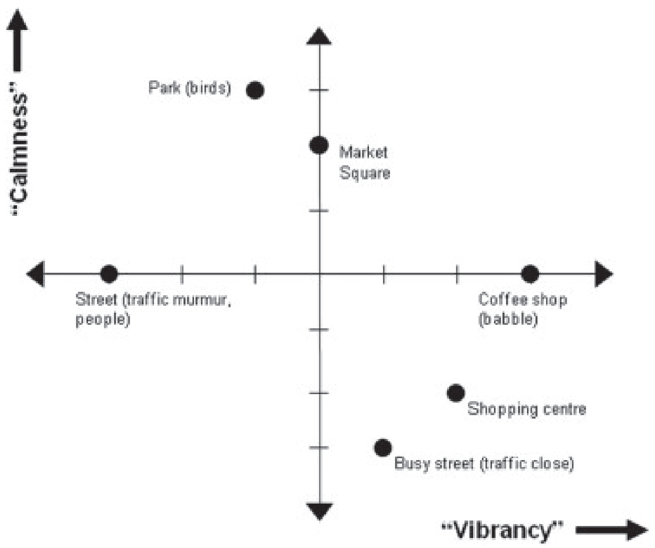
A study by Cain et al. (2013) emphasized the importance of considering the emotional dimension of a soundscape when evaluating the quality of sound in a specific location. The study also highlighted that understanding this emotional aspect can be a valuable tool for enhancing the overall quality of a soundscape. The data for this research was generated through the Positive Soundscape Project, where participants rated specific sound recordings. By conducting surveys for each soundscape, the results were plotted into a 2D space (Fig. 6 - 9), representing levels of calmness and vibrancy. Notably, this diagram differs somewhat from the earlier one, possibly due to the timing of this study, as it was conducted previously.

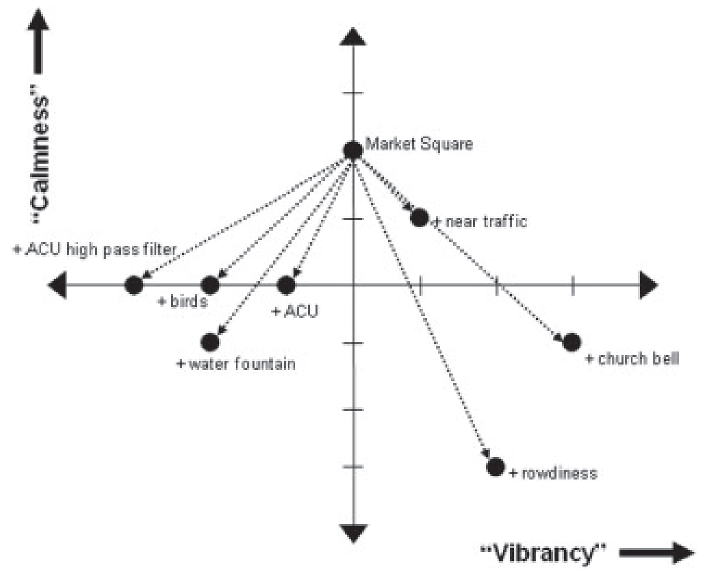
During the survey, participants listened to the same soundscape with a new element added each time, allowing researchers to plot the effects of specific elements. For example, in the case of the market square, it became apparent that adding elements reduced the calmness of its soundscape (Fig. 8). This approach helps identify design interventions that positively influence individuals' perception of their environment. Additionally, analysis of the different dB(A) levels (Fig. 6) revealed that the variations in loudness between design interventions were not significant. This finding serves as evidence that relying only on physical measures is insufficient to





< Fig. 6, > Fig. 7
Designing with soundscapes
(Cain et al., 2011)





< Fig. 8, > Fig. 9
Designing with soundscapes
(Cain et al., 2011)

fully understand how soundscapes are perceived by listeners.

The next step in the study involved identifying the ideal position of the soundscape within the perceptual space. A key challenge for future research is helping planners understand how specific design interventions can shape soundscape perceptions to align with desired outcomes. The study's conclusion emphasises the need for further evidence to better understand how various design interventions can influence and position different soundscapes within the perceived environment (Cain et al., 2013).

A study by Kang (2023) emphasises the need to integrate soundscapes into urban design guidelines, noting that this is often overlooked in current practice. Simply reducing sound is insufficient for enhancing soundscape quality; instead, sounds should be treated as resources to be designed, rather than wastes to be eliminated. Kang proposes a framework for incorporating soundscape considerations into urban sound design and planning, focusing on four key components: sound source characteristics, spatial acoustics, user socio-demographics, and other physical conditions, including factors such as temperature and landscape features.

Analysing with soundscapes

The previous sections have demonstrated initial connections between sound sources, their spatial characteristics, and the governing idea behind soundscape theory, shifting the core focus from traditional acoustic indicators, to a layered conceptualization of the perception of sounds within an context, i.e. in space and time, by humans. To enable more systematic research into soundscapes within and around the Rotterdam port area, the development of a standardised model that links spatial context to soundscape typologies would be able to facilitate a more consistent integration of spatial analysis with soundscape analysis, allowing for a deeper understanding of how the built environment influences the perception and quality of urban soundscapes.

Research in 2017 (Margaritis, Kang) started on developing such a standardised model to aid soundscape planning and to assess its effectiveness. The model uses a three-step approach to map urban soundscapes. Whereas the first step consists of translating audio recordings during soundwalks into sound categories by using machine learning algorithms, in which the sound categories are natural, anthrophonic and technological. Translating these categories into the categories previously mentioned, would divide natural sounds into both geophonic and biophonic sounds -since these categories of sounds are all sounds not generated by human activity-; and anthophonic and technological sounds into anthrophonic sounds –since these categories are both sounds generated by human activity-. The study revealed that a high number of natural sources were most prominent in exclusive residential areas, areas close to parks, and other places with a high degree of natural elements, but also areas with a high amount of vegetated gardens. Besides, anthrophonic sources were mainly evident in proximity to natural elements -providing a source of relaxation and restoration-, as well as in locations that facilitate social interaction, such as market squares or areas with commercial functions.

The second step of the model links sound sources to perceptual attributes– pleasant, chaotic, exciting (lively), uneventful, calm, unpleasant, eventful, and monotonous (boring)–through the use of regression models. These perceptual attributes correspond to the soundscape categories outlined in the previous section. The findings indicate a negative correlation between traffic noise and perceptions of pleasantness and calmness, whereas natural sounds are positively associated with these soundscape qualities. A related study by Kang et al. (2018), based on the same dataset, further highlights that calmer sound environments are typically characterised by a reduced presence of both traffic noise and eventful sounds, such as sirens, industrial activity, loading of goods, and construction noise–categories into which port-related sounds may also be classified.

Finally, the third step translates the model's outcomes into GIS maps, providing further insights into spatial patterns. These maps reveal that greener, quieter areas are generally perceived as more pleasant and calm, whereas areas dominated by traffic noise not only register the highest measured noise levels but are also the least associated with calm and pleasant soundscapes.

However, as this study was conducted within the context of a case study in Sheffield, the development of a more universally applicable model would require a broader and more diverse dataset in order to account for variations in spatial and acoustic contexts.

Soundscapes through scales

While it is important to acknowledge that preferences for soundscapes can vary between individuals due to physical, socio-cultural, and psychological differences (Aburawis & Dokmeci Yorukoglu, 2018), potentially resulting in different design needs and responses, the adverse effects of high exposure to severe prolonged noise on physical and mental health are universal (Münzel et al., 2014). Therefore, the implementation of general guidelines remain essential from a public health perspective, even though certain individuals may be more sensitive or affected than others.

In the Netherlands, sound and noise are also taken into account when formulating guidelines for what is referred to as a 'healthy city'. In 2016, the National Institute for Public Health and the Environment (RIVM) published a report outlining such guidelines, in which several spatial recommendations specifically addressed noise-related issues. These included themes such as 'healthy and safe environments', 'bicycle-friendly design', 'healthy buildings', and 'informality'.

The final diagram from the RIVM's study on the 'healthy city' presents the key topics in a simple visual way. Larger circles represent the topics considered most important, while smaller circles show those seen as less important. The topics are also arranged from most to least important. Within this overview, the guidelines related to noise and sound are clearly highlighted (Fig. 10).

Greenery was frequently mentioned, which could also contribute to such restorative spaces and enhance people's perception of sound. Furthermore, the results show that places that focus on slow traffic are seen as places of quality. Neighbourhoods with restrictions on freight traffic and low car presence in general, influence the overall liveability of both the city as a whole and its individual neighbourhoods.

Within the 'healthy buildings' category, it becomes evident that calm atmospheres with respect to noise are increasingly valued.
Drawing from this publication, it is hypothesised that

Fig. 10
Healthy city guidelines (RIVM, 2016, edited)

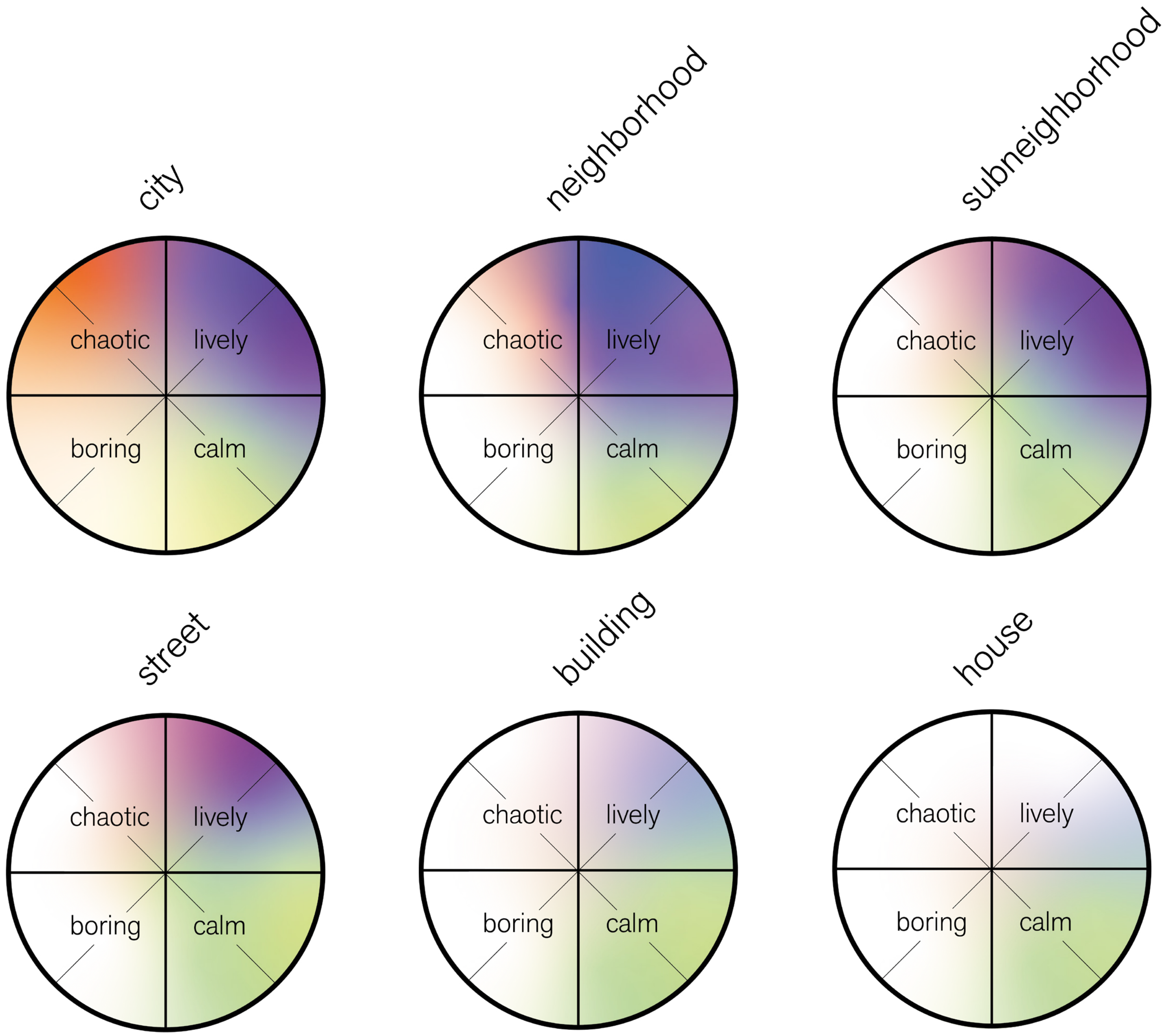


Fig. 11
Desired soundscapes through scales (authors, 2025)

the importance of quiet spaces becomes greater at smaller spatial scales. This can be illustrated by a diagram of soundscapes across scales, demonstrating that the need for calm soundscapes – which are perceived as the most restorative – becomes greater as we move from the city scale to the neighbourhood and building scales.

The influence of scale on soundscapes is also highlighted in the systematic review by Zhang et al. (2025). At the macroscale, spatial patterns in the landscape, such as shapes, areas, aggregation, and diversity, play a role. The mesoscale focuses on elements like buildings, water, and green space ratios, while the microscale involves a variety of sensory factors that shape individual perception of the soundscape.

Contextual approach and research

Having established that soundscapes can be categorised into four types, each associated with specific spatial characteristics, these insights can now be translated into an analysis for examining the context within and around the Rotterdam port area.

Since the desired soundcape varies by scale level (Fig. 11), it is appropriate to conduct the analysis across different scales as well. At each scale level, distinct approaches are applied to examine the dimensions and spatial distribution of sounds.

The context of the port

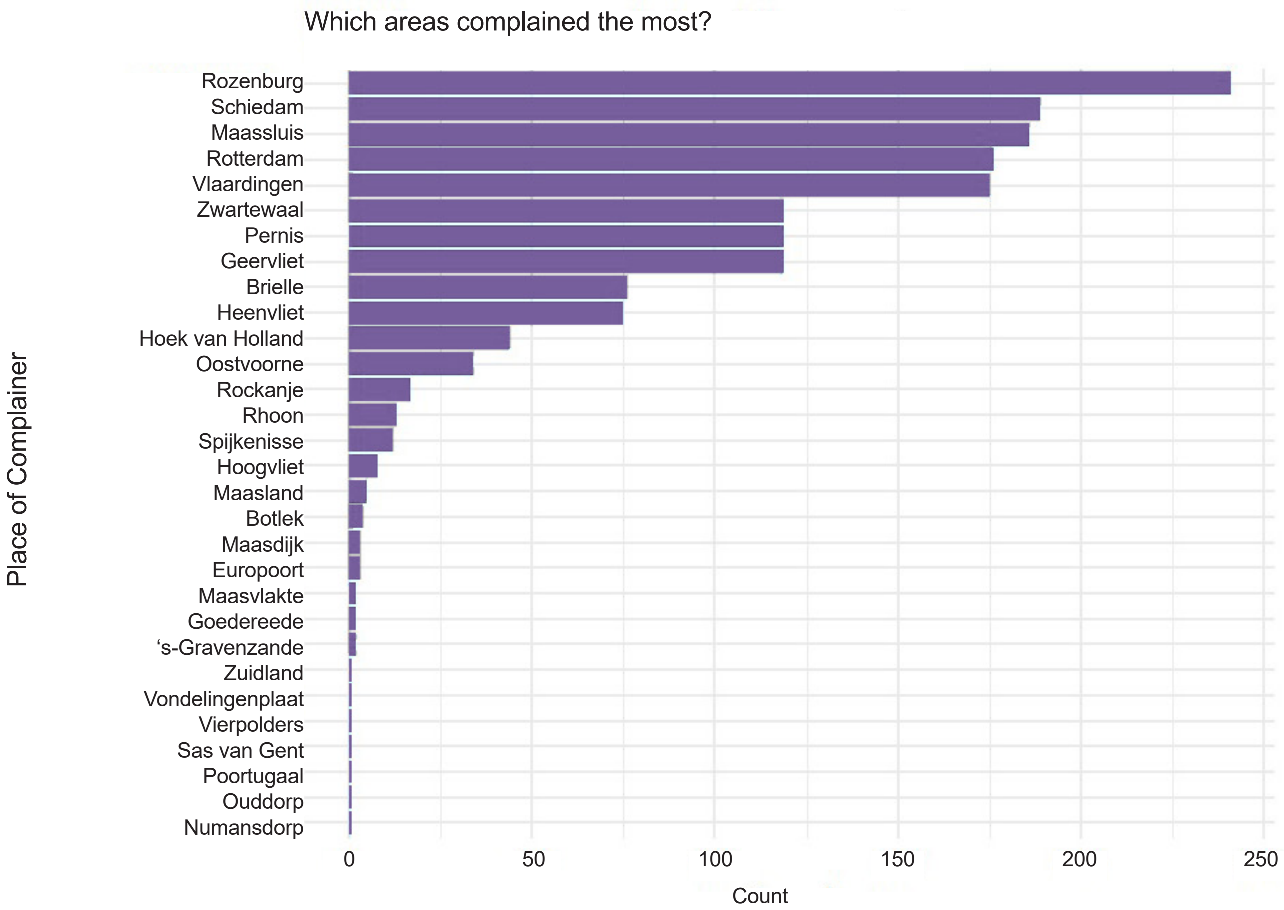
DCMR provided NOISELab with a dataset containing noise complaints caused by port-related activities throughout 2024, within and around the borders of the Port of Rotterdam.

The dataset was converted into both R and QGIS, enabling analysis of its statistical and spatial components. In R, various diagrams were created to visualise the distribution of complaints over different timeframes, as well as the specific sources of the complaints within those timeframes (Fig. 13).

By importing the dataset into QGIS, the spatial dimension of the complaints became visible, allowing us to analyse their geographic distribution in relation to the actual sources of noise pollution. Additionally, the temporal data could be visualised spatially, illustrating, for example, the distribution of complaints across different times of day: mornings (6 am – 12 pm) (Fig. 15), afternoons (12 pm – 6 pm) (Fig. 16), evenings (6 pm – 12 am) (Fig. 17), and nights (12 am – 6 am) (Fig. 18).

The heatmaps indicate that complaints are more widely dispersed during the daytime, whereas at night they are primarily concentrated in Rozenburg and Schiedam, which also account for the highest number of complaints overall (Fig. 12).

Fig. 12
Complaints per area
(data source: DCMR, 2024; own elaboration)



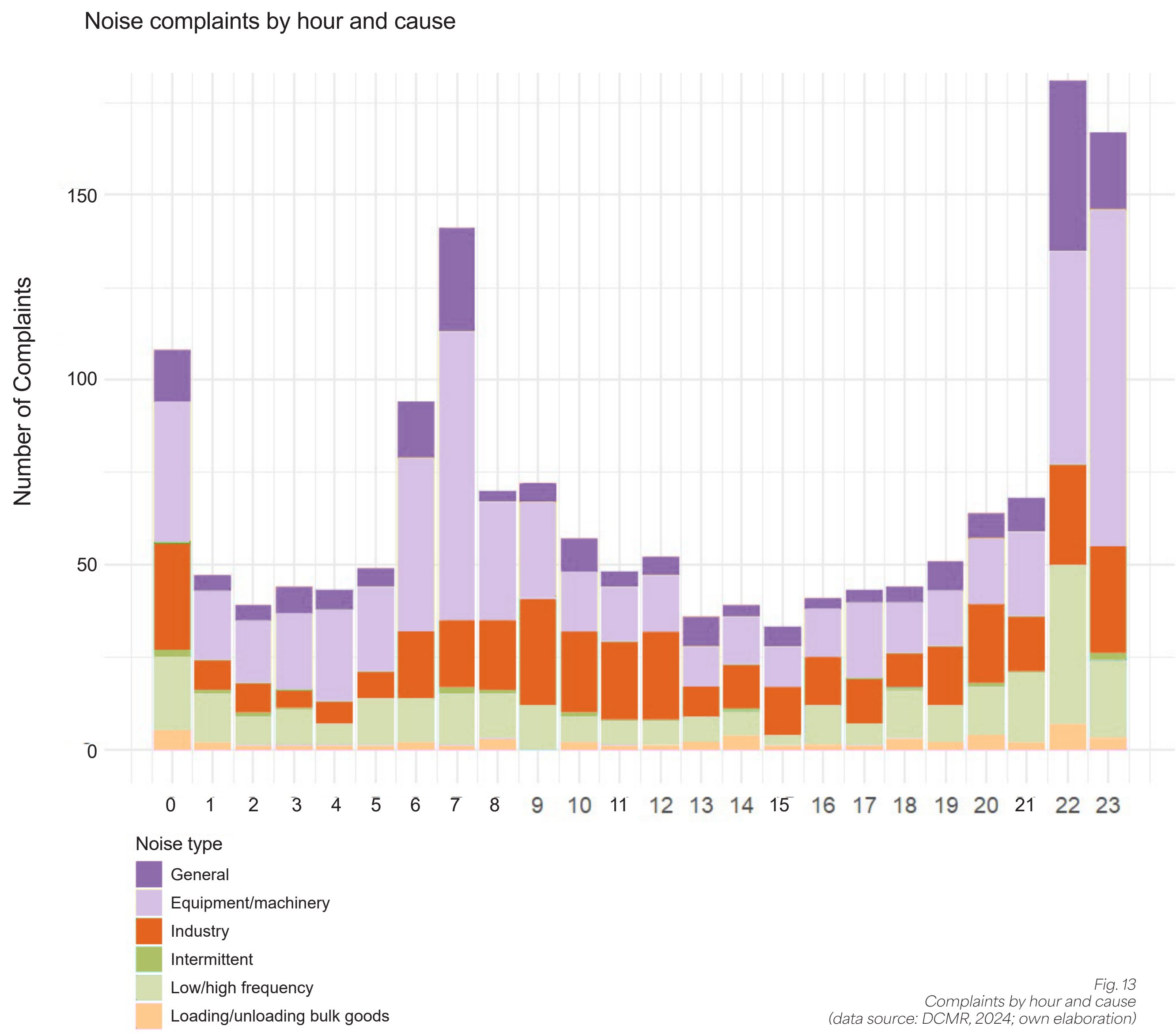


Fig. 13
Complaints by hour and cause
(data source: DCMR, 2024; own elaboration)

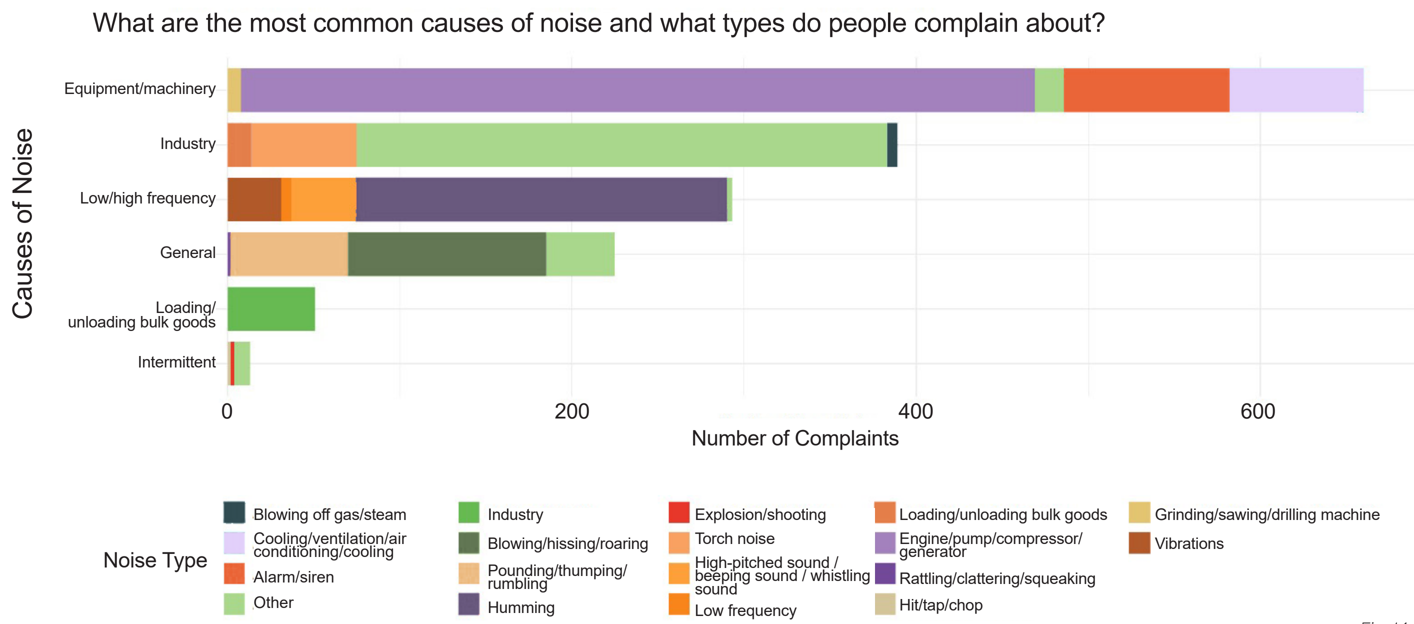


Fig. 14
Causes of complaints
(data source: DCMR, 2024; own elaboration)

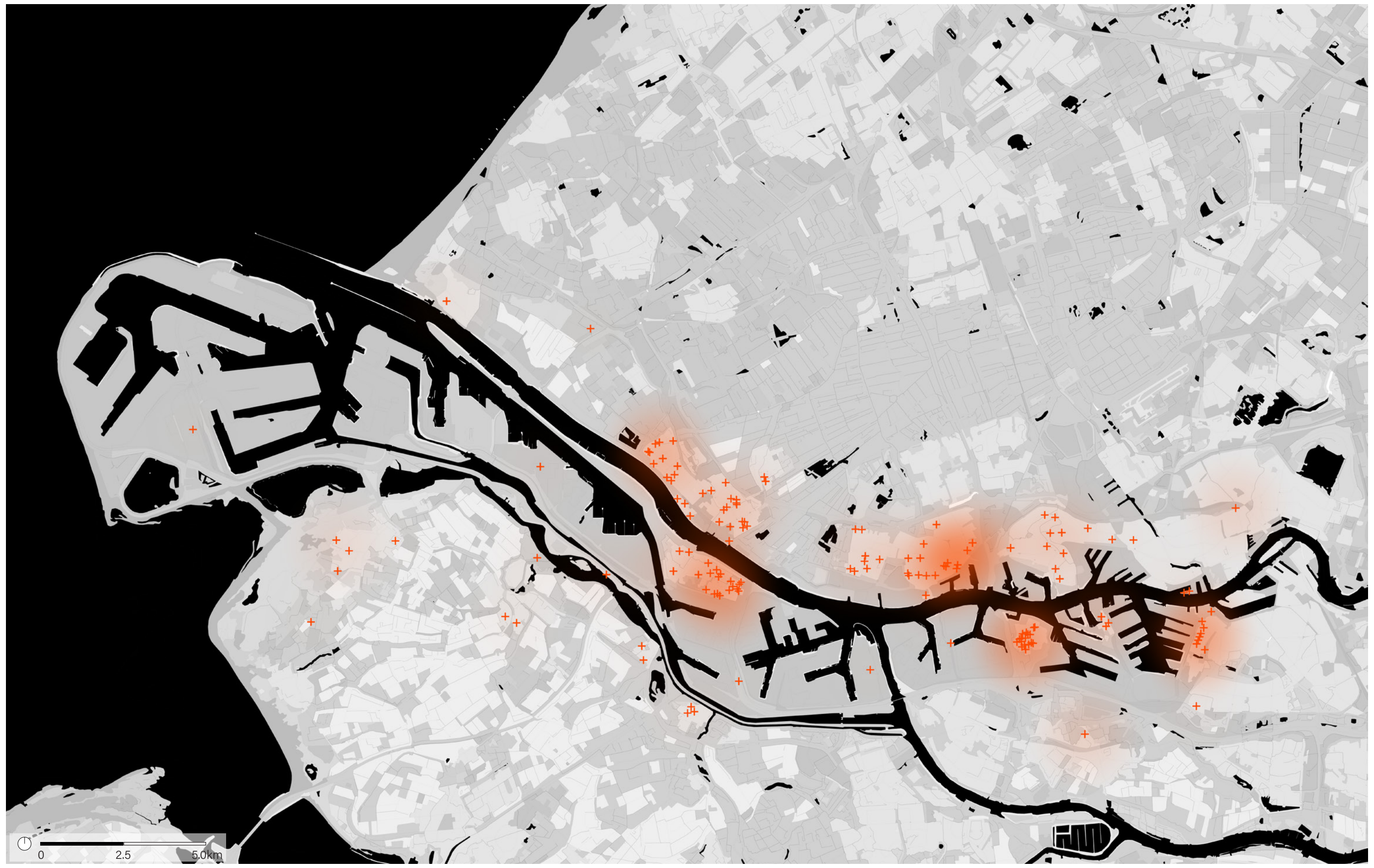


Fig. 15
Port sound complaints - morning
(data source: DCMR, 2024; own elaboration)

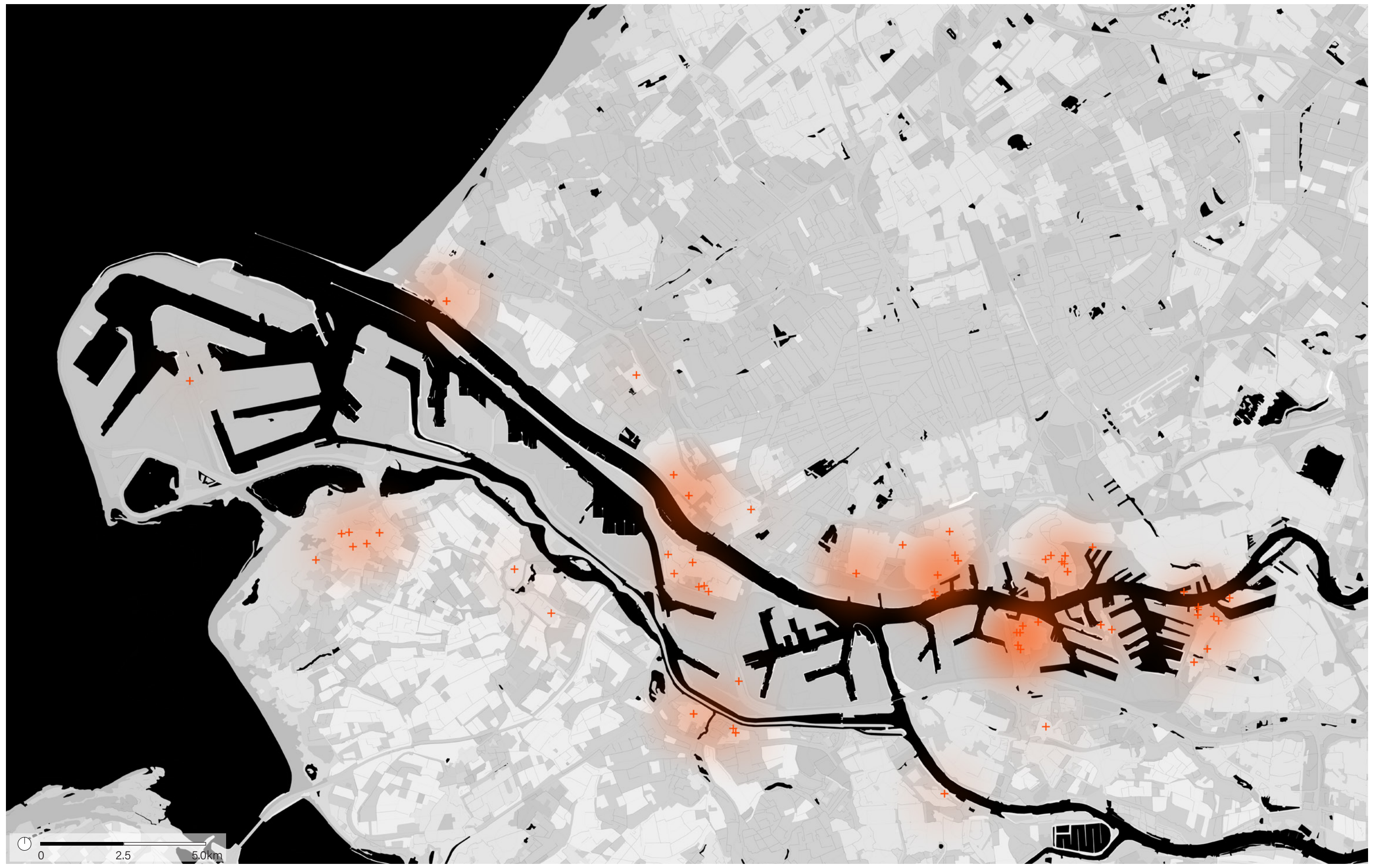


Fig. 16
Port sound complaints - afternoon
(data source: DCMR, 2024; own elaboration)

the city

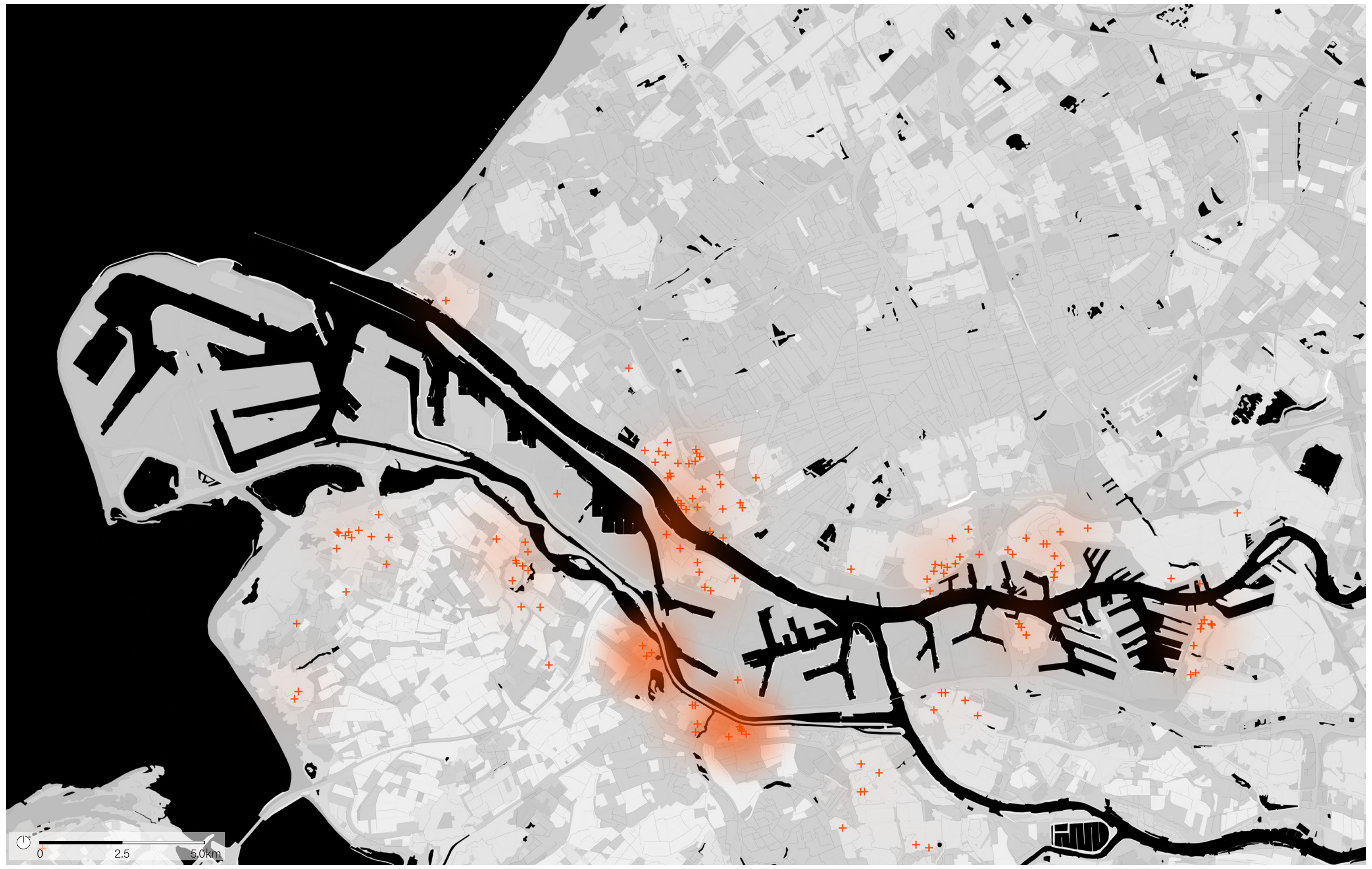


Fig. 17
Port sound complaints - evening
(data source: DCMR, 2024; own elaboration)

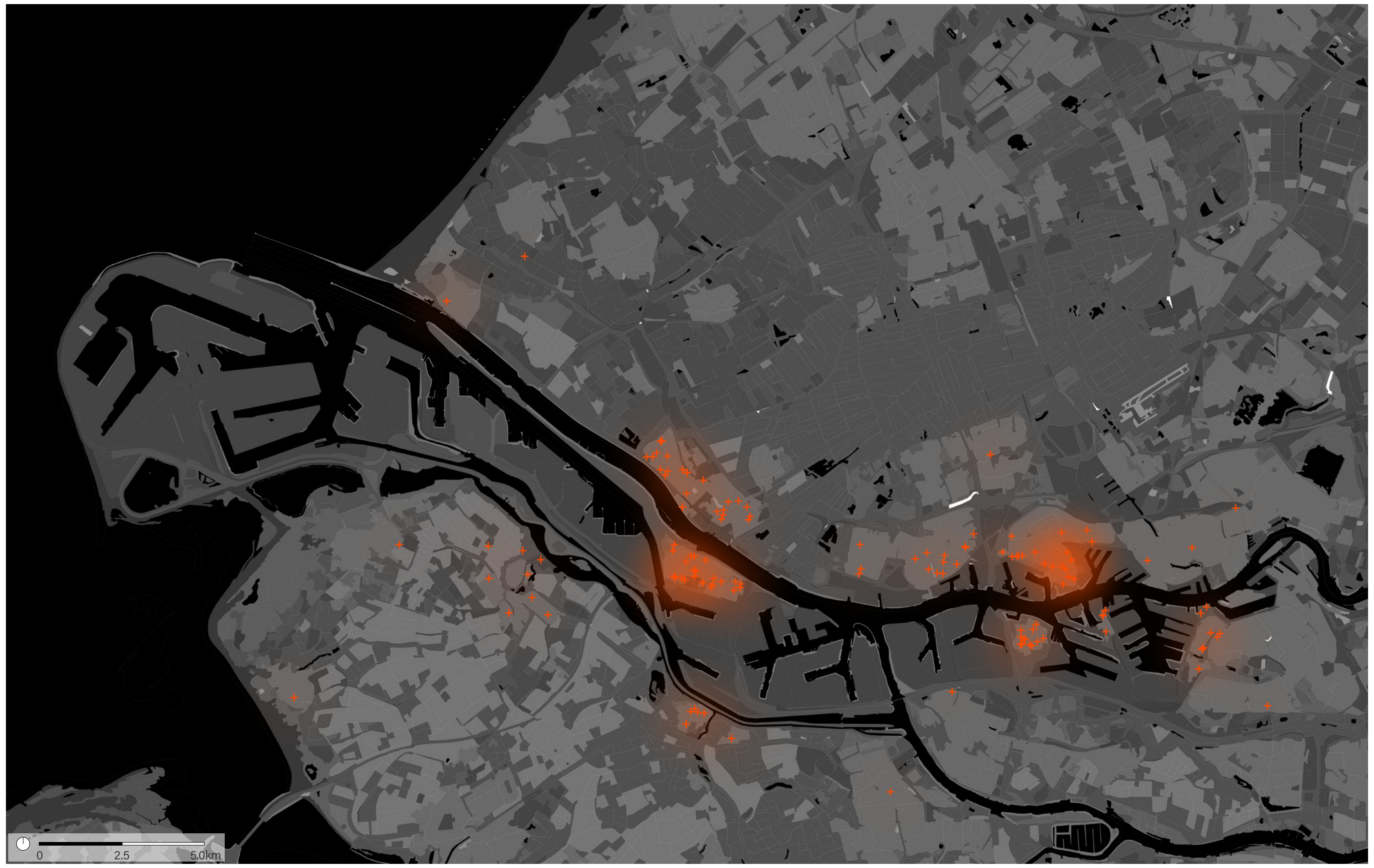


Fig. 18
Port sound complaints - night
(data source: DCMR, 2024; own elaboration)

the neighbourhood

Charlois

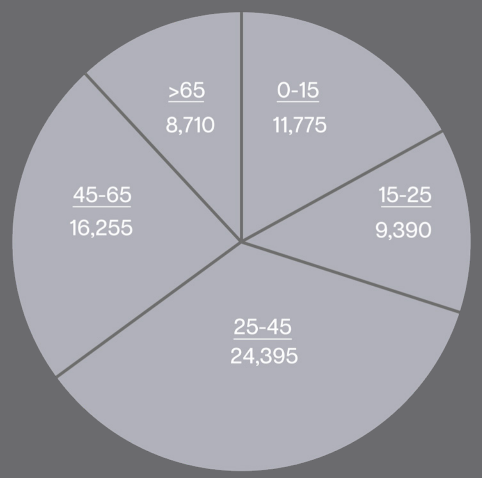
CBS, 2024

People

> 70,525 inhabitants

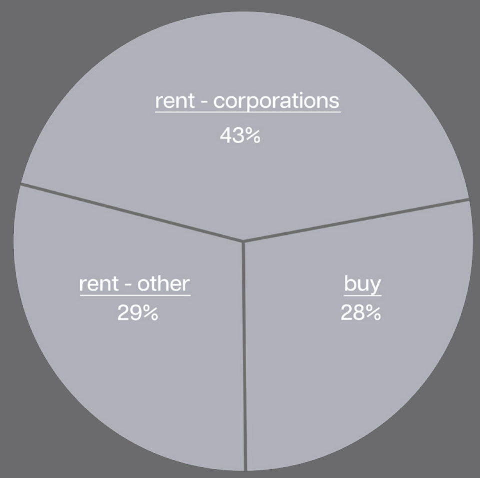
> (below) average income: 24,600

> age distribution:



Housing

> ownership:



> year of construction:

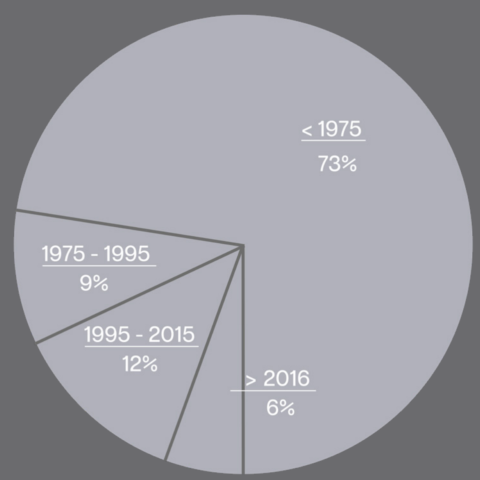
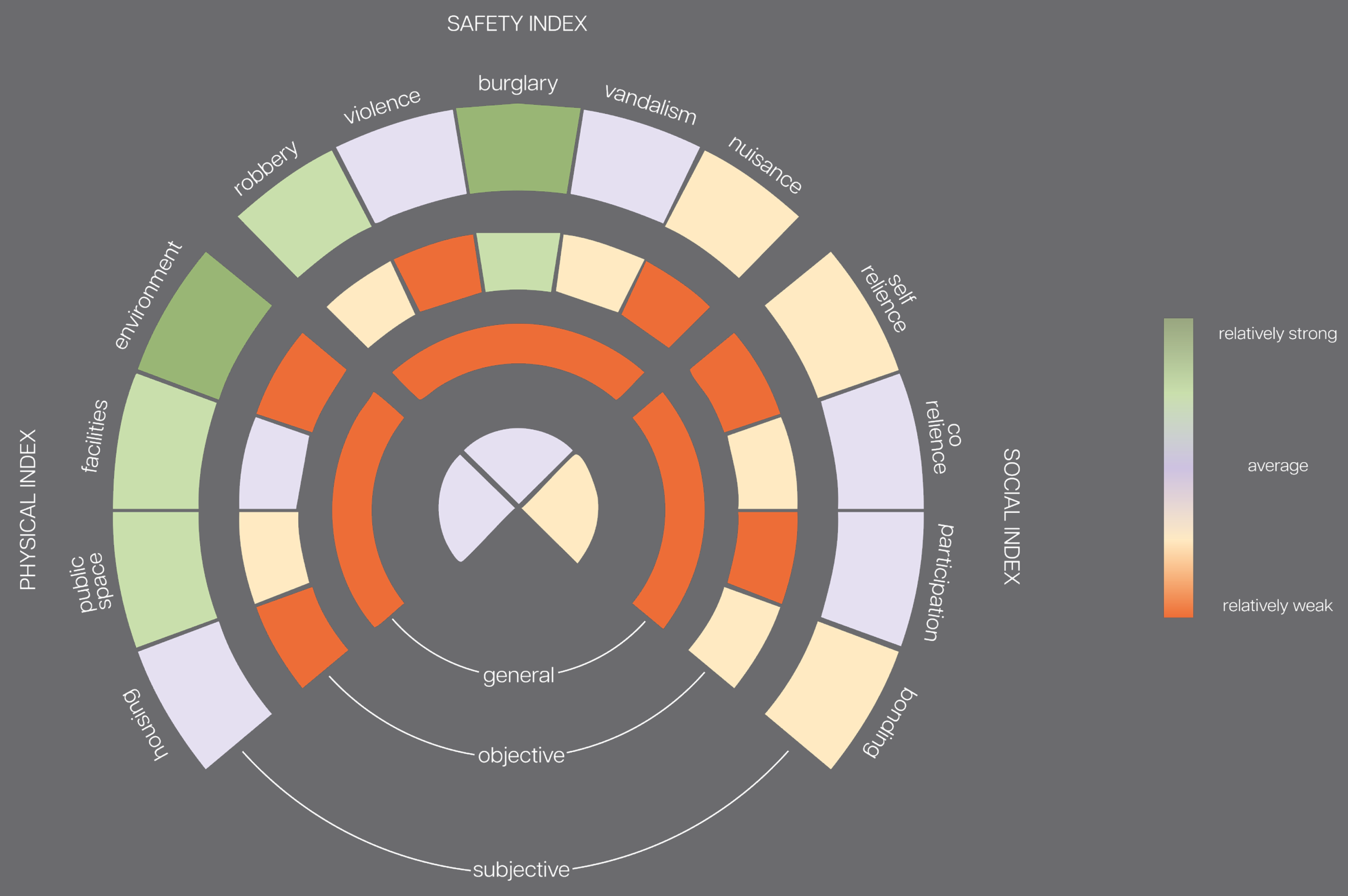


Fig. 19
Wijkprofiel
(Gemeente Rotterdam, 2024, edited)



The context of Charlois

As shown in the maps on the previous page, complaints related to port activities originate from several neighbourhoods surrounding the Port of Rotterdam. One of these is Charlois, located on the southern bank of the river. Charlois is a historically distinct and culturally diverse neighbourhood, with a population of approximately 70,525 (CBS, 2025). Originally founded as an independent village in the 15th century, it was officially incorporated into the municipality of Rotterdam in 1895. This integration marked the beginning of its transformation from an agricultural village into a densely urbanised district with a rich cultural mix.

To better understand the sound environment of this area, a spatial analysis has been carried out. This analysis forms the foundation for identifying and distinguishing the various types of soundscapes present in Charlois.

Fig. 20
Charlois near the port of Rotterdam
(authors, 2025)

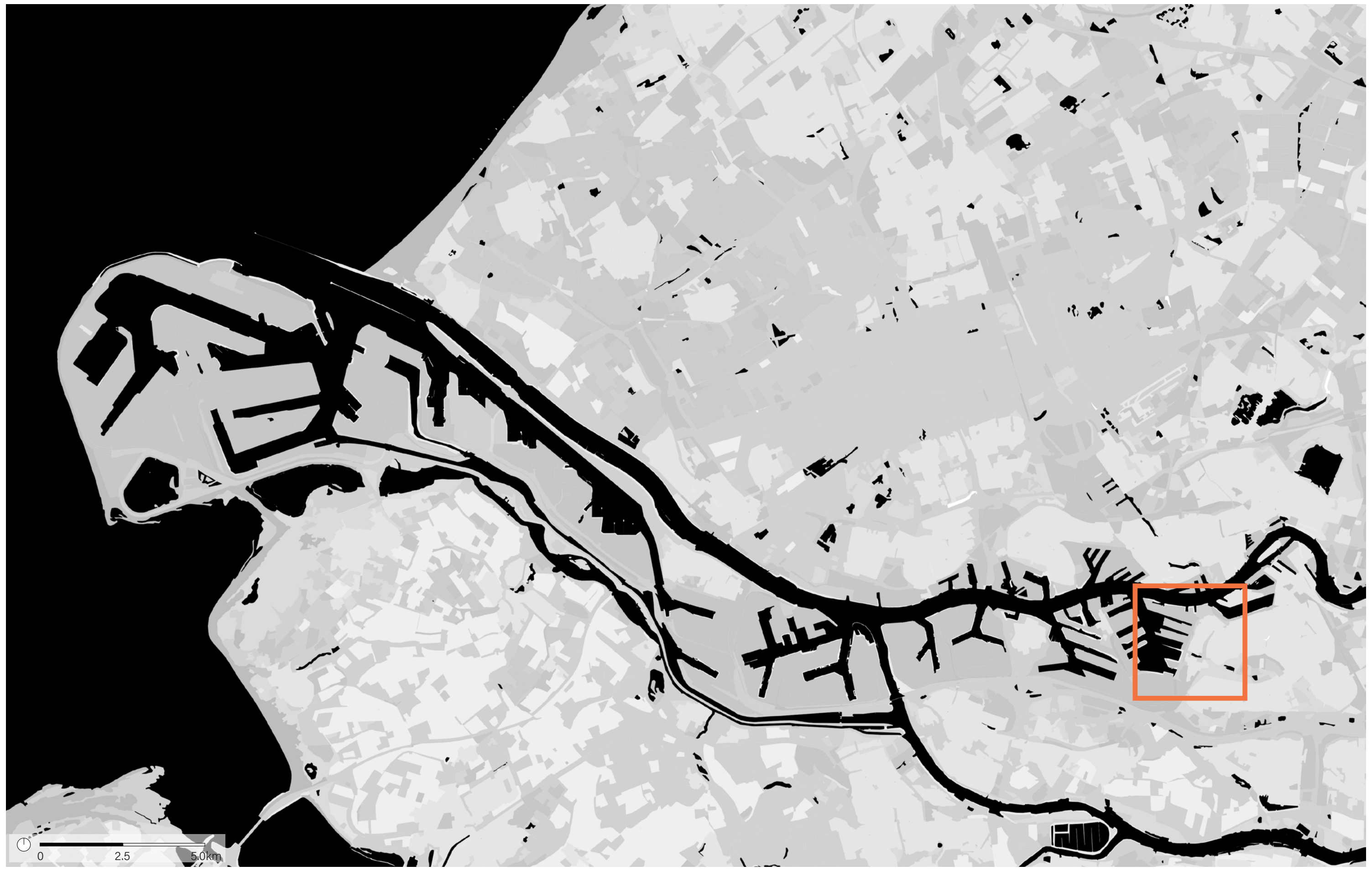


Fig. 21
Charlois
Charlois (de Zeeuw, A., n.d.)

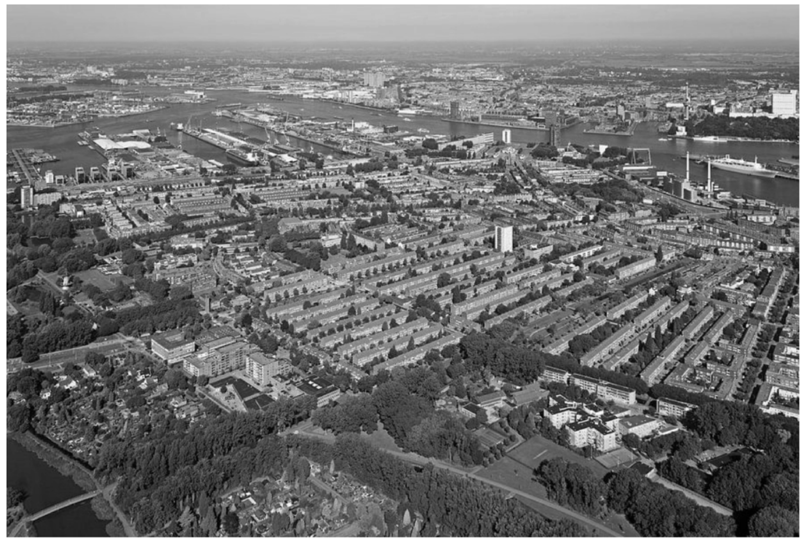
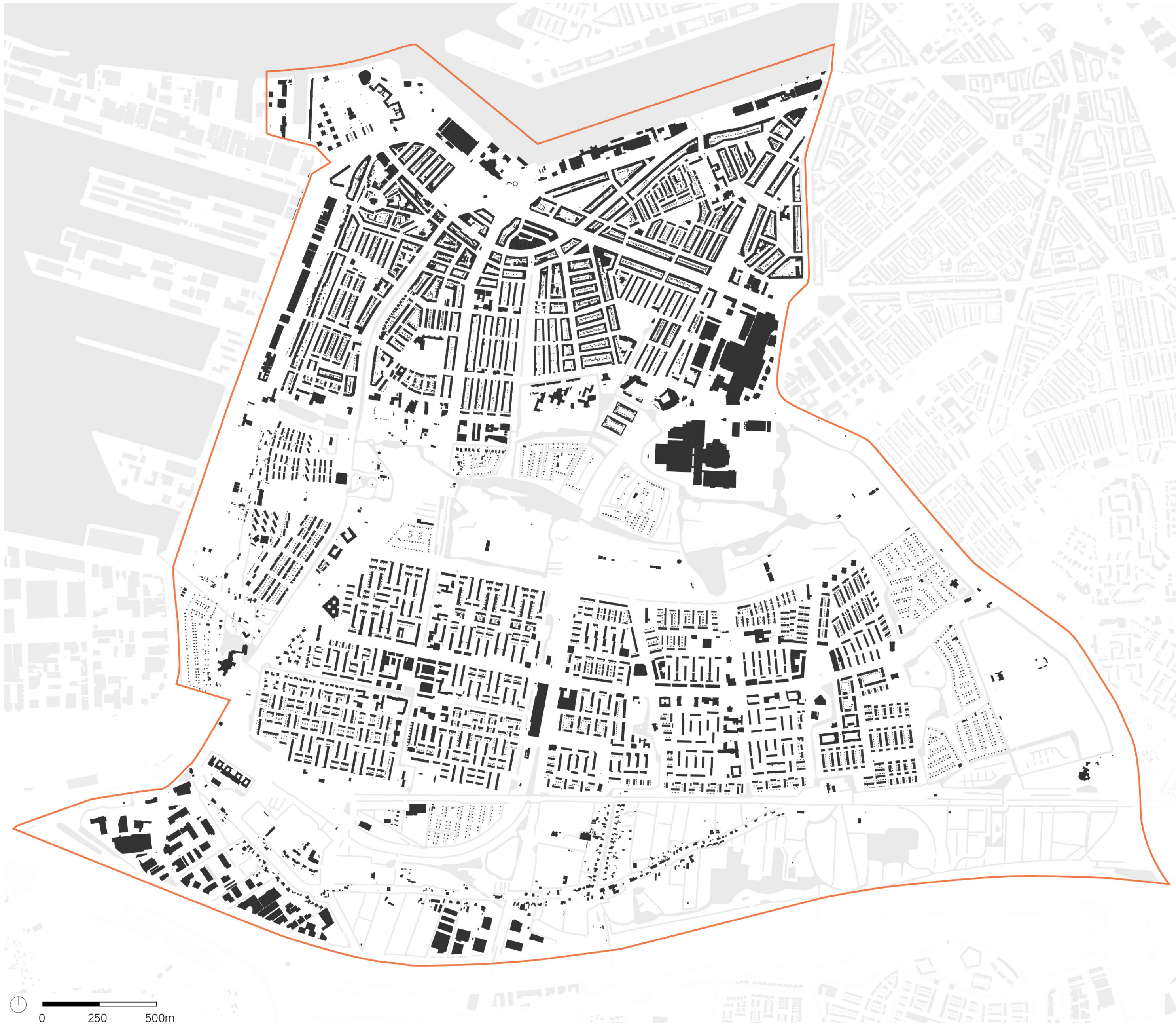


Fig. 22
Charlois within context
(authors, 2025)



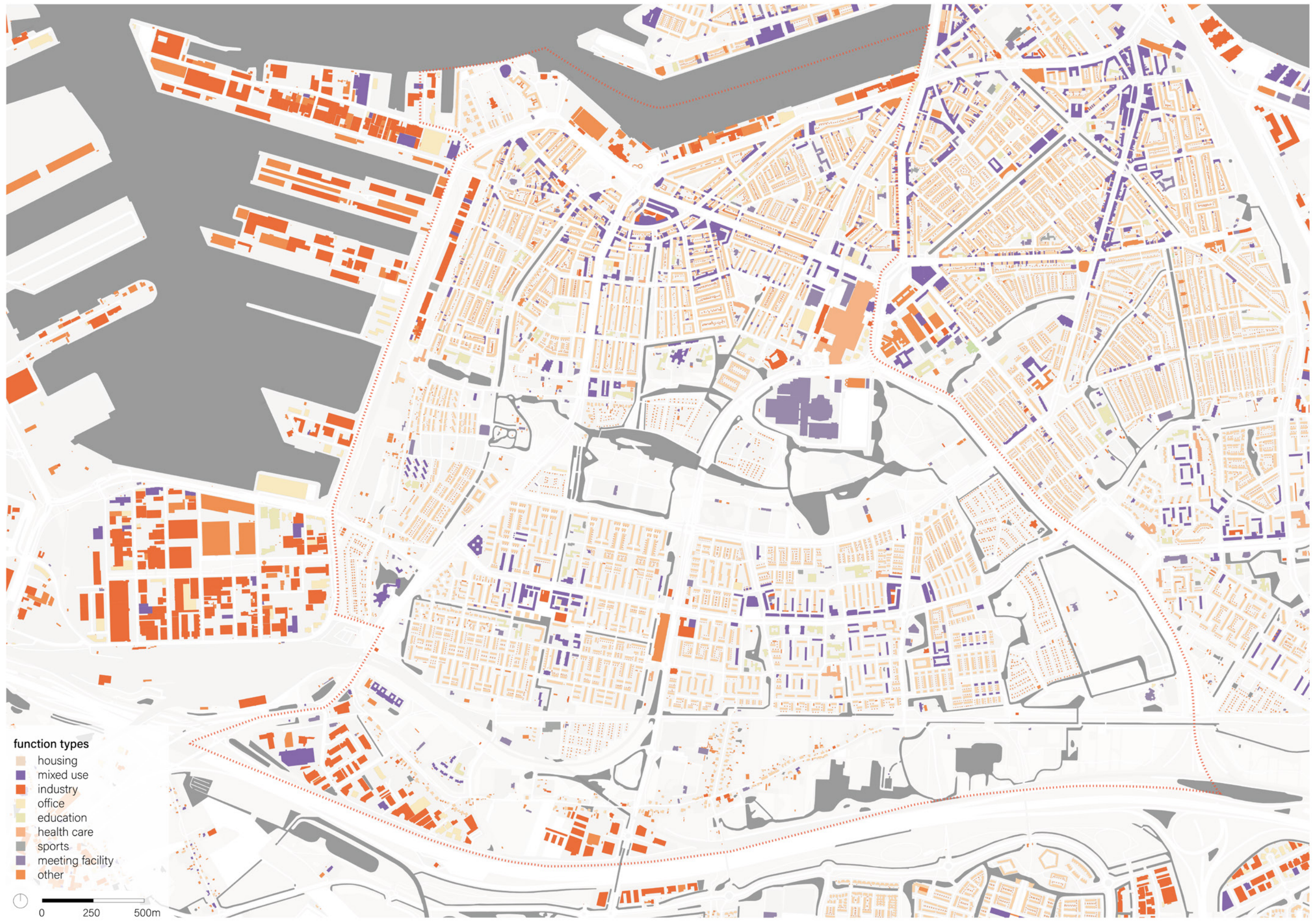


Fig. 23
Functions of Charlois
(data source: Kadaster, TOP10NL, 2025; own elaboration)

Fig. 24
Lively soundscapes within Charlois
(authors, 2025)

Functions

A first step in identifying the types of soundscapes was to analyse the spatial distribution of functions across the area. This analysis reveals that the neighbourhood is largely surrounded by industrial zones—including port-related activities to the west of Charlois—and contains several concentrated areas of mixed-use functions. Despite these clusters, the area is predominantly residential. This functional diversity plays a key role in shaping the local soundscapes. Research shows that certain land uses are directly correlated with specific types of sounds—for example, busy roads with traffic noise or green infrastructure with natural sounds. Moreover, these sounds are strongly linked to how people perceive the environment: busy roads are often experienced as "chaotic" and "unpleasant", while quiet, green spaces tend to be perceived as "calm" and "pleasant" (Margaritis & Kang, 2017; Kang et al., 2018).

Lively soundscapes

To identify areas characterised by a lively soundscape, it was assumed that such soundscapes would be present in locations where residential functions intersect with amenities such as retail and hospitality. Furthermore, educational institutions (and thus playgrounds), sports facilities, and public gathering spaces were also considered potential sources of a lively soundscape. The analysis reveals that certain concentrations of these functions emerge.

LIVELY

Fig. 25
Greenery of Charlois
(data source: Kadaster, TOP10NL, 2025; own elaboration)

Fig. 26
Calm soundscapes within Charlois
(authors, 2025)

Greenery

As studies show (Fig. 8) that natural sounds contribute to a soundscape perceived as calm (Kang et al., 2018), green spaces were identified using GIS data (Fig. 25). These green spaces were categorised based on vegetation density, as densely vegetated areas with trees can block more noise. Moreover, vegetated areas with a diversity of heights, such as a combination of bushes and trees, attract various species, including birds, which further enhance the perception of a calm soundscape, since they provide additional nature sounds (Van den Bosch, 2015).

Calm soundscapes

Translating green spaces into calm soundscapes reveals that the neighbourhood of Charlois is characterised by two green corridors running from east to west: one centrally located (Zuiderpark) and another along the southern edge near the highway.

However, conducting noise measurements is essential to assess the effectiveness of these green borders in proximity to significant noise sources, such as roads.

Furthermore, combining noise measurements with individual surveys and spatial analysis would provide deeper insight into the effectiveness of specific typologies within calm soundscapes, such as whether areas with greater tree cover exhibit improved sound quality.

CALM

Fig. 27
Different traffic types of Charlois
(data source: Kadaster, TOP10NL, 2025; own elaboration)

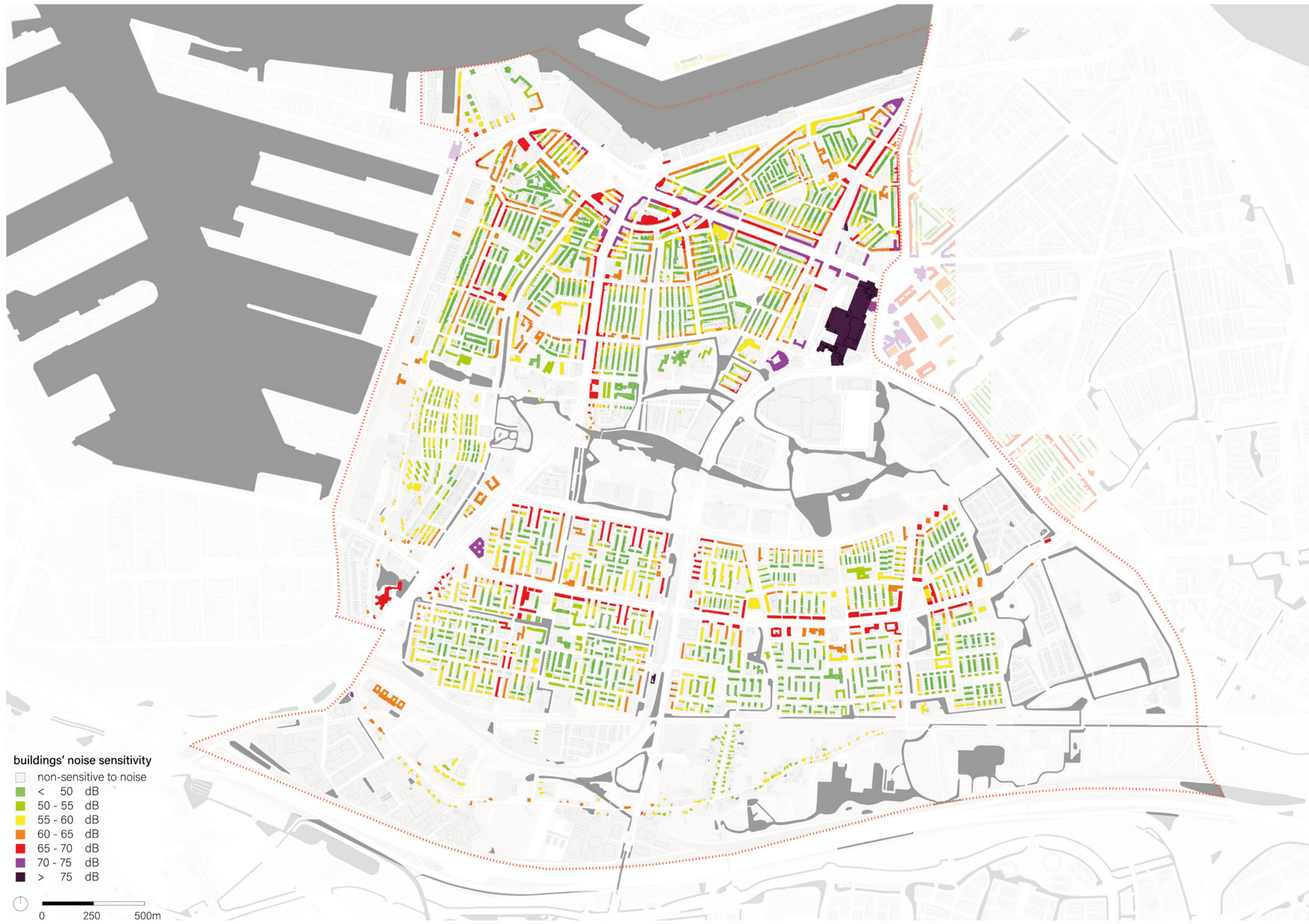


Fig. 28
Noise sensitivity of buildings within Charlois
(data source: DCMR, 2021; own elaboration)

Traffic

A major contributor to the chaotic soundscape in Charlois is the combination of traffic and industrial noise. As noted earlier, the neighbourhood is bordered by industrial zones; however, it is also important to consider the impact of traffic-related noise. A map extracted from GIS (Kadaster, 2025) reveals that Charlois is exposed to multiple sources of traffic noise. One of the most prominent is the highway from east to west, which generates continuous background noise. In addition, railway tracks running through or near the area contribute significantly to the acoustic environment. A main road connecting northern Rotterdam to this part of the city further increases traffic flow and associated noise levels. Finally, the neighbourhood's proximity to the water introduces yet another layer of sound, as ships and port-related activities on the river produce additional noise disturbances.

Noise sensitivity of buildings

When examining the map showing the levels of noise exposure for buildings within the neighbourhood of Charlois, a direct correlation with traffic sources becomes evident, as shown by comparing Fig. 27 with Fig. 28. Buildings located along noise sources, such as main roads, experience higher levels of noise exposure compared to those situated elsewhere. However, since some of these buildings do not serve functions where a calm soundscape is essential, noise sensitivity may only pose a significant issue for residential buildings, educational facilities, or offices.

Moreover, although no apparent relationship between building typologies and noise sensitivity is evident at first sight, it would nevertheless be valuable to investigate variations in noise exposure across different typologies through noise measurements.

CHAOTIC

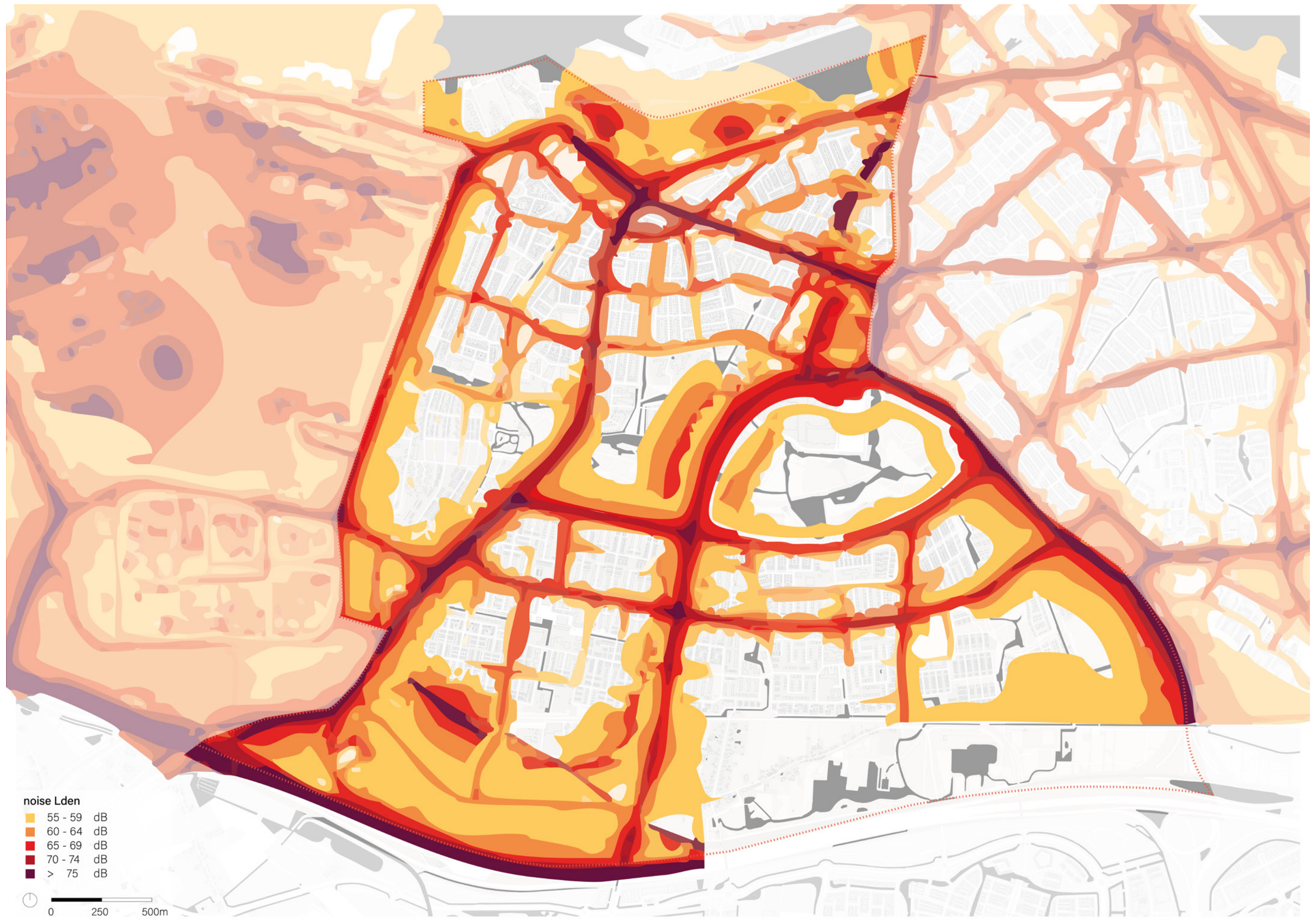


Fig. 29
Noise pollution, daytime
(data source: DCMR 2021; own elaboration)

Fig. 30
Industrial noise pollution + Noise complaints caused by port activities, daytime
(data source: DCMR, 2021 & 2024; own elaboration)

Fig. 31
Noise pollution, nighttime
(data source: DCMR, 2021; own elaboration)

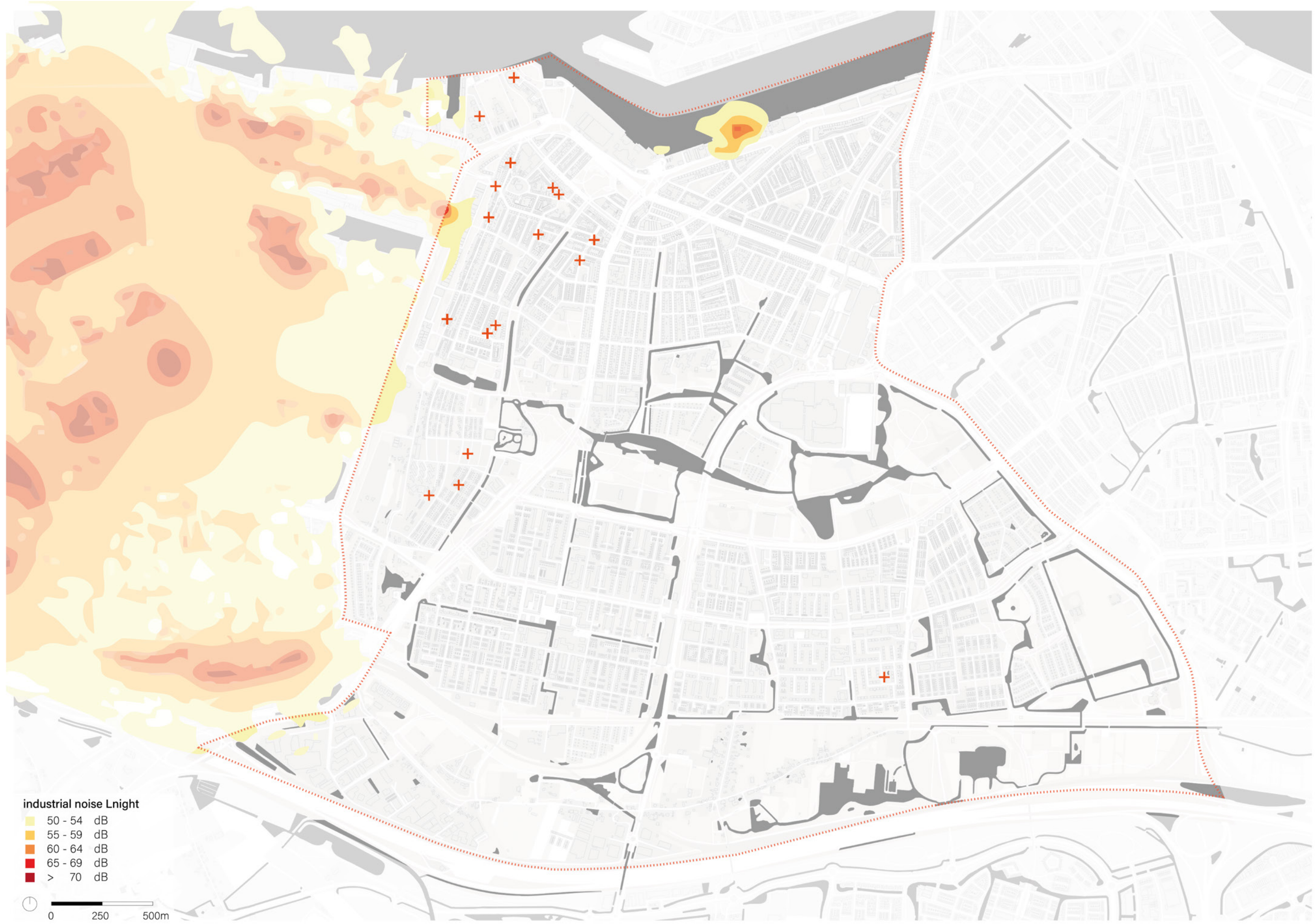


Fig. 32
Industrial noise pollution + Noise complaints caused by port activities, nighttime
(data source: DCMR, 2021 & 2024; own elaboration)

Noise maps
In addition to maps showing functions or noise sources, actual noise pollution maps are also available. However, these maps present calculated noise levels (Lden, Lnight) rather than experienced noise pollution, which may differ from what is represented. The overall noise pollution maps (Fig. 29 & 31) show a cumulative representation of noise generated by traffic (roads, railways, and aircraft) and industry. However, the industrial noise data does not include noise produced by activities on the water, which leads to potentially misleading results when focusing on port-related activities.

Noise by day
The omission of certain port activities from the industrial noise pollution maps becomes evident when comparing these maps with the complaints related to port activities collected by DCMR (Fig. 30 & 32). This comparison, showing industrial noise levels during the daytime alongside daytime complaints, reveals that not all complaints are situated within the areas designated as industrial noise pollution zones.

Noise by night
The map illustrating the discrepancy between industrial noise pollution and actual noise complaints during the night shows an even greater difference between these two datasets. Night-time noise complaints appear to be more widely dispersed throughout the neighbourhood of Charlois, occurring at locations even further away from the areas projected to experience industrial noise pollution. This is particularly notable given that the projected industrial noise levels during the night are actually lower.

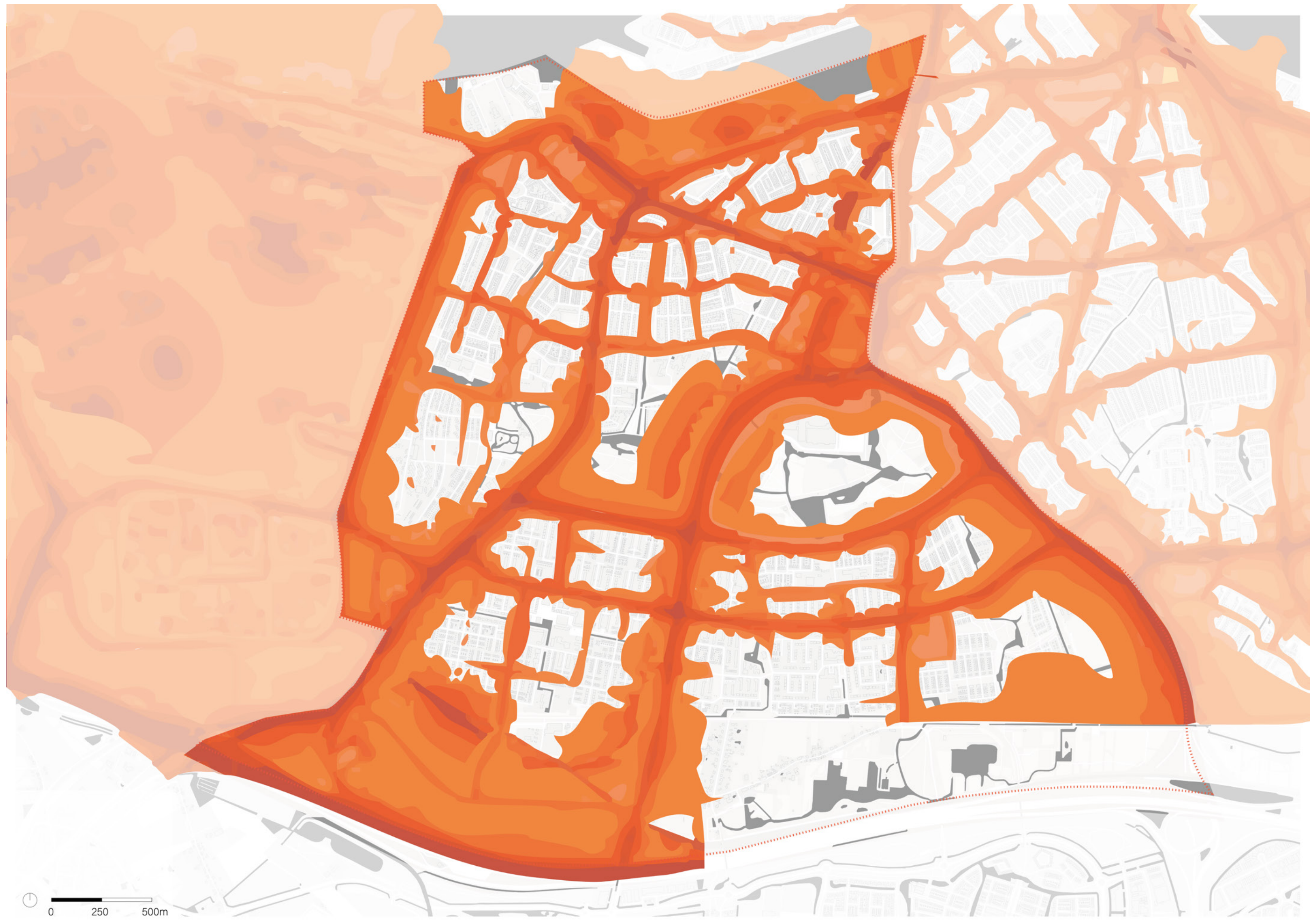


Fig. 33
Chaotic soundscapes of Charlois
(authors, 2025)

Chaotic soundscapes
According to the GGD, a healthy living environment should not exceed noise levels of 40 dB Lnight and 50 dB Lden at the façade, allowing residents to keep their windows open without being disturbed by noise. However, the noise maps provided by DCMR indicate pollution levels starting from 55 dB during daytime hours and 50 dB during nighttime hours, meaning that these projections already exceed the recommended maximum levels.

To produce a concluding map of the chaotic soundscape in Charlois, the overall noise pollution data from the DCMR noise maps are used as a projection. Nonetheless, it is important to acknowledge that actual noise pollution likely exceeds these values, as the maps are not comprehensive. They exclude experienced noise perception and only represent pollution levels starting from 50 dB as a source of noise pollution. For a better understanding of the actual chaotic soundscape within the neighbourhood of Charlois, further research is needed.

the neighbourhood

Overlapping soundscapes

After analysing the different types of sound sources and categorising them into lively, calm, or chaotic soundscapes, these soundscape categories can be overlaid. In doing so, it is assumed that chaotic soundscapes are always the most dominant, followed by lively soundscapes, and lastly by calm soundscapes. When these three soundscape types are overlaid, the areas that remain uncovered are assumed to represent a boring soundscape, as shown in Fig. 34.

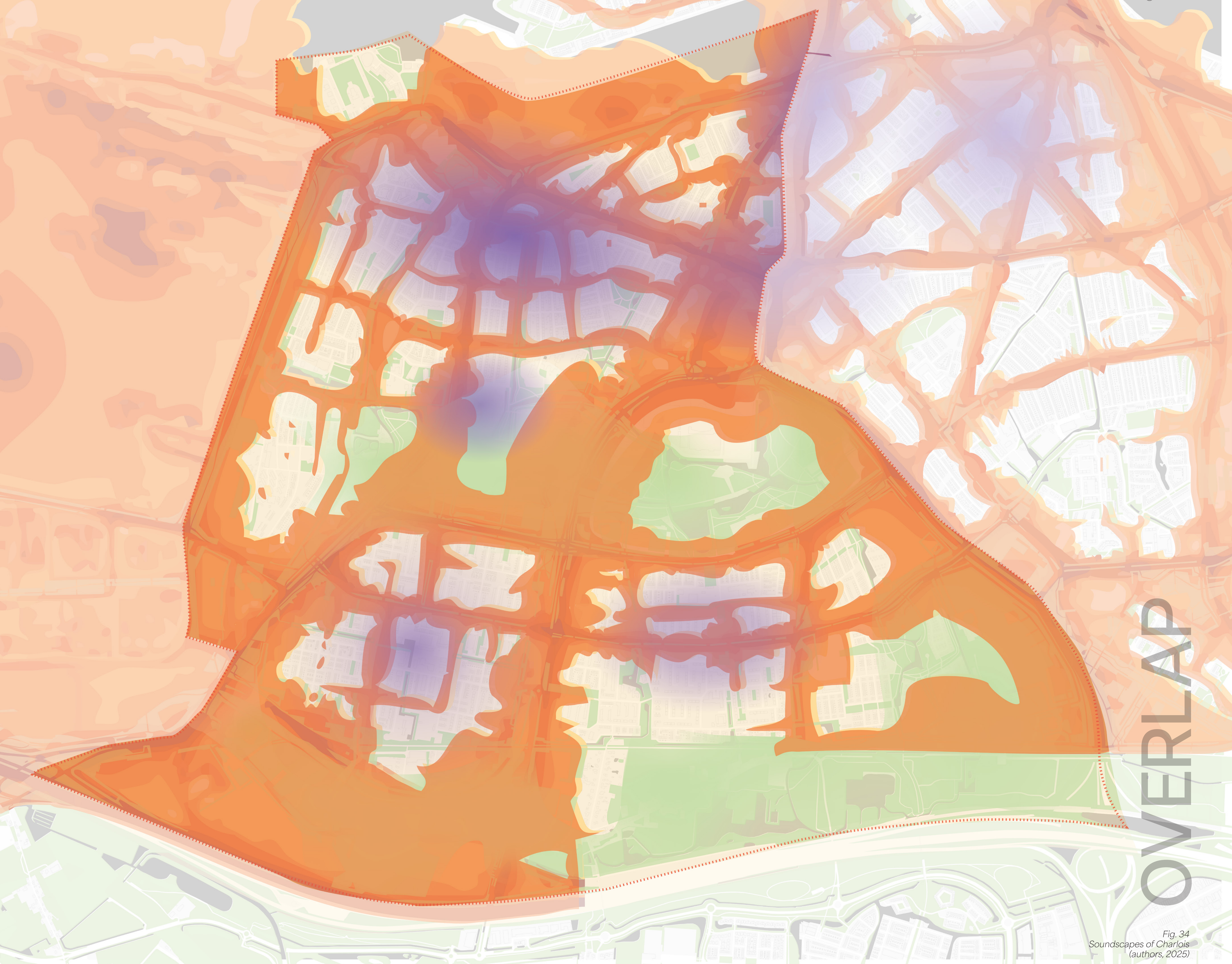


Fig. 34
Soundscapes of Charlois
(authors, 2025)

the subneighbourhood

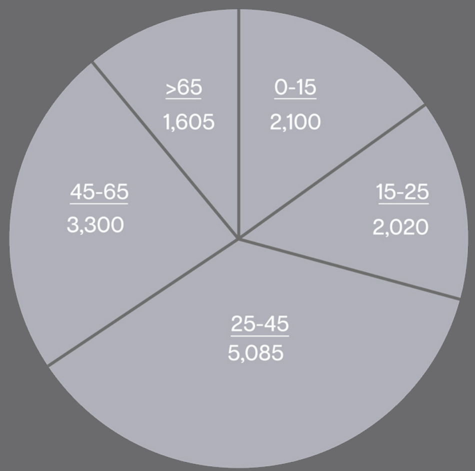
Oud-Charlois

People

> 14,120 inhabitants

> (below) average income: 26,000

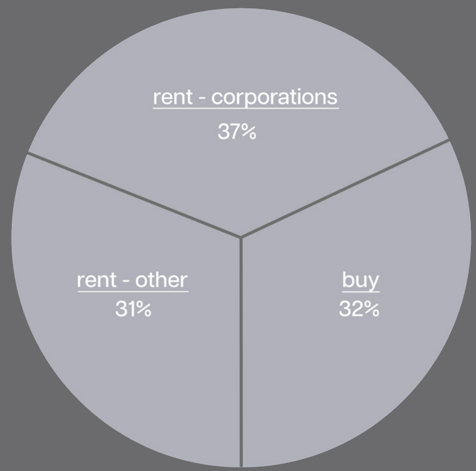
> age distribution:



CBS, 2024

Housing

> ownership:



> year of construction:

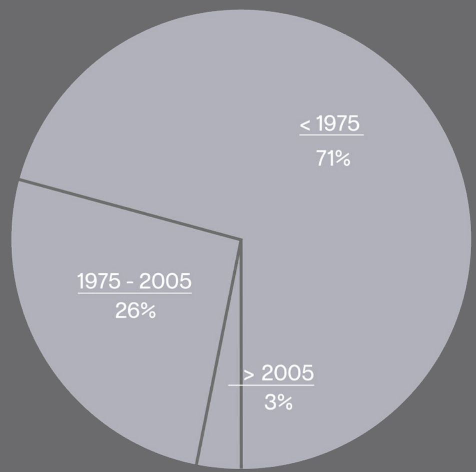
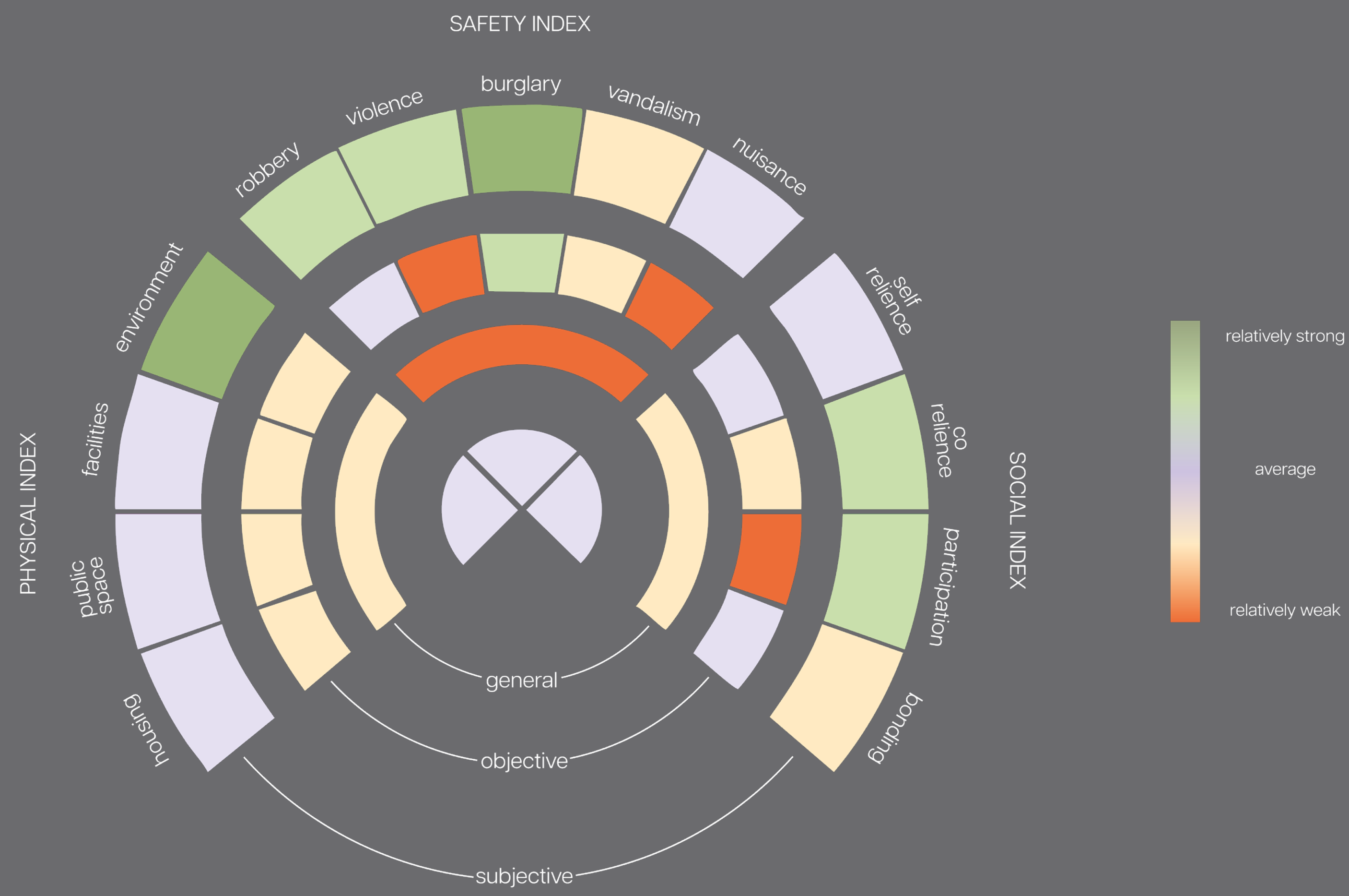


Fig. 35
Wijkprofiel
(Gemeente Rotterdam, 2024, edited)



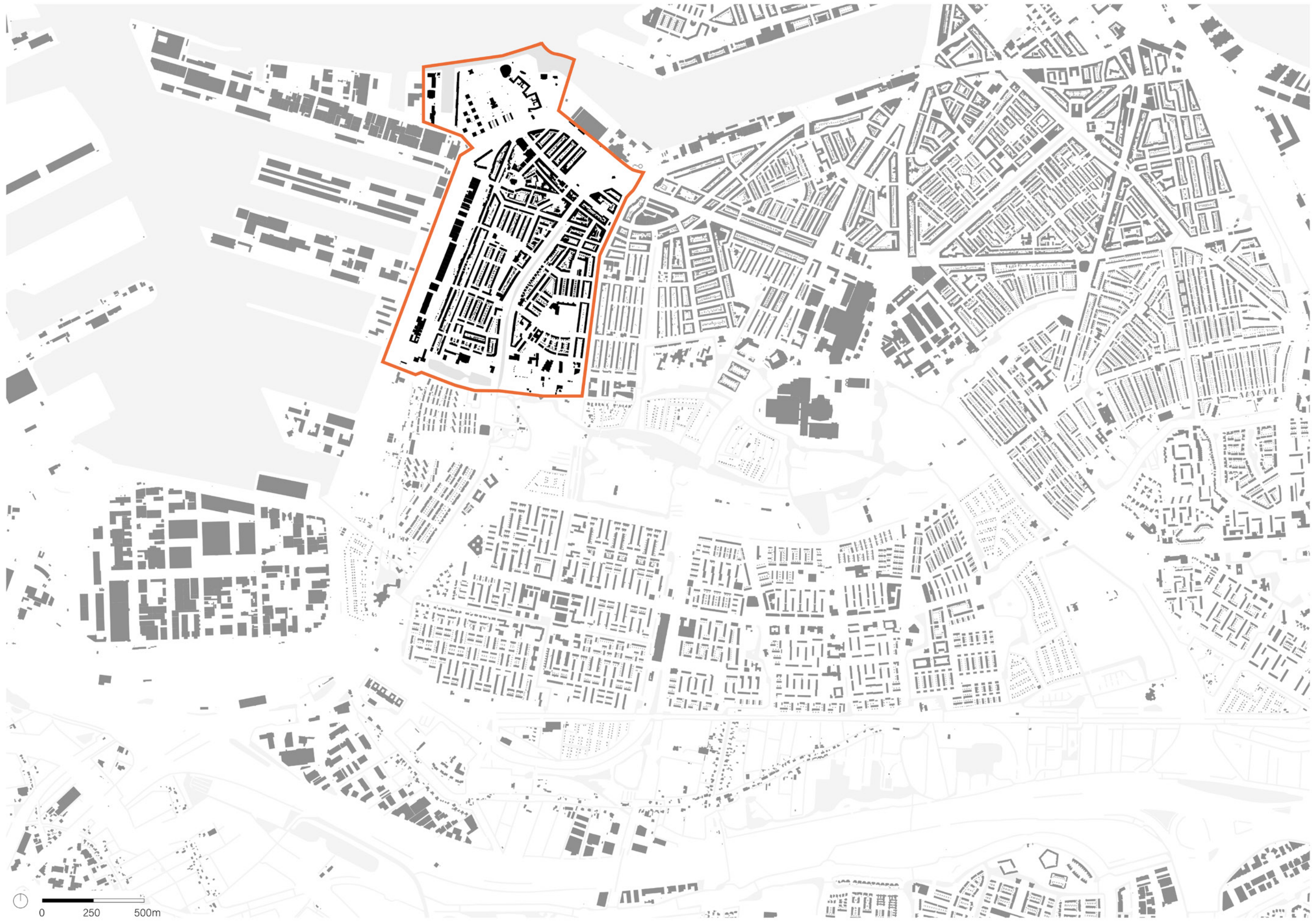


Fig. 36
Oud-Charlois
(authors, 2025)

The context of Oud-Charlois

For further research into soundscapes, a subneighbourhood has been selected: Oud-Charlois, located next to both land-based and water-based port activities. This area offers a diverse mix of spatial elements, including waterfronts, mixed-use zones, green spaces, and schools. and features a variety of urban typologies. These characteristics make Oud-Charlois a particularly interesting case for exploring the quality and character of local soundscapes.

Overlapping soundscapes

When analysing a section of this subarea that spans the transition from the port area to industrial zones and then to residential areas (Fig. 38), differences in soundscapes become clear. To determine the soundscapes within these sections, the existing maps indicating categorised soundscapes are used as a base layer. By visualising the functions within each section, the atmosphere of each street becomes visible.

Streets experiencing noise pollution as a result of mainly traffic are shown in orange, while gardens are assumed to be both lively and calm, as many of these spaces contain natural elements and appear to be actively used, as observed in satellite images.

Fig. 37
Section of Oud-Charlois
(authors, 2025)

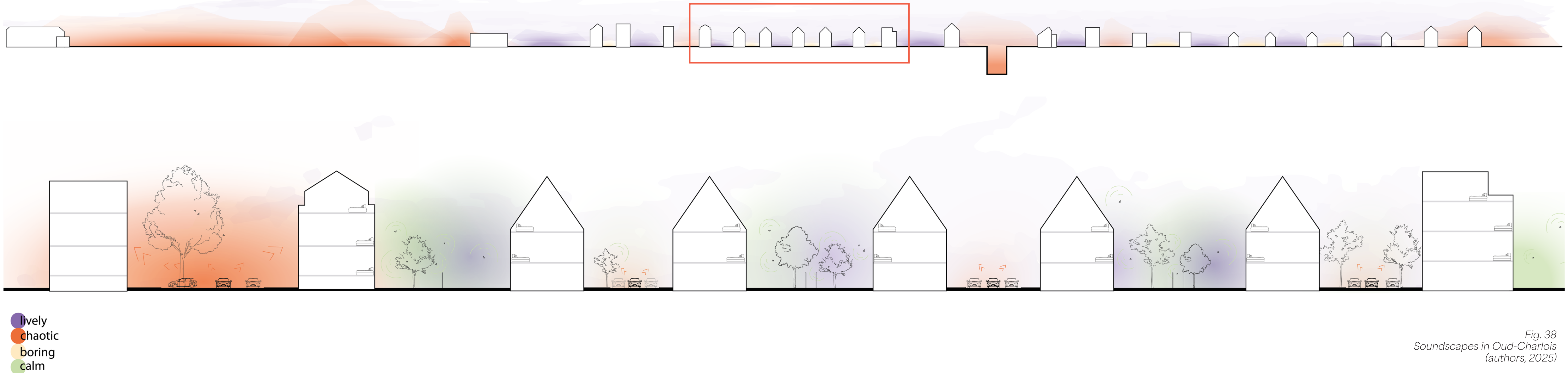


Fig. 38
Soundscapes in Oud-Charlois
(authors, 2025)

the street

Possible transitions in soundscapes

Whereas most streets today function primarily as routes for movement, generating noise from car traffic, potential transformations (Fig. 40 - 44) could enable these streets to become places of residence and social interaction. By improving their quality and prioritising slow traffic, such as pedestrians and cyclists, noise levels would decrease while social interactions would be encouraged. Moreover, since the perception of noise is influenced by various factors, creating a higher-quality environment could also positively affect how noise is perceived. A possible suggestion is shown in a section below (Fig. 39).

Fig. 39
Possible soundscape transformation
(authors, 2025)

Fig. 40
(Pinterest , n.d.)

Fig. 41
(Pinterest , n.d.)

Fig. 42
(Joëlle Payet , n.d.)

Fig. 43
(Stichting Tussentuin , n.d.)

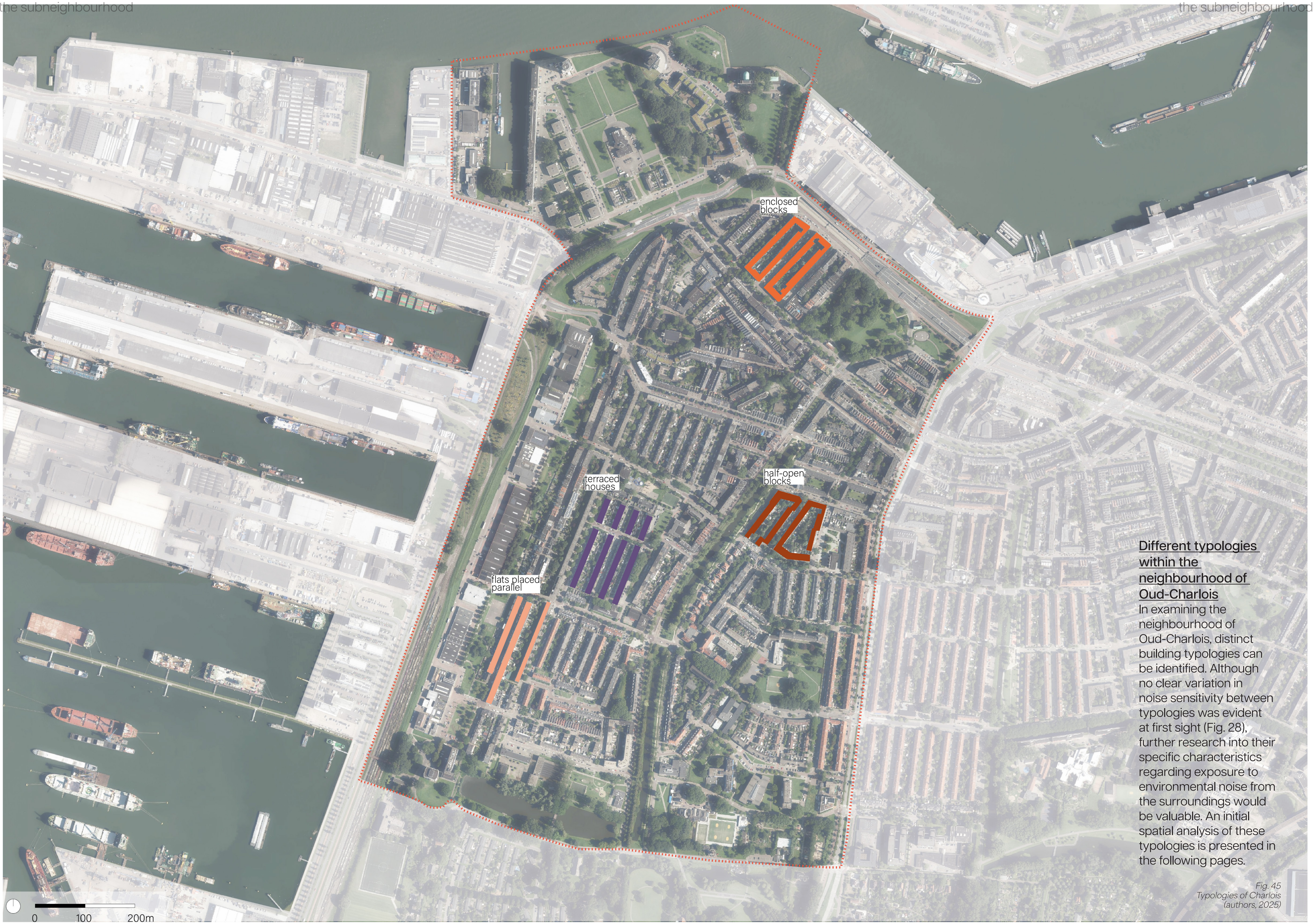
Fig. 44
(Nadia Sluijsmans , n.d.)

References

Examples of high-quality residential spaces demonstrate two clear concepts: an inner courtyard serving an entire urban block, and a street designed primarily for pedestrians and cyclists, with no access for cars.

Functions such as gardening areas, seating facilities, and playgrounds could further enhance the quality and use of these types of spaces.

the subneighbourhood



Different typologies within the neighbourhood of Oud-Charlois

In examining the neighbourhood of Oud-Charlois, distinct building typologies can be identified. Although no clear variation in noise sensitivity between typologies was evident at first sight (Fig. 28), further research into their specific characteristics regarding exposure to environmental noise from the surroundings would be valuable. An initial spatial analysis of these typologies is presented in the following pages.

Fig. 45
Typologies of Charlois
(authors, 2025)

Enclosed blocks

Enclosed blocks are characterised by their complete enclosure by their own façades. This form leads to reduced penetration of noise from the building's surroundings, creating an environment that is quieter than its external context. The inner part of the urban block often consists of private gardens, but it also holds potential to function as a collective garden, thereby fostering interactions between neighbours.

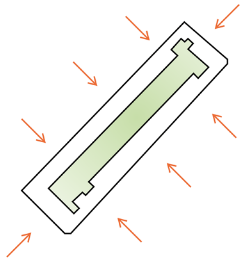


Fig. 46
Typologie 1
(authors, 2025)

Half-open blocks

This typology appears quite similar to the enclosed block, but it contains an opening between the inner space and its surroundings. As a result, noise from the external environment can enter through this gap, and the building is unable to block noise from that side. Furthermore, this configuration can lead to the reflection of noise between the façades, which may be even more disturbing for residents.

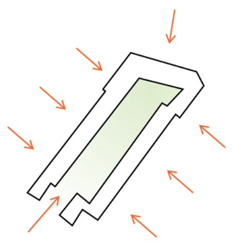


Fig. 47
Typologie 2
(authors, 2025)

Terraced houses

Terraced houses, are often positioned parallel to each other. In the case of terraced houses, this configuration often results in one side consisting of gardens facing each other and the other side facing the street. This creates a relatively quiet side; however, the openings between the houses allow additional entry points for noise. This can lead to sound reflections between the buildings, but it also creates more opportunities for noise to disperse away from these façades.

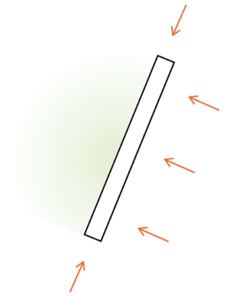
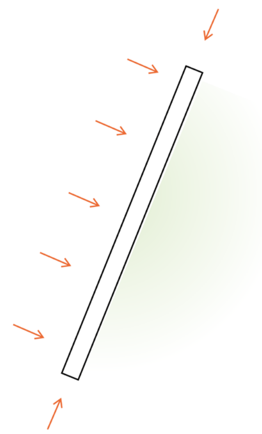


Fig. 48
Typologie 3
(authors, 2025)

Flats placed parallel

Flats positioned parallel to each other function similarly to terraced houses in terms of noise exposure. However, the presence of more open space between the buildings allows greater opportunities for noise to enter, while also reducing the potential for echoes. In contrast to terraced houses, the garden areas between flats are often publicly accessible, meaning residents have less control over who uses these spaces. This lack of control can lead to irritation, which may in turn influence people's perception of noise.



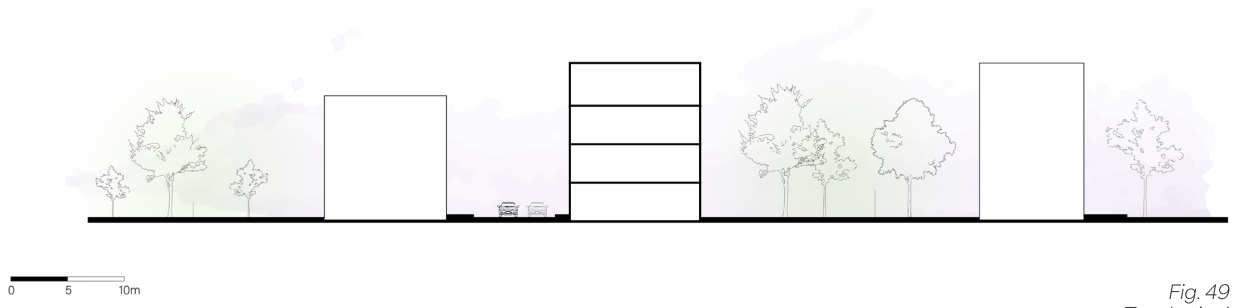


Fig. 49
Typologie 4
(authors, 2025)

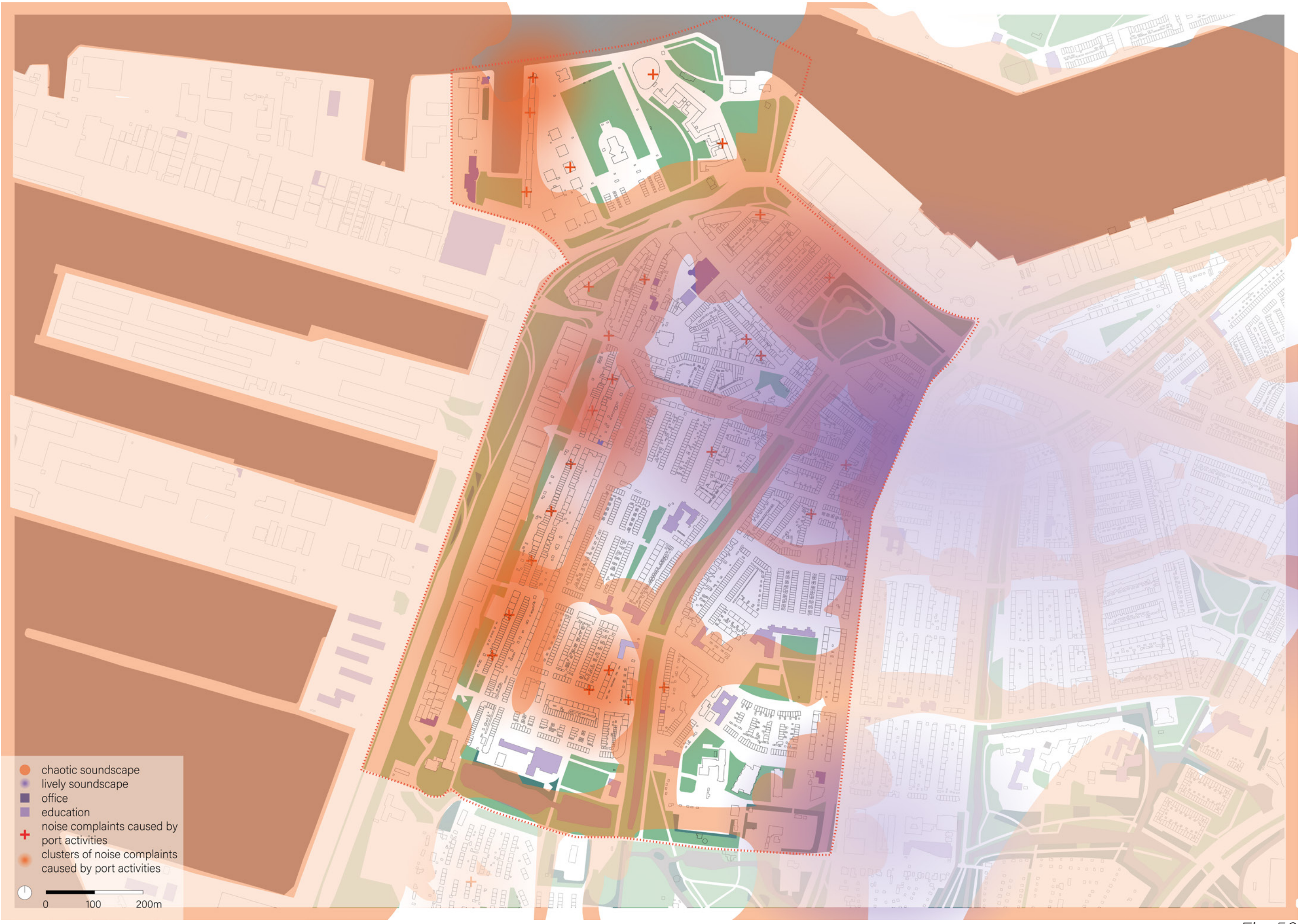


Fig. 50
Soundscapes of Oud-Charlois (authors, 2025)

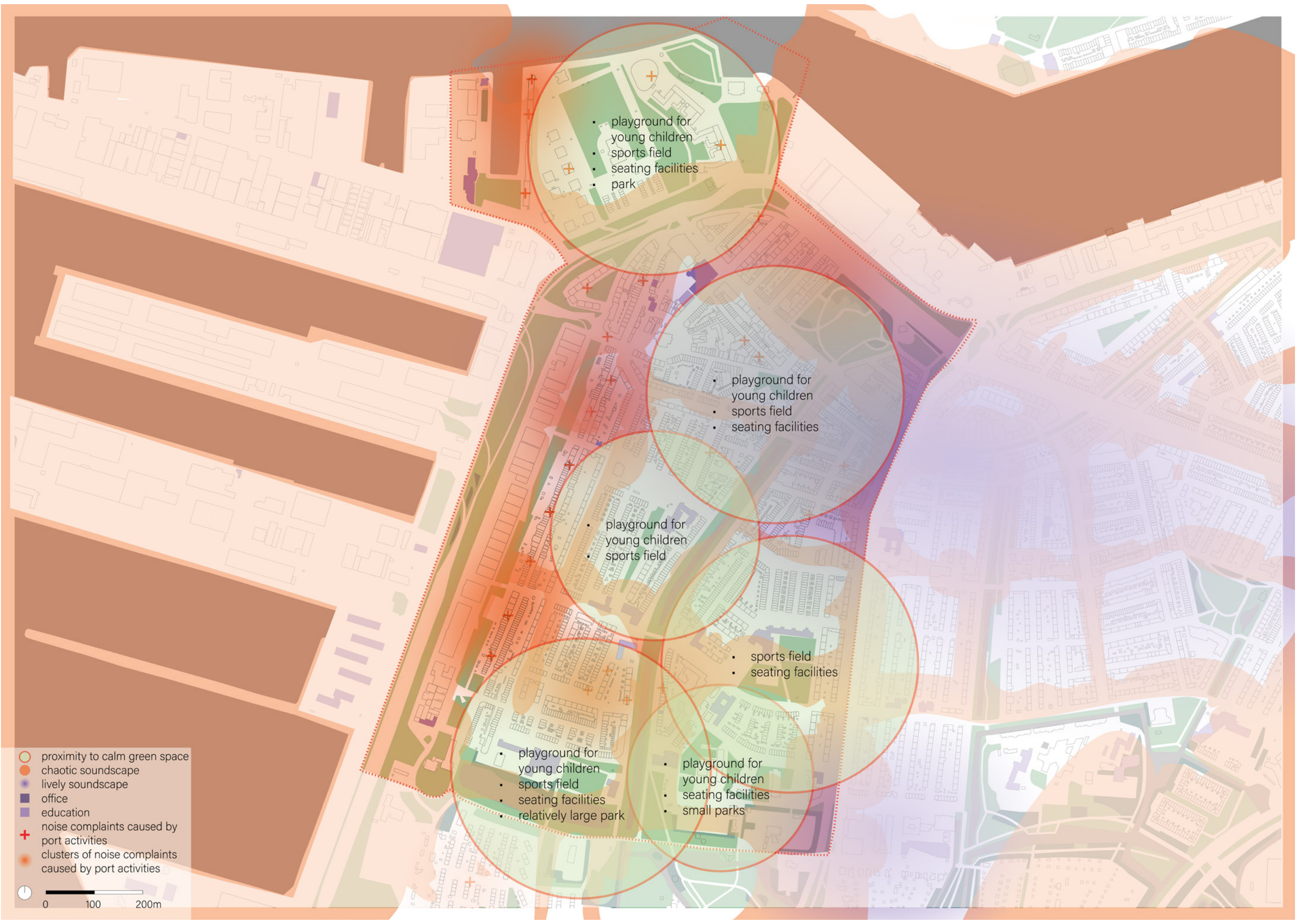


Fig. 51
Green qualities within Oud-Charlois (authors, 2025)

Overlapping soundscapes

By situating the overlapping soundscapes derived from the analysis of the entire Charlois district within the specific context of Oud-Charlois, it becomes evident that noise pollution is predominantly concentrated around industrial areas as well as major roads. However, this analysis also reveals that certain noise complaints recorded in the DCMR dataset (2024) do not correspond to the projected noise pollution levels. This discrepancy once again highlights that measured noise pollution does not fully capture subjective noise perception and/or individual disturbances.

Green qualiities

For further insight into the neighbourhood of Oud-Charlois, the green qualities of areas that did not (entirely) fall within the boundaries of the calculated noise pollution were also examined (Fig. 51). This analysis can, for instance, provide insight into the compensatory capacity of such places, or whether specific elements have been introduced to attract people to these calmer soundscapes. However, a significant number of complaints from the DCMR dataset are indeed located within these green spaces.

 the subneighbourhood

Potential research locations within the neighbourhood of Oud-Charlois

To conclude, a proposal was developed for the locations to be further investigated within Oud-Charlois.

1) Firstly, there is a site located directly along the harbour boundary. Several DCMR complaints have been recorded here, and calculated noise pollution levels are also significant. The apartment buildings along the waterfront are of particular interest for recordings, given their proximity to the adjacent park.

2) A second location is situated within the park along the Maas. Although no calculated noise pollution is visible here, complaints have been reported in the DCMR dataset. The presence of several residential complexes further adds to the site's relevance for continued investigation.

3) Another location is positioned within a closed-off urban block that appears to be outside the calculated noise pollution zones, yet from which complaints have nonetheless been recorded. The enclosed interior of this block makes it an interesting case for (soundscape) research.

4) Additionally, there is a site with a green outdoor space located near the harbour area, from which noise complaints have also been reported.

5) Another location concerns a street lined with apartment buildings on both sides. Although this does not create a fully enclosed built environment, it does result in a degree of separation from the surroundings. Despite appearing calm in the measured noise data, complaints related to harbour activities have been registered here as well.

6) Finally, there is a site surrounded by several schools, making it an important location in terms of the need for tranquillity. However, this location also lies on the boundary of calculated noise pollution, with some complaints reported in the DCMR dataset.

Fig. 52
Potential research locations of Charlois
(authors, 2025)

Evaluation

This section evaluates and reflects on the work conducted so far, highlights the questions that have emerged from the initial findings, and outlines the next steps for further research.

Reflection

The aim of this research was to gain an initial understanding of the relationship between soundscapes and the built environment, using Oud-Charlois as a pilot area within the context of the Rotterdam port region. First, the research project focused on conducting a review of literature about different sources of sound, the way sound is perceived and how soundscapes relate to the built environment. This revealed that soundscapes, consisting of geophonic, biophonic, and anthrophonic sounds (Farina, 2013), can be positioned along a spectrum ranging from boring, chaotic, calm, to lively, based on two axes: pleasant vs. unpleasant and eventful vs. uneventful (Andringa et al., 2013). Additional studies indicate that specific sound elements, combined with the subjectivity of individual perception, can shift soundscapes along this spectrum (Cain et al., 2011; Margaritis & Kang, 2017; Kang et al., 2018).

Individual perception of soundscapes is influenced by physical, socio-cultural, and psychological factors (Aburawis & Dokmeci Yorukoglu, 2018), with spatial-physical attributes operating across three scales: the macroscale (landscape patterns such as shapes, diversity, and area types), the mesoscale (landscape elements including water, greenery, roads, and buildings), and the microscale (multisensory factors such as humidity, temperature, and color) (Zhang et al., 2025).

Traditional acoustic indicators, while useful for assessing health risks, are limited in explaining these individual-level differences. Merely reducing noise is insufficient for improving soundscape quality; instead, sounds should be regarded as resources to be designed, rather than wastes to be eliminated (Kang, 2023). The limited integration of soundscape considerations in urban design and research has hindered the establishment of clear links between soundscapes and health outcomes, highlighting an important direction for future studies.

The insights from existing research allowed for indicating associations: calm soundscapes are often linked with green infrastructures, chaotic ones with busy traffic environments, and lively soundscapes with social or mixed-use areas (Margaritis & Kang, 2017; Kang et al., 2018). The boring soundscape, however, receives little attention in literature. Within this research, it is interpreted as the “residual” category - what remains when a soundscape lacks distinctive features from the other types.

Although existing research has been published on studies linking soundscapes and spatial morphology, and often based on casestudies. This means that extrapolation of results can be difficult without further research. Also, soundscape research methods mostly focus on the imminent surrounding, e.g. streets, parks, squares. This means that to map soundscapes at district or city level, these methods are less suitable and labour intense.. This raises the question to what extent existing noise and geo-spatial data is deployable for such analytical purposes, within acceptable error margins.

Based on the reviewed literature and studies, a method was developed to identify different soundscapes within the Rotterdam port district. While producing generic maps may seem contradictory to the problem statement—since the subjective dimension of sound perception is central to this research—it nevertheless provides valuable insights into critical locations that warrant closer examination in future studies.

The first step involved mapping the entire port area, incorporating a curated dataset of geolocated noise complaints related to port activities, derived from DCMR. This dataset added an essential qualitative layer to the analysis.

Subsequently, the context of Charlois was examined. A comparison between noise maps published by DCMR (2021) and the DCMR noise complaints dataset (2024) revealed that objective measurements alone are insufficient to capture lived soundscapes, as personal experiences are based on instant situations, while noise maps present average calculated noise levels, aggregated for a year. Even though the datasets do not correspond to the same year, it is important to note that port activities have been located around Charlois long before 2021, justifying the comparison.

At this scale, lively soundscapes were primarily identified around commercial functions, while calmer ones were associated with green areas. However, since lively and chaotic soundscapes tend to dominate over quieter environments, the latter are sometimes perceived not as calming but rather as monotonous or “boring.”

DCMR has also published a noise sensitivity map, highlighting buildings most affected by proximity to major infrastructure. This raises further questions about how socio-demographic characteristics are distributed across these sensitive buildings.

Zooming into Oud-Charlois, the role of building typologies emerged as a next line of inquiry. Initial hypotheses suggest that noise distribution may vary across typologies, making it relevant to examine these differences both quantitatively and qualitatively.

Finally, the potential influence of green qualities on sound perception was considered. A preliminary list of spatial characteristics shows that some green public spaces lie outside areas of calculated noise pollution, while others coincide with nearby DCMR noise complaints. This suggests that certain green areas may help absorb noise or positively influence people’s perception of their sound environment.

Future recommendations

Based on these findings, further research is needed to validate the soundscape mapping method, as well as, the relationship between the design of the built environment and its soundscape. Going forward, it is recommended to combine sensor-based noise measurements, capturing loudness, frequency, and duration, with source identification technologies. In parallel, a citizen science approach involving surveys and interviews would allow for a comparison between objective sound data and subjective perceptions. This combination would strengthen the findings by incorporating both quantitative and qualitative insights, highlighting how sound is interpreted in specific local contexts. Moreover, since soundscapes are dynamic rather than static, shifting over the course of a day, season, or year, longitudinal studies are essential to reveal recurring patterns and to identify disruptive or noteworthy sounds.

At the neighbourhood scale, special attention should be given to green spaces, as they may play a role in absorbing or masking urban and industrial noise. However, the perception of these soundscape qualities is likely influenced by the loudness and masking effects of surrounding noise sources, such as roads or industry. This suggests that thresholds exist beyond which the positive effects of greenery on the soundscape become less noticeable. To better understand these dynamics, further research could combine individual surveys with acoustic recordings and spatial analysis, examining how different types and configurations of green infrastructure shape the perceived soundscape.

On a smaller scale, research should also differentiate between street types: for example, does a street designed with more space for social interaction generate a different sensitivity to noise compared to one designed primarily for fast traffic?

Similarly, differentiation in building typologies is needed to better understand how variations in the built environment influence soundscapes.

Finally, it is important to consider the socio-demographic context of the people included in the research, in order to understand how social and demographic factors shape sound perception.

Suggested research continuation

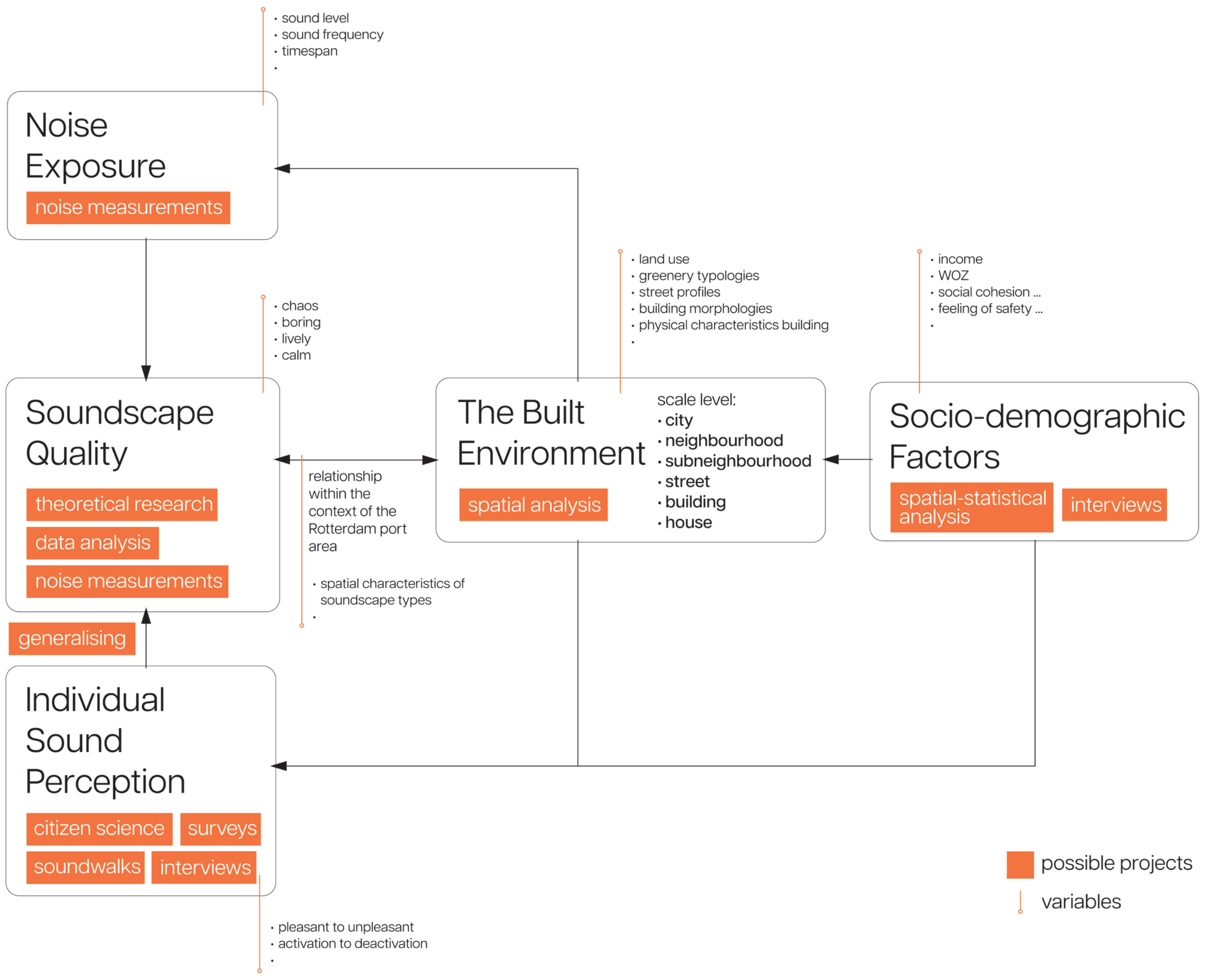


Fig. 53
Suggested research continuation
(authors, 2025)

An updated framework illustrates the relationships between different projects that could evolve from the initial study on soundscapes in and around the Rotterdam port area. To move forward, conversations with involved stakeholders are essential in order to define concrete next steps and explore possible directions. One thing is certain: the integration of soundscapes into urban development is a necessary element for further elaboration.

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