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MASTER'S THESIS

Towards Urban Climate Justice: Integrating Social Vulnerability in Climate Adaptation Planning. A case study of Oostende, Belgium.

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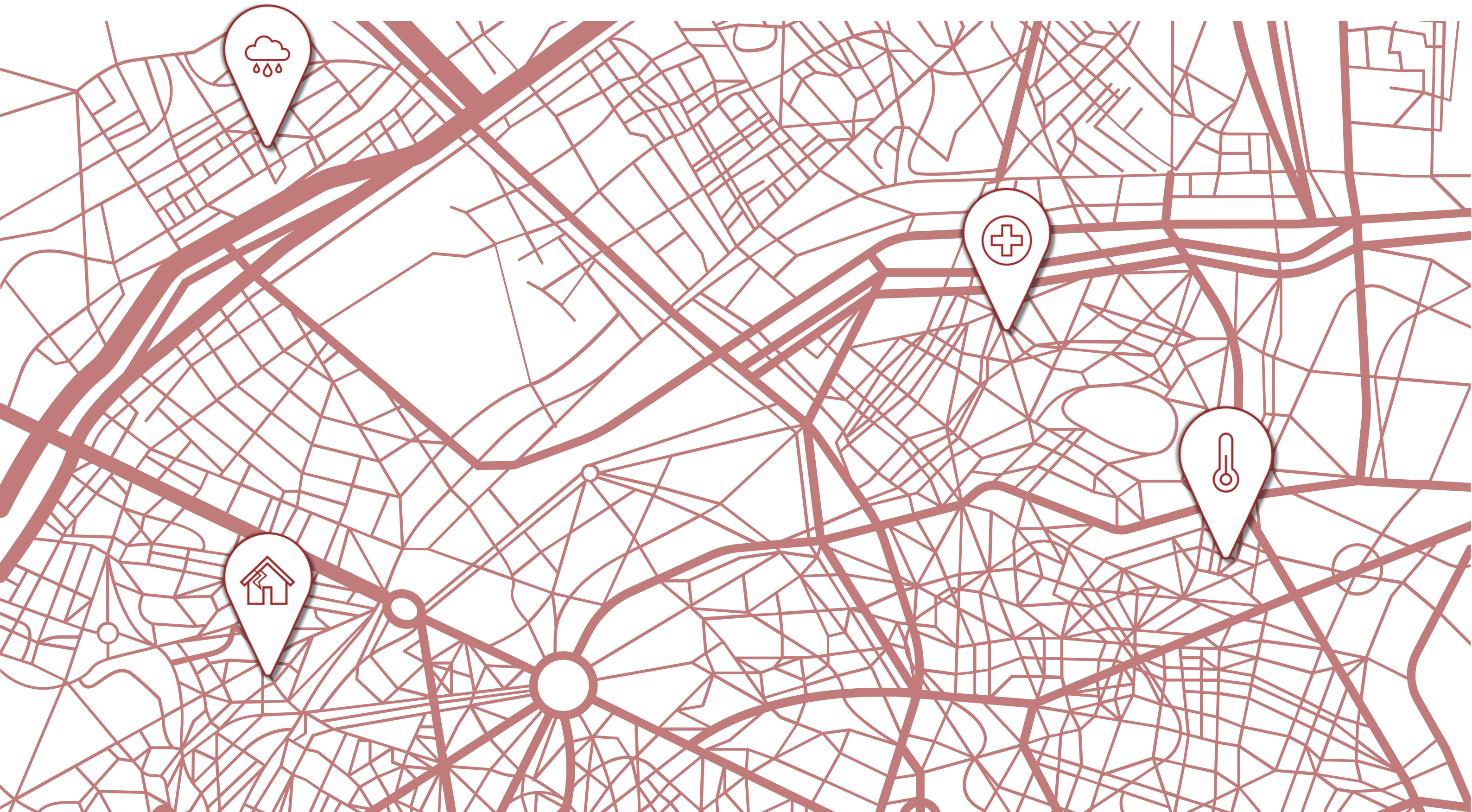

Preface

This thesis was written as the last chapter of our study “Urban, Energy and Environmental Planning: Cities and Sustainability” at Aalborg University. The research is affiliated with the NBRACER (Nature Based Solutions for Atlantic Regional Climate Resilience) project, a four-year EU project targeting regions located at the Atlantic coast to improve their climate risk management and adaptation strategies, focusing on nature-based solutions. The city of Oostende, used as our case study, is located in one of the partaking provinces, the province of West-Flanders (Belgium).

Following the project, we were part of in our second semesters of our study, with the topic of making the distribution of green infrastructure more just, we became more and more intrigued with the interface of (climate and environmental) justice, urban planning and climate adaptation. It is from these interests that the idea emerged of working together on the topic of this thesis.

We are very thankful for our inspiring supervisors, Lars Bodum and Thomas Elliot, to guide us through the process of writing this thesis, their constructive criticism, helpful suggestions and positive mindset.

We would also like to thank our many interview partners, the municipality of Oostende in particular, for the nice collaboration and interesting talks. We hope the contents of our report will provide you with some helpful insights and ideas!

Abstract

Climate change causes an increase in occurrence and intensity of extreme weather events, especially in densely built cities. Consequently, inequities are created as not only the exposure is different across areas, but also the sensitivity and adaptive capacity towards climate impacts, which can differ on an individual level. According to the urban climate justice perspective, these inequities need to be considered in climate adaptation planning practices, something that is currently lacking in many municipalities. This research therefore attempts at answering the question: “How can municipalities assess social vulnerability for a more just approach to climate adaptation planning?”. A case study of the coastal city of Oostende (Belgium) is employed for developing and testing a possible method for combining climate exposure and social vulnerability, with the goal of creating priority maps for climate adaptation measures. This is done through literature reviews, interviews with people from the municipality and other stakeholders, case-specific data collection and analyses. The approach is feasible and easy to implement by other European coastal cities and will help planners with raising awareness for social climate vulnerability and to gain insights in problem areas, making it easier to make spatial priorities for climate adaptation measures. The method is evaluated through the lens of Urban Climate Justice, concluding that it is a valuable method for municipalities to consider social vulnerability in their climate adaptation planning.

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List of Abbreviations

CPC	Climate Policy Coordinator
EEA	European Environmental Agency
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
mTAW	Belgian sea level reference ("Tweede Algemene Waterpassing")
SDG	Sustainable Development Goal
SoVI	Social Vulnerability Index
SRQ	Sub-research question
SVC	Social vulnerability class
UCJ	Urban climate justice
UN	United Nations
VITO	"Vlaamse Instelling voor Technologisch Onderzoek", literally translated to Flemish Institute for Technological Research

1. Introduction

Since 1850, CO_2 emissions have been rising continuously, and it is anticipated that the global temperature rise will surpass the 1,5 °C threshold by 2100. The implications of these developments are already and will, in perspective, be far-reaching. The primary contributor to greenhouse gas (GHG) emissions are the energy supply sector and industry. (IPCC, 2023) Cities are major hubs for energy consumption and GHG emissions, being responsible for 80 % of global emissions (Seto et al., 2014). Urbanisation is considered to be a driver for climate change, as an increase in urban population often means higher income, which is associated with higher GHG emissions (IPCC, 2022b). Additionally, an increase in building activity further increases the emission of GHGs (ibid.). At the same time, urban areas are projected to be largely affected by climate change. Cities are especially at risk, as they are densely populated and hold crucial infrastructure and services (Allam et al., 2020). In the European Union (EU), 75,45 % of the population lives in cities (Statista, 2022). Mid-latitude cities are projected to, by 2050, suffer twice the levels of heat stress than rural areas (IPCC, 2023). Europe is also expected to suffer from effects of droughts on food production, of heat on the health of the population and of extreme weather events on people and infrastructure (EEA, 2024).

Overall, it has been found that cities are not adapted sufficiently for the risks they are facing, which is referred to as the urban adaptation gap (IPCC, 2023). This has also been recognised by Leena Ylä-Mononen, Executive Director of the European Environment Agency (EEA):

> "[..} Europe faces urgent climate risks that are growing faster than our societal preparedness. To ensure the resilience of our societies, European and national policymakers must act now to reduce climate risks both by rapid emission cuts and by strong adaptation policies and actions." (In: EEA, 2024)

On a global level, the United Nations (UN) have developed the Sustainable Development Goals (SDGs), a framework comprised of 17 goals. For urban climate adaptation, the following goals can be seen as especially important (see also Fig. 1):

- Goal 3: ensure healthy lives and promote well-being for all at all ages.
- Goal 9: build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.

- Goal 10: reduce inequality within and among countries.
- Goal 11: make cities and human settlements inclusive, safe, resilient, and sustainable.
- Goal 13: take urgent action to combat climate change and its impacts.

Figure 1: Relevant SDGs for this research. From UN (2015).

The IPCC (2022) calls to take "[…] integrated action for climate resilience to avoid climate risks, which requires urgent decision making for the new built environment and retrofitting existing urban design, infrastructure and land use." This also highlights the opportunity for urban planning to shape cities and promote transformative processes in order to adapt to the increasing risk imposed by climate change (Egerer et al., 2021). Part of this action is the development and implementation of climate adaptation plans, which have become standard practice in most cities (ibid.). The responsibility and opportunity for urban planners to control these processes and outcomes will be subject to this research. The following chapter will foster a more targeted analysis of the problem that will be investigated.

2. Problem Formulation

In this chapter, the aim of the research, as well as the outline and approach will be presented. The first part will explore and analyse the main problem that will be investigated in the research. In a second step, the research will be divided into research questions, after which the research design will be shaped and discussed, showing the strategy through which each of the questions will be answered.

2.1. Problem Analysis

As mentioned in the introduction, cities face the perspective of being greatly impacted by climate change in the future. Though most cities already experience changes, it is expected that they will have to deal with more and more effects, caused by sea level rise and extreme weather events, as for example droughts, rain, and heat waves. While this is a global phenomenon with global impacts, the effects are not distributed evenly over space and between low- and high-income countries. Researchers have found that low-income countries suffer more from climate change than high-income countries (IPCC, 2022a; Islam & Winkel, 2017). Additionally, low-income countries often do not have the financial capacity to sufficiently adapt to a changing climate, resulting for example in poor housing quality, accelerating this uneven impact (Islam & Winkel, 2017).

The same dynamic can also be seen on smaller scales, within cities and between neighbourhoods. Even when dealing with the same climatic changes, people can have different levels of vulnerability towards climate change impacts. Swanson (2021) describes how the city can be viewed within two categories: the climate-resilient elite and the climate-vulnerable poor. Vulnerability is becoming a more widely used concept (for example within the IPCC assessment reports) and is based on multiple factors that might be physical, socio-economic, or political. This concept will be explored in more detail in Chapter 4. Generally, it can be said that people who have a higher vulnerability experience stronger impacts from climate change (Tee Lewis et al., 2023). As an example, heat is an increasing hazard all over Europe, where in 2022 more than 60 000 people died due to high heat, of which more than 36 000 were over the age of 80 (Tagesschau, 2023). This demonstrates that elderly people are overall more at risk to be harmed by heat waves, an effect that can be reinforced if those people also have less income and cannot afford air conditioning or have less access to health care. In environmental justice research, it was observed that often household income is used as the sole factor to determine vulnerability (Calderón-Argelich et al., 2021), which does not consider how people can be affected by other factors or multiple factors, such as health or age, that amplify each other.

Climate adaptation planning has been making its way into urban planning practices. However, measures are often only taken where the highest climate impacts are, not taking the underlying conditions and processes into account (European Environment Agency, 2022). Climate adaptation is sometimes framed as a wicked problem, which means that it is a very complex task with many interconnections and implications for other matters (Perry, 2015). This can mean that understanding the system and understanding the problem can take so long that in that time the conditions change, or it can mean that there are so many impactors and effects that it seems impossible to fully consider everything (ibid.). Simultaneously, climate adaptation has the potential to influence and decrease the vulnerability of the population. An example or this would be to improve mental health through implementing green spaces as part of a nature-based solution (Sharifi et al., 2021).Climate adaptation planning has been making its way into urban planning practices. However, measures are often only taken where the highest climate impacts are, not taking the underlying conditions and processes into account (European Environment Agency, 2022). Climate adaptation is sometimes framed as a wicked problem, which means that it is a very complex task with many interconnections and implications for other matters (Perry, 2015). This can mean that understanding the system and understanding the problem can take so long, that in that time the conditions change, or it can mean that there are so many impactors and effects that it seems impossible to fully consider everything (ibid.). Simultaneously, climate adaptation has the potential to influence and decrease the vulnerability of the population. An example or this would be to improve mental health through implementing green spaces as part of a nature-based solution (Sharifi et al., 2021).

A city that is facing challenges with implementing climate adaptation measures for vulnerable people is Oostende, which has a high percentage of elderly and low-income households. This research will investigate the city of Oostende as a case study for facilitating the process of implementing vulnerability into adaptation planning.

2.2. Research Questions

The main research question that will guide this research is the following:

How can municipalities assess social vulnerability for a more just approach to climate adaptation planning?

To take on a structured approach to answering this question, it is split into these three sub-research questions (SRQs):

1. What are methods to assess vulnerability, and which one is feasible to use in the context of this research?

The first question aims at understanding the existing ways to assess vulnerability in different contexts. As there are multiple definitions in use for the concept of vulnerability it is important to clarify the employed definition. Finding a suitable method for assessing vulnerability is also a crucial step, as the approach as well as the specific indicators determine the type and quality of results that are achieved.

2. Which are the specific circumstances and challenges in the case city?

Investigating the second question will give a deeper insight into Oostende as a city. As every city is dealing with individual challenges, answering this question will help with understanding and interpreting the results. Further this offers the opportunity to get in touch with local actors and get their perspective on the issues the city is facing.

3. What are barriers for the case city to include social vulnerability in their planning processes?

While the concept of social vulnerability is increasingly gaining attention in research, municipalities often do not incorporate it within their adaptation planning efforts. Through answering the third question, it will be possible to find out if and how the method applied in the frame of this research could also be used in the future, by the municipality or other actors in the city.

2.3. Research Design

The previously presented research questions were translated into a comprehensive research design, showing the strategies and methods envisioned for answering the subresearch questions, and eventually the main research question. This research design can be found in Figure 2.

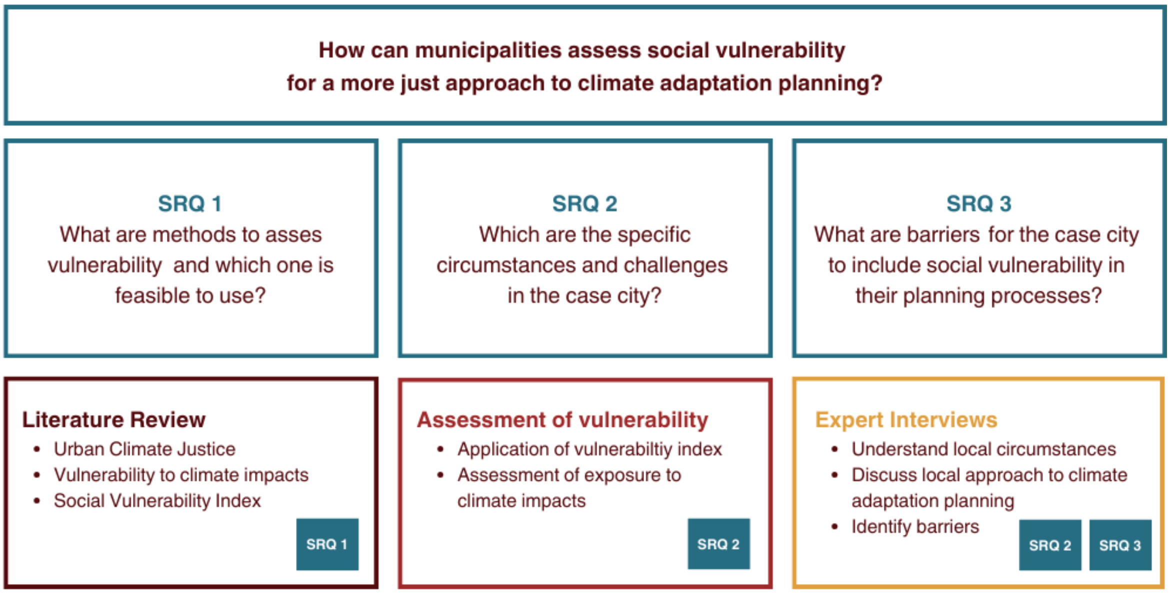

Figure 2: Research Design.

To answer the first sub-research question, a literature review for the concepts of urban climate justice, vulnerability and vulnerability indices will be conducted. For the investigation of sub-research question two, data obtained from the vulnerability assessment and the expert interviews will be combined in order to get an understanding of the conditions in Oostende regarding the climate challenges, social situation and current planning practices. To investigate what is currently hindering Oostende from including social vulnerability in their planning practice, the data from expert interviews will be analysed in that respect.

3. Conceptual Approach: Urban Climate Justice

Justice as a concept has been part of philosophy for hundreds of years and has been an integral part of research since the 1950s, occupying researchers of many disciplines, including sociologists, political scientists and psychologists (Sabbagh & Schmitt, 2016). In the development of current streams of justice research, different interconnected branches emerged, ranging from social to spatial to environmental and climate justice. As these are intertwined and their developments have overlapped, there are common terms that are used across the disciplines as well as different definitions and applications for the concepts.

Social justice has been conceptualized in many ways, and is often seen in a three-dimensional way, meaning that redistribution, recognition, and representation are required (Fraser, 1998). Redistribution refers to the distribution of resources and goods in a just manner while recognition calls for recognising differences without demanding adjustment to, for example, cultural norms (ibid.). Representation can be seen as social belonging in the sense of “inclusion in, or exclusion from, the community of those entitled to make justice claims on one another” but it can also mean representation at a political level (Fraser, 2005).

Spatial justice as a concept is a result of the “spatial turn”, as coined by Soja (1989), which marks a turning point towards viewing matters through a spatial lens. Through this shift, social sciences started recognising the role of space, and disciplines such as geography or architecture started gaining attention (Soja, 2010). Foundational for this strand of research was Harvey’s work on “Social Justice in the City” (1973) applying social justice theory to the urban realm.

The concept of environmental justice as another strand emerged at the same time in the 1980s in the United States, mainly focusing on the impacts soil pollution had on people of colour (Schlosberg & Collins, 2014). Since then, the concept has developed into investigating and proving that “in general, ethnic minorities, indigenous persons, people of colour, and low-income communities confront a higher burden from air, water and soil pollution from industrialisation, militarisation, and consumer practices” (Mohai et al., 2009, p. 406). Climate justice overlaps, in part, with the conception of environmental justice, such as the basic assumption that climate change “violates human rights of life, health, and subsistence” (Caney, 2006; in Schlosberg & Collins, 2014, p. 365). The debate about climate justice was, in the past, held mainly on an international scale. More recently several researchers applied this conception to the urban scale, resulting in urban climate justice (UCJ) as a newer research avenue. UCJ is explicitly looking at the urban scale, recognising the diversity of human and non-human experiences in cities (Steele et al., 2015).

Steele et al. (2015, p. 123) point out 3 facts to pay attention to when discussing UCJ:

1. “Climate change is a crisis of society as well as the natural environment, wherein the impacts are felt mostly by the most marginalised segments (both in the human and non-human realm);
2. Society and nature are simultaneously, mutually and constantly, reconfigured by the ways that urban relations are played out, making it difficult to ascertain the justice implications of climate change without considering society and nature;
3. We must better take into account the complex and dynamic links between human society and the natural environment in the transition to environmentally sustainable futures.”

In UCJ research as well as works on justice in climate adaptation planning, justice is viewed within four dimensions: recognition, distribution, procedure, and restoration (Juhola et al., 2022; Prall et al., 2023; see Fig. 3).

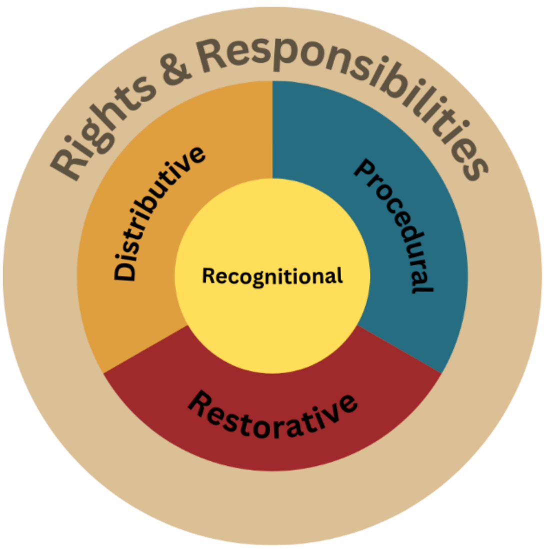

Figure 3: Dimensions of Urban Climate Justice.

As mentioned above, recognition as an integral part of justice has been introduced by Fraser. This conceptualisation has been strengthened by Bulkeley et al. (2014), who stress that justice cannot be considered without understanding the recognitional dimension. **Recognition** in an urban climate change context means acknowledging the systemic influences on (in)justice, for example through politics or policy (ibid.). **Distribution** refers to the distribution of climate impacts as well as of adaptive measures across the city and across the population (Prall et al., 2023). **Procedure** in climate adaptation planning means examining, which population groups are represented in or are part of decision-making processes (Juhola et al., 2022). **Restoration** is a more recent addition to the traditional dimensions of justice and refers to acknowledging the harm that has been or is being caused by injustice and climate change, pointing out responsible actors (Juhola et al., 2022) and then working towards decreasing injustices by prioritising adaptation measures for the ones that were harmed or are more vulnerable (Prall et al., 2023).

Within these dimensions responsibilities and rights of actors are often considered to assess potentials and dynamics for action. “Responsibilities” in climate justice refers to the unequal distribution of the responsibility for climate change globally as well as intergenerationally (Meyer & Roser, 2010). Some see high-income countries in the responsibility to bolster adaptation and mitigation efforts in low-income countries (Okereke & Coventry, 2016). This can also be translated to the local scale to ask the question which structural inequalities influence the cities’ responses to climate change (Hughes & Hoffmann, 2020). “Rights” refers to two different types of rights. The first is the right to benefit from the measures that are taken, and the second is the right to be protected from climate impacts (Bulkeley et al., 2014).

Equity and justice as guiding principles are often used interchangeably or as inseparably linked. Equity is often only viewed in the distributive dimension of justice but Meerow et al. (2019) call for viewing the concept as part of all dimensions. This is stressed by Reckien et al. (2018) who describe three different kinds of equity:

1. outcome-based, distributive or consequential equity (relating to, for example, the consequences of a policy),
2. process-oriented or procedural equity (for example regarding the fairness in processes) and

3. contextual equity (considering conditions that influence equity).

In this research, equity is seen as a normative principle embedded in seeking justice. Recognising that people are impacted differently by climate change is a foundational assumption for just planning, wherein vulnerability plays an important role. This concept and its implications for planning will be explored more in the upcoming chapter.

4. Vulnerability

Vulnerability is a contested concept that has been and is being used in various contexts without a universal definition. In the sixth IPCC report, vulnerability is defined as “the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (IPCC, 2022a, p. 5). Globally, 3,3 to 3,6 billion people are considered to be vulnerable towards climate change. Vulnerability is known to be linked to unsustainable land use and ecosystem destruction. It is also be accelerated if multiple climate risks interact with each other, which is likely to occur more and more often. (ibid.)

Vulnerability is often defined in three parts: exposure, sensitivity, and adaptive capacity (see for example Bigi et al., 2021; Le, 2020). A usual way to put them in relation to each other can be seen in the equation presented by Bigi et al., (2021):

Vulnerability = (Exposure * Sensitivity) / Adaptive Capacity

Exposure is “the inventory of elements in an area in which hazard events may occur” (Cardona et al., 2012, p. 69). This refers to the physical presence of people, species, or resources (be it economic, social, or cultural) in places that are put in harm by climate risks and physical hazards (IPCC, 2014). This means if there was no infrastructure or population in an area that is affected then there would be no exposure (Cardona et al., 2012). Exposure alone is not a sufficient indicator for vulnerability (ibid.).

Sensitivity can be defined as “the physical predisposition of human beings, infrastructure and environment to be affected by a dangerous phenomenon due to lack of resistance and predisposition to suffer harm as a consequence of intrinsic and context conditions” (Bigi et al., 2021, p. 3). A system can be sensitive due to physical factors, such as quality of infrastructure, or societal factors, for example population density (Zebisch et al., 2021).

Adaptive capacity is defined as “the ability of a system to endure any perturbation, adjust to a disturbance, moderate potential damages, exploit opportunities or cope with the consequences” (IPCC, 2014), so the system’s ability to withstand or recover from the exposure. It is represented by 3 levels, namely the institutional adaptive capacity (e.g. the influence of governance), collective adaptive capacity (e.g. credibility of decision makers) and autonomous adaptive capacity (e.g. the access to decision-making processes) (Le, 2020).

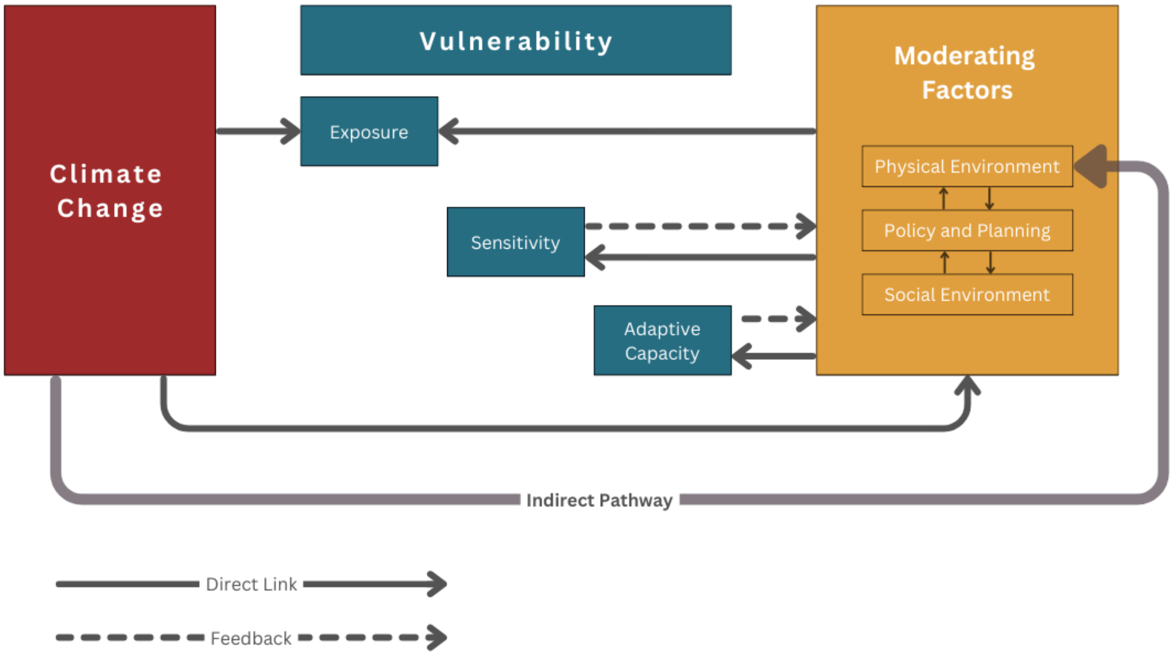

Figure 4: Conceptual Framework showing how different factors influence vulnerability. Adapted from Jurgilevich et al. (2023) according to the definition of vulnerability and the thematical focus relevant for this research.

Jurgilevich et al. (2023) created a framework (see Fig. 4) that stresses the interconnectedness of climate change, vulnerability, and the urban fabric. While climate directly affects the exposure, it also has indirect influences on the other vulnerability components. This happens through the impacts on the moderating factors meaning that it slowly changes the physical environment, provokes new policies, or changes the way people interact. All these changes can have an influence on the components of vulnerability and are within the scope of action of municipalities. Through these impacts, a feedback effect can occur. An example of this would be if health is impacted negatively by the physical environment, it can create the need for a new public health strategy. How vulnerability can be measured will be explored more in the following chapter.

Vulnerability Indices

Assessment methods attempt to examine and integrate interactions between humans and their social and physical surroundings. In literature, this is mostly done using vulnerability indicators. These identify the processes contributing to vulnerability, provide a means of monitoring vulnerability over space and time, and set priorities for strategies that reduce vulnerability. (Shah et al., 2013) They are therefore a powerful tool in aiding decision-makers to develop adaptation and mitigation plans, prioritize budgets and take necessary actions for the most vulnerable populations and therefore decrease potential harm.

One type of index are climate vulnerability indices. One of those is for example used by the US government and is made up of 184 indicators, connecting baseline vulnerabilities with climate change risks within 4 categories: Health, Social and Economic, Infrastructure and Environment (Fig. 5). (Environmental Defense Fund, 2024; Tee Lewis et al., 2023)

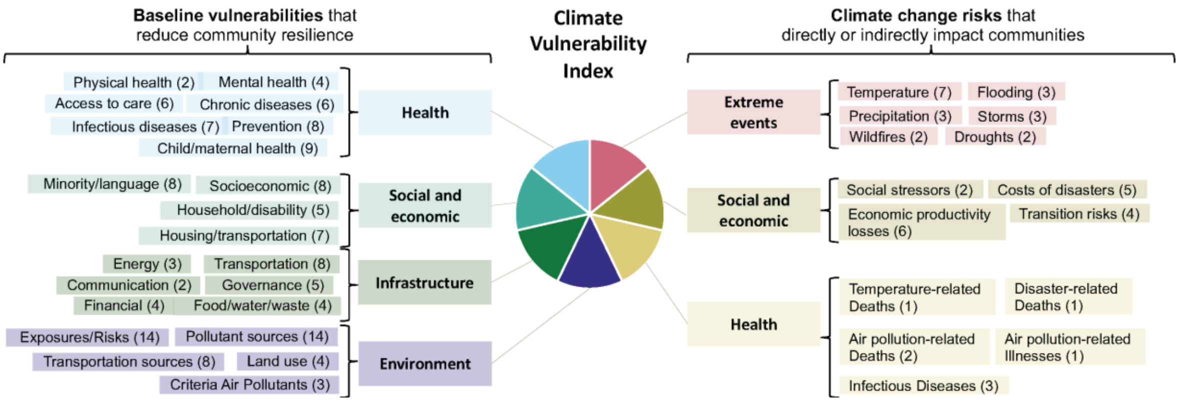

Figure 5: Climate Vulnerability Index as assessted by the US Government. From: Environmental Defense Fund (2024).

Another type of indices are flood vulnerability indices, which is a more specialised kind of index, focusing on vulnerability in areas affected by flooding. Moreira et al. (2021) conducted a review of 95 peer-reviewed articles (2002-2019) focusing on these indices and found that most indicators used are within the social dimension (e.g. population density, illiteracy rate), followed by economic (e.g. per capita income), physical (e.g. households without sanitation) and coping capacity (e.g. early warning system). One of these is the Coastal City Flood Vulnerability Index, which was developed to recognise how coastal systems are dynamic and complex in how they are affected by natural hazards as well as human intervention (Balica et al., 2012). This index uses seven hydro-geological indicators (e.g. soil subsidence or river discharge), six social indicators (e.g. population close to coastline, cultural heritage), three economic indicators (e.g. growing coastal population) and four politico-administrative indicators (e.g. uncontrolled planning zones) (ibid.).

Both climate vulnerability indices and flood vulnerability indices are often complex and require data that is often not assessed by or available to municipalities as they often lack financial or human resources for these thorough analyses. On the other hand, socioeconomic data is collected though censuses and thus more accessible.

To use social or socioeconomic data for assessing vulnerability towards climate impacts, multiple researchers have combined the concept of social vulnerability with climate data and climate projections (see for example Englund et al., 2023; García & Dias, 2023). The concept was established to “separate the biophysical from the human dimension of natural hazards” (Otto et al., 2017, p. 2).

Cutter et al. (2003) established the foundation for the assessment of social vulnerability, developing the Social Vulnerability Index (SoVI). Its original application was to assess the social vulnerability towards environmental hazards (Spielman et al., 2020). Since then, it was used on different scales (local to international) and across disciplines (ibid.). The SoVI was developed in a US context, using the following factors:

- Personal wealth,
- Age,
- Density of the built environment,
- Single-sector economic dependence,
- Housing stock and tenancy,
- Race and Ethnicity,
- Occupation and
- Infrastructure dependence.

While the approach by Cutter et al. assesses social vulnerability for the purpose of using it for environmental hazards, only social factors are used, which apply only to sensitivity and adaptive capacity as parts of vulnerability. For later assessments that have been conducted in the context of climate impacts, these indicators were adjusted to also include exposure in the assessment. Some vulnerability indicators (such as the Coastal City Flood Vulnerability Index by Balica et al. (2012)) were also based on the method by Cutter et al. (2003). In the case study done by Englund et al. (2023) in Sweden, the indicator “average distance to areas exposed to flooding” was included for this purpose. Garcia & Días (2023) created and combined two maps, one from their SoVI results and one from the areas that would be flooded. More on this process of including exposure to environmental factors will be discussed in Chapter 5.3.5.

5. Methods

The following chapter presents all relevant methods used throughout this research. The first part will present the procedure of the conducted literature reviews, followed by the method for the case study. The next part will show how the social vulnerability index was applied and added to the climate exposure data. Lastly, the interview method and the interviewed experts will be presented.

5.1. Literature Review

The research method of literature review entails the careful identification and synthesis of relevant literature with the goal of comparing the findings of prior published studies in the research domain (Paul & Criado, 2020). This provides the researcher with a state-of-the-art understanding of the topic and possibly identifying key research gaps. The goal of the literature review in this research was gaining a profound understanding of urban climate justice (through theory-based review), climate impact vulnerability and social vulnerability (through domain-based review). In addition, a goal was to gain an insight into existing climate and social vulnerability indices, their differences, and indicator-based methodologies (through method-based review). (ibid.)

For the research, SCOPUS was used as the main database. After filtering the subjects of the results, abstracts were scanned for important keywords such as "urban/city", "climate adaptation" and "(social) vulnerability". This made it possible to gather the relevant articles.

5.2. Case Study

The primary approach to this research is a case study. Case studies allow researchers to investigate a case in more detail and to understand, and draw conclusions from, the context of the case (Flyvbjerg et al., 2011). Generally, there are two different approaches to case studies: single or multiple case studies (Tight, 2022). In many instances a comparative case study consisting of multiple cases can offer valuable insights, especially for drawing conclusions that are case independent. At the same time, a single case is often more interesting for the people who are involved in the case (ibid.). It is also able to produce knowledge that can be generalised, contrary to popular belief (Flyvbjerg, 2006). Flyvbjerg (2006, p. 227) also stresses that generalisation is not always the only value of a case study:

> "That knowledge cannot be formally generalized does not mean that it cannot enter into the collective process of knowledge accumulation in a given field or in a society. A purely descriptive, phenomenological case study without any attempt to generalize can certainly be of value in this process and has often helped cut a path toward scientific innovation."

For this research, a single case study was chosen as the appropriate approach. An important part of the process was to find and apply a suitable method to a specific context. Due to the complexity of the method as well as the scope of the research, one case was deemed to be sufficient. Through this procedure, it was possible to understand not only the results of the analysis but also the surrounding conditions and planning practices of the city of Oostende. It also allowed for an additional feedback discussion with actors from Oostende and the Danish city of Esbjerg to evaluate the method and the results in order to take a first step towards applying it in another city of similar size and challenges.

5.3. Index Analyses

Englund et al. (2023) include exposure to flooding as a single indicator in their general vulnerability analysis ("distance to flooded areas"). As this is only one indicator as part of the total analysis, the impact of the indicator is small in comparison to the total value.

García and Dias (2023) include flooding in their assessment through modelling a flood event and creating a map which they then combine with the results of their vulnerability analysis. As there are multiple indicators relevant to exposure for this research, a combined approach was chosen.

The Flemish Government has conducted a deprivation analysis before, based on the following eight indicators (West-Vlaanderen, 2023):

1. Single households,
2. Single-parent households,
3. Renters 35-79 years,
4. Population not born in the EU,
5. Students in primary school who do not speak Dutch at home,

6. Students in secondary school who do not speak Dutch at home,
7. Population with an increased compensation for health care and
8. Population who has not visited a dentist in three consecutive years.

While this analysis can be seen as a first step into visualising vulnerability, the indicators that were used are quite limited. In the analysis conducted in this research, the indicators are based on current research and aim to offer a more comprehensive result of vulnerability. Additionally, these results have not been integrated into planning, which might be made possible through an integrative approach, as in social climate vulnerability, which will be assessed through the methods presented in Chapter 5.3.5.

5.3.1. Climate data analyses

For the climate analysis, open access data from the Flemish government were used (Flemish Environment Agency, 2024a). The four largest climate threats for Oostende are storm surges (increasing due to the rising sea levels), pluvial flooding, fluvial flooding, and extreme heat. For each type of threat (category), the most extreme scenarios, existing for each indicator within the category, were used. In Tables 1 to 4 an overview is provided of the used indicators per category and their scenario. While not all scenarios are for the same year or project the same intensity, the objective was to use data that is already available to the city of Oostende. The aim was not to create a combined climate projection but to show how the population will be affected by climate change. All indicators have a positive correlation with vulnerability. More in-depth information on the indicators can be found in the Appendix A.

Table 1: Indicators used for the category heat, using the projection year 2100 and a yearly event, except for “Number of vulnerable people exposed to heat” which uses the same year but a 20-year event. Data downloaded from: “Klimaatportaal catalogus” (Flemish Environment Agency, 2024a).

Indicator	Description
Number of vulnerable people exposed to heat	The number of vulnerable people (aged between 0-4 years and over 65 years) exposed to significant heat stress. More specifically, it refers to vulnerable persons where the daily

Indicator	Description
	maximum and daily minimum sensory temperatures during an extreme heat day (20-year return period) are exceeded to the extent that the combined threshold reaches score 4 or more at which severe health damage is expected.
Weight heat waves	The multi-year average of the weight of heat waves according to KMI definition per year (°C). (A 'heat wave' is defined as a period of at least 5 consecutive days with a maximum temperature of at least 25°C, with the maximum temperature being greater than or equal to 30°C for at least 3 days.; the weight of heat waves is the sum of the degrees of all heat waves in 1 year)
Number of days with an average temperature > 25 °C	The multi-year average of the number of days per year with an average temperature of 25 °C or more.
Number of days with a max. temperature of > 25 °C	The multi-year average of the number of days per year with a maximum temperature at 2 m altitude of 25 °C or more.

Table 2: Indicators used for the category pluvial flooding, using the projection year 2050 and a 1000-year event. Data downloaded from: "Klimaatportaal catalogus" (Flemish Environment Agency, 2024a).

Indicator	Description
Vulnerable institutions with inundation	Vulnerable institutions (childcare, pre-school, primary and special education, hospitals, and care homes) at risk of flooding due to intense rainfall.
Number of buildings affected by inundation	Number of buildings per statistical sector with a probability of once per 1000 years at inundation due to intense rainfall.

Indicator	Description
Water depth at precipitation event	The maximum water depth in case of flooding due to intense precipitation with a probability of once in 1000 years.

Table 3: Indicators used for the category storm surge, using the projection year 2075 and a 1000-year event. Data downloaded from: "Klimaatportaal catalogus" (Flemish Environment Agency, 2024a).

Indicator	Description
Institutions vulnerable to flooding by 1000-year storm surge	Vulnerable institutions (childcare, pre-school, primary and special education, hospitals, and care homes) at risk of flooding in a 1000-year storm surge.
Number of buildings affected by 1000-year storm surge	The number of buildings per statistical sector at risk of flooding in a 1000-year storm surge.
Water depth at a 1000-year storm surge	The potential floodable area and associated water depth for the occurrence of a 1000-year storm surge on the coast, calculated using the sea wall in the year 2015. A 1000-year storm surge is a storm surge in which there is 1 chance in 1000 of this storm surge occurring each year.

Table 4: Indicators used for the category fluvial flooding, using the projection year 2050 and a 1000-year event. Data downloaded from: "Klimaatportaal catalogus" (Flemish Environment Agency, 2024a).

Indicator	Description
Number of buildings affected by flooding	The number of buildings per statistical sector with a probability of flooding once every 1,000 years.
Water depth at flood event	The water depth at a flood event with a probability of once in 1000 years.

The climate projection data obtained from the Belgian governments open access database were divided into the smallest administrative scale in Flanders. These small neighbourhoods are called statistical sectors and correspond to on average 10 streets. This scale was chosen for the most detailed and accurate data analysis.

The values per indicator were then normalised using the min-max method to provide values between 0 and 1. This was done using the following formula:

$$X' = \frac{X - X_{\text{min}}}{X_{\text{max}} - X_{\text{min}}}$$

Subsequently, the normalized values were aggregated per statistical sector for each category to showcase which areas would be more or less affected by climate change compared to each other. The obtained values were then divided according to a ranking scale from 1 to 5, using a fixed rank ([0,0.2[; [0.2,0.4[; [0.4,0.6[; [0.6,0.8[; [0.8,1]). These results were then visualised in QGIS.

5.3.2. Choosing a suitable vulnerability index

Based on the results of the literature review, different indicators for vulnerability (see Chapter 4) were compared in terms of what kind of vulnerability they assess, in which context they have been applied and which data is used for the assessment. Choosing which kind of index is appropriate can prove to be difficult due to the number of indices and the lack of standardised language. Further, many papers, especially on flood vulnerability, use case studies based in low-income countries, which has the effect that some of the indicators that are used are not as relevant in high-income countries, such as the amount of people living in informal settlements or households without sanitation. Due to the similarity in research objective, the indicators were largely based on the work of Englund et al. (2023) and García & Dias (2023), as well as on Flanders' previous analysis of deprived areas.

5.3.3. Vulnerability indicators

Following the literature mentioned above and available data sources, 15 indicators were selected, which were considered to be the most representative for the social vulnerability analysis in Oostende. The result is the following list of indicators. A more detailed list of indicators and information on data processing can be found in the Appendix B.

Table 5: Social vulnerability indicators per category. The column “effect on vulnerability” shows whether the indicator has a positive or negative correlation with social vul-nerability. Data are all downloaded from the databank “Provincies in Cijfers” (Provincie West-Vlaanderen, 2024)

Category	Indicator	Effect on vulnera-bility	Indicator based on (source)	Year of data source
Age	Inhabitants younger than 15 years (% of total inhab-itants)	+	Englund et al. (2023); García & Dias (2023)	2023
	Inhabitants older than 74 years (% of total inhabit-ants)	+	Englund et al. (2023); García & Dias (2023)	2023
Language proficiency	Non-EU birth nationality (% of total inhabitants)	+	Englund et al. (2023); West-Vlaanderen (2023)	2023
	Children not speaking Dutch at home (% of chil-dren in primary and sec-ondary school)	+	West-Vlaanderen (2023)	2022-2023
Health	Inhabitants with a statute of chronic conditions (% of inhabitants with health insurance)	+	Chosen as substi-tute due to limited data availability	2022
Educational attainment	Highest educational at-tainment being primary school or less (% of all in-habitants over 25)	+	Englund et al. (2023); Cutter et al. (2003)	2017
	Highest educational at-tainment university or sim-ilar (% of all inhabitants over 25)	-	Englund et al. (2023); Cutter (2003)	2017

Category	Indicator	Effect on vulnera-bility	Indicator based on (source)	Year of data source
Single parent households	Single parent households (% of all private house-holds)	+	Englund et al. (2023); Cutter (2003)	2023
Vehicle own-ership	Number of vehicles per 100 households	-	Englund et al. (2023)	2022
Housing	House renters (% of households with known property title)	+	West-Vlaanderen (2023); Cutter (2003)	2023
Financial vul-nerability	Disposable income per consumption unit (€)	-	Englund et al. (2023); Cutter (2003)	2021
	Inhabitants with an in-creased compensation for health care (% of inhabit-ants with health insur-ance)	+	West-Vlaanderen (2023)	2022
	Households with income below 60% of the national median (% of total inhabit-ants between 20 and 64)	+	Englund et al. (2023) ; García & Dias (2023)	2021
	Households with income 200% over the national median (% of total inhabit-ants between 20 and 64)	-	Englund et al. (2023) ; García & Dias (2023)	2021
Unemploy-ment	People without a job searching for a job on the 1st of January (% of in-habitants between 18 and 64)	+	Englund et al. (2023)	2021

Age

Research shows that people below 15 and above 74 suffer in a greater amount from heat stress. They have limited resistance and adaptability against extreme temperatures. Elderly also have a reduced body heat regulation and decreased sense of thirst. Elderly living alone are especially vulnerable due to the lack of support. (Klimaateffectatlas, 2024)

Age is also a critical factor influencing mobility during a disaster, as young children and elderly are more dependent on others for evacuating in case of extreme flooding or heat (Ajtai et al., 2023). Elderly also often have difficulties accessing information and are more likely to have various health conditions (Englund et al., 2023).

Language proficiency

Language barriers inhibit information access, for example about how to make homes more climate adaptive, what are the climate risks they are facing or how to evacuate in a climate crisis (Englund et al., 2023). As language is hard to monitor on a national level and direct data is not available, two proxy indicators are used for this. A non-EU birth nationality can be correlated with not speaking the local language (Dutch). Moreover, foreign-born persons may also lack an understanding of the Belgian crisis management system, not follow the national news (which are often spread in Dutch) or may not be registered in the flood/storm warning text system and therefore not know, for example, about where to collect their state-funded sandbags. Another proxy for which data was available is children not speaking Dutch at home.

Health

Health conditions and impairments can increase vulnerability. People who are ill will be more vulnerable to extreme heat, for example when they have a fever. Moreover, people in poor health often have a dependency on others due to mobility impairment, developmental or intellectual disability, which may prevent them from finding a cool spot or from adapting their living conditions. (Englund et al., 2023)

As health data are sensitive and protected, not a lot of data were available on the statistical sector scale. Data on chronic diseases were available and deemed as a good indicator for health. The Flemish government defines the statute of chronic disease as follows: if expenses for medical healthcare per three months exceeded 300 € for eight subsequent terms (in the two previous calendar years) or if total own expenses (outside of health insurance) exceeded a certain amount in two subsequent years or in case of a rare disease.

It should be noted that this definition does not cover all ill or disabled people that will be affected by climate change impacts.

Education

People who have not finished secondary school are more likely to be less informed about the risks of flooding or heat and have therefore likely not taken measures in their homes. Low educational attainment also correlates with low income. (Cutter et al., 2003)

Single-parent households

Single-parent households are more vulnerable to extreme climate events as the parent or guardian is less likely to share the responsibility with another adult. They need to take care of the children, take decisions and displace everyone in case of need. (Englund et al., 2023)

Vehicle ownership

People owning a vehicle are less dependent on public transport in case of emergency, for example in an extreme flood event. They are therefore less vulnerable. (Englund et al., 2023) It can also be argued that cars are less of a priority for people who haven't satisfied their basic physiological needs (food, water, shelter, and clothes), following Maslow's hierarchy of needs theory. Therefore, the assumption can be made that households with multiple cars have their basic needs fulfilled and are less socially vulnerable. (Maslow, 1943)

Housing

For this indicator, there are different ways to interpret the data. Englund et al. (2023) evaluate that renters are less vulnerable, as they can rely on their housing association to take prevention measures. On the other hand, renters often have less financial resources (Cutter et al., 2003) and do not have the power to take adaptive measures themselves. For this research, renting is considered to increase the vulnerability.

Financial vulnerability

Households below average income have less capacity to take adaptive measures, such as air conditioning, awnings, de-paving their gardens or good insurance for their living environment and to cope in the case of an extreme event. Therefore, the indicator number of households with a certain income was used, for which 60 % of the national median was the cutoff. People with over 200 % of the median income will be a lot less vulnerable so this was chosen as a negatively correlated indicator.

Income is not balanced with the amount of people in a household. A person providing for 2 children will be more vulnerable than one who lives alone. The indicator "disposable income per consumption unit" accounts for this: it takes all net incomes in a household, weighted based on the number of people in a household (where children get a lower weight). This gives a more accurate image of what is available for a household.

Additionally, the indicator "number of people with an increased compensation for health care" is included. These are unemployed people, elderly with low financial means, people with disability, orphans, and unaccompanied non-Belgian minors.

As described in the hierarchy of needs, people who don't have enough money to provide in their basic needs will not have the capacity to consider climate risks and therefore might not think about or have the money to adapt their houses or think of an escape plan in case of need. (Maslow, 1943)

Unemployment

The indicator unemployment has an influence on the availability of financial resources and reliance on government systems. Next to the fact that implementing climate adaptive measures in their homes being low on the priority list (Maslow, 1943) and not affordable for them, it is also more difficult to recover from the disaster afterwards (Cutter et al., 2003).

5.3.4. Social Vulnerability Analysis

After acquiring a list of necessary indicators for a social vulnerability analysis, the most recent (oldest 2021) corresponding data was accessed from the Flemish open database (Provincie West-Vlaanderen, 2024). The analysis was made on the same scale as the climate analyses: the statistical sectors. For some indicators, the data was not available on this scale. These data points were substituted with the data from a bigger scale, which is the neighbourhood level. In a few instances, the indicator values were not available for either the statistical sector or the neighbourhood scale. In that case, the average available data from the statistical sectors per neighbourhood were calculated and used as a substitute.

To correspond to the indicators in research as much as possible, some calculations were performed. This was for example summing up age classes or adding two separately collected indicators into one, more information on the data processing as well as the exact sources can be seen in the Appendix B. After calculations, the data were normalised to a scale of 0 to 1 using the following formulas for positive and negative correlations:

$$X' = \frac{X - X_{\min}}{X_{\max} - X_{\min}}$$

$$X' = \frac{X_{\max} - X}{X_{\max} - X_{\min}}$$

This created values in the range [0,1] in order to make comparisons between the indicators. For each statistical sector, these values were then summed up.

These aggregations were then divided into equal intervals to create five social vulnerability classes (SVC) ranging from 1, very low social vulnerability, to 5, very high social vulnerability using the QGIS function “Natural Breaks (Jenks)”. This finds natural groupings of data with a maximum variation between classes and a minimum variation within each class (Ajtai et al., 2023). In addition, the data were mapped using the QGIS-software to represent the spatial distribution of the social vulnerability.

5.3.5. Assessment of social climate vulnerability

First, the scores (1-5) from the climate factors were filtered and the statistical sectors with categories 1 and 2 were taken out in every category in order to focus on the areas that suffer the highest impact.

Following this, the social vulnerability class, and the climate class were summed with equal weights, resulting in a scale ranging from 4-10. This way a storm surge, pluvial and fluvial flood and heat vulnerability score was obtained per statistical sector with at least a moderate issue for these categories. The classes were visualised using QGIS. The combined value will from this point on be called “social climate vulnerability”, which always refers to the result of this analysis and not to other possible meanings of the term.

5.4. Expert Interviews

The interviews were performed with experts from different backgrounds in order to get an insight from multiple perspectives. A full overview of the interviews is given in Table 6. The type of interview used was semi-structured interviews. This means they were guided by questions but flexible towards an organic flow of conversation, exploring ideas and different topics with follow-up “why” and “how” questions. The dialogue can meander around topics on the agenda rather than determinately sticking to the fixed structure. This way thoughts and ideas can be explored, in the interest and knowledge of the participant, and unforeseen issues in the research area may be discovered. (Adams, 2015) Each question was clearly connected to the purpose of the research, drawing data from the experience of the participant and data that are theory laden, guided by existing constructs in the field (Galletta, 2013).

For the analysis of the interviews, they were typed out and then coded with the help of the software NVIVO, according to topics and types of statement.

Table 6: Overview of interviews conducted for this research.

Organisation	Person	Goal for information	Date
West-Flanders Province (Belgium) and Research Institute VITO	Project assistant NBRACER & coordinator of integrated rural development & project coordinator and expert water and landscape (VITO)	• Information about the NBRACER context • Potentially interesting case studies in the province • Necessary datasets • Acquiring contacts with people in Oostende	14th March
Municipality of Oostende (Belgium)	Climate Policy Coordinator (CPC)	Specific for Oostende: • Organisational structure • Climate adaptation planning practices	5th April

Organisation	**Person**	**Goal for information**	**Date**
		• Climate impacts • Social vulnerability in climate adaptation planning	
Water Management Consultancy Sumaqua	Consultant for climate adaptation plan of Oostende	• Collaboration with municipalities • Approach for climate plan and risk analysis • Identifying barriers and solutions	8th April
Research Institute VITO	Project Coordinator and expert water and landscape	• Collaboration with municipalities • Planning context Flanders • Potential solutions	9th April
Municipality of Oostende (Belgium)	Strategic Coordinator (EU projects) & Urban planner	• Process of conducting the City River Project in Oostende • Participation and stakeholder engagement	29th April
Municipality of Esbjerg (Denmark)	Climate Policy Coordinator	Specific for Esbjerg: • Organisational structure • Climate adaptation planning practices • Climate impacts • Social vulnerability in climate adaptation planning	17th May
Municipality of Esbjerg (Denmark) and Municipality of Oostende (Belgium)	Climate Policy Coordinator (DK) & Climate Policy Coordinator and Proposal writer for climate projects (BE)	• Evaluation of the social climate vulnerability approach • Barriers for implementation	24th May

6. Case study: Oostende, Belgium

This chapter will showcase the results from the described analyses. After an introduction to the area, the exposure to climate change impacts, the social context and vulnerability and planning conditions and challenges will be analysed before drawing conclusions on the social climate vulnerability in Oostende.

6.1. The city of Oostende

The West-Flanders province is located in the West of Belgium, bordering the coastline of the North Sea. West-Flanders has 1 222 700 inhabitants (2023), with the main language being Dutch. The capital of the province is Bruges, with about 8 million visitors each year. Another economic cornerstone for the province is the presence of the 2 ports, in Bruges and Oostende. (Statistiek Vlaanderen, 2023)

The city of Oostende is situated in the centre of the Belgian coastline (Fig. 6). It spreads over an area of 4 095,30 ha, consists of 8 neighbourhoods and a population of 72 175 (01/01/2023) people, with a population density of 1 762 inhabitants/km^2 (Statistiek Vlaanderen, 2023). The use of land by human activities is 60,4 % of the total area (2022), with a total of 34,6 % of paved surfaces (2022). This is one of the highest shares of paved surfaces in Flanders (average 15,3 %) (ibid.).

Figure 6: Satellite view of Oostende and location of the city within Belgium.
From: OpenStreetMap (2024).

The average age is 46,9 (compared to 42,5 in Flanders in 2023) and 28,9 % of the population is older than 65 (compared to 21,1 % in Flanders in 2023). Since 1990, this age group has grown by 55,1 % (2023). This is likely due to many elderly moving to the coast after their retirement (CPC Oostende Municipality, 5 April 2024). In summer, the population can mount up to 400 000 people, mostly Belgians (81,7 % in 2022) due to the many hotels and camping grounds, but also the many secondary houses which means that many apartments or houses are empty for most of the year. (Vlaamse Overheid, 2023) A challenge for Oostende is to attract more people and families to live in the city. According to the CPC from Oostende Municipality (5 April 2024), the municipality is trying to do this by investing in culture (events, theatre, casino) and city development (CPC Oostende Municipality, 24 May 2024).

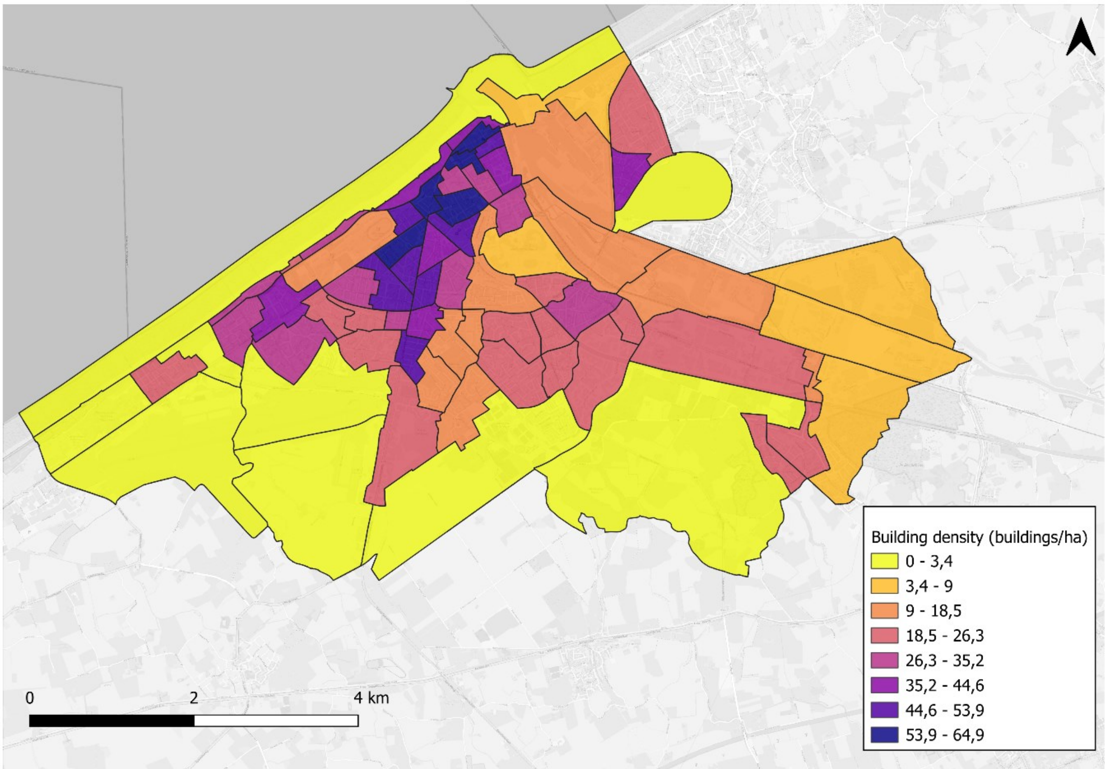

Figure 7: Number of buildings per ha for every statistical sector in 2019.
Data obtained from: Downloadtoepassing (Vlaamse Overheid, 2024).

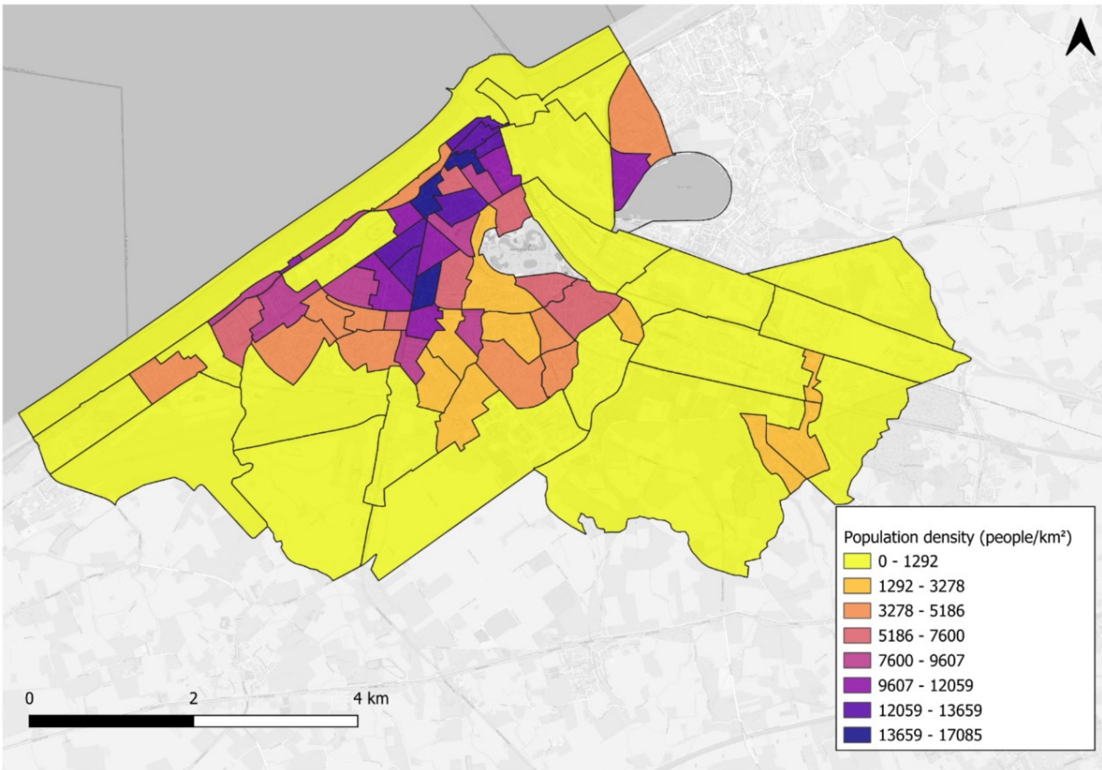

Figure 8: Number of people per km^2 for every statistical sector in 2023.
Data obtained from: Provincies in Cijfers (Provincie West-Vlaanderen, 2024).

Oostende is a “centre city” which in the Spatial Zoning Plan of the Flemish Government refers to cities with a relatively high number of inhabitants compared to its surroundings and has a central function in terms of employment opportunities, healthcare, education, culture, and leisure (Vlaamse Overheid, 2023). The main economic activities in Oostende are tourism (hospitality) and industry due to the presence of both a harbour and an airport. The industry is mostly blue economy, such as offshore wind turbines and offshore aquaculture. Besides that the industrial activities also include sustainable energy, such as hydrogen, the food industry and the transport and logistics sector. (De Schuyter, 2024)

As can be seen in Figure 9, the city can be divided in 3 main parts: the dense city centre, stretched along the dyke (clearly visible in Fig. 10) with mostly houses, shops and recreation, the harbour in the east, which is next to the railway and surrounded by industry, and the less urbanized agricultural area in the south. Aside from the sea and its many recreational opportunities (orange in Fig. 9), there is one large park, the Maria Hendrikapark close to the train station, a large golf course in the north-western area by the coast and a sports park in the south. 94,5 % of inhabitants live within 400 metres of a green area (of at least 0,2 ha) and 84,4 % within 800 metres of a 10 ha green area (Provincie West-Vlaanderen, 2024).

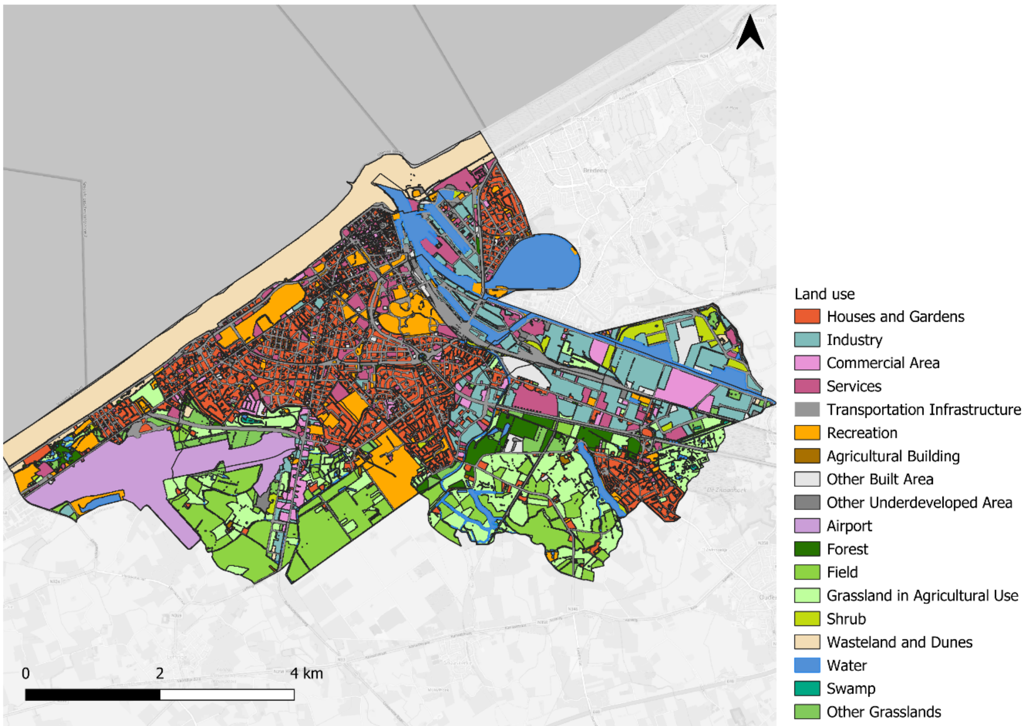

Figure 9: Land use map for Oostende in 2021. Data obtained from: Downloadtoepassing (Vlaamse Overheid, 2024).

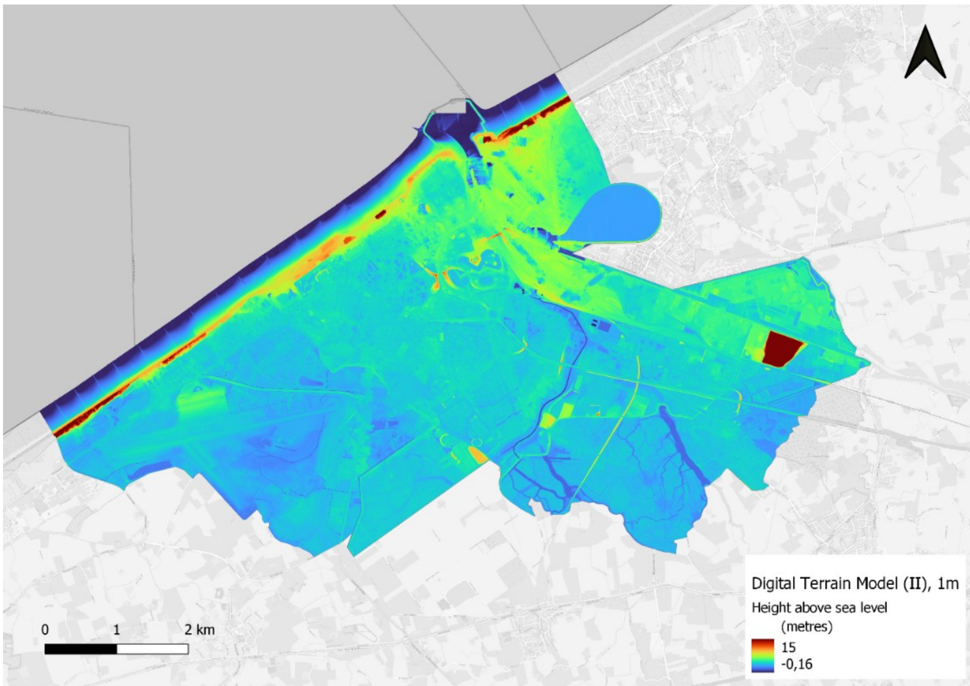

Figure 10: Digital Terrain Model for Oostende. Data obtained from: Downloadtoepassing (Vlaamse Overheid, 2024).

Three sectors (a beach “Strand”, a park “Maria Hendrikapark” and a lake “Spuikom”) were excluded in the analyses as there are no inhabitants in these areas. The values of the climate exposure and social vulnerability per statistical sector can be found in Appendix C & D (social) and E & F (climate).

6.2. Climate challenges in Oostende

Flanders is already experiencing climate change in multiple ways. The average temperature in the region has increased by 2,6 °C, the precipitation has increased as has the sea temperature. Based on climate projections, the region is expecting an increase in winter rainfall of 7 % by 2050 and up to 20 % by the end of the century, coupled with a higher intensity of rain events. Sea level is projected to rise by 80 cm by 2100. (Flemish Environment Agency, n.d.)

By 2100, the entire municipality will have at least 28 days with an average temperature over 30 °C (Flemish Environment Agency, 2024a). The experts point out that heat, which currently does not play a large role in planning practices, will pose a great threat in the future (Consultant Sumaqua, 8 April 2024; CPC Oostende Municipality, 5 April 2024). This can be expected as the city is largely made up of sealed surfaces and generally built quite densely (Fig. 7). There are also not many large green spaces in the city. Another impactor mentioned by the interviewed consultant from Sumaqua (8 April 2024) is that increased drought will lead to subsidence and damaged houses, which has already been observed in the last years in Flanders. As can be seen in Figure 11, heat exposure is highest in the city centre and becomes less towards the fringes of the municipality.

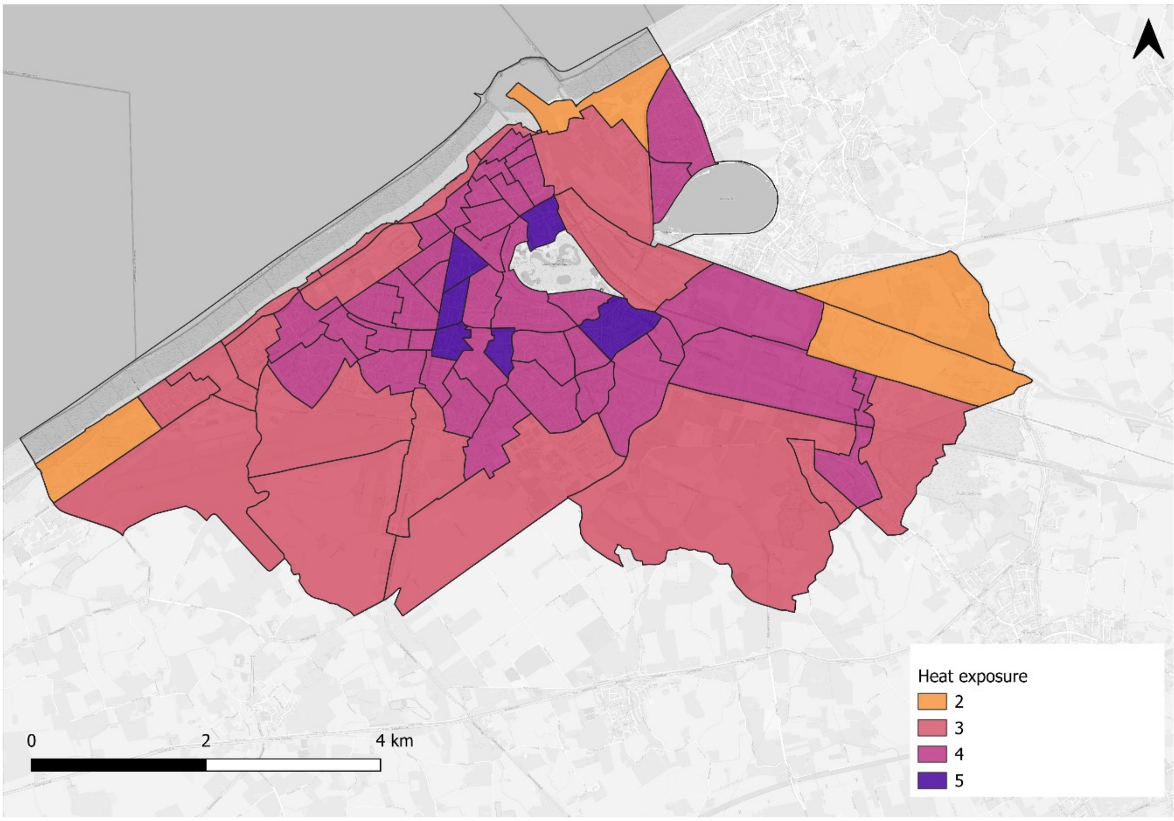

Figure 11: Heat exposure, based on number of vulnerable people exposed to heat, weight of heat waves, number of days with an average temperature > 25 °C and number of days with a maximum temperature > 25 °C (2100, 20-year event). Data obtained from: Klimaat-kaarten catalogus (Flemish Environment Agency, 2024a).

Yearly rainfall in Oostende will increase from 815 mm (2019) to 1029 mm (2100) following the high impact scenario (Flemish Environment Agency, 2024a). According to the consultant from Sumaqua (8 April 2024) and the CPC from Oostende Municipality (5 April 2024), water-related climate impacts, such as flooding, will become a great risk to the city.

This is partly due to the topography of the surrounding region and the city, where the city centre is located lower than the dyke and the northeastern part of the city. This is apparent in Figure 10. The centre therefore collects water and does not have a natural way of irrigation towards the canal or sea (CPC Oostende Municipality, 5 April 2024). Currently a large pump is active in the city. This pump is, however, not dimensioned for the future, where more intense pluvial flooding is very likely. In Figure 12 the exposure from pluvial flooding is shown. As mentioned, the city centre has a high risk due to the "valley" shape, but also because it houses many vulnerable institutions (childcare, pre-school, primary and special education, hospitals, and care homes). Important to remark is that the area “Renbaan”, situated in the northwest next to the dyke is marked as a priority area. As pointed out by the Proposal Writer from the Municipality of Oostende (24 May 2024) this area consists primarily of a golf course, which is lying lower than the surrounding parts of the city (Fig. 10). It is, however, still a priority area due to the many buildings affected in the area and the many vulnerable institutions that can flood, according to the province’s models.

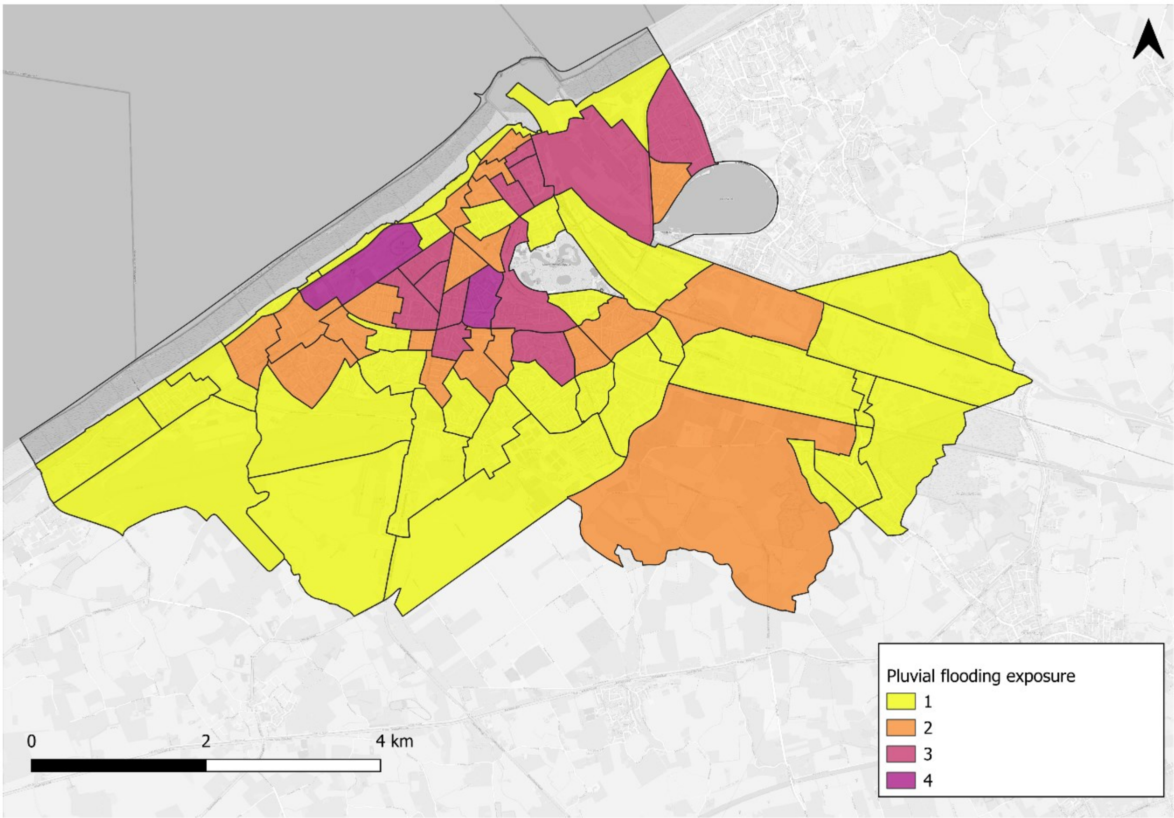

Figure 12: Exposure to pluvial flooding, based on number of vulnerable institutions with inundation, number of buildings affected by inundation and water depth at a precipitation event (2050, 1000-year event). Data obtained from: Klimaatkaarten catalogus (Flemish Environment Agency, 2024a).

Oostende is situated along the North Sea Coast. There, sea level is expected to rise by 80 cm towards the end of the 21st century (in a middle impact scenario). The dykes might still protect inhabitants from the sea at this level, but in case of storm surges (from the northwestern direction), many areas will be flooded as the water level can currently reach 7 mTAW[1] and 7,5 mTAW by 2075 during a 1000-year storm event (Fig. 13). The Flemish government, who is in charge of protecting the Belgian

[1] mTAW (metres “Tweede Algemene Waterpassing”): the Belgian reference used for water height. It describes the water height at low tide and is 2,33 m lower than the sea level which is used as a reference, for example in the Netherlands or Germany. (Agentschap Natuur & Bos, 2024)

coastline, has performed an assessment for the whole coastal area. Following this, they have made a Masterplan Coastal Safety in 2011 for protecting the coast until 2050 (for example by sand replenishments (7 mTAW+ 30 cm sea level rise)) (CPC Oostende Municipality, 5 April 2024; Flemish Environment Agency, 2024b). The harbour of Oostende and its surrounding areas will still be vulnerable however, as can be seen in Figure 13. At a severe storm surge today, a zone of about 4000 ha would flood. For this, a climate adaptation design plan has been drawn up (May 2024) for, amongst other measures, a closable storm surge barrier. (Flemish Agency for Maritime and Coastal Services, 2024) The government is also working on a long-term Coastal Vision for a scenario of 3 metres sea level rise by raising and broadening the dunes and dykes and moving the shoreline 100 metres seawards by 2100, creating a large buffer (Flemish Government, 2023).

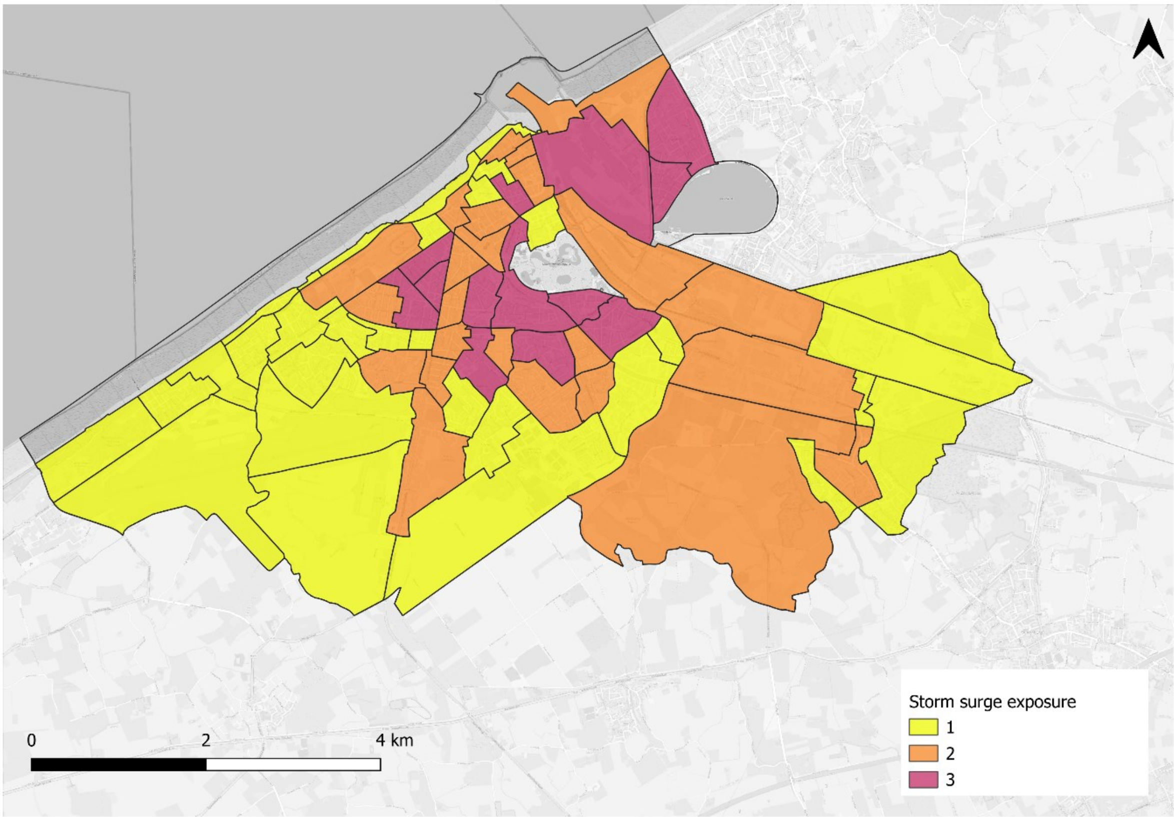

Figure 13: Exposure to storm surge flooding, based on number of vulnerable institutions to flooding by a 1000-year storm surge, number of buildings affected by this storm surge and water depth (7,5 mTAW by 2075, 1000-year event). It is important to note that the data do not take into account the recently decided measure of moving the shoreline. Data obtained from: Klimaatkaarten catalogus (Flemish Environment Agency, 2024a).

The canals and docks of the harbour are prone to floods, just like the many creeks in Oostende. This makes the municipality moderately vulnerable for fluvial flooding. As can be seen in Figure 14, the statistical sectors “Konterdam” and “Konterdam Koebrug” are vulnerable due to the neighbouring dock and the “Keignaartwijk” neighbouring the Creek “Grote Keignaart”.

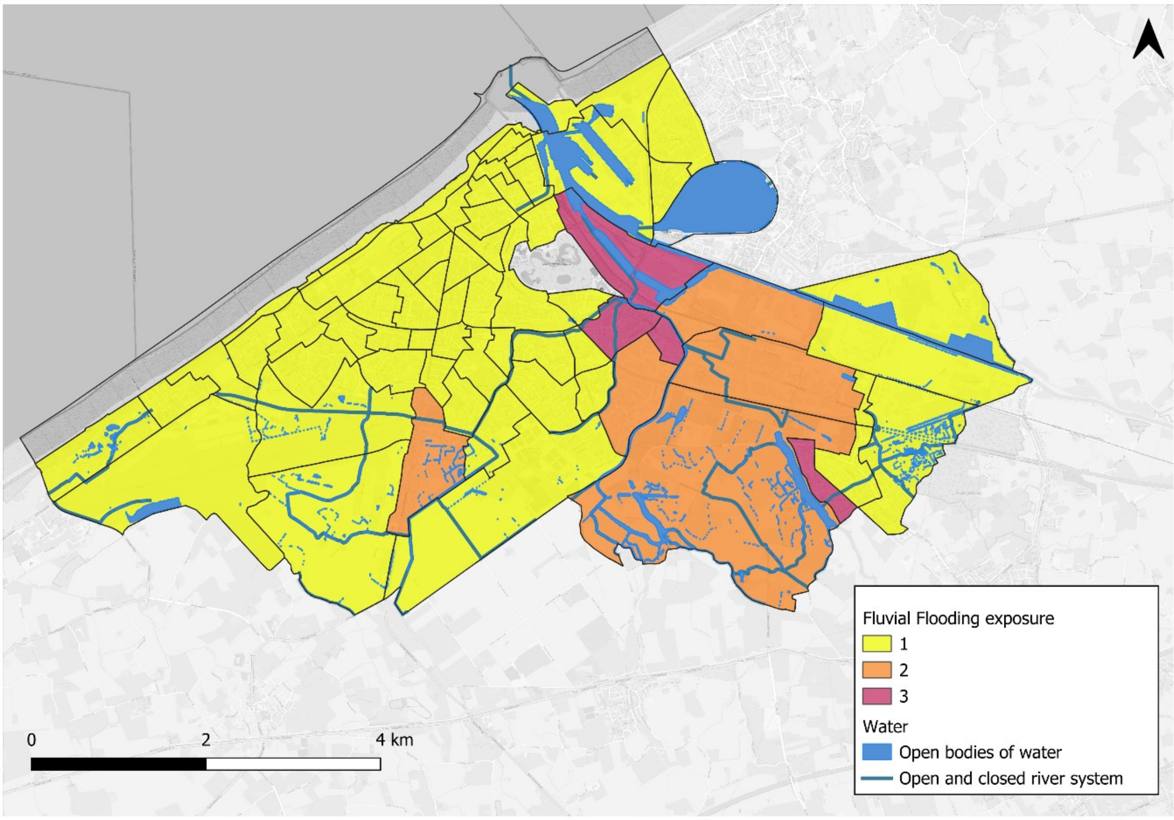

Figure 14: Exposure to fluvial flooding, based on number of buildings affected by flooding and water depth at a flood event (2050, 1000-year event). Data obtained from: Klimaatkaarten catalogus (Flemish Environment Agency, 2024a).

6.3. Social vulnerability in Oostende

Oostende is a multicultural city with 27,8 % of its inhabitants having a foreign origin (2023). This is high compared to the Province of West-Flanders (15,3 %) and the Flanders region (26 %). The city also has the 3rd highest unemployment grade of Flanders (9,7 % in 2022) and a high percentage of long-term job seekers. (Belpaeme, 2020; Vlaamse Overheid, 2023). The median income per declaration was € 24 806 in 2021, which is lower than West-Flanders (€ 27 983) and Flanders (€ 28 909) (Provincie West-Vlaanderen, 2024).

Most of the residential units in Oostende are apartments (59,9 % in 2023). This number is also increasing. At the moment, 78,4 % of households in the city consist of one (46,7 %) or two (31,7 %) people. In total 45,2 % of people rent their homes, which is a lot more than the 30,7 % in the province of West-Flanders (2023). 9,1 % of households live in social housing. (Provincie West-Vlaanderen, 2024) These are mostly situated in the southwestern part of the city centre (CPC Oostende Municipality, 5 April 2024).

The Flemish government has great attention for children growing up in deprivation. They use the term “kansarmoede” which in literal translation means “opportunity poverty”. This means a persisting situation in which people are restricted in their ability to participate fully in society. To break the cycle, the government focuses on children and scores every city and neighbourhood on 6 criteria: total household income, employment situation, education, housing, health, and children’s stimulation level. For the city of Oostende, the deprivation index is 28,6 % (2022), which is the percentage of children born in a deprived household. Figure 15 shows the criteria for which deprived children had insufficient scores. For example, 91,9 % of deprived children had an insufficient score for household income. (Vlaamse Overheid, 2023)

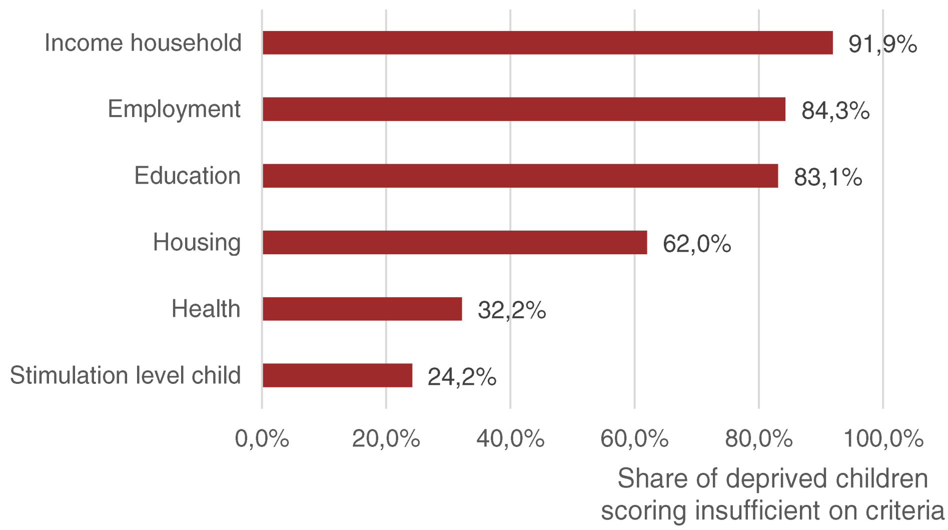

Figure 15: Number of children in deprivation with insufficient score on several criteria.
Adapted from: Gemeente in vogelvlucht, Oostende (Vlaamse Overheid, 2023).

In the city structure the CPC from the Municipality of Oostende (5 April 2024) recognises a lot of segregation depending on wealth. In Oostende there are different areas that are separated by income level. The city has made efforts to attract high income families to move to the area adjoining the coast, which is why the income level is especially high in that area (CPC Oostende Municipality, 5 April 2024). The suburban areas also have a higher income, while low-income populations tend to live in the city centre (ibid.). Due to this distribution the CPC from Oostende (5 April 2024) sees the priority for climate adaptation action in the city centre and not in the suburban areas, as those in most cases have the means to do some of this work themselves. In past floods (for example in 2021), many people were not insured for flood damage and were not aware of the risks, which is why the consultant from Sumaqua (8 April 2024) advocates for informing residents of climate risks.

For this part of the analysis, the social vulnerability index was assessed for the whole city of Oostende, showing the vulnerability of the people living in the statistical sectors in relation to each other.

As can be seen in Figure 16, most socially vulnerable statistical sectors are situated in the city centre. According to the used indicators, in order of vulnerability, the most socially vulnerable sectors are “Cardijn” (0,74), “Hospitaal” and “Wapenplein” (both 0,69), “A. Buylstraat” (0,63), “Nijverheidsstraat” (0,62) and “Renbaan” (0,61). In Figure 17, an overview is given of these six sectors and what indicators make them vulnerable. It can be seen that the strongest impact on the SoVI is caused by the negatively correlated indicators (high income, number of vehicles, disposable income, and high education). A socially vulnerable neighbourhood will, for example, have less cars (which would have made them less vulnerable). Following these are, in order of importance, non-Dutch speaking of children at home, chronic diseases, people who rent, elderly and unemployed people.

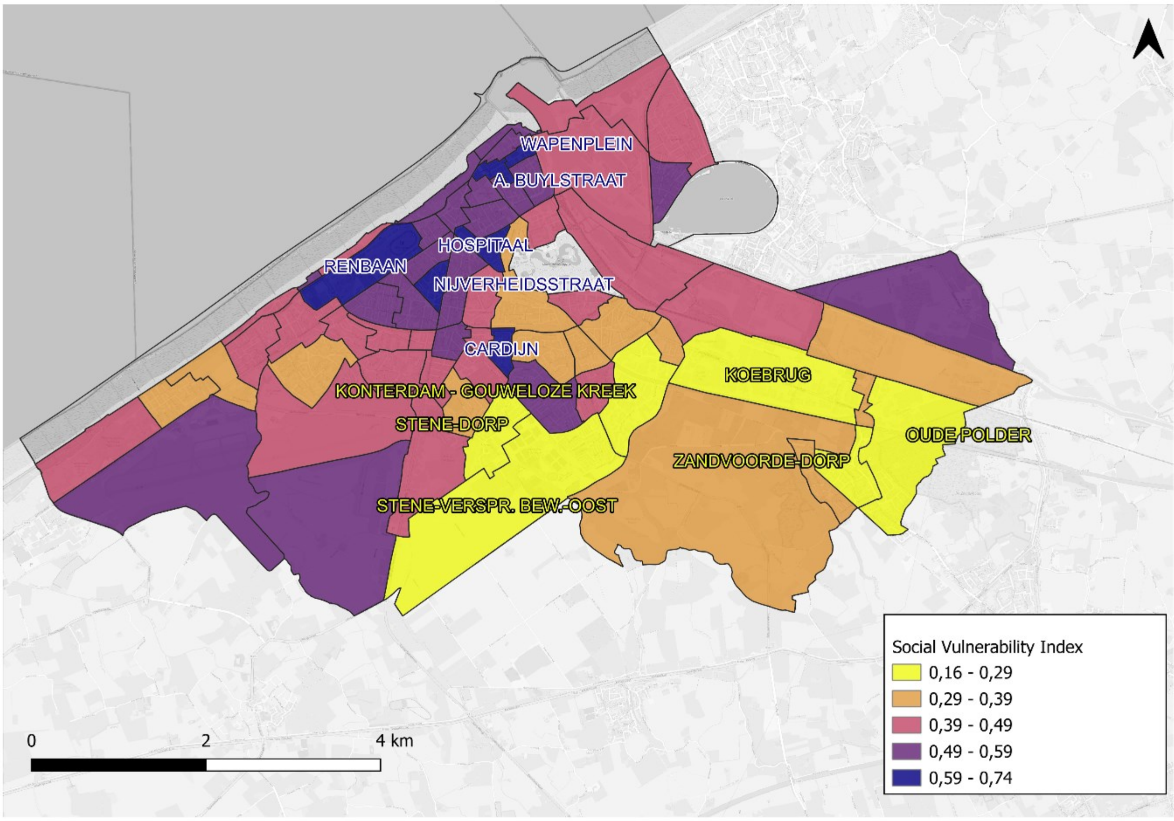

Figure 16: Social Vulnerability Index (SoVI) for the statistical sectors in Oostende. Data obtained from: Provincies in Cijfers (Provincie West-Vlaanderen, 2024).

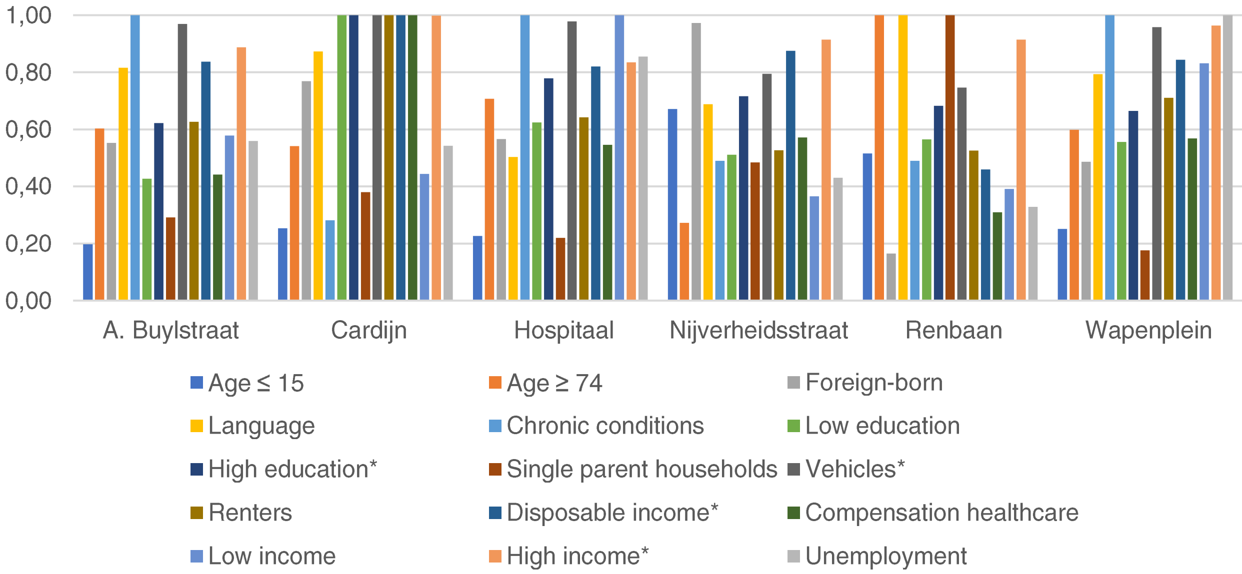

Figure 17: Social vulnerability indicator scores (0-1) for the statistical sectors with a total vulnerability class of 5 (average SVC > 0,59). Indicators with a negative correlation are indicated with a *, as they are indicators for lowering vulnerability. Due to the rescaling process as presented in 5.4.3, a higher score indicates a higher vulnerability also for the negatively correlated values.

6.4. Assessing social climate vulnerability in Oostende

After calculating the climate and social vulnerabilities for the different statistical sectors, the exposure to the events of fluvial flooding, pluvial flooding, storm surges and heat was combined with the social vulnerability to find areas where people are affected by both a high SoVI and high exposure.

Due to its high density and generally high share of sealed surfaces, the whole city will be affected by heat. As can be seen in Figure 18, the distribution of high heat impacts is spread throughout the whole city, but especially in the areas that are mostly residential. The highest value can be found in the sector “Cardijn”, which is located in the centre. It is also the sector with the highest SoVI. One reason for this might be that it includes a social housing project. The sector has a share of 31,2 % of inhabitants who are not born in Belgium and 57,4 % do not have a high school diploma. Furthermore, 96,8 % of inhabitants are home renters. (Provincie West-Vlaanderen, 2024)

The areas with a lower combined risk in the south-eastern part of the city have a lower building density as well as a high share of unsealed surfaces, as the houses in this area are mostly detached and semi-detached houses with attached gardens. These factors might be the reason for the difference in heat distribution in the area. Here, the SoVI is quite low, as the there is, for example, a low share of population over the age of 74 (7,82 %) as well as a lower amount of people not born in the EU (4,40 %). (Provincie West-Vlaanderen, 2024)

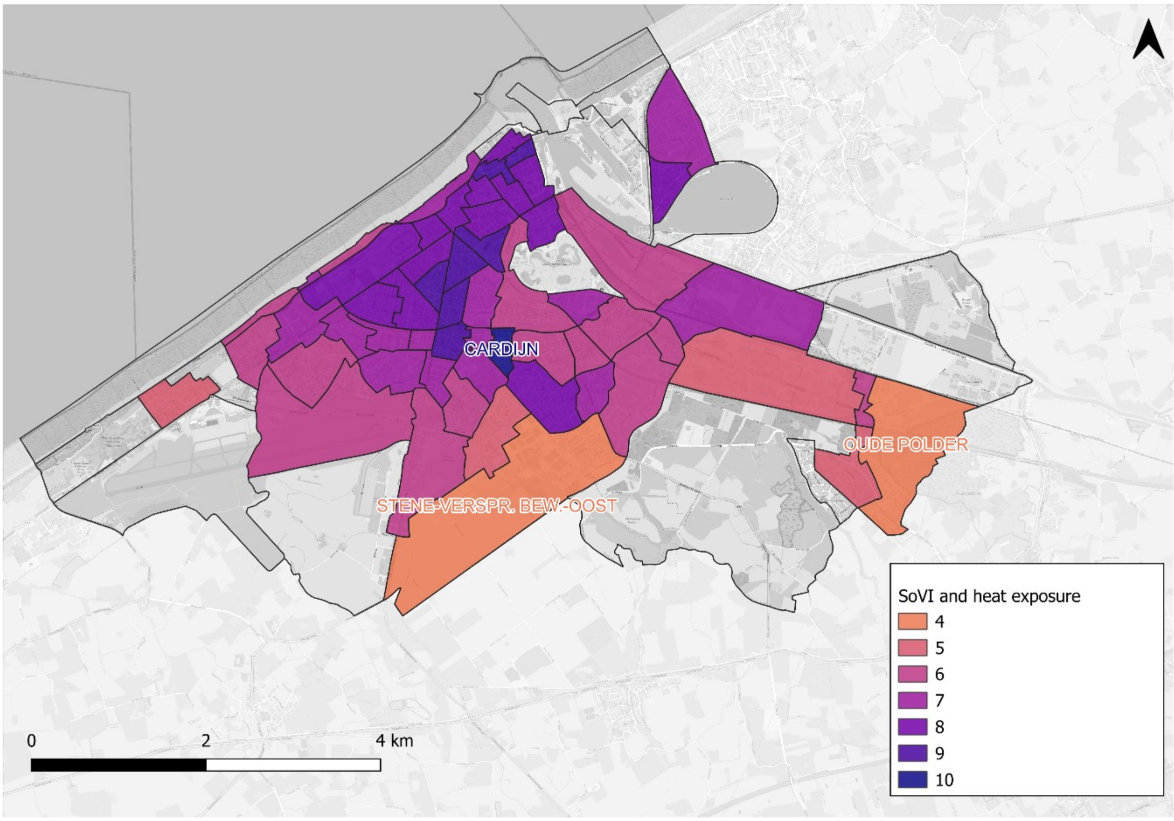

Figure 18: The total score of the SoVI and heat exposure.

The combined value for areas affected by pluvial flooding and SoVI is shown in Figure 19. Partly explained by the topography of the city mentioned earlier (Fig. 10), the pluvial flooding exposure is highest in the central and northern parts of the city. This is also where the highest SoVI values can be found. The highest combined risk is in the sector “Renbaan”, a part of the city close to the centre and to the coast. As mentioned before, this area contains a large golf course but also many buildings and vulnerable institutions that get flooded. Next to this exposure, it is also a socially vulnerable area due to the 33 % of people over 74 years old (mostly living in the retirement home) and the low level of education, with 38,8 % having no secondary education. (Provincie West-Vlaanderen, 2024)

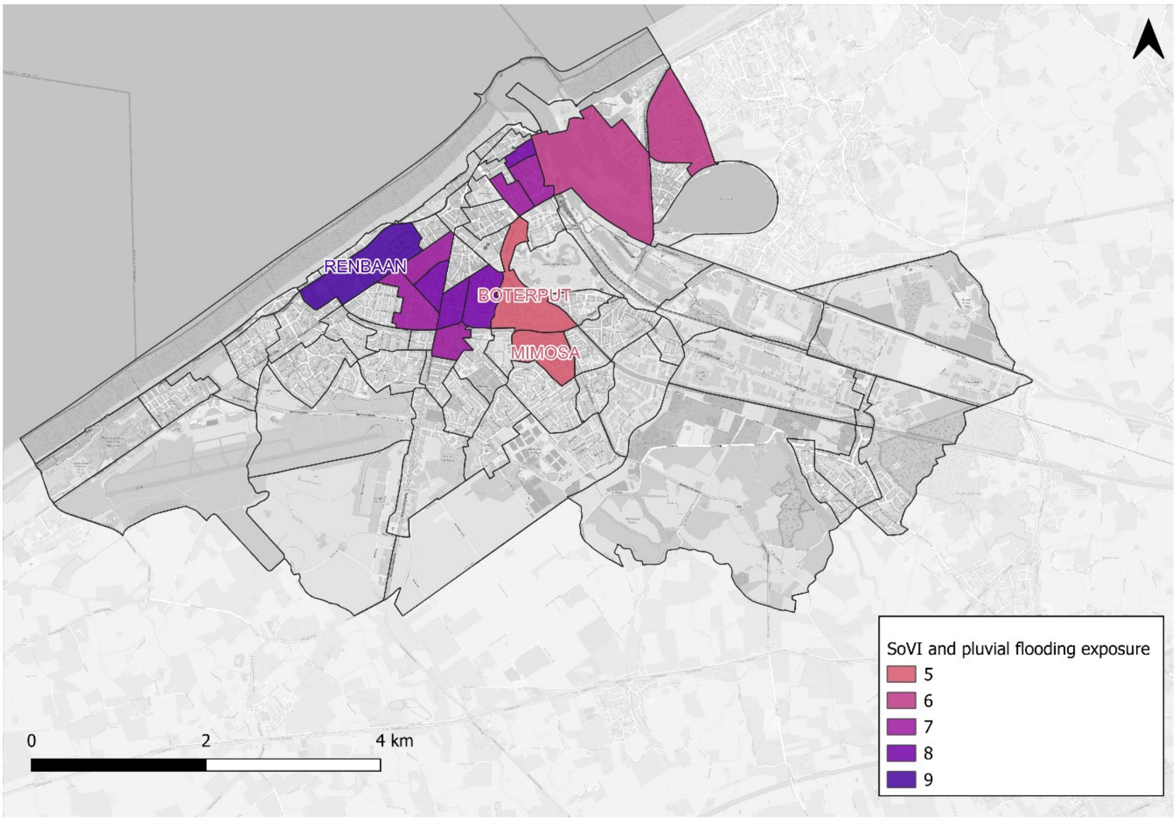

Figure 19: The total score of the SoVI and pluvial flooding exposure.

For storm surges, the highest combined risk is again in the city centre (see Fig. 20). The sector with the highest value is “Nijverheidsstraat”. The population has a higher share of people not born in the EU (35,4 %) as well as a high share of renters (53,6 %). With 18,33 % being under the age of 15, the population is also younger than in most other sectors in the city. (Provincie West-Vlaanderen, 2024) Similarly to the pluvial flooding effects, the water gathers in the city centre due to the topography (CPC Oostende Municipality, 5 April 2024) leading to a high value in the water depth (115,48 cm) and affected buildings (2373) in a 1 000-year storm surge event in the year 2115.

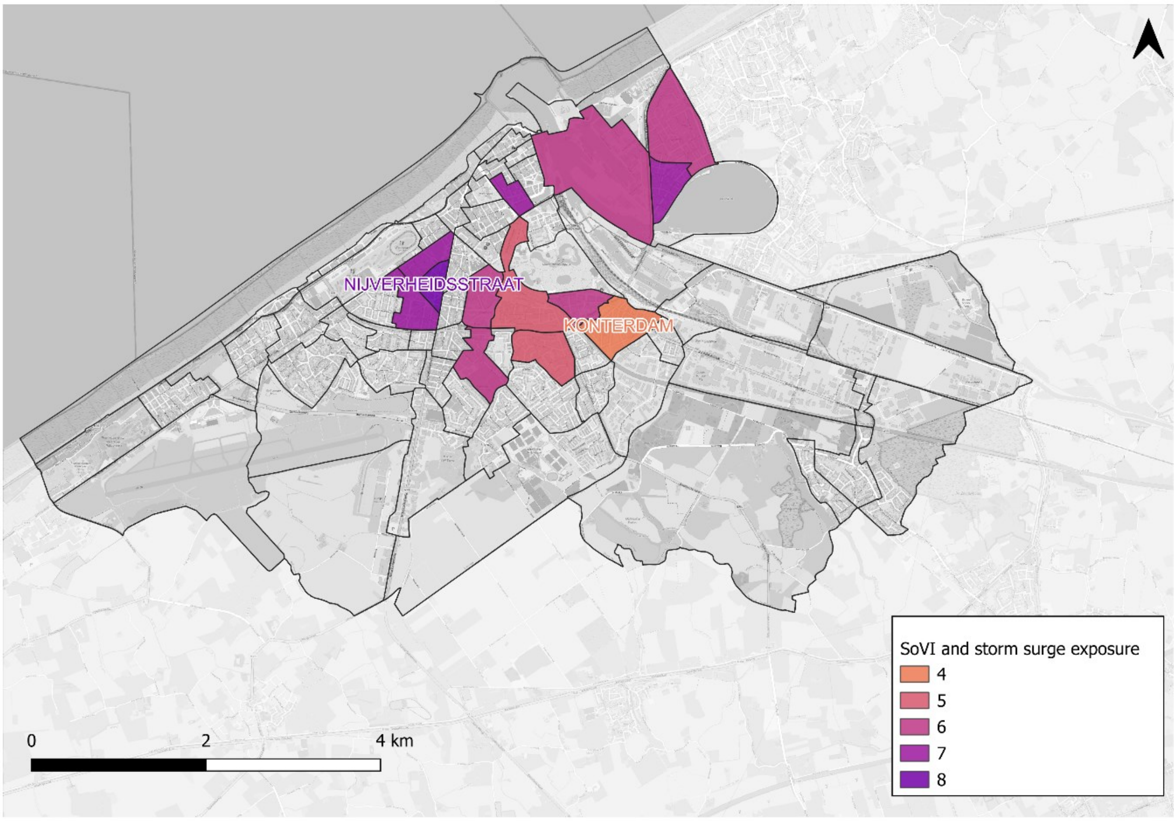

Figure 20: The total score of the SoVI and storm surge exposure.

Fluvial flooding is only an issue in small parts of the city, as can be seen in Figure 21. Due to the streams and creeks being located in the south-eastern part of the city, this is also where the flooding effects can be seen. As large parts of this area are being used agriculturally (as seen in Fig. 9), not many people are affected by fluvial flooding. This was also confirmed by the CPC from the Municipality of Oostende (5 April 2024) who does not evaluate fluvial flooding as a major concern for the city. Still, 3567 inhabitants live in the four depicted areas and are socially vulnerable as well as exposed to fluvial flooding.

The area with the highest combined value is “Vlotdok”, located north-east of the city centre. This area has 216 people, of which 41,8 % do not have an education above primary school level and 46,73 % of children do not speak Dutch at home.

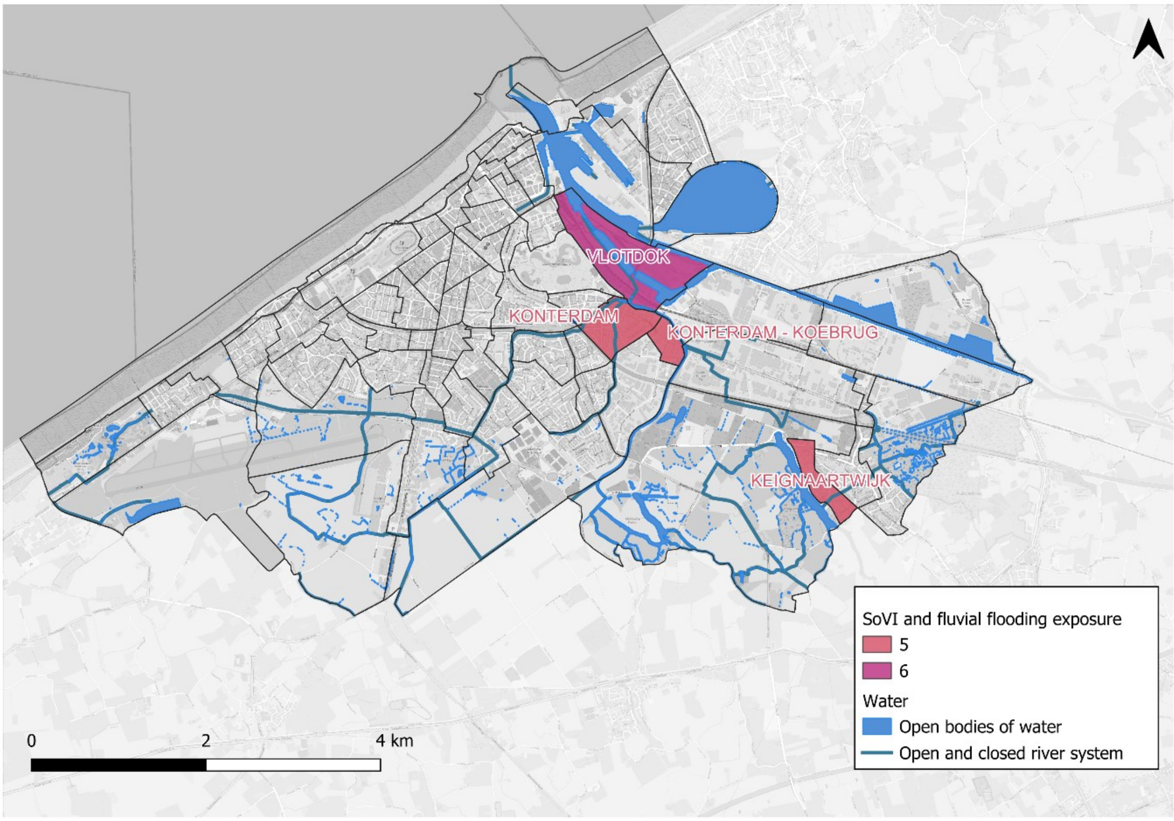

Figure 21: The total score of the SoVI and fluvial flooding exposure.
This map also shows the river system of Oostende.

The radar chart in Figure 22 shows for every social vulnerability class how the average climate vulnerabilities are scored. From this figure it is clear that heat is affecting Oostende on the largest scale, and fluvial flooding is only a minor vulnerability for the city. The chart also shows that the higher social vulnerability classes are also more impacted by heat, storm surges and pluvial flooding. This is in part due to the use of the indicator “vulnerable institutions” (childcare, hospitals, care homes) in the climate exposure scores of storm surge and pluvial flooding and the indicator “number of vulnerable people exposed to significant heat stress” (aged between 0 and 4 and over 65 years) in the climate exposure score of heat. These indicators are assumed to have a dependency with some of the social vulnerability indicators.

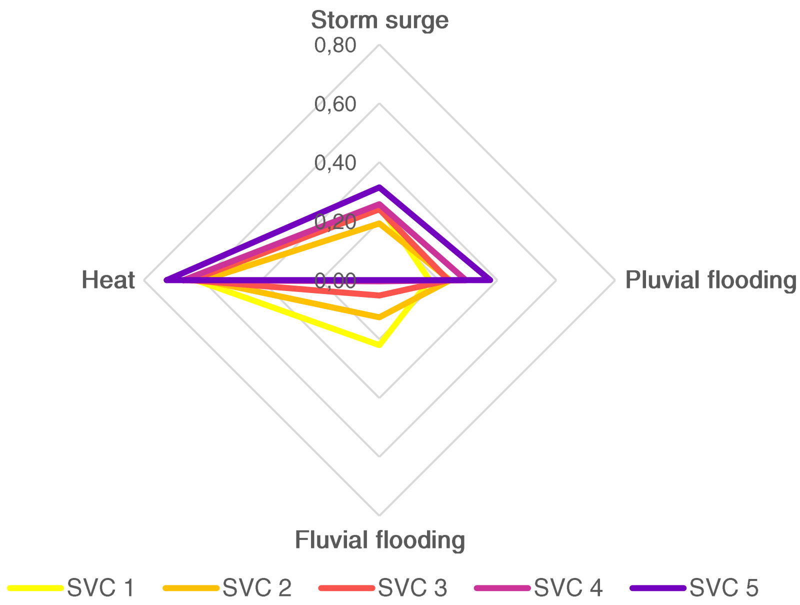

Figure 22: Radar chart showing the average climate vulnerabilities (0-1) for every social vulnerability class (SVC).

Summarising, vulnerable populations in Oostende will be affected by climate impacts, especially by storm surges, pluvial flooding, and heat. Influencing factors are the density in the city centre as well as the topography of the city, which makes water flow towards the centre, where most of the more vulnerable people live.

Priority in adaptation measures should be directed to the sector "Nijverheidsstraat" and the surrounding area (for example the two sectors with the identical name "H. Hartplein"). Those can be seen to be affected by a high SoVI as well as by all climate impacts excluding fluvial flooding.

6.5. Planning practices in Oostende

The municipality of Oostende is working on a climate adaptation plan, at the time of this research. The plan is to be published around July 2024. A consultancy has conducted risk and impact assessments, to see how projected climate change impacts will influence the city. The main part of the plan will be more than 50 actions with specific goals for the city to meet. In the process of making this plan, different stakeholders were engaged in different workshops. (Consultant Sumaqua, 8 April 2024) In contrast, the CPC from the Municipality of Oostende (5 April 2024) evaluates that there was not much participation for the adaptation plan. For many of the interviewees, including vulnerability was interpreted as having the same meaning as participation. In the City River Project[2] participatory measures consisted mostly of informing people living in neighbouring areas and inviting them to a workshop (Strategic Coordinator, 29 April 2024). In the beginning of this project, there was no clear strategy on how to create opportunities for participation, which is why they had to create an action plan for the participatory measures:

> "[The funding proposal to the government] was first denied because we didn't involve enough citizens. It was a correct remark, so we rewrote our project application, and we spent a big deal of the project into something we called the co-creation project. The fact that the application was denied and then we had to rewrite it to really involve the citizens was a trigger for the policy makers that we really had to put more effort into those participation processes, for which we didn't have a good culture yet. We always took participation into account, but we didn't have good methods to do so and to reach people. That co-creation part was picked up and we launched a proposal for experts to help with this. We spent 2,5 years on a really thought-through project trajectory linked to the city renewal effort." (Strategic Coordinator, 29 April 2024)

In the collaboration of the municipality with consultancies, the consultant from Sumaqua (8 April 2024) identified that in some instances it would be better to create synergies between efforts in order to avoid that several entities work on the same issue. Within the municipality it has been recognised that there is generally a silo-approach, where departments do not work together as much as they could (CPC Oostende Municipality, 5 April 2024). Additionally, overlapping plans, such as the climate adaptation plan and the rainfall and drought plan, are often managed by different consultancies and municipal departments, leading to misaligned efforts and actions (Consultant Sumaqua, 8 April 2024). To counteract these issues, the CPC from the Municipality of Oostende (5 April 2024) is working on establishing a new governance structure, where interdisciplinary teams work more together more horizontally.

[2] The City River is a recently built artificial river that is part of a new, prestigious developmental area (residential) in the eastern part of Oostende. The area is not yet inhabited. The construction is a nature-based solution, as the water is allowed to infiltrate into the ground, preventing inundation in the area and forming a barrier against the salt water, preventing salinization. (Strategic Coordinator; Urban Planner, 29 April 2024)

Another issue the municipality is facing is the financing. For many problems, there is a technical solution, but those are often expensive and need a lot of specific knowledge, for which the municipality doesn't have the resources (CPC Oostende Municipality, 5 April 2024). At the same time, in some cases people see a lack of financial resources as a reason not to work on an issue, dismissing opportunities (CPC Oostende Municipality, 24 May 2024). The CPC from the Municipality of Oostende (24 May 2024) speculates that some people who work in the municipality are very used to their way of working and are not open for a change in procedure.

The consultant from Sumaqua (8 April 2024) described that current efforts and implementations are quite slow. In the business-as-usual scenario the company calculated for the adaptation plan, the renovation of 0,5 % of paved surfaces per year (about two streets in the city centre) will be too slow to reach their goals (ibid.). Generally, the dense structure of the city makes implementations difficult (Consultant Sumaqua, 8 April 2024). Especially nature-based solutions need a lot of space, which is why the Researcher from VITO (April 2024) advocates for a hybrid approach of nature-based and grey solutions.

7. Discussion

This chapter aims at putting the results presented in the previous chapter into context. In the first part, the application of the method will be discussed from the perspective of the chosen framework of Urban Climate Justice. In the following part, the limitations of the results will be pointed out. Lastly, there will be a look to future applications of the method and other research avenues that can flow from this research.

7.1. Social climate vulnerability through the lens of Urban Climate Justice

To evaluate whether the strategy of combining climate exposure with Social Vulnerability can contribute to a more just urban planning practice, the conceptual framework of urban climate justice as introduced in Chapter 3 will be employed. This framework defines justice within 4 dimensions: recognitional justice, distributive justice, procedural justice, and restorative justice. As has been addressed before, the dimensions are always to be seen in relation to each other and cannot be separated completely. For structuring this chapter, they are used as a frame, but their interconnectedness should be kept in mind. The following parts will dive into each of these justice dimensions for a qualitative assessment of the strategy proposed in this research.

Recognitional justice

Recognitional justice emphasises the diversity of societal actors, their varying adaptation needs and abilities. It is the recognition of the existence of disadvantaged positions of minority groups. (Juhola et al., 2022) Bulkeley et al. (2014) suggest that recognitional justice should be regarded as the lens through which the other dimensions of justice should be viewed.

The strategy of combining climate exposure with social vulnerability assists municipalities in identifying injustices in the city. The combined maps reveal areas where people are particularly affected by, for example, flooding. This assessment also highlights how vulnerability depends on multiple factors and not just poverty, as is often associated with the term. Implementing a multi-factor approach can help raise awareness for the complexity of the concept and raise awareness among local stakeholders, such as social housing organisations or citizens. Although this assessment considers a broad range of factors contributing to vulnerability, it is important to recognise that it cannot encompass every socially vulnerable individual. Individual situations can highly differ within the statistical sectors. By deciding on certain indicators, some people will, per definition, be excluded. Relevant factors for social climate vulnerability that were not taken into account in this research are people living in social isolation, disabled people (who might not always be included in the indicator "chronic diseases"), pregnant people (who for example will suffer more from heat stress) and incarcerated people (who do not have a say in their own living conditions) (Baciu et al., 2017). Other population groups that are socially vulnerable, which may indirectly affect their vulnerability for climate impacts are people of colour, people identifying as LGBTQIA+, women and other marginalized populations. (ibid.)

It should also be noted that using indicators simplifies the reality which means that assumptions inevitably are made about people's competences and financial means that might not be right for the individuals living in the statistical sector (CPC Oostende Municipality, 5 April 2024). While the analysis makes overarching patterns across the city visible, it cannot account for individual assessments. It is merely a first step, after which it might be possible to go to a smaller scale on this basis.

Distributive justice

Distributive justice concerns how climate impacts are distributed in society as well as the distribution of adaptation measures and their impacts (Juhola et al., 2022). These can be both benefits and burdens carried by the area where the measures were implemented or elsewhere.

The climate and social vulnerability strategy aims at influencing distributions of climate measures and leads to a more targeted distribution to people who need them more. The maps aid municipal planners in setting just priorities for using their limited budget and resources. This way climate adaptive measures are distributed in an equitable rather than equal way across the municipality.

In Denmark, as reported by the CPC from Esbjerg Municipality (17 May 2024) the houseowner is usually responsible for taking risk-prevention measures. That has the effect, that some people cannot afford the necessary adaptive measures at their properties. It can also mean that people who rent depend on their landlords or property management to protect them from extreme events. One way that the municipality of Esbjerg counteracts these effects is to use taxpayer money to build flood prevention to protect a low-income area in the city centre.

Procedural justice

Procedural justice looks at how climate adaptation planning processes are designed and executed. It concerns the inclusivity of processes throughout planning, implementation, monitoring, and evaluation (Juhola et al., 2022).

When considering social vulnerability in climate adaptive planning becomes a standard procedure, more inhabitants will be included in the planning process. As this analysis was conducted using the data that is already available to the municipality, it poses a manageable and accessible option. This could make it less burdensome to include the notion of social vulnerability and adopt it as standard practice.

Furthermore, adopting these methods will make it possible to raise awareness about the importance of linking the climate and social domain within the municipality.

> “It helps to go towards thinking in a collective way and open new innovative solutions of cooperation.” (CPC Oostende Municipality, 24 May 2024)

> “We have to do everything. Addressing climate adaptation but also poverty, we have to do it collectively, we have to make a collective approach.” (Proposal Writer Oostende Municipality, 24 May 2024)

The maps as a visual and approachable result could help opening up a conversation and be used as a communication tool for urban planners (CPC Oostende Municipality, 24 May 2024). Related to this is the breaking of the silos within the municipality. By showing the importance of the social-climate link, planners might see it useful to work together on this topic and form interdisciplinary project groups. This intention is starting to approach reality as the CPC from the Municipality of Oostende (5 April 2024), is seeking to restructure the workflow within the municipality to establish a more horizontal approach. Identifying common issues and points of action, such as through the applied analysis, might help start these collaborations. An important remark made here is that people making the decisions are often influenced by the predominant culture, learned habits as well as personal values (CPC Oostende Municipality, 24 May 2024).

An important consideration in the procedural justice is the responsibility of the municipality to monitor gentrification within the socially vulnerable areas. Researchers have identified the risk of “climate gentrification” (Keenan et al., 2018; Shokry et al., 2020, 2022). On the one hand this can mean that areas that are less affected by climate change have an increase in value, making safe housing less accessible to some (Keenan et al., 2018). It can also refer to the danger that implementing adaptation measures can increase the value of an area, pushing vulnerable populations to different areas of the city (Shokry et al., 2020). This has also been identified as a risk by the Proposal Writer from Oostende Municipality (24 May 2024). They stress that if more vulnerable people are moved to other parts of the city, it might look like the vulnerability has changed, while there are other people living in the area. One strategy they mentioned is to keep social housing project in the areas of adaptation to prevent this process.

Influencing how much social considerations find room in the planning efforts of the municipality, is which consultancy is hired. In case of the developing climate adaptation plan, the consultancy that is responsible for the plan is specialised in blue-green solutions, which is why this is what the plan is focused on (CPC Oostende Municipality, 5 April 2024).

> “If you don’t ask it very explicitly that they need to integrate the social component into the studies, the consultancy companies don’t deliver it. In that sense, it adds up a new layer. “ (CPC Oostende Municipality, 24 May 2024)

The municipality holds the right to choose who to collaborate with and what aspects need to be included, thus impacting the outcomes.

Another layer to the procedural level is that, according to Dhar & Khirfan (2017), research on adaptation often highlights that community-led, bottom-up assessments of vulnerability are crucial, when in practice adaptation efforts mostly happen top-down. In this regard this analysis could be expanded, for example through having a dialogue with inhabitants and other stakeholders and point towards issues that cannot be assessed from socio-economic and climate data only.

Restorative justice

Restorative justice addresses the restoration of negative impacts of climate change, by first acknowledging that an injustice exists due to the suffered losses and damages, subsequently identifying the victims and offenders and then taking inventory of possible compensations and repairs (Juhola et al., 2022).

Considering how the applied method could influence the aspect of restorative justice, it could be said that making differences in impacts for different kinds of populations visible could be the first step to taking action to decrease injustices. This could mean that special attention is paid to who was affected by extreme events in the past and seeing how they coped with it and if they need support in recovering. In Flanders, it was identified that in past floodings many people were not aware of the risks of flooding to their homes (Consultant Sumaqua, 8 April 2024). To work restoratively could mean increasing awareness and through that, increasing adaptive capacity. This could even out differences within the population and make vulnerable people more able to prepare for future events.

Further, applying this method can highlight the need to adjust compensation according to the impact climate change has. This could be another part of recognising that not everyone shares the same baseline conditions.

Another way of contributing for the restorative qualities of the method would be to add a factor wherein existing adaptive structures are and where the ones in the new adaptation plan are located. Investigating if the distribution of those differs between the areas (and whether they match the vulnerability) can be the starting point of redistribution. As restoration always focuses more on past events and this analysis works mainly with projection data, it cannot contribute much more to this dimension.

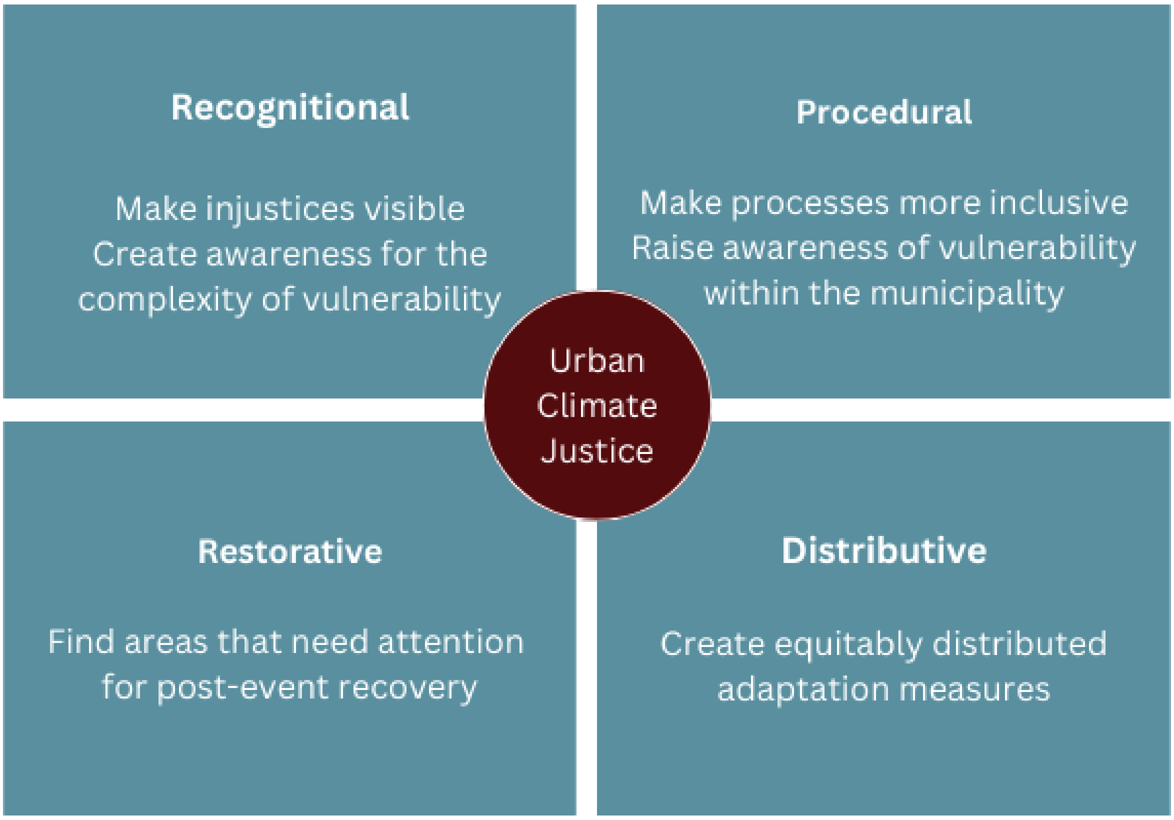

Figure 18: Summary of the potential impact of assessing social climate vulnerability on just planning.

In summary, the approach in this research adds most to the recognitional and procedural dimension and less to the distributive. Figure 18 shows a summary of what implementing an assessment of social climate vulnerability can contribute to just urban planning.

7.2. Limitations

When considering the previously presented results, there are several points that should be considered that limit their significance. One aspect is that some values for the statistical sectors were substituted by data on neighbourhood level. That might be an inaccurate representation, due to the high fluctuation in numbers between statistical sectors. If the municipality would conduct an analysis like this in the future, the preciseness of the results would benefit from a better data availability at a smaller scale. Another issue is that there was no data available for, for example, the condition of buildings to consider in the SoVI assessment. Including more indicators, covering more aspects, would make it increase the possibility to identify the root cause for why people are vulnerable (Proposal Writer Oostende Municipality, 24 May 2024).

Another analysis that might be of value for the municipality is finding to what extent there is a correlation of social vulnerability and climate impact exposure in Oostende. While the attained data was able to point towards the areas that are affected by both, there was no statistical assessment of the relationship.

Additionally, it should be considered that the socio-demographic data used in this analysis mirrors today’s society, while the climate data projects the impacts in the year 2050 or 2100. In the time period between now and then, the society might change depending on, for example, the demographic development, gentrification or policy changes. This is also mentioned by Steele et al. (2015, p. 123), as presented in Chapter 3: “Society and nature are simultaneously, mutually and constantly reconfigured by the ways urban relations are played out […].”

This also points to another limiting factor. This approach only includes humans, neglecting the non-human world completely. While this research is aimed at including all people in an equitable way, many ecological justice researchers representing a more-than-human approach would argue that just planning cannot exclusively be aimed at humans (see for example Celermajer et al., 2021; Pineda-Pinto et al., 2022). For a less anthropocentric approach it might be possible to include indicators that express the vulnerability of ecosystems towards climate impacts.

By choosing a single case study instead of a comparative case study, the possibility of generalisation of the results was decreased, but still exists to an extent (Flyvbjerg, 2006). The talk with the municipality of Esbjerg clarified that this method can also be applied outside of Oostende.

Lastly, while answering the third sub-research question offered an insight into the planning processes of Oostende, these results are solely based on the conducted interviews. For this question it would have been profitable to additionally interview people from social or other departments and to also look at the new adaptation plan, which was not possible as it was not published yet at the time of this research.

8. Conclusion

According to the IPCC (2022b), cities are more affected by climate change as they are densely populated and hold crucial infrastructure and services. In addition, they are not adapted sufficiently for the risks they are facing. This is referred to as the urban adaptation gap (IPCC, 2023). Within these cities, the effects are not equally distributed. Exposure to climate events such as extreme heat or pluvial flooding will differ spatially. Sensitivity, influenced by intrinsic and contextual conditions, as well as adaptive capacity will differ on an individual level. These 3 terms are the components of vulnerability, where people with a high vulnerability will suffer from stronger impacts of climate change. This vulnerability is unevenly divided throughout cities.

Municipalities have the power to influence justice, by working on the moderating factors of vulnerability, namely the physical environment (e.g. climate adaptation measures such as flood prevention or Nature-Based Solutions), policy and planning (e.g. provide funding for people with low income and non-adapted houses, legislation for including climate adaptation in social housing) and the social environment (e.g. start the conversation, increase awareness, provide information in multiple languages). However, it can be hard for municipalities to make plans for increasing resilience since climate adaptation planning is a wicked problem due to the complexity, changing conditions and the abundance of impactors. As a result, measures are often only taken where the highest climate impacts are (exposure), an, not taking the underlying conditions and processes into account (European Environment Agency, 2022).

This research has focused on answering the question of how municipalities can assess social vulnerability for a more just approach to climate adaptation planning. It has attempted to do so by combining climate exposure maps with the Social Vulnerability Index (SoVI) method, through the use of the case city of Oostende. Interviews with people from the municipality, a research centre and consultancy company were performed for gaining insights in the local context, identifying barriers for using social vulnerability in their climate adaptation plans and evaluating the proposed method.

After applying the approach for the city of Oostende, the conclusion can be drawn that the method is feasible and relatively easy to implement for European municipalities, on the condition that the necessary data are available. According to the municipality of Esbjerg, this would also be possible for them to implement (CPC Esbjerg Municipality, 24 May 2024). The approach will help urban planners with raising awareness for social climate vulnerability within the municipality, facilitate cooperation between departments and breaking silos, motivate integration in policies, gain insights in problem areas based on facts and make spatial priorities for climate adaptation measures.

The social climate vulnerability approach is reducing the urban climate injustice gap, as deducted by evaluating the approach for each dimension of urban climate justice. The approach contributes most to procedural justice as it makes it more manageable and accessible for municipalities to include more inhabitants in the planning process and plan in a more integral way, across silos. A danger for the procedure is that the municipality might base decisions solely on the maps, instead of having dialogues with inhabitants and other stakeholders about their situations and needs. The maps need to be perceived as a first step in the process.

The aspect of identifying injustices in the city and raising awareness, contributes to the recognitional justice dimension. It is important, however, to acknowledge that the social vulnerability per statistical sector does not account for every individual circumstance and assumptions are inevitably made due to simplifications.

The distributive dimension is addressed, as the social climate vulnerability maps aid municipal planners in setting priorities for the limited budget and resources, to distribute climate adaptation measures in an equitable way. The approach is contributing less to restorative justice as this dimension focuses more on past events. It could be added in the future by attaching a new indicator to the SoVI, wherein existing adaptive structures are scored.

For a more in-depth analysis, for example into one specific scenario, the municipality of Oostende would need to create more datasets that project the same event at the same intensity. Additionally, an analysis like this would benefit from a better data availability on the smallest possible scale in order to get the most specific results.

For future actions by the municipality, it would be important to look into which actions they are already planning on implementing, as these might have an influence on social climate vulnerability. For research, this might also be a future avenue, to see which factors of social climate vulnerability can be impacted by adaptation planning measures, in order to create a guideline for decision-makers.

To build on the results of this research, future investigations should apply this method in other European coastal cities. While the CPC from Esbjerg Municipality (24 May 2024) was confident that the municipality of Esbjerg (Denmark) would be able to conduct this analysis, the results highly depend on the indicators that are used and thus on data availability. There is no vulnerability index that can be universally applied, as the local context always impacts what is important to investigate in the area.

In closing, by combining social vulnerability with climate exposure, municipalities have the opportunity to transform climate adaptation practice in urban planning, ensuring a more equitable and just future.

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Appendix A - Indicators Climate Exposure

Category	Indicator Dutch	Indicator	Projection Year	Projection Event	Description Dutch	Descripition English
Storm surge	Overstroombare kwetsbare instellingen door 1000-jarige stormvloed	Institutions vulnerable to flooding by 1000-year storm surge	2075	1000-year event	Kwetsbare instellingen (kinderopvang, kleuter-, lager- en buitengewoon onderwijs, ziekenhuizen en verzorgingstehuizen) met kans op overstroming bij een 1000-jarige stormvloed.	Vulnerable institutions (childcare, pre-school, primary and special education, hospitals and care homes) at risk of flooding in a 1000-year storm surge.
	Overstroming door 1000-jarige stormvloed per statistische sector	Number of buildings affected by storm surge	2075	1000-year event	Het aantal gebouwen per statistische sector met kans op overstroming bij een 1000-jarige stormvloed.	The number of buildings per statistical sector at risk of flooding in a 1000-year storm surge.
	Waterdiepte bij 1000-jarige stormvloed	Water depth at a 1000 year storm surge	2075	1000-year event	De potentiële overstroombare oppervlakte en de bijbehorende waterdiepte bij het optreden van een 1000-jarige stormvloed aan de kust, doorgerekend met de zeewering in het jaar 2015. Een 1000-jarige stormvloed is een stormvloed waarbij er elk jaar 1 kans op 1000 is dat deze stormvloed zich voordoet.	The potential floodable area and associated water depth for the occurrence of a 1000-year storm surge on the coast, calculated using the sea wall in the year 2015. A 1000-year storm surge is a storm surge in which there is 1 chance in 1000 of this storm surge occurring each year.
Inundation	Kwetsbare instellingen met wateroverlast	Vulnerable institutions with inundation	2050	1000-year event	Kwetsbare instellingen (kinderopvang, kleuter-, lager- en buitengewoon onderwijs, ziekenhuizen en verzorgingstehuizen) met risico op een wateroverlast door intense neerslag.	Vulnerable institutions (childcare, pre-school, primary and special education, hospitals and care homes) at risk of flooding due to intense rainfall.
	Wateroverlast per statistische sector (gebouwen)	Number of buildings affected by inundation	2050	1000-year event	Het aantal gebouwen per statistische sector met een kans van eens per 1000 jaar op wateroverlast door intense neerslag.	Number of buildings per statistical sector with a probability of once per 1000 years at inundation due to intense rainfall.
	Waterdiepte bij wateroverlast	Water depth at precipitation event	2050	1000-year event	De maximale waterdiepte bij wateroverlast door intense neerslag met een kans van eenmaal in de 1000 jaar.	The maximum water depth in case of flooding due to intense precipitation with a probability of once in 1,000 years.
	Overstroming per statistische sector (gebouwen)	Number of buildings affected by flooding	2050	1000-year event	Het aantal gebouwen per statistische sector met een kans van eens per 1000 jaar op een overstroming.	The number of buildings per statistical sector with a probability of flooding once every 1,000 years.
	Waterdiepte bij overstroming	Water depth at flood event	2050	1000-year event	De waterdiepte bij een overstroming met een kans van eenmaal in de 1000 jaar.	The water depth at a flood event with a probability of once in 1000 years.
Heat	Aantal kwetsbare inwoners blootgesteld aan hittestress	Number of vulnerable people exposed to heat	2100	20-year event	Het aantal kwetsbare personen (tussen 0-4 jaar en boven 65 jaar) dat wordt blootgesteld aan belangrijke hittestress. Meer concreet betreft het kwetsbare personen waarbij de dagmaximum en de dagminimum gevoelstemperaturen tijdens een extreme hittedag (terugkeerperiode van 20 jaar) dermate worden overschreden, dat de gecombineerde drempelwaarde score 4 of meer bereikt waarbij ernstige gezondheidsschade te verwachten is.	The number of vulnerable people (aged between 0-4 years and over 65 years) exposed to significant heat stress. More specifically, it refers to vulnerable persons where the daily maximum and daily minimum sensory temperatures during an extreme heat day (20-year return period) are exceeded to the extent that the combined threshold reaches score 4 or more at which severe health damage is expected.
	Gewicht hittegolven	Weight heat waves	2100	Yearly event	Het meerjarig gemiddelde van het gewicht van hittegolven volgens definitie KMI per jaar (°C). (Een 'hittegolf' is gedefinieerd als een periode van minimum 5 opeenvolgende dagen met een maximumtemperatuur van minstens 25°C, waarbij de maximumtemperatuur minstens 3 dagen groter of gelijk is aan 30°C.; het gewicht van hittegolven is de som van alle graden van hittegolven in 1 jaar)	The multi-year average of the weight of heat waves according to KMI definition per year (°C). (A 'heat wave' is defined as a period of at least 5 consecutive days with a maximum temperature of at least 25°C, with the maximum temperature being greater than or equal to 30°C for at least 3 days.; the weight of heat waves is the sum of the degrees of all heat waves in 1 year)
	Aantal dagen met een gemiddelde temperatuur > 25 °C	No. of days with an average temperature > 25 °C	2100	Yearly event	Het meerjarig gemiddelde van het aantal dagen per jaar met een gemiddelde temperatuur van 25 °C of meer.	The multi-year average of the number of days per year with an average temperature of 25 °C or more.
	Aantal dagen met een maximale temperatuur > 25 °C	No. of days with a max. temperature of > 25 °C	2100	Yearly event	Het meerjarig gemiddelde van het aantal dagen per jaar met een maximum temperatuur op 2 m. hoogte van 25 °C of meer.	The multi-year average of the number of days per year with a maximum temperature at 2 m altitude of 25 °C or more.

Appendix B - Indicators Social Vulnerability Index

Category	Name in English	Effect on vulnerability	Data source in Dutch	Data source in English	Processing	Indicator source	Changes to indicator used in source
Age	Inhabitants younger than 15 years (% of total inhabitants)	+	demografie-bevolking-geslacht en leeftijd-leeftijd- leeftijdsklassen 5 jaar	age classes of 5 years	sum of age classes 0-5, 5-10 and 10-15 divided by total inhabitants	Englund et al. (2023); García & Dias (2023)	/
	Inhabitants older than 74 years (% of total inhabitants)	+	demografie-bevolking-geslacht en leeftijd-leeftijd- leeftijdsklassen 5 jaar	age classes of 5 years	sum of age classes 0-5, 5-10 and 10-15 divided by total inhabitants	Englund et al. (2023); García & Dias (2023)	/
Language proficiency	Non-EU birth nationality (% of total inhabitants)	+	demografie- nationaliteit, herkomst en taal- Geboortenationaliteit- % niet-Europese geboortenationaliteit (tov inwoners)	% non-European birth nationality (compared to number of inhabitants)	/	Englund et al. (2023); West-Vlaanderen (2023)	non-EU born instead of non-Belgian born (west flanders vulnerability)
	Children not speaking Dutch at home (% of children in primary and secondary school)	+	demografie- nationaliteit, herkomst en taal- Thuistaal- Thuistaal leerplichtonderwijs- leerlingen basisonderwijs die thuis geen Nederlands spreken and leerlingen secundair onderwijs die thuis geen Nederlands spreken (op basis van de woonplaats van de leerling) AND Onderwijs- Basisonderwijs- volgens woonplaats van de leerling- leerlingenaantallen- leerlingen basisonderwijs and leerlingen secundair onderwijs	primary school students that don't speak Dutch at home and secondary school students that don't speak Dutch at home (both according to living area of the student) AND number of primary school and secondary school students	sum of primary school and secondary school students that don't speak Dutch at home in numbers, divided by sum total primary and secondary school	West-Vlaanderen (2023)	/
Health	inhabitants with a statute of chronical conditions (% of inhabitants with health insurance)	+	samenleving&welzijn- gezondheid&handicap- gezondheidstoestand- chronische aandoeningen- statuut chronische aandoeningen	% people with statute of chronical conditions (compared to people with health insurance)	/	Chosen as substitute due to limited data availability	Chronical diseases instead of the average number of sick leave days (data availability)
Educational attainment	Highest educational attainment being primary school or less (% of all inhabitants over 25)	+	onderwijs- hoogste onderwijsniveau van inwoners 25+ jaar- %laaggeschoold (t.o.v. 25-plussers)	% primary school (compared to all 25+) (no diploma from secondary school)	/	Englund et al. (2023); Cutter et al. (2003)	
	Highest educational attainment university or similar (% of all inhabitants over 25)	-	onderwijs- hoogste onderwijsniveau van inwoners 25+ jaar- %hooggeschoold (t.o.v. 25-plussers)	% diploma from university or comparable (compared to all 25+)	/	Englund et al. (2023); Cutter (2003)	change from at least 2 years to diploma (data availability)
Single parent households	Single parent households (% of all private households)	+	demografie- huishoudens- LIPROindeling-percentages- %eenoudergezin met minstens 1 minderjarig (LIPRO) kind (t.o.v. private huishoudens) + %eenoudergezin met enkel meerderjarige (LIPRO) kind(eren) (t.o.v. private huishoudens)	% single parent households with at least 1 child below 18 years old (compared to private households) + % single parent households with children above 18 years old (compared to private households)	sum of below and above 18 year olds	Englund et al. (2023); Cutter (2003)	
Vehicle ownership	Number of vehicles per 100 households	-	mobiliteit&verkeersveiligheid- mobiliteit-toegang tot vervoersmodi- wagenbezit door huishoudens- wagens per 100 huishoudens	Number of vehicles per 100 households	/	Englund et al. (2023)	
Housing	House renters (% of households with known property title)	+	wonen&ruimtegebruik- wonen-huurder/eigenaar- %huurders(t.o.v. Huishoudens met gekende eigendomstitel)	% house renters (compared to households with known property title)	/	West-Vlaanderen (2023); Cutter (2003)	house renters instead of house owners (as in west flanders vulnerability)
Financial vulnerability	Disposable income per consumption unit (€)	-	samenleving&welzijn- welvaart&armoede-fiscale statistieken- fiscale inkomens van personen- gemiddeld netto belastbaar inkomen per gewijzigde verbruikseenheid	average net taxable income per modified consumption unit	/	Englund et al. (2023); Cutter (2003)	
	Inhabitants with an increased compensation for health care (% of inhabitants with health insurance)	+	samenleving&welzijn- welvaart en armoede-tegemoetkomingen- verhoogde tegemoetkoming (VT)- % personen met verhoogde tegemoetkoming (tov personen in de ziekteverzekering)	% of people with an increased compensation for health care (compared to people in health care)	/	West-Vlaanderen (2023)	added

Category	Name in English	Effect on vulnerability	Data source in Dutch	Data source in English	Processing	Indicator source	Changes to indicator used in source
	Households with income below 60% of the national median (% of total inhabitants between 20 and 64)	+	samenleving&welzijn- welvaart&armoede- fiscale statistieken- fiscale inkomens van personen- inkomen naar aangifte- inkomen per inkomensklasse- % aangiften inkomen 1-10000€+ 10001-15000€	% of declarations income 1-10000€+ 10001-15000€	median of Flemish region is €28909 so 60% is 17345€ but classes of €5000 so we chose €0-15000, where €15000 is 51,89%; summing up the 2 classes and dividing by number of inhabitants	Englund et al. (2023) ; García & Dias (2023)	52% instead of 60% (data availability)
	Households with income 200% over the national median (% of total inhabitants between 20 and 64)	-	samenleving&welzijn- welvaart&armoede- fiscale statistieken- fiscale inkomens van personen- inkomen naar aangifte- inkomen per inkomensklasse- % aangiften inkomen 60001-75000€+ >75001€	% of declarations income 60001-75000€+ >75001€ (median of Flemish region is €28909 so 200% is 57818€)	median of Flemish region is €28909 so 200% is 57818€ but classes of €15000 so we chose >€60000, where €60000 is 207,55%	Englund et al. (2023) ; García & Dias (2023)	208% instead of 200% (data availability)
Unemployment	People without a job searching for a job (WZW) on the 1st of January (% of inhabitants between 18 and 64)	+	werken&ondernemen- arbeidsmarkt- werkloosheid- werkzoekenden zonder werk op 1/1 (statistische sector)- % WZW (tov inwoners 18-64 jaar)	%people without a job searching for a job (WZW) on the 1st of January (compared to inhabitants between 18 and 64)	/	Englund et al. (2023)	no information on how long they are unemployed

Appendix C - Values Social Vulnerability

Wijk	Statistical Sector	Younger than 15 (%)	Older than 74 (%)	Non-EU birth nationality (%)	Children not speaking Dutch at home	status of chronic conditions (relative to persons in health insurance) [2022]	Highest educational attainment primary school or less (%)	Highest educational attainment of at least 2 years at university or similar (%)	Single parent households (%)	Number of vehicles (per 100 households)	House renters (%)	Disposable income per consumption unit (€)	Increased compensation in healthcare	Households with income below 60% of the national median (%)	Households with income 200% over the national median (%)	Unemployment of population aged 18-64 at 1/1 (%)
Centrum	A Buylstraat (35013A02-)	7,91	20,30	20,10%	55,45%	26,4%	32,90%	22,10%	7,30%	43,40	62,70%	24528,00	31,00%	35,63	9,03	11,20%
Centrum	Albert I-Promenade-Oost (35013A041)	4,35	25,79	11,30%	62,75%	26,4%	32,30%	25,00%	3,40%	53,40	51,70%	26649,00	27,20%	35,46	16,78	5,60%
Centrum	Albert I-Promenade-West (35013A242)	3,58	29,13	12,40%	49,96%	26,4%	27,60%	29,50%	17,36%	55,40	48,90%	26067,00	22,40%	33,93	10,50	7,00%
Centrum	Hazegras (35013A10-)	5,36	21,17	14,50%	20,59%	26,4%	37,90%	21,10%	6,20%	60,80	55,60%	28190,00	24,40%	22,80	17,42	4,70%
Centrum	Hospitaal (35013A232)	8,56	23,78	20,60%	36,30%	26,4%	41,30%	15,90%	5,50%	42,40	64,10%	25281,00	37,10%	49,48	10,50	16,70%
Centrum	Langestraat (35013A03-)	5,24	20,97	16,00%	49,96%	26,4%	35,80%	18,60%	5,20%	44,60	64,60%	26639,00	31,30%	33,93	10,50	4,50%
Centrum	Leopold I-Plein (35013A211)	7,68	22,89	17,10%	22,65%	26,4%	35,70%	23,00%	5,10%	48,00	56,50%	24756,00	29,90%	30,33	9,35	6,90%
Centrum	Leopoldpark (35013A222)	4,64	33,08	6,70%	49,96%	26,4%	33,00%	28,00%	5,00%	55,50	51,40%	29298,00	26,90%	33,93	10,50	10,50%
Centrum	Maria Hendrikapark (35013A19-)															
Centrum	Oostende-Centrum (35013A001)	6,00	22,40	14,30%	42,57%	26,4%	40,80%	19,90%	7,00%	47,50	59,90%	25446,00	30,20%	27,45	6,66	8,70%
Centrum	Post - Mercatordok (35013A01-)	4,19	27,17	12,50%	45,74%	26,4%	35,60%	26,50%	6,00%	45,80	60,30%	25247,00	31,00%	27,90	12,52	8,50%
Centrum	Sint-Jozef (35013A201)	11,88	18,40	25,80%	27,45%	26,4%	35,10%	22,70%	6,60%	49,20	57,50%	25243,00	32,10%	19,29	6,31	8,40%
Centrum	Wapenplein (35013A052)	9,09	20,14	17,70%	54,03%	26,4%	38,40%	20,40%	4,40%	44,70	70,40%	24161,00	38,40%	43,97	6,89	19,40%
Konterdam - Meiboom	Boterput (35013A13-)	14,00	16,67	9,20%	8,87%	18,7%	31,10%	33,20%	8,90%	92,00	33,50%	34147,00	18,80%	20,20	18,62	2,50%
Konterdam - Meiboom	Konterdam - Gouweloze Kreek (35013D372)	11,46	10,17	4,70%	19,17%	18,7%	26,00%	36,70%	13,29%	155,30	18,70%	36242,00	7,40%	20,20	16,96	5,00%
Konterdam - Meiboom	Konterdam - Koebrug (35013D311)	20,92	10,17	9,10%	23,32%	18,7%	36,30%	25,60%	13,29%	104,70	12,50%	29718,00	11,40%	20,20	13,42	4,60%
Konterdam - Meiboom	Konterdam (35013D30-)	17,11	6,86	12,30%	23,32%	18,7%	34,00%	23,60%	8,80%	96,50	22,10%	28777,00	16,00%	20,20	13,42	4,60%
Konterdam - Meiboom	Meiboom (35013D32-)	13,10	8,51	17,50%	23,32%	18,7%	37,90%	24,60%	9,60%	81,30	42,60%	25727,00	24,80%	20,20	13,42	2,30%
Konterdam - Meiboom	Oprit-Noord (35013D511)	16,77	8,46	11,50%	19,87%	18,7%	25,50%	34,70%	8,40%	109,90	14,90%	32686,00	14,20%	17,02	11,25	6,50%
Konterdam - Meiboom	Oprit-Zuid (35013D522)	15,74	12,07	19,70%	11,88%	18,7%	39,40%	21,50%	12,70%	87,70	46,30%	25310,00	31,30%	20,20	16,97	1,50%
Mariakerke - Nieuwe Koers	Klooster (35013F600)	17,78	13,33	10,20%	48,86%	21,2%	34,60%	32,00%	8,70%	97,50	24,00%	31383,00	15,10%	34,16	10,09	11,20%
Mariakerke - Nieuwe Koers	Kruishof (35013F280)	20,43	12,99	5,80%	47,13%	21,2%	15,90%	33,70%	8,20%	106,30	30,00%	39135,00	7,30%	30,14	8,81	9,70%
Mariakerke - Nieuwe Koers	Mariakerke - Derbylaan (35013F700)	12,16	13,26	17,50%	26,51%	21,2%	36,30%	21,70%	7,60%	69,50	48,30%	27464,00	26,20%	22,29	14,66	5,00%
Mariakerke - Nieuwe Koers	Mariakerke - Distelbaan (35013F71-)	11,84	16,16	13,20%	26,51%	21,2%	33,40%	28,50%	8,20%	80,70	44,00%	29239,00	25,60%	22,29	14,66	5,10%
Mariakerke - Nieuwe Koers	Mariakerke - Duin (35013F780)	13,67	14,83	12,70%	41,57%	21,2%	16,70%	38,90%	0,00%	116,70	25,00%	54523,00	19,90%	25,57	9,68	8,10%
Mariakerke - Nieuwe Koers	Mariakerke - Strandplein (35013F721)	13,67	22,67	7,10%	26,29%	21,2%	35,40%	26,70%	12,91%	62,00	56,10%	28579,00	27,20%	25,59	13,10	6,60%
Mariakerke - Nieuwe Koers	Mariakerkelaan - Batterij (35013A622)	14,19	14,41	20,60%	26,51%	21,2%	28,00%	31,10%	5,80%	84,30	33,20%	29262,00	19,00%	22,29	14,66	5,10%
Mariakerke - Nieuwe Koers	Mariakerkelaan - Eigen Haard (35013A611)	17,38	15,32	15,90%	26,51%	21,2%	26,20%	36,20%	8,60%	88,80	28,10%	34126,00	15,20%	22,29	14,66	10,50%
Mariakerke - Nieuwe Koers	Mariakerkelaan - Vredestraat (35013F733)	12,35	16,35	16,20%	47,22%	21,2%	31,50%	29,90%	8,90%	90,40	36,30%	31126,00	18,70%	22,29	14,66	7,10%
Mariakerke - Nieuwe Koers	Nieuwe Koerswijk (35013F200)	15,15	13,77	8,00%	30,09%	21,2%	30,00%	35,50%	9,40%	101,50	17,10%	33877,00	13,40%	22,29	18,32	4,40%
Mariakerke - Nieuwe Koers	Raversijdestraat (35013F749)	5,54	18,55	12,70%	39,84%	21,2%	34,30%	23,00%	4,50%	60,40	36,70%	26381,00	19,80%	22,29	14,66	4,70%
Raversijde	Raversijde - Vliegveld (35013F9MJ)	9,09	16,96	10,20%	34,46%	24,9%	36,50%	13,50%	10,35%	93,20	23,80%	23201,00	20,40%	22,68	8,63	8,20%
Raversijde	Raversijde-Oost (35013F900)	9,10	17,61	10,40%	18,40%	24,9%	37,50%	24,80%	6,30%	93,30	28,40%	30475,00	21,90%	21,79	34,00	0,80%
Raversijde	Raversijde-West (35013F92-)	9,09	16,96	11,50%	14,94%	24,9%	30,40%	19,60%	10,35%	80,60	51,60%	29736,00	28,80%	19,81	20,41	3,10%
Raversijde	Stene-Verspr Bew -West (35013F299)	22,73	16,96	0,00%	53,80%	24,9%	31,33%	12,90%	0,00%	93,30	28,20%	29736,00	21,10%	25,59	6,73	8,90%
Stene	Cardijn (35013D552)	9,15	18,21	28,00%	58,93%	19,5%	57,40%	7,20%	9,50%	39,90	96,80%	16706,00	63,50%	31,22	5,92	10,90%
Stene	Hoge Barriere (35013E42-)	18,65	7,30	20,90%	34,59%	19,5%	42,70%	17,60%	10,30%	78,00	41,50%	24744,00	23,60%	25,38	14,89	5,00%
Stene	Mimosa (35013D533)	10,58	21,83	5,40%	37,50%	19,5%	25,10%	41,90%	5,50%	134,60	5,50%	37226,00	7,50%	34,68	8,58	7,70%
Stene	Oud Vliegveld (35013E02-)	18,02	13,51	6,00%	19,72%	19,5%	36,60%	29,00%	6,30%	110,60	8,50%	32177,00	14,10%	23,19	20,63	1,30%
Stene	Sint-Jan (35013E400)	19,15	8,41	30,70%	34,33%	19,5%	38,30%	17,50%	10,30%	74,60	45,90%	23735,00	29,60%	27,52	11,50	6,70%
Stene	Stene-Dorp (35013E000)	15,25	6,77	4,90%	25,86%	19,5%	24,90%	32,90%	6,10%	124,00	8,10%	37466,00	7,90%	23,19	25,09	2,00%
Stene	Stene-Verspr Bew -Oost (35013E099)	25,56	10,55	4,60%	25,86%	19,5%	14,60%	46,60%	11,10%	131,60	11,30%	35360,00	6,00%	23,19	25,34	1,80%
Stene	Stuiverstraat (35013E411)	16,90	8,22	23,00%	25,86%	19,5%	34,70%	20,60%	11,00%	94,60	37,40%	24987,00	27,90%	23,19	13,58	5,70%
Stene	Vettegras (35013E010)	14,29	10,00	16,70%	39,58%	19,5%	27,90%	23,40%	17,70%	116,70	23,60%	30543,00	23,30%	33,82	10,71	9,80%
Stene	Zilverlaan - Lotus (35013D542)	12,57	12,98	19,40%	55,31%	19,5%	43,10%	21,70%	10,00%	88,90	54,20%	27335,00	38,10%	32,36	8,12	9,80%
Vuurtoren	Fort Napoleon (35013B38-)	14,48	25,32	6,40%	33,57%	20,3%	29,60%	45,70%	18,20%	117,40	27,40%	55948,00	22,70%	23,35	11,81	14,30%
Vuurtoren	Sint-Antoniusplein (35013B301)	17,12	9,43	26,50%	21,32%	20,3%	44,50%	15,30%	10,40%	67,80	60,10%	22401,00	36,60%	22,40	14,64	7,60%
Vuurtoren	Spuikom (35013B39-)															
Vuurtoren	Taboralaan (35013B332)	14,20	12,51	14,50%	33,57%	20,3%	39,60%	21,60%	11,00%	95,40	34,80%	29956,00	23,70%	23,35	11,81	9,80%
Vuurtoren	Vaartblekers (35013B37-)	14,48	11,16	12,00%	33,57%	20,3%	39,80%	11,40%	18,20%	98,10	25,50%	28602,00	20,40%	23,35	11,81	7,60%
Vuurtoren	Vaartdijk-Noord (35013C19-)	14,48	11,16	0,00%	46,56%	20,3%	49,00%	14,30%	18,20%	84,60	44,10%	28602,00	27,10%	27,58	6,52	11,70%
Vuurtoren	Vlotdok (35013B179)	11,11	6,02	14,80%	46,73%	20,3%	41,80%	19,40%	9,40%	92,20	41,00%	25847,00	17,70%	22,57	11,81	5,80%
Vuurtoren	Voorhaven (35013B079)	14,48	11,16	18,00%	50,72%	20,3%	33,00%	29,20%	18,20%	113,50	26,10%	64591,00	5,90%	32,13	9,18	10,60%
Westerkwartier - Vlaams Plein	Godelieve (35013A511)	11,14	19,60	11,80%	47,59%	21,5%	46,20%	16,70%	9,30%	72,50	45,40%	26754,00	34,20%	28,64	8,28	8,80%
Westerkwartier - Vlaams Plein	H Hartplein (35013A501)	18,97	8,66	30,90%	9,39%	21,5%	36,80%	19,00%	10,00%	60,90	52,70%	22080,00	35,20%	28,64	20,76	2,40%
Westerkwartier - Vlaams Plein	H Hartplein (35013A522)	16,86	9,20	26,80%	47,59%	21,5%	36,40%	21,00%	11,40%	70,50	42,90%	23549,00	29,80%	28,64	20,51	1,90%
Westerkwartier - Vlaams Plein	Nieuwlandstraat (35013A42-)	20,38	6,55	33,70%	47,59%	21,5%	33,50%	21,50%	12,20%	71,90	45,60%	23171,00	36,20%	28,64	8,28	8,80%
Westerkwartier - Vlaams Plein	Nijverheidsstraat (35013A543)	18,33	9,16	35,40%	47,59%	21,5%	36,50%	18,40%	12,10%	63,60	53,60%	22688,00	38,60%	28,64	8,28	8,80%
Westerkwartier - Vlaams Plein	Ooievaarslaan (35013A43-)	11,46	24,07	14,70%	37,31%	21,5%	38,80%	26,70%	6,70%	79,60	39,90%	31745,00	27,20%	28,64	8,28	4,90%
Westerkwartier - Vlaams Plein	Prinsenlaan (35013A44-)	18,64	7,15	36,40%	25,33%	21,5%	28,90%	27,80%	9,70%	62,40	60,00%	23949,00	34,50%	21,12	13,42	6,20%
Westerkwartier - Vlaams Plein	Renbaan (35013A59-)	14,92	33,65	6,00%	66,67%	21,5%	38,80%	19,70%	25,00%	69,20	53,50%	42563,00	23,30%	29,50	8,28	6,90%
Westerkwartier - Vlaams Plein	Troonstraat (35013A752)	3,70	26,82	9,00%	47,59%	21,5%	30,10%	32,30%	3,30%	64,20	46,00%	26244,00	28,80%	28,64	8,28	9,50%
Westerkwartier - Vlaams Plein	Velodroomstraat (35013A532)	8,82	16,49	15,50%	47,59%	21,5%	33,00%	27,40%	6,80%	57,10	59,00%	27758,00	30,20%	28,64	8,28	8,80%
Zandvoorde	Grintweg (35013C099)	16,44	8,31	5,20%	36,79%	16,8%	20,20%	40,40%	5,37%	128,30	11,10%	31967,00	10,70%	25,48	10,02	8,40%
Zandvoorde	Keignaartwijk (35013C022)	13,43	17,42	8,50%	5,56%	16,8%	43,80%	20,10%	11,40%	104,80	26,30%	28658,00	21,10%	16,66	18,48	5,30%
Zandvoorde	Koebrug (35013C179)	14,57	8,31	9,20%	5,56%	16,8%	36,60%	18,90%	5,37%	124,60	16,70%	28807,00	11,30%	16,66	18,48	3,40%
Zandvoorde	Oude Polder (35013C08-)	16,87	8,31	1,30%	5,56%	16,8%	20,40%	40,30%	9,30%	155,00	5,90%	37610,00	5,30%	16,66	29,19	1,90%
Zandvoorde	Plassendale - U C B (35013C07-)	16,44	0,00	33,30%	62,86%	16,8%	16,80%	30,93%	0,00%	124,90	15,60%	31967,00	11,80%	16,66	18,48	13,00%
Zandvoorde	Zandvoorde - Station (35013C010)	13,51	8,31	8,10%	5,56%	16,8%	44,00%	16,40%	5,37%	104,10	11,60%	26642,00	15,00%	16,66	18,48	3,40%
Zandvoorde	Zandvoorde-Dorp (35013C00-)	19,91	7,82	4,40%	6,81%	16,8%	34,70%	29,30%	9,10%	120,10	14,70%	31440,00	11,10%	16,66	17,15	2,30%
	Strand (35013X0JQ)															

Wijk level numbers obtained from the website
Wijk level numbers generated by statistical sector means
Excluded (sectors without inhabitants)

Appendix D - Values Social Vulnerability (normalised)

Wijk	Statistical Sector	Code	Younger than 15	Older than 74	Foreign-born	Children not speaking Dutch at home	chronic conditions (relative to persons in health insurance) [2022]	Highest educational attainment primary school or less	Highest educational attainment of at least 2 years at university or similar	High education*	Single parent households	Number of vehicles (per 100 households)	Vehicles*	House renters	Disposable income per consumption unit	Disposable income*	Increased compensation in healthcare	Households with income below 60% of the national median	Households with income 200% over the national median	High income*	Unemployment of population aged 18-64 at 1/1	Total social vulnerability	Spalte1	Vulnerability class
Centrum	A Buylstraat (35013A02-)	35013A02-	0,20	0,60	0,55	0,82	1,00	0,43	0,38	0,62	0,29	0,03	0,97	0,63	0,16	0,84	0,44	0,58	0,11	0,89	0,56	9,41	0,63	5
Centrum	Albert I-Promenade-Oost (35013A041)	35013A041	0,04	0,77	0,31	0,94	1,00	0,41	0,45	0,55	0,14	0,12	0,88	0,51	0,21	0,79	0,38	0,57	0,39	0,61	0,26	8,15	0,54	4
Centrum	Albert I-Promenade-West (35013A242)	35013A242	0,00	0,87	0,34	0,73	1,00	0,30	0,57	0,43	0,69	0,13	0,87	0,48	0,20	0,80	0,29	0,53	0,16	0,84	0,33	8,50	0,57	4
Konterdam - Meiboom	Boterput (35013A13-)	35013A13-	0,47	0,50	0,25	0,05	0,20	0,39	0,66	0,34	0,36	0,45	0,55	0,31	0,36	0,64	0,23	0,11	0,45	0,55	0,09	5,02	0,33	2
Stene	Cardijn (35013D552)	35013D552	0,25	0,54	0,77	0,87	0,28	1,00	0,00	1,00	0,38	0,00	1,00	1,00	0,00	1,00	1,00	0,44	0,00	1,00	0,54	11,08	0,74	5
Vuurtoren	Fort Napoleon (35013B38-)	35013B38-	0,50	0,75	0,18	0,46	0,36	0,35	0,98	0,02	0,73	0,67	0,33	0,24	0,82	0,18	0,30	0,20	0,21	0,79	0,73	6,11	0,41	3
Westerkwartier - Vlaams Plein	Godelieve (35013A511)	35013A511	0,34	0,58	0,32	0,69	0,49	0,74	0,24	0,76	0,37	0,28	0,72	0,44	0,21	0,79	0,50	0,37	0,09	0,91	0,43	8,45	0,56	4
Zandvoorde	Grintweg (35013C099)	35013C099	0,58	0,25	0,14	0,51	0,00	0,13	0,84	0,16	0,21	0,77	0,23	0,06	0,32	0,68	0,09	0,27	0,15	0,85	0,41	4,59	0,31	2
Westerkwartier - Vlaams Plein	H Hartplein (35013A501)	35013A501	0,70	0,26	0,85	0,06	0,49	0,52	0,30	0,70	0,40	0,18	0,82	0,52	0,11	0,89	0,51	0,37	0,53	0,47	0,09	7,64	0,51	4
Westerkwartier - Vlaams Plein	H Hartplein (35013A522)	35013A522	0,60	0,27	0,74	0,69	0,49	0,51	0,35	0,65	0,46	0,27	0,73	0,41	0,14	0,86	0,42	0,37	0,52	0,48	0,06	7,73	0,52	4
Centrum	Hazegras (35013A10-)	35013A10-	0,08	0,63	0,40	0,25	1,00	0,54	0,35	0,65	0,25	0,18	0,82	0,55	0,24	0,76	0,33	0,19	0,41	0,59	0,21	7,24	0,48	3
Stene	Hoge Barriere (35013E42-)	35013E42-	0,69	0,22	0,57	0,48	0,28	0,66	0,26	0,74	0,41	0,33	0,67	0,39	0,17	0,83	0,31	0,27	0,32	0,68	0,23	7,42	0,49	3,00
Centrum	Hospitaal (35013A232)	35013A232	0,23	0,71	0,57	0,50	1,00	0,62	0,22	0,78	0,22	0,02	0,98	0,64	0,18	0,82	0,55	1,00	0,16	0,84	0,85	10,30	0,69	5
Zandvoorde	Keignaartwijk (35013C022)	35013C022	0,45	0,52	0,23	0,00	0,00	0,68	0,33	0,67	0,46	0,56	0,44	0,23	0,25	0,75	0,27	0,00	0,45	0,55	0,24	5,49	0,37	2
Mariakerke - Nieuwe Koers	Klooster (35013F600)	35013F600	0,65	0,40	0,28	0,71	0,46	0,47	0,63	0,37	0,35	0,50	0,50	0,20	0,31	0,69	0,17	0,53	0,15	0,85	0,56	7,18	0,48	3
Zandvoorde	Koebrug (35013C179)	35013C179	0,50	0,25	0,25	0,00	0,00	0,51	0,30	0,70	0,21	0,73	0,27	0,12	0,25	0,75	0,10	0,00	0,45	0,55	0,14	4,36	0,29	1,00
Konterdam - Meiboom	Konterdam - Gouweloze Kreek (35013D372)	35013D372	0,36	0,30	0,13	0,22	0,20	0,27	0,75	0,25	0,53	1,00	0,00	0,14	0,41	0,59	0,04	0,11	0,39	0,61	0,23	3,97	0,26	1
Konterdam - Meiboom	Konterdam - Koebrug (35013D311)	35013D311	0,79	0,30	0,25	0,29	0,20	0,51	0,47	0,53	0,53	0,56	0,44	0,08	0,27	0,73	0,10	0,11	0,27	0,73	0,20	5,79	0,39	2
Konterdam - Meiboom	Konterdam (35013D30-)	35013D30-	0,62	0,20	0,34	0,29	0,20	0,45	0,42	0,58	0,35	0,49	0,51	0,18	0,25	0,75	0,18	0,11	0,27	0,73	0,20	5,70	0,38	2
Mariakerke - Nieuwe Koers	Kruishof (35013F280)	35013F280	0,77	0,39	0,16	0,68	0,46	0,03	0,67	0,33	0,33	0,58	0,42	0,27	0,47	0,53	0,03	0,41	0,10	0,90	0,48	6,18	0,41	3
Centrum	Langestraat (35013A03-)	35013A03-	0,08	0,62	0,44	0,73	1,00	0,50	0,29	0,71	0,21	0,04	0,96	0,65	0,21	0,79	0,45	0,53	0,16	0,84	0,20	8,69	0,58	4
Centrum	Leopold I-Plein (35013A211)	35013A211	0,19	0,68	0,47	0,28	1,00	0,49	0,40	0,60	0,20	0,07	0,93	0,56	0,17	0,83	0,42	0,42	0,12	0,88	0,33	8,28	0,55	4
Centrum	Leopoldpark (35013A222)	35013A222	0,05	0,98	0,18	0,73	1,00	0,43	0,53	0,47	0,20	0,14	0,86	0,50	0,26	0,74	0,37	0,53	0,16	0,84	0,52	8,40	0,56	4
Centrum	Maria Hendrikapark (35013A19-)	35013A19-																						
Mariakerke - Nieuwe Koers	Mariakerke - Derbylaan (35013F700)	35013F700	0,39	0,39	0,48	0,34	0,46	0,51	0,37	0,63	0,30	0,26	0,74	0,47	0,22	0,78	0,36	0,17	0,31	0,69	0,23	6,94	0,46	3
Mariakerke - Nieuwe Koers	Mariakerke - Distelbaan (35013F71-)	35013F71-	0,38	0,48	0,36	0,34	0,46	0,44	0,54	0,46	0,33	0,35	0,65	0,42	0,26	0,74	0,35	0,17	0,31	0,69	0,23	6,49	0,43	3
Mariakerke - Nieuwe Koers	Mariakerke - Duin (35013F780)	35013F780	0,46	0,44	0,35	0,59	0,46	0,05	0,80	0,20	0,00	0,67	0,33	0,21	0,79	0,21	0,25	0,27	0,14	0,86	0,39	5,08	0,34	2
Mariakerke - Nieuwe Koers	Mariakerke - Strandplein (35013F721)	35013F721	0,46	0,67	0,20	0,34	0,46	0,49	0,49	0,51	0,52	0,19	0,81	0,55	0,25	0,75	0,38	0,27	0,26	0,74	0,31	7,45	0,50	4
Mariakerke - Nieuwe Koers	Mariakerkelaan - Batterij (35013A622)	35013A622	0,48	0,43	0,57	0,34	0,46	0,31	0,61	0,39	0,23	0,38	0,62	0,30	0,26	0,74	0,24	0,17	0,31	0,69	0,23	6,20	0,41	3
Mariakerke - Nieuwe Koers	Mariakerkelaan - Eigen Haard (35013A611)	35013A611	0,63	0,46	0,44	0,34	0,46	0,27	0,74	0,26	0,34	0,42	0,58	0,25	0,36	0,64	0,17	0,17	0,31	0,69	0,52	6,21	0,41	3
Mariakerke - Nieuwe Koers	Mariakerkelaan - Vredestraat (35013F733)	35013F733	0,40	0,49	0,45	0,68	0,46	0,39	0,58	0,42	0,36	0,44	0,56	0,34	0,30	0,70	0,23	0,17	0,31	0,69	0,34	6,67	0,44	3
Konterdam - Meiboom	Meiboom (35013D32-)	35013D32-	0,43	0,25	0,48	0,29	0,20	0,54	0,44	0,56	0,38	0,36	0,64	0,41	0,19	0,81	0,34	0,11	0,27	0,73	0,08	6,26	0,42	3
Stene	Mimosa (35013D533)	35013D533	0,32	0,65	0,15	0,52	0,28	0,25	0,88	0,12	0,22	0,82	0,18	0,00	0,43	0,57	0,04	0,55	0,10	0,90	0,37	5,12	0,34	2
Mariakerke - Nieuwe Koers	Nieuwe Koerswijk (35013F200)	35013F200	0,53	0,41	0,22	0,40	0,46	0,36	0,72	0,28	0,38	0,53	0,47	0,13	0,36	0,64	0,14	0,17	0,44	0,56	0,19	5,33	0,36	2
Westerkwartier - Vlaams Plein	Nieuwlandstraat (35013A42-)	35013A42-	0,76	0,19	0,93	0,69	0,49	0,44	0,36	0,64	0,49	0,28	0,72	0,44	0,14	0,86	0,53	0,37	0,09	0,91	0,43	8,90	0,59	4,00
Westerkwartier - Vlaams Plein	Nijverheidsstraat (35013A543)	35013A543	0,67	0,27	0,97	0,69	0,49	0,51	0,28	0,72	0,48	0,21	0,79	0,53	0,12	0,88	0,57	0,37	0,09	0,91	0,43	9,28	0,62	5
Westerkwartier - Vlaams Plein	Ooievaarslaan (35013A43-)	35013A43-	0,36	0,72	0,40	0,52	0,49	0,57	0,49	0,51	0,27	0,34	0,66	0,38	0,31	0,69	0,38	0,37	0,09	0,91	0,22	7,42	0,49	3,00
Centrum	Oostende-Centrum (35013A001)	35013A001	0,11	0,67	0,39	0,61	1,00	0,61	0,32	0,68	0,28	0,07	0,93	0,60	0,18	0,82	0,43	0,33	0,03	0,97	0,42	8,84	0,59	4
Konterdam - Meiboom	Oprit-Noord (35013D511)	35013D511	0,60	0,25	0,32	0,23	0,20	0,25	0,70	0,30	0,34	0,61	0,39	0,10	0,33	0,67	0,15	0,01	0,19	0,81	0,31	4,93	0,33	2
Konterdam - Meiboom	Oprit-Zuid (35013D522)	35013D522	0,55	0,36	0,54	0,10	0,20	0,58	0,36	0,64	0,51	0,41	0,59	0,45	0,18	0,82	0,45	0,11	0,39	0,61	0,04	6,53	0,44	3
Stene	Oud Vliegveld (35013E02-)	35013E02-	0,66	0,40	0,16	0,23	0,28	0,51	0,55	0,45	0,25	0,61	0,39	0,03	0,32	0,68	0,15	0,20	0,52	0,48	0,03	4,90	0,33	2
Zandvoorde	Oude Polder (35013C08-)	35013C08-	0,60	0,25	0,04	0,00	0,00	0,14	0,84	0,16	0,37	1,00	0,00	0,00	0,44	0,56	0,00	0,00	0,83	0,17	0,06	2,36	0,16	1
Zandvoorde	Plassendale - U C B (35013C07-)	35013C07-	0,58	0,00	0,91	0,94	0,00	0,05	0,60	0,40	0,00	0,74	0,26	0,11	0,32	0,68	0,11	0,00	0,45	0,55	0,66	5,26	0,35	2
Centrum	Post - Mercatordok (35013A01-)	35013A01-	0,03	0,81	0,34	0,66	1,00	0,49	0,49	0,51	0,24	0,05	0,95	0,60	0,18	0,82	0,44	0,34	0,24	0,76	0,41	8,41	0,56	4
Westerkwartier - Vlaams Plein	Prinsenlaan (35013A44-)	35013A44-	0,69	0,21	1,00	0,32	0,49	0,33	0,52	0,48	0,39	0,19	0,81	0,60	0,15	0,85	0,50	0,14	0,27	0,73	0,29	7,82	0,52	4
Raversijde	Raversijde - Vliegveld (35013F9MJ)	35013F9MJ	0,25	0,50	0,28	0,47	0,84	0,51	0,16	0,84	0,41	0,46	0,54	0,20	0,14	0,86	0,26	0,18	0,10	0,90	0,40	7,46	0,50	4
Raversijde	Raversijde-Oost (35013F900)	35013F900	0,25	0,52	0,29	0,21	0,84	0,54	0,45	0,55	0,25	0,46	0,54	0,25	0,29	0,71	0,29	0,16	1,00	0,00	0,00	5,40	0,36	2
Mariakerke - Nieuwe Koers	Raversijdestraat (35013F749)	35013F749	0,09	0,55	0,35	0,56	0,46	0,46	0,40	0,60	0,18	0,18	0,82	0,34	0,20	0,80	0,25	0,17	0,31	0,69	0,21	6,53	0,44	3
Raversijde	Raversijde-West (35013F92-)	35013F92-	0,25	0,50	0,32	0,15	0,84	0,37	0,31	0,69	0,41	0,35	0,65	0,50	0,27	0,73	0,40	0,10	0,52	0,48	0,12	6,52	0,43	3
Westerkwartier - Vlaams Plein	Renbaan (35013A59-)	35013A59-	0,52	1,00	0,16	1,00	0,49	0,57	0,32	0,68	1,00	0,25	0,75	0,53	0,54	0,46	0,31	0,39	0,09	0,91	0,33	9,09	0,61	5
Vuurtoren	Sint-Antoniusplein (35013B301)	35013B301	0,62	0,28	0,73	0,26	0,36	0,70	0,21	0,79	0,42	0,24	0,76	0,60	0,12	0,88	0,54	0,17	0,31	0,69	0,37	8,16	0,54	4
Stene	Sint-Jan (35013E400)	35013E400	0,71	0,25	0,84	0,47	0,28	0,55	0,26	0,74	0,41	0,30	0,70	0,44	0,15	0,85	0,42	0,33	0,20	0,80	0,32	8,12	0,54	4
Centrum	Sint-Jozef (35013A201)	35013A201	0,38	0,55	0,71	0,36	1,00	0,48	0,39	0,61	0,26	0,08	0,92	0,57	0,18	0,82	0,46	0,08	0,02	0,98	0,41	8,59	0,57	4
Vuurtoren	Spuikom (35013B39-)	35013B39-																						
Stene	Stene-Dorp (35013E000)	35013E000	0,53	0,20	0,13	0,33	0,28	0,24	0,65	0,35	0,24	0,73	0,27	0,03	0,43	0,57	0,04	0,20	0,68	0,32	0,06	3,80	0,25	1
Stene	Stene-Verspr Bew -Oost (35013E099)	35013E099	1,00	0,31	0,13	0,33	0,28	0,00	1,00	0,00	0,44	0,79	0,21	0,06	0,39	0,61	0,01	0,20	0,69	0,31	0,05	3,95	0,26	1
Raversijde	Stene-Verspr Bew -West (35013F299)	35013F299	0,87	0,50	0,00	0,79	0,84	0,39	0,14	0,86	0,00	0,46	0,54	0,25	0,27	0,73	0,27	0,27	0,03	0,97	0,44	7,72	0,51	4
	Strand (35013X0JQ)																							
Stene	Stuiverstraat (35013E411)	35013E411	0,61	0,24	0,63	0,33	0,28	0,47	0,34	0,66	0,44	0,47	0,53	0,35	0,17	0,83	0,39	0,20	0,27	0,73	0,26	6,94	0,46	3
Vuurtoren	Taboralaan (35013B332)	35013B332	0,48	0,37	0,40	0,46	0,36	0,58	0,37	0,63	0,44	0,48	0,52	0,32	0,28	0,72	0,32	0,20	0,21	0,79	0,48	7,09	0,47	3
Westerkwartier - Vlaams Plein	Troonstraat (35013A752)	35013A752	0,01	0,80	0,25	0,69	0,49	0,36	0,64	0,36	0,13	0,21	0,79	0,44	0,20	0,80	0,40	0,37	0,09	0,91	0,47	7,27	0,48	3
Vuurtoren	Vaartblekers (35013B37-)	35013B37-	0,50	0,33	0,33	0,46	0,36	0,59	0,11	0,89	0,73	0,50	0,50	0,22	0,25	0,75	0,26	0,20	0,21	0,79	0,37	7,27	0,48	3
Vuurtoren	Vaartdijk-Noord (35013C19-)	35013C19-	0,50	0,33	0,00	0,67	0,36	0,80	0,18	0,82	0,73	0,39	0,61	0,42	0,25	0,75	0,37	0,33	0,02	0,98	0,59	8,27	0,55	4
Westerkwartier - Vlaams Plein	Velodroomstraat (35013A532)	35013A532	0,24	0,49	0,43	0,69	0,49	0,43	0,51	0,49	0,27	0,15	0,85	0,59	0,23	0,77	0,43	0,37	0,09	0,91	0,43	7,86	0,52	4
Stene	Vettegras (35013E010)	35013E010	0,49	0,30	0,46	0,56	0,28	0,31	0,41	0,59	0,71	0,67	0,33	0,20	0,29	0,71	0,31	0,52	0,17	0,83	0,48	7,08	0,47	3
Vuurtoren	Vlotdok (35013B179)	35013B179	0,34	0,18	0,41	0,67	0,36	0,64	0,31	0,69	0,38	0,45	0,55	0,39	0,19	0,81	0,21	0,18	0,21	0,79	0,27	6,86	0,46	3
Vuurtoren	Voorhaven (35013B079)	35013B079	0,50	0,33	0,49	0,74	0,36	0,43	0,56	0,44	0,73	0,64	0,36	0,23	1,00	0,00	0,01	0,47	0,12	0,88	0,53	6,50	0,43	3
Centrum	Wapenplein (35013A052)	35013A052	0,25	0,60	0,49	0,79	1,00	0,56	0,34	0,66	0,18	0,04	0,96	0,71	0,16	0,84	0,57	0,83	0,04	0,96	1,00	10,40	0,69	5
Zandvoorde	Zandvoorde - Station (35013C010)	35013C010	0,45	0,25	0,22	0,00	0,00	0,69	0,23	0,77	0,21	0,56	0,44	0,07	0,21	0,79	0,17	0,00	0,45	0,55	0,14	4,75	0,32	2
Zandvoorde	Zandvoorde-Dorp (35013C00-)	35013C00-	0,74	0,23	0,12	0,02	0,00	0,47	0,56	0,44	0,36	0,69	0,31	0,10	0,31	0,69	0,10	0,00	0,40	0,60	0,08	4,27	0,28	1
Stene	Zilverlaan - Lotus (35013D542)	35013D542	0,41	0,39	0,53	0,81	0,28	0,67	0,37	0,63	0,40	0,42	0,58	0,53	0,22	0,78	0,56	0,48	0,08	0,92	0,48	8,45	0,56	4

Excluded (sectors without inhabitants)

* = negatively correlated indicators (rescaled, high value indicates high vulnerabiility)

Appendix E - Values Climate Exposure

Statistical Sector	Storm surge Points of Interest	Buildings affected storm surge	Point of Interest Pluvial flooding	Buildings affected Pluvial Flooding	Water depth Pluvial Flooding	Buildings affected Fluvial flooding	Water depth Fluvial flooding	No. of people affected by heat	Heat wave intensity	No. of days avg. temp >25	No. of days max temp >25
OOSTENDE-CENTRUM	2	1264	2	737	63,68	0	0	40,43	239,72	45,02	83,96
POST - MERCATORDOK	4	1439	3	414	51,68	0	0	34,27	238,73	44,74	83,96
A. BUYLSTRAAT	0	1020	0	663	43,47	0	0	48,10	230,85	43,04	81,79
LANGESTRAAT	2	943	1	561	28,03	0	0	47,68	222,82	42,01	80,05
ALBERT I-PROMENADE-OOST	0	476	0	173	15,67	0	0	47,24	217,56	39,68	77,67
WAPENPLEIN	1	1173	1	813	44,43	0	0	41,81	228,90	43,44	81,36
HAZEGRAS	0	762	0	271	43,50	0	0	25,59	269,60	46,70	88,75
BOTERPUT	3	2611	3	926	28,49	0	0	10,62	265,65	44,95	88,64
MARIA HENDRIKAPARK	1	1745	0	452	29,08	0	24,42213115	3,07	258,23	42,21	87,51
SINT-JOZEF	2	1447	0	401	23,94	0	0	41,69	246,53	45,42	85,28
LEOPOLD I-PLEIN	1	2465	0	1087	19,11	0	0	57,52	234,67	43,48	82,81
LEOPOLDPARK	1	804	0	141	94,55	0	0	32,86	244,53	43,14	84,79
HOSPITAAL	3	1570	0	733	31,70	0	0	38,06	255,96	45,55	86,94
ALBERT I-PROMENADE-WEST	0	819	0	697	22,08	0	0	30,36	232,95	41,06	81,49
NIEUWLANDSTRAAT	3	1378	2	718	28,42	0	0	45,29	256,00	45,67	87,08
OOIEVAARSLAAN	7	1648	3	779	41,64	0	0	22,29	264,19	45,36	88,21
PRINSENLAAN	0	1420	0	727	35,38	0	0	42,20	252,95	45,46	86,75
H. HARTPLEIN	2	2405	1	1390	32,72	0	0	40,90	243,42	44,96	84,95
GODELIEVE	1	1816	1	907	21,65	0	0	25,68	250,41	44,56	86,13
H. HARTPLEIN	2	2944	1	1517	31,29	0	0	36,14	249,53	44,99	86,22
VELODROOMSTRAAT	0	901	0	504	26,36	0	0	35,34	239,14	43,43	83,81
NIJVERHEIDSSTRAAT	3	2373	1	1383	33,08	0	0	39,59	249,61	45,57	86,31
RENBAAN	3	1688	3	1499	29,22	0	0	16,08	247,85	41,19	84,90
MARIAKERKELAAN - EIGEN HAARD	0	668	0	456	33,21	0	0	14,96	267,85	44,94	88,84
MARIAKERKELAAN - BATTERIJ	0	1193	0	722	31,62	0	0	20,97	263,45	45,22	88,55
TROONSTRAAT	0	12	0	11	0,00	0	0	23,12	241,84	40,97	82,74
VOORHAVEN	0	3111	0	1975	24,73	0	0	8,30	199,54	42,12	79,31
VLOTDOK	0	1373	0	393	37,97	4	170,1016636	7,74	231,14	44,07	84,44
SINT-ANTONIUSPLEIN	4	1942	2	391	25,11	0	0	36,24	246,74	45,68	86,37
TABORALAAN	4	2436	2	495	27,44	0	0	15,65	259,37	45,28	87,68
VAARTBLEKERS	0	1626	0	393	39,54	1	113,5944203	3,11	266,76	43,29	89,34
FORT NAPOLEON	0	1459	0	317	34,60	0	0	8,72	211,39	39,05	78,61
SPUIKOM	0	2814	0	587	19,89	0	0	13,80	124,85	37,72	70,38
ZANDVOORDE-DORP	4	1167	0	113	22,68	10	14,17128532	9,79	262,92	41,72	89,70
ZANDVOORDE - STATION	0	1007	0	82	26,05	0	0	8,05	271,00	41,29	90,73
KEIGNAARTWIJK	1	915	0	109	21,36	194	23,47666643	9,74	233,25	39,68	85,74
PLASSENDALE - U.C.B.	0	723	0	75	35,79	0	31,83076923	1,61	209,04	39,14	81,88
OUDE POLDER	1	868	0	53	35,28	1	44,14683724	8,92	255,78	38,52	88,95
GRINTWEG	1	1351	1	172	58,14	15	57,96956591	1,48	243,83	36,25	87,71
KOEBRUG	1	973	0	108	36,14	35	74,10812557	3,64	272,17	42,89	90,68
VAARTDIJK-NOORD	0	920	0	258	40,56	0	6,25	1,24	207,36	38,22	81,56
KONTERDAM	4	2249	1	504	49,86	88	98,02517483	21,35	278,50	45,97	90,80

Statistical Sector	Storm surge Points of Interest	Buildings affected storm surge	Point of Interest Pluvial flooding	Buildings affected Pluvial Flooding	Water depth Pluvial Flooding	Buildings affected Fluvial flooding	Water depth Fluvial flooding	No. of people affected by heat	Heat wave intensity	No. of days avg. temp >25	No. of days max temp >25
KONTERDAM - KOEBRUG	0	484	0	88	41,42	91	103,2344538	9,11	277,76	44,25	90,86
MEIBOOM	3	2016	0	495	30,28	0	0	24,20	271,39	45,16	89,56
KONTERDAM - GOUWELOZE KREEK	0	1347	0	257	27,73	16	54,74803307	3,40	276,31	43,06	91,18
OPRIT-NOORD	3	1056	1	359	34,33	0	0	14,02	274,91	45,45	90,55
OPRIT-ZUID	2	1869	0	344	30,38	0	0	15,12	276,24	44,13	91,03
MIMOSA	3	2074	3	511	34,18	0	0	8,22	274,04	45,48	90,35
ZILVERLAAN - LOTUS	0	2125	0	371	27,14	0	0	13,24	272,98	44,05	90,54
CARDIJN	0	2140	0	673	25,63	0	0	35,50	270,87	44,85	90,18
STENE-DORP	0	764	0	135	29,05	6	38,94776177	9,78	263,90	41,27	89,59
VETTEGRAS	2	1169	0	222	43,38	43	64,36640423	2,91	267,03	40,94	89,85
OUD VLIEGVELD	0	891	0	262	21,49	0	9,761605035	7,57	265,47	43,32	89,38
STENE-VERSPR. BEW.-OOST	0	956	0	158	36,89	0	58,32349553	7,68	250,39	36,48	88,39
SINT-JAN	4	1072	3	618	28,34	0	0	34,16	266,16	46,01	89,03
STUIVERSTRAAT	4	2286	1	765	25,14	0	0	18,12	271,31	45,06	89,96
HOGE BARRIERE	1	1644	0	867	22,62	0	0	30,23	256,54	44,55	88,06
NIEUWE KOERSWIJK	0	518	1	738	28,41	0	0	16,42	257,87	43,45	87,53
KRUISHOF	1	549	0	22	35,35	0	0	10,17	254,63	40,06	87,79
STENE-VERSPR. BEW.-WEST	0	592	0	110	32,38	0	21,61949686	0,91	246,68	36,41	87,44
KLOOSTER	2	852	0	326	29,23	0	0	13,94	263,05	42,86	88,81
MARIAKERKE - DERBYLAAN	2	83	1	908	23,68	0	0	26,45	255,32	44,37	86,46
MARIAKERKE - DISTELBAAN	0	222	0	837	24,96	0	0	20,28	245,13	41,77	84,95
MARIAKERKE - STRANDPLEIN	0	77	0	214	0,00	0	0	19,35	238,13	40,71	82,43
MARIAKERKELAAN - VREDESTRAAT	0	568	0	990	27,15	0	0	14,52	259,16	44,29	87,51
RAVERSIJDESTRAAT	0	65	0	374	31,52	0	0	29,24	239,08	40,87	82,67
MARIAKERKE - DUIN	0	210	0	249	34,97	0	0	5,57	238,07	38,37	83,66
RAVERSIJDE-OOST	0	29	0	60	28,20	0	0	13,66	239,88	40,67	84,07
RAVERSIJDE-WEST	0	106	0	29	34,31	0	0	1,53	232,56	37,04	82,93
RAVERSIJDE - VLIEGVELD	0	423	0	58	28,98	0	0	5,46	243,06	39,25	85,85
STRAND	0	105	0	77	34,64	0	0	20,68	218,10	35,80	78,19

Appendix F - Values Climate Exposure (normalised)

Wijk	Statistical Sector	Social vulnerability	Categorised social vulnera-bility	Storm surge total	Storm surge categorised	Social climate vulnera-bility (storm surge)	Pluvial flooding	Pluvial flooding categorised	Social climate vulnera-bility (pluvial flooding)	Fluvial Flooding	Fluvial flooding categorised	Social climate vulnera-bility (fluvial flooding)	Heat	Heat categorised	Social climate vulnera-bility (heat)
Centrum	A. BUYLSTRAAT	0,63	5	0,20	1		0,26	2		0,00	1		0,68	4	9
Centrum	ALBERT I-PROMENADE-OOST	0,54	4	0,08	1		0,08	1		0,00	1		0,53	3	7
Centrum	ALBERT I-PROMENADE-WEST	0,57	4	0,09	1		0,19	1		0,00	1		0,56	3	7
Konterdam - Meiboom	BOTERPUT	0,33	2	0,47	3	5	0,59	3	5	0,00	1		0,70	4	6
Stene	CARDIJN	0,74	5	0,26	2		0,20	2		0,00	1		0,84	5	10
Vuurtoren	FORT NAPOLEON	0,41	3	0,26	2		0,17	1		0,00	1		0,35	2	
Westerkwartier - Vlaams Plein	GODELIEVE	0,56	4	0,28	2		0,34	2		0,00	1		0,70	4	8
Zandvoorde	GRINTWEG	0,31	2	0,24	2		0,34	2		0,21	2		0,41	3	5
Westerkwartier - Vlaams Plein	H. HARTPLEIN	0,51	4	0,40	3	7	0,46	3	7	0,00	1		0,75	4	8
Westerkwartier - Vlaams Plein	H. HARTPLEIN	0,52	4	0,46	3	7	0,48	3	7	0,00	1		0,76	4	8
Centrum	HAZEGRAS	0,48	3	0,16	1		0,20	1		0,00	1		0,82	5	8
Stene	HOGE BARRIERE	0,49	3	0,25	2		0,23	2		0,00	1		0,76	4	7
Centrum	HOSPITAAL	0,69	5	0,36	2		0,23	2		0,00	1		0,80	4	9
Zandvoorde	KEIGNAARTWIJK	0,37	2	0,18	1		0,09	1		0,57	3	5	0,49	3	5
Mariakerke - Nieuwe Koers	KLOOSTER	0,48	3	0,21	2		0,16	1		0,00	1		0,67	4	7
Zandvoorde	KOEBRUG	0,29	1	0,22	2		0,14	1		0,31	2		0,66	4	5
Konterdam - Meiboom	KONTERDAM	0,26	1	0,51	3	4	0,37	2		0,51	3	4	0,82	5	6
Konterdam - Meiboom	KONTERDAM - GOUWELOZE KREEK	0,39	2	0,20	1		0,14	1		0,20	2		0,67	4	6
Konterdam - Meiboom	KONTERDAM - KOEBRUG	0,38	2	0,15	1		0,16	1		0,54	3	5	0,72	4	6
Mariakerke - Nieuwe Koers	KRUISHOF	0,41	3	0,13	1		0,13	1		0,00	1		0,56	3	6
Centrum	LANGESTRAAT	0,58	4	0,28	2		0,30	2		0,00	1		0,62	4	8
Centrum	LEOPOLD I-PLEIN	0,55	4	0,33	2		0,25	2		0,00	1		0,75	4	8
Centrum	LEOPOLDPARK	0,56	4	0,19	1		0,36	2		0,00	1		0,68	4	8
Mariakerke - Nieuwe Koers	MARIAKERKE - DERBYLAAN	0,46	3	0,11	1		0,35	2		0,00	1		0,71	4	7
Mariakerke - Nieuwe Koers	MARIAKERKE - DISTELBAAN	0,43	3	0,03	1		0,23	2		0,00	1		0,59	3	6
Mariakerke - Nieuwe Koers	MARIAKERKE - DUIN	0,34	2	0,03	1		0,16	1		0,00	1		0,42	3	5
Mariakerke - Nieuwe Koers	MARIAKERKE - STRANDPLEIN	0,50	4	0,01	1		0,03	1		0,00	1		0,52	3	7
Mariakerke - Nieuwe Koers	MARIAKERKELAAN - BATTERIJ	0,41	3	0,18	1		0,23	2		0,00	1		0,75	4	7
Mariakerke - Nieuwe Koers	MARIAKERKELAAN - EIGEN HAARD	0,41	3	0,10	1		0,19	1		0,00	1		0,73	4	7
Mariakerke - Nieuwe Koers	MARIAKERKELAAN - VREDESTRAAT	0,44	3	0,08	1		0,26	2		0,00	1		0,68	4	7
Konterdam - Meiboom	MEIBOOM	0,42	3	0,42	3	6	0,19	1		0,00	1		0,79	4	7
Stene	MIMOSA	0,34	2	0,42	3	5	0,54	3	5	0,00	1		0,74	4	6
Mariakerke - Nieuwe Koers	NIEUWE KOERSWIJK	0,36	2	0,08	1		0,33	2		0,00	1		0,67	4	6
Westerkwartier - Vlaams Plein	NIEUWLANDSTRAAT	0,59	4	0,34	2		0,44	3	7	0,00	1		0,84	5	9
Westerkwartier - Vlaams Plein	NIJVERHEIDSSTRAAT	0,62	5	0,44	3	8	0,46	3	8	0,00	1		0,79	4	9
Westerkwartier - Vlaams Plein	OOIEVAARSLAAN	0,49	3	0,55	3	6	0,61	4	7	0,00	1		0,75	4	7
Centrum	OOSTENDE-CENTRUM	0,59	4	0,35	2		0,57	3	7	0,00	1		0,74	4	8
Konterdam - Meiboom	OPRIT-NOORD	0,33	2	0,31	2		0,29	2		0,00	1		0,77	4	6
Konterdam - Meiboom	OPRIT-ZUID	0,44	3	0,35	2		0,16	1		0,00	1		0,75	4	7
Stene	OUD VLIEGVELD	0,33	2	0,13	1		0,12	1		0,03	1		0,66	4	6
Zandvoorde	OUDE POLDER	0,16	1	0,18	1		0,13	1		0,13	1		0,53	3	4
Zandvoorde	PLASSENDALE - U.C.B.	0,35	2	0,13	1		0,14	1		0,09	1		0,35	2	
Centrum	POST - MERCATORDOK	0,56	4	0,47	3	7	0,58	3	7	0,00	1		0,70	4	8
Westerkwartier - Vlaams Plein	PRINSENLAAN	0,52	4	0,21	2		0,25	2		0,00	1		0,81	5	9
Raversijde	RAVERSIJDE - VLIEGVELD	0,50	4	0,07	1		0,11	1		0,00	1		0,48	3	7
Raversijde	RAVERSIJDE-OOST	0,36	2	0,01	1		0,11	1		0,00	1		0,52	3	5
Mariakerke - Nieuwe Koers	RAVERSIJDESTRAAT	0,44	3	0,01	1		0,17	1		0,00	1		0,58	3	6
Raversijde	RAVERSIJDE-WEST	0,43	3	0,03	1		0,12	1		0,00	1		0,36	2	
Westerkwartier - Vlaams Plein	RENBAAN	0,61	5	0,35	2		0,69	4	9	0,00	1		0,57	3	8
Vuurtoren	SINT-ANTONIUSPLEIN	0,54	4	0,51	3	7	0,38	2		0,00	1		0,77	4	8
Stene	SINT-JAN	0,54	4	0,35	2		0,54	3	7	0,00	1		0,83	5	9
Centrum	SINT-JOZEF	0,57	4	0,30	2		0,15	1		0,00	1		0,78	4	8
Stene	STENE-DORP	0,25	1	0,11	1		0,12	1		0,13	1		0,62	4	5
Stene	STENE-VERSPR. BEW.-OOST	0,26	1	0,13	1		0,16	1		0,17	1		0,47	3	4
Raversijde	STENE-VERSPR. BEW.-WEST	0,51	4	0,10	1		0,13	1		0,06	1		0,42	3	7
Stene	STUIVERSTRAAT	0,46	3	0,47	3	6	0,33	2		0,00	1		0,76	4	7
Vuurtoren	TABORALAAN	0,47	3	0,55	3	6	0,40	3	6	0,00	1		0,71	4	7
Westerkwartier - Vlaams Plein	TROONSTRAAT	0,48	3	0,00	1		0,00	1		0,00	1		0,56	3	6
Vuurtoren	VAARTBLEKERS	0,48	3	0,26	2		0,20	2		0,34	2		0,64	4	7
Vuurtoren	VAARTDIJK-NOORD	0,55	4	0,18	1		0,18	1		0,02	1		0,33	2	
Westerkwartier - Vlaams Plein	VELODROOMSTRAAT	0,52	4	0,13	1		0,18	1		0,00	1		0,67	4	8
Stene	VETTEGRAS	0,47	3	0,26	2		0,19	1		0,30	2		0,59	3	6
Vuurtoren	VLOTDOK	0,46	3	0,28	2		0,20	1		0,51	3	6	0,56	3	6
Vuurtoren	VOORHAVEN	0,43	3	0,58	3	6	0,42	3	6	0,00	1		0,41	3	6
Centrum	WAPENPLEIN	0,69	5	0,27	2		0,40	3	8	0,00	1		0,66	4	9
Zandvoorde	ZANDVOORDE - STATION	0,32	2	0,15	1		0,10	1		0,00	1		0,64	4	6
Zandvoorde	ZANDVOORDE-DORP	0,28	1	0,34	2		0,10	1		0,07	1		0,63	4	5
Stene	ZILVERLAAN - LOTUS	0,56	4	0,27	2		0,16	1		0,00	1		0,73	4	8