Mapping the liveability of the elderly during heat waves

An exploratory case study on the effects of climate change on the liveability of the elderly population

Source: https://www.amsterdam.nl/kunst-cultuur/grachtengordel/kijken/

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Amsterdam, 25 October 2019

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Problem

Climate change has been one of the most discussed topics in the past few years. The trend in climate change is expected to increase the occurrence of extreme heat waves and thus increase their harmful effects (Boa et al., 2015). The elderly are an especially vulnerable group to heat waves. To illustrate, the 2003 heatwave in Paris caused an excess mortality rate of 141% among the elderly (Wong et al., 2013). It is important to determine the liveability for the elderly during heat waves in Amsterdam to be able to improve areas with a lower liveability. Boa et al. (2016) mentions that individuals who are isolated, elderly, uneducated, low-income or with certain illnesses are more vulnerable to the effects of heat waves. Several studies show that the elderly are one of the most vulnerable groups when it comes to heatwaves (Vandertorren et al., 2006; Boa et al., 2015; Collins, 2009). The elderly have a harder time controlling their fluid balance due to the loss of the sensation of thirst and lower sodium intake, which means they run a higher risk of dehydration (Collins, 2009). A study by Walker and Beauchene (1991) shows that isolated elderly people often have a lower nutrient intake and loneliness causes dietary inadequacies. Lower health and isolation will make these individuals more vulnerable to the adverse effects of heat waves.

The global trend of rising temperatures will only increase the hazard for the elderly. It is especially difficult for the elderly to adapt to the changes that are required to reduce heat wave morbidity and mortality (Hansen et al., 2011). When the temperature rises and heat waves become more frequent, people have to change their normal ways in order to defend themselves overheating. This may be new and stressful for the elderly.

Furthermore, the document ‘Kerncijfers Amsterdam’ from the municipality of Amsterdam shows that the amount of elderly people (older than 65) in Amsterdam has increased from approximately 95.300 in 2014 to 105.500 in 2018 (OIS Amsterdam, 2018). While the growth of other age groups is slowing or have already started their demographic decline. This means that Amsterdam is aging, the elderly have will have access to a smaller support network and therefore the risk of isolation will increase. Another trend that is happening in mainly western countries is the rapid aging of the population. As the elderly are more vulnerable to dying from heat related causes, the group of vulnerable people rises as well. Furthermore, as the portion of elderly people in society grows, the portion of younger people declines (Długosz et al., 2011, Chłoń-Domińczak et al., 2014). The support networks that are needed to combat overheating consist mainly of younger people, such as children or health care workers.

The aim is to create a liveability map that visualises which neighbourhoods have a lower liveability and may need to be improved to decrease morbidity and mortality due to heat among the elderly. This might influence the choice elderly people make when choosing a new area to live. The variables that influence the increased mortality among the elderly on extremely hot days are listed in the chapter below.

Plan

The main question of this research is as follows: How is the liveability for the elderly during heat waves spatially distributed in Amsterdam? In order to ask these questions 12 indicators are composed which can be arranged in 6 subjects namely: Social network, temperature, economic capital, urban cool islands, heat resistant housing and care services. This division is based on the preferences and needs of the elderly which is based on literature research and is explained in the paragraphs below.

Social Network; Loneliness

Loneliness is an important factor influencing the vulnerability of the elderly. People who experience loneliness are physically and mentally more vulnerable and are prone to depression, cognitive decline and a number of health related issues (Amsterdam netwerk eenzaamheid, 2017). A study by Klinenberg (2016) shows that loneliness and isolation do not only depend on the individual but also on the environment they live in. The study assessed a heatwave in Chicago and discovered that poor areas with a low social infrastructure had higher mortality rates than poor areas with better social infrastructures. Areas with a low percentage of loneliness is more preferable for the elderly and therefore more liveable.

In Amsterdam, 13% of people experience severe loneliness. This is a rising trend, having grown from 10% to 13% from 2008 to 2016 (OIS, 2018). The demographic of the elderly has a larger chance of experiencing severe loneliness. This is a vulnerable and furthermore sizable and growing group in Amsterdam.

Temperature; Urban heat island effect

Another important factor influencing liveability for the elderly is the urban heat island effect. This effect is strongest at night (IPCC, 2001), causing the air temperature to cool less than in rural areas. Essentially heat is trapped in urban areas. Urban human settlements release heat, and also change evaporation patterns and alter the energy balance by intercepting long wave radiation with buildings, causing the urban heat island effect (IPCC, 2001). This directly increases the number of hot days in a year, which can cause health problems for the most vulnerable demographics like the elderly (Tan et al., 2010). Areas where the Urban Heat Island effect is the lowest is more liveable for the elderly during heat waves.

Economic capital: Poverty

Poverty is a factor strongly influencing heat related mortality. In the US, poor migrant workers are three times as likely to die from heat related causes than American citizens (Taylor et al., 2018). Also, heat related deaths in India are concentrated mainly in the slums (Tran et al., 2013). Poorer people have access to less means to keep cool and are therefore more likely to die from heat related causes.

Urban cool islands: Waterbodies, Parks and green, Trees

Public parks and green can create an urban cool island effect (Chang et al., 2007). These are important features during heat waves as they allow people to cool. The proximity and accessibility of these parks are important for the elderly on hot days.

Furthermore, water bodies lower the temperature of the immediate area (Gupta et al., 2019) as the vaporisation of water is an endothermic reaction and withdraws energy from its surroundings. Depending on the size of the water body, this effect can cause a temperature dip in the order magnitude of degrees. Water bodies and parks therefore are important factors which determine the liveability of the elderly.

The tree density in a certain PC4 area provide a good estimate of the conditions on the street on a hot day. These trees provide shade and can improve the conditions on the street for walking. Trees provide shelter from direct sunlight. Furthermore, trees reduce urban temperatures by increasing the albedo, providing shade and evapotranspiration (Solecki et al., 2005). Therefore, the tree density is a good indicator for the liveability conditions outdoors.

Heat resistant housing: Energy label, year of construction, wall plants, green roofs

Cool indoor temperatures are at least as important as outdoor temperature when determining liveability. It is therefore important to take heat resistance of housing into account for the liveability map. The insulation status of the homes in a specific neighbourhood influences liveability as it can keep a home cooler during heat waves. Older houses tend to be less well insulated, heightening the risk of overheating for its residents.

The energy label can also be an indicator for the insulation of homes. Homes that are not well insulated are susceptible to high temperatures during heatwaves. The energy label indicates the energy efficiency of a building (van der Hoeven, 2013). In this analysis a lower value indicates a higher vulnerability.

Green roofs are of great importance to take into account as an indicator for heat resistant housing. According to a study by Jaffal et al. (2012) the indoor air temperature of a house can decrease up to 2 °C during the summer due to a green roof. The plant walls retain a part of the heat that otherwise would penetrate the house (Othman et al., 2016).

Care service: Proximity to hospitals, proximity to senior centres

The ease of access to medical attention reduces the chance of death due to heat. However, when the access is restricted due to geographical factors, this may negatively influence liveability. In the Netherlands the accessibility of health care is not restricted by wealth, but rather by distance. People in rural areas, who have less access to health care facilities are less likely to receive preventative health care measures (Casey et al., 2001). While in the municipality of Amsterdam there are no isolated rural areas, the effect still holds.

In senior or community centres information about combating overheating may be distributed. Furthermore, social networks can be maintained and activities may be organised. In these centres there are people watching out for elderly people. Therefore, it is important to map the local availability of these centres.

Data

In order to execute the analysis, data must be collected for every indicator. The PC4 neighbourhoods basemap is used to create the final liveability map. The PC4 geographic units are chosen because it can reflect a wide variety for the liveability in Amsterdam. Using this format, it is possible to visualise spatial relations adequately, while also being clear.

The loneliness dataset was divided into 22 areas, and needed to be disaggregated in order to yield usable data. The inaccuracies would grow too large if the dataset was disaggregated to smaller units, like buurten. To transform every dataset to PC4 areas, the data therefore needs to be edited to the basemap's format. In this chapter this process is discussed per dataset, together with considerations that have been made concerning outliers, availability and errors.

In appendix 1 on page 19 a table of the data sources and resolution is included. Appendix 2 on page 20 contains a schematic overview of the used data. In addition to this report, a liveability atlas has been made in which each indicator is shown in a map.

Average percentage severe loneliness

There were different datasets available on loneliness in Amsterdam. For this study the dataset 'Snapshot of loneliness' from the municipality of Amsterdam was used. This dataset displays severe loneliness. Other datasets contain statistics about loneliness where loneliness is defined by the question; 'Do you ever experience loneliness?'. When loneliness is measured in this way, the results are very different. For this study, severe loneliness is more interesting. This is because elderly people experiencing severe loneliness do not have a social network to fall back upon at all.

A problem with this dataset is that it only represents the severe loneliness per Amsterdam 22 areas. This is a low resolution and conversion into PC4 areas was necessary. Nevertheless, we found this dataset to be very relevant and it was included in the analysis. The loneliness areas shapefile and PC4 areas are joined using the 'union' tool which creates the lonelinessunion shapefile. It is important to keep the disaggregation and its weaknesses in mind while looking at the final map.

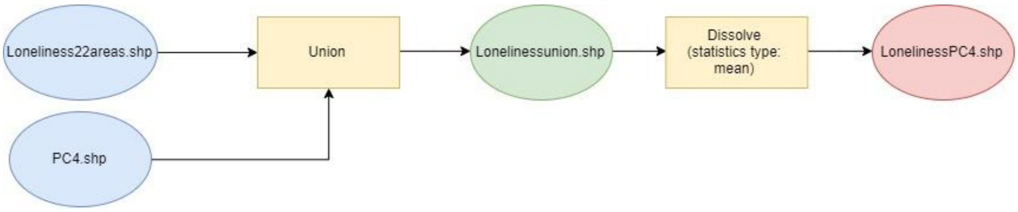

Figure 1 Modelbuilder Average percentage severe loneliness

Average urban heat island effect (UHI)

For this indicator, data from the Rijksinstituut voor Volksgezondheid en Milieu (RIVM) is used. This dataset visualises the urban heat island effect in degrees Celsius for the Netherlands. The data is based on the following variables; population density in the city, wind speed at a height of 10 meters, urbanisation, green and blue spaces. The resolution of this dataset is high with 10 meter per cell. To prepare the data it was clipped with the PC4 area. Then, the tool 'zonal statistics as a table' is used to obtain the mean UHI for every PC4 neighbourhood. Finally, this table needs to be joined to the PC4 area to obtain the prepared dataset.

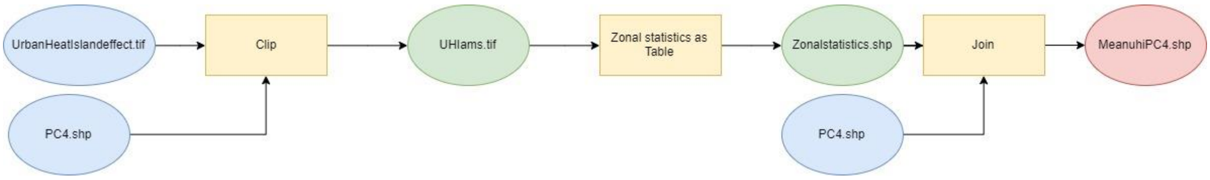

Figure 2 Modelbuilder; Average urban heat island effect (UHI)

Average income

The dataset about average income is obtained from the municipality of Amsterdam and shows the average income for the PC6 neighbourhoods. As there are more spatial entities in this dataset than PC4 areas, it needs to be transformed. The data layer and PC4 basemap are combined in one layer with the Union tool. The dissolve tool is used to aggregate the average income map.

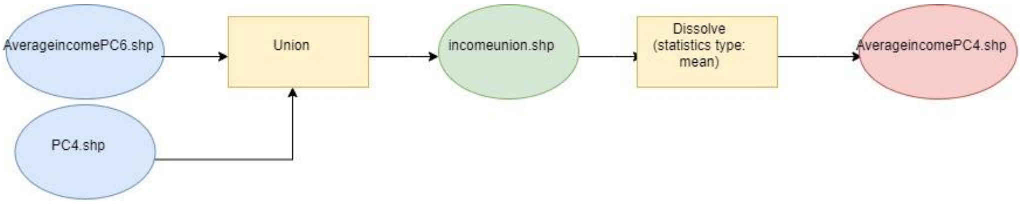

Figure 3 Modelbuilder: Average income

Average distance to parks and green

The data about parks and green from the municipality of Amsterdam is used to determine the average distance to parks and green. Polygons of the parks and green in Amsterdam are used to determine the distance. The decision is made to include the parks and green of the dataset around Amsterdam to minimise the MAUP problem. Firstly, the Euclidean distance tool is used to create a tif file. Then, 'zonal statistics as table' is used to calculate the mean distance to the parks and green per neighbourhood. Finally, this table is joined with the PC4 area to create a useful map.

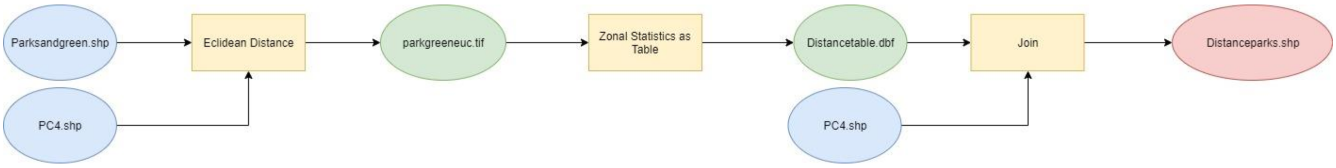

Figure 4 Modelbuilder: Average distance to parks and green

Percentage water area

To determine the percentage water area per neighbourhood, remote sensing is used. The remote sensing data is collected by the European Space Agency (ESA). For this research, Sentinel 2 data with 10m resolution is used to determine the percentage water area per PC4 area. With the use of supervised classification 2 categories has been created; water and not water, after which this is reclassified. Zonal statistics as a table creates a table from the reclassified raster, where the values of the water raster which lay within the PC4 zones are summarized. This table is then joined to the PC4 layer after which a field is added. For this new field the field calculator is used to calculate the water area, by dividing the area of water by the total area of the PC4 area.

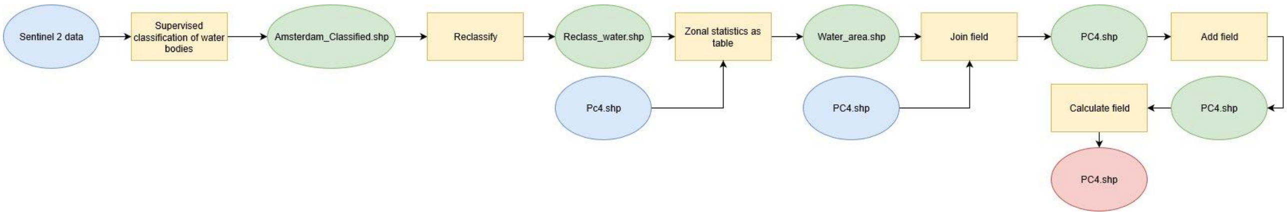

Figure 5 Modelbuilder; Percentage water area

Tree density

In order to determine the tree density, data of the municipality of Amsterdam is used. These are point data shapefiles divided in four parts because of the size of the data. Spatial join is used to to add the four files one by one so the computer was able to process it. The Trees1 shapefile was spatially joined with the PC4 area and this resulted in the TreesPC41 shapefile which consisted of the amount of trees from tree file 1, per PC4 area per Neighbourhood. This process was repeated for the other point data shapefiles. When all data is included, the attribute table contains 4 fields with the amount of trees per PC4 neighbourhood. A new field has to be created to calculate the total amount of trees per neighbourhood. A total amount of trees per neighbourhood does not provide useful information. Therefore a new field which calculated the area per PC4 area in square kilometres is made. Then in a new field the tree density is calculated by dividing the number of trees by the geometry.

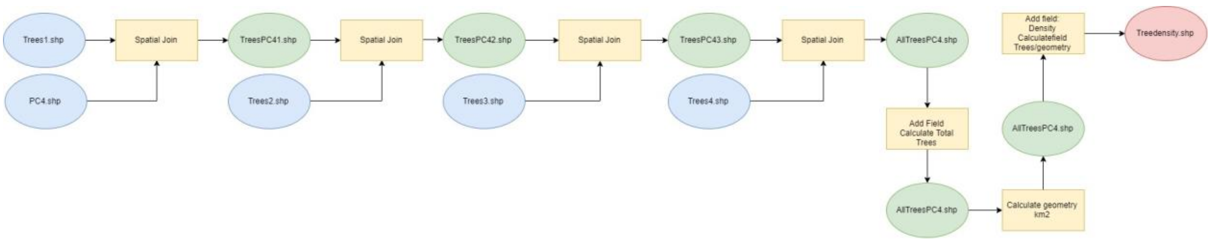

Figure 6 Modelbuilder; Tree density

Average energy label

The average energy label data originates from the municipality. It is an excel file with an energy label per building per PC6 area. The dataset does not contain all buildings in Amsterdam, but only the ones where an energy label has been given. Also, three PC4 areas were missing, so for these the average energy label was used. The energy label is given in letters from A to G, these were converted to numbers from 1 to 7 to be able to calculate the average energy label. The PC6 area column needed to be transformed into PC4 to create the desired map, the excel function "LEFT" is used for this. After which the average per PC4 is calculated. Those two operations in excel are made with a pivot table. Then in Arcmap the PC4 and energylabelsPC4.csv files are joined resulting the prepared map of energy labels.

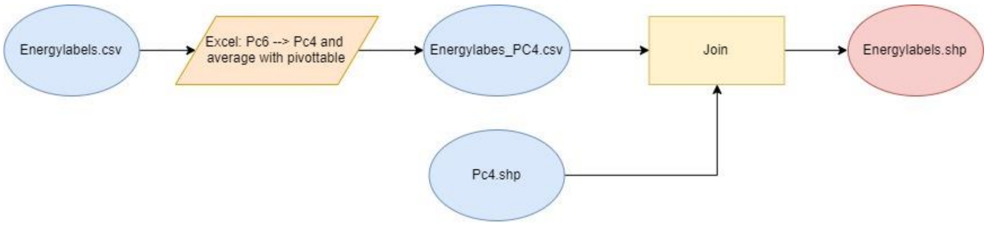

Figure 7 Modelbuilder; Average energy label

Average year of construction

The BAG data is obtained from canvas which is provided by Maurice de Kleijn. This data comes from Publieke Dienstverlening op de Kaart (PDOK) and contained the year of construction for each building. With ArcPro it is possible to use the tool ‘summarize within’ which provided the average year of construction in a PC4 area.

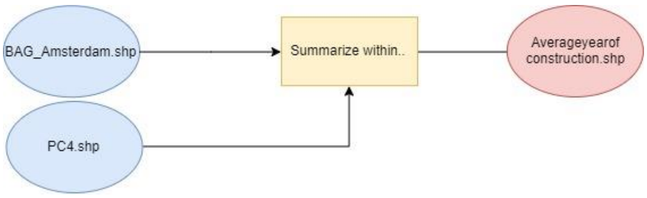

Figure 8 Modelbuilder: Average year of construction

Green roof density

The municipality of Amsterdam provides open data about the location of green roofs and this dataset is updated frequently. Then the ‘summarize within’ tool is used to determine the number of green roofs per PC4 area. The number is not meaningful enough for the analysis, so the density needs to be calculated. To calculate the green roof density a field is added to calculate the geometry in square kilometres. Finally, the density is calculated in a new field by dividing the number of green roofs by the area.

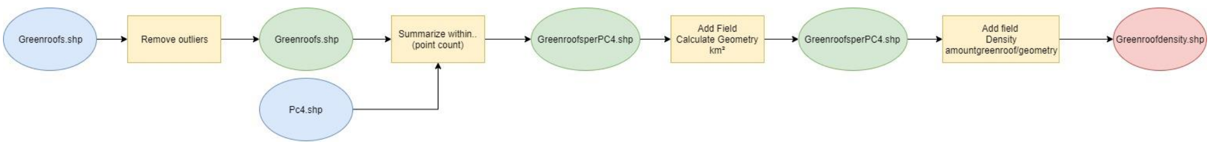

Figure 9 Modelbuilder; Green roof density

Wall plant density

Also for this indicator the data is retrieved from the municipality of Amsterdam. The prepared dataset Wallplantdensity.shp is created in the same way as the green roof density. The tool ‘summarise within’ gives the number of green roofs per PC4 area. A new field with the area in square kilometres is created and a field is added to calculate the density by the number of wall plants divided by the area.

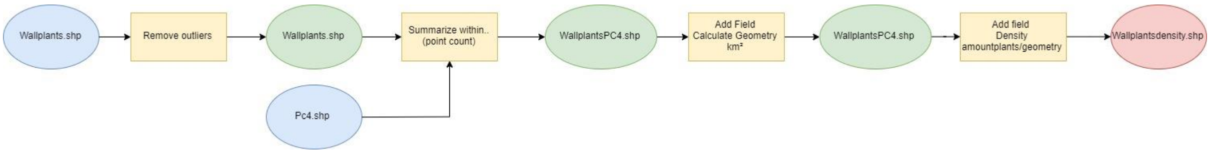

Figure 10 Modelbuilder; Wall plant density

Average distance from hospitals

To create this map the ‘functiekaart’ of the municipality of Amsterdam is used which consists of polygons of different functions for the city. For this dataset only the hospitals are needed. They are selected by attributes and with these attributes a new layer is created. Polygons are transformed into points because for this analysis only the location is needed. Then the Euclidean distance tool is used which creates the Eucledeanhospi.tif file. The ‘zonal statistics as table’ tool creates the mean distance per neighbourhood and finally this table needs to be joined to the PC4 to create the map of distance to hospitals.

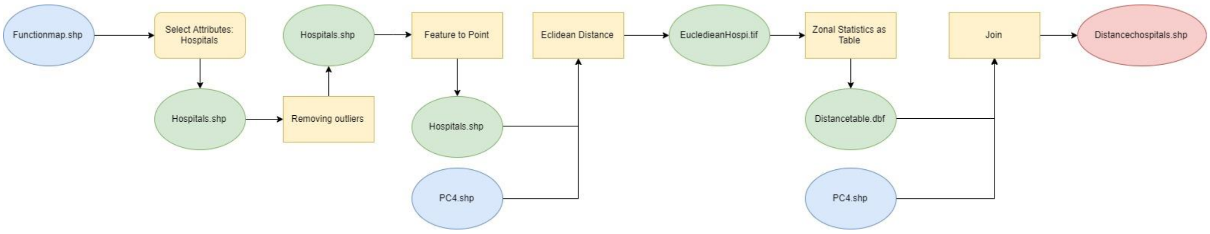

Figure 11 Modelbuilder; Average distance to hospitals

Average distance from residential care complexes

This dataset is transformed with a similar process as the dataset above. The same ‘functiekaart’ is used. This time the residential care complexes are selected and the new layer ‘Rescare.shp’ is created. With the ‘euclidean distance’ tool, Eucledeancarecom.tif is created. This is added into a table with the ‘zonal statistics as table’ tool. The mean distance from this table is joined to the PC4 shapefile to create the prepared map about the average distance to care complexes.

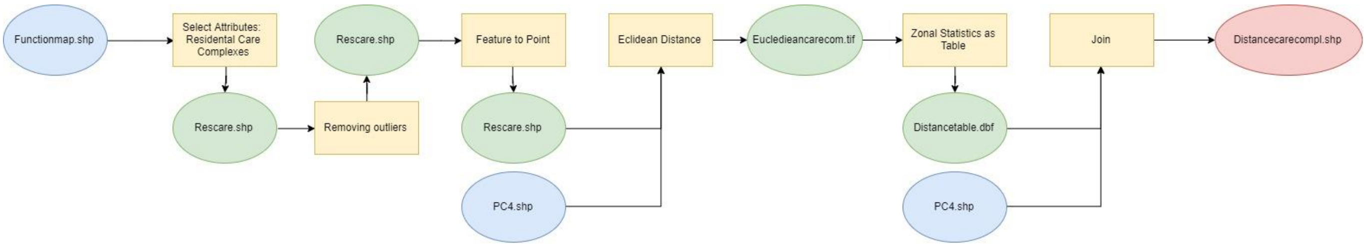

Figure 12 Modelbuilder: Average distance from residential care complexes

Analysis

The data should be normalised in order to execute a multi criteria analysis to map the areas of high and low risk of excess death during heat waves among the elderly in Amsterdam. This will be done according to the different weights assigned.

Figure 13 Analysis

The factors that have a stronger influence on heat mortality among the elderly are weighted more heavily.

The year of construction of buildings has a weight of 0.5. This, together with the energy label of buildings, which also has a weight of 0.5, will give an image of the insulation status. This is because counting them both with a weight of 1 would be double, as both give an indication to insulation status. These factors certainly influence liveability during heatwaves. However, to prevent double counting the weight is adjusted accordingly. This factor is important to take into account. A well-insulated home is vital for vulnerable groups during heatwaves.

The urban heat island effect is assigned a weight of 2 as this is an important factor to take into account. The heat trapped in urban areas contributes to extended periods of heat, which in turn increase mortality. Future climate change could increase the effect as well. That is why the factor urban heat island effect is weighted double.

Parks and waterbodies both have a weight of 1. Both these factors represent the physical assets that are available for the elderly when they are trying to cool off. Parks can act as small urban cool island effects, so living close by is beneficial. Large water bodies can cool the surrounding air temperature up to several degrees. An effect this large may not be achieved with the canals, but the cooling effect is significant nonetheless.

Loneliness is social factor strongly influencing heat related mortality. This factor will be weighted double. Neighbourhoods with an inadequate social infrastructure are more vulnerable to heat mortality. This is especially detrimental to the elderly as a good social infrastructure is beneficial to them. Loneliness makes an individual more vulnerable to depression and other health issues which also makes them more vulnerable to heat waves. Loneliness in not only based on the individual, but also on the environment they live in. This would mean that the liveability for the elderly would be better in locations with a better social infrastructure.

The factor tree density is weighted at 1. Trees both directly cool through evapotranspiration and provide shade. This factor cannot be overlooked.

Proximity to hospitals and elderly centres are socioeconomic inhibitors of heat related mortality. Both of these factors will also carry the weight of 1. Proximity to elderly centres can act as a prevention of heat mortality, where hospital proximity acts as a remedy. They reinforce one another and are very important in combating heat mortality.

Income also has a weight of 1. This socioeconomic factor influences vulnerability to heat related death.

To create the liveability map the values of the indicators need to be normalised to be able to aggregate them together. Normalising creates a value between 0 and 1 for every PC4 area for every indicator. This is done by adding a field and typing the following function into the field calculator (see appendix 2 for the model builder):

$$normalised\ value = \frac{(value\ -\ minimum\ value)}{(maximum\ value\ -\ minimum\ value)}$$

Normalisation is done to give the indicators values within the same range to be able to compare them. A value close to 1 is high and in our case positive for the liveability, a value close to zero is bad and thus negative for the liveability. Not all indicators with high values have a positive effect, for example the distance to a hospital, when the distance is high, this would give a high normalised value, but for the liveability of the elderly a long distance from the hospital is not good. So we need to invert the normalisation of this indicator. This can be done by subtracting the normalised value from 1. This way the value gets inverted and a long distance will give a low normalised value.

The normalised values of the different indicators can be summed per PC4 area and divided by the amount of indicators to create the liveability index map.

Conclusion

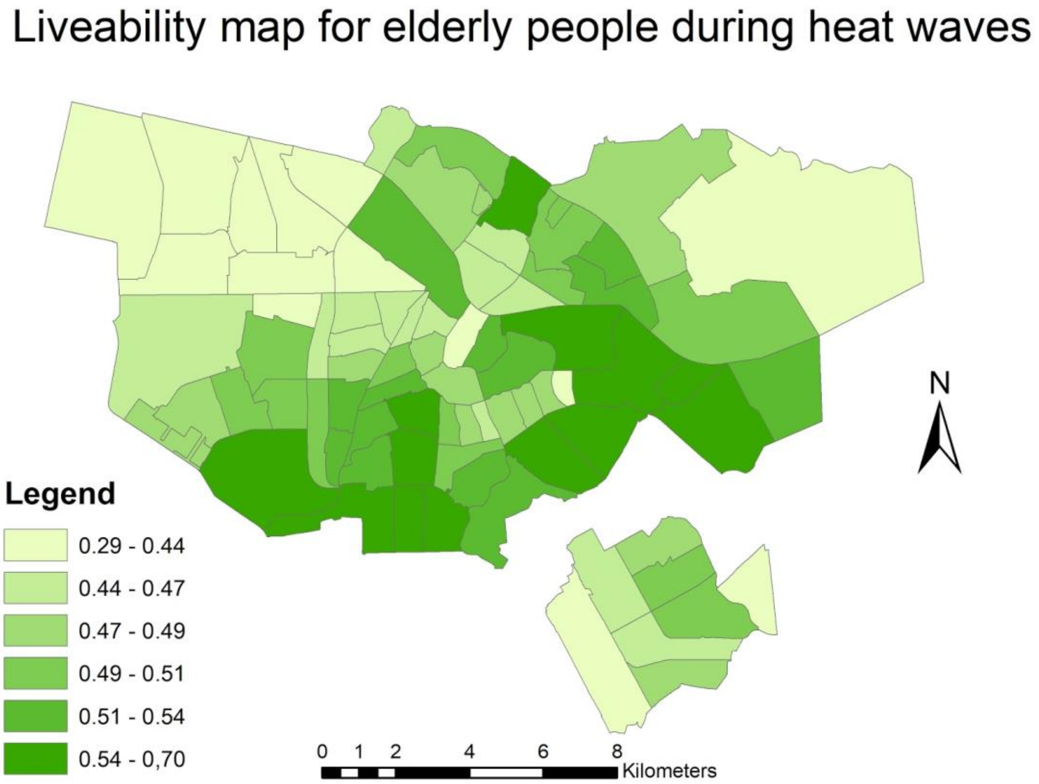

Figure 14 Liveability map for elderly people during heat waves

This map shows the areas with the highest liveability for the elderly during heat waves in Amsterdam. The western docklands and parts of the Bijlmer are the least well-equipped to prevent heat related mortality. Waterland scores low as well, despite being close to a large water body. The parts of Amsterdam scoring the highest are the southern and eastern parts. With the exception of the west, areas of high liveability seem to form a circle around the city centre where liveability is relatively lower.

Furthermore, the values of the different PC4 areas show some variation. Most values however, lie between 0.44 and 0.54, with some outliers.

Recommendations

This liveability map shows some areas lacking in heat wave mortality prevention measures. We are hopeful that measures will be undertaken to improve the areas with insufficient heat protection. New research is needed to determine the most effective and cost efficient measures for the specific areas.

It could also be very interesting to create a map of liveability of the elderly during heat waves on a neighbourhood scale. This way problematic areas and spatial relations could be identified with greater precision.

Another recommendation we would like to make, is to repeat this study for a wider area. This way, features in the periphery of Amsterdam are also included in the analysis, creating a more accurate image of the liveability of the elderly during heat waves in Amsterdam. The focus would still be on Amsterdam, but the MAUP we encountered with the municipal borders would be minimised.

Weaknesses

MAUP has occurred in multiple instances. The map that displays the percentage of severe loneliness for PC4 areas has been disaggregated from a map of Amsterdam depicting 22 areas. This process can never create perfect results and should therefore be mentioned as a possible inaccuracy.

Also the proximity analysis may have suffered from MAUP. It is possible that a hospital or elderly care complex is located just outside the administrative border of Amsterdam. As an administrative border is non-existent in real life, these buildings can also provide service to people living in Amsterdam. They have however been omitted from our proximity analysis, causing possible inaccuracies or omissions from our results. This is also the case for amount of water close by and the distance to parks. While our analysis yielded good results, we would still like to mention this as an area for improvement.

A possible shortcoming of the methods used is that only proximity to parks holds weight, as opposed to polders or agrarian green areas. These types of land use also combat the urban heat island effect. In future research it is interesting to include these types of land use in the analysis. Waterland is the only area with polders and agrarian green instead of parks, so the change would only have an effect there. Also, Waterland borders the IJmeer which as a large water body has a very strong cooling effect. However, the lake is not within municipality borders, and thus being omitted in the analysis.

Appendix 1: Data

Preferences of the elderly: *Having the social, physical and economic means to stay cool during heat waves*	Preferences translated into concepts	Variables translated into indicators	Data
Physical	Heat resistant house	**Year of construction**	Title: BAG Amsterdam Resolution: High Fit for purpose: Yes, the BAG file contains the year of construction for each building in Amsterdam. Source: PDOK (n.d.) Basisregistratie Adressen en Gebouwen (BAG) https://www.pdok.nl/introductie/-/article/basisregistratie-adressen-en-gebouwen-ba-1
		Wall plants	Title: Wall plants Resolution: High Fit for purpose: yes, the dataset contains the amount and location of wall plants in Amsterdam. Source: Gemeente Amsterdam - Muurplantenwerkgroep van de Koninklijke Nederlandse Natuurhistorische Vereniging (KNNV) afdeling Amsterdam (2014) *Muurplanten* https://maps.amsterdam.nl/muurplanten/
		Green roofs	Title: Green roofs Resolution: High Fit for purpose: yes, the dataset contains the amount and location of green roofs in Amsterdam. Source: Gemeente Amsterdam - Ruimte en Duurzaamheid (2019) Groene Daken https://maps.amsterdam.nl/groene_daken/
		Energy label	Title: Energy labels of Amsterdam Resolution: High Fit for purpose: Yes. Energy labels indicate the insulation status of the home, which is a factor in heat mortality. Source:

			Gemeente Amsterdam (2016). Energielabels in Amsterdam. https://data.amsterdam.nl/datasets/rV-5t8Wzy6TWzA/energielabels-in-amsterdam/
	Temperature	**Urban Heat island effect (UHI)**	Title: Urban Heat Island effect in the Netherlands Resolution: High Fit for purpose: Yes. This dataset is exactly fit for purpose. Source: Rijksinstituut voor Volksgezondheid en Milieu (RIVM) (n.d.) *Stedelijk hitte-eiland effect (UHI) in Nederland.* https://www.atlasnatuurlijkkapitaal.nl/kaarten
	Urban Cool Islands	**Parks, gardens and recreational green**	Title: Parks, gardens and recreational green Resolution: High Fit for purpose: Yes, this file contains all the info about parks, gardens and recreational green of Amsterdam. Source: Gemeente Amsterdam - Ruimte en Duurzaamheid (2014) *Parken, plantsoenen en recreatief groen* https://maps.amsterdam.nl/open_geodata/?k=99
		Water Bodies	Title: Sentinel 2 data Resolution: High Fit for purpose: Yes, by using supervised classification the water bodies of Amsterdam can be classified. Source: Copernicus open access hub (2016-09-08T10:50:22.027Z) Sentinel 2, 0.0 Cloud Cover https://scihub.copernicus.eu/dhus/#/home

		Tree density	Title: Trees Resolution: High Point data converted to tree density per PC4 area Fit for purpose: Yes, the dataset contains all the information of every (municipality owned) tree in Amsterdam. Source: Gemeente Amsterdam - Ruimte en Duurzaamheid (2014) *Bomen* https://maps.amsterdam.nl/bomen/
		Proximity to Hospital	Title: Function map Resolution: Low Fit for purpose: Yes, this dataset contains the location of every hospital in Amsterdam Source: Gemeente Amsterdam - Ruimte en Duurzaamheid (2014) *Functiekaart* https://maps.amsterdam.nl/functiekaart/
		Proximity to Senior or community centres	Title: Function map Resolution: Low Fit for purpose: Yes, but we needed to select all the senior and community centres manually. Source: Gemeente Amsterdam - Ruimte en Duurzaamheid (2014) *Functiekaart* https://maps.amsterdam.nl/functiekaart/
Economical	Economic capital	**Income distribution**	Title: Average income per neighbourhood Resolution: Low, Wijken / Gebiedbuurtcombinaties Fit for purpose: Yes, this dataset contains information about the income. Source: Gemeente Amsterdam, Onderzoek, Informatie en Statistiek, (2019) *Standgegevens 1 januari 2019* https://data.amsterdam.nl/datasets/468V7Fy2ECy-HQ/kerncijfers-wijken/

Social	Social network	**Loneliness percentage per neighbourhood**	Title: Percentage of people experiencing severe loneliness Resolution: Low, Amsterdam 22 areas Fit for purpose: Yes, but the resolution is not good. Source: Gemeente Amsterdam (2012) Snapshot van eenzaamheid in Amsterdam https://assets.amsterdam.nl/publish/pages/813474/aanpak_eenzaamheid_amsterdam_3_6.pdf

Appendix 2: Model builder

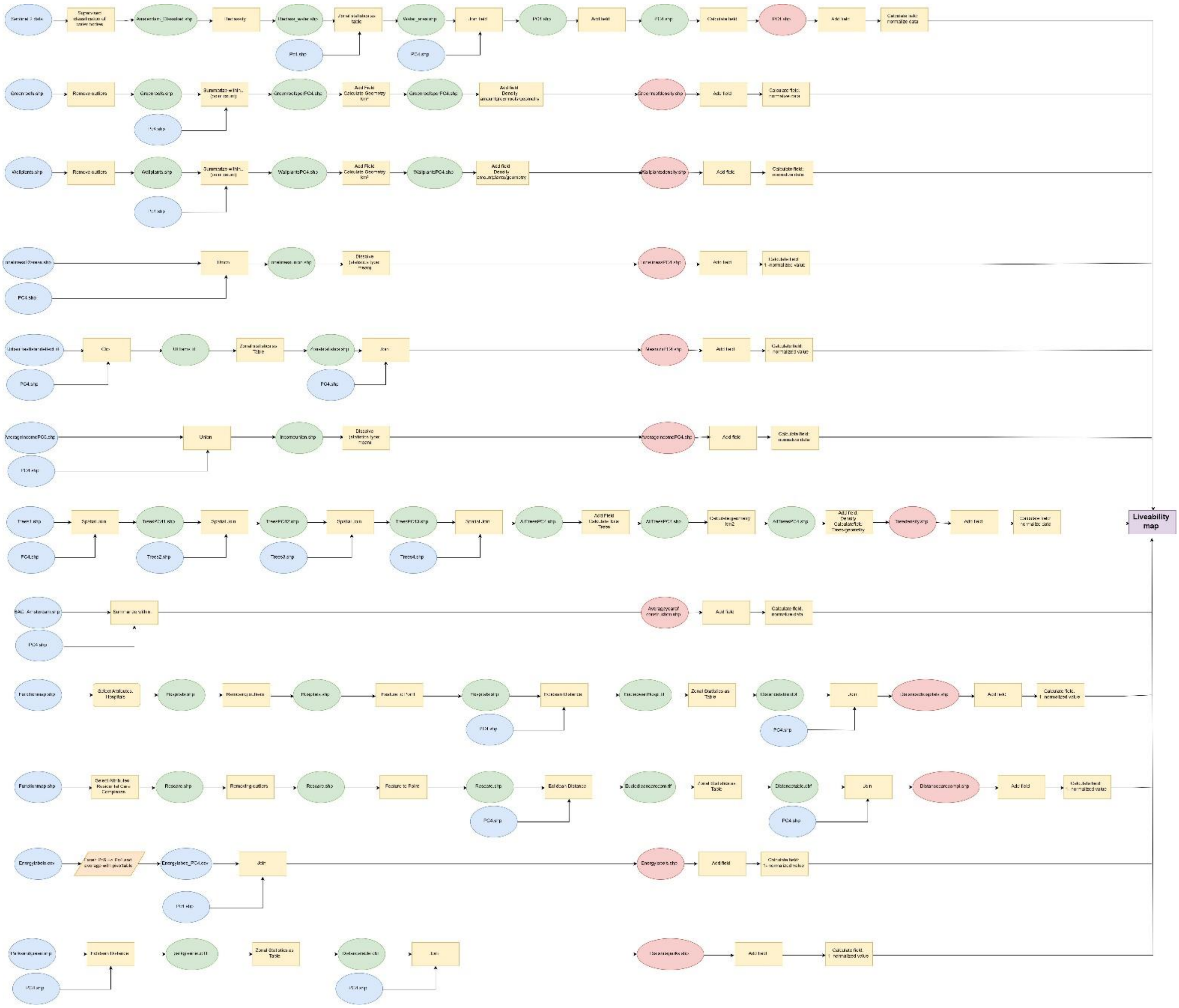

Figure 15 Model builder (see separately enclosed file on Canvas for details)

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