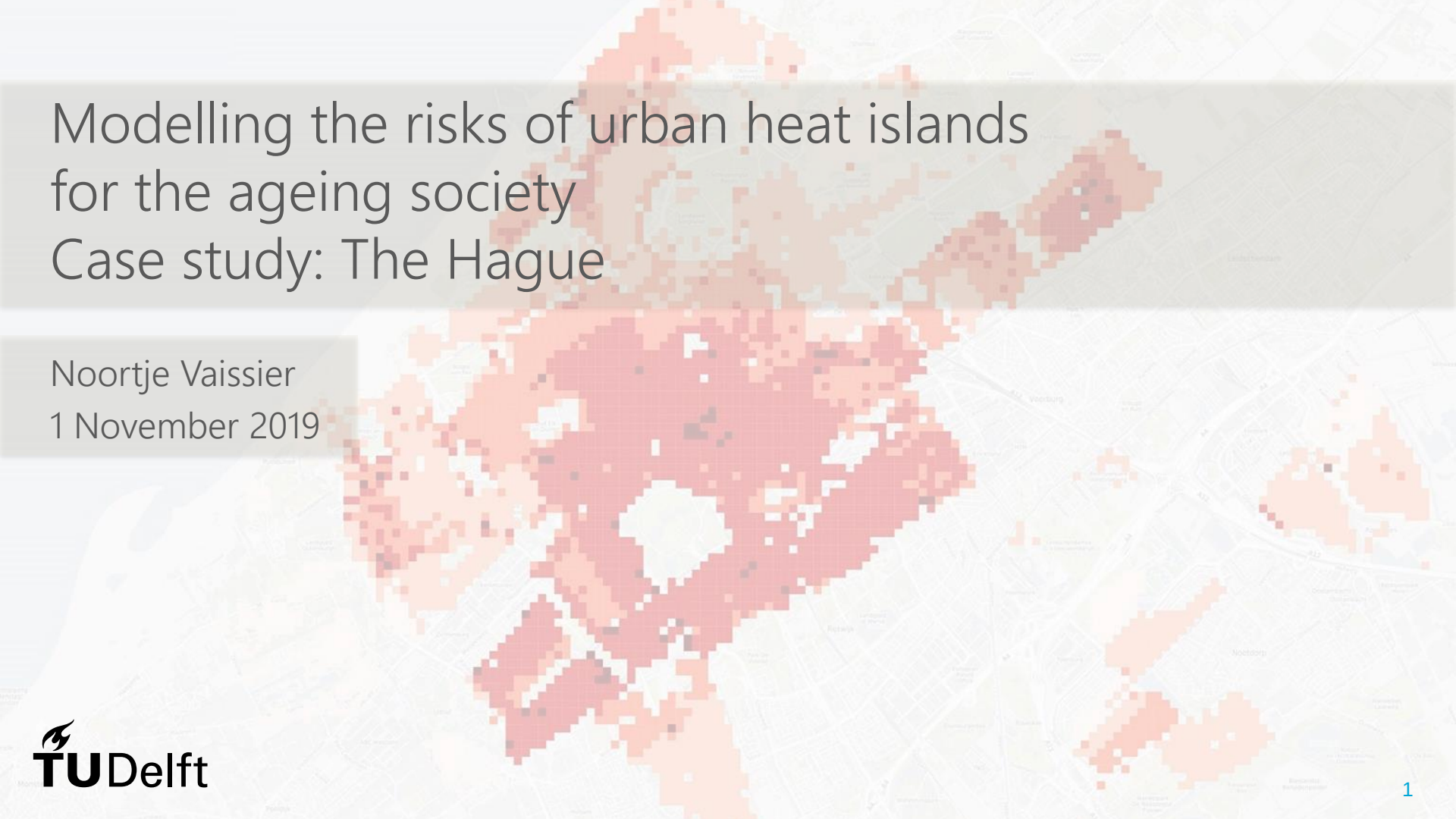
Modelling the risks of urban heat islands for the ageing society
Case study: The Hague

Noortje Vaissier

1 November 2019



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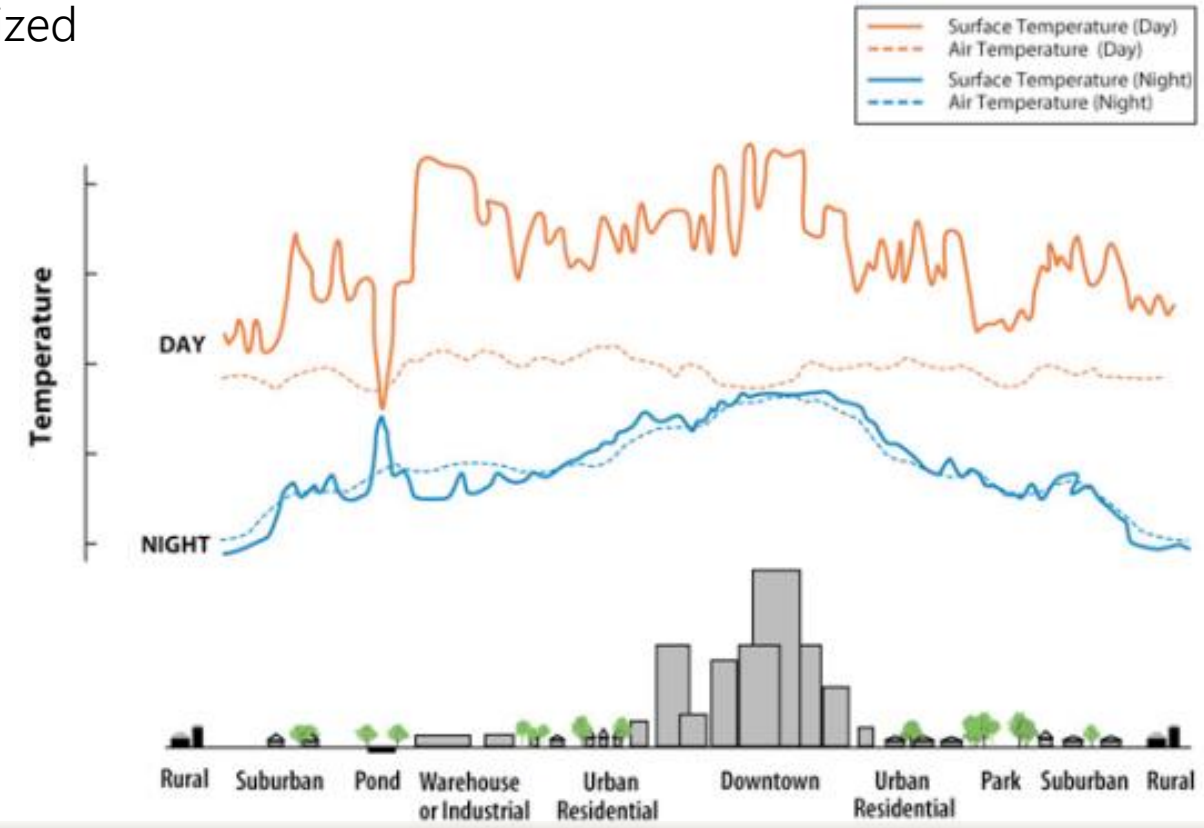
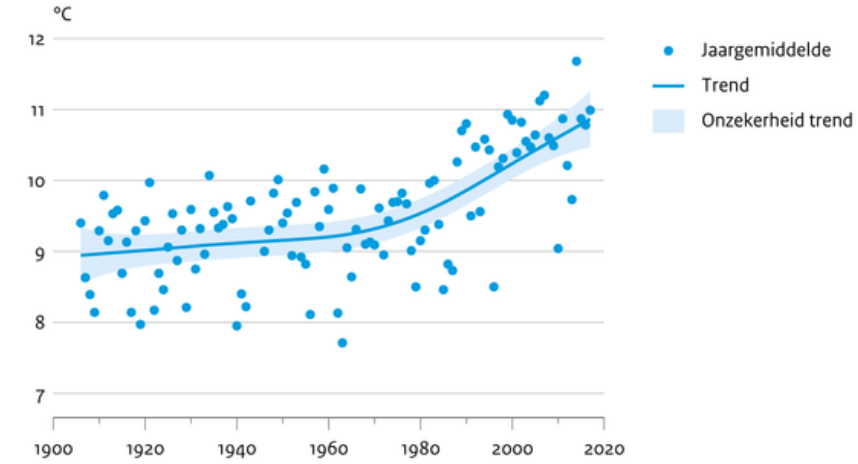
Urban heat island is recognized as one of the leading environmental issues of the 21st century cities

(Memon, Leung, & Chunho, 2008)

The urban heat island (EPA, 2008)





Bron: KNMI

PBL/mrt18
www.clo.nl/nl022613

Weeronline Actueel Wereldweer Weercijfers Mijn Plaatsen

Nieuws / Hittemaximum voorbij: de eindstand

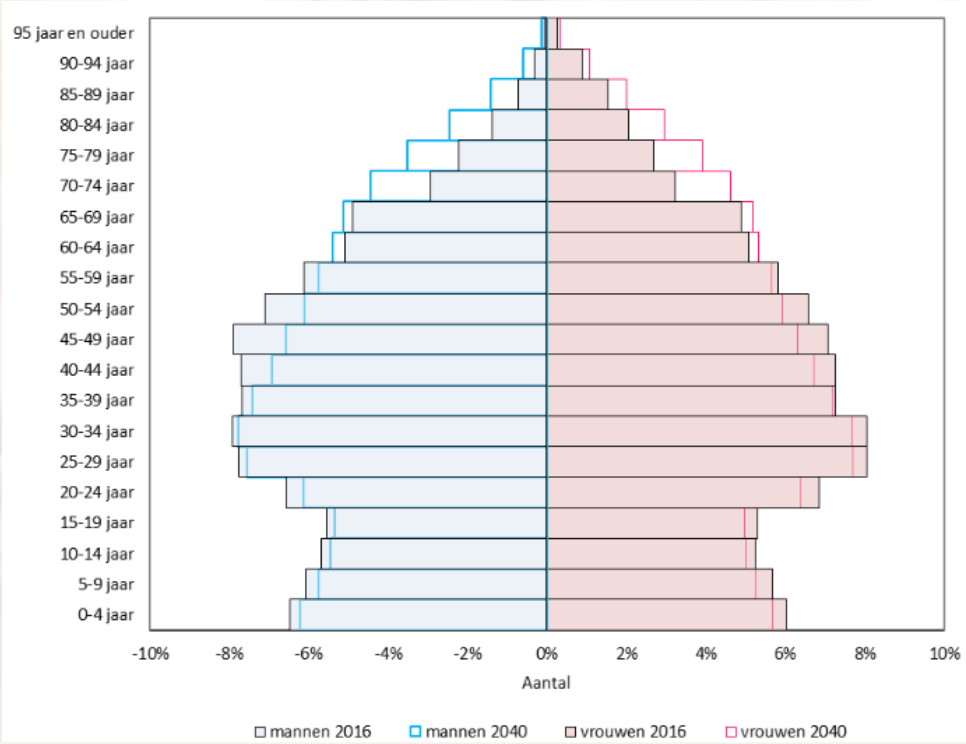
Hittemaximum voorbij: de eindstand

Een zeer hete dag nadert zijn einde en inmiddels is de maximumtemperatuur bereikt. De hoogste temperatuur werd vandaag gemeten in Westdorpe (Zeeuws-Vlaanderen) en Arcen (Limburg) met 38,1 graden. Het was officieel de warmste 27 juli sinds het begin van de metingen met in De Bilt een maximum van 35,4 graden. Het vorige record van 32,3 graden uit 1933 werd daarmee verpulverd.

Ook in Hoek van Holland was het opvallend warm. In de Zuid-Hollandse kustplaats werd een maximumtemperatuur van 37,9 graden gehaald. Hiermee was het op dit meetstation niet eerder zo warm. Het vorige record werd gehaald op 19 juli 2014 en bedroeg 36,5 graden. De zuidoostenwind in combinatie met het warme duinzand zorgde voor deze extreem hoge temperatuur. Ook in het Brabantse Gilze-Rijen was het met 37,5 graden verzengend heet.

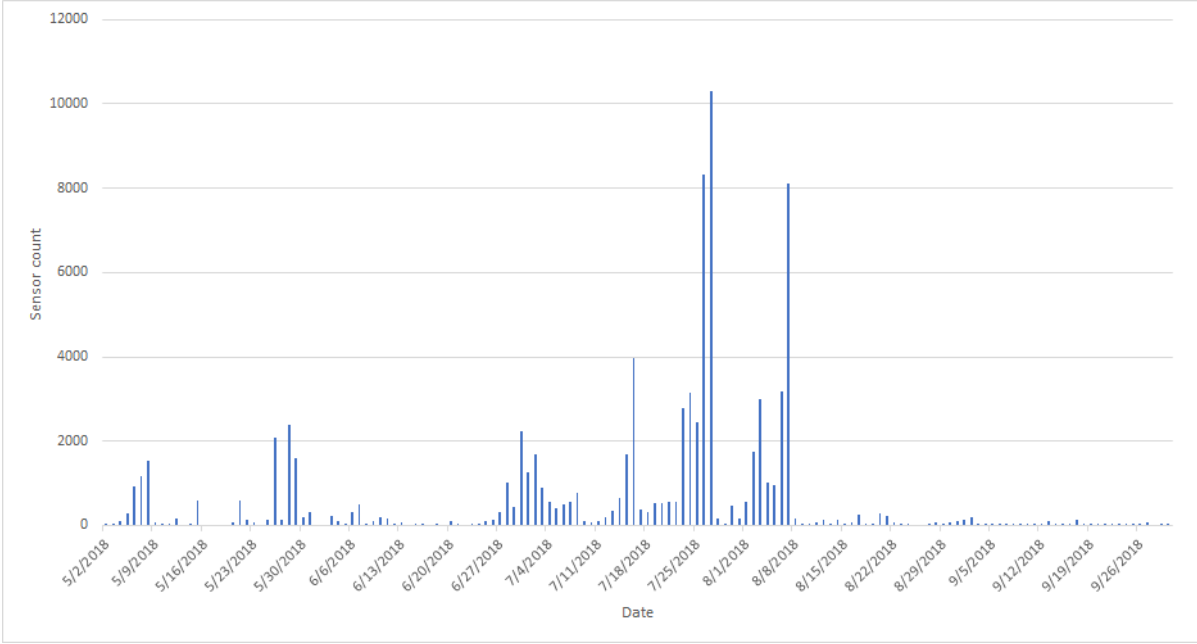
Seniors are widely recognized as a heat vulnerable population

(Kestens et al., 2011)



Case study: The Hague

- 27 July 2018 hottest day in The Hague



Motivation

- Surveillance and alertness needs to be improved when responding to events of heat stress
- More insight into:
  - indicators
  - Vulnerable groups and places

Goal

Model the risks of urban heat islands for the ageing society in the city of The Hague

Research questions

How to model the urban heat related risks for the ageing society in the city of The Hague?

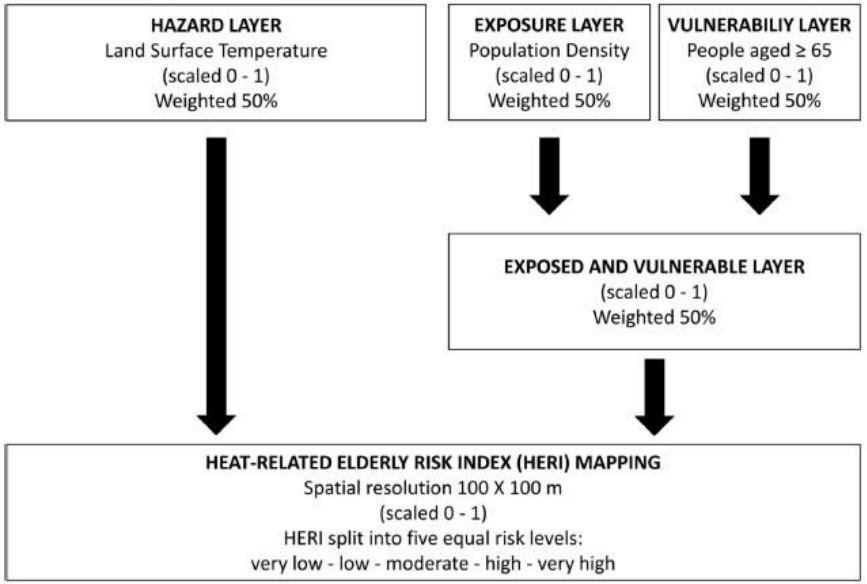
- Indicators?
- Framework?
- Where?
- Spatial resolution?

Risk

- Crichton's triangle of risk (Morabito (2015), Tomlinson(2014))
  - Hazard layer
  - Vulnerability layer
  - Exposure layer
- Each layer contains 1 or more indicators of risk

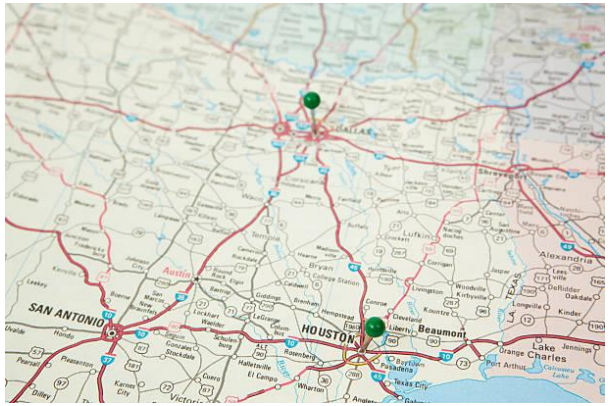
Layer structure

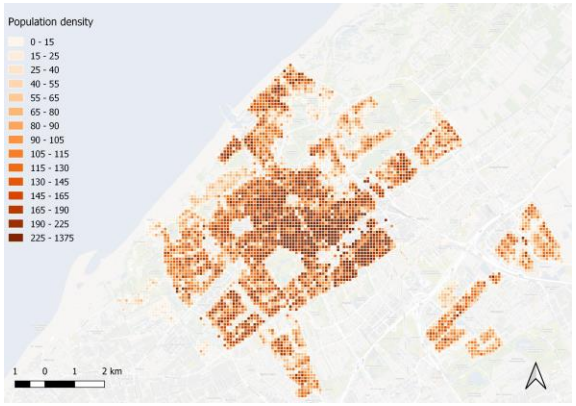
- Based on Crichton's triangle of risk
- Equal weights

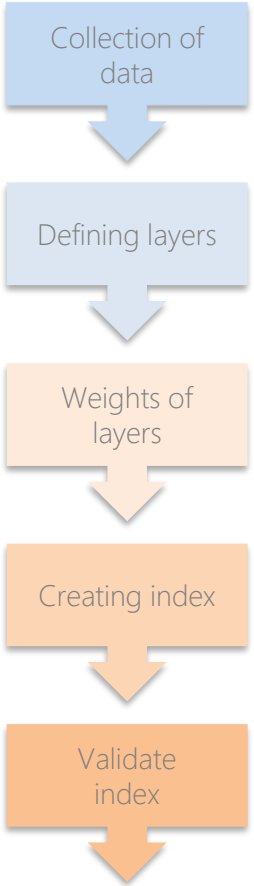


What is a spatial data layer

- Identifies the geographic **location** of features and boundaries on Earth
- Stored as coordinates and topology
- Data that can be mapped





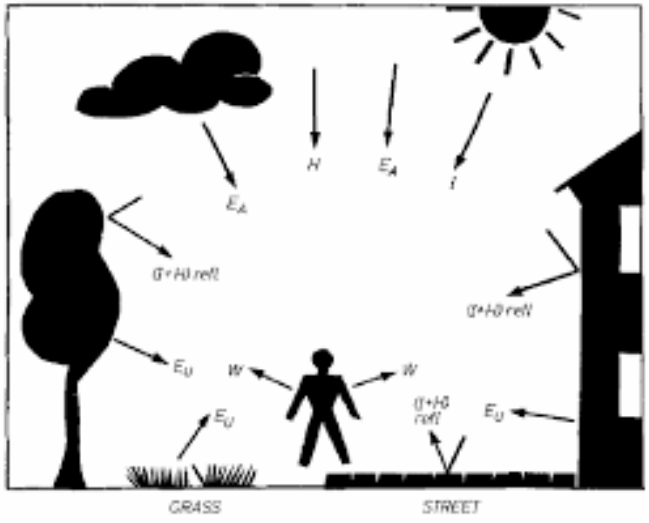


Implementation

HAZARD

- Physiological Equivalent Temperature
- Indoor temperature

Physiological Equivalent Temperature



$$M + W + R + C + E_D + E_{Re} + E_{Sw} + S = 0$$

PET (°C)	Physiological stress category
Above 41	Extreme heat stress
35 - 41	Very strong heat stress
29 - 35	Strong heat stress
23 - 29	Moderate heat stress
18 - 23	No thermal stress
13 - 18	Slight cold stress
8 - 13	Moderate cold stress
4 - 8	Strong cold stress
Below 4	Very strong cold stress

Collection of data

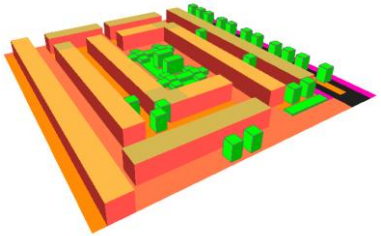
Defining layers

Weights of layers

Creating index

Validate index

Locations → Building models → Simulation → Temperature maps



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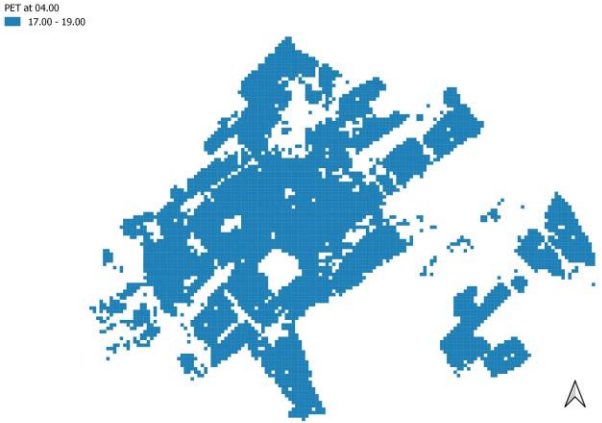


Three timestamps:

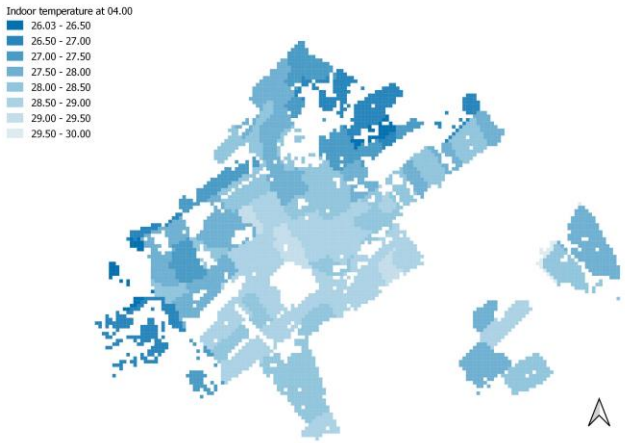
04.00 in the morning

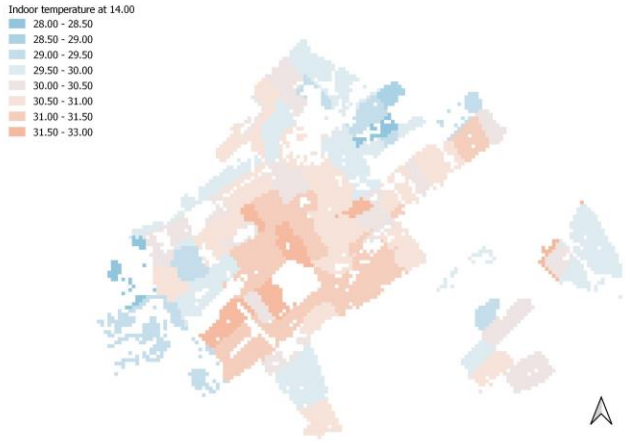
14.00 in the afternoon

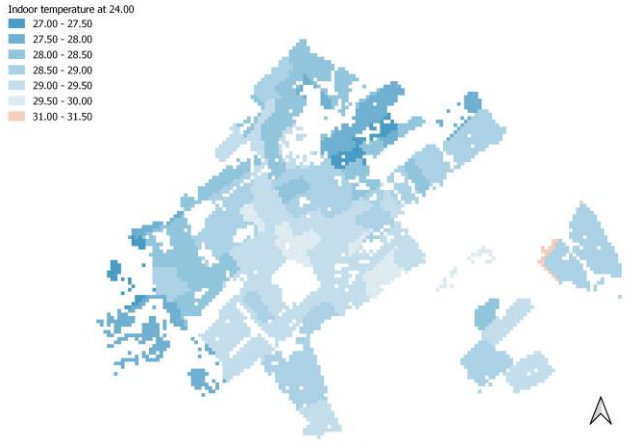
24.00 at night

Indoor temperature

- Quby Sensor inside homes
- Measured per neighbourhood







Three timestamps:

- 04.00 in the morning
- 14.00 in the afternoon
- 24.00 at night

Collection of data

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EXPOSURE

- Population density

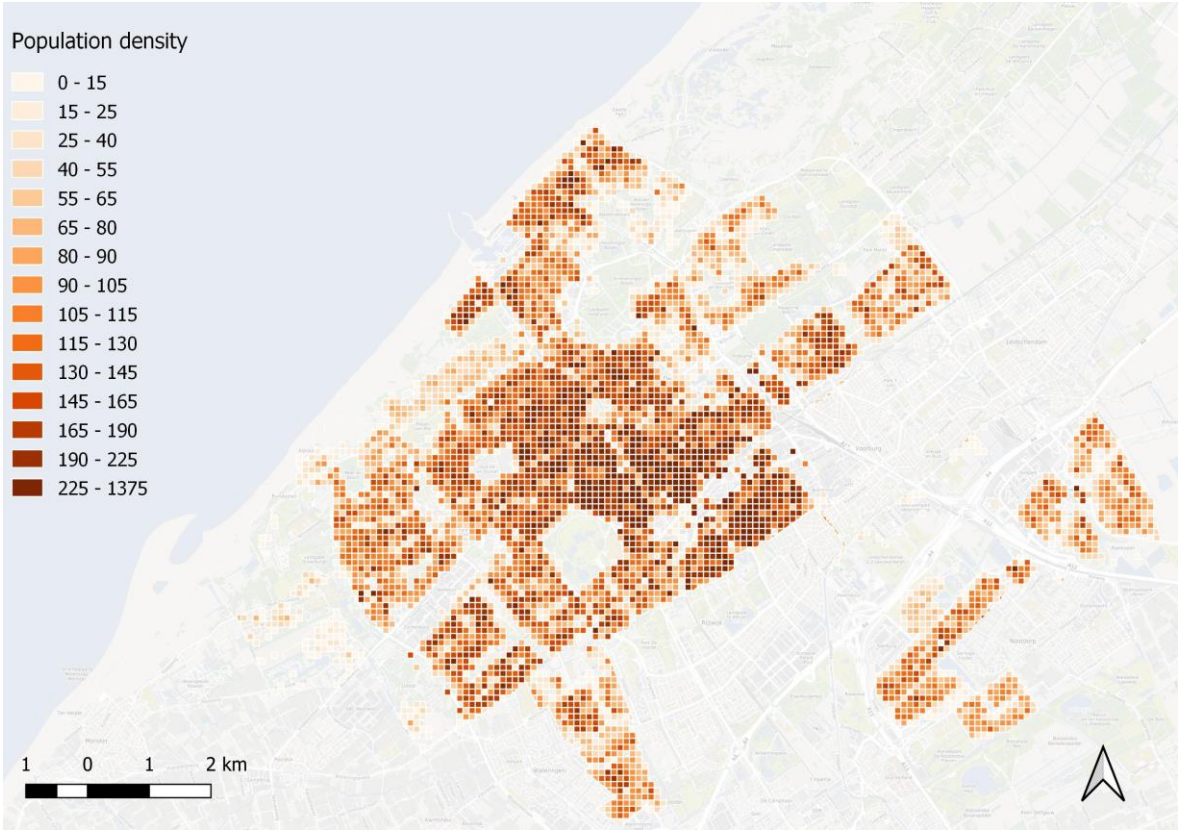
Collection of data

Defining layers

Weights of layers

Creating index

Validate index



VULNERABILITY

- People aged 75 years and older
- Loneliness amongst the elderly

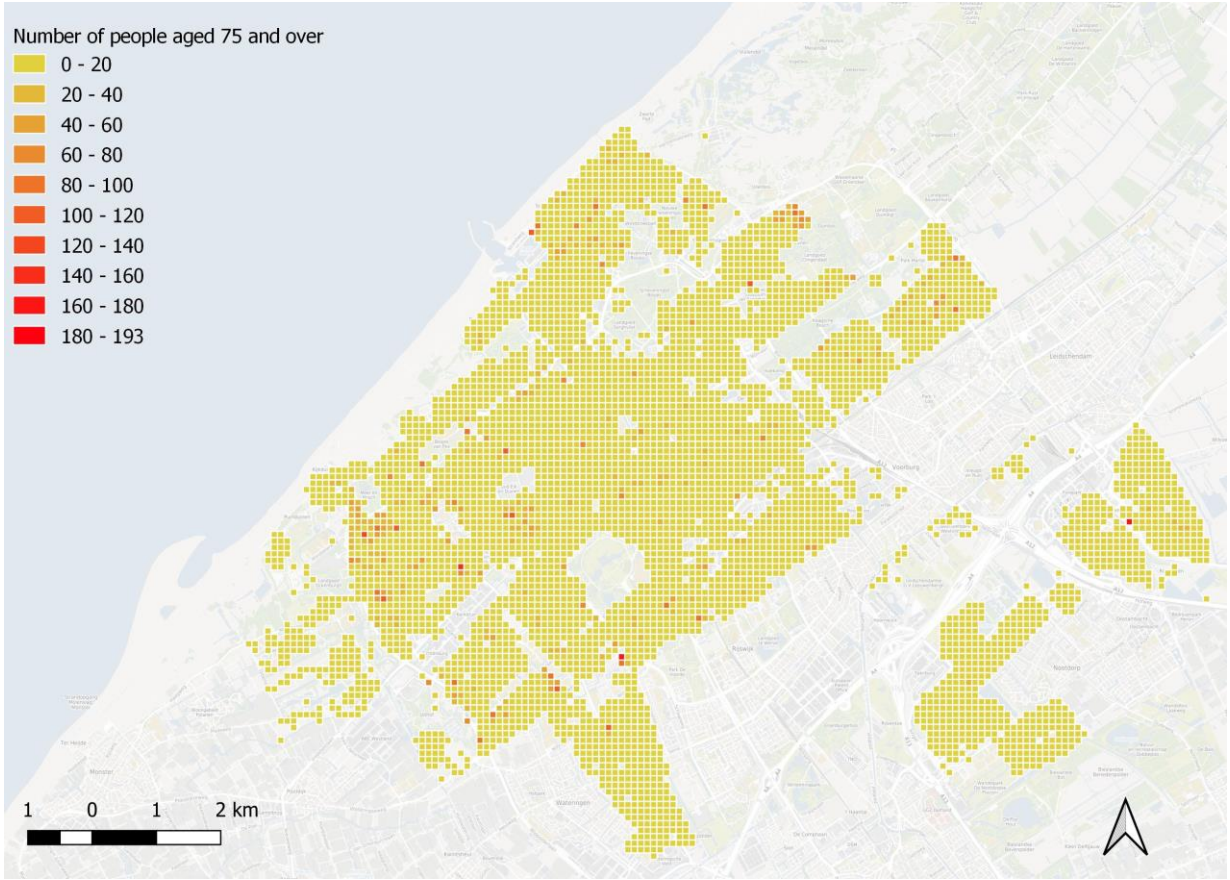
Collection of data

Defining layers

Weights of layers

Creating index

Validate index



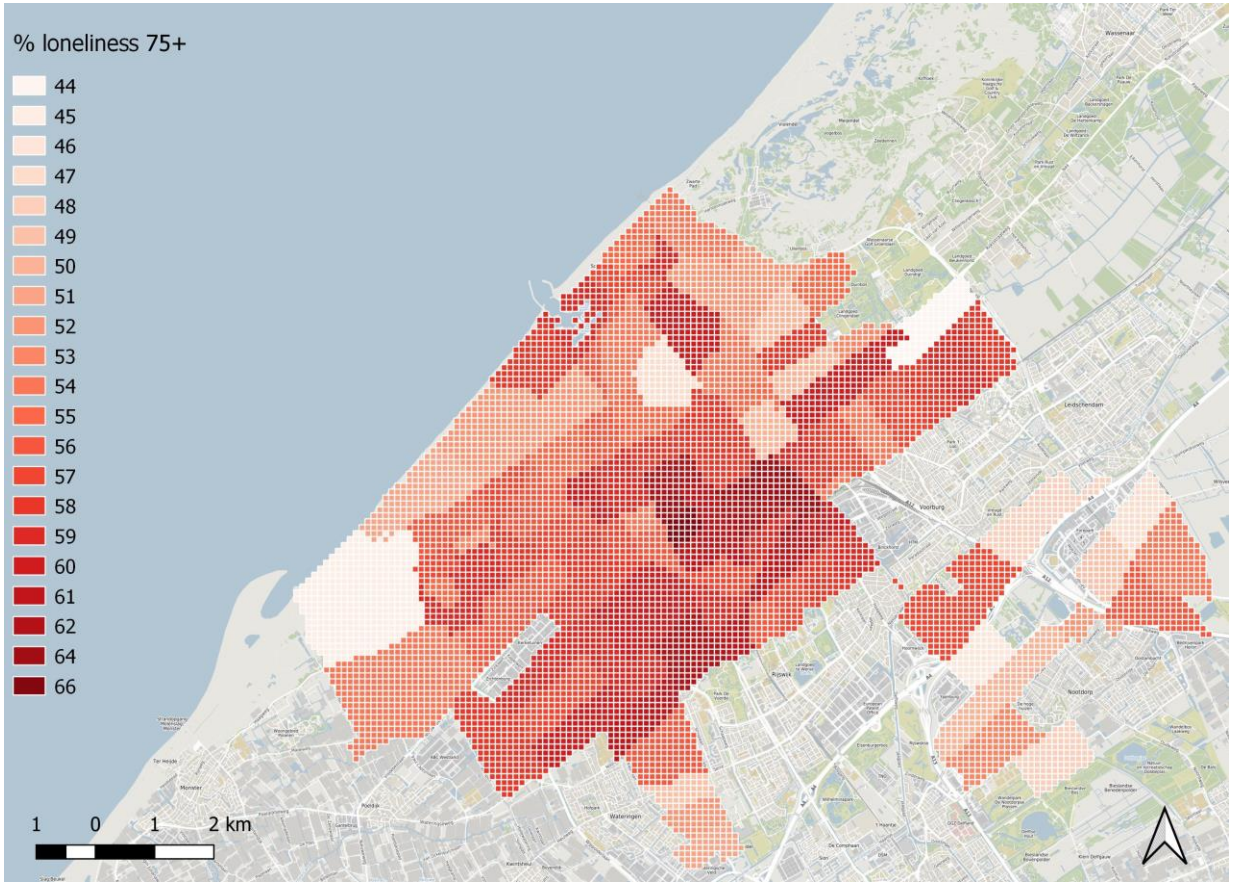
Collection of data

Defining layers

Weights of layers

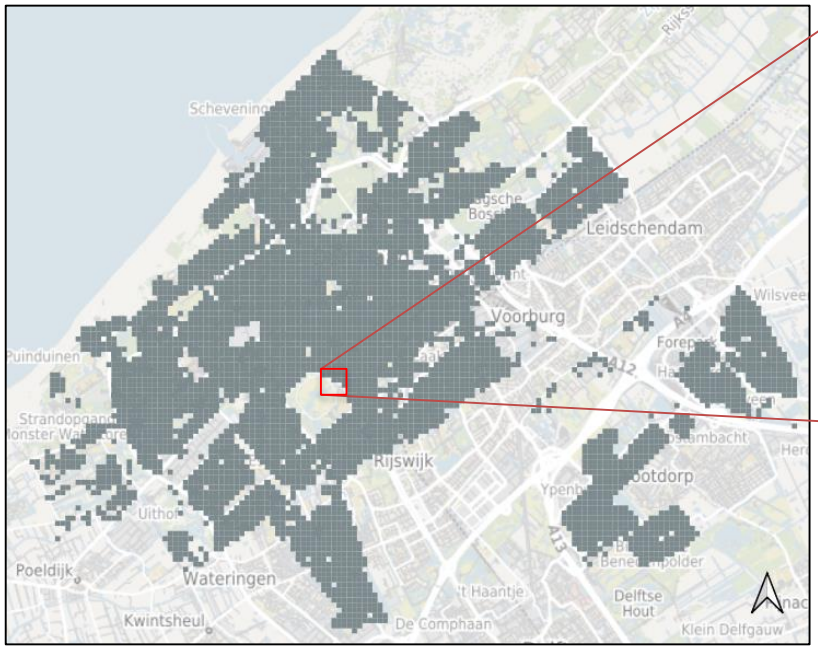
Creating index

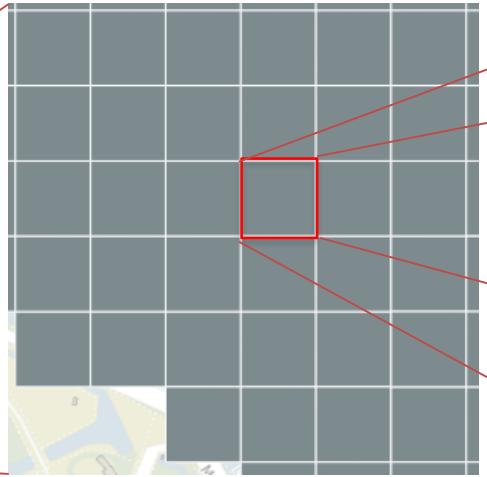
Validate index

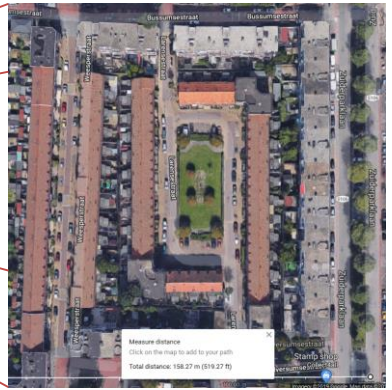


Spatial resolution

- 5 indicator layers
- 100 meter by 100 meter grid

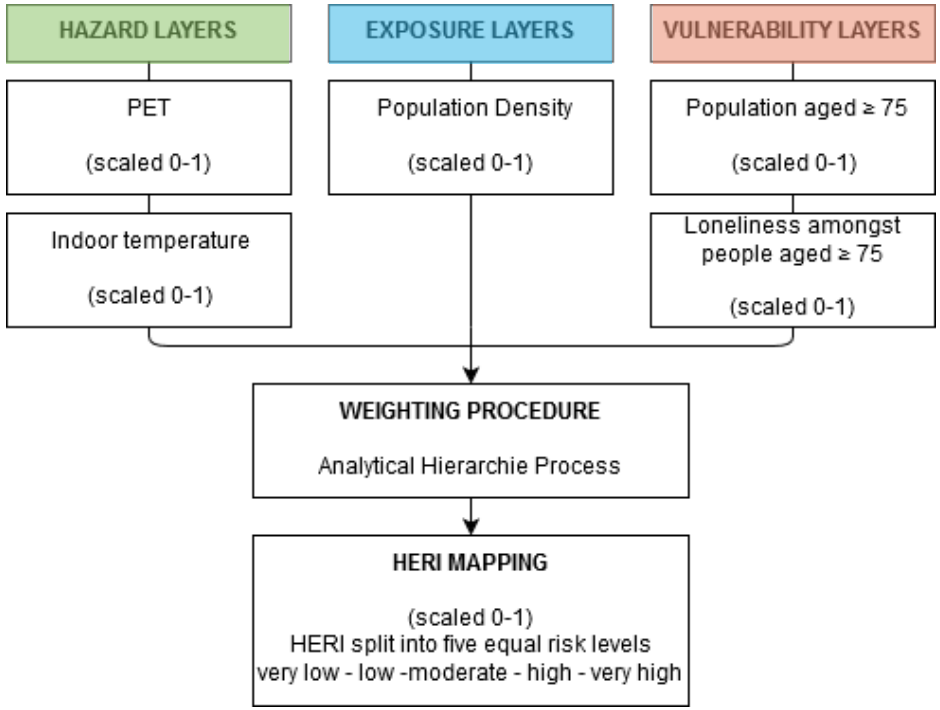


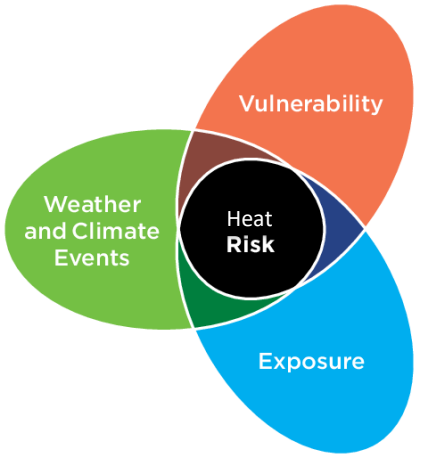




- Physiological equivalent temperature
- Indoor temperature
- The amount of elderly (75+)
- Loneliness amongst elderly
- Population density

Spatial risk layers





) FROM IPCC 2012.[452]

Analytical Hierarchy Process

- Assign weights to indicators
- Most popular approach in GIS studies (Chen et al.,2009)
- Analysing complex decision problems under multi-criteria

→Expert judgements gathered

→Pair-Wise Comparison Matrix

Questionnaire

- 5 experts, 1 questionnaire
- 5 indicators

Compare the relative IMPACT with respect to: Vulnerability to heat for the elderly
Please assign the color red to the chosen number.

1=equal 3=moderate 5=strong 7=very strong 9=extreme

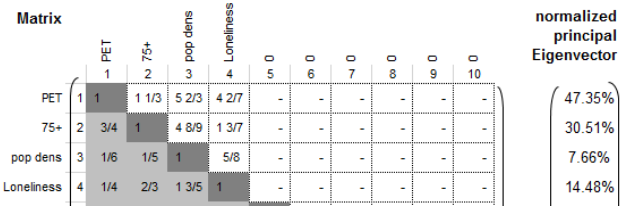
1	PET	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Loneliness
2	Age 65+	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	PET
3	Orientation of the façade	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Age(75+)
4	Population density	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Orientation of the façade
5	Loneliness	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Population density

- Indoor temperature added later

- 2 sets of indicators
- Two Analytical Hierarchie Processes to determine weights

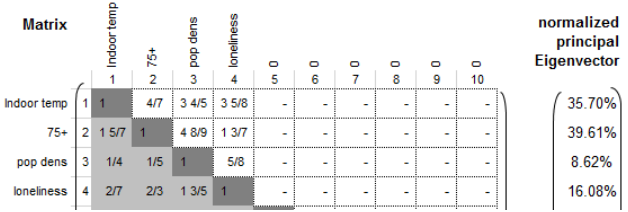
Set-2	Set-3
PET	Indoor temperature
75+	75+
Loneliness	Loneliness
Population density	Population density

Indicator weights



Set-2

Indicator	Weight
PET	47.4%
Elderly (75+)	30.5%
Loneliness amongst elderly	14.5%
Population density	7.7%



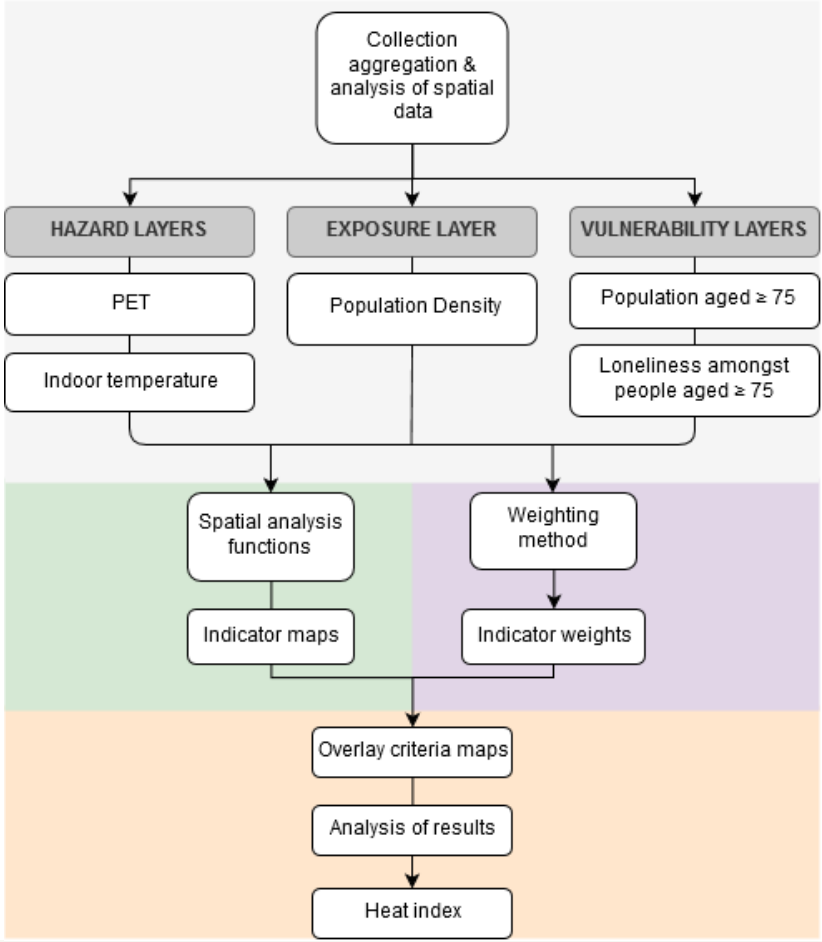
Set-3

Indicator	Weight
Elderly (75+)	39.6%
Indoor temperature	35.7%
Loneliness amongst elderly	16.1%
Population density	8.6%

Recap

- 5 indicators:
  - Physiological Equivalent Temperature
  - Indoor temperature
  - Being 75+
  - Population density
  - Loneliness amongst elderly

- Set-2 & Set-4:
  - Two types of HERI maps: HERI-2 and HERI-3



Overlay indicator layers

Normalizing values in the layers (0-1)

Multiply with given weight

Adding the layers together

Results

- HERI maps for three timestamps:
  - 04.00 morning
  - 14.00 afternoon
  - 24.00 midnight

Set-2

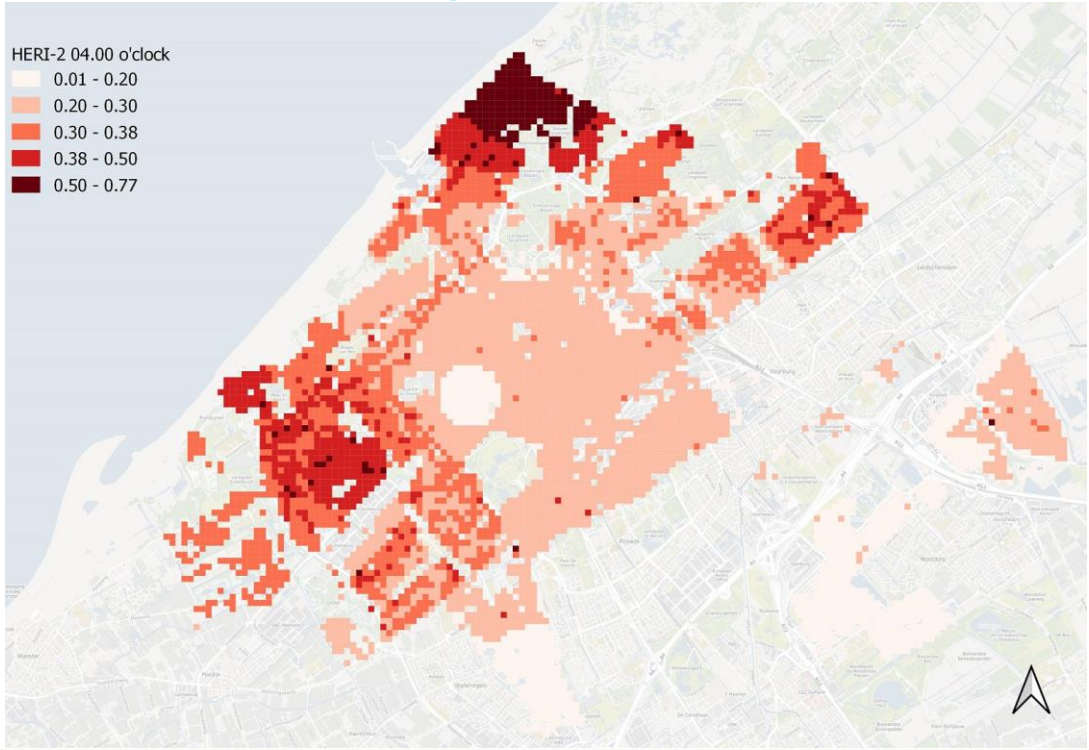
Normalizing values in the layers (0-1)

Multiply with given weight

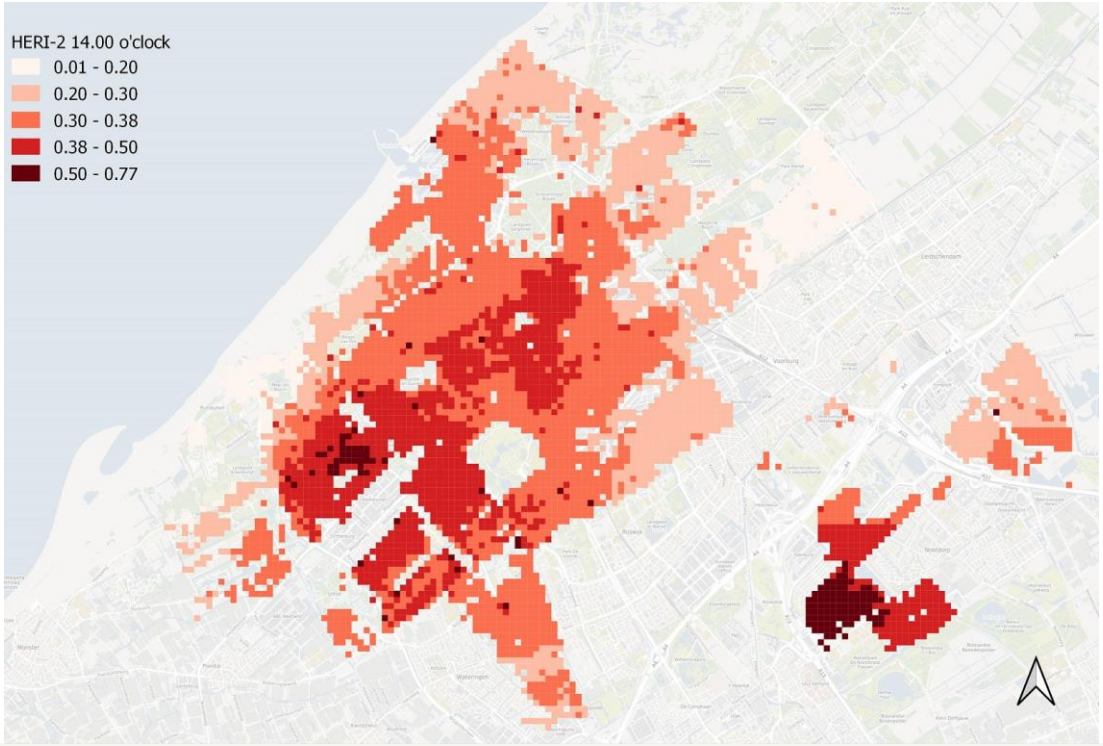
Adding the layers together

Physiological equivalent temperature	*	47.4%
Elderly (75+)	*	30.5%
Loneliness amongst elderly (75+)	*	14.5%
Population density	*	7.7%

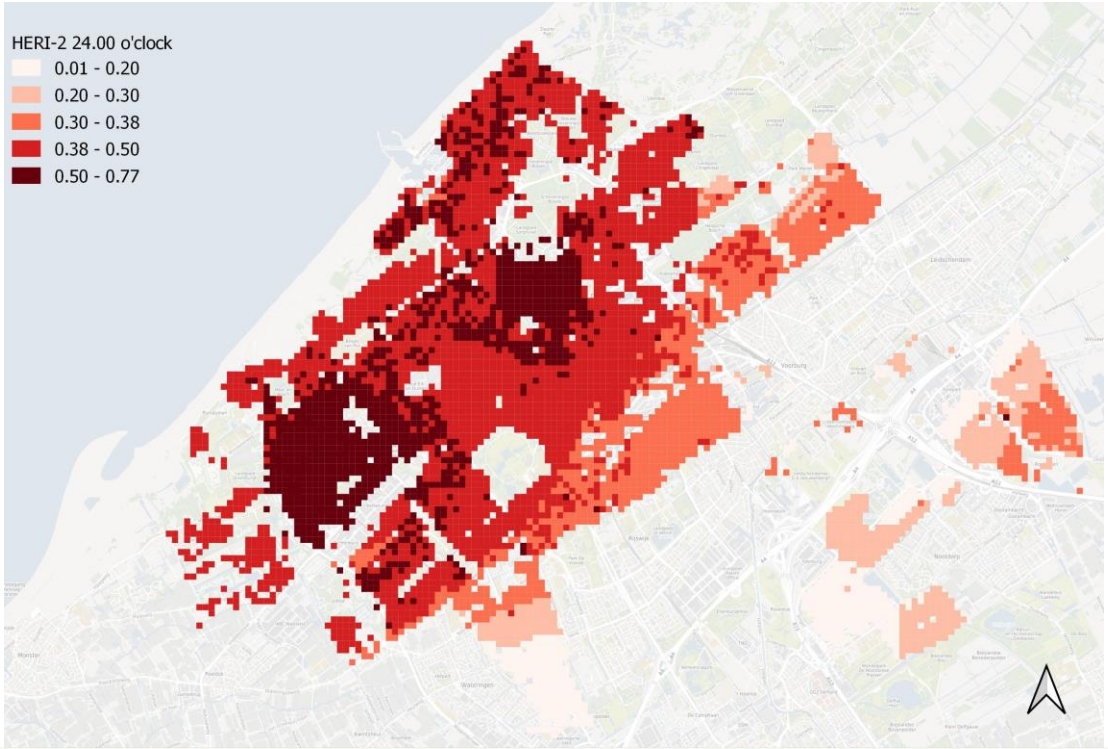
HERI-2 map 04.00 morning



HERI-2 map 14.00 afternoon



HERI-2 map 24.00 midnight



Set-3

Normalizing values in the layers (0-1)

Multiply with given weight

Adding the layers together

Indoor temperature	*	35.7%
Elderly (75+)	*	39.6%
Loneliness amongst elderly (75+)	*	16.1%
Population density	*	8.6%

Collection of data

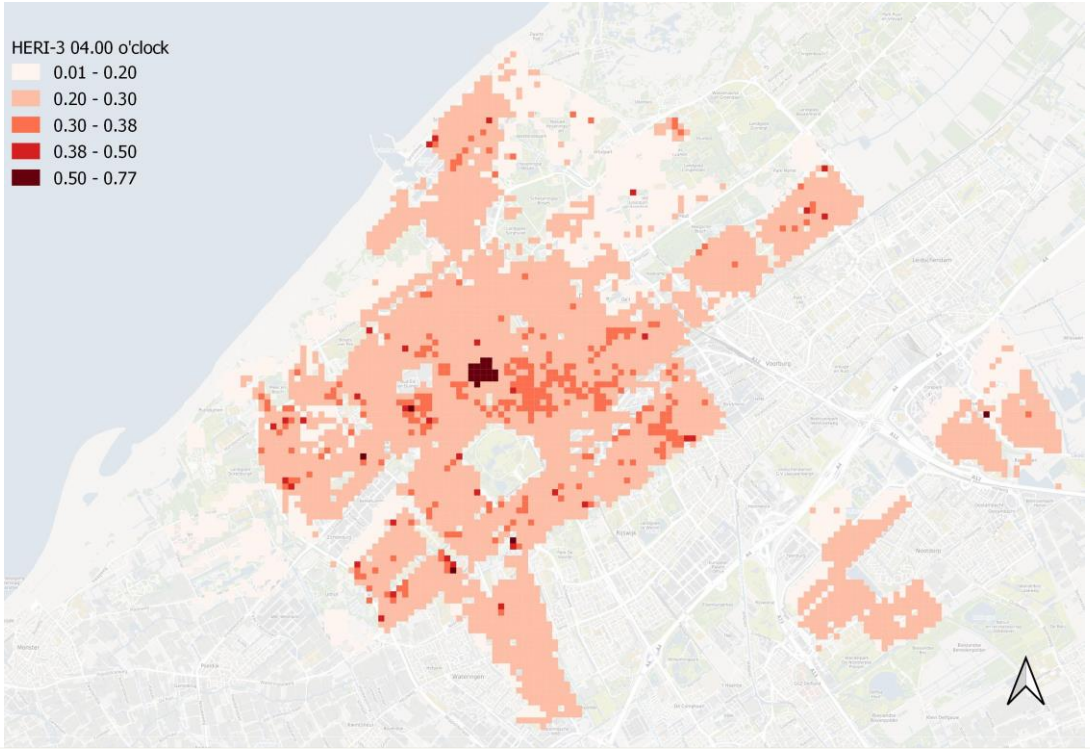
Defining layers

Weights of layers

Creating index

Validate index

HERI-3 map 04.00 morning



Collection of data

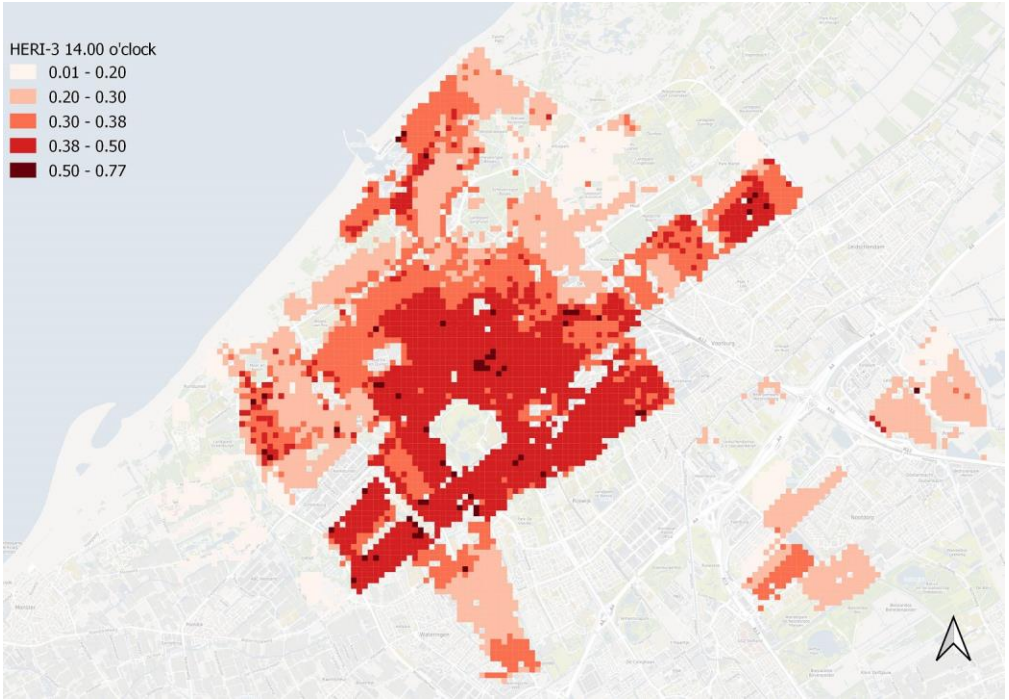
Defining layers

Weights of layers

Creating index

Validate index

HERI-3 map 14.00 afternoon



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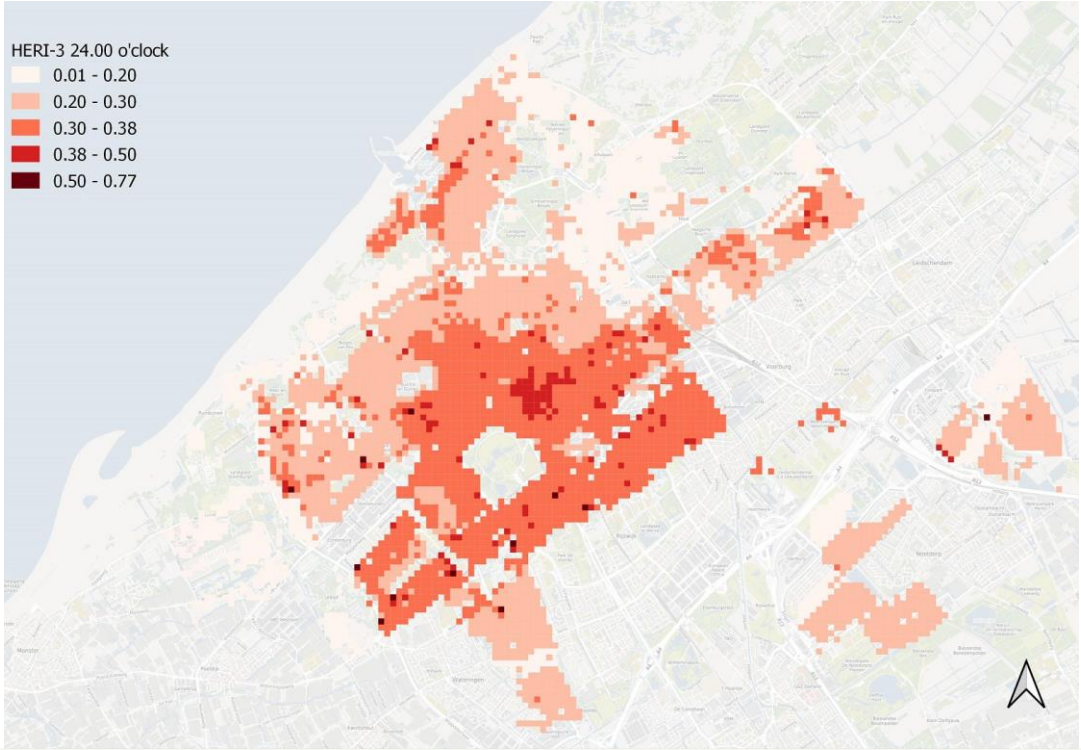
HERI-3 map 24.00 midnight



Collection of data

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Weights of layers

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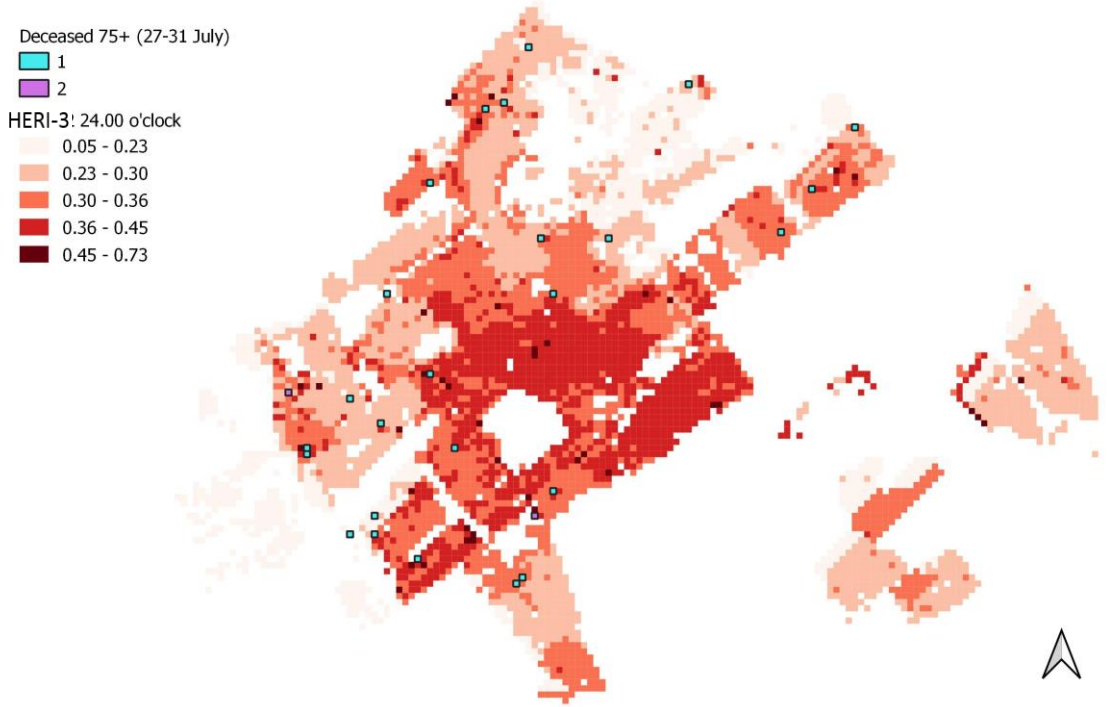
Validation



Bivariate Pearson Correlation

		Mortality	HERI-2 at 04.00	HERI-2 at 14.00	HERI-2 at 24.00
Mortality	Pearson Correlation	1	.073**	.060**	.064**
	Sig. (2-tailed)		0.000	0.000	0.000
	N	5708	5708	5450	5708

**. Correlation is significant at the 0.01 level (2-tailed).

		Mortality	HERI-3 at 04.00	HERI-3 at 14.00	HERI-3 at 24.00
Mortality	Pearson Correlation	1	.106**	.078**	.089**
	Sig. (2-tailed)		0.000	0.000	0.000
	N	5708	5539	5348	5562

**. Correlation is significant at the 0.01 level (2-tailed).

Independent samples t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
HERI_3_24	Equal variances assumed	18.111	.000	-6.261	5560	.000	-.091524	.014618	-.120182	-.062867
	Equal variances not assumed			-4.091	26.107	.000	-.091524	.022369	-.137496	-.045553

	sterfte1_0	N	Mean	Std. Deviation	Std. Error Mean
HERI_3_24	0	5535	.30985	.075533	.001015
	1	27	.40137	.116115	.022346

Conclusions

What are the indicators that influence the heat related health risks the elderly population is being exposed to?

Conclusions

What framework is most applicable for analysing the urban heat related risks for the elderly?

Conclusions

Where in The Hague are the elderly population affected the most by urban heat islands?

Conclusions

What spatial resolution is most appropriate to visualize the urban heat related risks for the elderly population?

Discussion

- The spatial resolution
- Only three moments
- PET
- Weights of the indicators
- Inclusivity
- Validation

Future work & recommendations

- More research on indicators
- More inclusive index
- Create heat index for other extreme age group
- Dynamic viewer
- Less costly -> other software

Thank you

Supervisor:	Dipl.ing. A. Wandl
Supervising Professor:	Dr.ir. F.D. van der Hoeven
Exam committee:	Prof.ir. R.J. Dijkstra

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