City-scan Rotterdam: a method to assess climate change vulnerabilities at street and neighborhood level

Rick Heikoop[1,] Floris Boogaard [2,3,4]

Abstract

The international City-scan is a new method used to assess vulnerabilities at street and neighborhood level and create awareness about climate change adaptation. Adaptation measures to address the negative effects of climate change has to take place in our cities, our neighborhoods, our streets and even in our homes. Local authorities would like to have better insight into the level of exposure to climate change, the vulnerabilities at street level and the progress of climate adaptation measures, in a specific street or neighborhood. The City-scan method defines a set of measurement parameters that are relevant to a specific locality, which could, for example, determine if a street is climate proof. During a city climate scan, the current state of climate adaptation in a street and city and its vulnerabilities are assessed and the adaptation ambitions for the coming years are formulated.

Keywords: *City-scan, City climate scan, Rotterdam, Resilient, Plastic*

Introduction

The majority of the world's population is living in cities and urban areas. Persistent urban issues and emerging challenges due to increased urban populations include urban growth, increased residency in slums and informal settlements, increasing pressure on service delivery, such as water and sanitation, and climate change (United Nations Human Settlements Programme (UN-Habitat), 2016). As of 2018, 55% of the world population is urban, compared to 30% in

[1] Senior Lecturer Water Management, Rotterdam University Applied Sciences, G.J. de Jonghweg 4-6, 3015 GG Rotterdam, The Netherlands. **Email:** t.h.heikoop@hr.nl

[2] Professor at Hanze University of Applied Sciences (HUAS), Zernikeplein 11, Groningen, The Netherlands

[3] Senior Researcher at University of Applied Sciences Rotterdam, G.J. de Jonghweg 4-6, 3015 GG Rotterdam, The Netherlands.

[4] Senior consultant TAUW BV, Zekeringstraat 43, PO 20748,Amsterdam, The Netherlands

1950 (ABC news, 2018). In 2050, 68% of the world's population is projected to be urban. Experts of insurance company Munich Re have researched and documented 36 000 single loss events during the last 40 years worldwide in urban and rural areas. The rise in the number of natural catastrophes is predominantly attributable to weather-related events, like storms and floods (Hoeppe, 2016). Concentrations of urban population in cities make these cities and their citizens more vulnerable to the negative impacts of climate change. In addition to this cities are also increasingly vulnerable for heat stress and draught because of rising temperatures in our cities. The month of June 2018 was among the ten driest and hottest months ever recorded since 1906 in The Netherlands by Royal Netherlands Meteorological Institute (Royal Netherlands Meteorological Institute, 2018). Drought and heat make cities unpleasant to live in as cities increasingly becoming concrete jungles, becoming urban heat islands, where heat is captured - making it uncomfortable and even dangerous for its residents. The heat is trapped in the city at night, and vulnerable groups like babies, infants and the elderly are susceptible to heat-related health impacts (Sahadat, 2018).

Another major challenge is urban vulnerability to floods (Wu & Chiang, 2018; Runhaar et al., 2011), which is a serious threat in Rotterdam, where most of the city's territory is located below sea level. Extreme rainfall and sea level rise due to climate change may increase the risk of flooding and may threaten lives and property (Wu & Chiang, 2018). Chen identified the adaptation options and a list of urban adaptation assessment indicators for the primary urban hazards; flooding, heat wave and drought (Chen et al., 2016).

Local governments own just part of the land and can only partially decide about measures that should be taken 'on the ground' (Pieneman, 2018). Local governments are therefore highly dependent on individuals, communities and businesses to adapt, transform and to take action in their own garden, street or district (Wamsler & Raggers, 2018). Cities and their residents often do not know if a city or street is 'resilient', or 'climate proof' or what actions they could take at the local level. The aim of the City-scan method is to create awareness, connect practitioners, and generate data for policy makers and adaptation practitioners.

Methodology

The City-scan method was developed by Rotterdam University of Applied Sciences to gather essential data on primary urban hazards; flooding, heat waves, drought and pollution. The data is collected by young professionals and practitioners that helps them to assess the level of resilience of a specific neighborhood or city in a short period of time (1-2 weeks). The City-scan method is a combination of different data collection methods that together give a better insight in the degree of resilience in a street. In this article the following parameters are discussed:

Infiltration capacity

Infiltration capacity can be measured with an infiltrometer. The meter consists of two rings of metal or plastic. These rings should be placed at a location that is representative of the infiltration capacity of the (paved) soil. The bottom rim of the rings needs to be impermeable to prevent leakage. In unpaved areas this can be achieved by pressing the rings into the soil. In paved areas this can be done by using clay. The infiltration capacity of the surface in a number of streets in Rotterdam was measured using the infiltrometer. The different infiltration rates on different locations with different street surfaces gave policy makers and communities insight in the overall infiltration capacity of a street. This is valuable information which helps to decide if the infiltration capacity is sufficient to accommodate a certain amount of rainfall during an extreme rain event. The infiltration capacity can also indicate if measures should be taken at the street level to increase infiltration capacity or rainwater collection.

Heat stress

Heat stress was measured using heat cameras and infrared cameras. Temperature at different heights and at different locations was measured at set distances. The surface temperature of different horizontal and vertical surfaces was measured. The aim was to identify relationships between surface temperature and air temperature on local scale. Secondly, the measure aimed to identify relations between surface material and surface temperature. Stone facades, green facades, lawns, streets and railroad tracks were examined (Heikoop, Boogaard, Sandt, & Oudendammer, 2017). The temperature measurements at different locations in a street gives an indication if the temperature in a street is acceptable to the users and the community (**Figure 1**), and could indicate if actions should be taken at the street level to create a (natural) cooling with vegetation, trees, shadow, open water or other adaptive action.

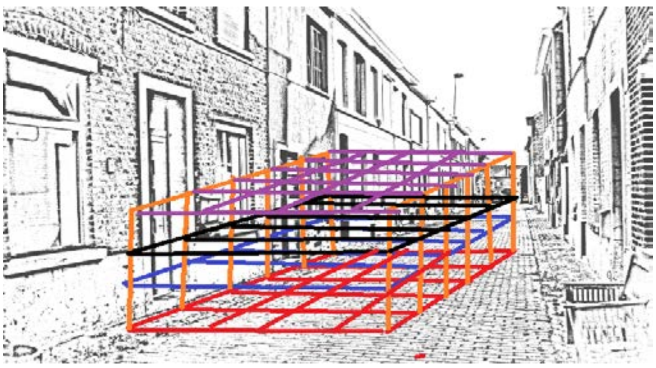


Figure 1. Example of experimental street temperature grid
(Heikoop, Boogaard, Sandt, & Oudendammer, 2017)

Micro pollution, water quality strips

The micro pollution was measured using the Akvo Caddisfly water quality strips, using different parameters that can be measured with the Akvo test strips (**Table 1**). Samples of the water quality in different canals in Rotterdam were taken and the quality was tested on the spot using the Akvo app on smartphones. All the results were geo-located on a Climate Scan open source map (see **Figure 2** for the different transects), and more results can be uploaded - accessible to anyone with the Climate Scan application. At this City-scan, and for the purposes of this research, we focused on test strips nitrate and phosphate (N, P) and sensors for electrical conductivity and temperature.

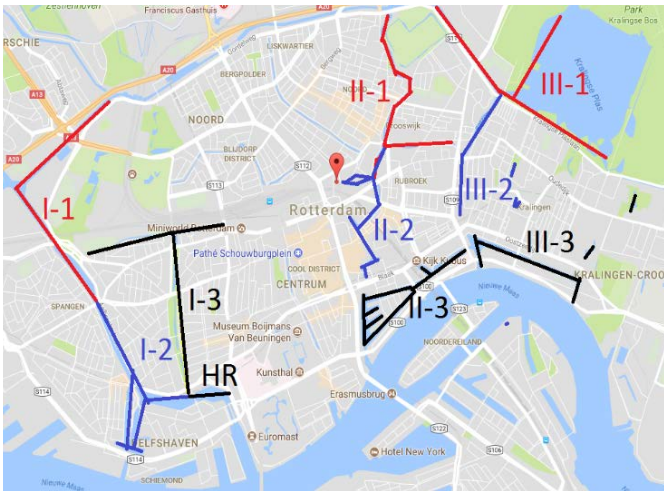


Figure 4. Transects for different water quality measurements of different canals in Rotterdam (Source: Heikoop, Boogaard, Sandt, & Oudendammer, 2017)

	Colorimetry	Test Strips	Tester	Sensors
Alkalinity	•	•		
Aluminium	•			
Ammonia	•	•		
Arsenic		•		
Chloride	•	•		
Chlorine	•		•	
Chromium	•			
COD	•			
Electrical conductivity				•
E. coli				
Fluoride	•			
Hardness	•	•		
Iron	•	•		
Nitrate	•	•		
Nitrite	•	•		
pH	•		•	•
Phosphate	•	•		
Potassium	•	•		
Sulphate	•			
Suspended solids	•			
Temperature				•
Turbidity	•			

Table 1. possible parameters for indication of water quality (Source: Akvo, 2018)

Macro pollution and plastic pollution

Plastic pollution in the world's oceans and seas is under growing attention and the full impact of plastics on the environment is only recently being studied. It is, however, known that much of this plastic pollution comes from urban areas, where disposed plastics are discharged through rivers and streams to finally end up in the oceans (Jambeck et al., 2015). How much plastic is actually discharged through rivers is debatable, because uniform monitoring data is lacking. The discharge can be measured by surface measurements (visual camera registration of floating items), river body monitoring (actual sampling in the water column using nets and filtration systems), and riverbank monitoring (monitoring of plastic litter deposited on river banks) (Gonzalez, et al., 2016). Since there is a strong variation in river morphology and amount of plastic discharged between rivers as well as within a river basin, a standardised method is needed to be able to validate recorded data on plastic riverine litter. For marine litter, the OSPAR beach monitoring method is long-standing (OSPAR commission, 2010). An adapted OSPAR methodology for rivers has been developed by Rotterdam University to be able to compare marine and riverine results. Three measuring methods were used.

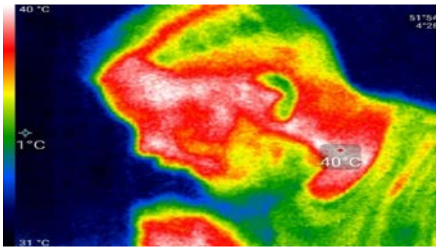
- Standard OSPAR riverbank monitoring
  For the length of a 50m transect parallel to the waterline all items found on the riverbank, using the OSPAR monitoring form, were registered. This was done for all visible litter while standing, up to 5m from the waterline.
- Randomised OSPAR riverbank monitoring
  For the length of 50m transect parallel to the waterline, all items visible when standing were measured within a 1m x 1m quadrat at 10 random locations. 10 quadrant locations every 5m along the transect were selected by throwing a dice, with the numbers on the dice corresponding to the relative distance to the waterline.
- High water level mark monitoring
  At 5 randomly picked spots along the high water level mark, samples were taken in a 50 x 50cm grid. Five unique random distances between 0 – 50m were generated by using www.randomiser.org. At these spots, all non-organic material was collected and categorised using the OSPAR form.

Results

Table 2 shows some of the City-scan methods that were used during the City-scan Rotterdam event and the results it generated. The city of Rotterdam was the host organisation of the event and was involved in the programming of the event and the locations where measurement took place. For the city of Rotterdam, more data is needed in general at street level and local level on infiltration capacity, heat stress, pollution levels, and plastic waste so that the city can undertake specific interventions to address these problems. The results were used in discussions and evaluations with the city of Rotterdam. Water quality mapping with free apps, such as Agpo Water quality app, gave detailed insight into the water quality in canals and water bodies at street or neighborhood level. Urban heat measurements at the street level provided insight into how heat differs in different neighborhoods and streets. Plastic waste measurements at riverbanks can now be systematically analyzed and the data will give insight and awareness on the contribution of plastic waste pollution in (urban) river systems. Infiltration capacity of open spaces and street surfaces and the contribution of infiltration capacity to reduce floods is not known in detail, but the City-scan in Rotterdam with the infiltrometer clearly showed that open spaces have 3 to 6 times higher infiltration capacity than the paved surfaces in urban areas.

More than 25 BMPs in climate adaptation are mapped on the open source web-based international knowledge exchange tool, Climate Scan.

Table 2: Challenges, approach and results City-scan Rotterdam 2017 (Source: Boogaard, et al., 2018)

Challenge	Monitoring method	Results
1. Flood risk 	• The infiltration capacity of different urban soils and surfaces is measured and bottlenecks are mapped using the infiltrometer.	• Measuring infiltration capacity. • Map with measurements and results are presented at www.climatescan.nl,
2. Heat stress 	• Dynamic and static measurements of the temperature of different urban surfaces using heat cameras and infrared cameras.	• Map that depicts temperature differences in the city and shows the temperature differences between urban areas and blue and green areas in the city.
3. Urban water quality, micro pollution 	• With apps and test strips and using underwater drones with cameras and sensors, the micro pollution is measured.	• Maps with the results of test strips of the water samples and results of the nutrient measurements. • 3-D scans of water quality and continuous sensor measurements, indicating the location and sources of pollution
4. Urban water quality macro-pollution 	• 'Quadrant method' which identifies the composition of the plastic pollution and sources of the pollution in water bodies and along river beds.	• Detailed insight in the plastic pollution per m2. • Detailed method that can help to create awareness and generate concrete data that can be compared to the pollution of rivers and water bodies worldwide.

Conclusions

The City-scan method is still in the process of being developed, but the preliminary results show that the tool gathers valuable multidisciplinary data at street- and neighborhood level, that gives new insights into the level of resilience at this level. It provides data that is currently not collected at all (such as infiltration), or on an irregular basis (plastic pollution), and on data of different variables that are not generally combined in this way. The analysis of these results shows that it could eventually lead to a resilience index at street level. The City-scan method is the first steps towards creating a toolbox of different measurement tools that are free or low-cost and of low-technology, and can be applied in cities around the world in a rapid appraisal. The results of the City-scan method gives better insights on infiltration capacity, pollution, plastic waste, heat stress and can help to creates awareness at community level, and gives valuable data and insights for policy makers.

References

ABC news. (2018). *Europe's heatwave has brought a savage summer as climate change slashes the odds of more like it.* Retrieved July 27, 2018, from http://www.abc.net.au/news/2018-07-27/europe-heatwave-and-climate-change/10040604

Akvo. (2018, September 16). *Available Parameters in Akvo Caddisfly.* Retrieved from Akvo: http://flowsupport.akvo.org/article/show/37972-which-parameters-can-akvo-caddisfly-measure_)

Boogaard. (2016). *Flood Free Manila.* Retrieved July 1, 2018, from https://www.youtube.com/watch?v=8Cfbir1-EIA

Boogaard, F. (2017). *Impressie pressure cooker Cebu climate City Scan.* Retrieved July 1, 2018, from https://www.youtube.com/watch?v=d4Wwv3rPX5Y

Boogaard, F., & Heikoop, R. (n.d.).

Boogaard, F., Heikoop, R., Oudendammer, T., Sandt, K., & Oostra, A. (2018, January 25). *H20 waternetwerk.* Retrieved Juy 1, 2018, from https://www.h2owaternetwerk.nl/vakartikelen/1664-internationale-city-climatescan-rotterdam-voorbeeld-infiltratie-in-het-stedelijk-gebied

Chen, C., Doherty, M., Coffee, J., Wong, T., & Hellmann, J. (2016). Measuring the adaptation gap: A framework for evaluating climate hazards and opportunities in urban areas. *Environment Science & Policy, 2016*(December 2016), 403-419.

Gonzalez, D., Hanke, G., Tweehuysen, G., Bert, B., Holzhauer, M., Palatinus, A., . . . Oosterbaan, L. (2016). *Riverine Littering - Options and Recommendations.* Luxembourg: European Commission.

Heikoop, R., Boogaard, F., Sandt, K., & Oudendammer, T. (2017). City Climate Scan Challenge Manual. Rotterdam: Rotterdam University of Applied Sciences.

Hoeppe, P. (2016). Trends in weather related disasters - consequences for insurers and societu. *Weather and Climate Extremes*(Volume 11), 70-79. doi:https://doi.org/10.1016/j.wace.2015.10.002

Hotz, R. L. (2015, February 12). *Which Countries Create the Most Ocean Trash?* Retrieved July 1, 2018, from https://www.wsj.com/articles/which-countries-create-the-most-ocean-trash-1423767676

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., & Perryma, M. (2015). Plastic waste inputs from land into the ocean. *Nature*(Vol 347), 768-771.

Lee, Y. H., & Kim, Y. (2015). Analyzing interaction in R&D networks using the Triple Helix method: Evidence from industrial R&D programs in Korean government. *Technological Forecasting & Social Change*, 93-105.

Leydesdorff, L. (2010, December). The Triple Helix, Quadruple Helix, …, and an N-tuple of Helices: xplanatory Models for Analyzing the Knowledge-based Economy? Retrieved from Leydesdorff.net: https://www.leydesdorff.net/ntuple/

Mees, H. (2017). Local governments in the driving seat? A comparative analysis of public and private responsibilities for adaptation to climate change in European and North-American cities. *Journal of Environmental Policy and Planning, 2017*(Issue 4), 374-390.

OSPAR commission. (2010). *Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime area.* Retrieved September 15, 2018, from https://www.ospar.org/ospar-data/10-02e_beachlitter%20guideline_english%20only.pdf

Pieneman, J. (2018, May 1). Community participation in adaptation.

Royal Netherlands Meteorological Institute. (2018). *Juni in top 10 droogste junimaanden*. Retrieved July 20, 2018, from https://www.knmi.nl/over-het-knmi/nieuws/juni-in-top-10-droogste-junimaanden

Runhaar, H., Mees, H., Wardekker, A., Sluijs , J., & Driessen, P. (2011). Omgang met hittestress en wateroverlast in de stad. *Milieu, 2011*(17-2), 22-25.

Sahadat, I. (2018, July 8). *Woestijnen van beton: hoe maken we onze steden hittebestendig?* Retrieved September 15, 2018, from https://www.volkskrant.nl/nieuws-achtergrond/woestijnen-van-beton-hoe-maken-we-onze-steden-hittebestendig-~b3ede253/

United Nations, Economic & Social Affairs. (2018). *World Urbanisation Prospects: The 2018 Revision.* Retrieved September 14, 2018, from https://esa.un.org/unpd/wup/Publications/Files/WUP2018-KeyFacts.pdf

United Nations Human Settlements Programme (UN-Habitat). (2016). *Urbanisation and Development: Emerging Futures: World cities Report 2016.* Retrieved September 15, 2018, from https://unhabitat.org/wp-content/uploads/2014/03/WCR-%20Full-Report-2016.pdf

Wamsler, C., & Brink, E. (2014). Interfacing citizens' and institutions' practice and responsibilities for climate change adaptation. *Urban Climate, 2014*(Volume 7), 64-91.

Wamsler, C., & Raggers, S. (2018). Principles for supporting city–citizen commoning for climate adaptation: From adaptation governance to sustainable transformation. *Environmental Science and Policy, 2018*(Volume 85), 81-89.

World Economic Forum. (2016). *The global risk Report 2016.* Retrieved September 15, 2018, from http://www3.weforum.org/docs/GRR/WEF_GRR16.pdf

World Economic Forum. (2017). *The Global Risks Report 2017.* Retrieved September 15, 2018, from http://www3.weforum.org/docs/GRR17_Report_web.pdf

World Economic Forum. (2018). *Global Risks Report 2018.* Retrieved September 15, 2018, from http://www3.weforum.org/docs/WEF_GRR18_Report.pdf

Wu, C.-L., & Chiang, Y.-C. (2018). A geodesign framework procedure for developing flood resilient city. *Habitat International*(Volume 75), 78-89.