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Climate-proof urban design and infrastructure in dialogue

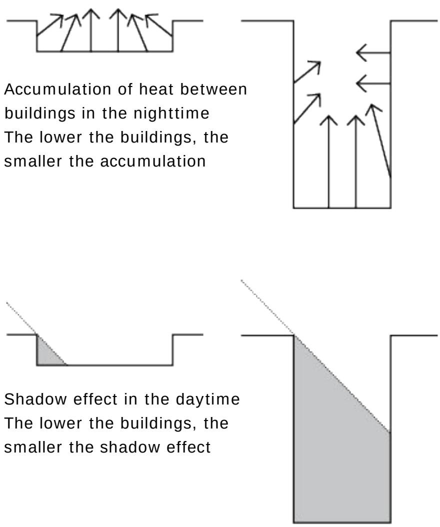
Climate change has a significant impact on urban microclimates, the performance of transport systems, and people's travel patterns. Policymakers need to become climate-minded so as to be able to make cities and infrastructure more climate-proof, which they can do by making more strategic use of vegetation, water, building height and density in order to provide urban dwellers with a comfortable microclimate. Two requirements for this are interdisciplinary learning and learning to speak a common language.

As established by the most recent report of the Intergovernmental Panel on Climate Change (IPCC, 2013), climate change is increasingly regarded as an established fact. Meteorologists at the Royal Netherlands Meteorological Institute (KNMI) are expecting temperatures in the Netherlands to rise over the next 35 years, along with an increase in precipitation. There have also been a growing number of studies focusing on the effects of these changes on urban areas and traffic; these studies tend to focus mostly on extreme weather conditions, including heat and excessive precipitation. There has been relatively little focus to date on the more dormant – but no less impactful – weather changes set to affect us in the coming years. Both extreme and gradual climate and weather changes can have a major impact on the functioning of cities and transport systems, as well as on the travel patterns of individuals.

Urban microclimate

Cities have a microclimate which can vary significantly from the surrounding areas; for example, differences in temperature between rural and urban areas become clearly visible on low-wind, overcast days. The atmosphere close to the Earth's surface cools down in the evening. Buildings tend to retain the heat longer and ensure that the city remains relatively warm for a long period of time. Meanwhile, night temperatures in rural areas can be up to six degrees lower. This difference in temperature is known as the "urban heat island effect" (Theeuwes et al., 2013; Steeneveld et al., 2014). The strength of this effect depends on the weather, as well as on the design of the built environment. For example, more vegetation in the city tends to reduce temperature differences with rural areas.
Another factor relevant to Dutch cities is the ample presence of water. Since water retains temperatures for longer periods of time, bodies of water can both cool and heat the environment. Well-mixed bodies of water – including ponds and other open-water bodies – generally remain cooler during the day than the air, causing air temperature to be reduced. This,

Figure 2: The impact of buildings: accumulation of heat in the nighttime and daytime shadow effect are opposing processes. Which of these two processes dominates under what circumstances? (source: Theeuwes et al., 2014)



in turn, improves thermal comfort on hot days. In the evening and at night, however, bodies of water have a heating effect on the environment as the water temperature rises above the air temperature. Cities containing bodies of water remain warmer in the evening time, as shown both by a model study (Theeuwes at al., 2013) and through observation (Steeneveld et al., 2014).
In addition, street geometry also affects urban temperatures and the urban heat-island effect. A new conceptual model demonstrates that

street temperatures are made up of a combination of shadows, solar radiation and thermal radiation retained by buildings. The proportional relationship between building height and street width (known as the “aspect ratio”) determines how much solar radiation enters the street and how much thermal radiation is preserved. In cities with high buildings and narrow streets, it is difficult for thermal radiation to escape, resulting in higher temperatures. On the other hand, only a small amount of solar radiation penetrates into these streets, which has a temperature-reducing effect (Theeuwes et al., 2014). The ultimate effect of aspect ratio on the heat-island effect therefore depends on the season. In the summer, higher buildings and narrower streets reduce street temperatures, while in the winter they increase these temperatures. Based on this observation, it would be recommended to build higher and more compact structures as part of future urban design plans. Furthermore, an intelligent vegetation and water plan could be developed for the built environment in order to keep urban temperatures within acceptable limits/the required limits during the summer and winter.

Problems during the summertime.

Besides having an impact on urban environments, weather conditions also influence the condition of the road and railway infrastructure. Motorists and train passengers experience this impact year-round, even if it may vary by year and depend on the location. During the winter months, periods of frost followed by periods of thaw can potentially damage the road surface, while snow and ice can cause technical problems on the railway tracks. In the summer, high temperatures can potentially cause overheating of the railway systems. In addition, at any time of the year sections of the railway and road networks may become blocked through flooding or torrential downpours. Analysis shows that the likelihood of bottlenecks in the railway network increases when temperatures rise above 20 degrees Celsius, and when snow levels rise to above ten millimetres. The probability of damage being caused to the road network increases if there are more than twenty periods of frost followed by thaw each winter (Oslakovic et al., 2012; Kwiatkowski et al., 2014).
One effect of climate change will probably be a reduced likelihood of damage and technical malfunction during the winter months on account of the expected milder temperatures and an increased likelihood in the summer due to the expected higher temperatures. Although road and railway operators can respond to these trends (for example, by

increasing the drainage capacity of drainage systems), the evaluation of how weather-sensitive the infrastructure is and the related investment decisions that must be made cause significant uncertainty. Besides the effect of various weather conditions and the expected climate change on malfunction involving, and damage to, the existing road and railway infrastructure, the latter are also affected by factors such as age, condition, materials used, traffic density/congestion, and traffic intensity.

For operators of road and railway networks, this means, in particular, that they must organise the management as a learning process, characterised by ongoing monitoring and a dynamic evaluation and decision system. They must be able to identify high-risk areas which are sensitive to weather conditions and important for traffic flow and accessibility. Based on an ongoing risk estimate, they are then able to take measures which provide further insight into weather-related influences (e.g. the impact of frost on asphalt) and which can reduce such influences in the short term (for example through the use of a winter service) or prevent them in the long term (e.g. the use of a different type of asphalt).

This requires that management and maintenance by public infrastructure operators be professionalised. Unfortunately, data collected on climate effects has tended to be too incomplete, inconsistent and outdated to facilitate this. In addition, investment decisions regarding road and railway infrastructure are rarely made on the basis of an integrated approach. This type of approach links the various risk factors involved (i.e. weather and traffic), the impact on infrastructure (i.e. condition and obsolescence) and services (i.e. accessibility and traffic flow) to the whole life cycle of infrastructure. Climate-resilience will need to become a criterion of infrastructure design and redesign.

Bicycle use patterns by season

The impact of the built environment on the urban microclimate also extends to day-to-day mobility. There is relatively little information available regarding the combined effects of urban weather conditions, the emotional perception of weather, and the effects on travel patterns (Böcker et al., 2013a). Over the long term (i.e. by 2050), climate change may create a significant increase in the amount of bicycle transport in the Randstad conurbation in relation to car usage (Böcker et al., 2013b). However, there are substantial differences between summer and winter. Whereas milder temperatures coupled with a slight increase in precipitation in winter result in an increase in bicycle usage versus car usage, an increase in heat results in

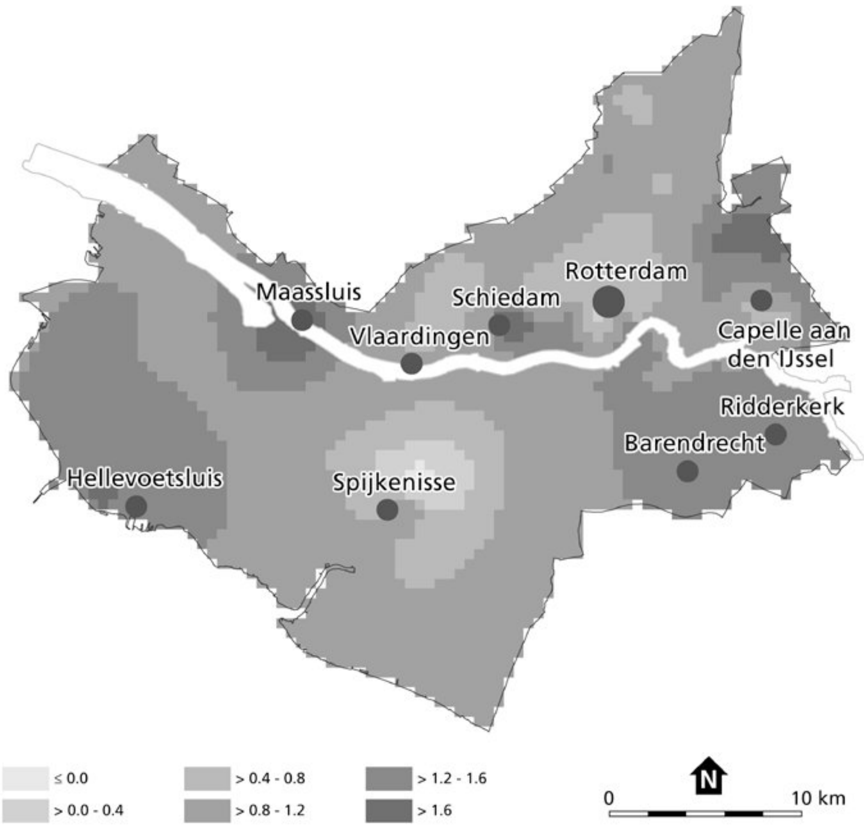


Figure 1 Spatial differences in the effects of outdoor air temperature on recreational bicycle use patterns in the Greater Rotterdam Area (source: Helbich et al; forthcoming publication)
Legend: Dark = high parameter coefficient = strong effect on temperature. This means that: Recreational bicycle use patterns in open, peripheral the Netherlands) are more influenced by air temperatures than in compact urban areas such as Rotterdam's city centre.

reduced bicycle usage. In addition, it also has an impact on destination choice, particularly when it comes to recreational activities. Milder winters can result in a shift from indoor to outdoor leisure activities such as hiking and cycling, while hotter summers have the reverse effect. In Rotterdam, precipitation and wind speed had a negative linear relationship with bicycle use, particularly in relation to car usage. The effect of temperature on bicycle use has proved to be non-linear: up to a daily maximum air temperature of 25 degrees Celsius, an increase in

temperature results in an increase in bicycle usage; if air temperatures rise above this level, we see a decrease in such usage (Böcker & Thorsson; forthcoming publication).
The impact of weather conditions on bicycle use patterns varies significantly between various areas in the greater Randstad conurbation (Helbich et al.; forthcoming publication). This impact has been demonstrated to be relatively small among residents of densely populated, central areas, while the weather would appear to play a more significant role in more remote, sparsely populated areas. Possible causes for this are the relatively short distances and the higher level of protection in the city/city centre. A notable exception to the above is the relatively strong wind effects on cycling in Rotterdam's city centre, which may be caused by unpleasant wind turbulence around standalone high-rise buildings.
Böcker et al. (2014) have developed a new conceptual model which illustrates the complex correlation between objectively measured weather conditions, weather perception, choice of mode of transport, and emotions during the journey. This model demonstrates that a large amount of precipitation and wind and a large number of clouds, along with low temperatures or heat, cause a more negative perception of emotions en route. Additionally, the study also shows that pedestrians and, especially, cyclists experience less thermal comfort than motorists, who are much more protected from the elements. This correlation between the weather and the emotional experience related to travel is of direct relevance to policies aimed at creating a liveable city, particularly in view of our future climate, in which heat and extreme precipitation could end up playing a substantial role. Developers of urban public space and key bicycle routes can anticipate these correlative weather elements, for example by using covering vegetation which can provide relief and protection when necessary. Besides improving emotional well-being, this could also result in an increase in the use of active modes of transport. This requires proper coordination with the above-mentioned urban design in order to create an acceptable (or desirable) urban microclimate.

Climate expertise in planning

Research on climate effects on urban microclimates, infrastructure and travel behaviour must be integrated into policy processes. Support planning tools are designed primarily to support policymakers in this process, and not to simulate reality as closely as possible. Although this may seem self-evident, Pelzer et al. (in a forthcoming publication) have demonstrated that there are still many improvements to be made in this area. This study into Planning Support Systems (PSS) reveals that the quick wins in terms of policy are not necessarily related to more refined measuring models, but rather to making sure the basic requirements are clear. This might include, for example, a skilled moderator who monitors the group process; a clear calendar for interactive workshops; sufficient preparation time, and a focus on the interface and visual output of tools and instruments.

Using Planning Support Systems in practice (photo by: Peter Pelzer)

Scientists can improve the knowledge-sharing process with policymakers by making a preliminary selection of the findings. What are the real policy priorities, and what are some of the insights which should be incorporated into a PSS? In addition, the role of scientists extends beyond merely supplying data or designing an algorithm. Complex subject matter such as climate change requires additional interpretation and explanations. The current urban planning context is a communication process involving a large number of stakeholders. Climate researchers could, without a doubt, be one of these parties, supported by smart and fast calculation models and attractive visualisations.

Research into multidisciplinary learning (i.e. knowledge exchange between various disciplines) demonstrates that traffic experts and environmental experts are far more accustomed to using quantitative models than are urban design experts, who work largely on an intuitive and creative basis (see forthcoming publication by Pelzer et al.). The key is finding a shared language that unites various disciplines. Digital map tables (see Pelzer, 2013) improve knowledge sharing in group processes, whereas computer support in planning and policymaking processes traditionally creates barriers to social interaction. Cooperation between designers and analysts is particularly relevant in discussions on the urban heat-island effect. Heat islands in urban areas require a different type of design than, for example, squares and streets. Climate models reveal the effects of weather conditions on transport choices; however, the aesthetic and design aspect are at least as important.

Ongoing dialogue

Climate-proof transport requires effective interaction between scientific and administrative disciplines. The complexity of the impact of climate change on the built environment and on society cannot be sufficiently understood and influenced using the specialist concepts and analysis and planning methods of separate disciplines.

Meteorologists and urban designers are likely focus in particular on the strategic use of vegetation, water, building height and density in developing urban microclimates which provide an effective solution to the anticipated climate changes.
The meaning of “effective” in this case depends to a large extent on the perception and possible and desired behavioural choices of users of cities and transport systems – issues to which social geographers can provide a solution. Finally, policymakers and infrastructure operators will need to both represent the interests of users and consider other public interests, including those relating to the urban economy and the environment. Policymakers will need to aim for multidisciplinary scientific knowledge and tools to be incorporated into interactive decision-making processes. A multidisciplinary scientific and policy-related dialogue is an essential condition for the development of sustainable and climate-proof cities and transport systems.
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