

CLIMATE CHANGE IN THE NETHERLANDS : CHALLENGES FOR A SAFE AND ATTRACTIVE URBAN ENVIRONMENT

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Summary: Climate change in cities has so far been underexposed in Dutch research on climate change adaptation. High population density and high economic values make Dutch urban areas nevertheless vulnerable to climate change. Even with stringent mitigation policies Dutch cities will be subject to warmer summers, more peaks in rainfall and wetter winters. Some scenarios project dryer summers. Impacts will be felt by various societal and economic sectors, such as households, building sector, transport and the health sector. As investments in the built environment (e.g. buildings, infrastructure) have a long depreciation period, it is efficient to take adaptation into account in current decisions. Possible synergies with climate change mitigation need to be explored. This paper summarizes possible urban adaptation measures and describes a systematic approach to their implementation. It concludes with elements for a research agenda.

Key Words: climate change, urban planning, adaptation, mitigation, complex systems, the Netherlands.

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1 Introduction

With over 60% of the land area below sea-level, the Netherlands is particularly vulnerable to the impact of climate change to the water system. Not only sea level rises but also increased river flows threaten the Dutch population in the delta of the rivers Rhine and Meuse. The Dutch research and policy development on climate change has so far been mainly concerned with water management at a national and regional scale. The countries' long history of flood protection and land reclamation has resulted in extensive expertise in the field of water management. This expertise is now used to develop adaptation strategies to protect the country against sea and river level rise due to climate change (e.g. Veerman et al., 2008). The consequence of the pre-occupation with flooding is that, so far, the impact of climate change in the cities has been underexposed in Dutch climate and urban research.

That climate change will impact cities is increasingly recognized (e.g. VROM, 2008). Cities are generally vulnerable because of the high population density and economic values (buildings, infrastructure, cultural heritage, industry etc.) in those areas. Particularly in the Netherlands with many large cities in a relatively low and seaward location, vulnerabilities are high. Temperature rise, flooding risks, increase of extreme weather conditions and longer periods of drought will influence the social, ecological and economical systems of cities. Local adaptation measures are required in order to prevent or reduce negative effects at present and particularly in the future. Developing adaptation strategies does not imply that the efforts on reducing climate change (mitigation) are no longer needed. Cities play a crucial role in the reduction of climate change due to their high contribution to global greenhouse gas emissions (approximately 78% according to Stern, 2006). Mitigation and adaptation are both crucial in order to maintain safe, livable and healthy cities and need to be incorporated in sustainable urban development, preferably in an integral way. Decisions in the short term are required, not only to be well prepared in time, but also because many measures are part of urban elements with a long life cycle or construction period (e.g. infrastructural works, buildings and urban configuration).

TNO, the Netherlands' Institute for Applied Science, has carried out an exploratory study on the impact of climate change in cities. This paper gives an overview of the various consequences and possible measures for different sectors, at the scale of buildings, districts and the city as a whole. We consider possible interactions between adaptation and mitigation measures and finally we describe a systematic approach to develop adaptation strategies. With this we hope to provide an analysis framework for climate and cities, and a better understanding of the governance challenges that are involved. The aim of this paper is to identify the main knowledge gaps and develop a research agenda for climate adaptation in urban areas. Although based on the Dutch

situation, the approach and knowledge gaps described in this paper apply to climate change in urban areas elsewhere.

2 Impact of climate change on the Dutch city

Future climate in the Netherlands

Projections of climate change are mostly done using global climate models. For projecting future emissions of greenhouse gases these models use a range of scenarios that are known as the IPCC SRES scenarios. These scenarios reflect a wide spectrum of possible futures with respect to population growth and economic development (IPCC, 2000). It is important to note in advance that the IPCC SRES scenarios are reference scenarios, which means that they do not take into account future climate policies and measures. If worldwide stringent climate policies would be implemented, then the climate effects may be less than currently projected.

For the Netherlands the outcomes of global climate models, and thus the range of possible futures as reflected in the IPCC scenarios, have been applied for designing national climate scenarios (Van den Hurk et al., 2006). Four national climate scenarios have been developed by the Netherlands Meteorological Institute (KNMI). They combine the range of outcomes of the global scenarios in a regional climate model. The resulting scenarios focus on the variability in climate outcomes and differ on two main variables: temperature increase and direction of circulation.

The, so called, G scenarios are based on a worldwide average temperature increase of 1°C in 2050 compared to 1990, and the W scenarios on an increase of 2°C. The G and W scenarios assume an unchanged circulation pattern, while the G+ and W+ scenarios assume changed circulation leading to warmer and wetter winters because of more western winds and warmer and dryer summers because of a prevailing eastern circulation. .

In summary the results for the Netherlands are (all figures 2050 compared to 1990):

- Temperate winters and warm summers will occur more frequently. The average temperature increase will vary from 0.9 to 2.3°C in winter and 0.9 to 2.8°C in summer. In 2050 the temperature in Dutch cities will resemble that of cities in the centre to the south of France nowadays.
- Winters will become wetter on average, with precipitation going up between 4 and 14 percent. Also the peaks in extreme precipitation will be higher.
- The intensity of extreme rainfall in summer increases, but the number of rainy days decreases. On average summer precipitation increases by 3 to 6 percent assuming unchanged circulation. It decreases, however, with 10 to 19 percent with more eastern circulation in the + scenarios.
- The calculated changes in wind are small compared to the natural variability.
- Sea level continues to rise, varying from 15 to 35 cm until 2050.
- Higher river peak flows, and lower river flows in dry summers.

The projected temperature rise will intensify the urban heat island effect; heat absorption by buildings and infrastructure, and local heat production results in significant temperature differences between urban and surrounding areas. The urban heat island effect has barely been investigated in the Netherlands so far. The only measurements documenting the urban heat island

effect date back to 1970-1971. For the city of Utrecht the average temperature difference between the city centre and the rural surroundings was 1.9°C in winter and 2.7°C in summer (Conrads, 1975, cited in Rahola, 2009). A first investigation of the energy balance of the city of Rotterdam suggests a potential urban heat island effect up to 7 °C (Van Harmelen et al., 2008). The impact of climate change on the characteristics of the urban heat island effect is unknown as yet (Rahola et al., 2009).

Effects in the city

The changes in climate variables summarised above will undoubtedly influence the physical and social conditions of Dutch cities in the coming decennia. Many citizens will enjoy positive consequences of climate change like warmer summers and are happy to adapt naturally by spending more time outside in parks or terraces. However, for several impacts of climate change natural adaptation will not be enough. A concise overview of these impacts is given below. Section 3 continues with adaptation measures that could be necessary.

In **buildings**, an important impact of climate change will be temperature increases. Especially the higher outdoor temperatures in summer will lead to higher indoor temperatures and a decrease in comfort. Although there will be less need for heating in winter, the demand for cooling in summer will increase. The durability of building materials may be negatively affected: the combination of higher temperatures and more precipitation affects porous building materials like bricks and concrete. Other consequences for buildings relate to constructional safety; flat roofs will be affected by the impact of high precipitation extremes.

In **urban areas**, the impacts of climate change will show in higher temperatures and decreased air quality: warmer summers will enhance formation of low level ozone and smog. In compact urban areas the increased amounts of precipitation may pose problems because it exceeds available discharge and storage capacity: there is simply not enough space in some cities to stow the water. As a result, streets and basement might be flooded, and problems are expected due to pressure on sewerage systems. Not all Dutch cities are, like Amsterdam, equipped with canals! Salinisation, an increasing salt content of water systems due to sea level rise, in combination with increased groundwater extraction might endanger drinking water supply in Dutch cities (Jonkhoff et al., 2008).

Heavy precipitation and high water may also impose problems for **mobility and logistics**. Like in many metropolitan areas road traffic is very dense in the western part of the Netherlands. Extreme weather conditions already cause heavy traffic jams, and this problem will only become worse in and around major cities. Accidents both in road and rail transport appear to increase with adverse weather conditions (Koetse and Rietveld, 2009). Impacts are also foreseen for the infrastructure: possible impacts are road subsidence, flooding of tunnels, increased expansion of railways and bridges as a result of higher temperatures, and lower headroom at bridges with high water tables. In a dry scenario (G+ or W+) inland navigation might be confronted with lower water tables and problems to reach some city harbours. Additionally, Koetse and Rietveld (2009) mention possible impacts on mobility due to changing patterns of tourism and recreation, and impacts of mode choice decisions under changed weather conditions.

The best known impact for the **health sector** is the impact of heat waves (Kirch et al., 2005; Huynen et al, 2008; Rahola et al., 2009). Temperature rise may result in heat stress which has various consequences for the human health. Rising temperatures do not only have a direct influence on health but also several indirect effects. High nightly temperatures during heat waves can disrupt sleep. Disrupted sleep can, in turn, affect health, productivity and learning performance. As mentioned above, heat waves often coincide with periods of summer smog, with high concentrations of ozone on ground level which can trigger asthma attacks and aggravates breathing difficulties.

Finally, floods and other extreme weather conditions possibly mean higher risks for **external safety and security**: drifting of tanks, chemical installations, or waste and the collapse of buildings can lead to injuries, lives lost and environmental damage (Döpp and Albers, 2008).

We have presented the impacts by societal sectors, because it are the sectors that will experience the consequences of climate change. It is the building sector confronted with lower durability of building materials, it is the transport sector suffering from more traffic jams in bad weather conditions, and it is the health sector that has to cope with the impacts of heat waves. But it is not necessarily the same sectors that have to take adaptation measures. The building sector can improve buildings to prevent the extreme effects of heat waves, for instance. This decreases the pressure on the health sector. The last, however, still has to prepare emergency plans. We will touch briefly on the difference in stakeholders with regard to impacts and interests in section 5, where we discuss social dynamics in the city and the implementation of adaptation measures.

The consequences of climate change for Dutch cities in terms of vulnerability and in terms of impacts on structures and processes in cities that are mentioned above have not been expressed quantitatively yet. This will be necessary for prioritisation and implementation of adaptation measures.

3 An overview of possible adaptation measures in Dutch cities

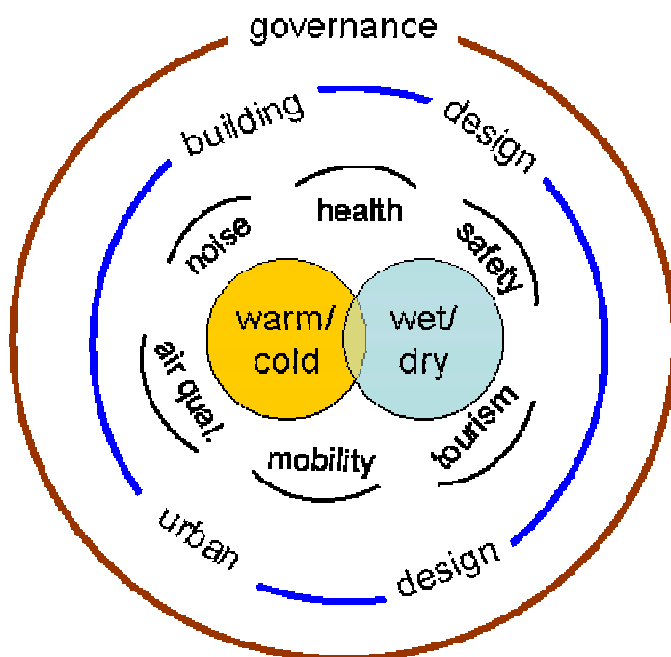
From the overview of impacts above it is clear that most adaptation measures in Dutch cities centre around heat and water (Figure 1). The heat aspect relates to adapting to increased temperatures by better isolation, by bringing “cold” into buildings and the neighbourhood, and links with energy issues. The water aspect concerns several issues: preventing flooding, getting rid of excess rainwater, but also being prepared for water shortages in dry summers. Common to both the heat and water aspect is that sometimes there is too much, sometimes too little. Solutions will have to be found to match supply and demand. Sometimes excess water has to be stored to cater for water needs in dry periods. Heat can also be stored, for instance in the soil, to be used again in winter times. The overlap between ‘warm/cold’ and ‘wet/dry’ in Figure 1 indicates that there might be adaptation solutions combining both aspects. For example, ponds may serve as a buffer for excess rainwater and at the same time relief heat stress. In Figure 1, around the ‘temperature and water’ core of adaptation measures a number of other themes for adaptation are mentioned, like petals around the stamen and the stigma of a flower. These other themes are derived from the general heat and water impacts. For example, decreased air quality and summer smog is a consequence of warmer summers. The need for adaptation in

mobility and transport is a consequence of both heat and water stress. Adaptation measures in tourism can also relate to higher temperatures and more or less precipitation.

In first instance technical solutions will need to be found for the central and the derived themes.

Figure 1 shows that these need to be incorporated in a design stage (of individual buildings or districts) and ultimately are subject to what is summarised here as governance: the whole of regulations, decisions, priority setting, financing, politics, etc. that govern the city. We will go into more detail about implementing adaptation measures and developing integrative strategies in section 5.

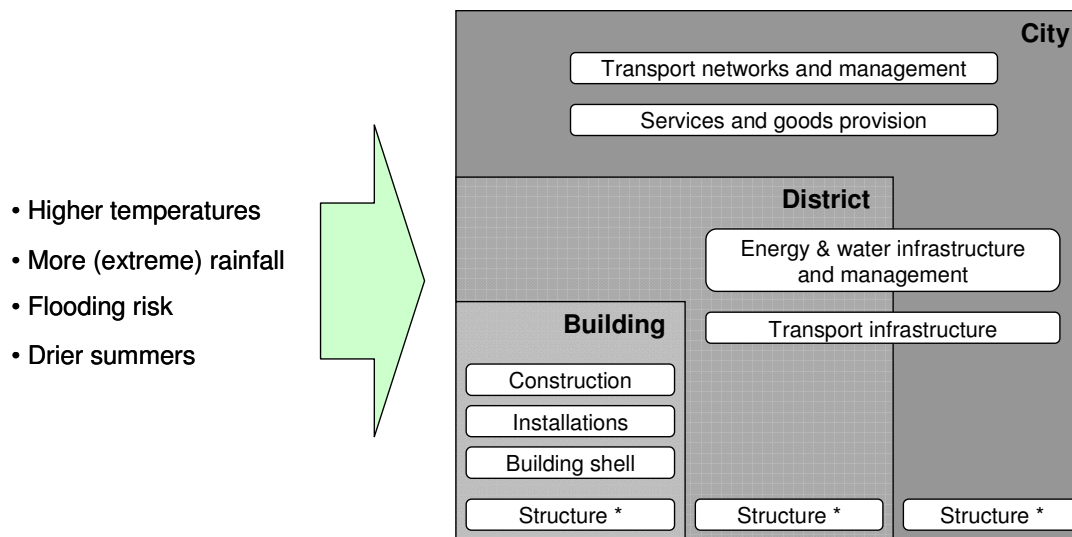
Figure 1. Adaptation aspects in Dutch cities



Source: TNO

In this section we will give a brief overview of suggested technical measures in order to reduce or prevent the impacts of climate change in cities that we described above. As it will still take many years before climate change impacts will be felt, only a limited number of these measures have been implemented yet. For the ease of discussion we distinguish three levels of adaptation measures: that of the building, the district and the urban area as a whole (Figure 2). Figure 2 is an attempt to structure the possible technical adaptation measures along the different urban levels. Within the building/district/city level, a distinction can be made into the various elements that make up a building or a city. Most of these are capital goods with long depreciation periods. Hence it is necessary for new developments to consider adaptation measures that could be integrated effectively and efficiently in current investment plans already now.

Figure 2: Structuring elements for a classification of adaptation measures in cities



Note: * structure refers to geometry, orientation, physical arrangement of elements determining the functions of the building, district or city.

Source: TNO

For **buildings** there is clearly a need for adaptation to increased temperatures and more precipitation. Adjustments on the indoor environment control include climate installations (like ventilation and cooling systems and adjustable sun- and climate screens). The need for cooling can also be translated in more attention on orientation and internal structure of buildings (which rooms will be used for what purpose), or to adjustments of the outer shell like isolation by green roofs (which is a mitigation measure as well).

Furniture and building materials are often a source of volatile organic compounds and biological agents that influence the air quality inside. Higher temperatures could have knock-on effects on in-house air quality as evaporation of chemicals and growth and dispersion of biological agents could be encouraged. If necessary, adaptive actions to prevent this could be taken.

Adaptation options to increased rainfall on and higher water tables under buildings involve among others creating buffering capacity for excess rainwater (for instance through green roofs), new building materials, constructions and/or maintenance regimes to prevent moulds and damage to building materials. Changing climate conditions may ask for more durable building materials and adjustments in design codes for structural safety.

All of the points mentioned refer to new buildings, however, also in renovation of existing buildings these adaptation measures should be taken into account.

On the **district** level higher outdoor temperatures will lead to a more intensive use of public space, which has its implications for the physical lay-out of open spaces and the facilities provided. There might be a need to provide shade by trees or other means. Increased noise, decreased local air quality, and possibly decreased quality of surface water will require more environmental control. More peaks in rainfall will require water buffers and discharge systems. At the same time dryer summers will increase the need for irrigation of green areas.

On the **city** level adaptation measures will be similar to those mentioned for districts. The scale is different, however: in areas prone to flooding special measures might need to be taken like quays and dikes. Other options for coping with excess water include less conventional solutions like floating buildings. Transport infrastructure may need special attention due to heat stress on railway lines, bridges and asphalt. More important for the transport infrastructure is adaptation to wet and dry periods: road transport infrastructure and traffic management systems need to be prepared for periods of heavy rain or snow; inland shipping will need to adapt to low water levels in rivers and channels. In low lying cities the basic infrastructure should be designed to function also in the case of evacuations. Emergency preparedness is also needed for heat waves, involving social services for the elderly and hospitals.

4 Adaptation and mitigation interactions

As both adaptation and mitigation measures are linked to the phenomenon of climate change and often involve adjustments in similar elements of the built environment, it is obvious that policy makers will ask if it is possible to integrate them.

And it is possible, although adaptation and mitigation differ in scope: mitigation consists of measures to prevent a global problem in the future, whereby the exact location of the physical measures is less important, while adaptation consists of measures to prevent a local impact with an immediate effect (IPCC, 2007). Essentially, mitigation consists of reducing the amount of fossil fuel energy used, and switching to renewable energy sources. Adaptation is primarily concerned with changes in structures and practices to reduce vulnerability. Nevertheless, in the context of a city it makes sense to investigate how adaptive changes in structure or process can benefit mitigation or which mitigative measures have a positive side effect on adaptation (McEvoy et al., 2006).

Table 1 lists in italics some starting points for considering combined adaptation and mitigation measures based on the classification proposed in Figure 2.

Table 1: Interaction adaptation-mitigation measures in cities - some examples

building	district	city
-structure: <i>use of sunlight.</i> -building shell: <i>isolation</i> -in-building infrastructure: <i>smart meters</i> -installations: <i>cooling and heating equipment</i>	-structure: <i>use of solar energy</i> -water infrastructure and management: <i>heating and cooling</i>	-structure: <i>use of solar energy, use of industrial heat</i> -water infrastructure and management: <i>heating and cooling</i>

Source: TNO

A clear example where potential adaptation and mitigation integration can be found is the design of a new house. This is a typical example of a project with a long investment horizon. The layout of rooms will have to take into account (1) the need to provide a cool space in warmer summers and (2) the need to make as much as possible use of solar radiation to save heating energy in winter time. Adjustable screens integrated in the building shell may enhance this feature. Isolation which is typically implemented to decrease fossil fuel consumption for heating, may keep the house cool in summer as well. There are, however, also trade-offs between mitigation

and adaptation. Where on a district level one might be inclined to promote green roofs to diminish the urban heat island effect (EPA, 2009), for an individual house it might make more sense to isolate the roof in another way and use the space on the roof for solar photovoltaic or solar thermal panels.

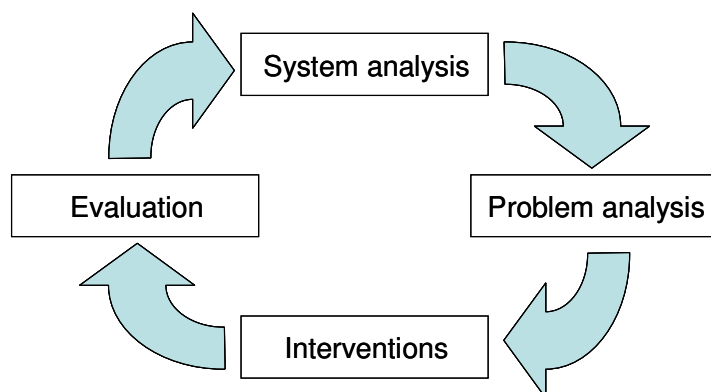
Similar examples can be developed for districts and cities. On these levels adaptation measures to store excess water in cities may well go together with energy buffers. Or expressed in another way: the possibility to use water bodies to store heat for creating energy buffers in a decentralised energy system may also become an adaptation measure to cope with peaks in rainfall. Combining mitigation and adaptation thus requires awareness to possibilities for combining functions and making investments more efficient.

5 Developing adaptation strategies: a systematic approach

Although some measures can be implemented relatively easily, such as planting shade trees, many adaptation measures can not. Adaptation is often an extra element in an already complex web of requirements to buildings and the urban environment in general. Especially because the benefits of adaptation will show only in future years, a systematic approach is needed for analysing a) the need for adaptation, b) the interaction of adaptation with other policies, and c) the design of the measures.

Our knowledge of the impacts and appropriate adaptation measures in cities is increasing, however developing comprehensive adaptation strategies is still a big challenge. As described in previous paragraphs, climate change influences cities on different scales (building, district, city) and in various sectors. Cities can be considered as complex adaptive systems; they are dynamic, connected and open systems which continually evolve to both internal interactions and external factors (Walker 2007, Bai, 2003). The complexity and diversity of climate adaptation raises a number of issues for local governance. In this paragraph, we aim to identify crucial elements in the process of developing effective adaptation strategies that deal with these challenges.

Figure 3: System approach



Source: TNO

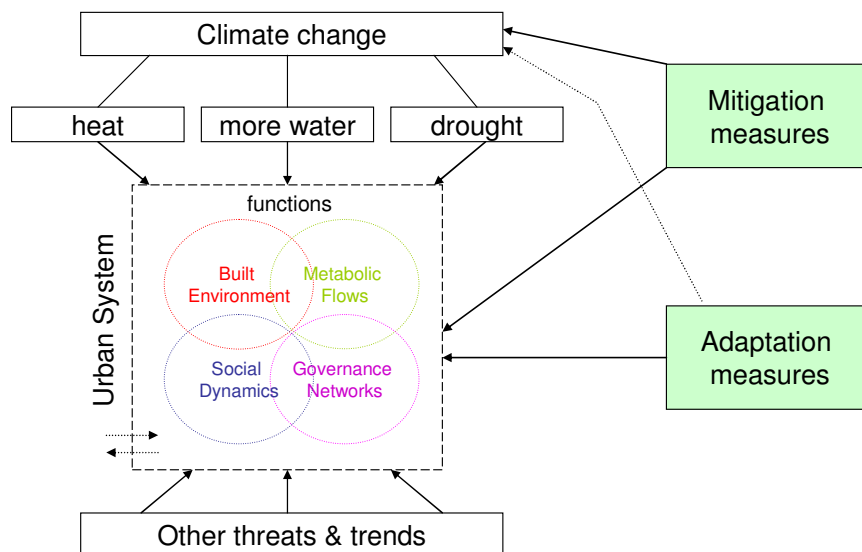
A conventional approach is to base adaptation decisions on risk assessments in which vulnerability is assessed from one particular perspective. In water management, for example,

vulnerability is often considered for flooding of a particular area. Despite high uncertainties in climate scenarios, it is relatively easy to develop ‘no-regret’ measures like raising dikes, based on flooding risks. However, such a straightforward risk based approach is often not suitable for adaptation issues in cities due to the high degree of complexity. For cities, adaptation strategies should be based on the vulnerability of the urban system as a whole .

As vulnerability in cities is determined by various internal and external interconnected elements and processes, a stepwise approach is necessary. Here we propose a system approach (Figure 3) and the framework in Figure 4 to analyze the urban vulnerability for climate change and deal with adaptation. The system analysis phase (Fig. 3) focuses on the total urban system as it currently functions (the central block in Fig. 4). It has proven useful to divide the urban system in four interrelated subsystems: Built environment, Metabolic flows, Social dynamics and Governance networks (Resilience Alliance, 2007). In the next step, the problem analysis, the impacts of climate change related stresses are considered in combination with other (not-climate related) developments shaping the city in the future. Adaptation measures are then implemented during the intervention phase. Finally, the climate change response measures (adaptation and mitigation) will need to be evaluated in terms of effectiveness, efficiency, costs, etc. in relation with all other planned measures in cities.

In the next section we illustrate this approach with the example of local water in the city.

Figure 4: Impact of climate change and measures on the city as a system



Source: TNO

System analysis

The physical part of the urban system, **built environment**, has to do with the local water itself and its position in the urban design. Physical characteristics of water include quantity, quality and temperature. A distinction needs to be made between ground-, surface and precipitation water. For adaptation it is important to know more about spatial orientation, but also the physical elements that make up the water system in a city like the sewage system and the (amount of) paved surface.

Understanding the **metabolic flows** of a city is about understanding the chain of production, supply and consumption of (organic) matter and energy that sustain human well-being and urban quality of life (Folke et al., 1997). Water plays a central role in the urban metabolic flows. The in- and output of water in the urban system is important to take into consideration. Not only for understanding the water flow itself, but also with respect to the different functions of water in other metabolic flows (e.g. supply of goods by river transport, sewage waste, spread of substances via ground- and surface water). There are various ways in which water flows in and outside the city (canals, groundwater, sewerage, etc). A distinction can be made between human controlled water flows and natural processes.

In the **social dynamic** part of the urban system, the different use of water is considered. Urban water is not only used for consumption (household, industry), but also for different types of recreation (swimming water, pleasure boating etc). Changes in socio-economic circumstances, lifestyle and demography influence the specific uses of water.

The **governance networks** that are relevant for adaptation and local water are all organizations and institutions that are concerned with local water. These include not only government institutions like municipalities or water regulatory authorities, but also industrial organisations, developers or (in)formal citizen networks.

Problem analysis

The next step is to analyse how climate change affects the system, and what kinds of problems and opportunities can be defined. To answer these questions it is useful to consider the elements of four subsystems described above, in relation to various climate stresses

From an adaptation point of view, the most important stress factors are 'more heat', 'more water' and 'drought', indicated at the top of Figure 4. As necessary, further specifications can be added: "more water" can be split into: more rainfall amounts, more extreme rainfall events, rising groundwater tables, flooding. Other related elements, like salinisation as a result of rising sea level, can be added too. Many climate stresses are interrelated in several ways, which should be taken into account in developing adaptation strategies.

Urban areas have to deal with higher amounts of water during periods of intense rainfall and higher river discharge. Many solutions require space. On the other hand, there will be more periods of summer drought in the future. Combining issues like these in adaptation strategies results in more effective measures (e.g. construction of temporal water storage solutions like ponds or water squares).

More heat in the city will cause an increased water demand. Not only for several types of consumption but also for recreational use. During long periods of drought, cities should be prepared to prevent serious water shortage.

In order to integrate climate adaptation effectively in the urban development, it is important to consider the main drivers of urban development now and in the future. Climate change is only one of the factors that will influence Dutch cities in the coming decennia. Examples of other threats and trends on the urban system (at the bottom of Figure 3) are ageing of the population, inaccessibility, urban sprawl, ghetto-development, ageing of the industry, reduced urban air quality, etc. (VROM, 2008). By fitting adaptation measures to existing urban development like urban renewal plans, costs can be shared and efficiencies can be reached more easily. For example, in city districts that suffer from impoverishment, water elements might contribute to a

better living environment, while serving as temporal water storage and reducing the urban heat island effect.

A complete analysis using the framework of Figure 4, thus integrates climate change adaptation and mitigation measures and policies with other city policies.

Intervention and evaluation

The most complicated part of climate adaptation in cities is the implementation phase (Figure 3). Implementing adaptation measures in cities is evidently a multi-actor problem, with sometimes conflicting interests. As we mentioned in Section 2, the extent of climate change impact that is experienced in a particular sector might be dependent on adaptation measures implemented in another sector. It is a challenge to bring those actors together and matching urban planning and design, policies and technical solutions. Decision makers face the task to make short term investments in urban development that will only pay off after a long period of time. The extent of pay off is often unknown, which makes these kinds of decisions even harder. Most adaptation measures are integrated in projects with specific goals (e.g. suitable housing, good working infrastructure etc). Usually there are additional costs in order to include the adaptive component, and it is difficult to translate these costs into quantitative benefits. For example: in order to be prepared for possible future precipitation amounts, investments are required in extra capacity for rainwater discharge. Obviously there is a need for better understanding of the effectiveness of adaptation measures and the impact of measures at the system as a whole, in order to complete the systematic cycle approach of Figure 3. This also raises the question on the type of indicators needed to describe the urban system with respect to the threats of climate change and the gains of taking adaptation measures.

6 A research agenda

As climate change and cities is still largely an uncharted territory, this paper presents some explorative entries into the discussion. There are a few general conclusions that we can draw from this paper. Obviously, climate change will influence cities in the future and it is worthwhile to study the causes, effects and possible measures in more detail. It seems that many adaptation issues are related to other urban issues that play an important role in the urban development already (living quality, social cohesion, accessibility etc.), including recent mitigation plans of cities. Looking for synergies between adaptation, mitigation and other urban issues contributes to an effective and efficient development of climate robust cities. Hence, a system approach is necessary for developing adaptation strategies in which all relevant elements and interactions of the urban system are considered.

Many suggestions given in this paper need further investigation. We conclude with the main topics for a research agenda.

Urban climate; What are the current and future meteorological conditions in cities?

- Measuring and modeling local climate conditions;
- The extent and impact of the Urban Heat Island effect in the Netherlands.

Vulnerability and impact; A better understanding of the size of impacts will be necessary for prioritisation and implementation of adaptation measures.

- Quantitative negative and positive effects in the different sectors;
- Direct and indirect economic impacts, including attractiveness for business.

Adaptation measures; There is a need for more knowledge on design and effectiveness of adaptation measures in the urban environment:

Buildings

- Technological solutions for safe and comfortable indoor climate, also taking mitigation into account (local energy production, energy efficient measures);
- Developing building materials that are sustainable vis-à-vis climate stresses;
- Adjustments of building design codes for extra loads to ensure constructional safety in extreme weather circumstances;
- Adaptation measures for existing buildings.

City / district level

- Configuration of buildings and urban spatial planning that contributes to reduction of urban heat island effect, water storage, cooling;
- Sustainable water systems in relation to sewerage and local water supply (e.g. decentralized water treatment systems).

Mobility

- Climate robust new and existing infrastructure (physical elements);
- Climate robust mobility networks; how to reduce disturbance and ensure safe evacuation routes;

- Adjustments in logistic processes (cooling during transport, other types of distribution).

Health

- Preventive measures for heat stress like adjustments in buildings and cities and communication plans during heat waves;
- Curative health care.

Safety

Dealing with flooding risks is a major national issue. For urban areas in particular adaptation concerning safety relates to:

- Local measures for water excess;
- Evacuation during calamities (evacuation routes, communication plans, temporal infrastructure);
- External safety (related to production, storage and transport of dangerous materials). Adaptation measures to prevent calamities during flooding or other climate impacts on industry.

Governance; Many research questions concern developing integrative adaptation strategies and implementation of measures. Some of the main issues are:

- Translation of long term benefits of adaptation in short term investments;
- Linking adaptation strategies with urban planning and building process;
- Collaboration between various actors in the developing, implementation and operation phase;
- Identification of adaptation and mitigation policy synergies;
- Impact of adaptation measures on the urban system as a whole.

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