TURAS
TRANSITIONING TOWARDS URBAN RESILIENCE AND SUSTAINABILITY

Deliverable D4.5
Improved planning for urban resilience and sustainability – tools, measures and recommendations

DOCUMENT PROPERTIES

Project Acronym:	TURAS
Grant Agreement No:	282834
Nature of Document:	Deliverable 4.5
Related Work package:	Work Package 4
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Dissemination level	Public
Version	Final

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Executive Summary

Urban regions face a wide spectrum of challenges. They are home to over half of the world population, but occupy a relatively small area, resulting in pressures related to a limited amount of natural resources such as space and water. Moreover, both the societal system and the natural system are in constant flux resulting in constantly changing boundary conditions. This relates to, inter alia, the climate, demographics and the economy. In order to adequately tackle todays and tomorrows challenges, urban areas need to anticipate and adapt in their planning policies for the city in a strategic way. This **strategic urban planning** concerns not only spatial planning, but relates to all sectors that are relevant in a city (e.g. energy, waste, water, transport). To support effective strategic urban planning, policy and decision makers need information on the changing state of their urban environment, on how certain measures/policies affects this, and how unwanted impacts (e.g. heat stress, flood risk, traffic jams) are reduced. Correspondingly, strategic urban planning requires the merge of environmental analyses and the policy process with all relevant stakeholders (which will be discussed in Chapter 2). This document reports on various tools and methods that have been developed to aid decision making within this joint analytical and policy framework. This research has been performed in various settings (cities) and related to various themes, namely energy (Aalborg), flooding and water management (Rotterdam and Ljubljana), green roofs (London), urban climate (Rotterdam) and transport (Ljubljana).

The study in **Aalborg** focuses on **district heating** (see Chapter 3). An urban Heat Atlas was developed, which includes detailed information related to heat demand at the building level for the entire municipality. Using this method, future energy use and costs are modelled for different scenarios. The results show that changing the heat supply in a renewable direction and implementing heat efficiency measures both reduces CO_2-emissions and minimizes the dependency on fuel import, thus increasing the economic resilience of the city.

In **Ljubljana**, transport and water management are the main focus. The transport case revolves around **mobility** of people in the Ljubljana urban region (see Chapter 4). Sustainable (and integrated) urban planning of transport should take into account initiatives and suggestions of all actors. In order to assure participation, an interactive WebGIS portal has been developed as micro-communication tool between all stakeholders (particularly citizens). The portal provides a basis for crowdsourcing better inputs for the evaluation of measures for sustainable mobility. Moreover, it allows for on-line validation of mathematical models for urban planning. It can be applied not only in the transport sector, but also other sectors such as energy, water and waste management.

The other case in **Ljubljana** relates to **water management** and revolves around the Podutik reservoir and flood management (see Chapter 5). The primary use of this reservoir is for retention of flood waters, but in this case using ecosystem technologies (ET) that mimic the natural environment, it can integrate many more ecosystem functions and services. Monitoring results show that the ecosystem technologies increased the water quality to good/high ecological status. The functions of the reservoir are being optimised for hydraulic retention capacity, ET performance, biodiversity and an educational and recreational path is being constructed. Such flood reservoirs are inherently part of a regional flood management system. This regional level needs more authority as it is the best level to arrange water management but is currently between the national jurisdiction and local implementation levels in Slovenia.

In **Rotterdam** two different themes have been addressed: urban climate and flood risks. The work on **flood risk** (see Chaper 6) focussed on topics which are have received little attention up to now in the Netherlands: flood risks outside the embankments (i.e. not protected), flooding from the regional water system, and damages due to flooding other than direct damage of assets. Flood damage models have been developed to evaluate damage-reducing measures in the unembanked area, revealing they can be very effective in reducing flood risk there. Additionally, an indirect damage model has been set up to estimate the indirect economic damages (e.g. business chain interruption). This showed that indirect losses make up almost as much as direct losses in terms of flood risk, especially for low-probability events. The case on regional barriers also illustrates the importance of damages other than the direct physical damage that is normally considered. Moreover, it also showed that innovative solutions can be devised to reduce flood risk (other than strengthening the embankment), such as compartmentalization of the regional water system.

In addition, in **Rotterdam** the provisioning of **ecosystem services** (ES) by urban green structures (such as trees ,grass strips, gardens, etc) has been analysed (see Chapter 7). A high-resolution GIS model has been set up to quantify the supply of six urban ecosystem services (air purification, runoff retention, cooling, noise reduction, recreation and carbon storage). Applying this model, it is shown that the supply of urban ecosystem services is not equally spread over Rotterdam. In some districts and neighbourhoods much more services are provided than in others. Moreover, the study show that several ecosystem services are supplied in combination and a single green space design can provide multiple benefits. The results and methodology allow for identification of areas with room for improvement and alternative local urban designs using the knowledge on the supply of ecosystem services by individual green urban structures. This will improve general liveability and result in a healthier and climate resilient city. In order to put topics like this on the policy agenda, a stress test has been developed to identify threats and opportunities resulting from the effects of a changing climate. Doing this also helps in connecting various stakeholders and departments in a city in order to raise awareness and trigger action if and when necessary.

Activities in **London** focus on the potential of **green roofs** (see Chapter 8). Like the urban green structures investigated in Rotterdam, green roofs have multiple complimentary benefits, related to runoff attenuation, reducing heat through evapotranspiration, improving air quality and providing novel recreational spaces. A tool has been developed to assess the potential of green roofs in the city. Analyses show that the potential is relatively high, but varies considerably among different districts. This tool can directly aid the planning process in identifying high potential areas for green roofs. Other issues should be kept in mind though. It is shown, for instance, that deprived areas are over-represented in potential flood zones. Considering the high costs of retrofitting, the probability of this happening in more deprived areas is less likely, meaning that greening policies may widen the gap in deprivation.

There are **many tools available** to aid strategic urban planning in various parts of the joint analytical and policy framework. These are driven by the availability of data, which can come from many different authorities. Given the specific context and challenges a city faces, mostly local data is used for strategic urban planning. Gathering, harmonization and distribution of detailed datasets (either at national or municipal level) will thus boost the development and use of such tools, directly aiding strategic urban planning in increasing urban resilience.

The variety of research discussed in this report clearly demonstrates that strategic **urban planning is a matter of integration**. This relates to actors, sectors, functions and developments that all operate in the same urban system. Integrating stakeholders does not only relate to different institutions, but also different departments within, for instance, a municipality. This is especially important in the light of integration between different sectors. Many of the tools and methodologies for strategic urban planning aid this integration in one way or another. For instance by explicitly bringing different stakeholders together (like the web portal in Ljubljana and the stress test in the Rotterdam region), taking an integrated view among different sectors (e.g. by linking spatial planning and flood management in Rotterdam and London), or investigating the various functions of certain elements in order for these multiple benefits to be integrated in policy formulation (as with the Podutik reservoir in Ljubljana or the urban green space in Rotterdam). Adequately addressing this integration can often open opportunities that were not conceivable otherwise and linkages with ongoing activities to improve resilience in an efficient way.

Experiences from not only the research performed, but also from explicitly reflecting on past activities shed some light on the **governance** associated with the policy process and implementation. These experiences teach us that people and timing play a crucial role in the actual execution. **Timing** relates to the time horizons of different actors (e.g. researchers, politicians, practitioners) and processes (e.g. urban development and maintenance of embankments), as well as seizing opportunities when possible. Co-creation of knowledge and plans is important here, which requires coordination and cooperation from the very beginning between different actors. Above all, strategic urban planning comes down to **people,** at all levels (policy analysis, policy making, decision making). People with an open mind who are dedicated, value an integrated approach, and can work in interdisciplinary settings with various stakeholders. Time to build trust and a dedicated coordinator to keep the process going are required for this. The best way to cooperate is to start acting. While **learning by doing**, capacity is built in terms of knowledge and the right mind-set of people involved who can then recognize future opportunities and keep awareness and support high. By investing and engaging in the knowledge base of its people, a city will become more resilient when facing new challenges in the future.

1. Introduction

Since a couple of years, urban areas around the world are home to more than half to the total world population (UN-DESA, 2009). Urban areas are more and more becoming the nexus of where man and environment meet, putting pressure on both the environment and the communities who live there. These pressures result not only from an increase in population versus limits to natural resources (such as space and water), but also constantly changing boundary conditions. These include, for instance, changes in demography, needs from economic sectors, preferences and climate change. As a result, urban planning is a continuous process that requires constant adjustment to new insights and needs. The big challenge is to: i) find sustainable solutions to accommodate pressures on the urban environment, ii) find ways to effectively implement such measures, while iii) taking into account the future.

The TURAS project aims to contribute to these challenges by bringing together researchers and practitioners in cities across Europe to help transition towards more resilient and sustainable states. There are of course many different facets to transitioning, resilience, sustainability and the process of improving the current state. This deliverable reports on the activities of Work Package 4 of TURAS, which focussed on strategic urban planning in the face of external developments such as climate change. Partners from Denmark, Netherlands, England, Slovenia and Spain all performed case studies related to various themes in various cities.

In this report activities carried out in the different cities will be presented in separate chapters (3 through 8). This will be preceded by a theoretical chapter on transition theory in an urban context and frameworks for environmental analysis and policy (Chapter 2). Here also the different activities will be introduced and placed within the coupled framework for strategic urban planning. After the case chapters, the findings will be synthesized in a couple of final chapters in order to formulate overall recommendations and present a toolbox of tools/activities resulting from this research that can be picked up by other cities in their strive towards increased urban resilience; an activity that will actually be picked up in the continuation of the TURAS project.

2. Urban transitioning and strategic urban planning

2.1 Conceptual Framework

Managing transitions is a relatively new field, but the amount of academic literature on it has grown rapidly (Vermeulen, 2014). These studies are concerned with "societal processes of fundamental change in culture and practices" (Franzeskaki and de Haan, 2009). Modern interpretations of transitions refer often to long-term transformation (spanning a generation or more; Rotmans et al., 2001), as opposed to radical revolutions. An example of an important transition in the system was the invention of the automobile, which had a huge impact on urban development and it can be argued that we are currently in an ICT initiated transition (Nykvist and Whitmarsh, 2008). In general, transition theory distinguishes four phases (from Rotmans et al., 2001): Pre-development (no visible change), ii) take-off (system begins to shift), iii) breakthrough (visible structural changes take place; presence of collective learning, diffusion and embedding processes), and iv) stabilization (speed of change decreases as new equilibrium is reached). Recently, a lot of focus in transition literature relates to sustainability transitions (see e.g. Grin, Rotmans and Schot, 2010). In this respect, urban areas play a central role as they are loci where sustainability problems arise, as well as centra where concrete action can be taken to tackle sustainability issues (Nevens et al., 2013).

An upward trend can be observed in activities of cities related to transitioning to more sustainable states (Vermeulen, 2014). This has been attributed to two drivers: i) climate/global change vulnerability and ii) contemporary pressures and increased competition (Vermeulen, 2014). Cities are particularly vulnerable to climate change as several pressures are already high there, which may be further exacerbated by climate change. These include flood risks due to, amongst others, increased exposure and sea-level rise (Hallegatte et al., 2013), relatively large warming due to the urban heat island effect (Stone et al., 2013), and issues with water quality and health related to climatic change (see e.g. Vermeulen and Hofstra, 2013). On top of climate change, other trends in global change (population growth, urbanisation, economic growth) may further impact those pressures in urban regions. There is, however, also a trend in urban competitiveness; with cities actively marketing their city to attract visitors, inhabitants and companies (Van den Berg and Braun, 1999). Together with considerations about limited natural resources and self-reliance, this has also instigated socio-technical transitions (Hodson and Marvin, 2010).

Transition theory gives a general framework to place the governance process related to transformation and many examples of ongoing transitions. It does not, however, go into the specifics of which concrete action is required on the ground and how to determine such action, as this obviously differs between different transitions (of which there may be many). In order to improve strategic urban planning to increase urban resilience and sustainability, other frameworks should be sought that take a more practical approach for the analysis of options and implementation of policy.

Many frameworks have been developed to give guidance to the management of complex processes. In environmental sciences, for instance, the DPSIR framework (see e.g. Borja et al., 2006) has been developed by the European Environment Agency (EEA, 1999) to analyse environmental problems, such as water quality (IMPRESS, 2003). DPSIR is basically an extension of the pressure-state-response framework (see e.g. OECD, 1993). The DPSIR framework is widely used to describe cause-effect interactions between environment and society in complex (environmental) systems, specifically in relation to certain policy aims. DPSIR has also been extensively used in an urban context (e.g. Haase and Nuissl, 2007; Jago-on et al., 2009). The DPSIR framework consists of five components, with causal relations between them (Figure 2.1). Roughly they form a cycle, from driving forces exerting pressure on the environment, which results in a change in state of the environment that in turn results in impacts on the natural and socio-economic system. Due to these impacts, a response is triggered by society aimed at reducing the consequences. Such a response can target each of the four other components and their preceding relations. A description of the drivers and relations, along with an example of flooding in an urban setting are provided in Table 2.1.

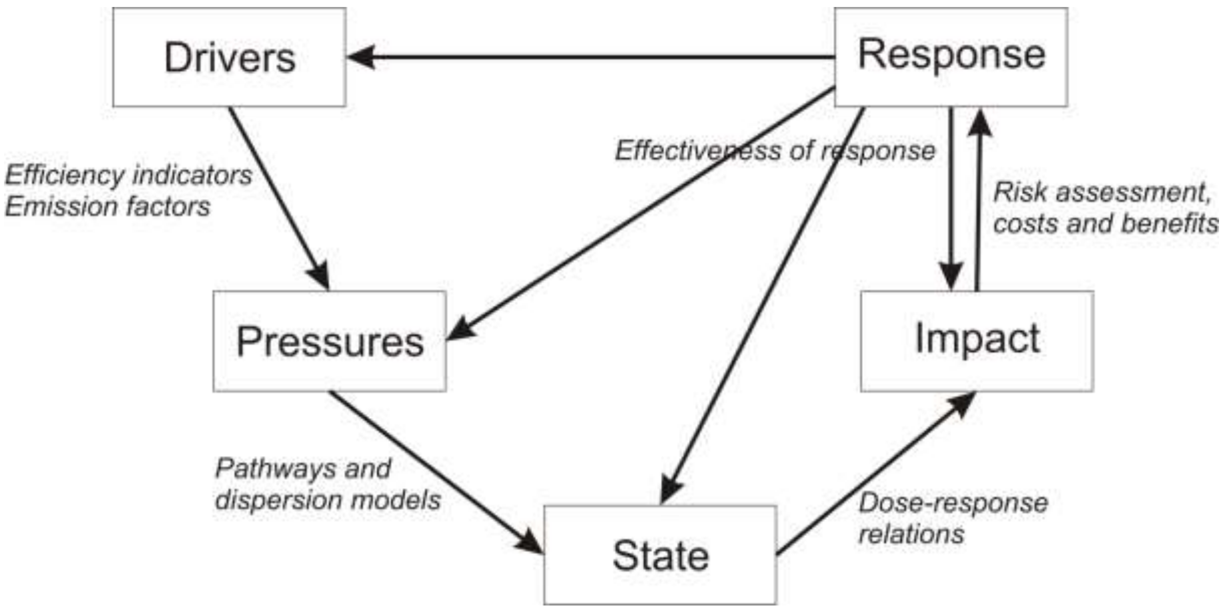

Figure 2.1: DPSIR frame work with linkages between components (modified after EEA, 1999).

Table 2.1: Components and relations in DPSIR framework with examples related to urban flooding and climate change

Component/relation	Description	Example urban flooding and climate change
Drivers	Social, demographic and economic developments	Population growth, urbanisation, economic growth
D-P relation	Efficiency and emission factors	Increase in demand for housing, transport, energy
Pressures	Release of substances, physical and biological agents and use of resources and land by humans	Changes in land-use; greenhouse gas emissions
P-S relation	Pathways and dispersion patterns	Spatial changes in land use due to geography, infrastructure, preferences; accumulation of greenhouse gasses in atmosphere
State	Features of natural and socio-economic system	Increased impervious area, exposure to flooding; increase temperature, sea-level rise, changing probability extreme events
S-I relation	Dose-response relations	Vulnerability of houses to damage; Increased flood hazard (faster runoff, slr, extreme events)
Impact	Changes in environmental functions affecting social, economic and environmental dimensions/functions	Higher flood risk
I-R relation	Risk awareness/perception	Risk becomes higher than socially acceptable
Response	Policy action directly or indirectly triggered by impact to prevent/reduce consequences	Development, evaluation and implementation of measures to reduce risk
R-D relation	Effectiveness of response	Curb population growth, urbanisation
R-P relation (+D-P)		Smart solutions to reduce footprints (related to housing, transport, etc) per person; reduce ghg emissions
R-S relation (+P-S)		Increase infiltration, give room to water, build levees
R-I relation (+S-I)		Flood proof building, insurance

The DPSIR framework is very much directed towards the physical environment, and not so much the policy process related to managing the environment in practice. To visualise, structure and give guidance to this process, the policy cycle has been developed. Many different versions of the policy cycle can be found, but most are based on four main components: i) agenda setting, ii) policy formulation, iii) policy implementation, and iv) policy evaluation (e.g. Jann and Wegrich, 2007; Jansen et al., 2010). These four components often include various elements themselves (Figure 2.2). Whilst portrayed as a cycle, it is widely recognized that the policy process is not a strictly one-directional process, but may go back and forth a bit between the components and various elements have strong linkages.

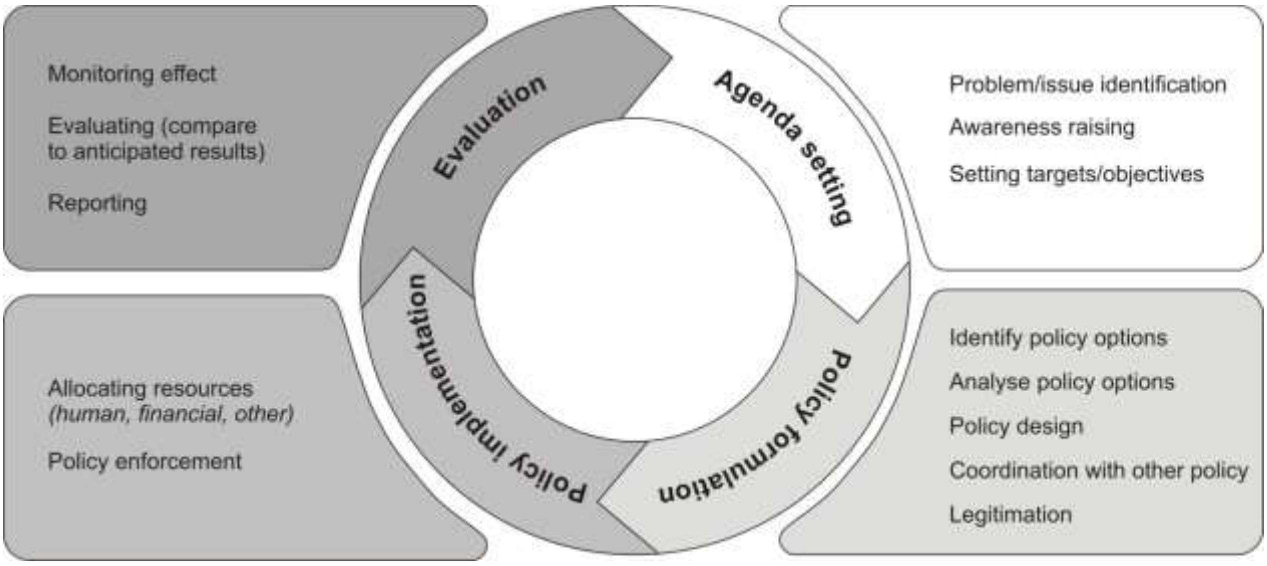

Figure 2.2: Schematic representation of the policy cycle with its four main components (bold in cirlce) and underlying elements.

In a sense, the policy cycle fills in the 'Response' component of the DPSIR framework. After an impact has been observed that is not desired, an issue is identified and the policy cycle starts to set up the response. The implementation of the response then affects the D-P-S-I components, resulting in a new state of the system with adjusted impacts. These adjusted impacts are monitored and evaluated in the last component of the policy cycle, where it is decided whether adjusted or further response is necessary. Inversely, the DPSIR framework is also part of the policy cycle. In the policy formulation component, various policy options are identified an analysed before final policies are designed to be implemented. This analysis of policy options generally consists of research on hypothetical response to see how they would affect D-P-S-I components. Based on these insights specific policies are then chosen and designed for implementation. Strategic assessments (using DPSIR) and on the ground policy (using the policy cycle) are thus intricately linked. Hence, both need to be considered for successful strategic urban planning in order to increase resilience to, for instance, adverse effects of climate change.

Figure 2.3 tries to capture this link between the analytical DPSIR framework, and the more implementation-oriented policy cycle. Drivers in the real world (top of figure) result in pressures, change the state of the system and eventually cause certain impacts on society. The occurrence of such impacts results in the identification of a certain problem/issue, starting the 'Agenda setting' in the policy cycle. During the course of the policy, it is imperative to include relevant stakeholders and keep interests of various parties in mind, who are ultimately of course the citizens in case of strategic urban planning. The actions performed within the cycle are for a large part the responsibility of local authorities, but also other authorities, businesses and academia/research institutes play a role in various parts. The 'Policy formulation' component starts with the identification of various measures/responses. These responses are then to be analysed, and their effects evaluated a-priori in order to provide a solid basis for a decision on policies and subsequent design. In the process of policy formulation, as well as the analysis and evaluation of measures/responses, an integrated look over different sectors is recommended; as certain responses can have unintended effects or co-benefits in other sectors (puzzle pieces) as well. After policies (measures/responses) have been selected and designed, the 'Policy implementation' commences. The effect of the policy results in changes in the drivers, pressures, state or impact in the real world. The effect of the policy is monitored in the 'Monitoring & evaluation' component, and the adjusted impact is observed in the real world. These effects may, or may not, result in a new start of the cycle in case adjustment is necessary or new issues arise.

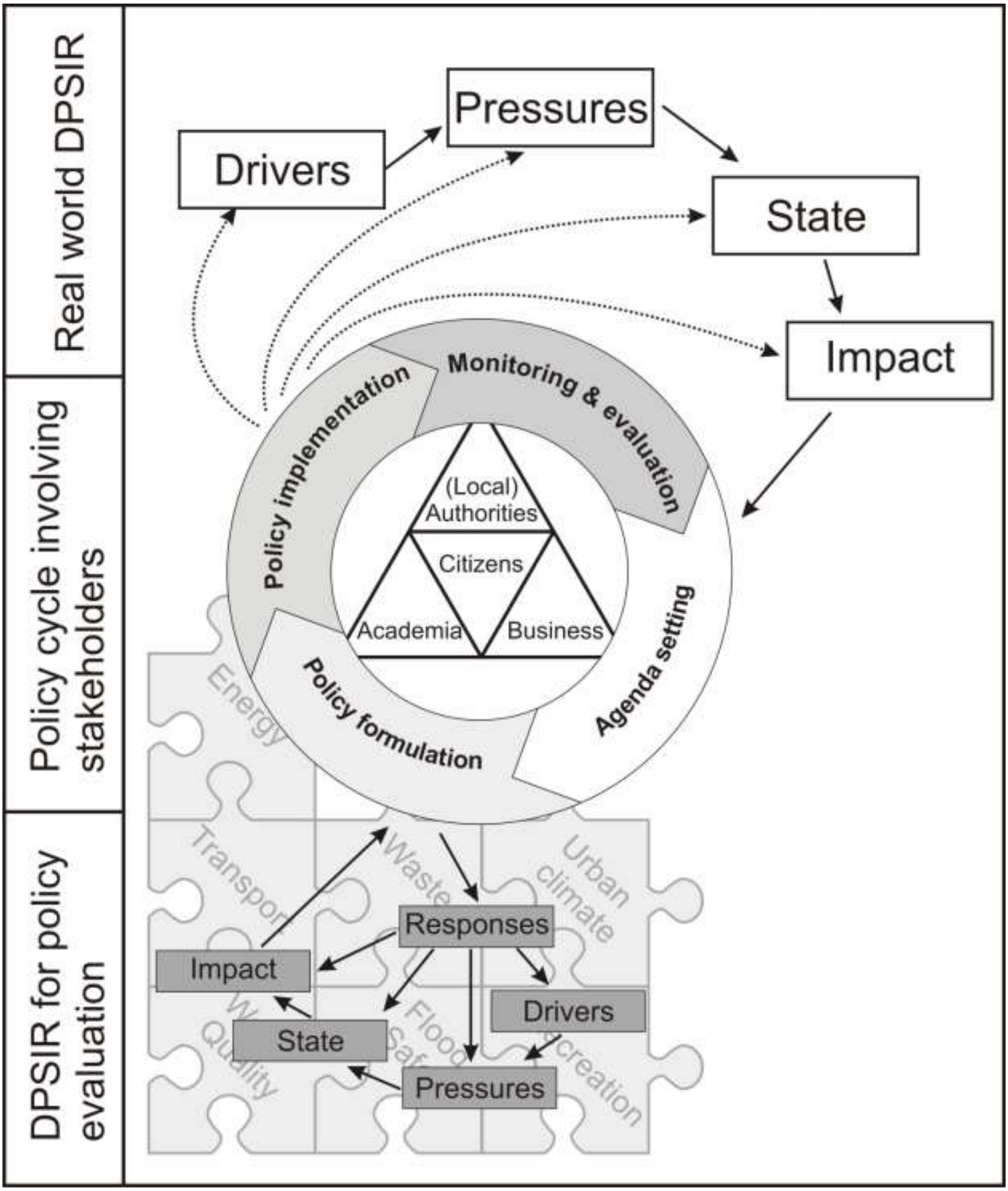

Figure 2.3: Interaction between the DPSIR framework and policy cycle for strategic urban planning.

2.2 Case studies and activities

In this report, activities and research have been performed which fall within different parts of this combined framework for strategic urban planning. In general, the activities within this work package (WP4) of TURAS revolve around the question: 'how to get to the right response for the right problem'. Correspondingly, most activities relate to the lower part of the Figure 10. Many of the activities relate to 'Agenda setting' and 'Policy formulation', as most studies are explorative in nature. Nevertheless, also 'Monitoring & evaluation' is addressed in for instance Ljubljana and in various cases an explicit reflection on policy implementation based om past experiences has been performed by the local stakeholder partners. See table 2.2 for an overview of the activities and where they fit in the framework.

Table 2.2: Topics addressed in the various case study cities and their relation to the policy cycle

City	Topic	Component framework	Description
Aalborg	Energy - Heat atlas	Policy formulation *-Identifying policy options* *-Evaluating policy options*	Creation of heat atlas and development of possible scenarios related to district heating
Ljubljana	Podutik reservoir	Monitoring & evaluation *-Monitoring effect* Agenda setting *-raising awareness*	Monitoring various benefits of ecosystem technologies related to flood reservoir. Development of information path
Ljubljana	Transport - GIS portal	Agenda setting *-Problem issue identification* *-Raising awareness*	Problem/issue identification and awareness raising whilst incorporating citizens in policy cycle.
London	Green roofs	Policy formulation *-Evaluating policy options*	Assessment of the potential of green roofs in city area with respect to placement and attenuation of storm water peaks
Malaga	Waste	Policy formulation	Improving waste management system in terms of resource efficiency and sustainability using ISWM
Rotterdam	Direct-indirect flood model and regional embankments	Agenda setting *-Problem identification* *-Raising Awareness* *-Setting targets/objectives* Policy formulation *-Identifying policy options* *-Evaluating policy options*	Evaluation of indirect damage damages of flooding and identification and evaluation of various policy options for flooding in the unembanked area and related to regional embankments
Rotterdam	Urban services	Policy formulation *-Identifying policy options* *-Evaluating policy options*	Contribution of green and blue elements to the provisioning of ecosystems services in the city
Rotterdam	Stress test	Agenda setting *-Problem identification* *-Awareness raising*	Raising awareness among municipalities to the issues and urgency related to climate change

3. Strategic Municipal Energy Planning – Aalborg

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3.1 Introduction

Municipalities find themselves in between global challenges and opportunities for local action. Many municipalities such as Aalborg in Denmark are exposed to the effects of climate change, while the residents and the economic activities within the municipality cause the emission of greenhouse gases, which contribute to global warming and its effects such as sea level rise, extreme weather and heat waves.

KEY MESSAGE

1. *Heat atlases are essential tools in implementing strategic energy planning in municipalities, as they allow for a detailed assessment of district heating potentials as well as heat reduction potentials within the local building stock.*
2. *The Aalborg case study shows that changing the heat supply in a renewable direction and implementing heat efficiency measures both reduces CO_2-emmissions and minimizes the dependency on fuel import, thus increasing economic resilience within the city.*

Aalborg municipality has recently presented climate change adaptation as well as mitigation strategies. Available high-resolution spatial data has been a precondition for both mapping possible damages due to climate change, as well as opportunities for a municipal energy system, which may become free of fossil fuels in the future. Aalborg University has prepared an Energy Vision for a 100% renewable energy system for the municipality by means of a mutual research agreement. This work is being reviewed (as it has not received EU funding) and its implications for a continued strategic municipal energy planning are going to be analysed and presented in this case study, with particular focus on high-resolution spatial data (funded by the present TURAS-project).

Challenges for municipalities are manifold when it comes to activities that use fossil fuels to maintain central urban services such as housing, transportation and industrial or other economic activity. The majority of such activities are rooted in private ownership and also the utilities that deliver electricity, heat and fuels to these sectors are often in private hands. Energy policies traditionally are formulated and administrated on a national scale, leaving municipalities with very limited decisional capacities on the subject of energy demand and supply, unless a municipality owns a large proportion of public housing or the public utilities that supply electricity and heat. Municipalities often are located “half-ways” between the national or international scale of governmental and the private, civilian scale of the individual owner. It is thus a remarkable feat to talk about *municipal* strategic energy planning.

Aalborg municipality

Aalborg municipality (Figure 3.1) is located in the North of the Jutland peninsula. It has a population of 197,000, which makes it the 6th biggest of 98 Danish municipalities. Most of its inhabitants (approx. 85%) live in the city of Aalborg, while another 10% live in smaller villages and towns surrounding the city. The land mass is 1144 km^2, which makes it the 3rd biggest municipality by area. The resulting population density is 175 per km^2. Aalborg is a former industrial town in a transition process to become a “knowledge” city, as Aalborg University (founded 1974) with its 3,500 staff and 19,000 students is getting highly visible in the city, attracting many knowledge-intensive businesses. But Aalborg also houses Denmark’s largest energy consumer, the Aalborg Portland cement factory, which employs 500 people and consumes about 2.4% of the primary energy consumption of the country, which has a total population of 5.5 million. About 95% of the heat demand in the city of Aalborg and most of the heat demand in its rural surroundings is supplied as district heating, and the municipality is the owner of the local district heating utility.

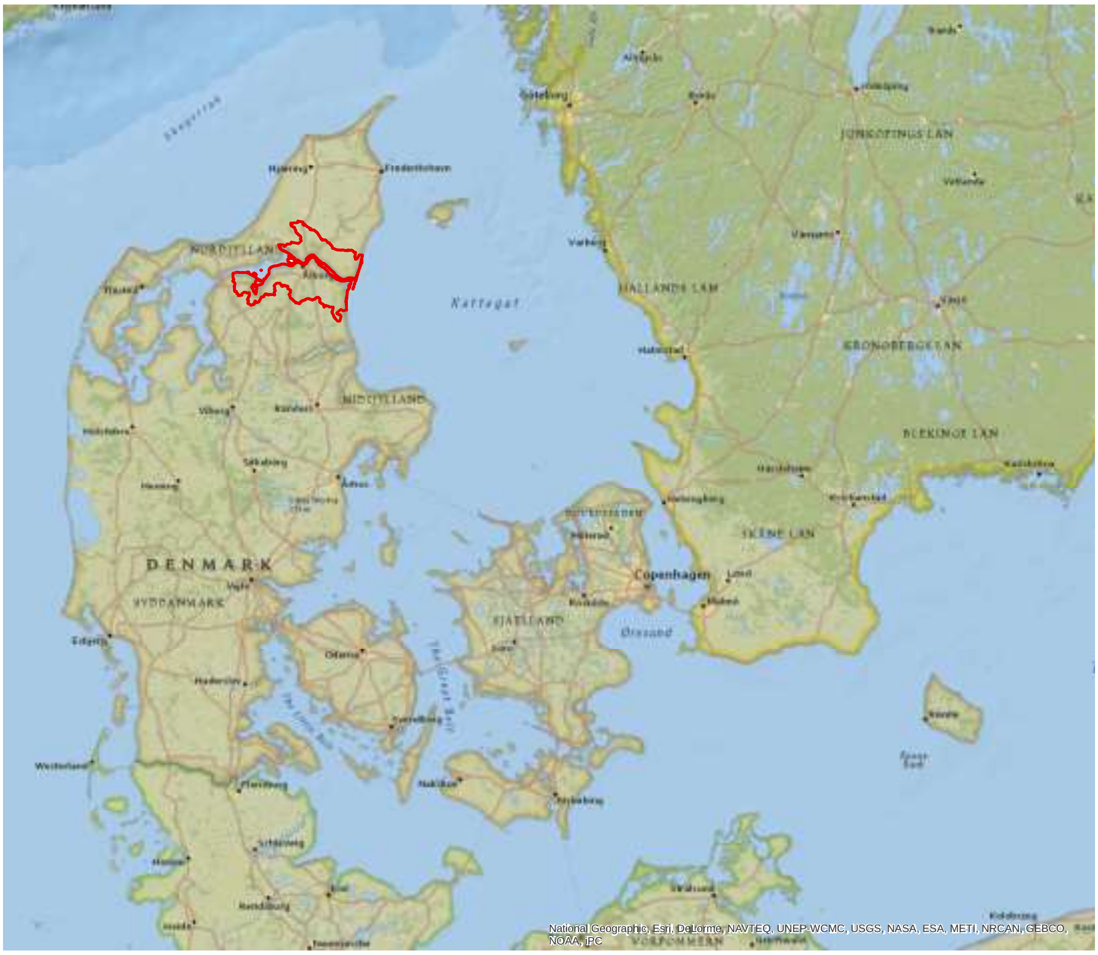

Figure 3.1: Location of Aalborg municipality, Denmark (Map source: National Geographic 2013)

The 100% renewable energy vision and the climate strategy of Aalborg Municipality

Aalborg has been a pioneer in the field of Sustainable Development for many years. In 1994, Aalborg was involved in the efforts of putting local sustainability on the agenda in Europe. Aalborg municipality has actively contributed for the creation of Aalborg Charter[1], a statement expressing that municipalities and its citizens have a great responsibility in creating environmental, social and economically sustainable communicates, in collaboration with the European Commission. Today, the Charter has been signed by over 2500 local authorities across Europe.

In 2004, the Aalborg Commitments[2] were adopted at the Aalborg + 10 Conference, as a follow-up of the Aalborg Charter. The Aalborg Commitments forces local authorities to pursue sustainable development through obligations to set concrete goals and actions within ten themes, including governance, local management towards sustainability, natural common goods, responsible consumption and lifestyle choices, planning and design, better mobility and less traffic, local action for health, vibrant and sustainable local economy, social equity and justice, and local to global responsibility. So far, the Aalborg Commitments have been signed by 650 municipalities and the number is increasing.

Based on the framework laid down by the Aalborg Commitments, the Sustainability Strategy 2008-2011[3] presents specific strategies comprising objectives and initiatives for local sustainable development. Specifically, the city of Aalborg adopted a target of reduction of CO_2 emissions in terms of energy supply of 33% during the period of 1990-

[1] http://www.sustainablecities.eu/aalborg-process/charter
[2] http://www.sustainablecities.eu/aalborg-process/commitments
[3] http://www.aalborgkommune.dk/images/teknisk/PLANBYG/ANDRE_PLANER/Baeredygtighedsstrategi_2008-11_Final.pdf

2012. This is however, only when excluding the CO_2 emissions from Aalborg Portland and the transport sector. Sustainability strategies and initiatives cover a broad range of issues including climate change prevention and adaptation, resource consumption, nature conservation, environment and health, and sustainable behaviours such as green purchasing and environmental management.

Figure 3.2 shows a hierarchy of Aalborg's sustainability strategies and initiatives.

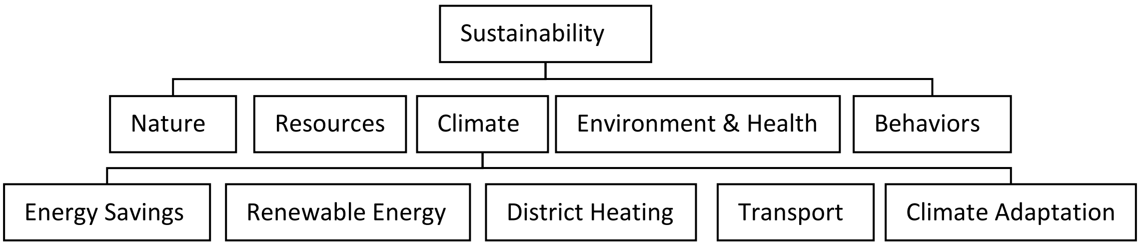

Figure 3.2: A hierarchy of Aalborg's sustainability strategies and initiatives

In early 2013 Aalborg municipality presented its 2013-2016 Climate Strategy[4], as a short-term course of action for mitigation of and adaption to climate change. Aalborg municipality in here accepts responsibility for the global challenges of a changing climate, e.g. by increasing the share of renewable energy sources in the energy and transport sectors, by reducing the final energy demand, or by planning new forests. The climate strategy therefore aims at preventing additional changes to the climate, and adapting to the anticipated changes. The strategy also aims at putting focus on climate change policies in all elements of municipal planning: urban development, energy, environment, nature, and transport planning as specified in the Aalborg Commitments and the Aalborg municipal sustainability strategy 2008-11. Central to the climate strategy is the vision to become independent from fossil fuels and achieve neutrality in the emissions of greenhouse gases by 2050. The strategy is a first step towards this vision, as it formulates a number of concrete targets for the reduction of CO_2.

Heat savings and district heating scenarios to realize the vision

The climate strategy includes targets and policy measures for energy savings and increased energy efficiency as well as renewable energy as preconditions for reaching international agreements but also the aims of Aalborg municipality as well as the Danish government to become fossil-free by the year 2050. This includes for Aalborg municipality a reduction of final energy demand by 40-50% in all energy end-use sectors: households, businesses, public administration, industry, agriculture and transport. The strategy is based on several years of experience: in the period from 1990 to 2012 the CO_2-emissions have been reduced by 30% already, primarily by efforts in the energy supply sector. Here industrial waste heat is being utilized for the production of district heating; energy plants have been made more efficient; and the share of renewable energy such as biomass, organic waste and wind energy has been increased. Currently the biggest emitter of CO_2 is the transport sector (500kt/a), followed by power production (400 kt/a), agriculture, heat supply and industrial process heat. Today the per capita CO_2 emissions are 7.8 t/a, which is well under the Danish average of 10 t/a. While the transport sector is almost entirely based on fossil fuels, the share of coal, oil and gas in power and heat production are roughly 50% each. Aalborg University has projected Aalborg's future energy demands in 2030 and 2050 based on its energy use in 2007 using governmental forecasts for business as usual. Specifically, electricity consumption is estimated to increase 20% from 1,000 GWh in 2007 to 1,190 GWh in 2050. Heat consumption will increase from 1,671 GWh in 2007 to 1,770 GWh in 2050 due to increased new construction, representing an increase of 5%. Transport energy consumption will have an increase of 11% from 1,869 GWh in 2007 to 2,067 GWh in 2050 if no new policies on energy efficiency in the end-use sectors are adopted [1].

To achieve the vision of 100% renewable energy systems, apart from substantial energy savings the municipality is going to utilize all available renewable energy sources that are economically, environmentally and socially sustainable, if possible from within its geographical boundaries. Currently comprising 30% of the total energy supply, this figure is to grow to 60% by 2030 and 100% by 2050. In addition to renewable energy, waste heat from industry and from waste incineration currently makes up about 50% of the input to district heating. By 2030 this share is to grow to 90%.

[4] http://www.aalborgkommune.dk/Politik/kommunens-politikker/Sider/Baeredygtighedsstrategi.aspx

District heating has several distinct advantages giving it a high potential as a central element of a sustainable energy system. For starters, it allows for more flexibility in the energy system, which is highly required in a system with high shares of – or completely based on – fluctuating and variable renewable energy sources. District heating also is ideal for using renewable energy and waste heat sources, which otherwise are not available in an energy system based on individual heat supply based on boilers, heat pumps etc. in each house. Geothermal heat is available at great depths below Aalborg, and municipal waste handling is largely based on waste-to-energy schemes, although the energy content of municipal household waste gradually will decrease due to higher recycling rates. District heating finally is a good solution as it allows for the large-scale use of heat pumps, which convert surplus electricity from wind and solar power plants to heat, which can be stored for less windy and sunny periods. This leads to the concept of flexible, or smart, energy systems, which in the long term also may include the conversion of electricity and biomass (which is a highly restricted resource) to transport fuels. In 2007, the share of district heating in the Aalborg municipality total heat supply was 83%, in which centralized district heating area was 89% and decentralized district heating area was 11%. The share of district heating supply in total heat supply is expected to be 86% with a central district heating area exceeding 95% by 2030. District heating expansion will lead to decreased CO_2 emissions due to shifts from individual heat supply from oil and gas, energy efficiency improvement of heating supply, conversion to alternative fuels such as biomass and waste, and increased utilization of renewable energy and industrial waste heat.

The energy vision includes some suggestions to the amount of renewable energy to be utilized in Aalborg municipality, based on a number of scenarios calculated by means of energy systems analysis. Wind energy is to comprise 80% of the electricity demand in 2050. As most of the areas within the municipality are already used, the energy vision assumes a general re-powering (a replacement of older turbines with new) and possibly an offshore wind farm. Solar energy is to be used for the production of electricity as well as heat. By 2020 at least 5,000 m^2 of solar cells are to be invested in (many of which are already implemented), while solar heat with heat pumps is to cover a major part of the heat demand in rural areas. Biomass fuels are another central element, but it has to be assessed carefully if biomass production is from sustainable sources. Straw, manure, wood and organic waste are already being used, but need to be utilized to a higher extent particularly for the production of automotive fuels. By 2030, 30% of the energy demand is to be covered from biomass resources sourced within Aalborg municipality. The energy vision opposes the idea of import of biomass: first, biomass from other countries may be subject to higher competition, and may not always be sustainable. Second, a national strategy for 100% renewable energy may be based on regional and local import balances that are neutral so that in average a typical municipality will consume as much biomass as it produces. This needs however to be modified as there are outspoken urban as well as rural municipalities, which will become net importers and exporters of biomass.

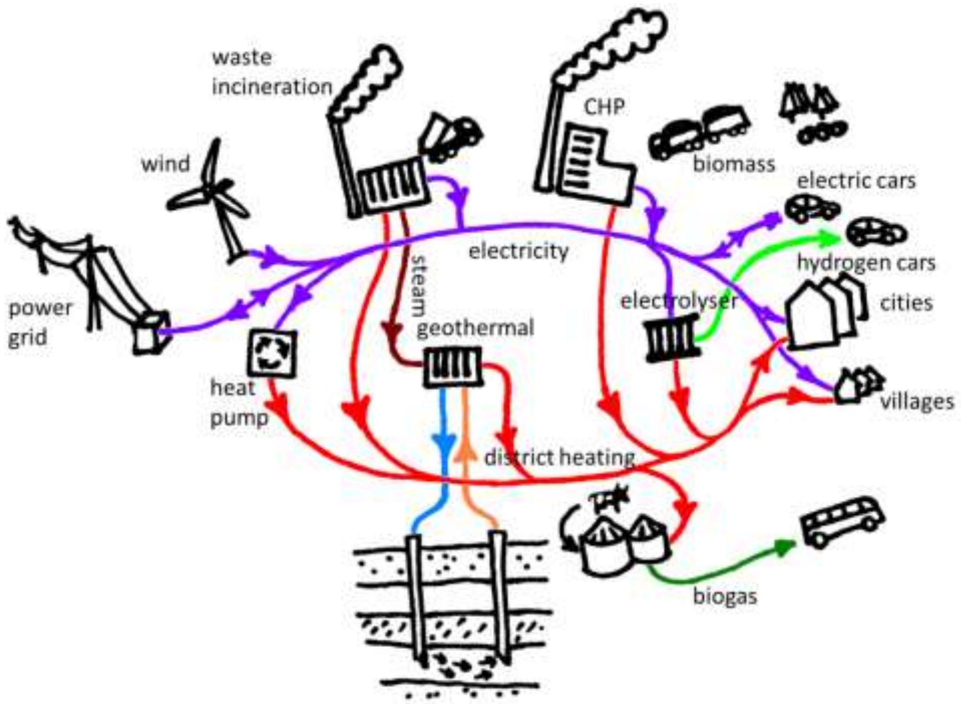

Figure 3.3: A schematic figure of future flexible energy system showing the interaction between different energy systems

Figure 3.3 shows how various renewable energy sources interact with an energy system based on electricity, district heating and fuels, in a future flexible energy system. Energy savings are an essential element of such a system, if the availability of renewable energy sources is limited by concerns about the economy, sustainability etc. of imported biomass and other renewable energy resources. Already now Danish energy policy requires energy companies to find 2% savings in primary energy demand each year, to be realized by end-use efficiency, conversion to less energy consuming heat supply, or other efficiency measures. The Energy Efficiency Directive by the EU aims at a total of 20% of efficiency gains in all European countries by the year 2020. The challenge is to implement savings in the individual households and businesses, where a very large number of basically independent decision makers have to cope with lack of decisional basis and other issues. In order to facilitate this enormous task of aiding house owners, businesses and the public administration with information on the feasibility and the effect of energy savings, reliable data on the current energy demand, current costs of energy and the costs of investing into alternatives such as building improvements and new machinery must be procured. This is a central element of the present case study, which aims at procuring high-resolution spatial data for the heat demand and supply of individual buildings.

3.2 Tools and analyses for strategic municipal energy planning

As a methodology chapter, this section contains an introduction to the subject of strategic municipal energy planning as planning on the intermediate level between national government and the individual household or company. Since the beginning of the 1990'ies Denmark has moved from a system with detailed heat plans towards a system based on individual projects. This made it harder for municipalities to carry out more long-term heat planning. However, since late 2009 this has changed with the increasing focus on climate change and renewable energy. It became apparent that most of the changes required to reach the climate goals in most instances involves the municipal level. Therefore, in 2010 the Danish Energy Agency and Local Government Denmark published a proposal to implement strategic energy planning in Denmark [2]. In this report strategic energy planning is described as:

"*a planning tool that enables municipalities to plan for local energy systems moving to a more flexible and energy efficient energy system with the aim of implementing more renewable energy and energy savings in the most efficient way from a societal point of view"* [2]

Strategic energy planning is voluntary, but most municipalities have already started to implement it. Strategic energy planning consists of four overall parts: mapping of energy consumption and supply, establishment of a reference scenario, finding reduction potentials and finding local energy sources. This Aalborg case study includes all of these aspects. Strategic energy planning aims at assessing long-term consequences for long-term decision making as well as it aims at broad and holistic energy planning. This also means that new tools needs to be developed in order to enable municipalities to carry out this new task, the heat atlas presented in the next is an example of such a tool.

The Heat Atlas methodology

Cities across the globe are developing plans to reduce their energy consumption and lower their carbon footprint by reducing energy-related greenhouse gas emissions. While initial efforts have focused on individual buildings such as incorporating more energy efficient lighting, windows, and building systems, deeper reductions will call for changes beyond individual buildings, requiring a rethinking of how future infrastructure and energy policies should evolve.
A Geographical Information System (GIS) based heat atlas can help the city mayor target areas where it can achieve the most energy savings and maximize carbon emission reductions. Specifically, a heat atlas of the city may provide information about energy use, renewable energy resources, infrastructure, CO_2 emission sources and serve as a useful tool for decision-makers in developing an energy plan and for residents to understand what is happening in their city in terms of current energy use and supply. In addition, a heat atlas of the city can be used for identifying potential insulation areas, recognizing available energy resources for distributed generation and identifying areas of further energy and financial savings. Heat atlases have been widely developed by cities and regions in U.S. and Europe for energy and low-carbon planning. For example, the City of Boston[5] created the Renew Boston Solar map to assist in tracking the community's clean energy progress in meeting the goal of reducing greenhouse gas emissions by 25% in 2020. The London Heat Map[6] provides users spatial intelligence on factors relevant to the identification and development of decentralized energy opportunities, such as major energy consumers, fuel consumption and CO_2 emissions, energy supply plants, community heating networks, and heat density. Another recent example is the Scotland Heat Map [7], which shows the heat demand in various resolutions from 50 m^2 to 1 km^2.

Design principles of a heat atlas

Heat atlases must represent the geographical heterogeneity of the real world. That means, that data must reflect the distribution of real world phenomena such as the distribution of the building stock or the distance to infrastructure. A heat atlas must therefore aim for the smallest possible geographical entity, which yields the highest available level of detail: ideally the single building. The single occupied building houses the smallest socio-

[5] See also in http://gis.cityofboston.gov/solarboston/#.
[6] See also in http://www.londonheatmap.org.uk/Content/HeatMap.aspx.
[7] See http://heatmap.scotland.gov.uk

economic entity to affect energy demand, the household, which also is the broadest basis for decision making on consumption, investment in the building stock, and energy-related behaviour [3].

Heat atlases must furthermore allow for decisions on “how far to go”, reflecting the significant difference between theoretical, technical, economic and socially or environmentally acceptable potentials of a technology. Each fraction of the potential comes at a specific cost. The heat atlas must be able to represent the marginally increasing costs of utilising a technology in a continuous way, using the marginal costs as a decision parameter. The marginal costs of a resource, however, are not the same for the whole country as potential resources are geographically distributed in space and with different density or availability and therefore different specific costs of utilisation. We consequently speak of a spatially continuous model, which maps fractions of the total resource base by costs, technical constraints, environmental impact or social consequences.

Heat atlases finally must provide a better basis for making energy systems analysis with computer models, like EnergyPLAN, which is used in the case study. This means that the heat atlas must be able to deliver consistent data on the potentials of a resource, its costs and impact. An example is the assessment of the conversion potentials of individual natural gas heating to district heat. To provide a reasonable figure, the less economically attractive portions of the total potential (all buildings with natural gas heating) must be excluded, e.g. by defining cut-off distances or maximal connection costs. The heat atlas is an integrated spatial database with associated analysis tools. As software for the GIS database and analysis ESRI’s ArcGIS version 10[8] has been chosen, which offers good analytical capabilities and data connectivity. The integrated spatial database is designed using the File Geodatabase, which allows for efficient handling of large datasets in the ArcGIS 10 environment. An open-GIS interface can be programmed, so that the Heat Atlas can be made available for project partners. A standard square grid with a uniform cell size between 100 × 100m and 1 × 1km could be used to summarize building properties, demographics, etc. within each cell, and to use the single cell as an operational unit for carrying out calculations of heat demand, savings potentials and contribution to the supply system.

Data sources and requirements

Heat atlases are data intensive. Various thematic data are contained, such as building points, network lines, and supply or planning areas. For each of these themes there is a geometrical representation (point, line or polygon) as well as associated attribute or descriptive data. The spatial database also comprises a geographical structure by means of hierarchy (administrative or supply boundaries) or by describing vicinity or neighbourhood. Two major sources of data were used to building a heat atlas. First, the national building and dwelling register BBR containing building areas, year of construction, use, construction materials, and number of floors, heat supply and up to 60 other individual data. The register is updated daily. In addition, an increasing proportion of Danish buildings have been subject to energy audits in recent years, which can be used to perfect a model of the current and future heat demand. Second, in the case of Aalborg available from the DH company’s website though documents describing where new expansions are planned. This is not always the case as it depends on how willing each DH company is to provide this type of information. Figure 3.4 illustrates the geographic detail level of the heat atlas, where each building is geocoded with coordinates of the actual building making the detail level as high as possible.

[8] http://www.esri.com/software/arcgis/arcgis-for-desktop/

Figure 3.4: Heat atlas example showing the construction year of buildings in Aalborg city centre

In Figure 3.4, each building is shown as a dot representing the building period in which it was constructed. It is on this detail level that all the heat atlas information is available, which gives the possibility to aggregate e.g. heat demands within specific areas and hence it is a good tool for strategic energy planning where this kind of detail is necessary. A great challenge however is the accuracy of the BBR, which is based on house owners' input. It can be observed, e.g. that the number of oil boilers is overestimated by a factor 2, since not all house owners have reported the replacement of such by a biomass boiler or the like. In addition, a higher quality level can be observed for urban areas compared to rural municipalities, which may reflect the effort made in public administration to achieve accurate registers. Another uncertainty is that the heat demand of a building still needs to be calculated using national averages of specific heat demand for types and age classes of buildings. These problems are about to be addressed though, as new legislation requires the registration of heating means and annual heat demand.

Recently a new BBR extract has been purchased, in which some of the issues seem to have been resolved. Since 2011 energy demand is registered from meter readings, however there are issues regarding privacy and correctness. Also, a coherent and updated system of reporting municipal heat plans is currently being implemented, which will allow for a better geographic delineation of present district heating and natural gas supply areas. Finally, access to a national district heating cost database and to a national energy producer database are on the way. The ultimate goal is a spatial database on the building or property level, which follows the entire energy supply chain from primary fuel input to end-use, and which allows for economic assessment of the energy saving potentials as well as the choice of heat supply for all buildings and properties in the country.

EnergyPLAN

The spatial data from the heat atlas is used as an input for an energy system analysis. For the energy system analysis carried out in this project, the software EnergyPLAN was used. The software is freely available from www.energyplan.eu and is developed by the Sustainable Energy Planning Research group at Aalborg University. The model has been broadly used in research around the world, where some recent projects includes studies of the European system [4], individual countries [5-7], the whole Danish energy system [8-10] and on a Danish municipality level [11-13] and many more which can be found on the website. The model is updated regularly but in this study version 8.3 was used to model the Aalborg case study. The EnergyPLAN model itself is a deterministic model, which is based on an hourly temporal resolution, making it capable of modelling future renewable energy scenarios with a lot of fluctuating energy production. The model includes all energy sectors: which in general can be divided into: heat, electricity, gas and transport systems. With a lot of renewable energy in the future systems, integration of these sectors becomes vital, this is what can be referred to as smart energy systems [14,15], and should not to be confused with smart grids which often only refer to electricity systems. By modelling the Aalborg case study in EnergyPLAN it is possible to estimate resource consumption, emissions as well as socio-economic costs of future alternative scenarios. Combining energy system analysis models with geographic models, like the heat atlas is essential, as the heat atlas provides the needed information for energy systems models to be able to estimate the future heat consumptions.

3.3 Findings of case study

The case study is divided into two parts. First the geographic boundaries are updated based on the new heat atlas as well as the expansion plans for DH, secondly the implementation of the energy vision scenario is presented and compared to the reference system.

Implementing the new heat atlas and DH expansion plans

The Aalborg case study is based on the current expansion plans for Aalborg district heating. The present situation is illustrated in the map in Figure 3.5. Where the red area is the DH area owned by Aalborg which has a major share of the heat demand, the green areas the smaller decentralised DH areas with smaller combined heat and power (CHP) units and the blue areas the area supplied only by boilers. The black areas are individual heating, where many of the largest areas are currently supplied by natural gas.

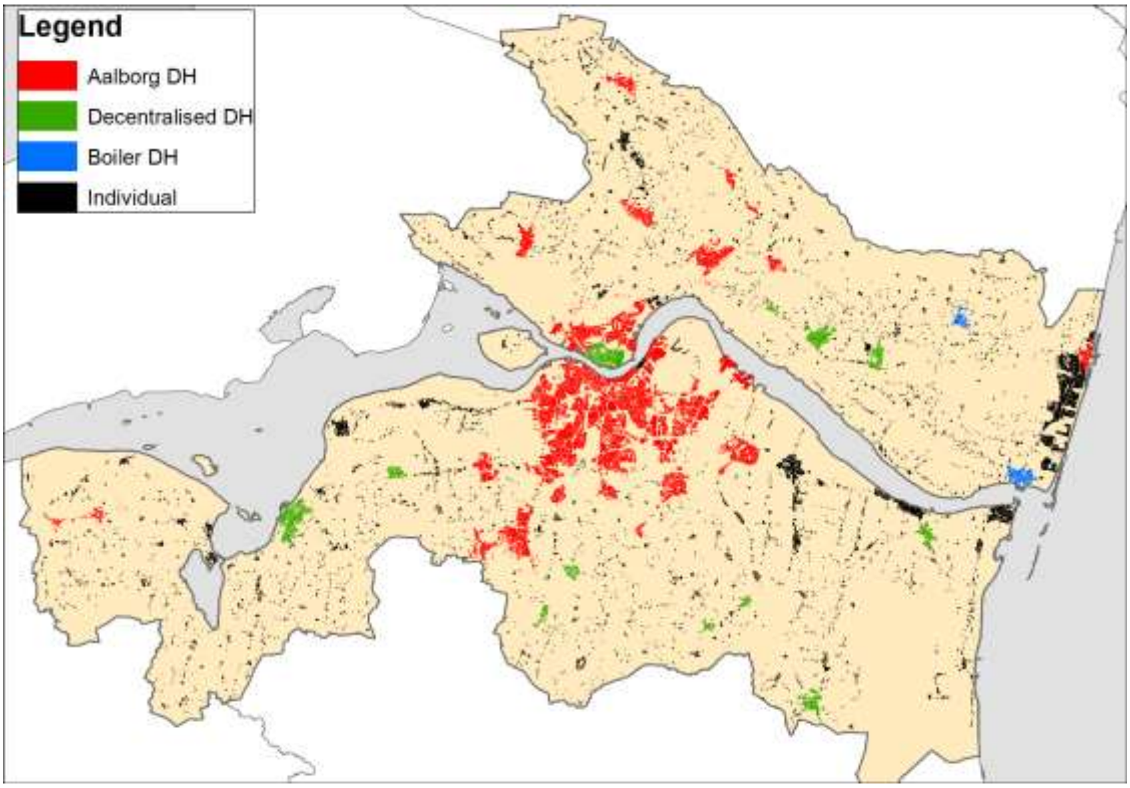

Figure 3.5: Current heat supply in Aalborg Municipality

In Figure the current plan for expanding the Aalborg DH area is shown. The expansions follow three corridors, north, southeast and west and are prioritised in the same order. Some of these areas have already decentralised DH and others have individual supply, but cover in total around 6,000 consumers. The plan is to expand to these areas if more than half of the consumers voluntarily agree to connect to the centralised district heating.

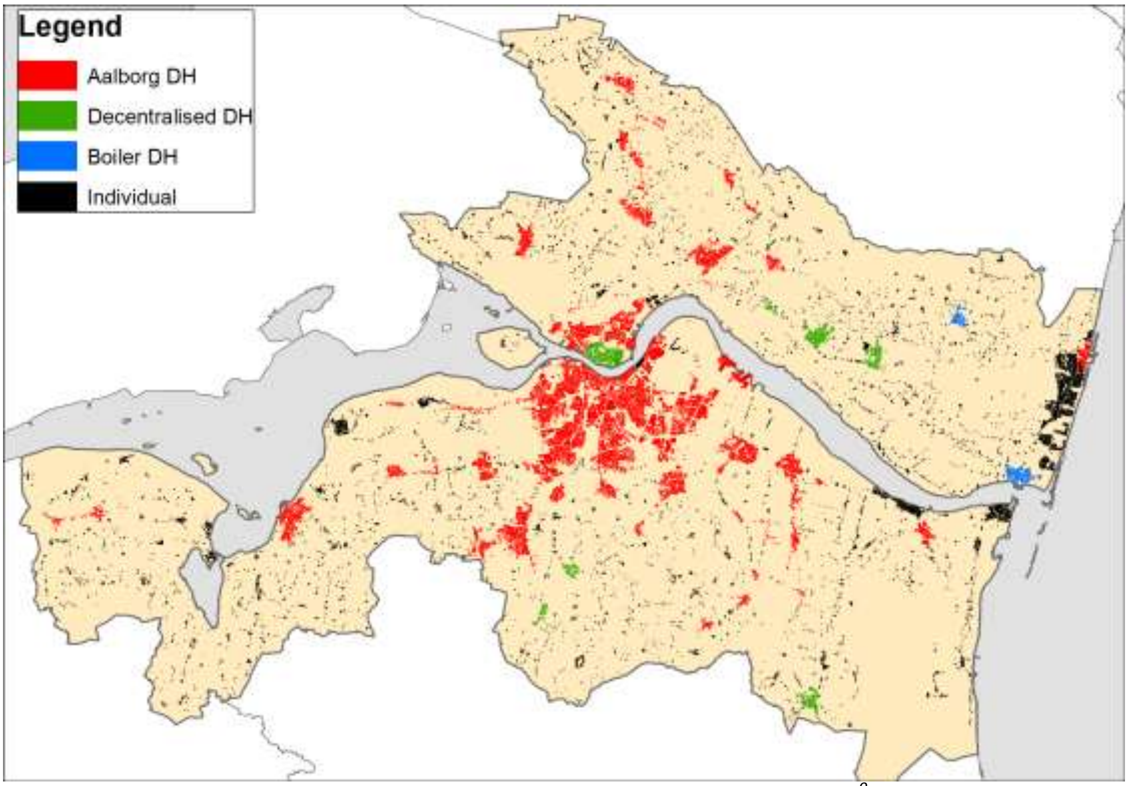

Figure 3.6: Planned heat supply in Aalborg Municipality[9]

Based on the geographic boundaries in Figure 3.6 the reference scenario is established. The idea behind the reference scenario is to show the energy system for Aalborg without implementing heat savings or the supply system from the energy vision. The reference is then in the analysis compared to a scenario including both heat savings and the supply system of the energy vision. In Table 3.1 the heat demand for three different energy systems is presented.

	Ref. 2050	Ref. 2050 new
Indv. Oil	80	120
Indv. Ngas	40	10
Indv. Biomass	190	50
Indv. Electric	5	46
Indv. HP	3	5
Aalborg DH	1,890	1,940
Decentralised DH	120	140
Boiler DH	40	30
Total	**2,368**	**2,341**

Table 3.1: Annual heat demand for new reference scenario in GWh/year

The first is reference system for 2050 used in the Aalborg Energy plan from 2010 [1], this represents what was used previously before implementing the new heat atlas. It is clear that the majority of the heat demand in 2050 was supplied by DH and the rest is supplied by individual biomass, natural gas or oil boilers. The "Ref. 2050 new" system shows how implementing the heat atlas gives an updated version of the heat demand. The overall heat demand is approximately the same when the heat atlas is used. The DH share is approximately on the same level, however the individual heating is different with a larger share of oil and electric heating, as well smaller share of biomass. This is mainly due to the data quality in the heat atlas that, as mentioned earlier, slightly overestimates oil boilers and electric heating in the more rural areas.

[9] http://www.aalborgforsyning.dk/varme/ny-kunde/udvidelser.aspx

Implementing the energy vision scenario

In the case study, the "Ref. 2050 new." is used as the basis and compared to the Energy Vision scenario, which implements the changes described in the last part of the introduction. The two are compared in relation to the following four parameters:

- Energy both in terms of final, secondary and primary consumption
- Environmental benefits (CO2 emissions)
- Socio-economy
- Urban resilience and sustainability

Energy

Sankey diagrams are used to visualize the energy flows from the primary energy resource to the end-use. In Figure 3.7 an output from EnergyPLAN which shows the 2050 reference system for Aalborg is illustrated.

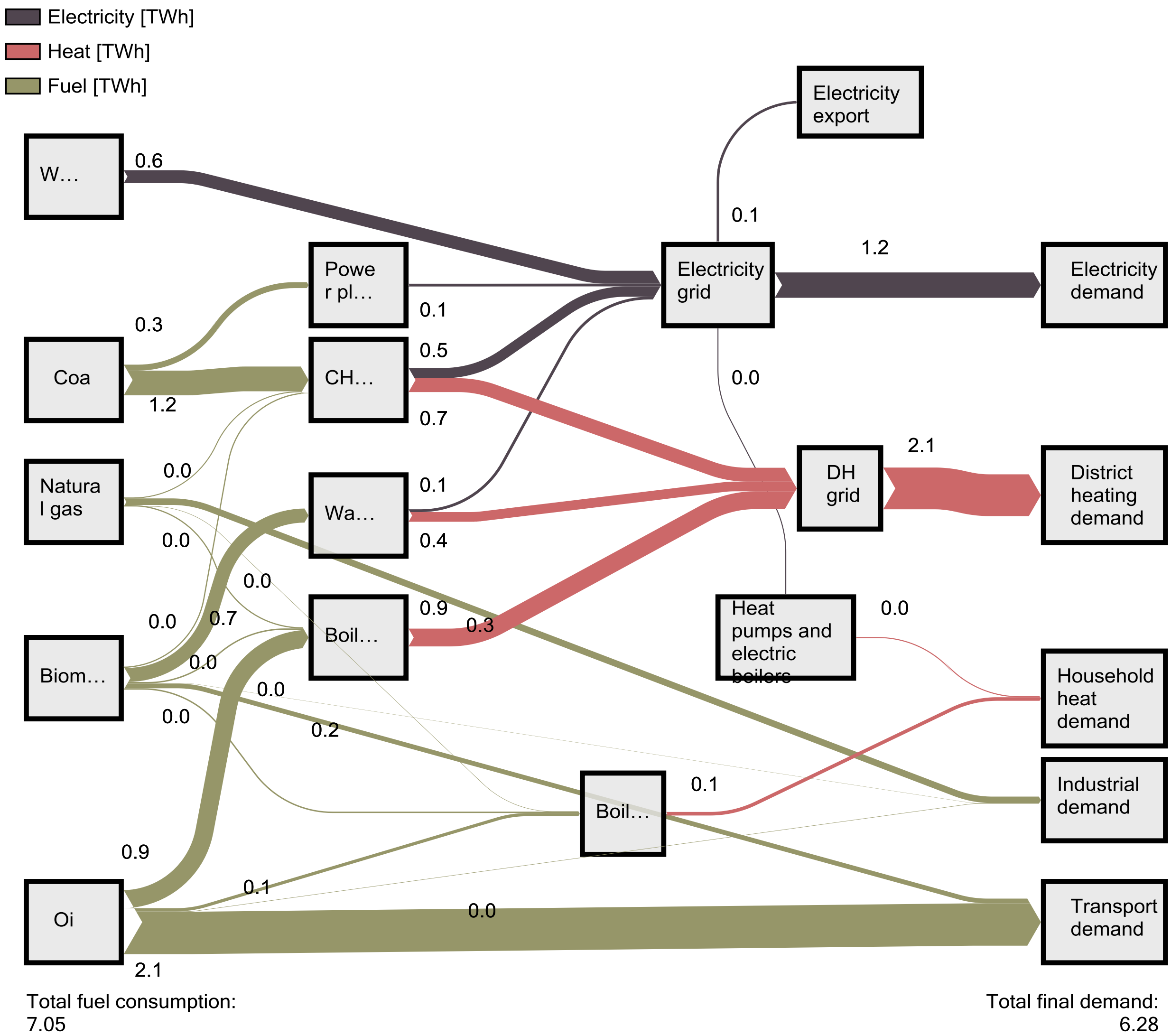

Figure 3.7: Sankey diagram showing the annual energy demands in the 2050 reference system

Starting from the right side of the figure, we see the demands in the municipality in the form of electricity, district heating, individual heating, industrial as well as transport demand. These are supplied by the energy sources in the left side of the figure. In the reference system the electricity is supplied by wind power, CHPs and power plant on coal and a small share from the waste incineration plant. The district heating is supplied by the coal CHPs, waste incineration and oil boilers. The individual heating is provided by oil and biomass boilers as well as electric heating.

The industrial demand is provided by natural gas and the transport demand is based on oil and a small share of biomass. In total the reference system has a final demand of 6.28 TWh and a fuel consumption of 7.05 TWh/year mainly based on fossil fuels.

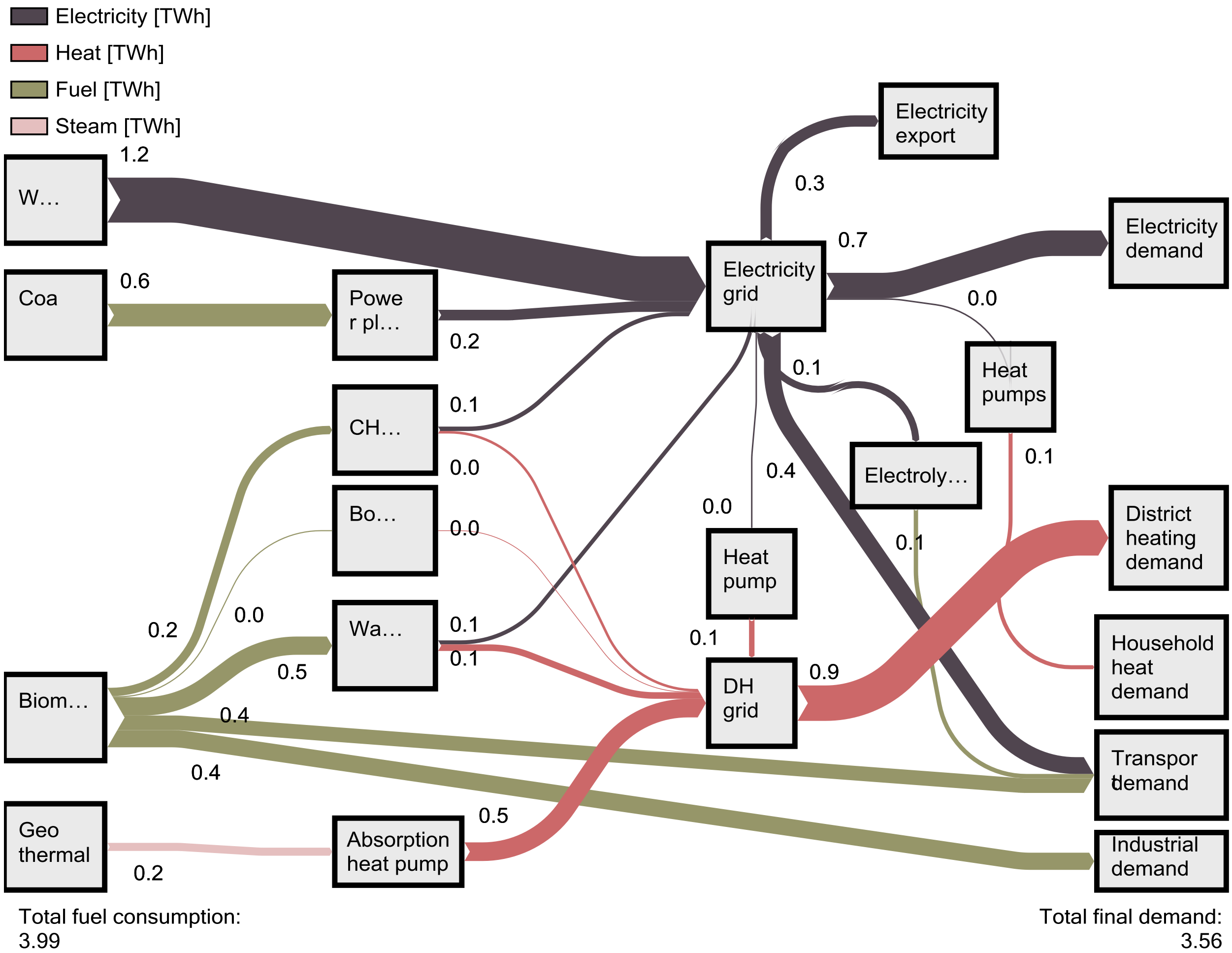

Figure 3.8: Sankey diagram showing the annual energy demands in the energy vision

The energy vision system, which is based on renewable energy, is illustrated in Figure 3.8. The energy vision includes a reduction in the final demand to 3.56 TWh/year, or around 44% of the reference system. The reasons behind the reductions are explained in section 0, but it has mainly been done reduce consumption of biomass. The energy transformation system is also changed, where a much larger proportion of wind is implemented. To utilize the wind in the system, a large part of the transport is converted to electricity and hydrogen (though electrolysers). All of the heat demand outside district heating is converted to heat pumps. In the system, the electricity grid is used as a buffer so that wind power is exported to replace the import from coal fired power plants. The rest of the transport, as well as the industrial demand, is provided by biomass. The heat for the district heating system is provided mainly by geothermal heat as well as waste incineration, and heat pumps utilizing electricity based on wind production.

Environment

The environmental benefits of the system can be measured in CO_2 emissions of the systems. The CO_2 emissions in reference gross 1.57 Mt/year and net 1.39 Mt/ year, in the energy visions these are zero when waste incineration and biomass is counted as CO_2 neutral. Using these resources emits CO_2 as they are used in combustion processes so the reason why these are often counted as neutral, compared to other fuels, is that biomass can be used sustainably and municipal waste is alternatively landfilled and will hereby emit the same emissions anyway. On the other hand, using these resources do mean that it is important to focus on recycling municipal waste as well as reducing the use of biomass, as overusing these resources will contribute negatively to reducing emissions.

Socio-economy

Another important aspect is the socio-economic costs of each system (Figure 3.9).

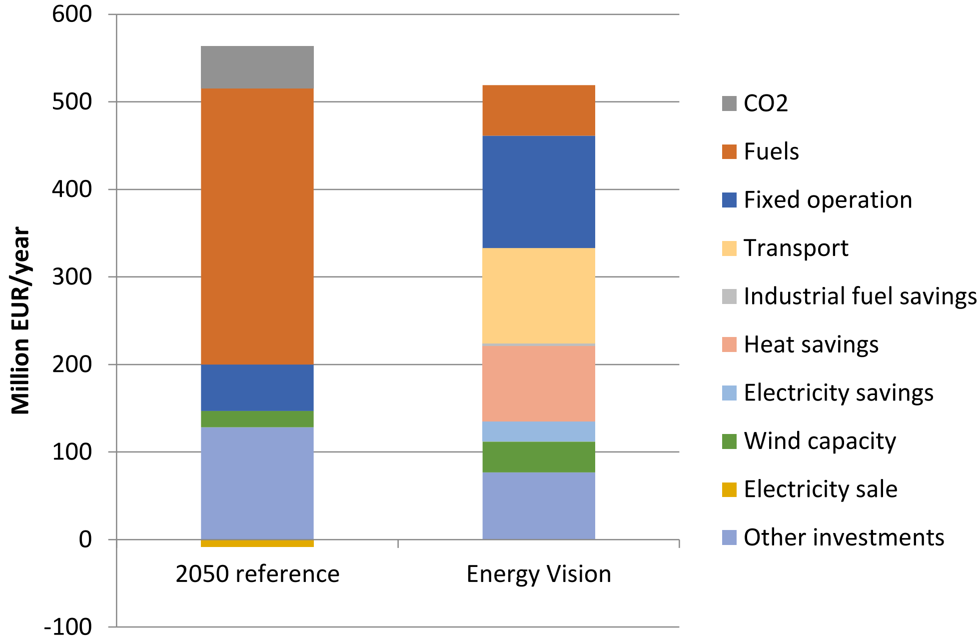

Figure 3.9: Socio-economic costs in the two scenarios

The economic savings in CO_2-emissions are prominent but also illustrate that the two systems have approximately the same annual cost if CO_2 emissions savings were not included in the analysis. What is also clear is that the expenditure for fuels is much lower in the energy vision than in the reference system, which is a significant change as this makes the energy vision more resilient to large changes in fuel prices. The 'Other investments' category is also lower, which is due to savings in boiler capacity. The energy vision includes some investments that are not present in the reference scenario, resulting in higher costs. These are mainly in transport, heat and electricity savings as well as the additional wind power capacity. The fixed operation cost is also considerably larger than in the reference system. In general, what is important to notice in relation to the socio-economic costs is that these are moved from fuel costs towards local investments, which is where the resilience of the energy system becomes relevant.

Urban resilience and sustainability

The Aalborg case study has to be seen in the broader transition towards renewable energy systems to explain its role in relation to urban resilience and sustainability. According to Hvelplund [16] the renewable energy development in Denmark can be divided into two phases. In the first phase the new renewable energy technologies is introduced, in the case of Denmark this is mainly wind power. The period 1976-2002 developed wind power to the mature technology we see today. One central aspect of this development, was that it was mainly initiated by new organisations in the form of cooperatives where neighbours to wind turbines both invested and owned them, strengthening the local economies and giving local ownership for the wind mills. In later years wind power has become more large scale both on land and in the form of offshore parks, leaving this more community oriented platform. In the second phase, which Denmark is currently in the beginning of, fluctuating renewable energy is starting to have such an high impact on the energy system that new infrastructure needs to be introduced to integrate the renewable energy sources. This can be done by implementing technologies like CHPs, heat pumps with storages and electric vehicles, all of which is part of the Aalborg case study. The important learning from the Danish wind experience is however, that local communities can benefit greatly from investing in local renewable energy sources instead of being dependent on import of fuels from outside. In relation to resilience research, this is an example of what according to Leichenko [17], is within the category: resilience of urban economies. That points out that an important aspect of urban resilience is diversity, flexibility and capacity for learning and innovation, which is all something that the Aalborg case study possesses.

3.4 Implementing measures

In the energy vision it is shown that from a socio-economic perspective heat savings gives long-term savings compared to the reference system [1]. However, this does not mean that heat savings are feasible from a private or business economic perspective. In Aalborg this is mainly due to the tariff structure for district heating in the municipality. In the present tariff structure there are two important aspects: the consumer price and the share of fixed costs for the consumer. The consumer price is based on an average production cost instead of the marginal production cost. This means that the municipality sets the consumer price lower than what it costs to produce heat on the most expensive production unit. This means that the saving that the municipality would gain by reducing heat production on the most expensive producer is not reflected in the consumer price. Furthermore, depending on the buildings type, around half of the annual heating costs is related to the heat consumption, while the other half is fixed though subscription and connection fees. This gives a structure where the investment in heat savings only affects around half of the heating bill, reducing the incentive for the building owner to invest in heat savings. A solution to solve these two issues is to change the tariff structure so that the whole consumer price is related to the heat consumption and base the heat cost on the marginal production cost instead of average cost. This would increase the incentive for investing in heat savings a lot. As district heating in Denmark is not allowed to profit, the earnings from the slightly increased heat cost, from average to marginal, should be redirected back to the heat consumers though cheap loans for energy renovation of the buildings. On a longer term, all heat consumers will benefit from this change, as the lower heat consumption reduces the need for the more expensive production units. This is only one concrete example of a policy change, which could help implementing heat savings, other suggestions for implementation of the energy vision scenario would be: building regulation that ensures energy savings, cheap consultancy in relation to energy renovation, a tariff structure that reflects future costs and opening for access of renewable energy producers.

3.5 Recommendations resulting from case study

The Aalborg case study shows an example of how municipalities can benefit from different tools when implementing strategic energy planning. The strategic energy planning is necessary to enable municipalities to help with the transition towards smart energy systems based on renewable energy. One main difference between strategic energy planning and how energy planning has been carried out historically, is that it has moved towards a planning approach where all sectors were planned individually (heat plans, wind plans etc.) towards holistic approach where the different sectors are all part of the strategic energy plan.

Consider different sector together in a holistic energy plan. This ensures that solutions that intersect sectors are included. A good example of this is placing more wind turbines and changing the transport to electricity, giving a solution that would not occur if these sectors were examined separately. The present Aalborg case study mainly focuses on the heat part of the energy vision. It is clear that the heat sector should also be integrated with the other sectors to be able to integrate more renewable energy into the system.

Develop methods that can help in the mapping energy demands as well as local energy resources. A heat atlas is such a method, where the heat demand related to buildings is estimated though a GIS model to give a detailed picture of where heat demands are located. The geographic location of heat demands is very important because it is a deciding factor in relation to choosing the right heat supply. In dense populated areas the heat demands will be dense as well giving benefits for district heating solutions, where less pipes and lower network heat losses is achievable compared to the more rural areas. Furthermore, the geographic location of the heat demand is also important, because it is required to determine the distance to existing heating infrastructure. This is mainly because buildings close to existing networks also have lower connection costs. Another property of the heat atlas is to assess possible heat demand savings. This is an aspect that is important as well, as the economic feasibility of heat savings is related to the heat supply of the building.

Improve the heat atlases by updating the building register information. The Danish building register is the basis of the heat atlas presented in this case study. The BBR register unfortunately often lacks correct information, which is mainly due to the ability of municipalities to ensure that the information in BBR is correct. This is related to the overall resource allocation in municipalities, so a way to improve the data quality in BBR would be to allocate more resources to ensure that the BBR information is correct. Another Improvement that could be made is the heat consumption models in the heat atlas, which as described are based on average Danish building categories. This could be improved by making more concrete heat demand models based on more detailed information about each building or by collecting data from metering of the buildings. Also the models for estimating the heat demand of large consumers should be looked into, as this is much more complex than in buildings.

4. Sustainable Mobility – Ljubljana

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KEY MESSAGE

Sustainable urban planning should take into account all founded public initiatives and suggestions for appropriate realisation of plans. To assure the possibility for all stakeholders to participate in dialogue, a WebGIS-based portal for micro-communication with stakeholders and residents for Ljubljana urban region (LUR) was designed and developed. The portal provides the basis for crowdsourcing better inputs, evaluation of measures (before/after), and on-line validation of models. It can be applied not only in transport sector, but also e.g. in environment, energy or waste.

Today 70 % of European population live in urban areas whose needs for mobility increases every day. But today's mobility in European urban areas does not meet the needs of their citizens. The current state refers to the increasing use of the private vehicles which results in a number of harmful effects. The rapid increase in the number of the private vehicles in the past twenty years indicates a rapid urban development of European cities, but on the other hand leads to long-term unsustainable traffic in cities. Aside from the constant traffic congestion, which is estimated to be around 80 billion euros, urban areas are the sources of a large share (about 23 %) of all CO_2 emissions from the traffic[10].

There are many reasons why people migrate to the countryside, while on the other hand jobs mostly remain in the cities. In this way, people are using private vehicles rather than public transport for journeys. This means more traffic, more pollution, including noise, more costs (for noise protection) and less benefits due to lower value of time on the congested road compared to the value of time e.g. at working place. Especially congested roads and polluted air are serious problems in many European towns and cities. We could say that such a transport could be one of the reasons for the climate change and the main question is: could we calm these trends and mitigate the environmental impact of the traffic? Many cities are aware of the problem, and with the help of many guidelines[11,12] they are planning and implementing sustainable urban mobility plans well. Planning is infinity process, which is well described[13] and well supported by EU policy[14,15]. Not only the planning process is the part of urban mobility, but also having the plan with effective measures and the policy to facilitate the implementation.

One of the measures is definitely sustainable oriented urban planning, where (nearly) all founded public initiatives and suggestions are taken into the consideration. Stakeholders could have different point of view, needs and requirements. To establish efficient and sustainable transport system all different opinions should be discussed in a "proposal dialogue" and the consensus should be achieved. To assure the possibility for all stakeholders to participate in dialogue, the web-portal communication was proposed as an alternative to existing practice of public participation. Within TURAS project interactive GIS platform as a tool for public participation for sustainable transport in Ljubljana urban region (LUR) was established to test and to evaluate proposed approach and process. New webGIS portal as a tool for RDA LUR for regional development and sustainable mobility in the capital city region of Slovenia represents alternative link between (sub)urbanisation, (sustainable) mobility and public participation to improve (sustainable) mobility in LUR.

Sustainable mobility has also clear links with processes of suburbanisation and urban sprawl as they affect transport demand. Correspondingly, limiting urban sprawl can be labelled as a measure to reduce demand in private traffic; a topic that is explored in WP5 of the TURAS project and which is reported on in other reports.

[10] EU Commission: Communication from the commission to the European Parliament, the Council, the European economic and Social Committee and the Committee of the Regions, Together towards competitive and resource-efficient urban mobility, p:1-2

[11] Guidelines: Developing and Implementing a Sustainable Urban Mobility Plan, 2011, http://www.mobilityplans.eu/

[12] Guidelines for ITS deployment in urban areas, January 2013

[13] Guidelines on the development and implementation of a Sustainable Urban Mobility Plan, January 2014

[14] GREEN PAPER: Towards a new culture for urban mobility, 2007 WHITE PAPER: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, 2011

[15] WHITE PAPER: Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, 2011

4.1 Introduction to issue and area

Challenges of sustainable mobility

Cities initiate further development, they are centres of connectivity, innovations and creativity. In addition, cities are centre of employment and services to surrounding areas and are an important factor in the overall and territorial development. Mobility in the urban areas is essential for the survival of urban agglomerations. Urban mobility is still looking for a solution in the use of private transport mode (vehicles). Due to the rapid expansion of cities and development of urbanization transport demand increased. There are series of the problems, e.g. unappropriated land use and transport planning that impairs sustainability and mobility in the urban areas. For this reason it is important to develop manner to achieve urban mobility and help improving the sustainability of the transport system at the same time. Sustainable urbanisation (through **spatial development**) is one of the main challenges of sustainable mobility. Spatial development also shows a potential to manage travel behaviour. Travel behaviour can be influenced on two levels. The first level is the regional development, which regulate the use of area on a superordinated standard. Residual areas for living, commercial areas (industry) and traffic zones have to be defined. One general objective consists in the alignment of the road system and of the public transport lines along axes to control and to manage traffic in an efficient and intelligent way. The second level of spatial development is the urban planning, which regulate the traffic in urban areas.

Towards sustainability we could use several approaches of traffic management. First, it is usually easier, we could introduce ITS, intelligent transport systems and services (Pattinson et. al., 1998). Introduction of ITS improve capacity and level of service of existing transport infrastructure network, traffic safety and environmental impact by implementing tools of communication, automatisation and data exchange in transport system. The second approach, which is not easy and can last longer to achieve the goal, is a change in travel behaviour and other habits, supported by different policy directions and strategies. Another distinction is between the concept of “Managing transport fleet” and the concept of “Managing transport infrastructure”. The right way is to combine both approaches in a way that the transport system is optimised. This means to manage the fleet and infrastructure in such extend that there is no need for increasing the number of motor vehicles and kilometres/acres of infrastructures, especially in the urban areas. From the viewpoint of fleet, the challenge is multimodal integrated public transport with alternatives, such as car-pooling, car-sharing, mass transit on demand, and multimodal integrated urban logistics. From the viewpoint of the infrastructure, cities are challenged to introduce traffic management system (TMS) to support the new era of "smart mobility'' where infrastructure, transport means, travellers and goods will be increasingly interconnected to achieve optimised door-to-door mobility, higher safety, less environmental impact and lower operation costs. In order to achieve efficiency at system-level, targeted efforts are necessary to develop and validate new solutions that can be rapidly deployed, notably on corridors and in urban areas[16].

A second challenge, besides spatial planning, is **transport policy**, which represents the balance between transport demand and supply. It prevents the increase of passenger car volume with the promotion of public transport systems. This promotion is strongly related to mobility behaviour and needs public communication to citizens. One of the objectives of transport policy is to promote an environmentally and socially sustainable traffic with internalisation of the transport system external costs. The users should be aware to bear the full costs of their respective mobility. That means e.g. the road transport user has not only to bear the direct costs like fuel and maintenance, but also external costs like environmental damages or the economic costs of caused accidents. There is another challenge from the viewpoint of transport policy: environmental targets. The impact of transport on the environment can be managed by setting environmental targets. Environmental targets can refer to specific emission or pollution levels for harmful substances of transport means, e.g. cars, buses or trucks emission levels e.g. in residential areas and noise levels by the implementation of certain technical standards. In residential areas or city centres strain levels for noise and pollution can mean maximum noise levels in the night or temporary driving bans.

The third challenge is **mobility behaviour**. Traditional traffic policy instruments alone are not the most effective measure to change mobility behaviour into an environmentally and socially sustainable traffic development. The traditional instruments should be accompanied by information, education and motivation measures, including public participation. These measures intend to achieve the objective to build up a public awareness of traffic

[16] Strategic Area Smart Mobility, TU Eindhoven, http://www.tue.nl/en/research/strategic-area-smart-mobility/smart-mobility/

alternatives (“conscious mobility“). "Mobility consciousness” encompasses not only the choice – for a particular trip – of an environmentally friendly, low-emission mean of transport, but it also covers a conscious opting for minimising of traffic activities, choosing destinations closer to home, making better use of existing automobile capacity, limiting private ownership of motor vehicles, and a variety of other mobility-oriented decisions.

Accordingly, there is a need for communication among policy makers, interested public and spatial designers (planners) (Figure 4.1). Traditionally the dialogue is set to the open public exhibition, conference or workshop, and it is usually used at the final stage of planning or design. New technologies, for example Web 2.0[17], have not yet been introduced into “real practice”. The use of new technologies is already known, but has not been implemented for the use in the process of the public participation. The basic hypothesis, that this technology can improve the basic inputs in the spatial design process, has been proven (Bizjak, 2014). The same hypothesis could be related to the transport planning process and traffic management.

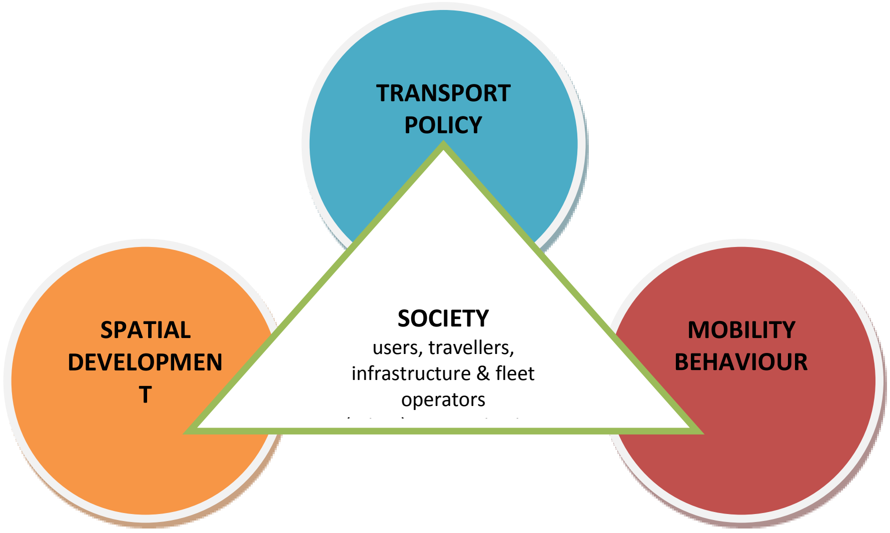

Figure 4.1: Challenges of sustainable mobility

The challenges of sustainable mobility in Ljubljana urban region

The Ljubljana Urban Region (LUR) is the central and the most densely populated region in Slovenia; it has the largest number of inhabitants, 25 % of all Slovenia population, and it is the second largest in terms of territory. About 535,000 people live in this region; with 272,000 people employed and 90,000 of pupils, upper secondary and tertiary students (SURS, 2013); the region is also the largest commuting centre in Slovenia.

The essential advantages of the region are its central position, good transport connections in all directions and the fact that the city of Ljubljana is strategically located at the intersection of two TEN-T corridors (Trans European Transport network): Baltic-Adriatic and Mediterranean corridor. Ljubljana‘s International Airport also contributes to the international migration flows. The City Municipality of Ljubljana is the regional gravitation centre within LUR, and the central place where all main regional and inter-regional flows converge. It attracts daily commuters to work, schools and shopping from the neighbouring municipalities and regions. On the other hand traffic flows within the region are unevenly distributed. Because of the dispersed spatial development and suburbanisation there are areas at the LUR periphery that are not accessible by public transport or the rail, and private cars are the only option there.

Considering these facts, flows in the region’s gravitation centre is concentrated and it results in traffic jams during peak periods. These traffic conditions - created mainly by daily commuters in cars - result in the delays in travel, environment overburdened by emissions from traffic, noise and poor traffic safety. These negative effects of the traffic reduce the quality of life of residents and commuters, as well as visitors.

[17] Web 2.0 is the term given to describe a second generation of the World Wide Web that is focused on the ability for people to collaborate and share information online, source http://www.webopedia.com/:

Despite a substantive increase in the mobility in Slovenia from 1990 to 2008, the annual number of passengers using public transport declined from 168 million to 90 million. The census data shows for the Municipality of Ljubljana that in 2002 nearly 63% of residents travelled to work as a car drivers, whereas only 21% used public transport for journeys to work. Even more drastic was the decline in the number of passengers in the inter-urban transport, which better indicates the overall state in LUR – it fell from 294 million passengers in 1990 to barely 68 million in 2003! Such a situation derives from a vicious circle whereby the increase in traffic generates congestion and exacerbates the need for new investments in road infrastructure. Better roads enable better mobility, thus generating more private car traffic, which eventually again produces deadlocks, and the circle is closed.

Constant and rapid growth in private car traffic is a result of a higher degree of motorisation driven by values linked to personal freedom and material welfare, as well as cheap fossil fuel. These fundamental driving forces were involved in investments to improve the road network, in the accelerated suburbanisation of the countryside in the past decade, as well as dispersed spatial development, which contributed a loop-hole for this type of development. In the long term, such organisation of transport and spatial development incurs immense social costs and reduces the quality of life of all residents in the urban region.

Present status of transport system and transport planning in LUR

Slovenia has established only two levels governance structure; the national government covering the whole state and the municipal governments at the local level, where some of 211 municipalities are too small to tackle the challenges exceeding their borders. The issues which go beyond the municipal level and are valid for the entire functional (urban) region such as public transport, waste management, natural environment protection, etc. can be most effectively dealt on a regional level, which is missing in the current state organization. Only i.e. statistic and / or development NUTS-3 regions have been developed, which have no regional governmental powers.

Slovenia has also not yet established a practice of strategic planning of urban traffic, neither at the national nor at the local level. For years traffic engineers and transport planners have dealt the traffic problems in terms of infrastructure facilities and services and the problem of urban transport not being addressed in a holistic, integrated and strategic way.

The development of the transport system in LUR (Slovenia) has been primarily oriented towards improving the road infrastructure and, consequently, improvements in the mobility of individual vehicle users, while the public passenger transport (PPT) stagnated; which applies to road public transport and to rail public transport even more so. This development resulted in the low mobility of non-motorised users, traffic jams, the environment burdened by emissions and noise, and poor traffic safety.

In the field of public transport system only partial plans for individual municipalities of the region have been made. In 2010 the Regional Development Agency of the Ljubljana Urban Region (RDA LUR) prepared a study called *Expert Basis for Managing Public Transport in the Region*, which became the unofficial "Public Transport Development Strategy for LUR". 'Unofficial' because there is no elected body at the regional level to adopt it, but it was 'accepted' as a wide consensus among the relevant stakeholders was achieved. Experts, local communities, state officials, public transport companies, neighbouring regions and general public all participated and agreed on the main projects for improving the public transport in the region.

The strategy, as the key project for the Ljubljana Urban Region, propose a positive response to the growing problems in the traffic system which can be achieved only by reducing the use of private vehicles. In order to improve mobility, a share of passengers must be shifted from private vehicles to the non-motorised modes of travel and to public transport. The shift to public transport can be accomplished by traffic restrictions followed by measures favouring PPT development, such as: the improvement of the regional railway system representing the backbone of the regional public transport, the construction of new P+R intermodal nodes to improve the accessibility of public transport, the introduction of high speed routes for busses on all major city axes and improvement of public transport management measures and policies. Among the management measures and policies unified both ticketing and timetables, congestion charges, integrated public transport management, parking policies, public transport financing and promotion are the most important measures.

In order to achieve the overall objectives from *the Public Transport Development Strategy* the cooperation on different levels is needed: national and local authorities, planners and the general public and various public and private actors in the transport sector. In the strategy a unitary body, Regional Coordinating Body, was suggested and agreed upon, to deal with the development and steering of public transport in the region.

4.2 Data for strategic sustainable mobility planning

Spatial planning, urban design, transport planning and traffic management are in relation. Urban design practices can have a huge impact on the level of future traffic congestion. For such a case, cities are preparing traffic studies to evaluate the consequences of the land-use planning policy alternatives. And similar, to evaluate the consequences of alternative spatial development strategies on transport system the infrastructure capacity should be forecasted, the role of public transport and the scope of non-motorised transport means defined and traffic safety assured. We could call this the evaluation of alternative scenarios of future development or "do something" scenarios. By preparing different scenarios many data are needed. We believe in the crowdsourcing as a model for better problem identification and solving (Brabham, 2009).

Data and contents for transport planning

A comprehensive and harmonised socio-economic and transport database is a prerequisite for transport planning. The data can be divided into two groups. The first group represents "Public records" and the second "Needs and suggestions for improvements". The first is usually obtained from the data warehouse managers and others with the researches and interviewing local communities, interested public and proposals made by experts in various fields, including demography, economics, land use and transport.

Public records usually available on request at different institutions are following (see Table 4.1 for Slovenian example):

- Surveying and cartographic data on spatial infrastructure:
    - Spatial units and addresses of real estates, zoning (borders of spatial statistical units),
    - Existing transport infrastructure data: roads, railways, public transport routes, etc.,
    - Generalized cartographic data: topographic maps, orthophotos, etc.
- Data related to the public activities:
    - Socio-demographic and economic (model) data: present and forecasted projection,
    - Land use and transportation policy data,
    - Data about travel habits, motorisation,
    - Data about population needs, expectations and suggestions especially for pedestrians and cyclists on the regional level is needed.

Table 4.1: Data availability in Slovenia for urban and transport planning

Data	Institution	Availability	Remarks
Socio-demographic and economic (model) data Central Population Register (CPR) Slovenian Business Register	Statistical Office of Slovenia The Institute of Macroeconomic Analysis and Development Ministry of the Interior Agency of the Republic of Slovenia for Public Legal Records and Related Services	On demand (off-line)	
Surveying and mapping - cartographic basis	The Surveying and Mapping Authority of the Republic of Slovenia	On demand (off-line)	
Land use and transportation policy data	Municipalities (public participation)	On demand (off-line)	No multi municipalities or regional transport policy
Data about travel habits	Municipalities	On demand (off-line)	Missing for a lot of municipalities, missing for the region
Data about population needs Traffic data, public transport schedules	Municipalities (public participation) Transport infrastructure managers Ministry of Infrastructure and Spatial Planning of the Republic of Slovenia	On demand (off-line)	

In the field of "public registers" databases a great deal was done in the past. Also public consciousness for participation has increased. Due to the modern lifestyle and information availability public participation could seriously affect the management of infrastructure and spatial development. In this case, the data should be set and used on-line to provide answers to public requests. It would be necessary to link or replicate this data into a common data warehouse on the regional or even at the national level. In such a way, it would be necessary to ensure the so-called "Service data management for urban and transport planning".

The data from the various institutions should be updated and harmonised regularly, e.g. every year. The harmonising and processing procedure of the data should be standardised, i.e. there will be a valid and consistent database available as a common and accepted basis for further steps of urban design, transport planning and traffic management.

4.3 Tools and analyses for sustainable mobility planning

A Sustainable Urban Mobility Plan (SUMP) is a way of tackling transport related problems in urban areas more efficiently. All steps and activities, including planning cycle, good practice examples, tools and references to support users in the development and implementation of SUMP are described in Guidelines on the development and implementation of a *Sustainable Urban Mobility Plan* (2014). Each phase in the process has availability to use different tools.

Transport arises as a consequence of the spatial division between economic and social activities. Transportation models are usually used as tools for analysing the results of (future) land-use and spatial planning, urban transport planning, public transport service planning, feasibility studies, designs and traffic management plans (Figure 4.2).

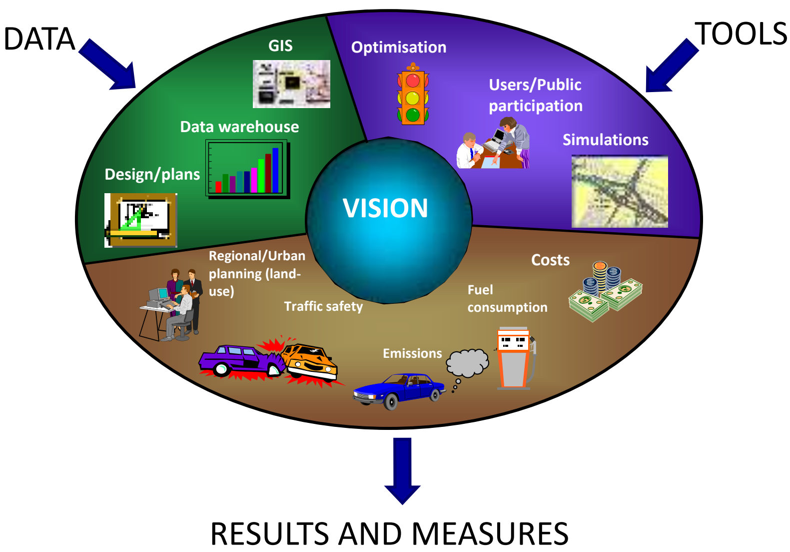

Figure 4.2: Modelling, information management and decision-making in the process (urban) mobility planning

Travel forecast models are used to project future traffic and are the basis for the determination whether new road or railway capacity is needed and whether changes transit service, in land use policies and patterns should be carried out. Travel demand modeling involves a series of mathematical models that attempt to simulate human behavior while traveling. The models are done in a sequence of steps that answer a series of questions about traveler decisions. Attempts are made to simulate all choices that travelers make in response to a given mode of transport, transit and policies. Many assumptions need to be made about how people make decisions, the factors they consider and how they react in a particular transportation alternative. The travel simulation process follows trips as they begin at a trip generation zone, move through a network of links and nodes and end at a trip attracting zone. The simulation process is known as the four step process for the four basic models used. These are: trip generation, trip distribution, modal split and traffic assignments. All models are based on data about travel patterns and behavior (mobility behavior). If this data is out-of-date, incomplete or inaccurate, the results will be poor no matter how good the models are. One of the most effective way to improve model accuracy and it is important to have a good basis of recent data to use then for the model calibration. In this validating process everyone (stakeholders, including travelers and other users) should have the opportunity to help shape the future of how people and freight will move across the city, region, state and the EU.

In the near future all the models are supposed to be based on a real-time data. Huge databases and supercomputing hardware with simplified models are needed. Everyone should be entitled to take the part of the process of land use/transport planning and may submit comments at any point of them and the authorities should be obliged to reply to all comments. There are good examples of finding effective communication channels such as blogs, mailing lists or web portal used by some municipalities of Ljubljana's urban region (LUR), but they are not integrated in a common way and usually they do not integrate different projects and themes in public debate.

Case study: Interactive GIS web portal platform as a tool for public participation

Quite many measures are known and indicated to improve public transport in LUR[18]. Mainly this was done for the City of Ljubljana. But, are the measures presented and opened to comment to the interested public all over the region of LUR for all transport modes? Are there any other ideas (especially low costs) to improve measures of introduced Ljubljana's SUMP independently of road and railway transport sector?

Encouraging and enabling citizens to join dialogue via a range of tools is also the challenge of mobility planning process. The spatial, mobility and traffic management plan's designers, decision makers or authorities usually inform the public about their results and proposals. They allow the public to participate, but mostly only during the public presentation after the preparing the draft documents. On the other hand different public initiative groups require that they are active part of the overall planning process. There are many methods (Bizjak, 2014) for public participation in the phase of planning process. Usually different activities and workshops are introduced for different stakeholders in the process: active laid-planning, mapping, e-mapping, modelling and simulation, photo analysis, risk assessment, and compliance questionnaires, interactive whiteboard or digital panel, gaming and ranging by priorities.

In this case study we explore micro-communication with stakeholders for more dialogues via **LUR Public Transport web Portal (LURPP)**. This means, that a user interface is introduced for e-participation, which enables people to be active in improving public transport. Within this work four main activities were realised:

- Data management;
- Assessment and definition of processes / workflows;
- Web application model definition and
- Web application development (including GIS application).

In the field of Data management all activities are directed on gathering all available spatial data to review and select the data, appropriate for GIS part of web application. Definition of processes was carried out via standard methods, first by defining participants and all information/data and its flow in processes, and later by defining process and workflow steps. Web application database model definition has two subfields; the first one to assure workflow support, and the second one to assure geolocation / GIS support for the main processes for initiative management.

To assure workflow support each initiative recordset has so-called administrative fields:

- *ID* –unique identification of initiative;
- *Date* - date and time of inserting initiative;
- *User* - user contact data as an option for active participation, including name, address, phone number and e-mail address user can also be Anonymous;

Each initiative could be geo-located (Location based initiative) by

- interactive GIS mapping input: point or line or rectangle or polygon topography or
- using standard spatial registers such as address ("municipality / street / house number"), or

without specified location (Description based initiative). In this case the description or picture is needed.

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[18] **Civitas Elan** web pages, http://www.civitas.eu/content/elan

To support the main processes for initiative management we defined technical fields of the “initiative” database:

- *Subject* – of initiative /required field/;
- *Location_XY* – required for geo-location base; vector field (geo-coordinates) or graphic elements;
- *File* - document, picture attachment /optional field/;
- *Infrastructure* – type of infrastructure; code list: road, railway, parking area, pedestrian areas, other;
- *Traffic* – transport mode; code list: pedestrians, cyclists, personal cars, urban/interurban/international bus transport, railway passenger transport, freight transport, parking management, other;
- *Type* – type of problem; code list: damaged infrastructure (need to repair), missing infrastructure (need for upgrade), redundant (to remove), to clean up, incorrect, dangerous, other;
- *Description of initiative* - comment text, initiative in words /required/.

The most difficult part in the sense of technical and performance issues is the “GIS part”; therefore the model for GIS support was developed first. We developed also the part for User administration and security. Web application development was, according to model definition, aimed to the GIS support main core development. Freeware technology MapGuide was used for this core at “web server” part and freeware technology MapServer was used for this core on “spatial data servicing” part. At this moment the core already uses all appropriate and available data as the “background”, acquired from RDA LUR (see chapter 4.2 Data for strategic sustainable mobility planning).

We developed the demo prototype of web application which could be a part of LURPP or standalone web application to enable communication between different groups of users, including the public transport users (existing and potential) and decision-makers. The application is integrated with the open-sourced GIS components and it is related to the geo-spatial transport database which allows users on the structured way to ask questions, comment, suggest and response by individual content sorted in different groups or themes. There is a direct link to the GIS in terms of feed origin, destination, travel time, public transport mode choice, proposed location (point of interest) such as parking place, stopping place or station, and public transport route or journey. This integration enables more effective and comprehensive analysis of each issue. The evolution from concept to demo prototype of platform user interface is shown on Figure 4.3.

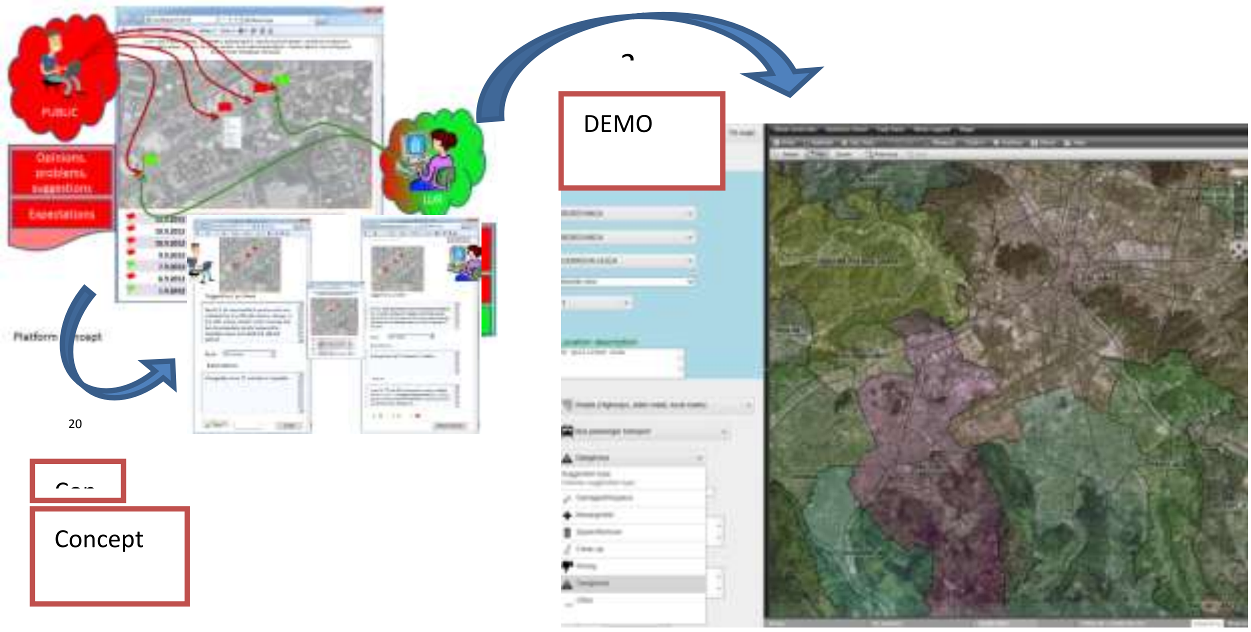

Figure 4.3: LURPP – From concept to demo prototype

Public Transport Initiative web Portal is interactive GIS platform with 4-step process of public participation (Figure 4.4):

1. Insertion of initiative, submission;
2. Initiative Acceptance;
3. Initiative Treatment;

4. Initiative Review.

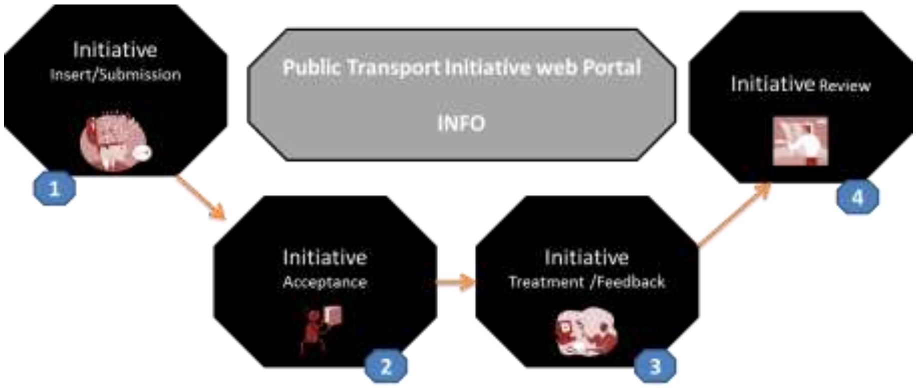

Figure 4.4: Four step process of Public Transport Initiative web Portal

In these processes the inserted initiative status is defined. The first one is “Submitted”, when the user submits the initiative. The second is “Accepted”, when the operator accepts, reviews and rejects/confirms the submitted initiative. The third is “Treated / In process”, when the initiative is forwarded to the competent authorities and in the process of solving and the final “Completed”, when initiative is rejected or solved by operator including feedback. On the webGIS map status of initiative is presented in different colours (Figure 4.5), red for “submitted”, yellow for “accepted”, magenta for initiative “In process” and green for “Completed” process of initiative management. Anonymous or registered users could look detailed information about the status and description of all “Accepted” initiatives, including graphical sketches and attached pictures (Figure 4.6). RDA LUR is proposed as the main operator for initiative management in LUR. Operator receives information on a new initiative by e-mail, portal application warning or any other communication channel produced by LURPP. Initiative is reviewed and updated by operator. The reply to user about acceptance is given and the status of status of the initiative is defined. Operator sends information on a new initiative to the competent authority (consultant). Initiative is treated by competent authorities and reply to operator should be done (Figure 4.7). Operator receives checks, updates (if necessary) and posts the answers (feedback to the user). The “Initiative Review” enables the users to search initiatives in GIS or text mode and to filter initiatives by different status, date and spatial area, which were introduced and treated in the past by other users.

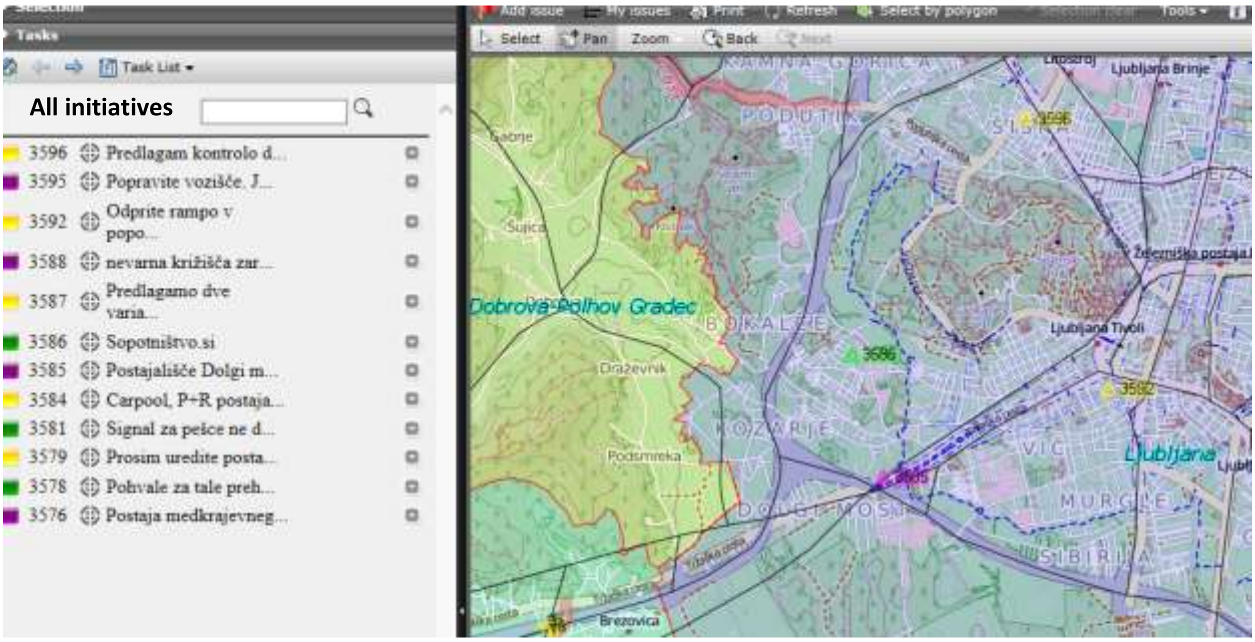

Figure 4.5: Status of submitted initiatives – WebGIS LUR PP: general viewer mode

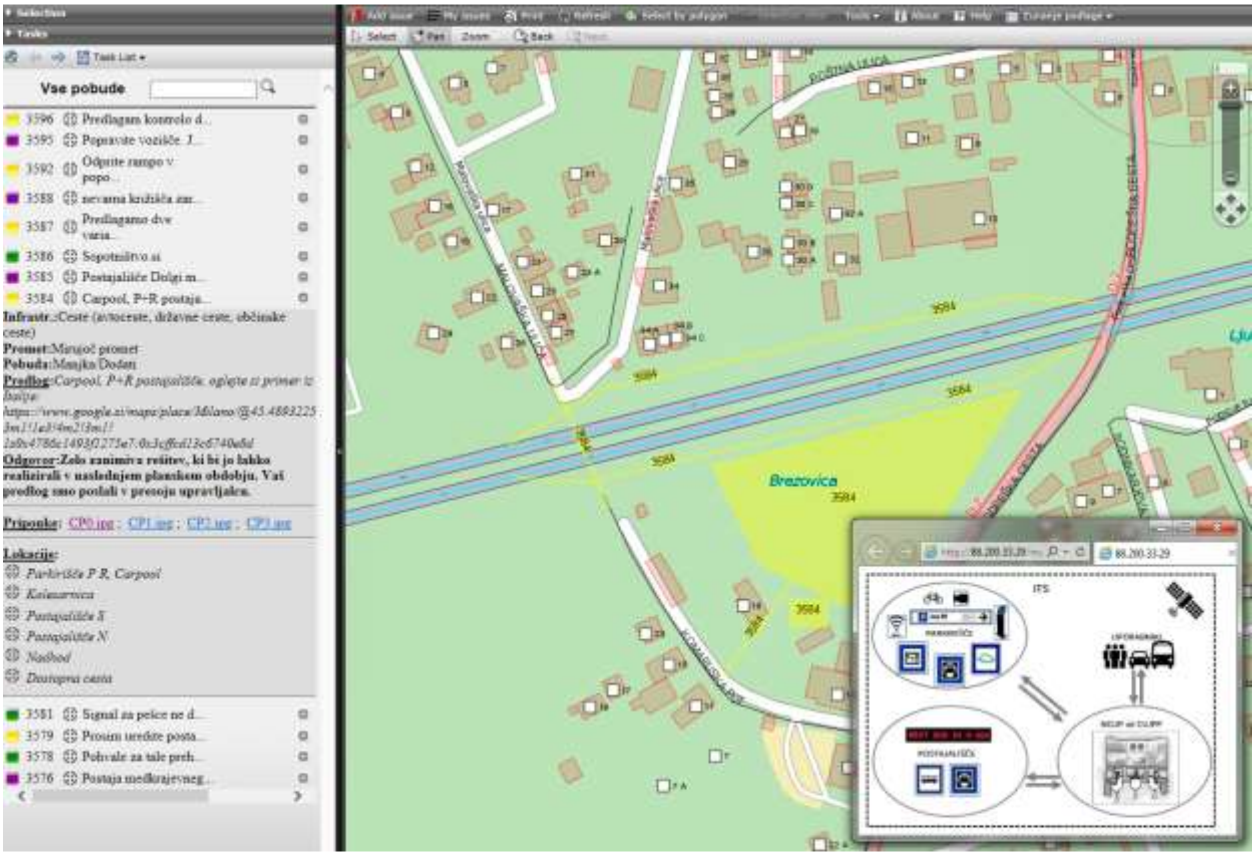

Figure 4.6: Status of submitted initiatives – WebGIS LUR PP: detailed viewer mode, e.g. Initiative #3584

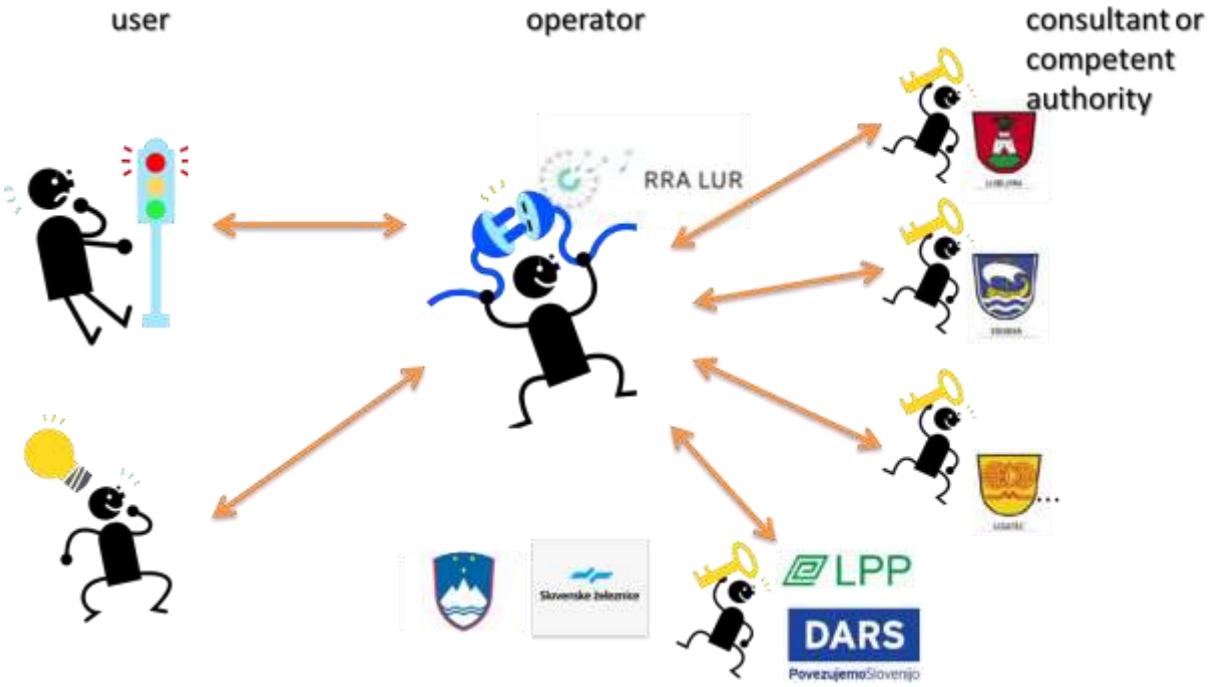

Figure 4.7: Concept of Initiative Treatment within LURPP – stakeholders

4.4 Findings from the case study

Before we define the plan of measures we the common sustainable mobility policy should be discus . We would like to know the transport problems and priorities from citizens and other identified stakeholders, at least from local authorities' decisions makers. In the past there were many EU projects on this subject (e.g. ITS City Pioneers, 1996-1998), but they were successful only in some cities (e.g. Eindhoven, Netherlands), and not in regions.

For a better dialogue on transport management's challenges in urban region we introduced micro-communication with stakeholders via regional WebGIS portal LURPP. The portal is ready to be transferred to the RDA LUR, who is preparing a demonstration project to test the tool. At the end of the test period the RDA LUR will give feedback about the usefulness of the portal.

During the development we have realized that the method for data collection and monitoring from various sources is applicable also for other purposes in traffic engineering, for example traffic management plans and real-time traffic and travel information, including information on incidents related to transport (e.g. road works, accidents, blocked road, floods). The process and tools for the communication with the public could be used for other cases, for example energy, environment and waste management.

4.5 Implementing measures

First of all, we established a link to the local authorities. Region Development Council of the LUR and the Council of the LUR are representative bodies with members from 26 municipalities. RDA LUR is the only body of organizational, technical and professional support of the regional development. By interviewing Deputy Director of RDA LUR Mr. Matej Gojčič many ways have been indicated to improve public transport in LUR. Some of them are very well known in the City of Ljubljana and they could be interesting also for the LUR. One of the measures for better public participation is presented with our case study – "The introduction of the micro-communication with stakeholders for more dialogs via RDA LUR for better public transport on the regional level". RDA LUR identified our case study as the first step to improve the link between different stakeholders in the process of urban-spatial management, including mobility.

The reason why this has not been done before is the lack of instruments for the implementation of polycentric concept in Slovenia. Instruments for the implementation of polycentric development are the following:

- Transfer (decentralization) of part of the state roles into the regions and regional centers;
- Transfer (concentration) of certain functions of the municipalities (municipal centers) at the regional level;
- Priority solving spatial conflicts in the regional centers and its surroundings (e.g. transport, environment);
- Concentration of social infrastructure of the national and regional importance in the regional centers;
- Land use management for the economic and social development of the regional centers.

Polycentric design is not just a matter of the spatial plans, but all the documents that have to do with any deployment, and promoting development of economic activities. (Cabus, 2010).

With the establishment of the RDA LUR some projects were realized:

- *Expert Basis for Managing Public Transportation in the Region*, 2009;
- *P+R Network in Ljubljana Urban Region,* 2014;
- *Project of Integrated Public Transport System in Slovenia, started* 2007 - (managed by Ministry of Infrastructure and Spatial Planning),

and some development documents related to turnover were prepared:

- *Regional Development Programme of the Ljubljana Urban Region 2007-2013* with three Implementation plans 2013-2015 (the actual one);
- *New Regional Development Programme of the Ljubljana Urban Region 2014-2020* (first draft, 2014).

Mostly all of them were quite "public participation and promotion" oriented on the classical way (e.g. workshops, small interaction groups meetings, etc.). This indicate positive trend in changing of mindset, that crowds are not important. The proposal of the new Regional Development Programme 2014-2020 has 3 priorities. One of the priorities with title "People-friendly region" has two programs:

3.1 "Sustainable mobility" program;

3.2 "Regional (spatial) planning" program.

Both programs propose many measures to: encourage the use of public transport, modernize and optimize the railway network, promote of non-motorized mobility, to regional plan for sustainable polycentric development, and develop and regulate urban and rural areas. In the programs alternative methods and tools for public participation should be used. Some of them were identified with the help of TURAS project.

WebGIS portal LURPP is going to be presented to the Region Development Council of the LUR and the Council of the LUR to decide about the usefulness of this tool as a common platform for alternative public participation in various processes of spatial and transport management.

Existing projects and measures

By interviewing Deputy Director of RDA LUR Mr. Matej Gojčič many positive and negative practices have been identified within two main projects managed by RDA LUR; initial constraints for the implementation, needed actions to overcome these constraints, and successes and failures were presented.

Project: **Expert bases for Managing Public Transportation in the Region, 2009**

The project is important as a step to a comprehensive and sustainable solution of the transport issue in the Ljubljana Urban Region. In the past 20 years Slovenia invested primarily in road infrastructure - the construction of highways, while the railway infrastructure and public transport system regressed. This has led to large motorization of the population, which has, together with the urban sprawl, reflected in the increasing problems associated with mobility. One of the key goals of the project was to acquire a basis for planning of the system for public passenger transportation according to the development of settlement and activities in the region, which could enable economic and efficient public transportation.

The purpose of the project was to prepare a comprehensive analysis of the public transportation in the region, to set a number of different public transport development systems, to carry out a comparative feasibility study of each of the systems and on the basis of all this, to lay down the set of measures and projects for introduction of sustainable passenger transport in the region.

The project was partly financed by the European Regional Development Fund as part of the implementation of the Operational Programme for Strengthening Regional Development Potentials 2007-2013 and co-financed by the 24 municipalities of the Ljubljana Urban Region participating in the project.

Initial constraints to implementation:

- No integrated transport strategy on national, regional or local levels;
- No major investments in public transport in the last 20 years;
- No valid legal basis and funds for regional planning (including transport planning).

Slovenia has not yet established a practice of integrated strategic planning of traffic at the national level and only a few local integrated transport strategies have been made in last couple of years. Transport has not been treated as a single system and has not been comprehensively planned; the road and rail systems are treated and planned rather separately. Furthermore transport is still planned in a traditional way in terms of infrastructure facilities planning, where central objectives are fluidity and speed of traffic. In the last 20 years there has been intensive investment planning into large and expensive road projects without integrated strategic orientation and assessment. Strategic transport planning on a regional scale, which would include integration of sectorial policies, and cooperation of various expert institutions and neighbouring local communities, have been ignored and investing in public transport has been neglected.

Actions taken to overcome these constraints:

- An initiative of City of Ljubljana for a wider / regional traffic system analysis and an integrated regional transport strategy;
- 26 municipalities of LUR have supported the initiative;
- Assigning RDA LUR to coordinate, prepare and manage this project;
- Obtaining funds for the preparation of expert bases for Managing Public Transportation in the Region.

The cause for the beginning of the project was a repeated proposition to reintroduce the tram system in Ljubljana. Ever since the removal of the tram in 1958, public transport in the City of Ljubljana has been based on bus traffic. With the increased number of passenger cars and investing only in road infrastructure and not in public transport services, public bus transport has become slow, unattractive and uncompetitive. Therefore proposals to introduce a modern light rail public transport system (Tram-train) have occurred in the 2000s, but no adequate feasibility studies to support political decision have been made. In the absence of appropriate political and financial support the "Tram-train" project was stopped, but negative impacts of car-based mobility escalated gradually. After obtaining support of all 26 municipalities of the region, which have recognized the need for a common *Strategy for managing public transport*, RDA LUR took over the coordination, preparation and management of this project and in financial perspective 2007–2013 succeeded in obtaining funds for the preparation of expert bases for the regional public transport strategy and started the implementation of the project.

Successes:

- Production of a sound analytical study with basic measures and guidelines for the development of the transport system in the region;
- Wide consensus among relevant stakeholders on the study, which became the unofficial "Public transport development strategy for the region";
- Implementation and founding for some of the measures foreseen.

The study with proposed measures and guidelines was made on a general, strategic level, which enabled wide consensus and support of municipalities, state officials, public transport companies, experts and general public and thus becoming the unofficial Public transport development strategy for the region. The measures proposed were: the improvement of the regional railway system, the construction of new P+R intermodal nodes, the introduction of high speed public transport on all major city axes and improvement of public transport management measures and policies. Some of the measures have been partially implemented: pilot high speed routes for busses, a temporary unitary body to deal with the development and steering of public transport in the region (KOJP - Coordination Committee for Public Transport) and a new study on new P+R intermodal nodes with implementation of first P+R locations. Unified ticketing, which was one of the measures foreseen, was launched with the support of the Cohesion Funds, on a national level as a project of *Integrated Public Transport System.*

Failures:

- Planned feasibility study of the proposed traffic systems was not carried out to the anticipated extent (only a generic estimate of the cost of each proposed system was made).
- Examples of synergies and conflicts that have been encountered;
- Conflict on an expert level on what should constitute the foundation of mobility in the future;
- Synergetic effect of the study and accompanying workshops on the national level, resulting in the reallocation of funds in favour of public transportation.

A wide range of stakeholders was involved in the preparation of the expert basis: various experts, local communities, state officials, public transport companies, neighbouring regions and general public. At the beginning of the process a strong conflict between the traffic experts has proved: part of the experts sees a private vehicle as the foundation of mobility and there is not yet a general consensus that the public passenger transportation, despite its disadvantages, should be basis for sustainable mobility in the future. Despite these conflicts the process of preparing the study (with several workshops and public debate) and the study itself have influenced the shift in transport policy on a national level. In the middle of the 2007-2013 financial perspective a part of the EU funds was relocated to support the development of public transport.

Project: **P+R Network in Ljubljana Urban Region, 2014**

The project was based on the *Expert Basis for Managing Public Transportation in Ljubljana Urban Region*, where it was foreseen as one of the measures of regional transport policy. Its goal was to propose an updated regional P+R (Park and Ride) network, with respect to the realistic possibilities of municipalities, to prepare the design and documents necessary for the construction of the 23 planned P+R intermodal nodes in the region and to elaborate a feasibility study of the network system.

The project is partly financed by the European Regional Development Fund (ERDF) as part of the implementation of the Operational Programme for Strengthening Regional Development Potentials 2007-2013 and co-financed by the 13 municipalities of the Ljubljana Urban Region participating in the project.

Initial constraints to implementation and actions taken to overcome these constraints:

- No major initial constraints for the implementation;
- Obtaining funds for the implementation of the P+R Network.

The logical continuation of the *Expert Basis for Managing Public Transportation in Ljubljana Urban Region* was to try and implement one of the proposed measures, P+R being the one for which it was estimated that it can bring the greatest impact with the least invested resources. The only constrain in starting the project was in obtaining adequate funds for its implementation. RDA LUR took over the coordination, preparation and management of this project and in financial perspective 2007–2013 succeeded in obtaining funds for the implementation of the project.

Successes:

- Preparation of all the documentation necessary to obtain funds for the construction of P+R nodes;
- Application for co-financing from the Operational Programme for Strengthening Regional Development Potentials 2007-2013;
- Already approved funding for 6 of the P+R locations.

One of the goals of this project was to prepare the documentation necessary to obtain funds for the construction, which was done in time to catch the last calls for co-financing within the framework of the Operational Programme of Environmental and Transport Infrastructure Development 2007-2013. Amongst the submitted projects 6 P+R locations received appropriations for the realization of their projects.

Failures:

- Planned financial model of the P+R network construction does not allow the construction of the entire system in the region at once, but in several stages;
- Ongoing construction is not guaranteed, since it is linked to acquisition of EU funds from the financial perspective 2014-2020.

Examples of synergies and conflicts that have been encountered

- Conflict between computational traffic modelling and the reality, which includes various social components;
- Synergetic effect during the implementation of the project, as 3 additional municipalities joined in, because they recognized the need for a common P+R system.

The traffic model used for determining the number of parking spaces for each P+R location has taken into account the intermodality only in the conventional sense (switch to bus or train) and not in the broader sense, where the need for additional parking spaces can arise from carpooling, carsharing and additional public and market services on the site. Thus a gap between the recalculated number of parking spaces and the real needs for the parking spaces occurred, which led to verifications on the site. During the implementation of the project 3 additional municipalities recognized the need for a common P+R system and joined the project, which shall contribute to a better connected and integrated regional P+R network.

4.6 Recommendations resulting from the case study

Model of public participation in the field of transport could be easily transferred to other Web tools (e.g. Blog, Wiki, Google+, etc.). Most of them are not directly supported by the GIS, but we know how to connect participation with the user's location, when the user is sharing it via location services. WebGIS LUR PP will have to be tested first and implemented at RDA LUR. At this stage we can only give recommendations for improvement of the GIS model and user interface created up to now:

Recommendation “Mobile WebGIS – Initiative”:

WebGIS for Initiative transmission in the field of mobility could be a part of mobile application or other public relation portal for public participation with appropriate coordinate system and projection.

Recommendation “Liking - ranking initiatives or measures”:
Future webGIS platform for initiative management and public participation could have the possibility for liking or ranking past initiatives and the possibility of setting priorities for measures in transport sector based on estimates of the general public; ranking of priorities and measures. There could be the possibility of choosing from the available variants for measures in transport sector based on estimates of the general public: selecting measures;

Recommendation “Crowdsourcing – calibration and validation of traffic model”:
Future webGIS platform could be used as a crowdsourcing tool for different purposes in the field of traffic management and engineering. There is the potential of using communication tool in real-time as sensors for calibration and validation of traffic models;

Recommendation “Crowdsourcing – measure evaluation”:
There is the possibility of using communication tool as sensors for evaluation different implemented measures in the field of mobility, energy, environment and waste management;

Recommendation “No-virtual organization to manage public participation”
One of the challenges is also “How to make it?” - the organization of micro-communication with users, including stakeholders, different experts and local authorities. We recommend there is the no-virtual organization to manage public participation in cases of spatial, transport planning and traffic management with some trusts. “Public participation @ Web 2.0+” should use the possibility of user identification via user accounts of social networks.

5. Multipurpose flood reservoir – Ljubljana

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5.1 Introduction to issue and area

KEY MESSAGE

1. *There is a need in Slovenia to establish a regional link for integrated sustainable water management between the national jurisdiction and local implementation.*
2. *Usage of ecosystem technologies (ET) in flood retention reservoirs can also benefit pollution mitigation, biodiversity and offer recreational and educational functions. The Podutik reservoir is the first multifunctional flood reservoir in Slovenia and shows that ET efficiently increase water quality to good ecological status.*

Sustainable water management in Slovenia

Sustainable water management cannot be enforced only through direct flood protection and flood damage restoration, but rather with the prior consideration of natural conditions and restrictions as well as sustainable development in the context of spatial planning. Protection against natural disasters is governed by strategies, laws, regulations and different plans on different levels of governance. Although the Slovenian legislation sets out the main preventive measures in case of natural disasters, the documents are mostly covering the natural disasters management and restoration, while too little attention is given to flood prevention.

Spatial development, water and flood protection and management are broad and interconnected fields but are determined by a number of sectorial laws and programs. The water sector is so highly divided among the different sectors (ministries, agencies and administrations) and among different levels of governance, that it is very difficult to assemble a general overview of competencies, responsibilities and tasks (Table 5.1).

Table 5.1: Important legislation regarding the management and regulation of flood areas in Slovenia in accordance with EU legislation (Rogelj, 2009).

Authorities responsible for the preparation of regulations and their implementation				
EU LEVEL	**NATIONAL LEVEL**		**REGIONAL LEVEL**	**LOCAL LEVEL**
EUROPEAN PARLIAMENT, EUROPEAN COUNCIL	**MINISTRY OF DEFENSE**	**MINISTRY OF AGRICULTURE AND ENVIRONMENT**		**MUNICIPALITIES**
Water Framework Directive (Directive 2000/60/EC)	National Programme for the Protection Against Natural and Other Disasters (NPVND, OG RS 44/2002)	Waters Act (ZV-1, OG RS 67/2002 + subsequent updates)		Municipal spatial plan
Floods Directive (Directive 2007/60/EC)	Protection Against Natural and Other Disasters Act (ZVNDN-UPB1, OG RS 51/2006)	Spatial Planning Strategy of Slovenia (SPRS OG RS 76/2004)		Expert bases for municipal spatial plan
		Resolution on National Environmental Action Plan (ReNPVO, OG RS 2/2006)		Flood studies and flood hazard maps for spatial interventions in flood areas
		Environmental Protection Act (ZVO-1-UPB1, OG RS 39/2006)		
	Rules on methodology to define flood risk areas and erosion areas connected to floods and classification of plots into risk classes (OG RS 60/2007)			
	Decree on conditions and limitations for constructions and activities on flood risk areas (OG RS 89/2008)			
Implementing acts				
	Protection and rescue plan in case of floods (NZIR) – national level	River basin management plan for the Danube Basin and the Adriatic Sea Basin (NUV)	MINISTRY OF DEFENSE Protection and rescue plan in case of floods (NZIR) – regional level	Protection and rescue plan in case of floods (NZIR) – local level
		Programme of river basin management measures (PU NUV)		

Slovenian Water Act (OG RS 40/2014, ZV-1D) foresees an integrated water management achievable by the management of larger water districts at the river basin or sub-basin level. The Act also states that the management of water, aquatic and waterside land is under the jurisdiction of the state, with the exception of tasks under the responsibility of the local community. In reality, only part of the tasks in the field of water management is provided by the state, a large part of the tasks is delegated to local communities, which accounts for several problems (Figure 5.1).

At the local level, local communities are represented by municipalities, which are due to their small size unfit to independently perform acquired statutory duties, partly because of the associated personnel and financial weakness, partly due to the small area they cover. A large number of municipalities and territorial fragmentation lead to a partial approach to water management, because each of the municipalities is governed according to their internal problems and only to the municipal boundaries.

On the other hand water management is geographically broader an interconnected phenomenon. In this context, there is a need in Slovenia to establish the missing regional level to deliver an integrated and sustainable water management. Regions should be given the responsibility and unifying role in the hydrographic basin, not only in protection against harmful effects of water, but also in the field of water use and coordination of all interests in the water and spatial development. It would make sense to transfer some of the rights and obligations from the state and municipalities to the regional level.

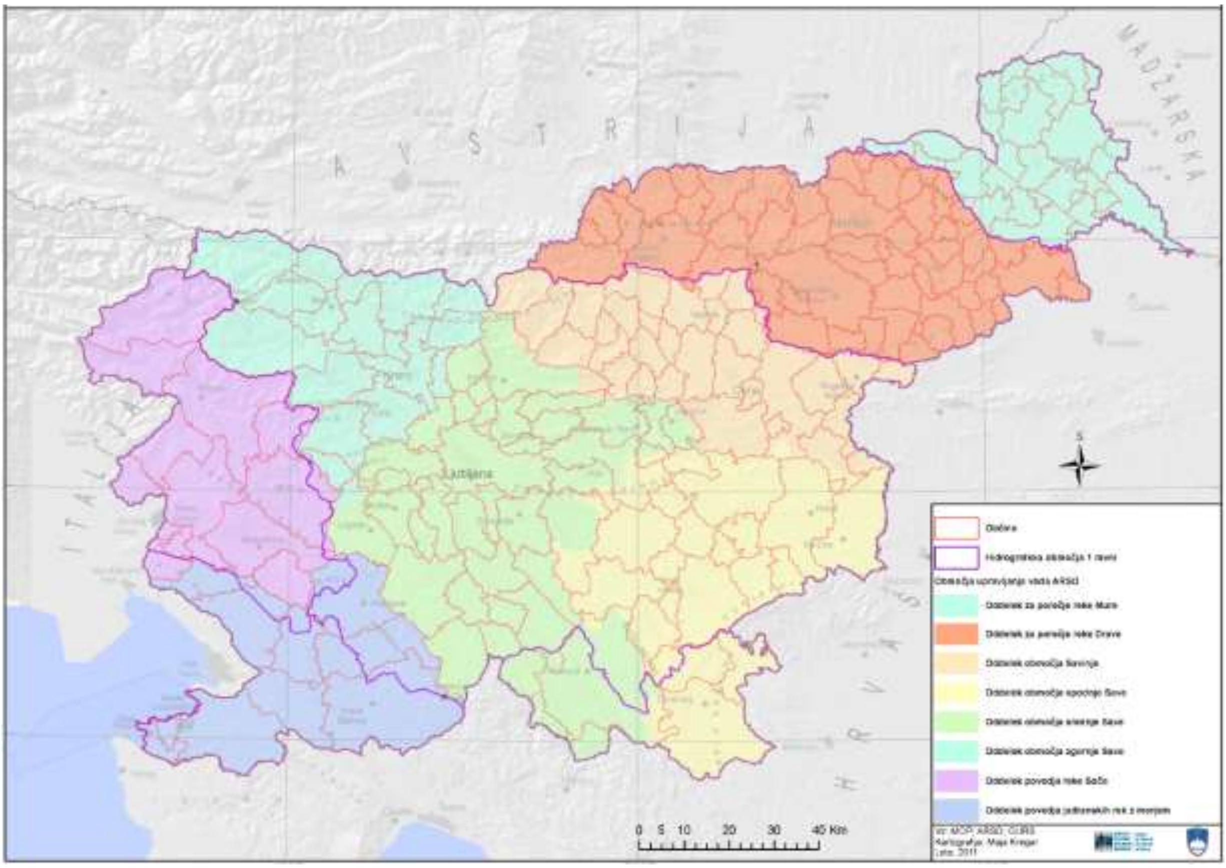

Figure 5.1: Administrative boundaries (municipal, regional) are not the same as hydrographic basin boundaries, which means difficulties in coordinating local and regional interests in the water sector; Map of the territorial bases for water management in the Republic of Slovenia (ARSO, 2011)

The main requirements of the Water Framework Directive (Directive 2000/60/EC) are to reach good ecological and chemical status of all inland, transitional and coastal waters by 2015 (2027 at the latest). All pollutants and their associated anthropogenic activities must be addressed on river basin scale to ensure that good status is attained and maintained. In 2009, the European Commission introduced the White Paper on adapting to climate change, presenting the framework for measures and policies to reduce the European Union's vulnerability to the impacts of climate change. The White Paper underlines the need "to promote strategies which increase the resilience to climate change of health, property and the productive functions of land, *inter alia* by improving the management of water resources and ecosystems." Ecosystem technology can be an example of those measures that contributes to good water quality.

Flood management in Ljubljana Urban Region

Ljubljana Urban Region (LUR) is located in the area of four major hydrographic areas i) the Sava River with its tributaries; ii) the Ljubljanica River with the karst and marshland hinterland and its tributaries; iii) the Gradaščica River with its tributaries; and iv) the Kamniška Bistrica River. In the south-eastern part of the region, there is also a part of a smaller Temenica River hydrographic area.

Ljubljana Urban Region is characterized by two types of floods: torrential flooding and karst type flooding. They differ in their scope, duration and frequency of occurrence, but they also influence each other.

Torrential floods are very severe and destructive floods caused by the torrential streams. They occur on small water catchment areas immediately after intensive rains or due to intensive snow melting. Flash flood waters rise very quickly and after only a few hours water levels decline. They are characterized by a great destructive power and erosion in the hills (accompanied also by other phenomena, especially landslides) and intense snow metalling in the planes. Torrential floods occur in almost all hydrographic areas of Ljubljana Urban Region, the torrential streams being: Kamniška Bistrica River (the largest Slovenian torrent), Glinščica River, Gradaščica River - all with their tributaries, Mali Graben and tributaries of the Sava and Ljubljanica River from the hilly fringes of the Ljubljana basin.

Karst type flooding or the so-called flooding of the karst fields, where water is slowly rising and then standing for several days or even weeks is the exact opposite of torrential flooding. Floods in karst fields usually occur a few times a year. Karst floods appear to varying extents on the Ljubljana Marshes (flooded by karst river Ljubljanica) and some of the karst fields in the region such as Radensko polje field, Planinsko polje field, and Dobrepolje field.

Ljubljana Urban Region has been dealing with flooding of rivers for many years (Figure 5.2). However, the events of recent years (2010) have pointed out that the flood protection needs additional measures, especially because settlements are gradually spreading to areas of periodic flooding of the Sava River, Ljubljanica River, Gradaščica River, Kamniška Bistrica River and their tributaries. In the last century, many of above mentioned rivers and streams were regulated. Key project to improve flood safety in the region was the construction of Gruber Canal between Golovec hill and Grajski Hrib hill in 1772 and 1782, which significantly changed the situation in the southern part of Ljubljana. Already in 1851, the Construction Office of City of Ljubljana advised the inhabitants of Ljubljana Marshes in the south-west of the city to raise their buildings to avoid flooding. Even for new constructions, they proposed a certain degree of precautions to avoid flood damage. This means that many flood events happened in the past, and almost each generation of Ljubljana inhabitants experienced at least one of the severe floods (2010, 1982, 1933, 1926, 1907, 1895 etc.).

An expansion of settlements and a construction of their infrastructure in the region did not take place in accordance with the water regulations and the provision of flood protection. Settlements, especially Ljubljana, have expanded in areas that are flood-prone. In the area near the Sava River flood protection increased because the riverbed of the Sava River started to deepen due to hydroelectric power plant Medvode.

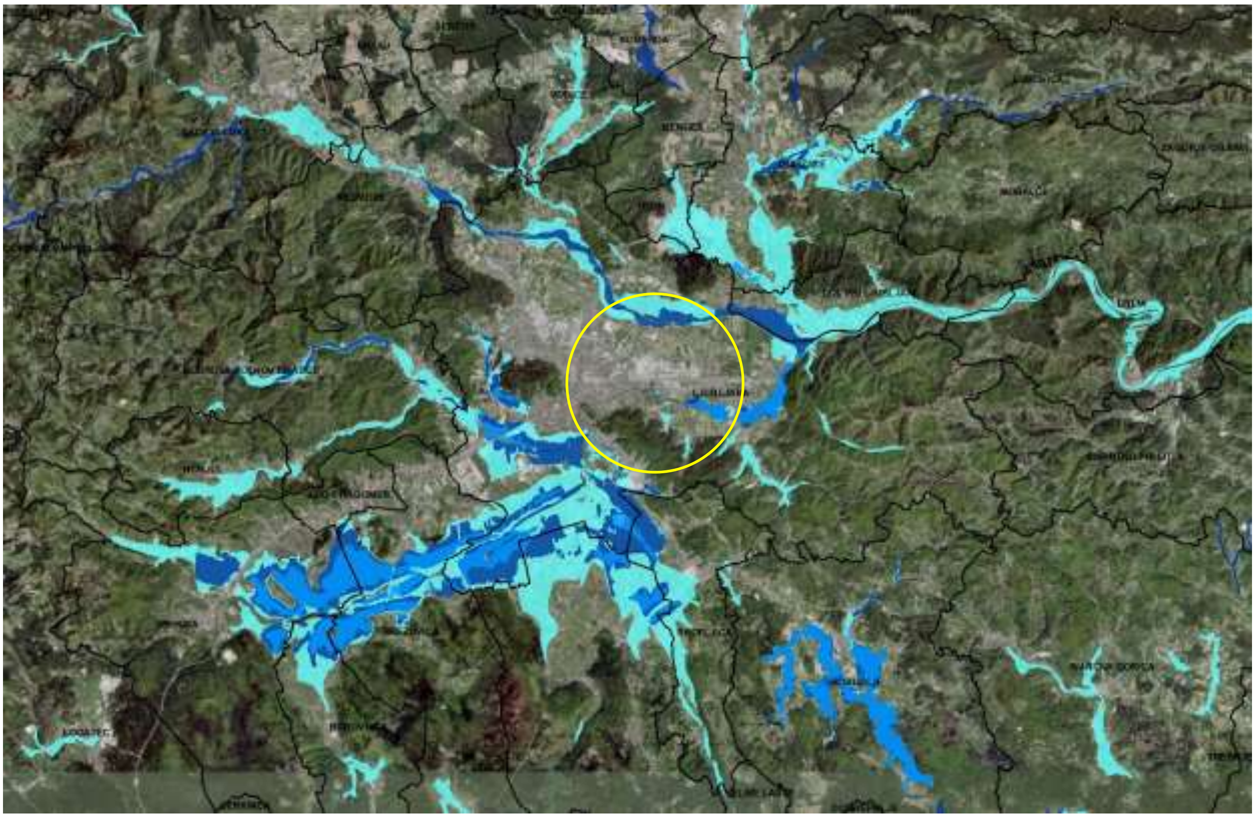

Figure 5.2: Areas of common, rare and very rare flood events in Ljubljana Urban Region-Flood warning map (light blue means very rare, dark blue means rare, and blue means common flood events) (ARSO, Atlas okolja, 2007).

The southern part of Ljubljana is exposed to flood threat because of several phenomena:
- the western part of Ljubljana is threaten because of the high-waters of Glinščica River and its tributaries, south-western part of Ljubljana is threatened by Gradaščica River and Horjulka River, south periphery and southern part is threatened by the floods on Ljubljansko Marshes and by tributaries from inland waters.

Glinščica River is a torrent. Torrential flooding depends not only on the intensity of the rainfall, but also on the soil humidity, the time of the year and the obliteration of the riverbed. A common feature of torrents is that it is difficult to predict the events and to protect endangered areas. For torrents there are common short and extremely extensive flooding events (flash floods), caused by a relatively short and intense rainfall in summer or by protracted rainfall in autumn. Although the torrents have lower flows than lowland rivers and are usually active for a short period of time from several hours to several tens of hours can cause serious damage due to the high flow velocity, depth of a riverbed and lateral erosion, and large quantities of transported material.

At regulated section of Glinščica River downstream of the flood reservoir Podutik, flood protection is provided only for events with a 5-year to 10-year return period, resulting in heavy flooding on the flat part of the area in times of high waters. Flood protection should be increased in the urban area downstream, both on the left and on the right bank of the Glinščica River. The measures that have been so far identified are needed throughout the river basin. In the upper Glinščica River it would be necessary to rearrange the drainage facility from the reservoir Podutik, raise the depression parts of the riverbanks and build a new dry reservoir downstream with increased bridge openings. On the left tributary of the Glinščica River replacement of inadequate bridge openings is needed with new ones and the re-arrangement of the stream channel for the 100 year event flow. Figure 5.3 illustrates flood events in the area of Glinščica River, namely in the area of the case study-flood reservoir Podutik.

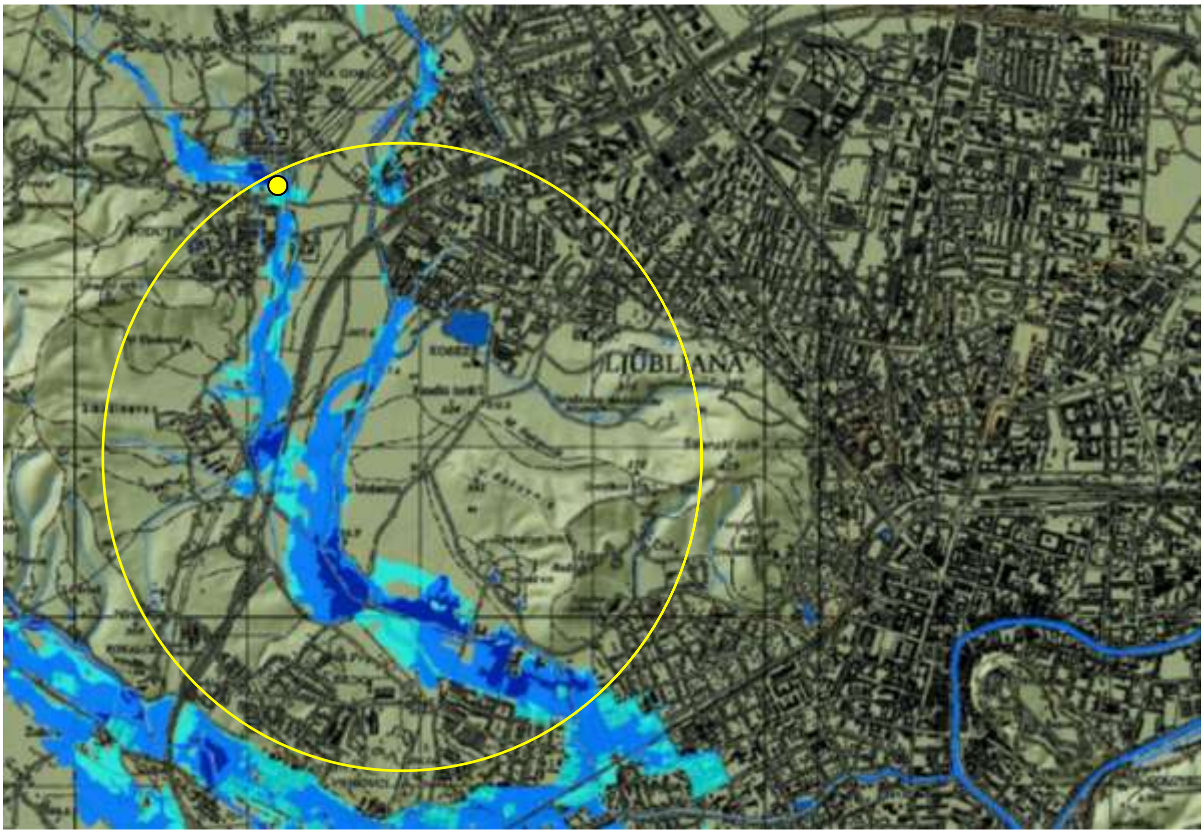

Figure 5.3: Flood hazard map for a section of Glinščica River and Podutik area (yellow circle), which shows the range of high, medium, and low probability flood events (Q10, Q100, Q500), also showing the location of Podutik reservoir (yellow spot) (light blue means low probability, blue means medium probability, and dark blue means high probability of flood events (ARSO, Atlas okolja, 2010).

In 2009 and 2010 flood hazard maps, based on flood protection studies, were made for the entire City of Ljubljana. The flood hazard maps were prepared with 2-D (or 1-D, where possible) mathematical models, showing results on maps at a scale of 1:5000 or eventually more precise, according to expert opinion. The maps were made in accordance with the "Decree on the conditions and restrictions for the implementation of activities and interventions in areas being at risk because of flooding and related erosion of inland and marine waters" (OG RS, 89/2008). The Decree represents the actual implementation of the Floods Directive (Directive 2007/60/EC) of the European Parliament and of the Council on the assessment and management of flood risks. It determines the conditions and restrictions on activities in urban planning and the implementation of activities in areas at risk of flooding and of related erosion of inland and sea waters. The Decree also determines interventions in the environment that could in case of flooding and related erosion threaten the aquatic environment, as well as land-use planning and preventive measures to reduce flood risk.

However, regarding flood protection, the solution is in sustainable water management without impact on neighbouring municipalities or even countries, which is also in accordance with international principles. For mitigation of the floods in the Ljubljana Urban Region, the establishment of regional level management and participation of the national authorities is essential, because they manage most of the mechanisms for the restoration and maintenance of waters.

Ecosystem technologies (ET) for sustainable water management

In the context of achieving resilience to climate change, especially to flooding, the usage of ecosystem technologies (ET) and similar ecoremediation methods that mimic natural environment could offer certain advantages. Their advantages lie mainly in the possibility of its inclusion in a favourable environment, in relatively simple technological implementation, lower operating costs and low investment costs compared to wastewater treatment plants, low energy consumption, efficient treatment processes, binding of the part of nutrients, especially nitrogen and phosphorus by vegetation, and treatment of organically low-loaded wastewater that cannot be treated by artificial methods. ET for sustainable water management merges “green infrastructure” as vegetated drainage ditches, waste stabilization ponds, storm water detention ponds, treatment wetlands, buffer zones, phytoremediation with dense woodland establishment, river revitalization, and in stream and bank side river techniques (Kadlec and Wallace, 2009, Bulc *et al*., 2011). One of the main aims of ET concept is to integrate, exchange, combine and use multi-functionality of different kind of "green technologies" to obtain innovative and sustainable solutions for environmental protection and ecosystem restoration (Bulc and Šajn Slak, 2009; Bulc *et al*., 2011).

The case study within Turas presents application of ET to gain multi-functionality of flood reservoirs. Multi-functionality of ET is considered as follows:

- **Flood prevention** and water retention: ET reduce hydraulic peaks by retaining water in the system and therefore prevent and mitigate floods and droughts. They can contribute to an improved water management, mitigate water abstractions and recharge groundwater.
- **Water treatment**: ET effectively treat a large variety of wastewater (sewage, grey water, agricultural, highway runoff, landfill leachate, industrial wastewater, composting facility runoff, etc.) and increase a self-cleaning capacity of natural or revitalized ecosystems.
- **Saving energy**: ET can provide their services with very little or no energy input if designed accordingly.
- **Enhanced biodiversity**: ET create a new habitat for wildlife and can contribute to an increased biodiversity in a barren landscape (*e.g*. spawning ground for frogs and toads, breeding sites for birds etc.).
- **Biomass production and nutrient recycling:** if designed for this purpose, ET can recycle nutrients from runoff to a large degree and convert them to biomass which can be used as energy or raw material source (*e.g.* thermal insulation).
- **Recreation**: ET can be designed with elements of landscape architecture and can create an attractive place for the population.
- **Education**: ET are a good and tangible example of a measure aimed to achieve sustainable development. They can be used to present the problems of pollution and its remediation in a natural way to different target groups (*e.g*. how a waste product can be transformed into something valuable).
- Identification of possible interactions of ET with **ecosystem services**.

Case study: Podutik – flood reservoir

On the Glinščica River, which is the subject of the case study Podutik, several regulatory projects were carried out in the past for high water retention and improvement of the ecological status of the watercourse. The first major action was conducted in 1986, when facility "reservoir III Podutik" was built to retain flood wave and protect a nearby settlement. The flood reservoir Podutik was built as a wet reservoir. In addition, the reservoir is receiving rainwater from the nearby settlements, and catchment area, occasional overflows from septic tanks, inflows from polluted tributaries from its catchment area and polluted surface runoff from individual gardens, nearby. At the end of the reservoir security gate with course screen (2 x 2 m) was installed. Since its construction, in the area of flood reservoir Podutik, two areas have developed: permanently flooded wetland and wetland areas that are occasionally flooded during heavy rainfall. As the slope of the terrain descends to the Glinščica River, the hydraulic retention capacity of the flood reservoir is probably sufficient without major interventions and without compromising the surrounding settlement, and as such is probably still serving its original purpose. However, there is no specific operating policy for its maintenance. The actually hydraulic retention needs therefore re-evaluation. On the other hand, dense vegetation stands within flood reservoirs which plays a remediation role and has a positive impact on water pollution mitigation caused by septic tanks' overflows, inflows from polluted tributaries from its catchment area, and polluted surface runoff from individual gardens as mentioned above. Given the various functions, a reservoir like Podutik can be seen as a green infrastructure object, of which various more are investigated in WP2 of the TURAS project.

Location of the case study Podutik

The case study Podutik (a multifunctional flood reservoir) is located in the area of flood reservoir III Podutik, which was built on Glinščica River in 1986 for retention of high waters in Ljubljana area (Figures 5.3 and 5.4). Flood reservoir III Podutik was the only flood reservoir in this area.

Recently, several other dry reservoirs were designed due to new building construction (settlements, highway) and severe flood events in the last 10 years. One of them is already under construction, while others are planned to be constructed in the next years.

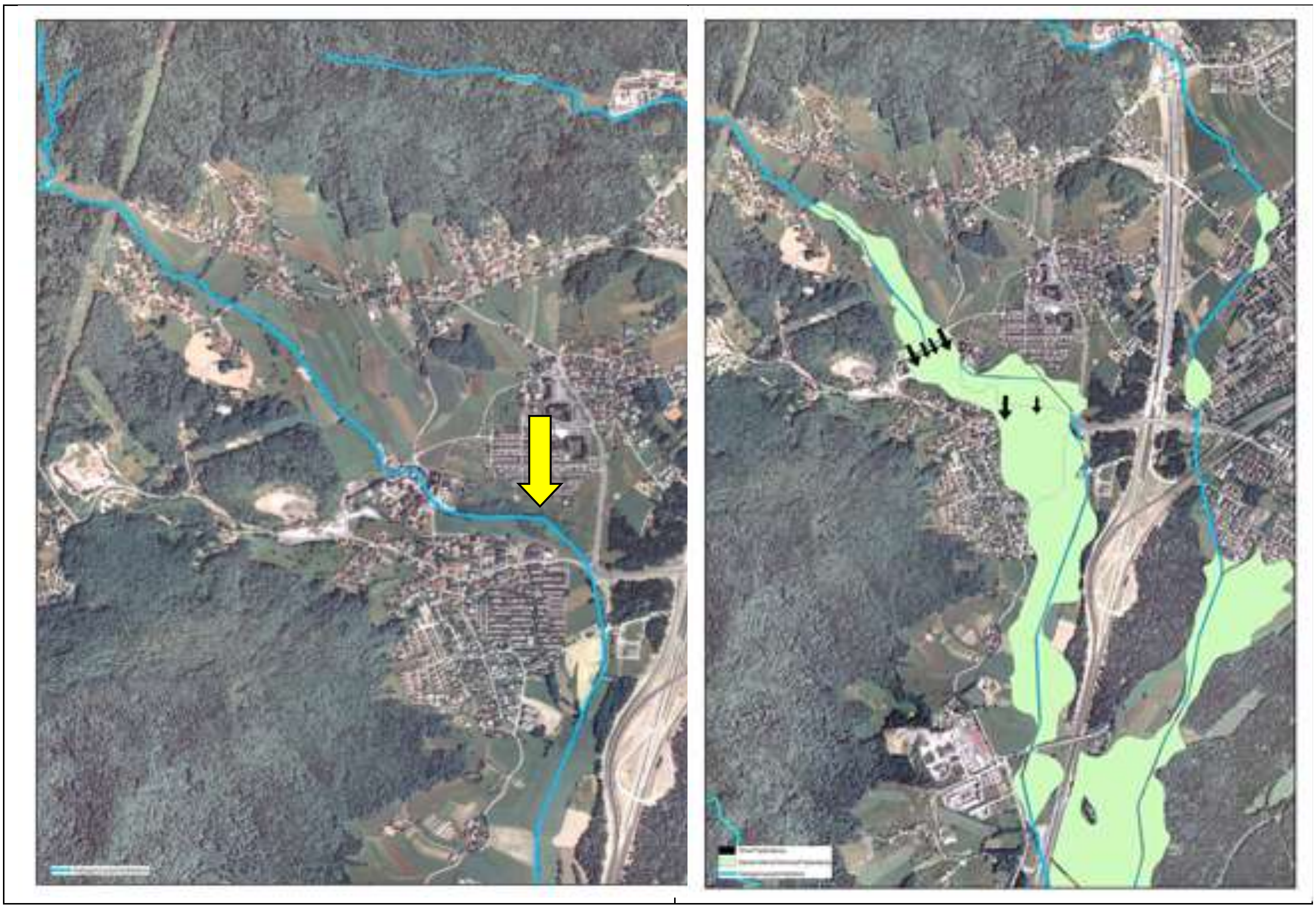

Figure 5.4: Location of the case study Podutik and direction of flooding along Glinščica River.

The case study Podutik development

Increased toxicity of Glinščica River as a main recipient of the water from the flood reservoir III Podutik was demonstrated in 2001 in the frame of monitoring financed by City of Ljubljana. The pollution of River Glinščica at that time indicated the need for additional water treatment in the catchment area of the flood reservoir.

In 2006, the ecosystem technology (ET) was constructed parallel to the tributary for Glinščica River protection consisting of a vegetated drainage ditches (VDD) designed according to a subsurface flow constructed wetland (SSF CW) principle and a new river bed with meanders (RBM), as an economical and environmentally sounds solution to decrease surface water pollution and increase water retention. The ET system treats the polluted water from torrential tributary of the Glinščica River prior inflow into a natural wetland and subsequently into receiving watercourse Glinščica. ET system with both segments (VDD and RBM) was built in a total length of 70 m and width of approximately 3 m at a depth of 1 m. Since the construction (Limnos Ltd., MOL 2005-2013) ET system has been monitored and maintained for efficient performance on a regular base.

Multifunctional flood reservoir in Podutik can provide several functions regarding environmental protection:

a) Flood prevention
b) Water pollution mitigation with the help of natural wetland and ET
c) Increased biodiversity of vegetation in the landscape
d) Establishment of recreation and education path

Flood prevention:

Nowadays the flood reservoir III Podutik represent a rich marsh biotope developed due to a long-term lack of maintenance, with lower hydraulic capacity, but with increased self-cleaning capacity and biodiversity. The marshland area consists of three different intertwined land types (1) swamp; (2) standing water; and (3) accumulated coarse-grained river sediment. The part with permanent standing water is gradually filling up due to erosion and sediments deposited by tributaries.

Water pollution mitigation:
Flood reservoir is an ideal reservoir of suspended and settleable solids. It acts as a sediment pocket for colloidal fractions and solid particles, since it has no corresponding pre-settling tank. Originally covered with grass, reservoir bottom is now covered with deposited material and is gradually becoming overgrown, which only accelerates disposal of material. Self-cleaning function of the reservoir is therefore increased. Additionally, the ET system treats the polluted water from torrential tributary of the Glinščica River, and surface runoff from individual gardens prior inflow into a swamp.

Biodiversity of vegetation/algae:
The area is overgrown with mature marsh vegetation corresponding to the three different land types mentioned above. Marsh vegetation in this area is extremely diverse. The same is true for algae species. Many species can be found in this area which are not present in the surrounding areas.

Education (learning path) and recreation:
With the appropriate arrangements, flood reservoir can become an interesting educational path (bird observation points, observation of self-cleaning elements of wetland and Glinščica River, ET) and recreational place (walking) in dry periods.

Given the accumulation of material and overgrowth of the reservoir in the last 30 years, it is clear that some of the features outweigh the other. Considering the fact that flood protection in City of Ljubljana is extremely important in relation to the events of the last few years, it is necessary to determine:

a) The actual retaining ability of the flood reservoir
b) The effectiveness and importance of the treatment function
c) The degree and significance of biodiversity

Based on the findings maintenance and regulatory changes can be planned out to improve flood protection, taking into account other functions (b, c).

In 2013 University of Ljubljana (Faculty of Civil and Geodetic Engineering) due to Turas project has received additional co-financial support from the City of Ljubljana to optimize four functions of multifunctional reservoir Podutik by 1) re-evaluating hydraulic retention capacity based on hydraulic-mathematical models, 2) optimize ET performance, 3) evaluate biodiversity, and 4) design educational and recreational path.

5.2 Data for strategic urban planning

Data used

An open access database survey was performed in year 2012-2013 regarding integrated water and flood management. The purpose was to check the one stop service information provided by multiple databases that can be useful for stakeholder LUR (Table 5.2).

Table 5.2: Data availability in Slovenia for water and flood management

Data	Database	Availability	Remarks
Water protection zones, Surface waters, Water sources, Flood hazard maps, Flood warning maps, Flood mitigation measures, and Municipal spatial plan (land use, communal infrastructure etc.)	URBINFO, City of Ljubljana	free online viewing	data for City of Ljubljana, allows search options, viewing and printing of maps (jpg format)
Areas of significant flood risk, Flood hazard maps, Flood warning maps, Past flood events, Record of Preliminary flood risk assessments and other Flood protection studies, Water protection areas, Hydrological and Hydrographical data, Geological data	Atlas okolja, ARSO	free online viewing and obtaining of data	data at the national level, allows search options, viewing and printing of maps (jpg, pdf format), some of the data is downloadable in SHP format
Database of different spatial data infrastructure and the existing spatial online	INSPIRE geoportal,	free online viewing,	geographically and thematically referenced data in a form and

portals and applications: Prostor, Atlas okolja, Real estate records, Naravovarstveni atlas, Map viewer etc.	GURS	obtaining data varies according to the type	manner consistent with the INSPIRE data specifications, allows viewing and managing
Spatial and other data for individual municipalities: Municipal spatial plan (land use, communal infrastructure etc.), Water protection zones, Surface waters, Water sources, national spatial planning documents and measures	PISO, Realis d.o.o.	free online viewing, payable application for municipal use	data at the individual municipal level, allows search options, viewing and printing of maps (jpg, pdf format), more options for payable municipal use
Hydrological, geological and pedologic data, Average amount of precipitation, Flood warning maps	GEOPEDIA, GeoZS, GIS, Sinergise d.o.o	free online viewing, downloading and uploading	allows search options, viewing and printing of maps (jpg format), downloadable data in SHP format, allows creating new data layers and uploading data
Statistical data (demographics, rainfall, land cover, water resources and the water quality, water management, waste water treatment, hydrological data on inland waters, natural disasters and damage etc.)	SI-STAT, SURS	free online viewing and managing, exporting in different formats	different data on national, regional and municipal level, allows viewing, editing and display of data, export in the form of tables, graphs and diagrams (jpg, pdf format), downloadable data in Excel and PC-Axis format

The open excess databases offer fairly good information system of general spatial data, mostly on national or municipal level. The encountered problems are associated with the access to the detailed data and the missing data for the regional level. More detailed information on flood management is not integrated in open access databases; it is usually part of a specialized database and available only on demand (for example individual flood protection studies, flood risk assessments or a comprehensive map of flood prevention measures etc.).
Data related to the municipal level (such as land use etc.) is not collected and thus cannot be viewed in a common spatial database, it is only available for each municipality individually, and not even in the same database (the majority is available on PISO), which is inadequate for regional level planning.

Table 5.3: The survey of the used data for hydraulic, pollution, and biodiversity evaluation of the flood reservoir Podutik. accessible on the web :

Data*	**Type**	**Methods**	**Remarks**
Hydraulic data	modelling	models: SWMM 5 (U.S. Environmental Protection Agency, SWMM, 2013), FLO-2D Basic (FLO-2D Software, INC, 2013)	validation with measured flow and runoff volume data during rain events
hydrological data	modelling	models; Horton (U.S. Environmental Protection Agency, SWMM, 2013), Greena and Ampta (U.S. Army Corps of Engineers, HEC-HMS, 2013), SCS (U.S. Army Corps of Engineers, HEC-HMS, 2013), SWAT (SWAT, 2012), HEC-2 (U.S. Army Corps of Engineers, HEC-2, 1991)	calibration with measured flow and runoff volume data during rain events. Data from our previous research and from existing maps of flood hazards were used.
	quantity and intensity of precipitation	measurement station Pržanec, which is located within the Glinščica River basin	available data from 1.11.2003 to 31.1.2004 and 17.-18.1.2003
watersheds	modelling	A digital model of elevation with resolution of 5 m	digital model of elevations is freely available for study and research purposes at Geodetic Office of the

Data*	Type	Methods	Remarks
			Republic of Slovenia.
Soil type characteristic	survey	soil type maps	
land use	survey	database Corine 2006 (CLC, 2006)	
water quality	analysis	parameters; suspended solids, ammonia nitrogen, nitrite, nitrate, total nitrogen, Kjeldahl nitrogen, total phosphorus, biological oxygen demand, and chemical oxygen demand	data were also obtained from ours previous research
self-purification elements	field survey	ecoremediation elements; e.g. pools, rapids, buffer strips, meanders	
ecological status	phytobenthos-based ecological assessment	field survey, sampling, sample treatment, result evaluation, assessment	for the element of phytobenthos
saprobic, trophic index	phytobenthos-based assessment	field survey, sampling, sample treatment, result evaluation, assessment	for the element of phytobenthos
biodiversity	field survey	Identification of plant and benthic and planktonic algae species	

*Most of the data for the case study were freely accessible on the web : (http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso).

5.3 Tools and analyses for urban planning

Evaluation of hydraulic capacity of multifunction flood reservoir Podutik started by testing different hydrological models (Horton, Greena and Ampta, SCS, SWAT model, HEC-2 model) and hydraulic-hydrologic model (Flo-2D, SWMM 5.0). Measured hydrologic and hydraulic data were used for the purpose of calibration and validation of the hydrological and hydraulic mathematical models constructed with SWWM 5.0 and FLO-2D. Calibrated and validated models were then used in the simulation of flood events with 10, 100 and 500 year return period.

ET efficiency performance was estimated based on the water analyses for following parameters: suspended solids, ammonia nitrogen, nitrite, nitrate, total nitrogen, Kjeldahl nitrogen, total phosphorus, biological oxygen demand, and chemical oxygen demand. Water samples were collected on 14th of November 2013 at 3 sampling points along the ET system. Laboratory analyses were performed the same day using standard methods and procedures.
The sampling of algae as biodiversity and ecological status indicator of the flood reservoir was conducted on 14th of November 2013 in five sampling points along the ET system. Ecological status was assessed according to Slovenian methodology (Methodology of ecological status evaluation for rivers with phytobentos and macrophytes, 2009). Saprobic index was calculated according to Pantle and Buck (1955), modified by Zelinka and Marvan (1961) and later by Rott (1997).

The results of the analysis of flood hazard in the form of flood maps are submitted for approval to the Environmental Agency, who will publish them on the web (http://gis.arso.gov.si/atlasokolja/profile.aspx?id=Atlas_Okolja_AXL@Arso).

Optimization of the flood reservoir will be delivered at the end of the project to the stakeholder City of Ljubljana in a form of operating rules and a set of necessary investments that will allow the proper operation of reservoir regarding all four functions; 1) hydraulic retention capacity, 2) ET performance, 3) biodiversity, and 4) educational and recreational path.

As described in previous chapters, in Ljubljana area there is a number of measures provided to reduce flood hazard. The measures include construction and reconstruction of retention basins, while an increase in hydraulic conductivity of rivers and floodplains in not populated areas and occurrence of property damage is not expected.

5.4 Findings of case study

The case study Podutik, which presents a demonstration of multifunctional flood reservoir within the TURAS project, is focused on re-evaluating hydraulic retention capacity based on hydraulic-mathematical models, optimisation of ET performance, evaluation of vegetation biodiversity, and on design of the educational and recreational function. The presented results in this report relate to hydraulic retention capacity, and ET performance, while a biodiversity survey is still ongoing.

Hydraulic retention capacity
Hydraulic retention capacity, as the most important function of the flood reservoir, was based on the usage of hydrological-hydraulic mathematical models (see chapter "Material and methods"). Results of these models were compared with the field data in the section of Glinščica River in order to determine the most appropriate model to simulate inflow into the flood reservoir, as the most important parameter of hydraulic estimation. Five different mathematical models were used. The best fit of measured data was achieved by the SCS model which was further used to simulate inflow into the flood reservoir. Based on the results achieved by SCS model, the hydraulic of the section of Glinščica River and the flood reservoir was simulated by Flo 2D and SWMM 5 mathematical models to determine the hydraulic retention capacity of the flood reservoir. The modelling of the data are still in process.

Optimisation of ET performance
The efficiency of the ET regarding water pollution and algae biodiversity within the multipurpose flood reservoir was evaluated from 2008 till 2013 (see chapter 5.3).

The efficiency performance of the ET was showing that pollutant concentrations met the outflow permitted levels. ET system efficiently reduced all the parameters measured except nitrite nitrogen (NO_2-N), which was higher in the outflow of the system, probably due to accumulation and degradation of fallen leaves in the system at the time of sampling. Biodiversity of algae in multifunctional retention basin Podutik is very high (52 algal taxa). According to the saprobic index, the multifunctional retention basin Podutik can be classified into I. class (oligo saprobic) or I.-II. class (oligo-betamezo saprobic).Ecological status of the multifunctional retention basin Podutik was high and good, respectively.

The results showed that ET efficiently higher the water quality in the reservoir by reducing the water pollution at the inflow to permitted levels, which was not the case before the construction of the ET. The water quality in the reservoir, also due to the ET, reached high to good ecological status.

5.5 Implementing measures

Expert bases for the preparation of the Regional spatial plan, 2009
Local authority: Regional Development Agency of Ljubljana Urban Region (RDA LUR)
Interview with: RDA LUR Deputy Director Matej Gojčič, date

The purpose of the project was to prepare a comprehensive analysis of the area and its spatial and social components, analysis of individual development fields and areas in the region and above all defining different spatial development scenarios and solutions in the form of spatial systems. The analysis should provide a basis for the preparation of an integrated Regional Spatial Plan of LUR.

The first part of the expert bases focused on analysis and evaluation of potentials for the development of activities based on the natural features and resources, taking into account all protected and restricted areas (Natura 2000, nature protection areas, water protection zones, aquatic and riparian land, agricultural land, forest reserves, etc.). In this part the topic of water management and flooding was also addressed and pointed to what information, tools and measures are missing to enable integrated water management and to reduce the risk and impact of floods on a regional level.
The project was partly financed by the European Regional Development Fund (ERDF) as part of the implementation of the Operational Programme for Strengthening Regional Development Potentials 2007-2013 and co-financed by the 22 municipalities of the Ljubljana Urban Region participating in the project.

Initial constraints to implementation

- Break with the tradition of spatial planning;
- Poor strategic and long term planning;
- No valid legal basis for regional planning;
- No assigned funds for the production of regional strategic spatial plans.

Until 1991, when the Republic of Slovenia became independent, there was a planning practice, which included territorial, social and economic approach to spatial planning and produced the long-term coherent strategic documents from witch only spatial component was used in first years of the new independent country so called "Spatial components of social plans". The first comprehensive renewal in spatial planning legislation was in 2002 with the Spatial Management Act (OG RS P-1, 110/2002) which introduced regional level of planning and foresaw a strategic act at the regional level – i.e. Regional spatial development plan. The Regional plan was conceived as a partnership agreement between the region and the state. With latter amendments to the Act resulting in new Spatial Planning Act (OG RS 33/2007) the preparation of Regional spatial development plans somehow stops. Under the current legislation there is no regional planning level and a Regional spatial plan is no longer a strategic document, but is considered as implementing act, a basis for the preparation of projects for obtaining a building permit for spatial interventions in the area of several municipalities. Up to now, there is still no legal basis for regional spatial planning and consequently no regional authorities, mechanisms or assigned funds for the production of regional strategic spatial plans.

Actions taken to overcome these constraints

- An expressed need of 22 municipalities for a joint /regional spatial development strategy;
- Assigning RDA LUR to coordinate, prepare and manage this project;
- Obtaining funds for the preparation of Expert bases for the Regional spatial plan.

Local authorities (municipalities of LUR) demonstrated a need for a joint spatial development strategy despite the fact that the current legislation does not foresee such a document on a regional level. RDA LUR took over the coordination, preparation and management of this project and in financial perspective 2007–2013 succeeded in obtaining funds for the preparation of Expert Bases for the Regional Spatial Plan and started the implementation of the project.

Successes

- Production of a sound analytical document, which is used as the basis for other development projects;
- Development of a cooperation model on a regional level;
- Joint participation of municipalities;
- Established cooperation between RDA LUR and the state authorities with the aim of re-introducing regional strategic planning.

In the process of preparing of the document the cooperation between the municipalities in Ljubljana Urban Region was needed, thus a cooperation model between RDA LUR as the initiator and the 22 municipalities has been developed. The project also gave rise to the cooperation between RDA LUR and the state authorities, Ministry of the Environment and Spatial Planning at the time, with the aim of re-introducing strategic spatial planning on regional level. RDA LUR is still striving for the introduction of strategic spatial planning on a regional level into the national spatial planning system.

Failures

- Document failed to sufficiently set different scenarios of spatial development of the region (LUR) and to establish consensus among different stakeholders.

Examples of synergies and conflicts that have been encountered

- Strong conflict between protection and development requirements;
- Development priorities are determined by the pressure from investors rather than long-term strategic plans;

- Despite these conflicts there is a strong interest from the municipalities for a joint strategic spatial planning document when the legislation will enable or at least facilitate its production.

While preparing the expert basis strong conflicts between protection and development requirements have become apparent. A large part of the region is under different protection regimes (Natura 2000, nature protection areas, water protection zones, aquatic and riparian land, agricultural land, forest reserves, etc.), but the municipalities wish to implement development projects also in this areas. There is no regional tool to promote development in suitable areas and to adequately preserve the protected areas in the region. There is also a strong pressure by investors on municipalities, determining development priorities and areas, irrespective of the strategic orientation of the municipalities. Despite all this conflicts there is a strong interest from the municipalities for a joint strategic spatial planning document when the legislation will enable or at least facilitate its production.

5.6 Recommendations resulting from survey and the case study

Flood hazards
Spatial interventions to reduce flood and related erosion hazard are planned within spatial planning documents based on “Regulation on the conditions and restrictions to implement activities and interventions in place in areas at risk from flooding and associated erosion of inland water and sea water; Official Gazette of the Republic of Slovenia, No. 89/08”. Spatial development, water and flood protection and management are broad and interconnected fields but are determined by a number of sectorial laws and programs, which causes difficulties o assemble a general overview of competencies, responsibilities and tasks.
Recommendations:
Spatial interventions should be designed as comprehensive measures and should be implemented before the start of new development in the area. There is also a strong need to establish the missing regional level to deliver an integrated and sustainable water management. Regions should be given the responsibility and unifying role in the hydrographic basin, not only in protection against harmful effects of water, but also in the field of water use and coordination of all interests in the water and spatial development. It would make sense to transfer some of the rights and obligations from the state and municipalities to the regional level.
Explanation:
In areas of significant impact of flood and erosion hazard comprehensive actions are planned at the national level, while the actions on all remaining areas are planned at local levels. New definitions of the area of flooding and related erosion or changes of the area, hazard class or hazard on the planned area have to be provided to the Ministry responsible for waters by the holder of spatial planning, to get an approval and registration in the water cadastre. Local communities (as clients) or the makers of flood hazard maps are therefore required to submit only the information on redefining the area of flooding and related erosion and not the hydrologic-hydraulic models or studies, which remain their property (or owned by the client) as a copyrighted work and are not (freely) available to the general public. However, in reality, only part of the tasks in the field of water management is provided by the state, a large part of the tasks is delegated to local communities, which accounts for several problems by strategic actions. Therefore regions should be given the responsibility and unifying role in the hydrographic basin, not only in protection against harmful effects of water, but also in the field of water use and coordination of all interests in the water and spatial development. It would make sense to transfer some of the rights and obligations from the state and municipalities to the regional level. The aim of such planning measures is to ensure at least an acceptable degree of risk, while taking into account the cost-benefit principle.

Flood maps and studies
Flood maps and studies are carried out at the municipal and national levels in accordance with the Regulation (OG RS No. 89/08).
Recommendations:
Data should be also collected on municipal and national levels for vulnerability and risk assessments defined by the Regulation (OG RS No. 89/08). Data protection should be re-considered in the areas of high risk.
Explanation:
According to the data held by local (LUR) and national authorities, the implementation of these assessments (vulnerability and risk assessments) is at the moment quite impossible, because in addition to the customary data, such as land use, also information on the activities in individual objects, value of the objects, the effects of mitigation measures, etc. are needed. Due to data protection these are not yet possible to implement.

The case study Podutik
Based on the fact that the case study Podutik is the first multifunctional flood reservoir in LUR area as well in Slovenia it offers new perspective in the future developments for water management and flood prevention.
Recommendation:
The existing and new flood reservoir should be seen beside their primary function, also an area with additional functions within urban areas.
Explanation:
Regarding climate changes, heavy rain events and droughts, the flood reservoir Podutik can play different role in certain period of the year. Beside flood prevention, it can offer water pollution mitigation by the usage of self-cleaning abilities, biodiversity, edible wild plants, recreation, education, and as such several ecosystem services.

6. Flooding – Rotterdam

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***Nick van Barneveld**, City of Rotterdam, the Netherlands*

6.1 Introduction

KEY MESSAGE

1. *The results of the economic damage analyses reveal that indirect economic losses due to large-scale flooding can be substantial. For very low probability events even larger than direct losses.*
2. *Integral analysis of flood risks sheds more insight in the actual consequences of a flood. In case of a level-controlled water system (like. canals) it is more efficient to take measures in the water system itself (e.g. closing compartments) than investing in spatial measures (e.g. adaptive building)*

Flooding as an urban challenge

Flooding causes considerable losses across the world, every year. In the past twelve years (2002-2013) weather related disasters, including flooding and hurricanes, caused on average about $ 120bn each year (Swiss Re, Sigma world insurance database). Urban areas are specifically at danger of flooding as they are often located along major rivers or on the coast or in low-lying deltaic areas (McGranahan et al., 2007). Not only their geographic location, but also several characteristics of urban areas put them at risk. Urban areas generally have a high fraction of impermeable surface, including roofs of buildings and asphalted roads. Correspondingly, there is little infiltration capacity, causing fast runoff of (extreme) rainfall that either needs to be accommodated, or will result in local flooding (Shuster et al., 2005). Moreover, high density urban areas generally leave little room for whatever river is flowing through their territory, meaning that high discharge will quickly lead to high water levels and threaten the city (Silva et al., 2001; Lammersen et al., 2002). Not only are urban areas at risk, also the consequences of flooding in urban areas are severe because of their high density of population and capital. Recent events in New York (hurricane Sandy in 2012), Bankok (flooding in 2011), the Philippines (typhoon Haiyan in 2013) and in Europe along the Elbe river (spring 2013) illustrate the devastating consequences, human drama and societal disruption such extreme events can cause.

The danger of flooding of urban areas can come from various sources. High rainfall can cause the groundwater table to rise, resulting in the flooding of basements. Extreme rainfall can also result in local flooding if the amount of water exceeds the drainage capacity of the water system in the city (pluvial flooding). Also rainfall upstream can cause flooding in urban areas, through either a river or regional water system (riverine flooding). Lastly, surges from storms or hurricanes/typhoons can result in flooding of coastal cities (coastal flooding). All these different types of flooding need their own analysis and different measures are needed for different types of floods. For instance, improving drainage capacity and (creative) storage of water in cities can be successful against pluvial flooding, but won't help against riverine or coastal flooding. Large protective structures like levees and surge barriers, on the other hand, protect against riverine or coastal flooding, but not against pluvial flooding. For all types of measures goes that in urban areas there is a large pressure on space. As most measure need space (i.e. for storage, or to build a defensive structure), this is a problem encountered in many urban areas. Smart integration of such measures with the build environment is then necessary.

General introduction to Rotterdam

Rotterdam is the second-largest city in the Netherlands and one of the largest ports in the world. It traces its origins back to a dam constructed in 1270 in the river Rotte. Since then, Rotterdam has grown into a major international commercial centre. It is strategically located on the coast of the North Sea in the mouth of the Rhine-Maas-Schelde delta. Rotterdam is an important transportation hub of rail, road, air and inland waterway networks that extend throughout the rest of Europe. The municipality has over 600,000 inhabitants and covers an area of 319 km^2, 206 km^2 of which is land.

In order to confirm its status as 'Gateway to Europe' Rotterdam is continuously improving the attractiveness of both the city and its port. In 2008, the Maasvlakte 2 project started, aimed at expanding the port by 20% by reclaiming land from the North Sea (see Figure 6.1). In 2014, 700 hectares more land has been created for business sites, generating an economic impulse which will hopefully also give the quality of the region's social environment a strong boost.

One of the consequences of expanding the port into the North Sea is that some of the industrial activities are moving from locations in the city centre to this new area (see figure 6.1). This offers the opportunity to redevelop these former industrial sites and transform the industrial areas into attractive housing areas. One of the bigger redevelopment areas is Stadshavens with a total area of 1600ha.

Figure 6.1: Location of Rotterdam and the Rotterdam port area (source: Port Authority Rotterdam). White location: new land reclamation for harbour activities called Maasvlakte 2.

The Rotterdam Adaptation Strategy

Being a low-lying delta city, Rotterdam takes its responsibility seriously in creating a sustainable city, region and Europe: "By linking sustainable ambitions to a strong economy, Rotterdam will become the most sustainable world port city" (www.rotterdamclimateinitiative.nl). In order to confront the challenge of climate change as an opportunity rather than a threat, the City of Rotterdam set up the Rotterdam Climate Proof programme at the end of 2008. Rotterdam Climate Proof will make Rotterdam resilient to climate change by 2025. Permanent protection and accessibility of the Rotterdam region are key elements.

Climate projections indicate that Rotterdam will experience more extreme weather conditions such as heavier rainstorms, longer periods of drought and more heat waves. One of the largest threats is sea level rise and a changing river runoff (in the Rhine and Meuse rivers), which increases the probability of flooding. Fortunately, throughout recent centuries, Rotterdam has already taken many measures. An ingenious and robust flood protection system currently keeps the city and its port safe and dry, making Rotterdam one of the safest delta cities in the world. Still, the effects and consequences of climate change on urban development are uncertain and potential consequences could potentially be catastrophic. Therefore, doing nothing is not an option.

One of the main results of the Rotterdam adaptation programme is the launch of the Rotterdam adaptation strategy (RAS) in October 2013. This strategy "sets the course that will enable the city to adapt to the changing climate. The goal is to create a climate proof city for all the people of Rotterdam both now and for future generations - a city that is both attractive and economically prosperous" (Rotterdam Adaptation Strategy, 2013).

The primary objectives of the Rotterdam Adaptation Strategy are:

1. The city and its inhabitants are protected from the flood risk of rivers and the sea
2. The city and its inhabitants experience minimal disruption from too much or too little rainfall

3. The port of Rotterdam remains safe and accessible
4. The inhabitants of Rotterdam are aware of the effects of climate change and know what they themselves can do
5. Climate change adaptation contributes to a comfortable, pleasant and attractive city in which to live and work
6. Climate change adaptation strengthens the economy of Rotterdam as well as its image.

Almost all these objectives are directly or indirectly linked to the challenge of keeping Rotterdam safe from flooding. Fortunately, Rotterdam has a long history of protecting the city and its inhabitants against the water. And while climate change forms an additional threat, at the same time it offers the opportunity to rethink the way Rotterdam is protected, stimulating innovative ideas to flourish and to be implemented.

Figure 6.2: View over Rottterdam Rijnhaven and the ‘floating Pavilion’.

Flood management: the system

Dikes and embanked areas

Rotterdam is protected by a primary flood defense system consisting of natural dunes along the coast and manmade dikes along the rivers. These structures form so called 'dike rings'. Each ring of primary dikes protecting the embanked area of Rotterdam has its own safety standard. The standards refer to the so-called 'frequency of exceedance'. This is the probability of water levels occurring that are higher than the normative high water levels (MHW) for which the dike was constructed. In a delta city such as Rotterdam, this normative high water level (MHW) is mainly dominated by the sea (storm tides); high river flows play much less of a role. In addition to the primary dike rings, there are flexible stormsurge barriers that can be closed when storm tides are expected (the Maeslant-, Hartel- and Hollandsche Ijssel). Within the inner-dike areas, there are many polders and water outlet systems. These polders lie beneath sea level, so any surplus of water (ground and/or rain water) has to be pumped upwards towards river and sea. The waterways in the inner-dike area are flanked by regional secondary dikes to prevent flooding of the polder areas (Figure 6.3).

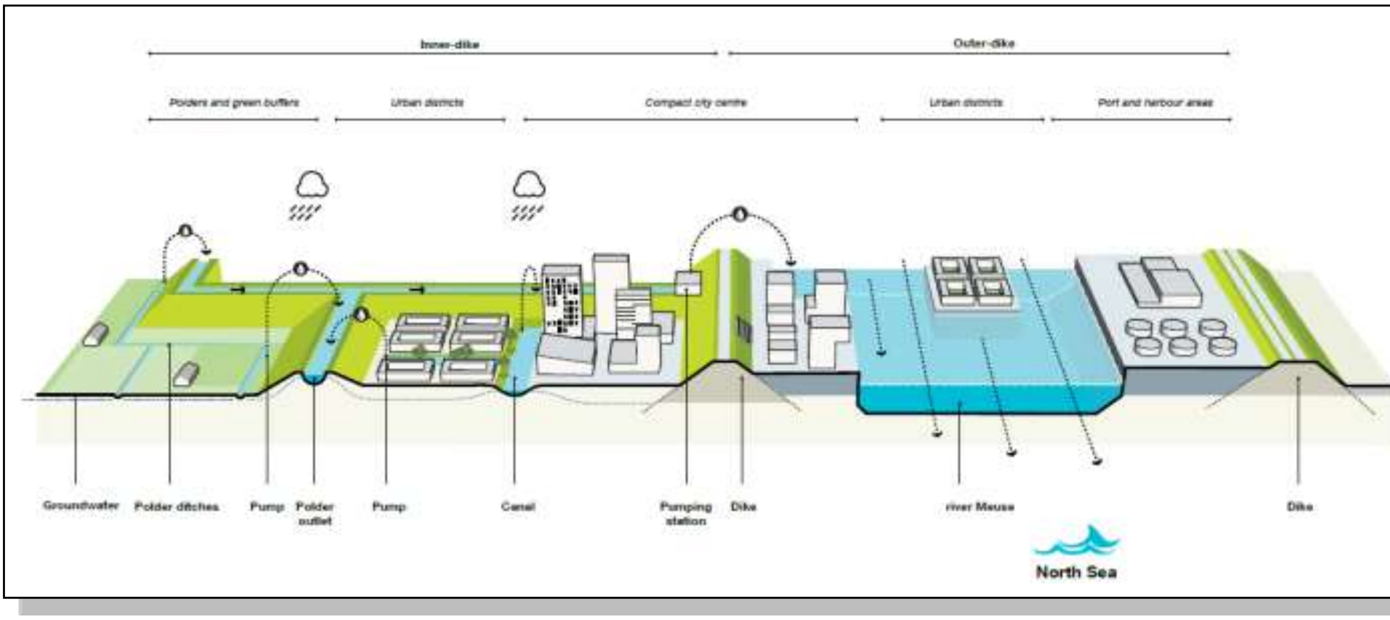


Figure 6.3: The Rotterdam water system (RAS, 2013)

In Rotterdam, the level of protection varies from 1:4,000 years in IJsselmonde (dike ring 17) to 1:10,000 years for the north bank of the river Meuse (dike ring 14, see figure 6.4). Given its location (mainly below sea level) and the potential catastrophic consequences of a flood, Rotterdam has one of the highest safety standards in the world. The dikes in Rotterdam do not only serve as a protection measure against flooding, they also are part of the spatial structure of the city and are frequently interwoven into the urban fabric. In some places the dikes are green and recreational, but elsewhere, such as the Boompjes, they are an integral part of the urban infrastructure. In addition to their protective function, the dikes have other functions such as major access roads or recreational cycle routes.

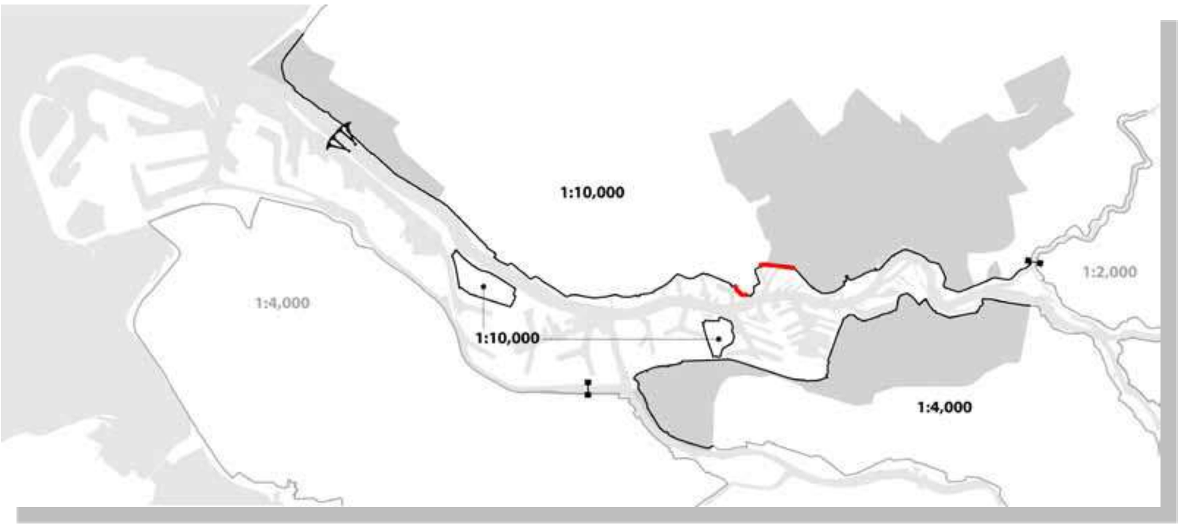


Figure 6.4: Current levels of protection in the Delta of Rotterdam. The dykes at the north side of the river and the two smaller dike rings have a frequency of exceedance of once in every 10.000 year. Southern part: 1 : 4.000.

Although the inner-dike areas are extremely well-protected from flooding, there is always a chance, however small, that a dike breaches or collapses. If flooding were to occur, the impact on the city and region would be considerable, both in terms of the number of casualties as in damage to the economy.
The consequences of flooding are shown in the risk map (see figure 6.5).

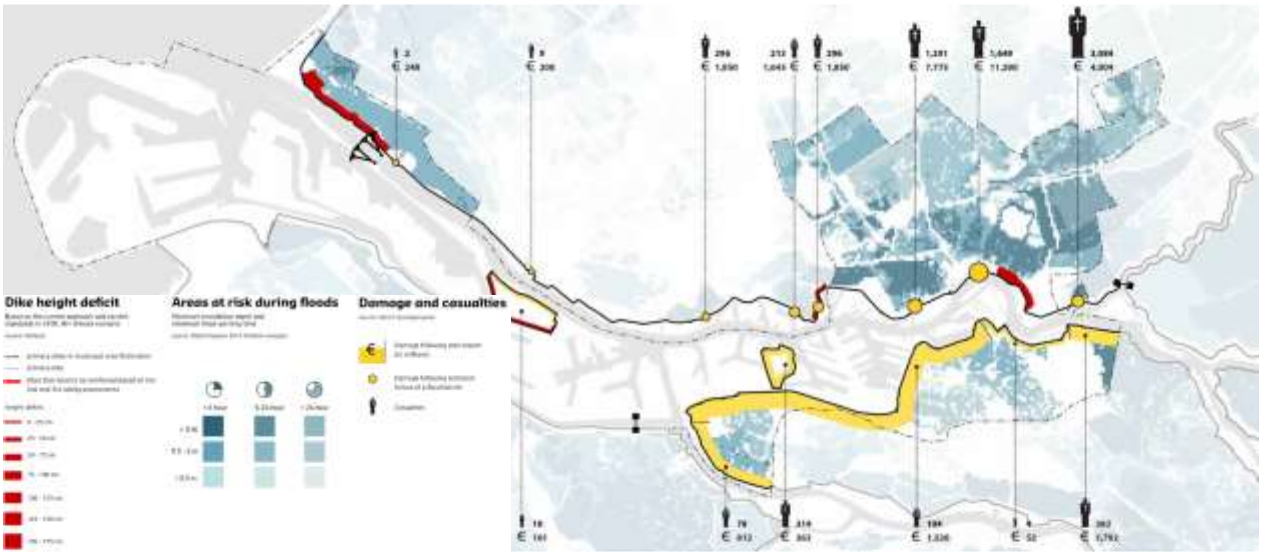


Figure 6.5: Inner-dike water safety risk map – 2100. The risk map shows the inner dike areas that are at risk of flooding together with the potential economic damage and the number of casualties resulting from a dike breach or the failure of a technical engineering works. In many places, such a situation would result in water rapidly flooding deep into the city.

Rising sea levels and changing river flows will lead to an increase in water levels. By 2100 the sea level is expected to have risen by between 35 cm and 85 cm. The frequency of exceedance of the normative high water levels (MHW) will increase and the dikes will then no longer meet the required standards. Legally, measures need to be taken. Another driving force behind the increasing flood risk is the increasing number of inhabitants and economic value of the inner-dike city. These have grown considerably over the past decades and they will increase further up to 2100.

The water levels in the polder outlets are maintained using a system of pumps and rain water storage in the polder itself. The risk of flooding can be controlled, even in case of increasing rainfall from climate change. Increasing periods of drought however can pose a new threat. This is because regional dikes in the western part of the

Netherlands are frequently constructed of or on peat and are therefore more vulnerable to drought. Compared to a dike breach in the primary system, the consequences of a failure in the regional water system are considerably less because the flood water volumes are much smaller. It can however cause wide-scale disruption and considerable damage because of the high densed areas.

Unembanked areas

The unembanked areas of Rotterdam are not protected by dikes and are directly affected by the water levels of the river and by the tide (see figure 6.3). This means that they are vulnerable to the effects of high water levels caused by storm tides at sea and high river levels. Most of the outer-dike areas are on higher ground than the inner-dike city. During development of the city and port, the outer dike areas have always been raised in order to reduce the risk of flooding. The elevation of the quaysides varies from a little less than 3 meters above NAP (+/- sea level) in the city to 5.5 meters above NAP in the industrial area of the Tweede Maasvlakte. The unembanked areas rise high above the polders, which can be as low-lying as 6 meters below NAP.

Due to the higher elevations and the effects of the tide, floods in the outer-dike areas are usually short-lived and the flood inundation depths are limited. The risk of casualties is very low. However, material damage and social disruption in these urbanized areas, including the largest port and industrial cluster in Europe, could be considerable. In addition to general disruption, the main effects will be damage to private property as well as damage to the public areas of the city. The disruption to business activities or the temporary inaccessibility of the area will cause economic losses. Furthermore flooding can cause environmental damage such as pollution resulting from the discharge of hazardous substances (see figure 6.6).

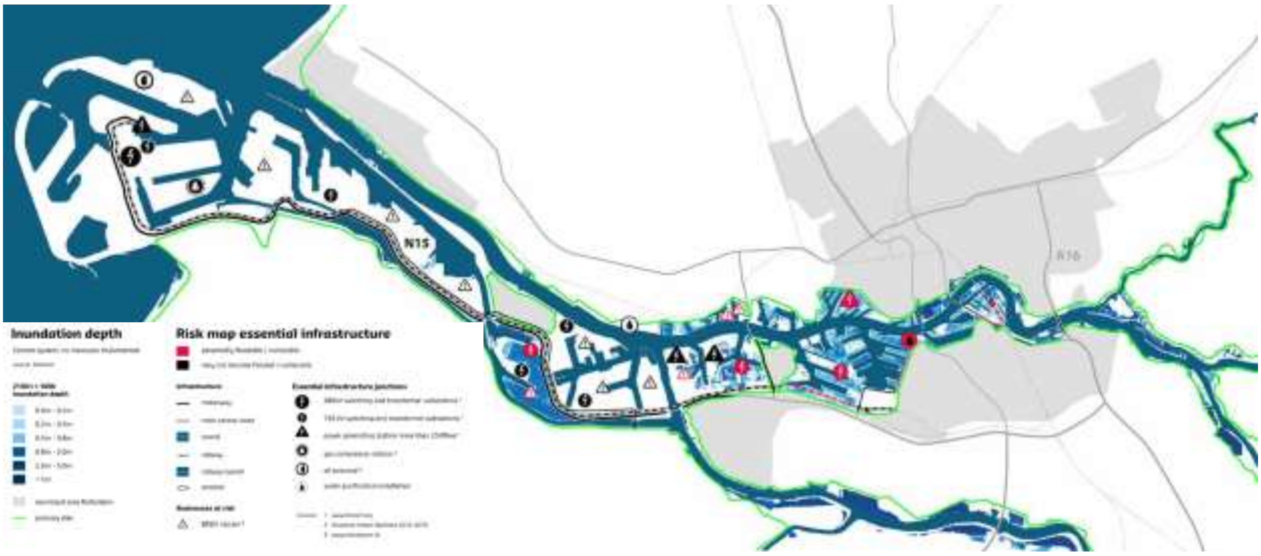


Figure 6.6: Unembanked water safety risk map – 2100. The risk map illustrates the essential infrastructure in 2100 that may potentially become flooded, based on the current system, assuming that no other climate adaptive measures are taken, and with a frequency of 1 x 1,000 years. The BRZO clusters (businesses with large quantities of hazardous substances), a number of essential power and transformer stations and some roads and railways are especially vulnerable.

Vital infrastructure in the outer-dike areas is in principle always vulnerable. This includes power stations, electricity supply, water purification plants, motorways, major roads, railways, the gas distribution network, sewers and ICT. Transformer houses and electricity substations in the historic outer-dike region of Rotterdam in particular are at risk. Many of these facilities and networks were sensibly constructed at the time on higher ground levels. However the higher water levels and their mutual dependence on various networks will make them more vulnerable. This is especially true for the port and industrial clusters. Power cuts or other disruptions to services can paralyze businesses and cause serious problems in inhabited areas. The utility networks in the unembanked areas serve the embanked areas of the city, so failures there can lead to large-scale disruption of social life in the city. If floods do occur, the resulting damage may lead to a long recovery period in which essential functions do not work properly for weeks or even months.

It is predicted that the economic value of outer-dike Rotterdam will increase over time. This means that, if no adaptive measures are taken, the risks of economic losses will also increase. This is especially true for the outer-dike urban redevelopment areas such as Stadshavens.

Flood management: the adaptation strategy

Both climate change and socio-economical development are potential threats to the delta city of Rotterdam. Sea level rise, a higher river runoff, drought, increasing population density will enlarge the current flood risk. Although the present safety levels against flooding are very high, the city needs to implement a long term flood adaptation plan. In figure x the flood adaptation strategy is shown which was established in 2013. The strategy involves a plan that focuses on the different elements of the current flood protection system:

1. Storm surge barriers
2. Embanked areas (primary dike rings)
3. Embanked areas (regional dikes)
4. Unembanked areas

The storm surge barrier (Maeslantkering) is capable to withstand 50 cm of sea level rise. The primary dikes will have to grow (step wise) with sea level rise. In the unembanked area new spatial developments must have flood proof designs (adaptive building). For a short period the flood risk of existing unembanked areas will increase but will stay in acceptable ranges. When flood risk grows even further, local protection measures can be introduced (such as flood barriers around the lower lying neighborhoods). When sea level rise exceeds the limit of 50 cm of the storm surge barrier, several strategies are possible for the river management (see figure x) next to the current one. In 2013 the steering committee of the regional Deltaprogramma Rijnmond-Drechtsteden[19] concluded that the current strategy is – even in the future - the most favorable one: storm surge barriers near the coast line combined with structural dike reinforcements (this is based on multi-criteria and cost/benefit analyses) . The strategy for the regional dikes in the embanked areas exists out of strengthening present dikes in combination with catching/storing/discharging surplus of rainwater (more details in paragraph 6.3.1).

One of the key questions involving the development of <u>resilient</u> adaptation strategies is how to deal with all the different and changing parameters like the level of sea level rise, quantity of rainfall, social development, economic development. The current flood adaptation strategy of Rotterdam takes these uncertainties into account by a stepwise approach in the development of new flood measures. This brings stronger guarantees that measures have a ‘no regret’ character.

TURAS activities

The Rotterdam Climate Proof program is an extensive program, involving a large number of different parties (governments, businesses, knowledge institutes). The city itself is the main actor and beneficial, but also other parties and programs contribute by financing and developing knowledge. Specific components of the Rotterdam adaptation strategy on flood management are investigated by TURAS. These involve (Figure 6.7):

1. Unembanked areas. In the Rotterdam region, a substantial area is not protected by dikes. These so-called unembanked areas are thus directly at risk when water levels rise. Most activities here relate to the harbour, but also some residential areas are present in the unembanked area. TURAS investigated the risk

[19] This steering committee consists out of political representatives of regional governments such as municipalities, Province, waterboards.

of these unembanked areas, the potential of flood proofing measures, and the indirect economic effects due to business chain interruption using detailed damage models and climate projections.

2. In flood research, the focus is often on catastrophic flooding originating from the river or sea. Also pluvial flooding resulting from extreme rainfall has a decent amount of attention from researchers and policy makers. However, flooding from regional waterways is much less in the picture. Nevertheless, it may amount to substantial risks. TURAS therefore joined in an effort to analyse this type of flooding better, and to develop strategies to decrease flood risk in current and future situations for a case study polder area in the Rotterdam region.

In the coming paragraphs these TURAS research activities are described in more detail. Because the city of Rotterdam has several years of experience on development of adaptation strategy also recommendations are formulated (on different levels: technical, political, governmental, financial etc.). These recommendations can be used by other European countries - especially delta cities - to develop their own resilient adaptation strategy.

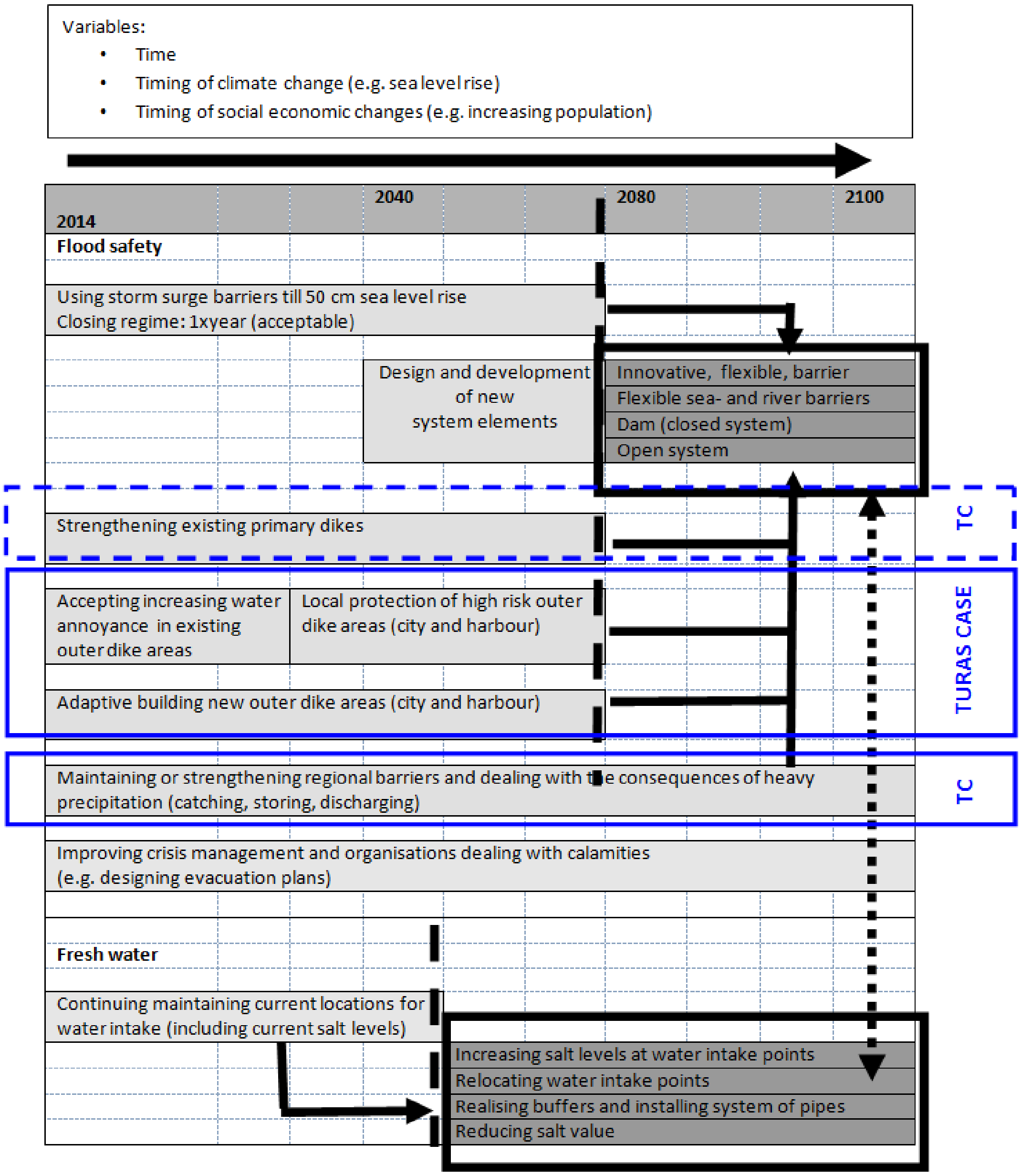


Figure 6.7: Flood protection measures, their timing and interrelatedness.

6.2 Data for strategic urban planning

Analyses of flood risks in urban regions require a plethora of information. This relates to data on the natural system and the flood hazard, data on the exposure to flooding and data on the potential consequences of flooding. Much of this information relates to the physical environment and the economy. An overview of data used in these flood studies is given in Table 6.1.

Table 6.1: overview of data used for analyses of urban flood risks

Name	Type	Available through
Hazard		
Elevation data	Spatial (raster)	Public infrastructure authority (Rijkswaterstaat) and the water boards (public)
Characteristics regional water system (dimensions of channels, location of water works etc.)	Distributed (points, line elements)	Water boards (available)
Hydrologic conditions (water levels, discharge)	Time series	Public infrastructure authority for national system (public) Water boards for regional system (available)
Exposure		
Land use	Spatial (raster)	National land registry agency (public)
Building types	Spatial (vector)	National land registry agency (public)
Industry types	Spatial (vector)	Harbour authority (available) National Labour Database (paid; hence not used)
Infrastructure elements	Spatial (points)	Electricity operator (confidential)
Consequences / Economy		
Regional Input-Output table	Table	Knowledge institutes (public)
Regional added value, traffic of roads and waterways	Table (distributed)	Central Bureau of Statistics (public) Specific studies (available)
Repair costs	Table	Specific studies (available)

Regional barriers case

The case study on regional barriers involved the commissioning of a separate study to develop a hydraulic model to estimate the inundation pattern for several breach scenarios in the polder (Nelen and Schuurmans, 2012). One of the most important inputs for such a study is the elevation data, for which the national elevation dataset AHN was used (Figure 6.8). Substantial efforts were made addressing the consequences of potential flooding. This goes for consequences within the polder, but also outside the polder as regional waterways will drain empty, which may damage boats, houses on the embankments and disrupts inland shipping. Existing studies on these subjects were used, for instance related to the costs of flooding of Schiphol airport (Keizer, 2008), shipping through the waterways (Quispel, 2008), counts of water homes (using satellite images) and information from electricity providers on assets.
For the exposure, the same land use information and damage model as was used for the unembanked case was used (see below).

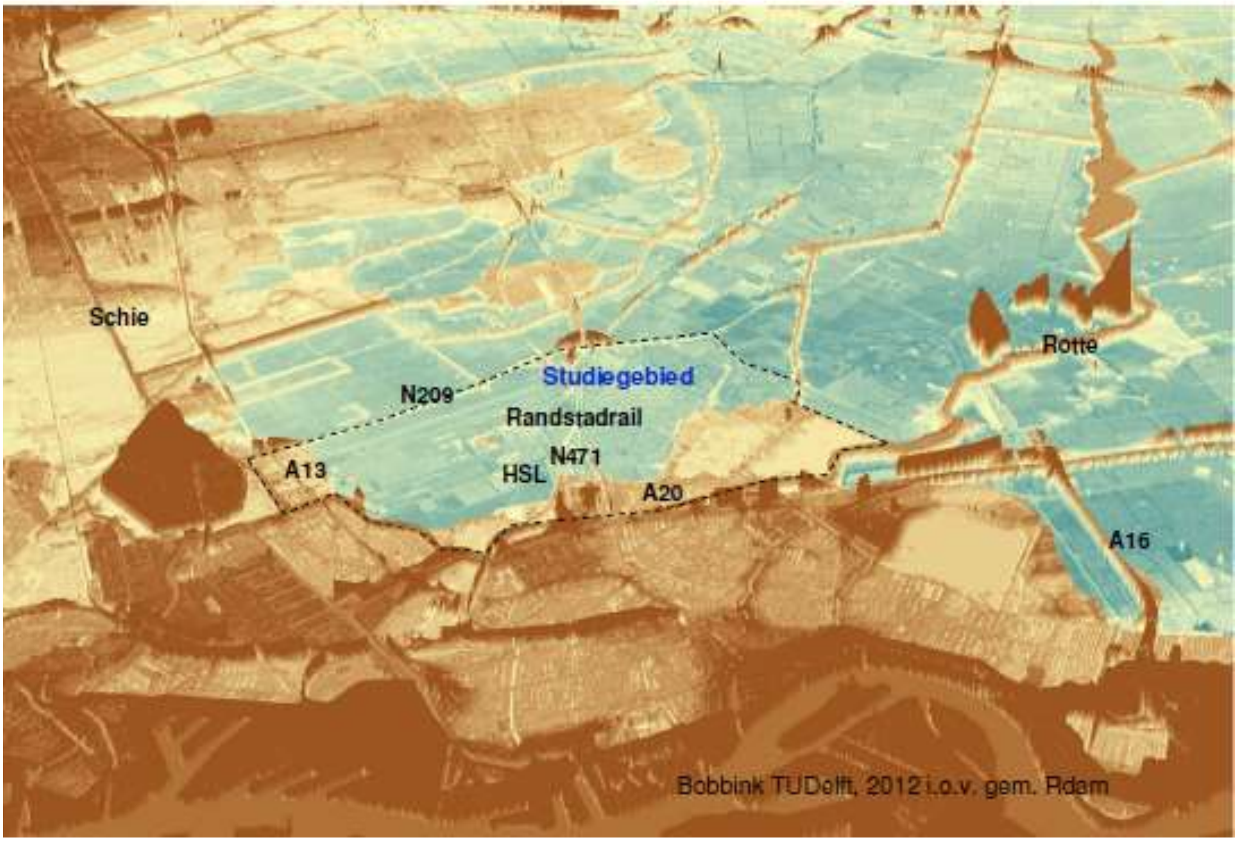


Figure 6.8: Elevation of the case study area for the study on regional embankments. Notice how the rivers Schie and Rotte are actually higher than the polder case study area (area within the dotted lines)

Unembanked area case

The modelling framework proposed to assess the direct and indirect losses due to a flood requires three data inputs: inundation maps, a land-use map and an I-O table, making it widely applicable. The inundation maps in this study are based on maps developed by Huizinga (2010), with flood return periods ranging between 1/10 and 1/10,000. In the harbour area, we assume the water flows away within one day for high-probability floods and up to one week for a low-probability flood. The land-use map (Figure 6.9) is a combination of two national land-use maps and a national asset database featuring 11 different types of buildings (De Moel et al., 2014). This map has been updated for the indirect economic by including 16 industrial land-use classes (Koks et al., in press).

For the indirect loss assessment, an Input-Output (I-O) table is required. For illustrative purposes, we make use of an I-O table for the year 1992, developed by IRIOS (Eding et al. 1999) and corrected for inflation. Even though this data is not recent, it allows us to test the modelling framework. As found in Nijdam et al. (2014), the relative industrial shares in the port have remained similar over time, which suggest that the industrial dependencies of the 1992 table are still relevant for the current port activities. However, the total losses might be possibly underestimated due to the large growth of value added in the Rotterdam port area since 1992 (Merk and Notteboom 2013). See Table 6.2 for a list of sectors that is included in this table.

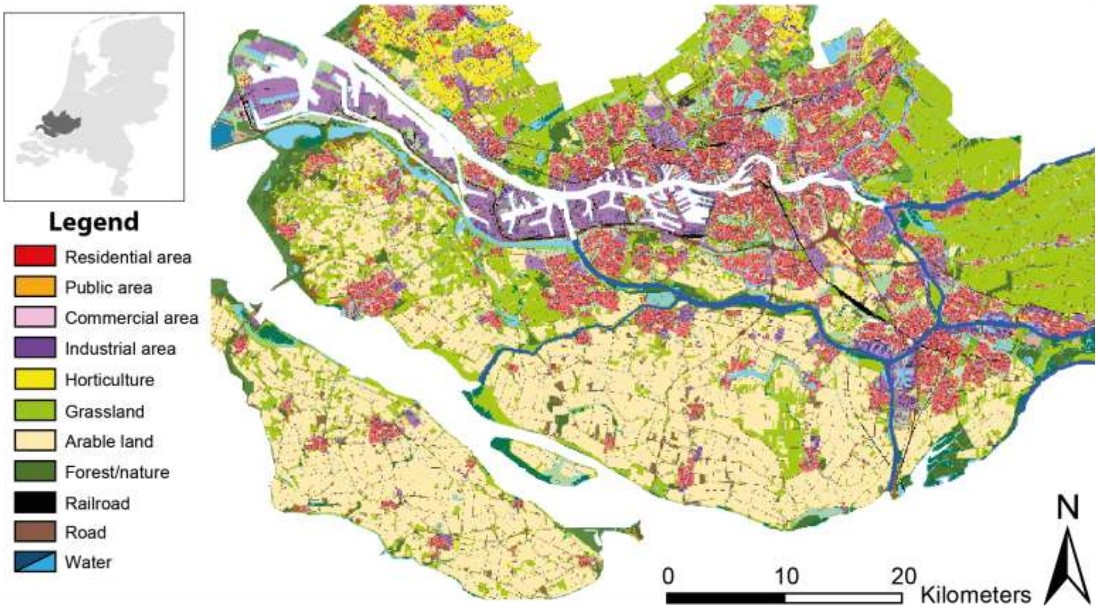


Figure 6.9: Land-use map of the greater Rotterdam area.

Table 6.2: Economic sectors in the Input-Output table

1	Agriculture, horticulture and forestry	20	Instruments, optical goods and other industry
2	Fishing	21	Public utilities
3	Mining and quarrying	22	Construction and installation of construction projects
4	Manufacture of dairy products	23	Wholesale trade, trade intermediaries and retail trade
5	Manufacture of other food products	24	Hotels, restaurant, cafe´s, etc.
6	Beverage and tobacco industry	25	Repair of consumer goods
7	Textiles industry	26	Sea and air transport
8	Clothing industry	27	Road transport and Supporting industries for transport
9	Leather, footwear and other leatherwear	28	Communication
10	Wood and furniture industry (excluding metal furniture)	29	Banking
11	Paper, cardboard and paperware industry	30	Insurance
12	Printing, publishing and related industries	31	Exploitation of and trade in real estate
13	Petroleum industry	32	Business services, renting machinery, other movables
14	Chemical, rubber and plastic-processing industry	33	Government, compulsory social security and defense
15	Building materials, earthenware and glass products	34	State and non-state subsidized education
16	Basic metal industry, manufacture of metal products and machinery	35	Social services
17	Electro technical industry	36	Health and veterinary services
18	Automobile industry	37	Cultural, sports and recreational services
19	Manufacture of other transport equipment	38	Other services

6.3 Tools and analyses for urban planning

Tools used in the case regional barriers

For the case on regional barriers, hydrodynamic models, damage models and a workshop on strategy development have been employed. Results from the integral damage analyses were shared in a workshop with several parties (mainly governmental) involved in risk management: three waterboards, Province of South of Holland, departments of the city of Rotterdam (spatial development, water, engineering), VU University of Amsterdam, design studio. Measures to reduce flood risk in de case study area were also explored by these parties. Measures varied from chance reducing ones, to measures that reduce the consequences of flooding.

Tools used in the case unembanked areas

To assess the consequences of a large-scale flood in the outer dike areas of Rotterdam, we propose and developed a framework for an integrated direct and indirect flood risk model and operationalize it for a loss assessment in the outer dike areas of Rotterdam. The framework consists of multiple steps and includes all elements for integrative loss estimation. Figure 6.10 presents an overview of the methodological framework. In the first stage, a direct loss assessment is conducted (De Moel et al. 2014), where we specifically focus on the various industries of the study area. Secondly, we show how direct losses in both capital and labour can be translated into loss in production per sector in a consistent manner, by making use of a Cobb-Douglas production function. This production loss is used to calculate the imbalanced post-disaster economic situation, by making use of the Basic Equation (Bockarjova 2007). We note that we allow for a pre-recovery period for the duration of the flood. The final step of the model is the recovery of the economy and reconstruction of the area. This final step is modelled by using a hybrid input-output model, based on the Adaptive Regional Input-Output (ARIO) model (Hallegatte 2008; Hallegatte 2014). Overall, the framework only requires three inputs: an inundation map, a land-use map and an I-O table, making it widely applicable.

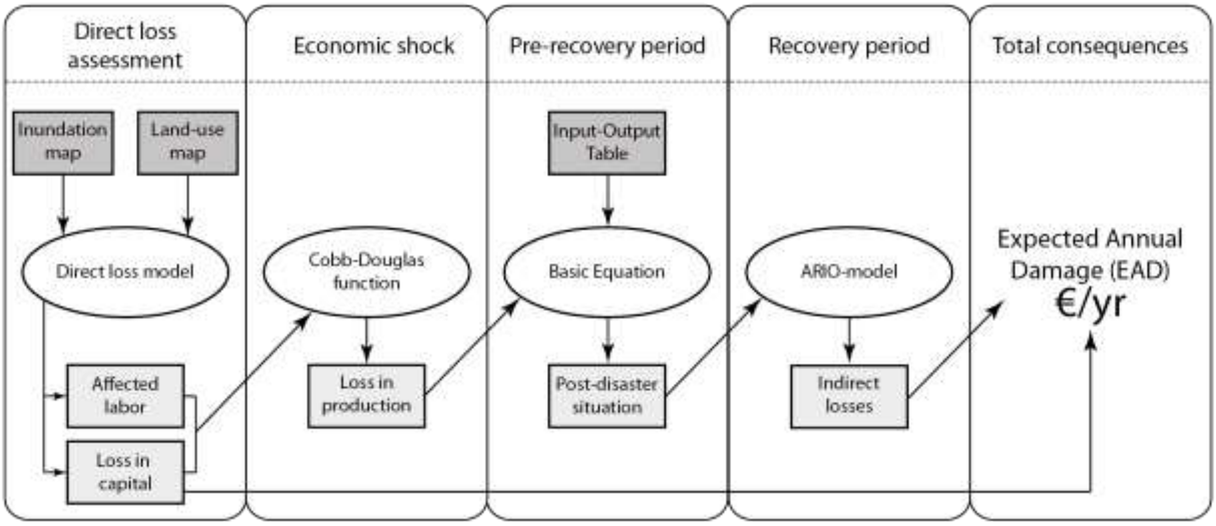


Figure 6.10: Overview of the different components of the framework. The dark grey squared boxes are the inputs, the ellipses are the different models and the light grey squared boxes are the model outputs.

Direct losses

The most common methodology for direct damage assessments is the use of depth-damage curves (Smith 1994). This approach calculates damage using spatial information on land-use classes or building types (the exposure) and inundation depths (the hazard). These maps of exposure and hazard are combined using depth-damage curves and maximum damages per class. The depth-damage functions indicate the vulnerability of each land-use class by relating the inundation depth to a fraction of the maximum damage at that inundation level (Koks et al. 2014). Every land-use class has a different amount of maximum possible damage and uses a different depth-damage function. See Figure 6.11 for examples of used depth-damage curves in this study. The maximum damages and depth-damage curves used in this study are based on De Moel et al. (2014). While in De Moel et al. (2014) two industrial classes are used, in our model we distinguish 16 different industrial classes in the harbour area, for which the maximum damages and depth-damage curves are based on Tebodin (1998; 2000). For a complete explanation of the direct loss assessment, please refer to De Moel et al. (2014). Using this model, the effects of future climate change which may increase the risk can be quantified, as well as the effect of specific measures aimed at reducing the flood risk. Such measures could include the elevation and flood-proofing of buildings (De Moel et al., 2014). Flood proofing has conceptually been divided in wet-proofing and dry-proofing. Wet-proofing entails the adjustment of buildings in such a way that damages are minimized when floodwaters enter the building (e.g. tile floors instead of wooden floor). Dry-proofing relates to sealing the building so floodwaters cannot enter (e.g. shields in front of doors/openings and making the walls water resistant).

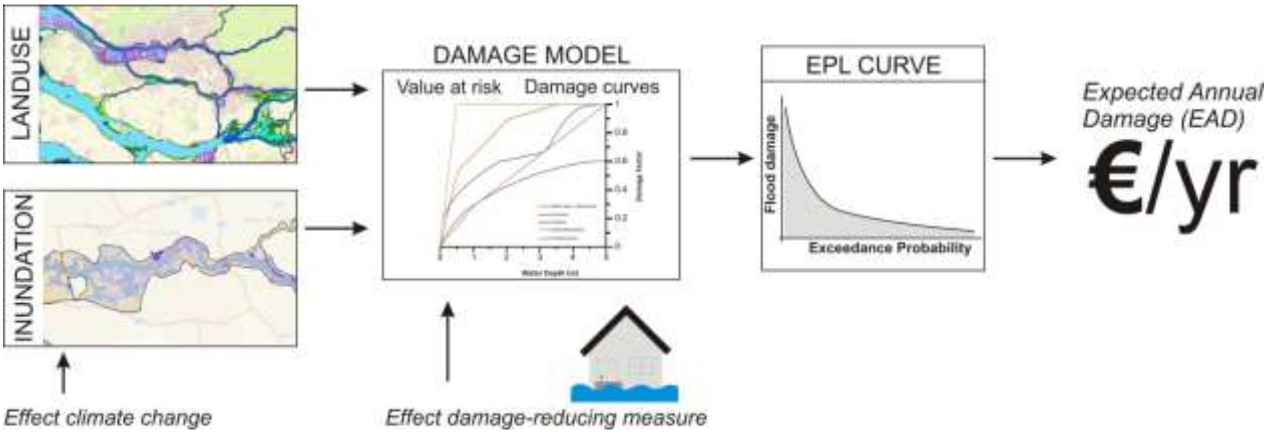


Figure 6.11: Conceptual frame of direct loss assessment using depth-damage curves

Economic shock
In economic modelling a natural disaster is often translated into an exogenous shock affecting the economy. This exogenous shock, however, is often estimated rather arbitrary by taking crude estimates of initial production losses in a specific area (e.g. Rose and Wei 2013; Li et al. 2013). Such an arbitrary estimation is accepted as the main focus in economic literature is often the modelling of the indirect effects and to gain insights in the economic processes. Besides, due to limited empirical data it is often uncertain what 'good' estimates are for this exogenous shock. Nonetheless, as has been shown in literature as well (Hallegatte 2008; Koks et al. in press), the size of the initial disaster losses has a considerable influence on the recovery duration and the size of the indirect losses. Therefore, if data is available, a more detailed assessment of the shock is desirable. By converting the direct damages to a reduction in value-added, the initial production losses due to the disaster can be assessed.

Pre-recovery period
After the economic shock is defined, the next step is to assess the production loss in the period directly after the flood. Floods in recent history (e.g. the floods in central Europe in 2002 and 2013) have shown that it can take a long time before all the water recedes. Thus, for the period of flood duration, everyday routines are distorted, firms are not able to produce, and reconstruction cannot begin. It is important to note that, due to the different types of floods and different characteristics of areas prone to flooding, assumptions about flood duration may vary substantially across the areas, and may lead to a high variability in model parameters related to flood duration (as will be discussed in Sections 3 and 5). A flood occurring in the outer-dyke areas is expected to be a briefer event than, for instance, a flood occurring in a polder area, where it can take up to several months before all the water is pumped out (Wagenaar 2012).

Recovery period
After the water has receded and the area is accessible again, reconstruction of the area can begin. For the recovery period, use is made of the ARIO model (Adaptive Regional Input-Output model) developed by Hallegatte (2008, 2014). The ARIO model is an Input-Output based model, modeling economic adjustments in response to a natural disaster. It allows accounting for the heterogeneity in goods and services within sectors, for consequences of production bottlenecks and substitution possibilities on the recovery of total output. See Figure 6.12 for an

overview of the most important modelling steps in the ARIO model and Hallegatte (2008, 2014) for an extensive explanation of the model. As the model is dependent on a large number of parameters, assumptions have to be made for the economic structure in the area under investigation. These assumptions are based on expert knowledge of the area (Merk and Notteboom 2013) and disaster modeling literature (Okuyama 2010; Hallegatte 2014). Flood damages to capital of both industries and households are added to the final demand in the input-output model, as we assume that the consequences of the flood result in additional demands of households and industries for goods and services in the retail and construction sectors. In modeling recovery, production will be increasing gradually during multiple iterations looped by day, until the initial situation is reached. At each step, the new production capacity is re-assessed, taking into account the reduction in remaining damage and increase in labor.

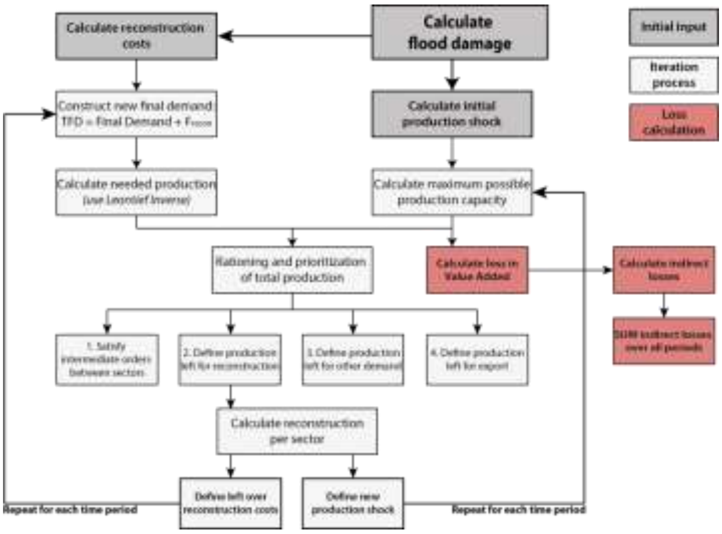


Figure 6.12: Modelling framework of the most important steps within the ARIO model.

The remaining direct losses will reduce over each time period, and the total output produced will converge to the pre-disaster level. From this calculation, we can derive the total indirect losses by calculating the difference between the total value added throughout the recovery period, if no flood had occurred, and the total value added for each time period in the recovery period. Finally, when adding the specific direct and indirect losses for each return period, we can calculate the expected annual damage for the case-study area.

Due to the large amount of parameters, uncertainty in the model outcome is inevitable. To overcome some of this uncertainty, we perform a global sensitivity analysis, which enables us to explore the variation in model output and to allocate the variation in this output to the different input parameters. Besides performing a global sensitivity analysis to investigate the effect of parameter uncertainty, we also explored in closer detail the effect of a couple of key modeling assumptions which cannot be explored in full detail within a global SA. They will either overrule the influence of other model parameters, due to their expected large influence on model output, or refer to assumptions in model structure that cannot be captured by a parameter (and thus cannot be included within a global SA). The former refers to the time of labor recovery and availability of inventories. Therefore, within the global sensitivity analysis, the distribution of these parameters is assumed to be within realistic boundaries. However, it is worth investigating what would happen if extreme situations occur during the recovery period. The second reason given applies to the restriction of stock in the construction and retail sector and for the variation in flood duration.

6.4 Findings of case study

Results from the case regional barriers

The case study of the regional barriers investigated current and future flood risk, including strategies to maintain current flood standards. Existing estimates of the flood damage involve 1600 million euro, resulting in the highest protection level for this polder area. In the case study a new damage assessment was done by running a dynamic model and a flood damage model (output flood maps: Figure 6.13). Because of the high accuracy of these models it was found that the old model overestimated the potential damage in the polder Zestienhoven Schiebroek. The new damage was estimated between 300 – 400 million euro.

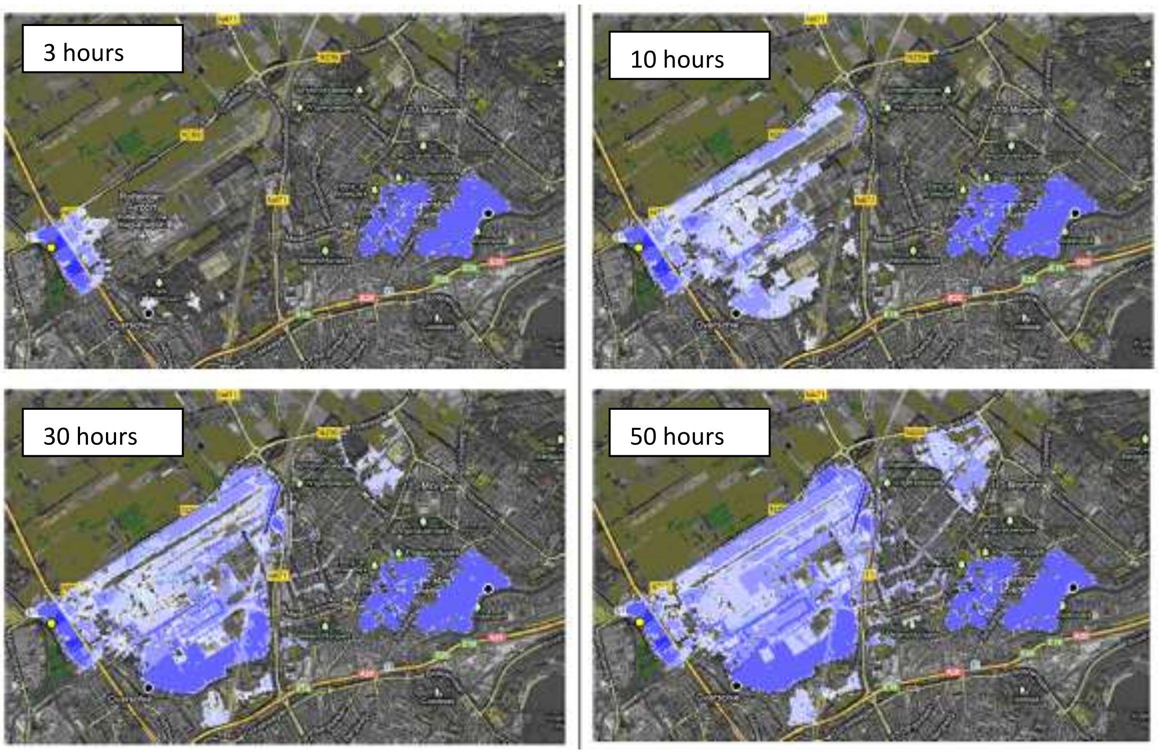


Figure 6.13: Floodmaps of case study area Zestienhoven-Schiebroek, 3/10/30/50 hours after a dike breach in the canal (yellow dot at the left).

This is a unique result because the new estimates also involve more and newly distinguished damage categories. Examples of these new categories include damage to airport and shipping facilities, foundations of buildings next to the canal (far away from the actual flood area), dike repair costs, and environmental damage (small scale pollution). It was also found that not all of the distinguished categories could be translated into financial damage. Further knowledge development is needed on these areas. Although the actual, quantified damage will be significantly larger, the overall conclusion was that this number is more in line with the used ranges within the current flood standards. Damage per category is shown in Table 6.3.

Table 6.3: Damage categories in case of the river Schie flooding into the polder Zestienhoven-Schiebroek

Damage category	**Expected damage in case of dyke breach along the Schie**
Land use (HIS model VU Amsterdam)	€ 230.000.000
Damage to airport and planes	€ 42.600.000
Repairing the dyke and the road	€ 50.000
Business interruption airport	€ 70.000 / day
Business interruption polder	€ 5.100.000 / day
Casualties	3
Damage category (costs unknown)	
Interruption of professional shipping	27 professional vessels / day
Interruption of recreational shipping	25 recreational vessels / day
Damage to the water system	Schie: 398 km quays (Rotte 249 km)
Damage to houses on the dyke	Damage to foundations (non-quantified)
Damage to road (highway A13) and rail (HSL-line) infrastructure	Non-quantified
Damage to other vital infrastructure (electricity)	Damage and potential interruption of 500 small relay stations
Environmental damage	2 locations with polluted top soil
Damage to houseboats and vessels	Schie: circa 10 houseboats Rotte 135 houseboats and more than 1.000 recreational vessels

Results from the case unembanked areas

Direct losses and damage-reducing measures
Flood damage for the unembanked area of Rotterdam has been calculated for six flood scenarios with different return periods (1/10 to 1/10.000 per year). By combing these damage estimates the average damage per year (or expected annual damage: EAD) can be calculated. This flood risk in terms of direct losses is roughly 36 million euro/year. This damage results mainly from the many industrial areas located in the unembanked areas (60% of risk), but also residential and other urban landuse (25% of risk). These lands only comprise about 7% of the total unembanked area of the larger Rotterdam region, whilst agriculture and nature/recreation comprise about 75% of the lands, but constitute only 6% to the total risk.

The potential to reduce flood risk using damage-reducing measures such as elevating and flood-proofing buildings is illustrated in Table 6.4. Here only the risk to residential buildings is shown (2.5 million euro/year). The results show that damage-reducing measures can considerably reduce the flood risk in this area. This is related to the relatively low water levels in the unembanked area as many tracks of land are already elevated a bit (see also Figure 6.8). For instance, elevating all houses by just 50cm would reduce the flood risk to residential buildings by about 80%. Table X also shows the effect of climate change on flood risk, almost doubling or tripling the risk by 2050 and 2100 respectively. Damage-reducing measures seem well-suited to adapt to this risk.

Table 6.4: Risk to residential buildings and the effects of climate change and damage-reducing measures.

EAD Residential buildings (€/yr)	Current		2050		2100	
	EAD	% change	EAD	% change	EAD	% change
No measure	**2.5**		4.5	+82%	6.9	+180%
Warning	2.1	-16%	3.8	+54%	5.9	+138%
Wet proofing	1.5	-40%	2.7	+11%	4.2	+71%
Dry proofing	0.3	-89%	0.6	-76%	1.0	-60%
Building +50cm	0.4	-83%	0.9	-63%	1.6	-34%
Building +100cm	0.1	-97%	0.2	-90%	0.4	-82%
Building +200cm	0.0	-99%	0.1	-96%	0.2	-93%

Indirect economic losses

For the unembanked areas of Rotterdam also the indirect losses (Table 6.5) were determined. For high-probability floods, we see that direct losses are almost two times higher than the indirect losses (0.22 billion Euro damage for direct losses versus 0.13 billion Euro damage for indirect losses). However, as soon as the flood becomes less probable and more severe, the indirect losses start to take a much higher share in the total losses (up to 60% for the 1/10,000 flood). From floods with a return period of 1/4,000 and higher (under current climate), we find that the indirect losses are larger than the direct losses. This difference can be explained due to the expected relative quick recovery with high-probability floods, which prevents large income losses within the affected area as well as elsewhere in the economy. At the same time, low-probability floods are more severe due to higher water depths, somewhat longer flood durations and a larger flood extent, thus leaving many more businesses directly affected. Besides, because a larger share of sectors is out of business, income that is lost over a longer period of time and a longer recovery period result in high indirect losses in the rest of an economy, and therefore high indirect losses for this type of floods. When combining the losses for different return periods into EAD we see that the indirect risk accounts for almost 40% of the total risk. When disaggregating the direct losses for the 1/10,000 flood, the largest share in damages can be found in the retail sector (35%), the oil sector (17%) and in residential areas (10%).

Table 6.5: Flood loss and risk estimates for the Rotterdam area

Return period	Direct losses (in billions Euro)	Indirect losses (in billions Euro)	Total losses (in billions Euro)	Time to recover (99% of initial production)
1/10	0.22	0.13	0.35	18 days
1/100	0.44	0.29	0.73	78 days
1/1,000	0.76	0.61	1.37	173 days
1/2,000	0.92	0.83	1.76	255 days
1/4,000	1.10	1.14	2.23	351 days
1/10,000	1.88	2.51	4.39	647 days
EAD (million Euro/year)	**36.1**	**23.4**	**59.5**	

Figure 6.14 shows the total output of the greater Rotterdam area (see Figure 6.9) in the post-disaster period for each time period. As can be seen, when the flood hits the area, the economy is not at its lowest point. The most important reason for this phenomenon is the fact that most of the firms still have inventories available. As soon as all the firms run out of stock, the economy hits the lowest point. Directly thereafter, however, we see a rather quick recovery in the first couple of months. The main reason is the recovery of labour which is assumed to last for maximum three months (this is assumed for all return periods). After labour is recovered, it is mostly capital that needs to be reconstructed. As seen in Table 2, for high-probability floods where the damages are low and relatively little capital is lost, recovery to the pre-disaster situation is quick (several weeks to several months). For the low-probability floods the recovery period can last up till several years.

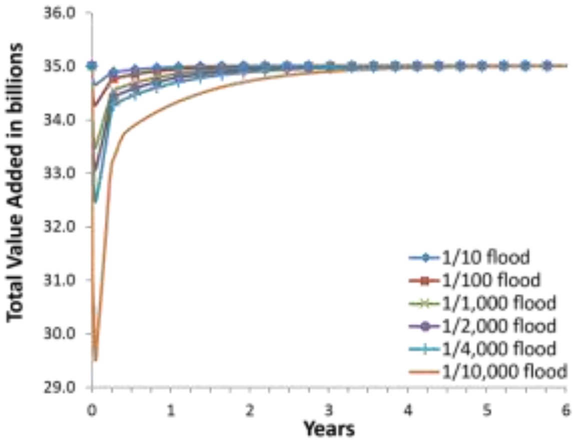


Figure 6.14: Total productivity (in Value Added) per time period in the post-disaster period for the total regional economy

Uncertainty and sensitivity

The histograms in Figure 6.15 visualize the variation in model output for three different inundation scenarios. The panel on the left shows the histogram of a 1/100 flood, which is much more normally distributed than the panel on the right (a 1/10,000 flood), which is particularly right-skewed and has a long tail going into higher indirect losses. These outcomes imply that the different model parameters have different influences across different severities of floods. This becomes evident from the diagrams in Figure 6. For the 1/100 flood, the speed of reconstruction exerts the highest influence on the model output (the green part), followed by the heterogeneity of the economy (the orange part). For the 1/1,000 flood, this is just the other way round (i.e. heterogeneity of the economy now has the highest influence). For both floods, labour recovery (the blue part) has the third highest influence, albeit much smaller than the other two. The 1/10,000 flood shows a slightly different pattern. Again, the heterogeneity of the economy and the speed of recovery have a large influence, but also the household to firm capital ownership ratio (the purple part) now shows a significant influence on the model output. This implies that for large-scale floods, damage estimates may vary substantially depending on whether predominantly local, privately owned businesses are hit by the flood, or large businesses that are less dependent on the regional economy.

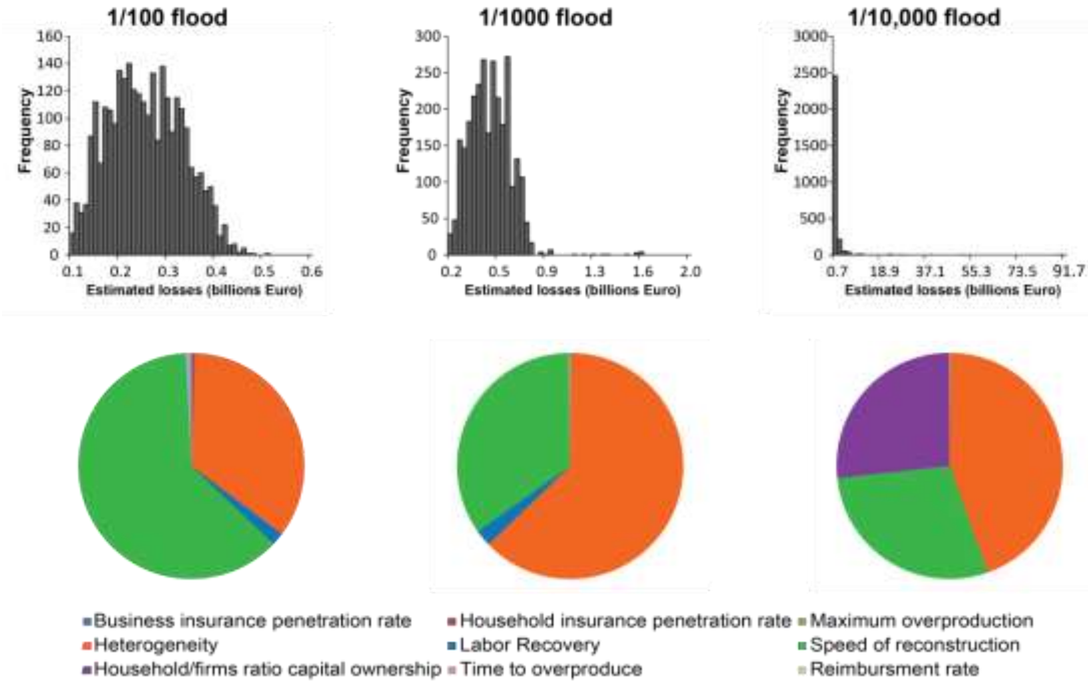


Figure 6.15: Results of the uncertainty (histograms) and sensitivity (pie charts) analyses for the 1/100, 1/1,000 and 1/10,000 floods. The histograms show the variation in the damage estimates resulting from the Monte Carlo analyses. Note that a different scale is used for the x and y-axis between the different floods. The pie charts represent the total variance of the output and indicate how much the uncertainty in each of the input parameter contributes to the variance of the damage estimates.

Figure 6.16 shows the different model outputs when varying labour recovery and flood duration. The left-hand panel of Figure 6 shows the post-disaster period for different labour recovery periods for the 1/10,000 flood, where up to 12 months there are no considerable changes in the recovery path. However, if labour recovery takes up to 24 months, the recovery takes much longer and the losses almost quadruple compared to a labour recovery period of three months. Similar results are found for the flood duration (right-hand panel of Figure 6). Up to 140 days of no recovery, the recovery path stays relative similar. However, when the area is inundated for up to 280 days, we find a significant increase in losses (losses triple). Flood duration can thus be an important factor impacting (indirect) flood losses. Both results imply that from a certain threshold in flood impact, the regional economy has severe problems in getting back to its pre-disaster state. However, it is important to note that for the labour recovery and flood duration, respectively, 24 months and 280 days are extreme cases and are expected to be rare occurrences. Nonetheless, it shows how vulnerable an economy can be when extreme events occur.

When we reduce the inventories of all sectors by 50% and assume also an inventory restoration that takes twice as long as in the baseline case, the indirect losses for the 1/10,000 flood double. It is important to note that this increase is only visible for the 1/10,000 flood. For the higher-probability floods, almost no differences occur. This implies that the size of inventories only matter for a particularly severe and spatially extensive flood. On the other hand, when we double the post-disaster inventory of each sector, the indirect losses for the 1/10,000 flood decrease by only 8%. This suggests that there might be an optimum value of stock available, which may have important implication for disaster preparedness measures. Finally, reducing the available inventories by more than 50%, the indirect losses increase exponentially (up to ten times). Sectors running out of inventories and thus unable to deliver therefore impose limitations on production possibilities of other sectors throughout the economy. This can eventually result in a full production stop, leading to economic collapse (Hallegatte 2014).

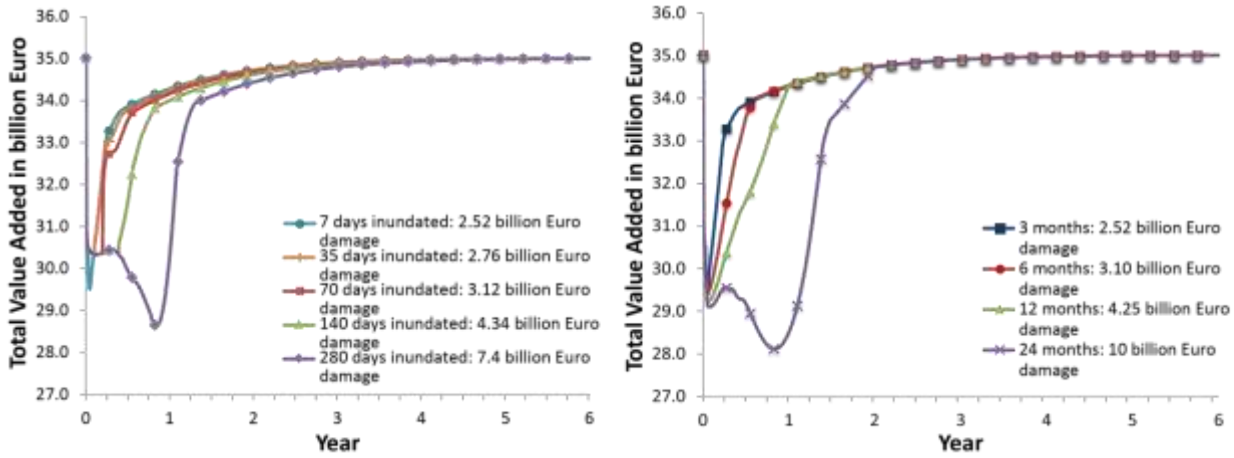


Figure 6.16: Recovery paths for the 'flood duration' (left panel) and 'labour recovery' (right panel) parameters for a 1/10,000 flood. The total flood damage for each scenario is shown in the legend of the graph.

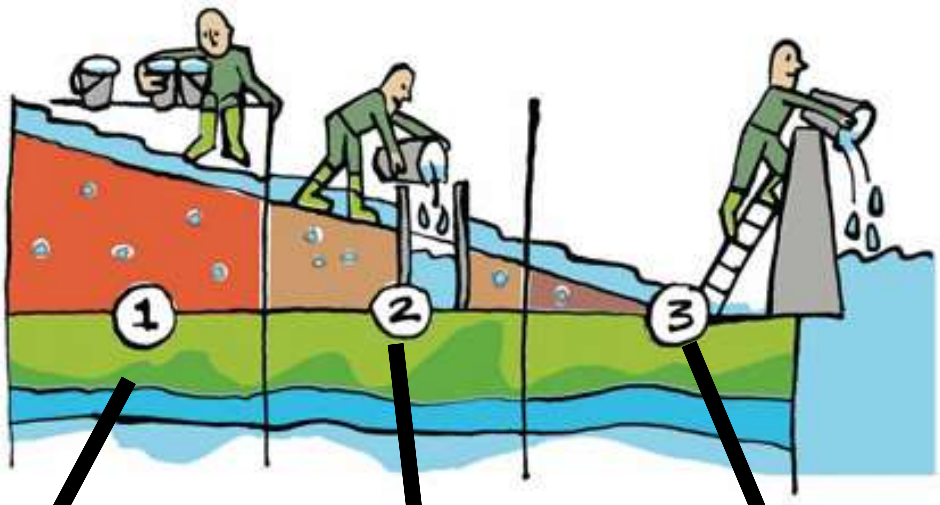
Conclusions

Case regional barriers:
In order to control the risks of a breach in the regional dyke, the following strategies have been identified in a workshop with all governmental stakeholders (province, water boards, city departments):

- Strengthening the dyke (current policy; reducing the chance of flooding)
- Controlled storage of flood water (in less dense areas so the damage will be less);
- Dividing the polder into different compartments (the flood will be restricted to a specific area)
- Dividing the polder outlets/canals into compartments (upstream dams can stop the flooding);
- Development of adaptive building (dry and wet proof houses, buildings and infrastructure);
- Evacuation of people from the entire area (focus on reducing casualty risk, not economical damage);

Because strong dykes (high flood standards) can reduce flood risk effective and continously, this strategy represents the core of both current and future risk policy. To reduce flood consequences even further other strategies can complement this core, prevention-based strategy. At first combined flood measures with spatial development (infrastructure, housing) looked promising because of the integral character and the ability to create attractive surroundings. However, the case study concluded that one measure in particular is very simple and effective to implement: damming the canal up- and downstream of the dike breach during a flood. This is possible because the volumes of floodwater from the canal are limited and therefore managable. This solution can be realised by technical compartments in the canal itself or by creating improvised dams of clay/big bags filled with sand. Cost benefit analyses also showed that adaptive building in new neighbourhoods is not efficient. Since all measures relate to the watersystem (dikes, dams) there seems to be no urgent matter for strategic urban planning. There are however exeptions like electric power plants, nuclear plants. But even in these cases it seems more effective to take protective measures at the level of the functions themselves (e.g. flood proof power plant).

In the case study and Rotterdam Climate Proof program it was also concluded that Rotterdam already has a sufficient, regional strategy to approach climate change up to 2100. Due to climate change heavier rainfall can cause direct flooding of the polder area as well as indirect flooding (after a dike breach). By seeking and maintaining an exact balance between retainment of rainwater, storing surplus of water in defined places and discharging it towards river and sea the hydrologic pressure on the canals can be controlled (Figure 6.17). Last couple of years Rotterdam implements new tactics by installing underground water storages and digging more open water spaces (retention areas), by unrolling green roofs on a large scale (retaining and holding water on the roofs), and by installing more and better pumps (discharging). Also these solutions have more benefits than only the reduction of flood risk: they help to increase the attractiveness of the city, make more efficient use of the heavilly occupied area in the city.



Water retainment on green roofs

Waterstorages: water squares and storage in a separate unit of an undergroundparking garage

Building new pumps and optimalized maintenance of existing drainage pumps,

Figuur 6.17: Possible solutions to maintain flood risk from heavy rainfall according to the principle of retain (1) , store (2), discharge towards river and sea (3).

Case unembanked areas:
From the case study unembanked areas (amongst other studies conducted under Rotterdam Climate Proof) it is concluded that the strategic urban planning is particularly suitable for the developments in unembanked areas because flood depths remain relatively low during flood. The risk profile exists mainly of flood damage rather than casualties. This facilitates large opportunities for adaptive building and policies specified per function. Vulnerable functions like hospitals, chemical plants, and vital infrastructure can be assigned higher safety standards because consequences of flooding would be relatively larger. In practice higher standards can be achieved by raising the ground where these objects are build or by dry/wet proofing certain vulnerable elements of buildings or chemical plants. In this way flood standards are customized by the type of functions in unembanked areas, whereas in embanked areas the flood standard is realized 'at the front door': the dike (regional and primary).
Above the specified ground level (basic standard) the inhabitants and companies in the unembanked areas are fully responsible for their own flood risk. Risks can therefore be further reduced by making residents and companies more aware about potential flood risks, both on the side of the chance of a flood as the potential measures they can take themselves.

From the results of the indirect loss assessment, we can draw two main conclusions to help improve flood risk management strategies. First, we find that there is a substantial difference between the assessment of the consequences of small and large-scale floods. This implies that the type of flood is important to consider when assessing flood risk for a specific region and making policy choices. Second, the results imply that maintaining an inventory to allow a certain degree of flexibility in the production chain should be an important focus in disaster preparedness and recovery planning. It is important that businesses in flood-prone areas can maintain and quickly restore their inventories to speed up the recovery process.

6.5 Lessons on process

From the two case studies as well as the Rotterdam Climate Proof program itself (since 2009) several lessons can be derived which are useful for other EU cities when developing climate change adaptation plans and strategic urban planning.

One of the most important lessons learnt is that a high quality problem analysis is essential: understanding both the system and the climate effects and link these to other relevant issues like spatial planning, social-economic developments. A high quality analysis also means looking beyond the city limits and involving different stakeholders, like water boards, researchers, companies and even other cities.

However, there is a huge gap between the world of policy makers and people working in the field. One essential factor is the difference in time horizon. While most researchers have four years or more for a thorough and high quality research assignment, the city's policy makers need immediate and probably more integral answers to fill current knowledge gaps. And even when policy makers do have time to wait for research results, dynamic topics like flood safety demand quick answers since research questions seem to be overtaken by new knowledge very fast.

Another gap is spotted between the policy makers from different fields of expertise. Time (to get to know each other) is the critical success factor here as well as the personality of people involved. Key players need to keep an open mind, think out of the box, have patience (but not too much) and value an integrated approach. Being able to translate flood proof knowledge into concrete indicators for spatial planners is another critical success factor. One main result of the RAS is that we have created a pool of policy makers which understand climate change and flood safety, who can read the signs and take action (or give information) when needed. We made the city more adaptive by enlarging our own adaptive capacity.

A very import factor for success is the ability to raise broad support, in order to be able to make an integrated problem analysis as well as invent integrated solutions. Specifically broad support is needed on management level. Rotterdam managed to get this broad support, mainly due to a visionary mayor and elderly woman and because of the momentum that was created when different developments merged. On a national level the Deltaprogramma was launched, on a regional level, Rotterdam became a so called hotspot for a national research program called Knowledge for Climate and on a local level, the city's International Advisory Board advised Rotterdam to focus on water and climate change as a unique selling point of the city.

Raising support is one step, keeping it is another. In order to keep climate change on the agenda, Rotterdam focused on three tracks: knowledge, action and image. Together with scientists and consultants, knowledge was generated helping the city to understand both the effects and challenges of climate change as well as the possible measures and chances. At the same time the city already took some clearly visible measures that strengthened the city's ability to adapt to climate change while also enhancing the city's attractiveness to citizens. By doing so, the city showed that adaptation measures have a clear added value for the city and its inhabitants and that its climate ambitions are for real. Moreover it underlines the city's innovative image and attracts worldwide attention, potentially generating a chance for new businesses in the region. The focus on action while doing research also had another advantage: by pointing out that a lot of climate adaptation measures have a high no-regret factor, since they benefit the city in other ways as well, Rotterdam can focus on prevention and make the city more climate resilient without having to face a disastrous event first.

However, although broad support is essential, as well as innovative results and positive media coverage, the underlying critical success factors are money and dedicated people who can actually devote their time to strengthening the city's ability to adapt to climate change. There's always a risk that short term project parameters weight heavier than long term maintenance or strategic objectives. By focusing on strategic urban planning instead of on specific projects Rotterdam tries to overcome this. Working with scenarios seems to help. Policy makers and others involved need to learn how to deal with uncertainties. Still, when granting a project to project developers, specific demands are needed instead of some band-with.

Finally, one other important learning (although it may sound simple): the focus on action besides focus on knowledge and image required a thru paradigm shift among policy makers. It turned out that the leading way of doing things is combining knowledge development together with taking action. In the RAS process civil servants were asked to act while the outcome was less certain. And off course, this has resulted in some mistakes. But as it turned out, using the experience of failed initiatives eventually leads to successful projects, strengthening not only the adaptive capacity of the city but that of the experts involved as well.

6.6 Recommendations resulting from case study

1. **Perform a good problem analysis, including an analysis of the system**. From the case study on regional barriers it is concluded that no direct strategic urban planning is needed to control current flood risk, like flood zoning or adaptive building. Measures can be taken on the level of the water system by placing dams in the canals after a breach.
2. **When performing a good problem analysis, look beyond the city limits and involve other stakeholders**. Flood proofing the city and strategic urban planning depends on decisions that are being taken at the national or even European level. An integrated view is the key to success, but that requires working together with a variety of parties and experts.
3. **Define questions with researchers at an early stage.** Working closely together with researchers has proven to be very beneficial. The challenge, however, is to define the right questions, preferably at an early stage and together with different stakeholders.
4. **Align the time horizons of researchers and policy makers.** If policymakers need to wait four years for an answer to their question, the momentum is lost and politicians will take a decision without having been able to take the researcher's input into account. Researchers might want to divide their work into smaller parts, each time focusing on finding partial answers which later on can be integrated into one large dissertation.
5. **Arrange support at a management level.** Making an integrated problem analysis with different experts takes time. Critical success factors for Rotterdam have been a visionary mayor and elderly woman and the luck that initiatives taken at different levels (national, regional) merged in the city.
6. **Start taking action, even when uncertainties remain.** While research was being done, Rotterdam already implemented some measures, clearly visible for the public, which strengthened the cities adaptive capacity and at the same time improved the quality of public space. By doing so, the city showed that adaptation measures have a clear added value for the city and its inhabitants and that its climate ambitions are for real. This also helped in keeping the (political) support that was raised.
7. **Exploit your success.** Visible, innovative measures underline the city's innovative image and attract world wide attention, potentially generating a chance for new businesses in the region.
8. **Invest in people…** A good team consists of people from different fields of expertise. It takes time for them to get to know each other and to develop a common language. Critical success factors for a good team are: Key players need to keep an open mind, think out of the box, have patience (but not too much), value an integrated approach and are able to translate flood proof knowledge into concrete indicators for spatial planners. In the end broad support is essential, as well as innovative results and positive media coverage, but the underlying critical success factors are money and dedicated people who can actually devote their time to strengthening the city's ability to adapt to climate change.
9. **… as well as in strategic urban planning.** The risk of short term project parameters weighting heavier than long term maintenance objectives, is (hopefully) being overcome by focusing on strategic urban planning instead of on specific projects. One tool that seems helpful in long term urban planning is the use of scenario's.
10. **Make use of pictures and illustrations.** The RAS document, presented in October 2013, tells a comprehensive story and is ornamented with lots of illustrations and pictures. As a result, the document attracts a variety of people like politicians, businesses, citizens and NGOs, besides policy makers, researchers and consultants. When people understand the story, they are more willing to take action!
11. **Don't be afraid to make mistakes.** The experience of failed initiatives eventually lead to successful projects, strengthening not only the adaptive capacity of the city but that of the experts involved as well.
12. **Be aware of changing governance/responsibilities**. In the outer dike areas, the city runs the risk of becoming a water manager. But that's not the aim nor the role.
13. **Develop new spatial instruments including flood management**. Spatial planning tools are needed in order to integrate water and flood safety issues practically into spatial plans for the outer dike areas. Examples are the *watertoets* for embanked areas, or the function specific design levels for developments in unembanked areas.

7. Urban climate – Rotterdam

This chapter discusses Rotterdam's urban climate. Due to climate change the city will face more extreme rainfall events and higher temperatures, leading to an increase in tropical days and nights. In order to increase the livability of the city, greening the city plays an important role. Still, cooling is only one of many ecosystem services that can be applied for improving the urban quality of life. For TURAS, research was done to try and uncover ways in which the ecosystem services concept can be applied for improving the urban quality of life. This chapter sketches the Rotterdam context, provides an introduction to urban ecosystem services, describes data and methods used, shows the first results, and gives policy recommendations.

KEY MESSAGE

1. *Rotterdam shows high spatial variation in urban green structures and the ecosystem services (ES) they supply. ES supply generally increases with increasing distance from the centre. The results show the existence of synergies rather than trade-offs among ES.*
2. *The best way to implement greening measures for ES supply is to link with ongoing projects. Climate adaptation is as such not the leading principle, but rather the attraction of the city to live, work, sport and recreate is.*

7.1 Introduction to Rotterdam and its urban climate

As described in chapter 6, Rotterdam is the second-largest city in the Netherlands and one of the largest ports in the world. Starting as a dam constructed in 1270 on the Rotte River, Rotterdam has grown into a major international commercial center. The city center witnessed the appearance of the Erasmus Bridge and the Kop van Zuid. Since then, the city has been boosting a skyline unique in the Netherlands. At the urban fringe beautiful residential districts have been built. New entertainment venues, restaurants and festivals have turned Rotterdam into a place with a young, trendsetting image. Anno 2014, the municipality covers an area of 319 km^2 (206 km^2 of which is land) with a population of 617,347. For the coming 25 years the city is expected to grow even further. The emphasis will be on compacting and gradually transforming the existing city, rather than on growth outwards, as was the case in the 20th century. In practice, building within the existing city means that Rotterdam has set a target for itself to increase the density of housing stock by 56.000 dwellings at inner urban sites. In particular the inner city (Rotterdam Central District), Stadshavens, and South Rotterdam are priorities for urban development.

Fig. 7.1: View over Rotterdam Central District (source: RAS 2013)

One consequence of stimulating the city to grow within its current limits is that optimal advantage will be taken of existing facilities. Moreover, the outskirts will be spared. This strategy also means however, that the city will become even more vulnerable to heat and heat stress. In order to remain an attractive and economically strong city, even in times of climate change, the Rotterdam Climate Proof Program was set up in 2008. Its goal: 'Rotterdam Climate Proof in 2025'.

The Rotterdam Adaptation Strategy

Being a low-lying, densely populated delta city, Rotterdam takes its responsibility seriously in creating a sustainable city, region, and Europe. As described in chapter 6: 'By linking sustainable ambitions to a strong economy, Rotterdam will become the most sustainable world port city' (www.rotterdamclimateinitiative.nl). Rotterdam aims at confronting the challenge of climate change as an opportunity rather than a threat, ensuring the city's attractiveness economically, physically, and socially.

Predictions indicate that Rotterdam will experience more extreme weather conditions such as heavier rainstorms, longer periods of drought and more heat waves, as well as higher water levels in the river Maas. Fortunately, Rotterdam has already taken many measures throughout recent centuries. An ingenious and robust system currently keeps the city and its port safe and dry, making Rotterdam one of the safest delta cities in the world. Moreover, the municipality has put a lot of effort into greening the city, for example by strongly increasing the amount of trees (6300 additional trees between 2010 and 2014).

Still, the effects and consequences of climate change on urban development are uncertain and potential consequences like an increase in heat waves can strongly affect urban livability. Therefore, the Rotterdam Adaptation Strategy (RAS) was launched in October 2013. This strategy 'sets the course that will enable the city to adapt to the changing climate. The goal is to create a climate proof city for all the people of Rotterdam both now and for future generations- a city that is both attractive and economically prosperous' (Rotterdam Adaptation Strategy, 2013). The primary objectives of the RAS are:

1. The city and its inhabitants are protected from the rivers and the sea
2. The city and its inhabitants experience minimal disruption from too much or too little rainfall
3. The port of Rotterdam remains safe and accessible
4. Inhabitants of Rotterdam are aware of climate change effects and know what they can do themselves
5. Climate change adaptation contributes to a comfortable, pleasant and attractive city to live and work in
6. Climate change adaptation strengthens the economy of Rotterdam as well as its image.

Objectives 4 and 5 are directly related to the topic of urban climate. Objective 4 stresses the importance of involving different stakeholders. Especially with regards to urban climate, the involvement of inhabitants is crucial since a lot of adaptation measures can be taken by individuals. For example installing a green roof, lowering sun screens, creating green facades, replacing pavement in gardens by plants, insolating houses, or adapting behavior (such as flexible working hours, drinking more liquids, etc.). Objective 5 stresses the importance of contributing to a comfortable and attractive city while adapting to climate change. This objective is very relevant since the urban heat island effect is likely to create great discomfort in the coming decades.

The leading principles of the RAS are (see Fig. 7.2):

1. ***Maintaining and strengthening the basics:*** Rotterdam needs to be able to continue to rely on its system of storm surge barriers and dikes, canals and lakes, outlets, sewers and pumping stations (represented by the inner circle in Fig. 7.2).
2. ***Making use of the entire urban environment:*** Adaptation involves solutions being found in all aspects of the urban environment that make it possible to alleviate the system and make it more resilient. In addition to the current system, small-scale measures will be taken in the 'arteries of the city', in public and private property (first ring in the figure).

Fig. 7.2: Leading principles of the Rotterdam adaptation Strategy (RAS) (Source: RAS 2013)

3. ***Working together and linking together other projects in the city:*** climate change adaptation requires cooperation with a variety of parties. Since adaptation concerns the urban environment, inhabitants, businesses, universities, colleges and interest groups can all participate and actively contribute to making Rotterdam climate proof. The role of the City of Rotterdam is to provide a framework and to facilitate and stimulate (second ring in the figure).
4. ***Added value for the environment, society, economy and ecology:*** Climate change adaptation provides a multitude of opportunities to strengthen the economy of the city and the port, to improve the living environment of neighborhoods and districts, to increase biodiversity in the city and to encourage the people of Rotterdam to become involved and actively participate in society (third ring in the figure).

For this chapter on urban climate, working together (principle 3) and adding value for the environment, society, economy and ecology (principle 4) are especially important. It is expected that this can be drastically improved, resulting in an attractive and economically strong city.

Rotterdam's urban climate

Cities are generally warmer than their surrounding rural areas and, depending on the urban structure, the difference can be substantial (Li *et al.* 2012; Deng & Wu 2013a; b). In Rotterdam, an urban heat island (UHI) of 7°C has been measured, as shown in Fig. 7.3. The UHI effect is caused by paved surfaces that impede evapotranspiration, dense structures that reduce wind speed, and dark building materials that absorb solar energy at daytime and release the heat gradually at night, slowing down the air cooling process (Wilby 2003; Weng, Lu & Schubring 2004). Combine this with high energy use, traffic, air pollution, and scarce vegetation, and cities turn into local heat islands (Radhi, Fikry & Sharples 2013).

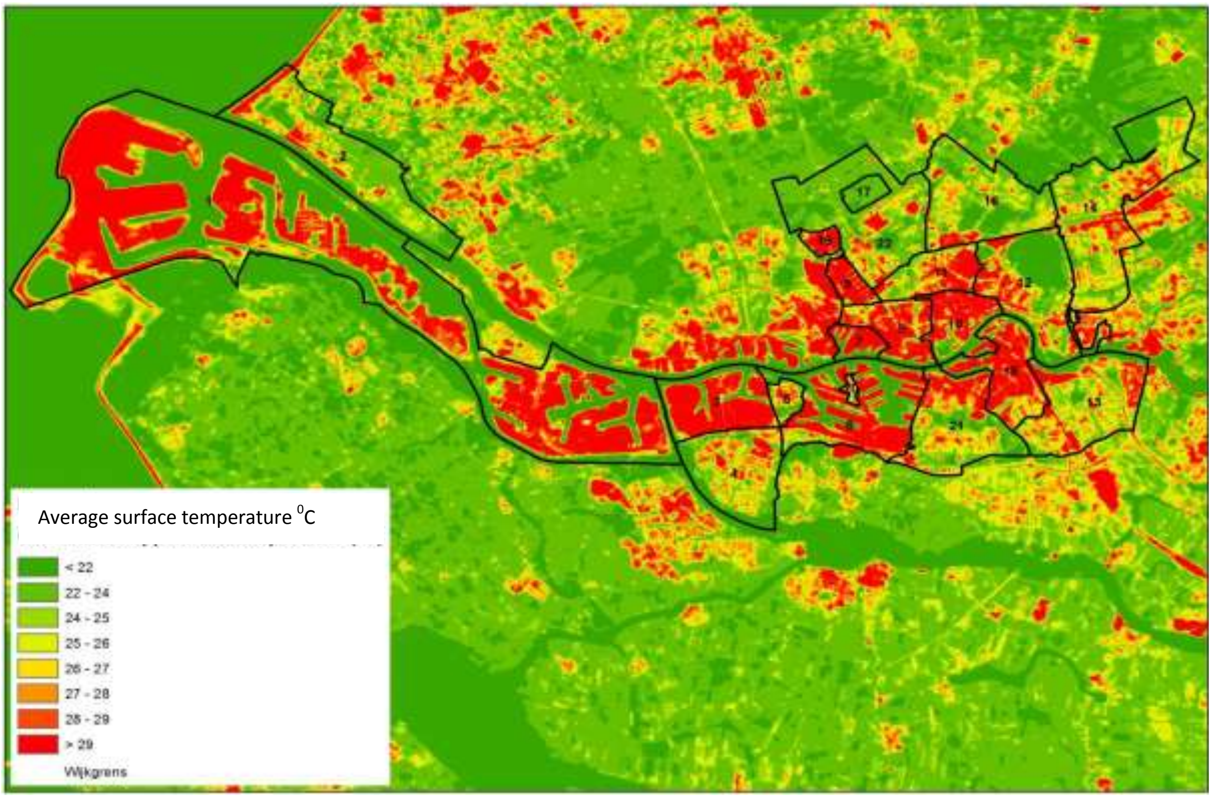


Fig 7.3: Average surface temperature around noon on warm cloudless summer days, based on 15 Landsat satellite images from the period 1987-2007 for 22 districts in Rotterdam (Klok et al., 2010)

Due to global warming, the number of summer days (warmer than 25^0C) and tropical days (warmer than 30^0C) will increase in Rotterdam, as will the likelihood of a heat wave, potentially creating great discomfort during daytime. At the same time, the urban heat island effect results in an increasing number of nights with minimum temperatures over 20^0C, resulting in heat stress and even deadly casualties. Fig. 7.4 illustrates the rising number of warm nights, especially in dense areas with high levels of paving.

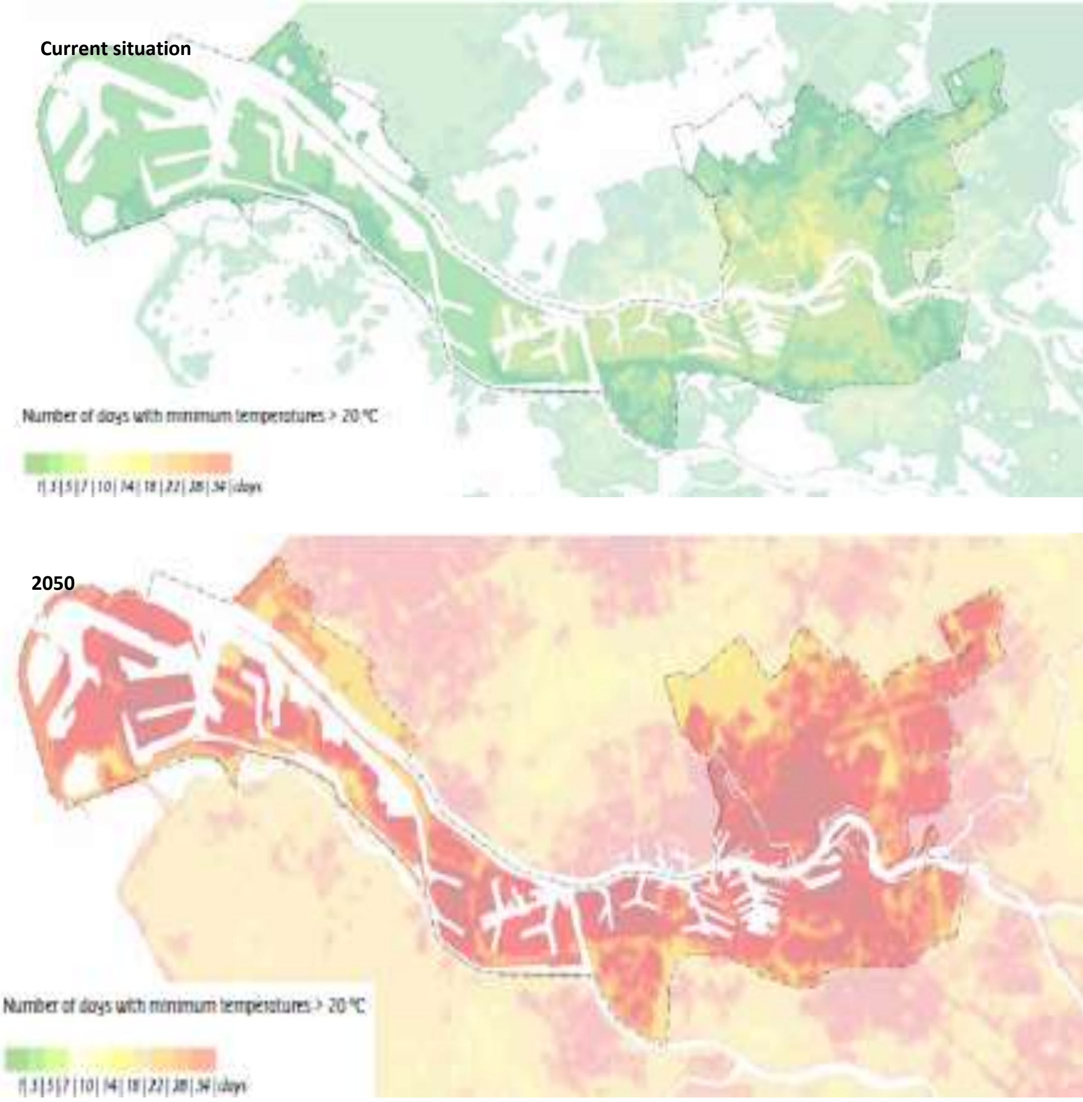


Fig. 7.4: Illustration of the Urban Heat Island Effect in Rotterdam. Top: in the current situation the number of nights with minimum temperatures over 20^0C ranges from 14 in the city centre to 1 or 0 in the outskirts. Bottom: in 2050, based on the W+ scenario of the Royal Dutch Meteorological Institute – with a temperature rise of 2 degrees in combination with changing air patterns – the number of days with minimum temperatures over 20^0C can exceed 34 days in heavily sealed areas (Goossen et al., 2012).

As stated in the RAS, higher temperatures affect public health and well-being, flora and fauna, and the functioning of the city as a whole. Especially the elderly and people suffering from cardiovascular and respiratory problems are vulnerable; significantly more people die during heat waves (between 1,000 and 2,200 people in The Netherlands during the heat wave of 2003). The declining air quality during warm periods leads to additional health problems. Higher temperatures also affect urban thermal comfort. Life inside the city's buildings as well as outdoors becomes less pleasant during prolonged periods of high temperatures. This leads to lower productivity in offices and factories. Moreover, energy consumption will increase during hot periods due to extra cooling demand, being contra-productive to the city's CO_2 reduction ambitions. Flora and fauna are affected because higher temperatures favor different species such as mosquitos and ticks. Furthermore, warm surface water leads to more blue algae and botulism which in turn will result in increased fish mortality and render the water unsafe for swimming. Another effect of high temperatures is an increased malfunctioning of the city's infrastructure. For example: bridges that don't open or close, or melting asphalt.

In summary, vulnerable spots in Rotterdam include:

- Compact urban areas with little shade or greenery
- Areas with high concentrations of vulnerable groups like nursing homes or homes for the elderly
- City parks and lakes
- Residential areas near motorways
- Bridges made of steel, asphalt roads and railways.

The role of ecosystem services for the urban climate

Green and natural areas can play an important role in adapting to climate change. A concept that builds on the benefits that ecosystems provide for society is ecosystem services. But although the importance of ecosystem services (ES) is increasingly being recognized and linkages with human wellbeing are becoming better established, the urban dimension of ES is still underexposed. Relatively few ES assessments have been carried out in the urban context (Gómez-Baggethun & Barton 2012) while the importance of studying ES for human wellbeing seems nowhere as evident as in cities. Cities are expected to become more sustainable and resilient to change, while at the same time human agglomerations need to deal with increased pressures from continued urbanization, resource depletion, socio-economic disparities, and global climate change. A typical city problem like heat stress can be moderated by urban nature. But that is not the only benefit supplied by urban green space (UGS). At the same time that urban green infrastructure supplies cooling services to moderate the urban heat island effect, it supplies air purification, noise reduction, carbon storage, rainwater runoff retention, and recreation services. So by tackling one challenge, many others can be tackled by the same urban green space solution. For each of these ecosystems services we illustrate its relevance below.

Cooling

One of the predicted effects of climate change is an increased occurrence and intensity of heat waves (IPCC 2012). This is a great concern as heat waves lead to increased energy costs (Gómez-Baggethun & Barton 2012), illness, and mortality – especially among vulnerable groups, such as elderly people (Reid *et al.* 2009; Johnson *et al.* 2012; Lung *et al.* 2013). These consequences are most pronounced in cities for two reasons: first because of the high population density, and second because of the so-called urban heat island (UHI) effect, the temperature difference between urban and rural areas (Yang, Lau & Qian 2011). Urban green space provides a cooling effect at local to regional scales that moderates the UHI, enhances human comfort, and reduces energy demand (Gill *et al.* 2007; Armson, Stringer & Ennos 2012).

Air purification

Cleaner air could prevent millions of deaths a year, as air pollution is currently the largest environmental risk for global health (WHO, 2014). In cities, waste treatment, industry, transport, and residential heating installations pollute the air, leading to increased occurrence of cardiovascular and respiratory disease (Leiva G et al., 2013). This negative impact can be moderated by increased abundance of vegetated areas which filter atmospheric particulates such as nitrogen dioxide (NO_2), particulate matter (PM_{10}), and sulphur dioxide (SO_2) (Gómez-Baggethun & Barton, 2012; Maas et al., 2006; Tzoulas *et al.* 2007).

Carbon storage

Global warming triggered interest in reducing atmospheric carbon dioxide (CO_2) emissions and with that, attention for the role of trees and forests as carbon sinks (Jo & Mcpherson 1995). Mitigation strategies acknowledge the importance of biomass for carbon storage and although the contribution of UGS is relatively small and undervalued by national assessments, its potential as carbon reservoir is significant (Hostetler & Escobedo 2010; Davies *et al.* 2011; Edmondson *et al.* 2012). Carbon storage is a continuous process; trees remove CO_2 from the atmosphere through photosynthesis and store it as carbon in their biomass so that they build a substantial carbon stock over the years, becoming carbon sinks. That is, until a tree dies or becomes harvested, as the stored carbon is then released back into the atmosphere through decomposition, turning the tree into a carbon source (Chaparro & Terradas 2009; Strohbach, Arnold & Haase 2012).

Noise reduction
Noise pollution is a common urban problem (Zannin *et al.* 2013). Nuisance from noise is detrimental to neighborhood livability, living comfort, and work environments, plus it can increase risk of serious health problems such as hearing loss and cardiovascular disease and thereby puts a financial burden on society (Bolund & Hunhammar 1999; WHO 2011). Urban ecosystems provide noise reduction services by serving as a natural sound buffer. Dense green infrastructure such as forests and shrub patches are a natural wall to sound waves that makes sound lose part of its energy when it travels through. Green belts attenuate noise by absorption, dispersal, and destructive interference of sound waves (Van Renterghem, Botteldooren & Verheyen 2012). Indirect noise reduction effects are generated by lessened wind speeds and the absorptive capacity of pervious soils.

Runoff retention
Projected increases in frequency and intensity of storms exacerbate the risk of urban flooding (Kazmierczak & Carter 2010; EEA 2012). When rainfall hits the city, up to 90% is directly lost as surface runoff because natural drainage is severely hindered by large scale sealing – with sewer overflow, street pollutant wash-off, obstruction of groundwater recharge, and damage to homes and businesses as possible consequences (Chaparro & Terradas 2009). Urban green space can mitigate these undesirable effects and support cities in adapting to climate change through natural storm water management: plants and trees intercept rainwater and let it infiltrate the soft soil so that only a minor share of precipitation runs off (Bolund & Hunhammar 1999).

Recreation
Recreation opportunity may be the greatest UGS benefit as perceived by people (Bolund & Hunhammar 1999; Plieninger *et al.* 2013). With nature becoming increasingly distant to city dwellers, its presence within the city is essential as a getaway from the daily routine and as a place for play, sports, and relaxation (Daniel *et al.* 2012; Maes *et al.* 2013a). Research points out that spending time in green areas results in improved physical and mental health (e.g. Kaplan and Kaplan 1989; Maas *et al.* 2006; Schipperijn *et al.* 2013) and that cities become more attractive when offering ample recreation opportunities (Rouwendal & van der Straaten 2008). By their physical appearance UGS provides the basic structure for recreation services.

Mapping ecosystem services

For policymakers, land managers, and environmental educators to work with the ES concept, information must be made suitable for their specific uses. Mapping exercises that depict which ES bundles are supplied, on which location, in what quantity, and by which green space type can support decision making by guiding the way to a more optimal allocation and design of UGS. But although requests from policymakers for such tools are considerable, maps still suffer from a lack of spatial detail to account for the small green features that supply ES in cities close to people's demand (Burkhard *et al.* 2012). In the following paragraphs we demonstrate a method to map the supply of multiple ES, based on the small green landscape features commonly found in cities, and discuss the results and conclusions for the city of Rotterdam.

7.2 Data for strategic urban planning

Strategic urban planning cannot do without data input from different sources. On the one hand, urban planning depends on the space available and environmental conditions. On the other hand, urban planning needs to take into account the needs of people and businesses – now and in the future. In a way, it is a question of supply and demand. The first TURAS project in the Rotterdam case study on urban climate deals with the first issue: what amount and types of urban green space are currently available, which ecosystem services does this provide, and how does ecosystem service delivery vary between neighborhoods? This project has been finalized and findings are reported upon in the next paragraphs. As a follow-up, a next study is planned that deals with the second issue: what amount and types of urban green space are needed according to residents, and are residents aware of the various benefits (ecosystem services) provided by urban green space? This study will focus on climate relevant ecosystem services (temperature regulation and storm water retention) and assesses residents' perception of climate adaptation measures that are part of the Rotterdam Adaptation Strategy (RAS). Here, however, only results from the first project about the supply of ecosystem services are presented.

Data for ecosystem services quantification

Quantification of ecosystem services provision generally happens through assessing biophysical structures, processes, and functions. To know the kind of biophysical structures you are dealing with, studies commonly use land use and land cover data. But up to today, the bulk of studies use rather coarse land cover data and classification methods. For an assessment of urban ecosystem services provision, this does not suffice. The urban context asks for an approach that makes use of detailed data that differentiate between all the small-scale landscape elements: patches of lawn and shrubs, street trees, gardens, etc. It is all these individual elements that make up a city's total green infrastructure.

For this reason, we used detailed GIS (Geographical Information System) data of urban green and blue landscape elements. These data were either made available by the municipality of Rotterdam or publicly accessible. GIS data include Rotterdam administrative borders, housing plots, roads and railways, and high-resolution land use and land cover data from which we could create eight urban green space (UGS) categories: street tree, woodland, tall shrub, shrub, herbaceous vegetation, domestic garden, water, and other green area (Table 1). These UGS categories are the basis on which quantification took place for each ecosystem service, and are shown in Fig. 7.5.

Data that were being missed were Leaf Area Index (LAI) data of individual trees which would have been beneficial in calculating e.g. air purification services. Also, more specific soil data would have been helpful for estimating belowground carbon storage and infiltration capacities for water retention services.

Table 7.1: Description of UGS types

UGS type[1]	Description
Tree	Individual trees, mostly street trees
Woodland	Clustered trees, small urban forest
Tall shrub	Shrubs and hedges sized 2-5 m
Short shrub	Shrubs and hedges sized <2 m
Herbaceous	Low vegetation consisting of non-woody plants, mostly grasses and herbs
Garden	Domestic gardens consisting of a mix of vegetation, water, and sealed surface
Water	Ponds, lakes, and streams (canals and rivers)
Other	Allotment gardens, cemeteries, golf courses, and camp sites

[1]All data were made available by Rotterdam municipality in vector format as polygons, except tree data (points and lines). Data are from 2012 except for tree (2008-2012) and garden (2010-2012) data

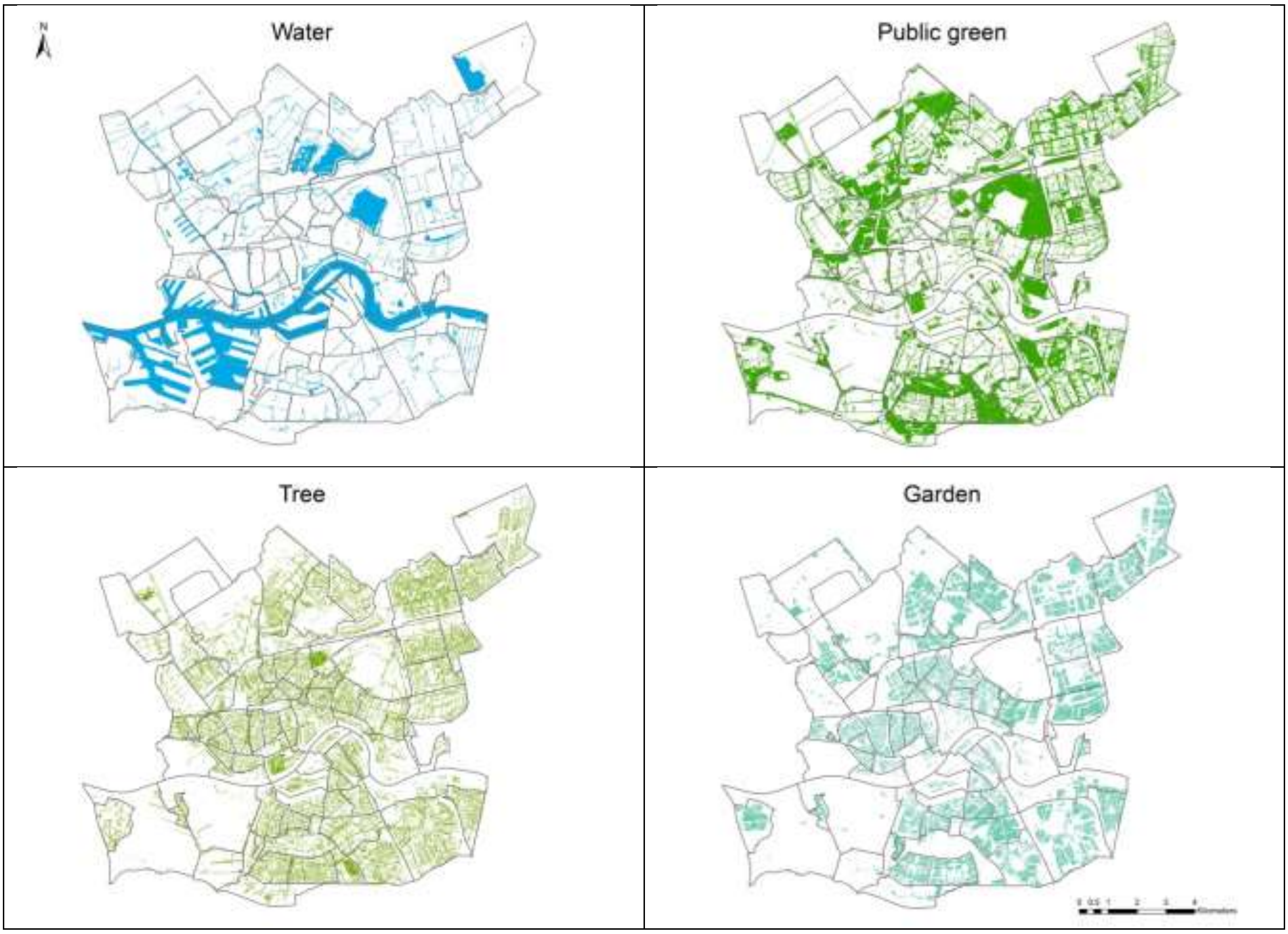


Fig. 7.5: Maps of Rotterdam with water, public green, tree, and garden cover

The data presented above relate to biophysical structures. The project also needed data on the processes and functions of biophysical structures, such as water infiltration rates and their capacity to moderate noise or air pollution. Because there were no resources (time, money, equipment) available for field measurements, such data was mined by literature review. We used indicators and quantification values from literature that were extracted following a step-by-step method of reviewing studies from ecosystem services (ES), non-ES, urban, and non-urban research domains. Each study was filtered for empirical evidence, applicable indicators, and quantification methods. The resulting indicators were applied to the green space GIS data in order to quantify and map the supply of six ecosystem services.

7.3 Tools and analyses for urban planning

The aim of the first project was to develop a high-resolution UES (urban ecosystem services) GIS model that can be applied for the quantification of ecosystem services supply in cities. The model consists of supply indicators for each ecosystem service, with supply rates per green space category. These rates can be used to quantify ecosystem services supply using high-resolution GIS data of urban green space. ES supply by UGS was calculated per unit of land cover (m^2), aggregated to neighborhood level, and normalized by area to enable comparisons between neighborhoods. Next to using maps for an analysis of spatial variation across the city, results can be used to characterize neighborhoods according to their UES supply bundle with cluster analysis, and tradeoffs can be examined using e.g. principal component analysis.

The high-resolution UES GIS model is designed to be applicable to other cities in Europe and can serve as a UES assessment tool. A prerequisite is the availability of green space data, preferably high-resolution data and of comparable categories as those used in this study. The indicators and supply rates of the model are based on empirical evidence which was extracted from relevant ES and non-ES literature, mostly from cities in a climatic zone similar to Rotterdam (Köppen classification Cfb: oceanic, marine west coast). When applying the model to other case studies, some supply rates might need to be adapted e.g. if cities are located in a different climatic zone or boast a very different urban structure.

7.4 Case study findings

For the first project, existing indicators and methods were adapted to quantify six urban ES in Rotterdam: air purification, carbon storage, noise reduction, runoff retention, cooling, and recreation. Quantification results for Rotterdam show spatial variation of ES supply which can be explained by the amount, type, and location of UGS. Woodlands are good carbon sinks, street trees contribute most to cooling and clean air, and tall shrubs are best for reducing traffic noise. Recreation is best provided by a mix of UGS because people prefer diverse landscapes such as a combination of vegetation and water. Below is a description of the spatial patterns of individual ES on neighborhood level and of ES bundles on district level.

Spatial patterns of individual ES

Trends and differences between neighborhoods can be analyzed from individual ES supply maps. The aggregated maps in Fig. 6 show two overall trends, starting with patterns for the different ES. Patterns vary from large variation in supply rates for carbon storage, noise reduction, and recreation to a more balanced variation for air purification, runoff retention, and cooling. A large variation in supply patterns indicates that neighborhoods differ substantially from each other in their performance for the ES. In other words, where few neighborhoods supply a high recreation service value, many others supply a low recreation service value. This indicates that the recreation value of low scoring neighborhoods can be improved. This does not necessarily mean that more green or blue space is needed; it can also be that the UGS needs to be designed differently. Sticking with the recreation example, the river waterfront could be developed in a way as to attract more visitors e.g. by creating waterfront boulevards.

From the maps in Fig. 7.6, the patterns for air purification and cooling seem most similar to each other. This is an indication that measures that increase the cooling capacity, such as planting trees and shrubs, also increase the air purification capacity. In this example, the location of UGS elements is particularly important and has to do with the demand for the ecosystem service. Trees and plants that are in close distance of an emission source, e.g. a busy road, can filter more pollutants from the air than vegetation that is far away from traffic. This has not much to do with the cooling capacity, but think of locations in the city where most traffic passes by – these are locations where most people gather for work, shopping, and living. These areas of human clusters emit more heat (from residential installations, office air conditioning, and traffic) than remote areas do. So, tree planting measures that aim to reduce citywide air pollution provide cooling services at the same time, and at the location where they are most needed.

Comparing the cooling map in Fig. 7.6 with the surface temperature map in Fig. 7.4, some remarks can be made regarding the ES supply-demand nexus. It appears that the neighborhoods that suffer most from high temperatures (the city center and districts west and south of the center) offer only limited cooling services. Neighborhoods in the outskirts that suffer less from high temperatures demonstrate a larger cooling potential. This indicates a spatial mismatch between service supply and service demand. In order to decrease the heat stress for residents and visitors in Rotterdam, which will only increase in the future, more green spaces are needed in the city center and bordering neighborhoods. Unfortunately, there is not much space available for new green area development in these neighborhoods because of their highly built-up and sealed character. It poses a challenge for urban planners to come up with innovative solutions in this compact urban setting, and Rotterdam has made some first steps by subsidizing green roofs, but more is needed to fully address the increasing problem of urban heat stress.

Fig. 7.6: Supply of six ES, aggregated to neighborhood level

Figure 7.6 also shows considerable variation between neighborhoods. The ES supply rate generally increases with increasing distance from the city center because central neighborhoods are the most built-up and least green. The northwest region, which is characterized by agriculture, business areas, and the airport, scores lowest for each ES whereas the natural area of *Kralingse Bos* east of the center scores highest. Also the *Zuiderpark* neighborhood in the south supplies relatively many ES, whereas the area next to it in the southwest supplies relatively few. Next to these general trends the maps show some ES specific patterns. Air purification is supplied most where a dense road network coincides with a high fraction of tall vegetation, which is the case just outside the city center and less in areas that border the river. Runoff retention shows a contrasting pattern with high supply in neighborhoods with a large water fraction along the central east-west (river) axis. Presence of large water surfaces also boosts recreation potential, especially when combined with forested areas.

As mentioned earlier, in many urban areas it is a serious challenge to increase service supply. If an increase in green cover is impossible on site, another option is to increase the connectivity between green patches and parks. Green corridors are beneficial for biodiversity and for many of the ecosystem services discussed here. They can serve as a connection between neighborhoods as well, enabling less green neighborhoods easy access to greener ones. An example from Rotterdam, in which an old railway area is transformed into a commercial center combined with a neighborhood park on top, is the so-called *Dakpark*. Although this is not so much an ecological connection, it is an interesting way of combining functions that creates benefits for local commerce, social cohesion between neighborhoods, and recreation options.

ES bundle types

The ES bundle map in Figure 7.7 depicts total ES supply and the share of each ES per district, enabling comparison between and within districts. Districts to the east and south of the center supply most ES, whereas those in the west supply least. Central districts score averagely. Rose plots depict the ES bundle composition per district and characterize districts according to their ES supply patterns. Districts with high total supply display high values for all ES in the bundle. Districts with moderate total supply display more variation within the bundle, e.g., three high service values and three lower ones. Districts with low total supply display low values for the entire ES bundle, except for two districts in the west that display extraordinary high values for runoff retention services.

To support the characterization of ES bundle types found across Rotterdam we performed a cluster analysis on neighborhood level. This resulted in five clusters with similar ES supply bundles (Table 2; Fig. 8). Cluster one (n=3) is characterized by a large supply of all ES and consists of neighborhoods that feature major city parks. Cluster two (n=5) is concentrated in the west and features a similar pattern, except that neighborhoods in this cluster supply more noise reduction and less recreation services, which might be related to the higher road density. The third cluster (n=30) is larger, spread over north and south Rotterdam, and characterized by a mixed ES bundle with no extreme highs and lows. Cluster four (n=12) is characterized by a high value for runoff retention, a moderate recreation value, and low values for other ES. Unsurprisingly, all neighborhoods in this cluster have a high water fraction. The fifth cluster (n=31) is large and consists of neighborhoods with low values for all ES, found in central Rotterdam, south of the center, northwest, and the extreme east. Cluster analysis shows that certain ES (e.g. runoff retention) can be supplied independently of other services, while other ES are supplied in combination (e.g. air purification and cooling). The dominant green space cover in a neighborhood can help explain the variation in ES bundle types; tree abundance leads to high values for air purification and cooling, whereas a large water surface is valuable for capturing rainwater and attracting recreationists.

Table 7.2: Cluster means

ES	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Air purification	.82	.80	.54	.18	.28
Carbon storage	.75	.44	.36	.11	.16
Noise reduction	.52	.73	.22	.11	.11
Runoff retention	.86	.52	.40	.80	.27
Cooling	.82	.81	.58	.20	.28
Recreation	.77	.29	.19	.36	.10

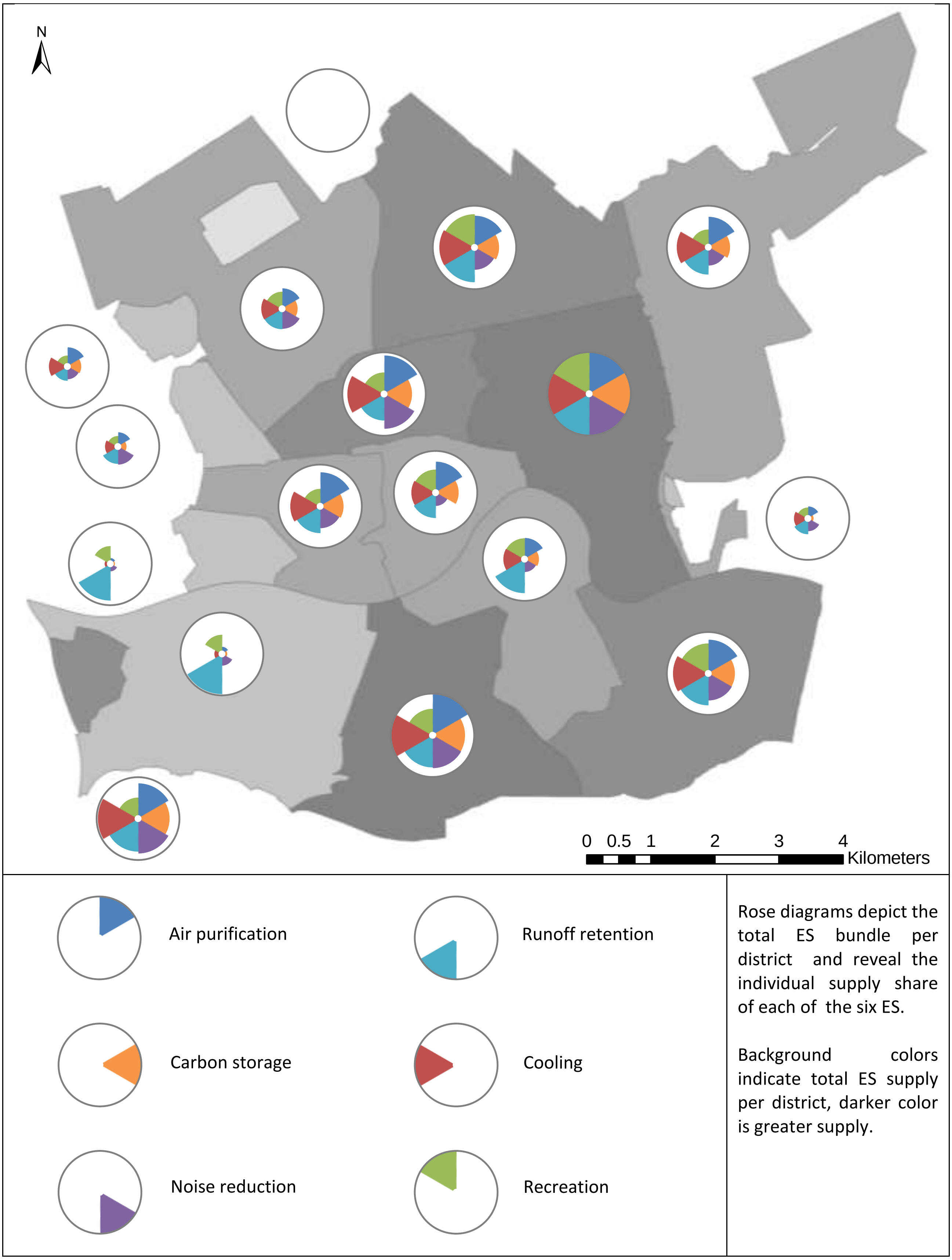


Fig.7. 7: Supply of ES bundles, aggregated to district level

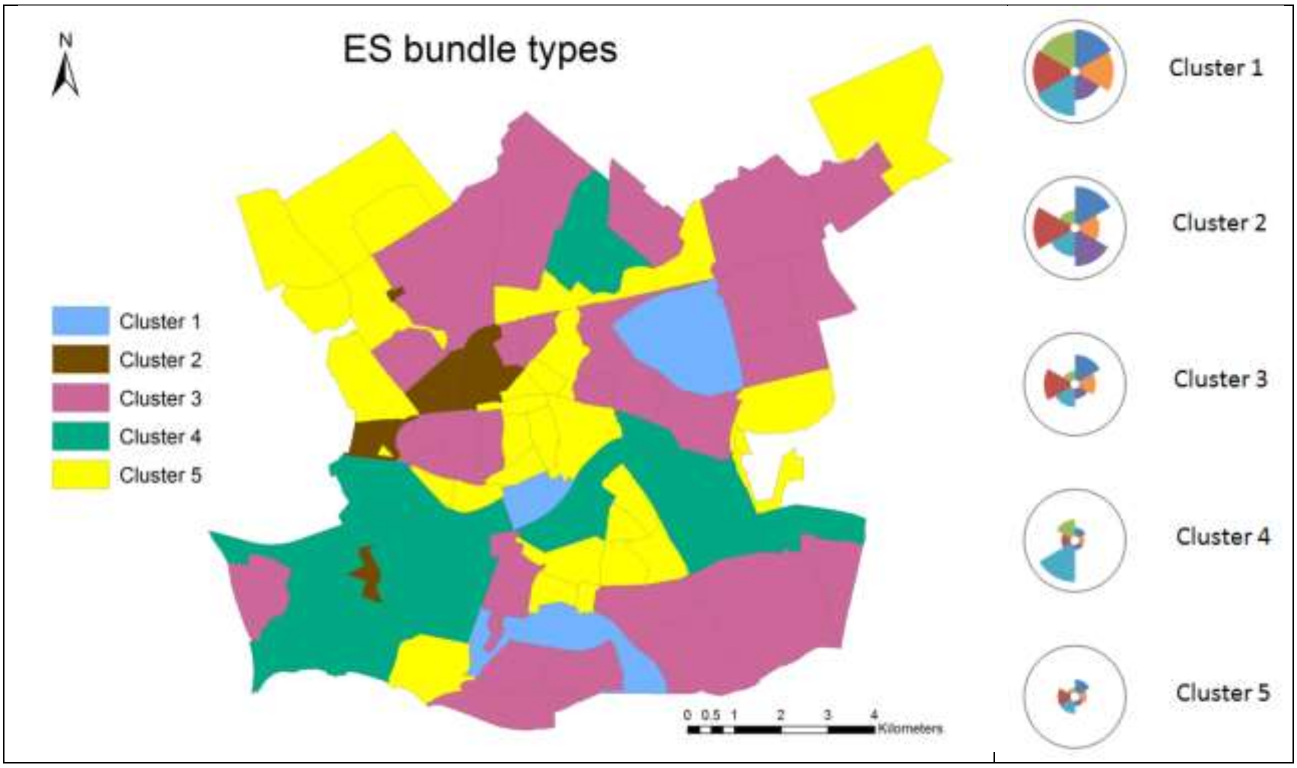


Fig. 7.8: Spatial distribution of ES bundle types

Conclusions

One of the project outcomes is that several ecosystem services are supplied in combination. In planning new green areas, or revitalizing neighborhoods, this means that a single green space design can provide multiple benefits. Planting trees along a street can result in noise reduction benefits so that residents who live close to the road suffer less from traffic noise. At the same time, the trees can improve overall air quality which delivers health benefits for the entire city. The cooling function of a tree brings benefits on multiple scales: very local cooling through shading, neighborhood cooling through evaporation, and, if a city's green infrastructure is set up as an extensive network of small and larger green spaces throughout the city, it can even provide citywide cooling. Finally, if a city has set climate mitigation targets, such as becoming CO2 neutral, street trees help reach these targets by means of their carbon storage capacity. Such insights can help policymakers and urban planners realize which benefits can be delivered by which green space types. In this example street trees are well equipped for noise reduction, air purification, cooling, and carbon storage. But although street trees are found to increase housing prices and neighborhood value, they offer less to recreationists who would be helped more by a neighborhood park or grass strip along the river. Also for the retention of storm water after heavy rainfall, street trees are not the best option to keep the streets free of excess water. A group of trees that stand in a lawn or under which smaller shrubs can grow are better able to deal with large rainwater quantities. The same holds for a pond in a park in which the water can run off. The findings of this research project can provide support in choosing new urban green space designs.

Another outcome is that the supply of ecosystem services is not equally spread over Rotterdam and that differences exist at the very local scale. Some districts hardly provide any ecosystem services whereas other districts provide all six services in large quantities. The produced maps can be used to point out districts that have a very low service supply; these are districts with room for improvement. Let's take the central district as an example. This district scores averagely compared to other districts, but shows quite some variation within: its neighborhoods score differently for the six ecosystem services – some high, some low. The neighborhood scoring best for all ES, Nieuwe Werk, borders the river and includes the central city park (*Het Park*) which makes that this neighborhood consists of a lot of green and blue space. The neighborhood always showing a low ES score, C.S. kwartier, includes very few green areas and no water surfaces. The same holds for Dijkzigt neighborhood which consists largely of sealed surface cover. The neighborhoods Cool and Oude Westen show low ES scores, except for air purification and cooling. They also provide some carbon storage services. This is because these neighborhoods feature quite some trees and gardens. The neighborhood Stadsdriehoek displays some of the lower ES scores within the central district, except when it comes to runoff retention. This neighborhood boasts a relatively large water surface which makes it suitable for capturing rain water. Thus, while the neighborhoods do not score that well individually, together they make up quite a complete picture for the ES bundle on district level. These differences among neighborhoods within the same district indicate that a very local approach is needed when it comes to assessing ecosystem services performance.

Related to the previous outcome is the conclusion that knowledge of the local context is essential for designing local policies. 'Greening the city' can be used as a strategy to increase ecosystem services delivery and as a climate adaptation measure that aims to improve urban quality of life. However, such an increase needs to be asked for in order to lead to an actual improvement. In other words: there needs to be a demand for the supply. Increasing the water retention capacity of an area does not make any sense if there are no people or buildings at risk from flood damage. Also, creating a beautiful recreation site with water and tree cover has no use when the site is inaccessible for possible users. A similar story can be told when a tree line is put up to reduce noise from a busy road, without the presence of any residential building blocks. So, looking at the district map in Fig. X it might be surprising that Bedrijventerrein Schieveen does not supply any ecosystem services at all. But knowing that this area has an agricultural history and that currently plans are being debated for turning it into a nature protection area, changes its story. Although this neighborhood currently does not supply any services that are directly relevant for Rotterdam's inhabitants, it is of high importance for several bird species and therefore for the regional biodiversity value. In the case of this neighborhood a low ES value does not mean that quality of life is at a low level and improvement is needed. That is why knowledge of the local context and local demands is essential in designing effective ES policies.

A similar ecosystem services assessment could be performed for other case studies in the TURAS project. A mapping exercise of the ecosystem services supplied by the green infrastructure in a city gives a good insight in the service stock currently available, and in the interacting processes between services. With the developed methodology other case study cities can perform the ES assessment relatively quickly. The ES indicators can be applied to GIS data, preferably high-resolution data, and this will result in an ES supply map that can be aggregated to neighborhood or district level just as in this study was done. From this, spatial patterns, tradeoffs, and synergies can be analyzed.

Knowing which green space elements supply which ecosystem services can aid planning processes for climate adaptation and general improvement of urban livability.

7.5 Implementing measures

As was mentioned before, for the next decades Rotterdam is planning to concentrate on growth within current city limits. This strategy poses a challenge for urban livability, especially in densely populated areas. The effects of climate change increase this challenge, but bring opportunities as well, for example new forms of recreation or a longer growth season. More importantly, there is a variety of adaptation measures that do not only bring the city coolness, but also increase its attractiveness. Think of the realization of green roofs, green facades, city farms, and fountains.

The RAS focuses on two elements:

1. Raise awareness among the public, in particular house and building owners and elderly people. They will be informed about what they can do themselves in order to create a pleasant indoor climate as well as what they need to do in case of an extreme heat event.
2. Adapt the physical design of the city in order to reduce or cope better with heat. The focus hereby lies on greening the city, since incorporating more green in the city provides more shade, has positive results on public health, cools the city due to evaporation, and improves the attractiveness of Rotterdam.

Measures include: Stimulating green roofs, green facades, sun blinds and green courtyards for private property, greening along infrastructure, extending parks and greenbelts, creating blue and green corridors, installing nature and wilderness playgrounds, restructuring highly paved areas, applying permeable pavement, and building with nature in public areas. These measures enhance the cooling capacity of the city by creating more room for small trees, grass, and water. At the same time these measures improve the quality of public space. This makes the city a more attractive as well as a healthier place to live, work and stay in.

With the help of the outcome of the first case study project, in the future, specific needs can be targeted by implementing specific types of urban green space. As such, the results can be used to assist the second RAS focal point: adapt the physical design of the city in order to reduce or cope better with heat. The study provides insights in which green space types are best fit for alleviating urban heat stress, while simultaneously showing that green space measures generate many more benefits for urban livability.

The case study finding that some districts have a low ecosystem services supply and therefore show room for improvement is only sideways used in the decision making process in Rotterdam. Besides the supply of ecosystem services, another leading principle when choosing locations for implementing adaptation and greening measures is the possibility to link in with other projects. In practice, it turns out that especially restructuring and maintenance activities are important drivers for implementing measures that improve the urban climate.

However, when discussing the research findings of the first project with policymakers, it turned out that the neighborhood clusters in Figure 7.8 are surprisingly similar to the neighborhood typology used by Rotterdam as a starting point of many policies and plans. Thus, the case study outcomes can support these plans by providing an additional scientific and ecological basis for decision-making, next to the existing one which is primarily based on historical city development and experience.

During the RAS process, a lot of lessons were learnt. For example: The RAS aims at integrating different climate topics into one general strategy. This resulted in one impressive report with a lot of maps and illustrations. But although the ambition was to write one cohesive, integrated story, not all themes have followed the same methodology or have worked out the implementation of specific measures to the same extent. Every topic demands its own approach and every neighborhood requires its specific combination of measures (whether they are based on the ecosystem services assessment model or not).

Another lesson concerns the political need for specific targets. During the RAS process it became clear that it was difficult to define specific targets for the urban climate topic, for example concerning the number of people suffering from heat stress, or the number of hot nights, or the maximum temperature accepted in the city. Moreover, the city prefers to stress positive aspects like thermal comfort instead of negative phenomena like heat stress. But without targets it is difficult to convince politicians of a sense of urgency and to define the success of measures. The solution was found in linking heat reducing measures to other important topics and ambitions in the city, which all contribute to the general goal of realizing an attractive city, like health, high quality public space, recreation or biodiversity. Climate adaptation as such is not a leading important item. It is the result that counts: an attractive city to live, work, stay, sport and dream in.

A third lesson concerns the role and responsibility of the city. It turns out that the city cannot take all measures by itself. It needs other actors such as housing co-operations, project developers, water boards, NGOs, and individual citizens to implement and maintain solutions. A disadvantage is that this takes a lot of time to reach agreement (on problem definition, choice of measures, division of responsibility, etc.). An advantage is that all these parties have different ideas which enlarge the pool of potentially successful measures, that they might be willing to take some action (like citizens) and that costs can be shared. Besides not being *able* to take all measures itself, the city is also not *willing* to do everything by its own. The general tendency is that the government takes a step back, leaving more room for private initiatives. The city sees a role in informing the general public about climate change, the effects of UHI, and the measures that can be taken. Moreover, the city can provide examples of green, cool roofs or high quality public space and define general ambitions concerning the quality of a project or an area. But Rotterdam is not planning to make measures compulsory. The city sets the boundaries and stimulates innovation, but in the end it is the specific actors involved in an area or a plan that decides how they are going to reach the desired level of climate adaptation or thermal comfort.

Fourthly, the RAS process was based on three pillars: knowledge, action, and image. This has proven to be a very important critical success factor. Together with scientists and consultants, knowledge was generated that supported the city in understanding both the effects and challenges of climate change as the possible measures and opportunities. *At the same time*, the city already took some measures that are clearly visible, such as green roofs and water plazas, and strengthen the city's ability to adapt to climate change while also enhancing the city's attractiveness. By doing so, the city showed that adaptation measures have a clear added value for the city and its inhabitants and that its climate ambitions are for real. It underlines the city's innovative image and attracts worldwide attention, potentially generating opportunities for new businesses in the region. The challenge in working together with scientists was to define the right questions, preferably at an early stage and together with different stakeholders. Another challenge concerns the different time horizons of researchers and policy makers. This is a gap that needs to be narrowed. While policymakers demand quick answers, it takes time to conduct thorough, scientific research. Still it would be advisable if researchers could divide their work into smaller parts, each time answering a part of a larger question. If policymakers need to wait four years for an answer to their question, the momentum is lost and politicians will take a decision without having been able to take the researcher's input into account.

Finally, during the RAS process, various paradigm shifts have occurred. One concerns a shift from focus on sun to shadow. With CO_2 emission reduction targets in mind, city planners have long been concerned with allowing the sun to enter our streets and houses. Now they are also taking into account the need for shadow and for public spaces that provide cooling (e.g. by using different materials, allowing wind flow, or planting trees). Another paradigm shift concerned the natural tendency of policymakers to, just like researchers, 'first know everything for sure' before involving other stakeholders. It was learned that it is not necessary to have a clear problem definition or strategy before you can go and talk to stakeholders. On the contrary, people feel more motivated to take action if they have been involved in the process from the beginning instead of only at the end.

7.6 Recommendations resulting from case study

Recommendations resulting from the case study:

1. **Perform an ecosystem service assessment**. A mapping exercise of the ecosystem services supplied by the green infrastructure in a city gives a good insight in the service stock currently available, and in the interacting processes between services. Knowing which green space elements supply which ecosystem services can aid planning processes for climate adaptation and general improvement of urban livability.
2. **Use the ecosystem service methodology to point out districts that have a very low service supply**. These are districts with room for improvement.
3. **Look for smart combinations of ecosystem services**. For example: street trees improve air quality, reduce noise, provide cooling and capture carbon.
4. **Use different types of green for different purposes**. For example: street trees are well equipped for the combination of services mentioned under 3). Recreationist would be helped more by a park or grass strip along the water whereas a group of trees that stand in a lawn are especially able to deal with large quantities of water.
5. **Match ecosystem service delivery to the local demand for the particular service**. For example, creating a beautiful recreation site with water and tree cover only has use when the site is accessible for potential users. In summary: there needs to be a demand for the supply and this is related to the very local context. Different neighborhoods within the same district have different scores for different ecosystem services, both on the supply and the demand side!

Recommendations resulting from the Rotterdam climate adaptation process:

6. **When designing a climate adaptation strategy, use a different approach for every topic as well as implement different measures in every neighborhood.** Every topic demands its own approach and every neighborhood – as was explained in the case study as well- requires its specific combination of measures.
7. **Link measures that improve the urban climate to other important topics and ambitions in the city, such as health, city greening, high quality public space, biodiversity and recreation and create an attractive city**. Climate adaptation as such is not a very important item. It’s the result that counts: an attractive city to live, work, stay, sport and dream in.
8. **Cherish and increase the involvement of other stakeholders.** When thinking about and taking action together (e.g. companies, water boards, citizens, universities etc.) , the pool of potentially successful measures, including opportunities to finance them, will be enlarged. Cities can focus on their (new) role: setting boundaries, stimulating innovative solutions and bringing together different stakeholders.
9. **Start taking action, even when uncertainties remain.** There will always be questions left to answer. Taking action underlines the city’s ambitions, motivate other stakeholders and create new business opportunities for both international and local companies.
10. **Define questions with researchers at an early stage.** Working closely together with researchers has proven to be very beneficial. The challenge, however, is to define the right questions, preferably at an early stage and together with different stakeholders.
11. **Align the time horizons of researchers and policy makers.** If policymakers need to wait four years for an answer to their question, the momentum is lost and politicians will take a decision without having been able to take the researcher’s input into account. Researchers might want to divide their work into smaller parts, each time focusing on finding partial answers which later on can be integrated into one large dissertation.
12. **Allow room for (or even stimulate) paradigm shifts**. Changing focus from sun to shadow enriched the city planners’ opinion with regards to an attractive public space. Moreover, changing the policy makers’ and researchers’ paradigm from ‘first know everything for sure’ into ‘involve stakeholders at an early stage’ motivates other stakeholders to take action and leads to a broad range of ideas concerning possible solutions.

8. Green Roofs – London

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8.1 Introduction to the issue and area

Community resilience in London faces four key issues: flooding, urban heat island, air quality and inequalities (Figure 8.1). These issues are not confined to London but affect most urban areas in the UK. However, London is a world city, a key link in the chain of global prosperity and well-being. Its resilience to phenomena such as climate change is therefore considerable importance.

Green roofs, that is roofs on which vegetation is intentionally grown, are considered to bring environmental, economic and aesthetic benefits: reduction in storm runoff through water retention, mitigation of the heat island effect through increased evapotranspiration, improvement in air quality[20] (Yang et al., 2008), energy savings and the provision of recreational spaces (see e.g. Wolch et al., 2014). Green roofs on their own are not a panacea but are an important infrastructural component alongside parks, community gardens, green walls and so on.

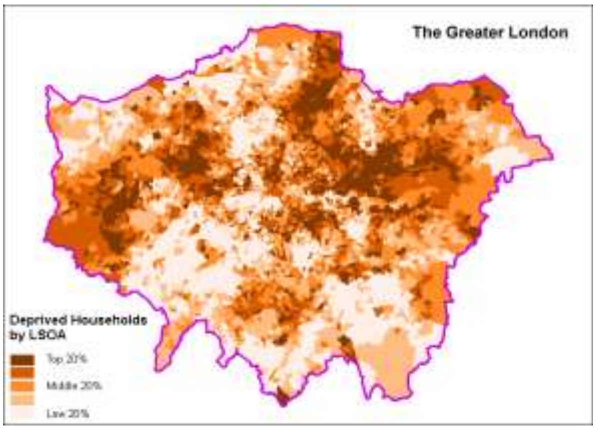
KEY MESSAGE

1. *Green roofs are important for resilient urban communities as they assist in runoff attenuation (reduce flooding), promote evapotranspiration (reduce heat stress), help improve air quality, result in energy savings and provide recreational spaces. There has been very little work on rapid appraisal of green roof potential.*
2. *The London case study shows that LiDAR can cost-effectively classify roof geometry for large areas accord to green roof design criteria as an input to the planning process.*

(a) flood warnings in force January 2014

(b) urban heat island effect 2013

(c) exceeding mean nitrogen dioxide objectives 2013



(d) household deprivation, 2011 census of population

Figure 8.1: Issues for community resilience, London

[20] Significant reductions in O_3, NO_2, PM_{10}

Whilst impact/effectiveness of green roofs largely rests on structural suitability, design of substrates, flora and fauna (all being researched through WP2 TURAS), there has been very little work on rapid appraisal of green roof potential in urban areas (except Luo et al., 2011 using conventional remote sensing imagery). This chapter addresses that need. The use of airborne LiDAR[21] is explored and evaluated as a rapid appraisal technique for rooftop geometry. LiDAR is widely used for mapping floodplain topography and green roof appraisal would be an important secondary use of the same data. The high resolution and consistent quality of LiDAR makes it particularly suitable for extracting roof geometries.

8.2 Data for strategic urban planning

The data used in this project has been sources from a number of agencies:

- LiDAR data are provided by UK Environment Agency (EA) Geomatics Group, and includes DSM (Digital Surface Model) and DTM (Digital Terrain Model). The data are provided in individual tiles of up to 1km^2 depending on resolution. Height values for measuring roof geometry are extracted from the DSM.
- Base mapping is MasterMap, provided by UK Ordnance Survey (OS), which has six thematic layers. Building features are extracted from the topography layer.
- Flood data is provided by UK Environment Agency, which contains Flood Map and NaFRA (National Flood Risk Assessment) FLC (Spatial Flood Likelihood Category) Grid. Flood map has layers of Flood Zone 3, Flood Zone 2, Flood Defences, Areas Benefiting from Flood Defences and Flood Storage Areas.
- Deprivation data is extracted from UK Census Statistics, Office of National Statistics (ONS).
- Land use data is adopted from UK Generalised Land Use Database, available through the ONS.

The data from ONS are open data and have been used in this project under Office of Public Sector Information (OPSI) license no. C2010001559. MasterMap was accessed under the University of East London EDINA subscription. LiDAR data and flood mapping were granted from the EA for the purposes of research.

Data quality: EA LiDAR data are all with a vertical accuracy in the range of 5cm to 15cm. Spatial resolutions are resampled at 50cm, 1 metre and 2 metres. For the topography layer of OS MaterMap, buildings are defined as roofed constructions, usually with walls and being permanent. This includes permanent roofed-constructions that exceed 8.0 m² in area (12.0 m² in private gardens). Overall position accuracy is 1.0 metre. The quality of EA Flood Map is assured by UK Environment Agency as a good indication of the areas at risk of flooding; however it cannot provide details at individual property level. EA Flood Map is constantly being updated. The deprivation data and land use data are central compiled and quality controlled by ONS.

8.3 Tools and analyses for urban planning

Study Areas

This study broadly investigates two areas: parts of Central and West London and London Borough of Newham. Study areas of Central and West London cover three smaller areas where green infrastructure audits[22] have been carried out as part of a programme for greening business improvement districts (BIDs). They are used in this study largely as 'control group' case studies. The area chosen are the Ravenscourt Park area of Hammersmith, the South Bank area around Waterloo station and the City of London itself. These are areas with high density of buildings and have a high proportion of commercial and public buildings. The study area of Newham is a typical inner London Borough with a high proportion of residential buildings at different heights as well as a wide range of commercial and industrial buildings. It was a traditional white working class borough and has evolved into a highly diverse multi-cultural borough. It also has some of the most deprived neighbourhoods in the country.

Methods

An innovative approach is developed in this study to estimate areas of potential green roofing. It is based on the computation of roof slope by LiDAR data and topographic data. It is a straightforward and effective approach to support initial planning, strategic assessment and impact study of green roof development. Most importantly, this new approach is generally applicable in UK with easy data access while it is also likely to be feasible in other EU countries where similar data are available.

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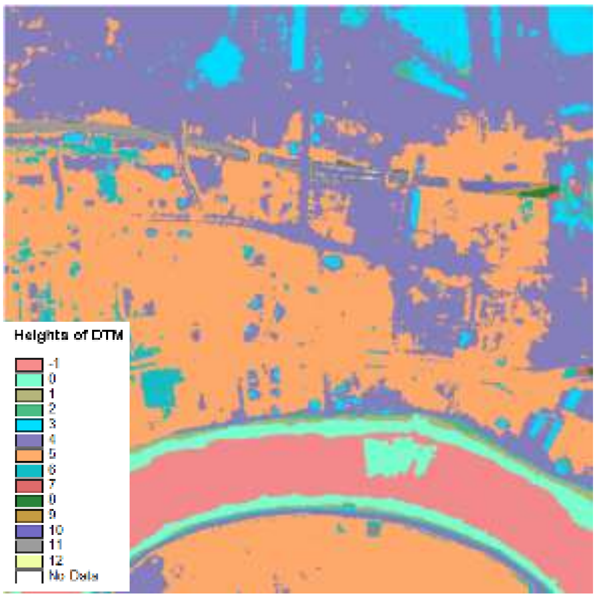
[21] Light Detection and Ranging (LiDAR) is a remote sensing technique for creating dense digital landscape models

[22] https://www.london.gov.uk/priorities/environment/greening-london/urban-greening/greening-bids

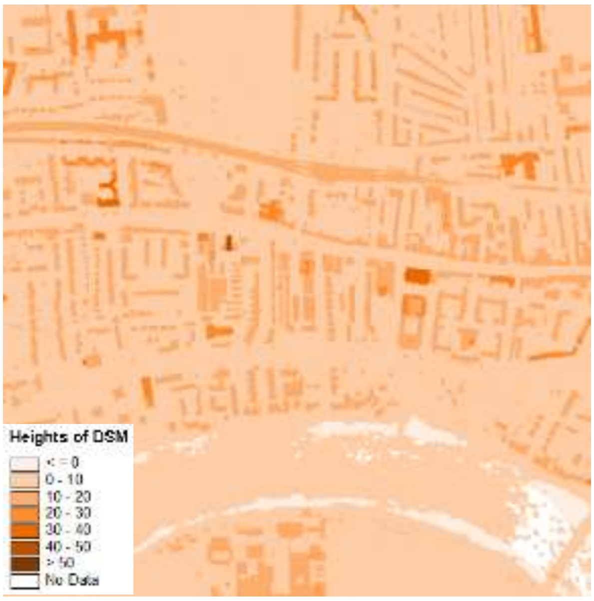
Spatial scales: This study has tested the sensitivity of computed slope to EA LIDAR data by spatial resolutions of 50cm, 1 metre and 2 meters. For cartographic representation, OS MasterMap topography layer is captured and designed for display at 1:1250, 1:2500 and 1:10 000 scales in urban, rural and mountain/moorland areas respectively. In GIS, OS MasterMap can be viewed and used over a considerable range of scales. In other word, it is scaleable. The deprivation data and land use data are analysed by OA (Output Area, average 300 residents) or LSOA (Lower layer Super Output Area, average 1,500 residents) which are small area geographies in UK census of population. Most UK social, economic and demographic data are based on this UK census geography.

Extraction of building height: The procedure of building height extraction is introduced here with the example in Ravenscourt Park of Hammersmith, London. This area (Figure 8.2a) has various types of buildings along with a range of geographic features such as river, bridge, park, major roads, minor roads and railway.

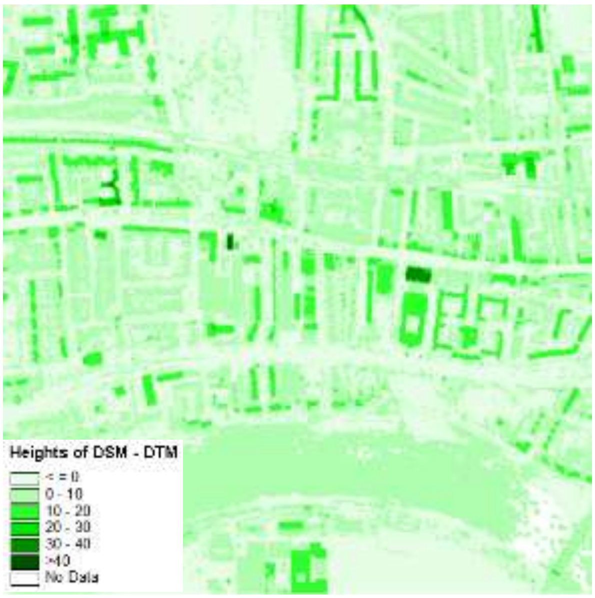
(a) Google Maps satellite image of Ravenscourt Park



(b) DTM height from LiDAR (2m resolution)



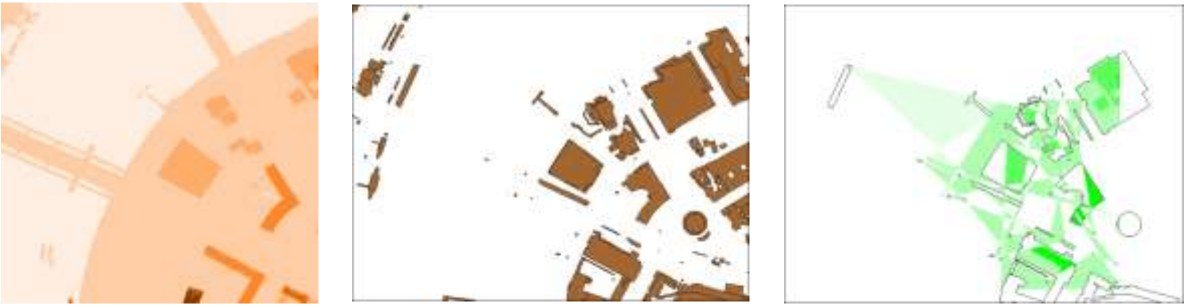
(c) DSM height from LiDAR (2m resolution)



(d) DSM subtracting DTM to give building height

Figure 8.2: Extracting building height from LiDAR DTM and DSM data (Ravenscourt Park, 2m resolution data)

LiDAR DSM data include height information of all features while LiDAR DTM data only represent the ground surface without buildings and trees. Subtracting DSM by DTM will result in the height of buildings above ground level (as opposed to height above datum in the DSM). However it will also extract heights of all landscape features such as bridge, flyovers, railways and even trees. It is thus difficult to separate the heights of building from all the other features. Figures 8.2(b) through (d) show this process using 2m resolution LiDAR. Building polygon from UK Ordnance Survey is defined as outline of manmade buildings. Although there is a standard command of cutting DEM by polygon in ArcGIS[23], it can introduce errors when DSM is cut by a number of separate polygons with complex shapes. An example can be seen in zoom-in maps of Figure 8.3 as below.



(a) DSM, 50cm (b) Building polygons (c) Errors in DSM cut by building polygons

Figure 8.3: Errors generated using standard GIS functions to cut LiDAR DSM by building polygons.

This study proposes to extract building height by a series of spatial operations in GIS. Firstly, building polygons will be rasterised as a grid with the same resolution as the targeted DSM tile such that the area between buildings has a null value. Thus when the rasterised building polygons and the targeted DSM are added together, the area between the buildings on the DSM tile will be excluded and consequently only the height data of buildings will remain. The spatial extent of study area will be determined by the map layer of building polygon. In other words, it can be a single roof, all roofs along a street, or all roofs within a specified administrate boundary. This method is therefore seamlessly scalable. However, there could be large number of DSM tiles and building polygons when the study area covers a wider region, which can lead to a heavy computation load. In such cases, sampling techniques can be used to select representative areas based on land-use variables (see section 8.4 below). Figure 8.4 shows the results of extracting building DSM data using this technique.

(a) rasterised building polygons (2m resolution) (b) LiDAR DSM (2m) cut by rasterised building polygons

Figure 8.4: Cutting LiDAR DSM by rasterised building polygons to give 'buildings only' DSM, Ravenscourt Park.

Calculation of Roof Slope: With reference to structure requirements of green roofing, roof slope must be taken into account. Roofs with slope of 20 degree or less will not require special structure measures. With a pitch in excess of 20 degree, structural anti-shear protection is needed, which is available on the market. Once the angle exceeds 30 degree, a separate set of construction calculations will be needed. German standards allow greening on the pitch roofs up to 45 degrees. Roof slope is calculated from the pre-processed DSM (2m) using standard GIS functionality.

[23] industry standard GIS software from ESRI Inc.

By querying the DSM cut by building polygons, the area of roofs having different classes of slope can be obtained. In this example, given in Figure 8.5, area of roofs with slope no more than 20 degree is 115,492 m^2, area of roofs in excess of 20 degree and up to 30 degree is 42,304 m^2, area of roofs in excess of 30 degree and up to 45 degree is 38,460 m^2.

Figure 8.5: Slope of building roofs from 2m resolution LiDAR, Ravenscourt Park.

The sensitivity of roof area estimate to DSM resolution has been tested on a curved green roof of progressively varying steepness at a bus depot. The bus depot is located between West Ham Station and Star Lane Docklands Light Rail Station in the London Borough Newham. Two roofs of this bus depot have been developed as green roof for several years (Figure 8.6 below). As shown in Figure 9, slopes have been calculated on 5cm DSM, 1m DSM and 2m DSM for the right roof of depot. Areas of pitch roof are then estimated.

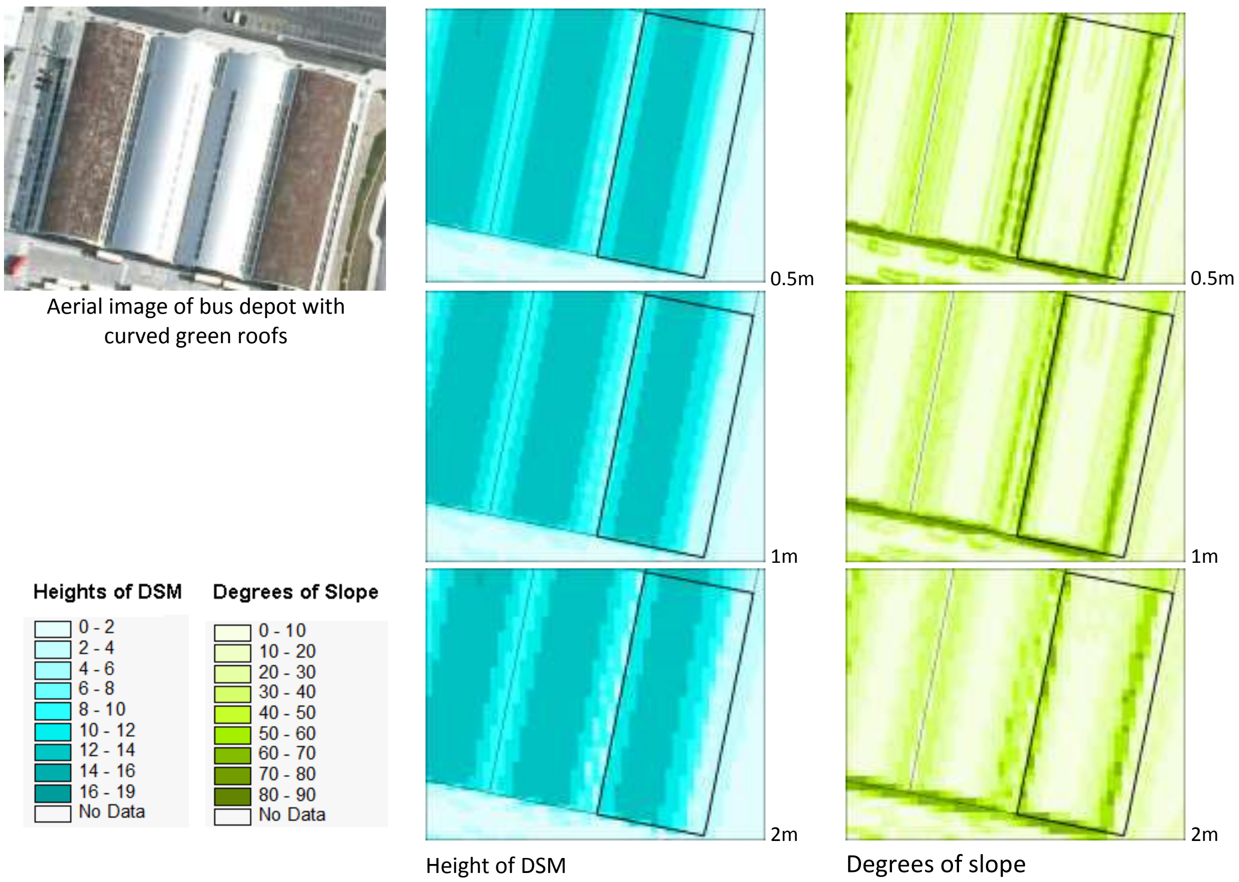


Figure 8.6: DSM height and roof slope for different resolution of LiDAR on a curved roof bus depot.

The following Table 8.1 gives area estimates for different classes of slope angle by DSM resolution. It can be seen that roof area estimate with slope of less than 20 degrees is only slightly sensitive to DSM resolution. Roof area estimate with slope of 20 degrees or more is sensitive to DSM resolution. When DSM resolution is increased from 2 meter to 1 meter, more area of steeper roof is identified. However it can be noticed that DSM resolution of 1 meter is still not sufficient to consistently separate roofs with slope of 20 – 30 degrees and slope of 31 – 45 degrees. When DSM resolution is increased from 1 meter to 0.5 meter, roof with slope of 30 – 45 degrees is better distinguished. Roof area estimate with slope between 31 and 45 degrees is sensitive to DSM resolution. Roof area estimate is clearly increased when DSM resolution is increased.

Table 8.1: Areas (m^2) at different ranges of slope by DSM resolution

	< = 20 degrees	20 – 30 degrees	31 – 45 degrees	Total roof area in m^2
50cm DSM	1002	344	402	2056
1m DSM	952	551	200	2055
2m DSM	1084	384	168	2048

Impact on environmental inequality: Estimates of potential green roof can be analysed along with other local variables in order to study potential environmental, social and economic impact on local communities. In this study, we initially focus on environmental inequality by small area geography. Environmental inequality reflects the linkage of deprived population and disadvantage environment. Green roofs, as a part of green infrastructure, if equitably implemented are expected to contribute towards the mitigation any environmental inequalities by reducing flooding risk, improving water and air quality and in general improving resilience to climate change. This impact study will explore different dimensions of deprivation with land use and flood risk to understand environmental inequality in London. Techniques of spatial data analysis and GIS functionalities are used to reveal spatial pattern of environmental inequality and therefore identify less resilient/needy communities. With estimates of potential green roof, evidence based assessment can be made to support public consultation, initial planning and strategic decision-making of green roof development.

8.4 Findings of the case studies

Urban greening in London

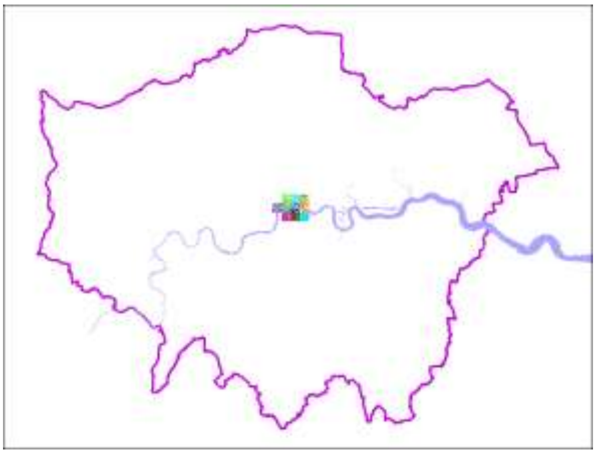
There are a number of green roofs in London, mainly at town centres or business districts – buildings with extensive flat roofs. Previous studies have been carried out in a number of areas around Central London where there is high density of commercial buildings. Here, two Green Infrastructure Audits are introduced for London Bridge, South bank and Waterloo Business Improvement Districts (BIDs). Findings in these reports reflect some common issues of roof greening at town centres / business districts in London. These case study areas are loosely used as a 'control group' for evaluating the effectiveness of rapid appraisal using LiDAR.

- *London Bridge BID*. This covers a total land area of 52.28ha, of which 39% is comprised of buildings, 17.23% is comprised flat roofs. Given the density of buildings, the greatest potential for greening can be found at roof level. There are four intensive and one semi-intensive green roofs are present within the BID as identified by the field survey. According to the results of the desk-based flat roof audit, there is potential to green 3.70ha of flat roof space which is 7.07% of the BID total land area. Preliminary structural surveys of 5 roofs are to be carried out. These have been identified as having high potential for retrofitting green roofs. Each roof was assessed individually for its potential to be greened by using aerial imagery followed by field survey.
- *South Bank and Waterloo BID*. There are already nine green roofs in the South Bank and Waterloo Quarter, eight of which have potential for further greening enhancement. These existing green roofs represent a tiny percentage of the total area with potential to be greened. Opportunities to reduce urban heat island, wind tunnel and surface water flooding effects are prioritised, in order to create a more comfortable and climate proofed environment for residents and workers. Of over 180 flat roofs assessed, 134 roofs were identified as having high potential for conversion to green roofs, mainly extensive green roofs as opposed to more intensive roof gardens.

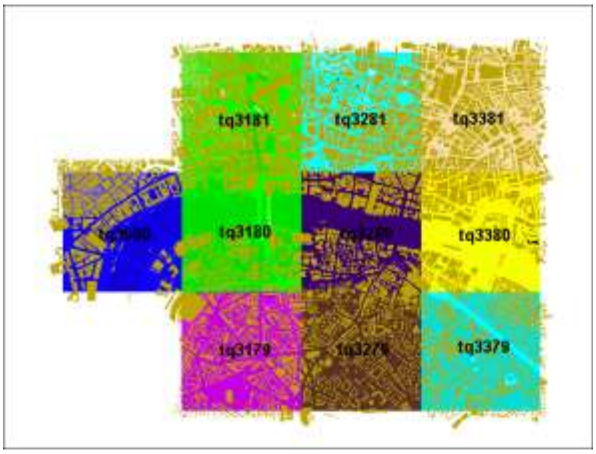
It is well recognised that there is considerable potential for green roof development in London. In previous studies, 'existing green roof' and 'potential green roof' are mostly flat roofs on non-domestic buildings, likely to be found in town centres / business districts. Each roof was assessed individually with special aerial data, reference data and field survey. A rapid appraisal using LiDAR can assess both flat roofs and sloping roofs of domestic and non-domestic buildings. It can cover a small, middle or large geographic area which could include business, industrial and residential districts. This LiDAR approach is also not as time-consuming as previous approaches and therefore can be used in the initial stages of planning and further to monitor changes in roofs in a specified area.

LiDAR Case Study in Central London and South Bank

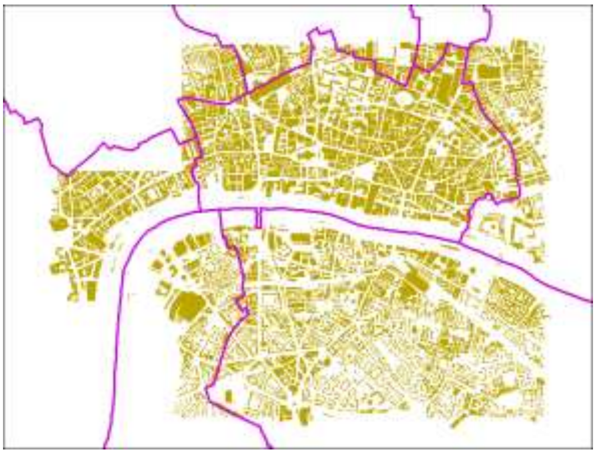
This case study area covers Central London and South Bank, where there are a number of government departments, commercial streets and business districts. In contrast, there are less residential buildings compared with the rest of London. The following map in Figure 8.7(a) shows the location of this case study area in London. All LiDAR DSM tiles within the case study area are displayed in Figure 8.7(b). All building roofs extracted from LiDAR for the case study are given in Figure 8.7(c).



(a) location of Central London and South Bank case study



(b) LiDAR tiles (2m resolution) for the case study area



(c) Extracted building roofs – 2m LiDAR

Figure 8.7: Location of Central London and South Band case study, LiDAR tiles and building roofs.

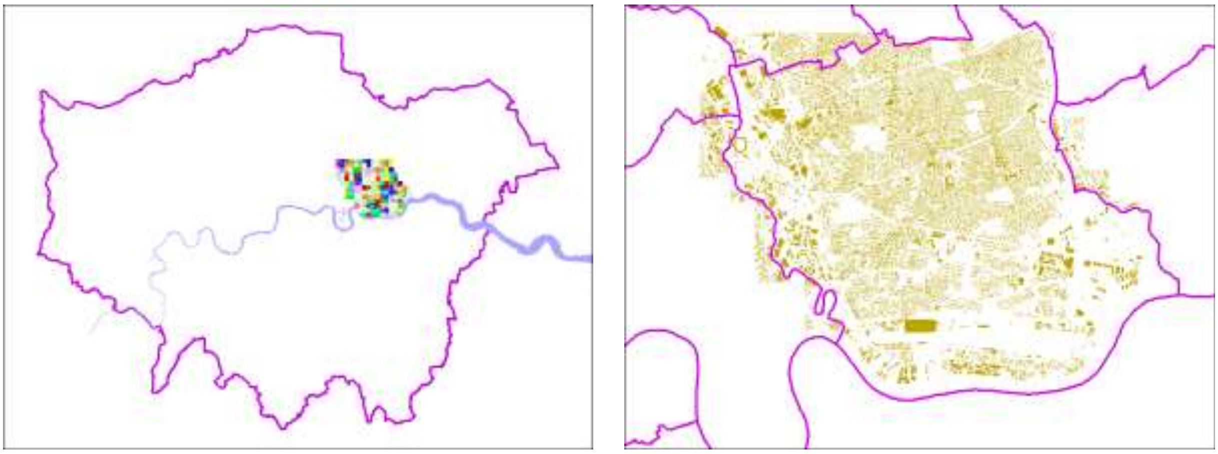
Many potential green roofs in this study area are non-domestic building roofs according to previous Green Infrastructure Audits. The focus of this case study is therefore on roofs of non-domestic building. It is not likely for most non-domestic building roofs to exceed 30 degree of slope. DSM with 2 meter resolution is then adopted, with which pitch roofs not exceeding 30 degree can be identified according the result of sensitivity test for the bus depot green roof discussed above. Table 8.2 shows the estimates of roof area (m^2) with slope not exceeding 20 degree and not exceeding 30 degree, which have greater potential to be greened. Estimates by small area geography (2m resolution LiDAR DSM tile in this case 1 square kilometre) are also provided. Overall, there is a large proportion of roofs with gentle slope (<= 20 degree) in this case study area, particularly to south of the river (tq3179, tq3279, tq3379). It is also noticeable that there considerable potential for green roof areas in the City of London (tq3181, tq3281, tq3381). These estimates can help to have a better understanding of local green roof potential, and effectively support policy decisions to develop initial plans of local roof greening. However, it is worth to point out that many buildings in Central London are listed for protection while some are government departments / agencies with limited accessibility. It is why it has been stressed in Section 8.3, and here again, that this newly developed approach mainly supports initial planning and strategic assessment. Detailed plan and design do need field works of each individual roof.

Table 8.2: Area (m^2) and percentage area of roof by slope class - Central London and South Bank

DSM Tile	Roof area (m2) by slope class		Percentage area of roof by slope class	
	< = 20 degrees	20 – 30 degrees	< = 20 degrees	20 – 30 degrees
tq3080_dsm_2m	118,040	11,224	35%	3%
tq3179_dsm_2m	141,652	11,395	41%	3%
tq3180_dsm_2m	123,680	31,272	45%	11%
tq3181_dsm_2m	187,100	67,984	35%	13%
tq3279_dsm_2m	128,788	40,928	43%	14%
tq3280_dsm_2m	158,612	45,500	43%	12%
tq3281_dsm_2m	163,392	59,576	31%	11%
tq3379_dsm_2m	142,140	43,312	45%	14%
tq3380_dsm_2m	116,028	36,904	38%	12%
tq3381_dsm_2m	176,472	68,188	34%	13%
Total	**1,455,904**	**416,283**	**38%**	**11%**

LiDAR Case Study in London Borough Newham

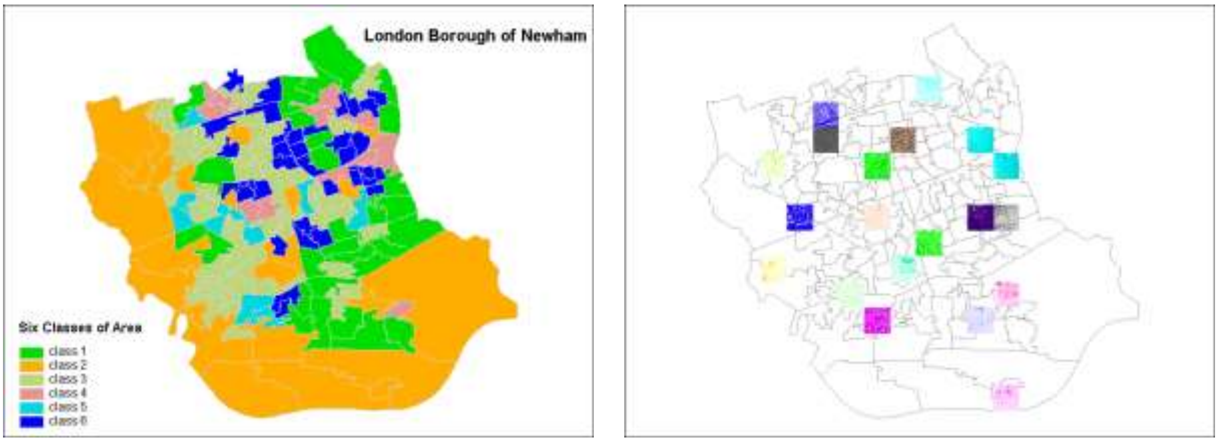
London Borough Newham is a typical urban district in UK. It has town centres, business areas, retail parks, industry areas, large residential areas as well as City Airport, the London 2012 Olympic Park and Athlete's Village. There have been a series of regeneration projects and new developments over years, some of which were on a large scale. Future developments in this borough are also being planned. Newham has a mix of old and new buildings, small and large buildings, residential and business/commercial buildings. It is dynamic, diverse, vibrant and prosperous - even in term of roofs. Figure 8.8 shows the location of Newham in London and the distribution of buildings in the borough.



(a) Borough of Newham in East London (b) Distribution of buildings in Newham

Figure 8.8: Location of London Borough of Newham case study and building roofs.

Since there are both a large number of residential buildings as well as commercial/public buildings in Newham, areas are estimated for all potential green roofs with slope from 0 degree to 45 degrees. Based on the sensitivity test in Section 8.2, DSM with 0.5 meter resolution is chosen to identify these potential green roofs. As a London Borough, admin geography of Newham is about 39 square km. It needs more than 100,000 building polygons and nearly 180 DSM tiles (0.5m resolution) to cover the whole of the borough (see Figure 8.8b). Such large amount of data will result in a heavy computational load. It will also bring planners/decision-makers more difficulties to understand more than 100,000 roof measurements. In order to control the computational load, the method of clustering and sampling has been implemented here.



(a) Six area types in Newham

(b) Sample of LiDAR 0.5m resolution DSM tiles

<u>Legend classes</u>

Class 1: Residential area with park / green space
Class 2: Town centre, Olympic Park, industrial areas, business areas, City Airport and retail parks.
Class 3: Residential area mixed with commercial buildings
Class 4: Residential area of housing estates
Class 5: Residential area with mix of estates and terrace houses
Class 6: Residential area, Victorian streets with mainly terrace houses

Figure 8.9: Six area classes from hierarchical clustering in London Borough Newham and LiDAR tile sample

Table 8.3: Area (m^2) and percentage area of roof by slope class - London Borough Newham

Area Class	LiDAR DSM Tile	Ward Name	Roof area (m2) by slope class				% area of roof by slope class		
			Total	<= 20	20 - 30	31 - 45	<= 20	20 - 30	31 - 45
Class 1	tq4281se	Beckton	31,897	9,055	6,061	11,595	28%	19%	36%
	tq4383sw	Wall End	42,643	12,131	8,696	14,337	28%	20%	34%
	tq4185ne	Manor Park	40,508	10,477	9,555	11,044	26%	24%	27%
Class 2	tq3884se	Stratford & New Town	93,409	57,278	10,769	7,741	61%	12%	8%
	tq3882se	Canning Town North	75,356	64,870	2,361	1,686	86%	3%	2%
	tq4182sw	Plaistow South	52,862	29,842	5,902	9,213	56%	11%	17%
	tq4379nw	Royal Docks	17,492	9,497	2,276	2,617	54%	13%	15%
	tq4381nw	Beckton	63,848	48,194	6,422	4,689	75%	10%	7%
Class 3	tq4081nw	Canning Town South	57,612	18,787	11,220	16,629	33%	19%	29%
	tq4084se	Green Street West	80,033	19,582	15,555	24,616	24%	19%	31%
	tq3984ne	Forest Gate South	79,721	25,508	17,028	20,219	32%	21%	25%
Class 4	tq4083se	Plaistow North	60,047	21,113	11,538	16,510	35%	19%	27%
	tq4384sw	Wall End	38,235	10,741	5,297	15,539	28%	14%	41%
	tq3985se	Forest Gate North	56,657	16,736	14,413	13,469	30%	25%	24%
Class 5	tq4081se	Custom House	60,200	25,595	12,762	10,808	43%	21%	18%
	tq3983sw	West Ham	46,524	15,169	14,602	8,373	33%	31%	18%
	tq4283se	East Ham Central	59,437	16,863	11,252	19,128	28%	19%	32%
Class 6	tq4182ne	Boleyn	71,500	13,850	13,612	29,096	19%	19%	41%
	tq4184nw	Green Street East	78,789	14,522	16,422	28,364	18%	21%	36%
	tq4284ne	East Ham North	60,948	13,726	12,494	21,830	23%	20%	36%

Firstly, a hierarchical clustering technique (Ward's Method) is deployed to classify Newham into different types of land use areas. In this case study, using land-use variables, the LSOAs of Newham are grouped into 6 classes. The clustering analysis takes into account land-use variables of domestic building, non-domestic building, domestic garden, green space, road, rail and water. The map in Figure 8.9(a) shows the spatial pattern of 6 land use area classes in Newham. Secondly, samples of LiDAR DSM tiles are selected to represent each class with local knowledge and map study. With class 2 covering a relatively larger area, five LiDAR DSM tiles are chosen for this class. Three DSM tiles are then picked for each of the rest of the area classes. Figure 9(b) shows the distribution of all 20 selected LiDAR 0.5m resolution DSM tiles which spread across the Borough of Newham. Each DSM tile covers 250,000 m^2 of land.

With this approach, potential green roofs are identified and roof areas / percentages are computed for each LiDAR DSM tile by roof slope. The results are given in Table 8.3 with each area class colour coded by the same colour scheme as the map in Figure 8.9(b). All estimates of 20 selected DSM tiles are listed in Table 8.3. Obviously, there is large proportion of roofs with potential to be greened across Newham. It is interesting to see that there is a high percentage of roof with gentle slope (<= 20 degree) in areas of class 2 (the class covering the largest area). In the industry area (DSM tile tq3882se) located in the Ward of Canning Town North, there are 86% of roofs (64,870 m^2) with gentle slope. In contrast, there are a high percentage of pitched roofs (31 - 45 degrees) in areas of class 6. In the Victoria style residential areas (DSM tile tq4182ne) located in the Ward of Boleyn, there are 41% of pitched roofs (29,095 square metres).

Environmental Inequality in London.

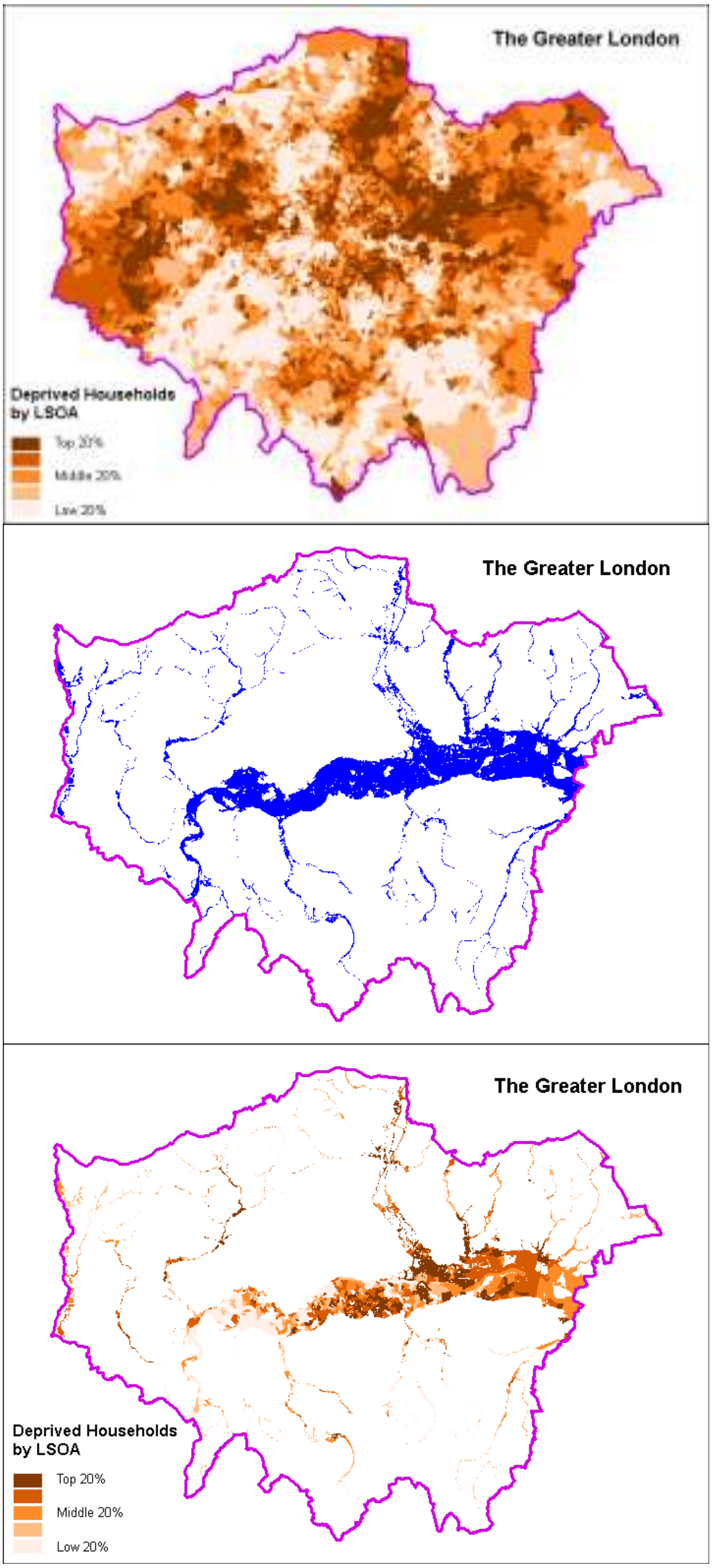
In this Section, initial analysis is carried to study the environmental inequality across London in terms of flooding risk. It will reflect the future impact of green roof development which is expected to reduce urban flooding risk and improve local environment for residents and workers. The UK 2011 Census defines four dimensions of deprivation as given below to classify a household as being deprived. This case study generally regards a household as being deprived if it is deprived in any of these four dimensions:

- Employment (any member of a household not a full-time student is either unemployed or long-term sick).
- Education (no person in the household has at least level 2 education, and no person aged 16-18 is a full-time student).
- Health and disability (any person in the household has general health 'bad or very bad' or has a long term health problem).
- Housing (a household's accommodation is either overcrowded, with an occupancy rating -1 or less, or is in a shared dwelling, or has no central heating).

The UK Environment Agency defines Flood Zone 3 as areas of land assessed, ignoring the presence of flood defences, as having a 1% or greater annual probability of fluvial flooding or a 0.5% or greater annual probability of tidal flooding. Flood Zone 3 covers areas of land at the highest risk of flooding in the Flood Map of UK Environment Agency. Spatial pattern of household deprivation across London is illustrated by quintiles of LSOA in Figure 8.10(a). In the top 20% of the most deprived LSOAs, each LOSA has more than 72.6% of households is deprived in at least one of the above four dimensions of household deprivation. These top 20% of the most deprived LSOAs cover 12.8% of total land area in London.

Figure 8.10(b) is the map of the area covered by Flood Zone 3 in London. As shown in Figure 8.10(c), Flood Zone 3 includes a higher proportion of these most deprived LSOAs than the London average. Within Flood Zone 3, these most deprived LSOAs cover 19% of land area within Flood Zone 3 of London, which is much higher than the percentage of the land area for London as a whole (12.8%).

This initial result shows that there is an inequality of exposure to flooding risk by household deprivation as the most deprived areas are over-represented in Flood Zone 3. Mitigation of flood risk through greening policies and in particular through retrofitting of green roofs would need to be London wide and not just within the flood risk zones. As was saw from the case study of Newham, there is the potential to vastly expand the area of green roof. As will be discussed below, the cost of retrofitting can be seen as high and thus in all probability is less likely to be carried out in deprived areas. Differentials in the benefits to be obtained from green roofs all household deprivations lines could widen if green roofs were more widely adopted.



(a) Quintiles of deprived households by LSOA across Greater London

(b) Extent of Flood Zone3 in Greater London

(c) Quintiles of deprived households by LSOA within Flood Zone 3 of Greater London

Figure 8.10: Six area classes from hierarchical clustering in London Borough Newham and LiDAR tile sample

8.5 Implementation issues

This study to assess the merits of rapid appraisal of green roofs has shown that large areas of roof are geometrically suitable to be retrofitted with green roofs. The Newham case study showed that some Wards had nearly 90% of their roof area as suitable. Even in areas of traditional Victorian-style terraced housing, up to 40% of the roof area is under 30 degrees slope. The Greater London Authority is already promoting green roof construction[24]. However, much of this relates to design elements of new developments applying for planning permission. Retrofitting is by and large up to individual owners of properties and may therefore have low take up, particularly in residential areas. In the present fiscal climate, the government is unlikely to offer extensive grants to home owners as it has done previously for home insulation to reduce energy consumption and costs. Currently, companies that have green roofs may be eligible for up to 80% tax relief on their energy bills. Another way in which proactive greening of roofs may catch on is through carbon offset, that is, companies agreeing to retrofit green roofs (any roof available, including bus shelters) in order to offset their carbon emissions[25].

Despite the widely lauded benefits of green roofs there remains a lack of guidance on green roof design[26] and lack of research in the UK to support appropriate design for UK weather patterns, available substrate materials and other technical issues, though some of these are being addressed through WP2 of the TURAS project. Commonly raised concerns are[27]: lack of standards, high costs, increased structural load, fire hazards, leakage through the roof and maintenance. These are beyond the scope of this report.

Planning studies of green roof potential in the UK have tended to be small scale and expensive to run. This study has shown that by using LiDAR, rapid and extensive surveys of green roof potential are feasible. This is likely to significantly reduce the cost of initial survey, providing evidence for policy and forms the basis targeting more detailed structural surveys of roof capacity. There is the question of the availability/coverage of LiDAR. In the UK it has been used extensively in floodplain areas for flood modelling and mitigation. These are the areas that would benefit from green roofs and the approach set out here provides an additional use of the existing data.

8.6 Recommendations resulting from the case study

Recommended next steps are:

1 This study should be extended to a full survey of London with sample site inspections to assess structural competence for retrofitting green roofs.

2 The data from this more extensive study should be used to estimate the benefits from London in water retention, evapotranspiration, removal of air pollutants, energy savings and wellbeing in meeting key London targets such as for improving air quality.

3 Calculate the cost/benefit to London so that policies and incentives towards retrofitting green roofs for community resilience can be properly evidenced.

[24] see Policy 5.11 Green Roofs and Development Site Environs in GLA (2011) *The London Plan*
[25] see for example http://www.greenroofoffsets.co.uk/index.php
[26] but see for example http://www.greenroofguide.co.uk/
[27] http://www.environment-agency.gov.uk/business/sectors/91967.aspx

9. Synthesis and recommendations

In this report, various case studies related to sustainable urban planning have been presented. As mentioned in chapter 2, all these studies have their own place in the coupled policy-DPSIR framework for strategic urban planning. In the next paragraph the studies will be placed in this framework again to illustrate the width of the activities performed. In addition, the activities performed have been summarized in so-called activity units which can be seen in Appendix A. These activity units give a quick overview of the work performed in the case study cities, but could also be carried out in other cities. In the follow-up part of the TURAS project, these activity units will be used to demonstrate the use and applicability of the activities in other TURAS cities.

KEY MESSAGE

1. *Data and tools for strategic urban planning are there.*
2. *Strategic urban planning is integration*
3. *Governance of strategic urban planning is all about timing, people and learning by doing*

Moreover, whilst the cases related to different topics, and were performed in different cities with their own geographic, socio-economic and political settings, there are many overarching issues that emerged and are relevant in different cases. In this chapter we will also reflect on these overarching topics. Lastly, the emerging overarching issues will be compared to some other international studies on transitions in urban areas.

9.1 Synthesis

The process of strategic urban planning has been represented as an integrated policy cycle and DPSIR framework (see Chapter 2 and Figure 9.1). Activities carried out in the research reported on mainly related to the main components 'Agenda setting' and 'Policy formulation'. Some activities targeted also the integration of various stakeholders (as illustrated by the triangle in the middle of the policy cycle). In Ljubljana, a GIS portal has been developed to facilitate communication between different stakeholders in the public transport sector. This not only relates to transportation operators and different levels of government, but also specifically the users of the transportation network: i.e. the citizens. Whilst developed for the transportation sector, it can also be employed for other sectors, such as water management.

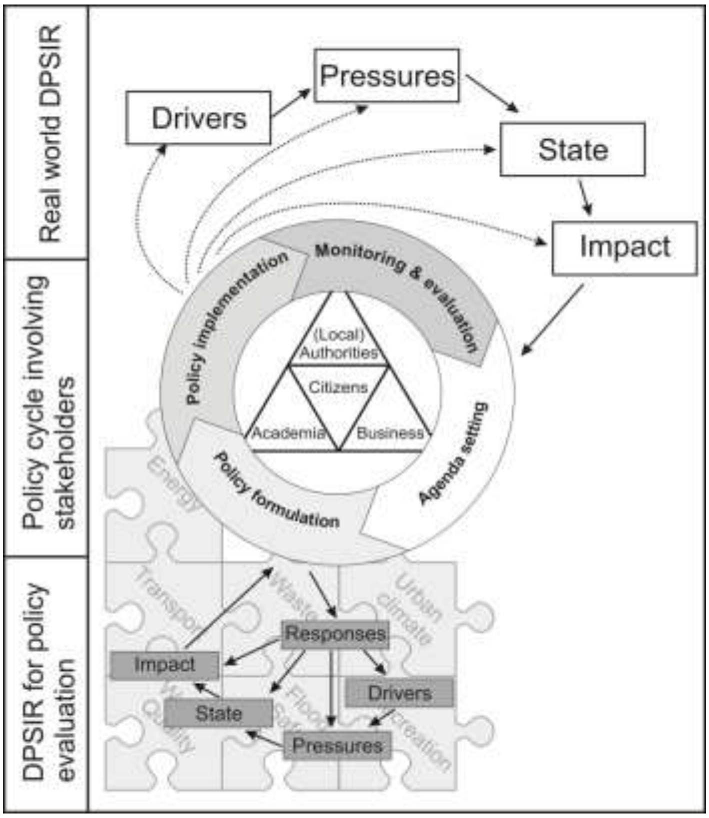


Figure 9.1: integrated policy cycle and DPSIR framework

Also in various activities related to 'Agenda setting' and 'Policy formulation' there was a component of integration of stakeholders as it automatically helps in raising awareness and as support for identified problems and possible solutions is critical for the success of strategic urban planning. In Rotterdam, for instance, a steering committee was set up that frequently met to discuss the progress of the project on regional embankments. This brought together academics, representatives from the municipality, the province, the different water boards involved, and external experts from consultancy companies. With the stress test for municipalities on climate threads and opportunities, one of the co-benefits of performing this stress test is to bring together actors from different departments within the municipality and stakeholders and actors from outside.

Agenda setting

Within the 'Agenda setting' component various activities related to raising awareness of identified potential problems. In Ljubljana, one of the many functions of the the Podutik reservoir will be to function as an educational site, with information boards explaining the need and workings of the reservoir; raising awareness among the general public. The stress test developed by the municipality of Rotterdam and first tested in Schiedam had as main goal to raise awareness on the potential threads of climate change to that municipality, i.e. the policy makers. Also for the project on regional embankments in Rotterdam one of the main goals was to identify whether the flood risk from regional waterways – a largely unexplored topic up to that moment – deserved more attention, and if so, raise awareness of the issue. The final report has also been disseminated to high-level policy and decision makers for that purpose. In this project, also the setting of targets and objectives, as part of the 'Agenda setting' component, was part of the project on regional embankments in Rotterdam as one of the key questions was whether the current safety standard still sufficed in the light of climate change, urban developments and land subsidence.

Policy formulation

Many of the studies performed related to the 'Policy formulation' component, related to the identification and evaluation of policy options through use of the DPSIR framework to assess a-priori the effect of possible measures. Various tools to allow for such evaluations have been developed and tested within the frame of the TURAS project. In Aalborg a heat atlas was developed and used to analyse scenarios on increased renewable input in the district heating system; quantifying the reduction in CO_2 emissions and dependency on fuel import.

In London a tool has been developed to assess the potential of green roofs in the city. Analyses show that the potential is relatively high, but varies considerably among different districts. One of the benefits of green roofs relates to the attenuation of storm water and subsequent urban flooding. It is shown that deprived areas are over-represented in potential flood zones, indicating inequality in exposure to flood risks. As the costs of retrofitting are considered high, the probability of this happening in more deprived areas is less likely. This means that such greening policies may widen the gap in deprivation.

In Rotterdam, a flood risk model has been set up to evaluate the effects of damage-reducing measures in the unembanked areas and assess the indirect economic losses associated with flooding in this region. This shows that there is a substantial potential for the use of such measures in this region; which can even offset the adverse impacts of climate change. It also shows that indirect economic losses are substantial – almost as large as the direct damage – indicating that such losses should be taken into account in policy evaluation and formulation. Also the work on urban ecosystem services in Rotterdam targeted the evaluation of measures. In this case the provisioning of various ecosystem services by green elements has been quantified. This model on the assessment of the effects of these green elements has also been employed to determine the current supply of these ecosystem services in a spatially explicit way. After analysis of the demand for such services, this can directly inform decision making on what elements would desirable in which place.

It is worth noting that tools/evaluations using of the DPSIR framework as described here are also of use for the 'Agenda setting' component. A-priori evaluations of future developments or unobserved events can point out potential problems which haven't been identified in the real world yet. With such information the start of a policy cycle can be triggered without an actual observed impact.

Policy implementation

As the research targeted strategic urban planning, no case studies directly targeted the implementation of measures (as opposed to other work packages of the TURAS project, such as WP2 and WP3, where this is explicitly the case). However, experiences from our local government partners have been tapped into in order to also be able to learn lessons and draw conclusions on this topic. This can be read in the chapters of Rotterdam (municipality) and Ljubljana (regional development agency), whose overarching conclusions are presented in section 9.4 below.

Monitoring and evaluation

Monitoring of the effects of real-life measures has been performed in Ljubljana, where the various functions of the Podutik reservoir are being monitored. This relates for instance to the storage capacity, water quality improvement and benefits to biodiversity.

9.2 Data and tools for strategic urban planning are there

The answering of any policy relevant question, be it for urban planning or any other goal, can only be done with the proper data and tools to answer said question. As shown in the cases, a wealth of information already exists. Given the right expertise, creativity and proper accessibility to those data sources, this has great potential to support strategic urban planning. Particularly spatial data seems to be important. In most cases presented in this report, extensive use is made of spatial data in various ways: as input for models, to create new models, to extract information for specific locations, to compare different areas, or to facilitate discussions between different stakeholders.

It is striking that in many instances, use is made of exceptionally high-resolution spatial data. Examples include databases with information at the building level as used for the Heat Atlas in Aalborg and for the flood risk model in Rotterdam, high resolution LIDAR elevation data at 50x50cm in London, and datasets on individual green elements (such as trees) in Rotterdam. The use of such high resolution data enables the answering of questions which were before not possible to study. The creation of models and tools is not only dependent on data availability, but also driven by data availability. Access to a particular type of data can trigger the creativity of researchers and give inspiration to embark on new research.

Consequently, availability of data is crucial. For most studies presented in this report, differ layers and types of data were extracted from different sources and combined by the researchers themselves. Sources of data include:

- National registers (e.g. for building datasets)
- National bureaus of statistics
- National agencies/authorities (like environment agency UK, surveying and mapping agency Slovenia, infrastructure authority Netherlands, etc.)
- Various Ministries and regional authorities (like water boards)
- Research institutes
- Companies
- Specific databases (usually devoted to a specific topic)

Interestingly, little use was made of international datasets such European datasets from the EEA (including e.g. CORINE land cover) or global datasets like OpenStreetMap and SRTM elevation data. This underscores the need for high-resolution data in solving strategic urban planning issues and results from the local setting in which urban planning operates. In case such local data is not available, there may be some coarser information that could be used, but in the cases reported this was usually not necessary.

Many of the used data sources were publicly available, meaning they could be downloaded directly from websites/servers. However, also a lot of information was used that came directly from specific institutions. Availability itself was not an issue as the data was freely provided without use on restriction. However, a-priori knowledge on the existence of that data, as well as some cooperation with such institutions was of course required. Only in a few cases was data used that was considered confidential: i.e. only to be used for a specific purpose and not to be transferred. This usually related to information from companies where wider availability of the data would have security and/or competitive consequences. In such cases, active involvement and mutual trust with such a stakeholder is required to gain access to such information.

The researchers from this work package also indicated which data they would have wanted, but was not available. It was found that it was surprisingly difficult to come up with desired but unavailable data. This is testimony to the notion that when researchers think about answering specific questions or developing certain models and tools, they start thinking from existing/known data sources. Hence, making available high quality and high resolution data enables the research community to create better tools to aid strategic urban planning practices. Also the gathering, harmonization and distribution of different datasets through a single outlet can have a positive effect on this. The EU INSPIRE regulation already forms a basis for harmonization, and there are various examples of portals that give access to a wide variety of data, such as the PDOK facility in the Netherlands[28] that gives access to high resolution elevation, topographic and building data and is heavily used since its foundation. Such portals are usually at the national level, but disclosure of high-resolution municipal data in a similar way may be similarly useful.

[28] https://www.pdok.nl/en

9.3 Strategic urban planning is integration

It is plain from the activities reported on here, that strategic urban planning is a matter of integration. Integration is crucial in a setting with so many actors, sectors, functions, and developments operating in the same system (the city in this case) simultaneously; often in a limited geographical space. Every action impacts the state of the system and correspondingly the interest and functioning of other actors and structures.

Integrating different actors to get things done is not uncommon for policy makers in urban planning who are dealing with their citizens, decision makers and a variety of stakeholders (e.g. owners, suppliers, etc) in basically every project they embark on. Not surprisingly, the integration of actors is implicitly present in basically all studies reported on in this report. It is, however, most explicit in the case of the web-portal in Ljubljana. The portal's specific goal is to let different actors communicate in order to improve the transport system of Ljubljana. Specifically, the inclusion of the general public as actor through this web portal is very special, as the public is not always involved in such a degree. Bringing together actors is not the only important thing though. The case on the stress test in the region of Rotterdam shows that it is also important to find the right person in order to acquire the relevant information and put a topic on the agenda.

The integration of different sectors in urban planning is also not uncommon for urban planners, though less engrained as compared to the integration of different actors. However, in practice municipalities – who are the main executor in urban planning – are often organized in sectoral departments (e.g. water supply, transport, etc.). This means that integrating different sectors means that different departments are involved, which may cause confusion to where responsibilities and coordination lies. Streamlining this is a challenge on its own. Nevertheless, experience and the cases shown in this report indicate a clear added value. For instance, linking spatial planning to flood management can have distinct advantages as shown in Rotterdam and taking an integrated view on all sectors involved in heat supply and demand opens up options that were not conceivable when taking a sectoral approach in Aalborg.

Closely related to the integration of different sectors in urban planning, is the integration of different functions. However, this relates to multiple functions of specific elements, rather than aligning different sectors in the same place. Several examples from the cases illustrate that, when managed properly, specific elements can supply a variety of functions or services. This relates, for instance, to the use of green roofs on buildings in order to (besides providing shelter), attenuate peak rainfall and provide insulation. Also the case of the Podutik reservoir shows that a reservoir primarily devoted to store flood water, can also help to increase water quality, biodiversity and function as an educational site. The case on urban services in Rotterdam shows that many of the green elements provide, like the reservoir, various services related to air pollution, noise, cooling etc. Moreover, it also shows that various elements can be integrated in a portfolio to obtain a certain objective, with various co-benefits because of the multiple services provided by the green elements.

Planning the urban environment is a continuous process due to constant developments that alter the boundary conditions of the system. Correspondingly, urban planning is not only done for the current situation, but ideally prepares for situations that are envisaged to come. Important developments that influence future situations relate to, for instance, climate change and demography. Both are essentially slow developments, at least for most human time scales (spanning various generations) and certainly for political timescales (spanning many election terms). Nevertheless, on the timescale of urban developments they are hugely relevant. The case on flood risk in Rotterdam shows that flood risk may increase substantially towards the end of the 21st century due to climate change if no action is taken. The Aalborg case shows that demographic changes alter the demand for heat and energy, a development that a sustainable energy plan has to account for given that infrastructure for both supply and distribution should have long life spans. Comprehensive plans like the Rotterdam Adaptation Strategy or the Aalborg Energy Vision illustrate that it is possible to adequately include such future developments in strategic urban planning, contributing to a more resilient urban environment.

9.4 Governance is all about timing, people and learning by doing

Successful strategic urban planning requires the proper tools/methods/models to evaluate options and is characterized by a high amount of integration between actors, sectors, functions and future developments. However, for strategic urban planning to be successful, also successful execution of studies and plans is required.

Well thought out plans and measures that should in theory work, may not come to fruition in practice. Often, plans or measures are developed from a technical point of view, but actual implementation should also be part of the measure, but is often not included. This relates to the on-the-ground governance of such projects, in which people play a central role. Various critical success factors related to the process of strategic urban planning have been identified over the course of this research, which could benefit actors involved in strategic urban planning to optimize their chances of success.

In the process of strategic urban planning, **time and timing** is crucial. Strategic urban planning is an arena with research, policy, action and many different stakeholders. However, time horizons of researchers and practitioners are vastly different, with researchers usually having longer time horizons as compared to practitioners. It is therefore very important to cooperate from an early stage and both parties have a flexible attitude. This enables the formulation of relevant questions for the research based on the needs of the practitioners, as well as the possibility to break up the research in smaller chunks. This has the advantage that researchers and practitioners can cooperate to resolve a certain research questions, learning from each other along the way (co-creation). Moreover, when such smaller chunks allow practitioners start acting without having to wait for the entire research to be finished. Besides time differences between research and practice, also the time horizons of different stakeholders may differ. For instance, a law may stipulate that an embankment has to have a certain standard at a certain time, whilst an urban development project with which it could be combined has a very different time schedule. Such clashes in time horizons can be resolved with flexible solutions, for instance by designating temporary uses to overcome the difference in time horizons after which a more permanent integrated solution can be implemented.

The issues related to time and timing boils down to **seizing opportunities** when possible and keeping momentum. Many successful projects are characterized by (among various things) a culmination of independent positive factors. For instance, the Rotterdam Adaptation Strategy (RAS) was initiated in a time that a national program on water management was set up, a research program was set up, Rotterdam had a visionary mayor and the advisory board of the city had formulated an advice to strategically focus on water and climate. These last two factors meant that there was support at a management level to develop a strategy like the RAS, which is essential for its success as it means that resources are freed up to support it. As strategic urban planning is a continuous process, keeping this support at management level is something to actively think about. This has everything to do with visibility. Strategies like the RAS should be well illustrated in order to be understandable and attractive to a variety of people, including the decision makers. In addition, measures and strategies should not be presented as a goal per se, but linked to important topics and ambitions for the city to immediately illustrate the added value. Lastly, visible success stories should be exploited to underline the added value not only to decision makers, but also to the outside world to attract possible follow-up activities or investments.

Strategic urban planning is the work of **people**. As mentioned, the support of management people is important, but just as crucial are the people at the policy making level. Strategic urban planning requires integration at various levels, meaning that a team is needed consisting of people with different expertise and from different stakeholders. Dedicated people with an open mind who value an integrated approach are needed there, but need time to know, trust and understand each other. This requires resources to make this happen as well as a clear dedicated coordinator to keep the process going strong. This process also improves the knowledge base of policy makers, which in the long term will benefit the municipality even more. By investing in the knowledge base of its people, a city will become more resilient when facing new challenges in the future. Within this project, a tool has been developed to raise awareness among different people and come to a joint problem analysis: the municipal stress test (more information can be found in appendix B).

Lastly, strategic urban planning is a matter of **learning by doing**. Urban systems are so complex that every place and problem requires a tailored solution. With so many differing factors, it is never possible to know everything before making a decision. Strategic urban planning is all about dealing with uncertainties. The presence of such uncertainties should not stop action from being taken out of fear of making mistakes. Innovation is always associated with mistakes, but a lot can be learned from such mistakes, enhancing the knowledge base of the people involved. When focusing on taking action parallel to doing research (instead of after another), one may find that many options have a high no-regret factor, benefitting the city and increasing its resilience anyway. This is a paradigm shift as opposed to earlier way of working, which must be allowed (or even encouraged) to take place. Taking action also underlines the ambition and motivation of the city, which may increase the reputation of the city helping to keep support at the management level.

9.5 Comparison with other studies

Efforts in cities to manage transitions in the area of sustainability are increasing around the globe. Various authors have investigated such transitions and identified lessons-learned from such cases. Here some of these studies will be compared to the findings in our cases to put them in a broader academic context:

- For Tulsa (USA), Meo et al. (2004) found that critical factors for the success of their acclaimed flood management program related to its dual ability to enable key individuals to facilitate innovation at levels of governance, and incorporating this into the organizational structure. Also the need for accurate scientific and technological information was stressed here.

- Brown et al. (2013) studied the transition in stormwater management in Melbourne (Australia), revealing that connected frontrunners from government, private, community and scientific sectors were instrumental in bringing the transition about. Also the support of bridging organisations and a collaborative learning-by-doing approach were found to influence the speed and direction of the transition.

- Mees and Driessen (2011) studied urban greening and climate adaptation in general for three cities considered frontrunners (Toronto, Rotterdam, London). They find that their success relates strongly to strong political will and leadership. Important constrains identified relate to institutional fragmentation, blocking the mainstreaming of adaptation measures, and a deficit in know-how of urban planners hampering the translation of general policy recommendations into concrete actions.

The three cases described above show very similar lessons learned as in our cases (see paragraphs 9.2 - 9.4). Successful strategic urban planning to manage sustainability transitions is characterized by active involvement of actors from various levels and sectors. Key individuals play an important role in bringing these actors together in a network that is characterized by collaboration and continuous learning. Institutionalization of this bridging is important to guarantee long-term success as transitions generally take several decades to generations before completion.

9.6 Concluding remarks

Strategic urban planning requires an effective policy process, as well as dependable underlying analyses of the environmental system. As such, the process can be described as a combination of the policy cycle linked with the analytical DPSIR framework. The studies and reflections described in this report all contribute to this process in order to aid strategic urban planning. Various concrete tools have been developed to bring stakeholders together and facilitate communication, such as the Webportal in Ljubljana and the stress in the Rotterdam region. Furthermore, many methodologies and models have been developed to evaluate a-priori adaptation measures, future scenarios, and aid in decision making. For instance, related to flood risks (Rotterdam, Ljubljana), green roofs (London), the supply of ecosystem services by other urban green spaces (Rotterdam), and energy systems (Aalborg). Also a measure that is already in place has been studied, the Podutik reservoir in Ljubljana, in order to monitor its performance and optimise its multiple functions. In short, the tools for strategic urban planning are available and more methods and tools can become available with increased access to detailed datasets, triggering the creativity of researchers.

Experiences during the studies and by reflecting on past practices revealed many factors that are important in the process of the implementing measures. Timing is very important in this regard, both to align different stakeholders and developments, but also to seize opportunities when they arise. For this, the right people are necessary. At high levels in order to safeguard political support and resources, but also at the policy analysis and policy making level in order to allow for effective cooperation and integration between many different stakeholders, sectors and functions. As there are many uncertainties about future developments such as climate change that can never be completely resolved, waiting is not an option. Rather, just taking action and learning by doing may prove more worthwhile. This also allows for co-creation of knowledge and plans between researchers, practitioners and various stakeholders. It trains people with the right mind set to recognize future opportunities and keep awareness high. Investing in the knowledge base of people thus also makes a city more resilient when facing new challenges in the future.

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Appendix A – Activity Units

In this appendix, the different activities on which the chapters reported on in this deliverable are summarized in so-called activity units. In the demonstration part of the TURAS project these activity units will be further used to test them in other cities.

	Heat Atlas
Problem to be tackled (societal)	There is a need to improve energy efficiency in buildings and reduce carbon emissions for climatic, economic and geo-political reasons. District heating can play an important role here, especially in larger urban areas where it can reach enough people and the input is sufficiently renewable. Additionally, district heating and end-use efficiency are local solutions, which improves the economic resilience by minimizing dependence on global fuel prices.
Task force (people involved)	Steffen Nielsen (Aalborg University)
Activities that are pursued (research)	Identification of options to extend district heating efficiently and change the input of the heat supply by combining high-detailed object based information on heating characteristics of buildings. This is done by establishing a heat atlas, which estimates existing as well as future heat demands of buildings within an area. To examine the change towards renewable energy supply in the district heating system, scenario analyses are applied in an energy systems analysis that simulates the whole energy system hour by hour.
Purpose/goal	Create a more sustainable district heating network and improving efficiency of heating sector.
Expected applicable output (measures)	Improved district heating system
Tags	Energy, district heating,
More information	Chapter 3

	Multi-purpose flood retention reservoir
Problem to be tackled (societal)	Floods generate high losses in the Ljubljana region. The creation of reservoirs can temporarily store flood waters to avoid inundation downstream. Such reservoirs can simultaneously be used for other purposes using ecosystem technologies that mimic natural environment (related to water quality, biodiversity, etc). However, the exact activities, focused on flood retention and co-purposes, need to be studied and monitored.
Task force (people involved)	Tjasa G Bulc and colleagues (University of Ljubljana)
Activities that are pursued (research)	Modeling and estimation of flood retention capacity Monitoring of ecosystem technology effects on biodiversity, water quality, etc.
Purpose/goal	Re-design of flood retention reservoir into multi-purpose unite
Expected applicable output (measures)	Reduced flood risk, improved water quality and biodiversity
Tags	Flood retention, water quality, biodiversity, recreation, education, urban green area with added value
More information	Chapter 5

	Interactive web-GIS for stakeholder communication and public participation
Problem to be tackled (societal)	Urban public transport and intelligent traffic management have the potential to reduce emissions, accidents and traffic jams. However, both sre not used very much and can be optimized according to the needs of stakeholders and users. A common basis of information and efficient information flows between stakeholders and users is necessary to accommodate this, which is currently not in place in Ljubljana Urban Region.
Task force (people involved)	Robert Rijavec and colleagues (University of Ljubljana); Gaja Trbižan and colleagues (RDA LUR)
Activities that are pursued (research)	Development and testing of online Web-GIS for communication between users and stakeholders.
Purpose/goal	Improve participatory planning and provide better frameworks for partnership between citizens, decision making authorities and planners, not only in the transport sector, but also in the case of energy, environment and waste management; Public participation for better inputs in the spatial design and transport planning process and traffic management (municipal, inter-municipal/regional and cross-border level).
Expected applicable output (measures)	Improved traffic models for spatial planning and traffic management; Evaluation of different implemented measures in the field of mobility, energy, environment and waste management (e.g. user satisfaction); Improved efficiency of public and private transport system in order to reduce use of cars;
Tags	Transport, Web-GIS, Public participation, micro-communication
More information	Chapter 4

	Indirect (and direct) flood damage assessment
Problem to be tackled (societal)	Estimates of the effect of flood events are necessary in order to evaluate flood management measures. However, damage models used for this relate mainly to direct damages due to flooding, while often ignoring the economy-wide losses, defined as the business interruption losses of the affected industries and the so-called ripple effects towards other (non-affected) economic actors, such as firms, households and governments. These economic losses can occur inside and outside the affected region, and after the flood event itself. The magnitude and extent of these economic losses are not well known though, while they might potentially have a substantial impact to a local or regional economy.
Task force (people involved)	Elco Koks and colleagues (VU University Amsterdam)
Activities that are pursued (research)	Development and application of a coupled direct and indirect flood loss model
Purpose/goal	Better insights in to the indirect economic effects of large-scale flooding
Expected applicable output (measures)	Improved risk estimates for cost-benefit analyses to aid decision making surrounding flood risk management.
Tags	Flooding, indirect damage
More information	Chapter 6

	Flood risk from regional waterways
Problem to be tackled (societal)	Flooding from the main rivers and the sea has received a lot of attention in both science and policy. However, flooding can also occur from regional waterways, This hazard and its consequences are much less studied and therefore the question remains if and what type of policy should be used to manage this risk.
Task force (people involved)	Nick van Barneveld (City of Rotterdam) and Hans de Moel (VU University Amsterdam)
Activities that are pursued (research)	Full risk assessment and identification and evaluation of management measures for a small polder area surrounded by regional waterways. Detailed impact assessment going beyond traditional direct damage models and stakeholder workshops to identify and develop possible management measures
Purpose/goal	Create insight into possible effects of flooding from regional waterways
Expected applicable output (measures)	Increased knowledge on detailed impact assessment and increased awareness on the flood risk potential of regional waterways in the policy domain.
Tags	Flood risk, regional waterways, impact assessment
More information	Chapter 6

	Urban ecosystem services model
Problem to be tackled (societal)	The provisioning of ecosystem services (ES) has received a lot of attention in rural landscapes. However, also urban settings provide ES that improve residents' wellbeing (related to e.g. air quality, noise, heat stress, and recreation). These ES are provided by small-scale green and blue elements (e.g. trees, grass, gardens, and water) that are scattered throughout the city. In order to aid strategic urban planning, the supply and demand for these services needs to be known. A first step is to determine the ES provisioning rate of different green and blue elements, and second, aggregate ES values to city planning units.
Task force (people involved)	Marthe Derkzen and colleagues (VU University Amsterdam)
Activities that are pursued (research)	Spatial modeling of ecosystem services provisioning at detailed (object) scale
Purpose/goal	Improved insights into urban ecosystem services provisioning by individual green and blue elements and the spatial distribution of ES bundles at city district level
Expected applicable output (measures)	Better balance between supply and demand of urban ecosystem services through better informed urban planning (i.e. which elements to put where)
Tags	Ecosystem services bundles, green infrastructure, mapping
More information	Chapter 7

	Potential of green roofs
Problem to be tackled (societal)	In urbanised regions, storm water runs off quickly due to low infiltration capacity. This can result in flooding with all its negative consequences. One way to combat this flooding is by attenuating the storm runoff by storing the rainwater temporarily on green roofs. Green roofs have further benefits for cooling, improving air quality and providing recreational space. In order to start fully assessing the benefits of green roofs for adding resilience to urban areas, rapid appraisal techniques are needed to assess the potential for green roof installation at the city/neighborhood scale.
Task force (people involved)	Allan Brimicombe and Yang Li (University of East London)
Activities that are pursued (research)	Spatial analysis using high-resolution LiDAR elevation data (and auxiliary thematic spatial data) to derive and test the method for rapidly classifying roof geometry over large areas and thus identify the places where green roofs can be established in an area. This is a fundamental step that then opens up the possibility for subsequent analysis of green roofs in adding resilience to urban areas.
Purpose/goal	To devise a technique for rapid appraisal of green roof potential as an input to policy and planning decisions on making urban areas more resilient.
Expected applicable output (measures)	Increased retention of storm water reducing effects of urban flooding, reduction of urban heat island effects, improvement of air quality and reduction in energy use.
Tags	Green roofs, storm water, flooding, LiDAR
More information	Chapter 8

	Stress test on impacts climate change
Problem to be tackled (societal)	Adaptation to climate change is a broad subject, covering many disciplines. As a result, municipalities often do not have one department which is the ‘problem owner’ of climate adaptation. Correspondingly, many municipalities have no comprehensive climate change adaptation strategy due to a lack of ‘problem owner’ and scattered expertise/responsibilities.
Task force (people involved)	Lissy Nijhuis and colleagues (City of Rotterdam and Rotterdam City Region)
Activities that are pursued (research)	Development and testing of a stress test to perform an analysis of threats and opportunities resulting from the effects of climate change. Based on the outcome of this stress test, municipalities can decide whether or not it is urgent and/or useful to develop and implement a climate adaptation strategy, and if so, where the focus should be.
Purpose/goal	Increased awareness among policy makers of a municipality on the threats and opportunities related to climate change in their region.
Expected applicable output (measures)	Development of municipal climate adaptation strategies when useful.
Tags	Climate change, adaptation, strategy
More information	Appendix B

	Integrated solid waste management
Problem to be tackled (societal)	Integrated solid waste management (ISWM) refers to the strategic approach to sustainable management of solid wastes covering all sources and all aspects. It recognises three important dimensions in waste management: (1) stakeholders, (2) waste system elements (generation, segregation, transfer, sorting, treatment, recovery and disposal) and (3) sustainability aspects in an integrated manner, with an emphasis on maximizing resource use efficiency. The aim is to understand the problems of urban waste management - by assessing the current situation in all its aspects – and, secondly, planning a more sustainable waste management system
Task force (people involved)	Pilar Zapata (BioAzul) and colleagues from Promalaga
Activities that are pursued (research)	Data compilation on the current waste management system in a concrete area of the city (historical centre of Málaga city) and their evaluation in the framework of the ISWM concept
Purpose/goal	Elaboration of recommendations to improve the current waste management system towards resource use efficiency and sustainability
Expected applicable output (measures)	Increased awareness on the waste management system of the city, especially in its weaknesses, and identification of corrective measures
Tags	Solid waste, waste management
More information	Forthcoming

Appendix B – TURAS Stress Test

1. Introduction:

In November 2013, the stadsregio Rotterdam (City Region of Rotterdam) launched the “Building blocks for climate adaptation strategies in the Region of Rotterdam”[29]. These building blocks are to form the basis for specific adaptation strategies for individual communities within the Rotterdam City region. Five steps form the core of the building blocks which (groups of) individual communities can use in order to strengthen their adaptive capacity:

1. Perform an analysis of threats and opportunities which affect the community, as a result of climate change.
2. Define ambitions related to climate adaptation
3. Select and Implement climate adaptation measures
4. Integrate climate adaptation into the community’s (spatial planning) process and systems
5. Monitor results

In the period March-June 2014 a pilot was conducted within the TURAS project in the city of Schiedam designing a quick and simple method (called a stress test) to perform step 1: Analysing threats and opportunities. The pilot also included conducting the actual analysis with the help of various experts from the city.

The pilot was conducted in Schiedam because this relatively small town is exemplary for other cities in the region. Moreover, policymakers and experts in Schiedam were very motivated and willing to participate: a key factor for success!

2. Goal:

The goal of the stress test or quick scan[30] in the region of Rotterdam is to identify threats and opportunities resulting from the effects of a changing climate. Based on the outcome of the stress test, (small scale) cities[31] can decide whether or not it is urgent and/or useful to design and execute a climate adaptation strategy and if so, what the most important issues are.

3. Results:

The result of the stress test is threefold

1. The stress test provides a rich analysis of threats and actual vulnerabilities and opportunities regarding climate change, providing a good basis for strengthening the climate adaptiveness of the community.
2. Executing the stress test and looking for answers to the questions asked in the test is raising awareness concerning climate change, the potential negative effects and the possible opportunities. The topic of climate change is linked to various themes within the city, making people aware of its integral character as well as of the possibilities that arise when certain activities are combined with each other [meekoppelkansen].
3. The test shows which information is currently lacking in order to make a well thought-off decision.

4. Central issues:

Based on analysis of the impact of climate change for the region of Rotterdam, the stress test focuses on four main topics:

- Rising sea levels
- Extreme precipitation
- Drought / desalinisation
- Heat

[29] Stadsregio Rotterdam (2013), “Bouwstenen voor klimaatadaptatiestrategieën in de regio Rotterdam”.

[30] At the start of the pilot project, the term ‘stress test’ was used, since this terminology is also used by the Dutch Ministry of Infrastructure and Environment which is responsible for the National Adaptation strategy (NAS). During the process it became clear that ‘stress test’ has a negative connotation and doesn’t sufficiently stress the importance of opportunities. Therefore the label ‘Quick scan’ was introduced.

[31] The region of Rotterdam consists of the following municipalities: Rotterdam, Maassluis, Vlaardingen, Schiedam, Lansingerland, Capelle a/d IJssel, Ridderkerk, Albrandswaard, Barendrecht, Spijkenisse, Brielle, Bernisse, Oost-Voorne en Hellevoetsluis.

5. Definition of climate adaptiveness:

Based on research, done within the context of the national research programme Knowledge for Climate, climate adaptiveness is defined as the [resultante] of three variables:

- Degree of exposure to the effects of climate change (e.g. there is high water in an unembanked area)
- Vulnerability of areas, people, objects etc for the effects (houses are built wet of dry proof, but streets become inaccessible)
- The adaptive capacity of the area and the people (high adaptive capacity: people with food and water stored in their home and with cars parked on designated, higher located place, low adaptive capacity: the opposite situation).

6. Methodology/ steps:

1. Identify exposure to the effects of climate change (climate effect map)
2. Identify vulnerability of people and objects in the area (questionnaire/workshop)
3. Identify adaptive capacity (workshop)
4. Identify potential measures which either decrease the exposure of the vulnerability or strengthen the adaptive capacity (workshop)
5. Identify opportunities (workshop)
6. Decide upon designing a climate adaptation strategy for the city (or a group of adjacent cities) (advice to politicians)

Based on a climate effect map that was constructed for the region of Rotterdam (Goossen et.al. 2013), the potential degree of exposure is clear. The stress test focuses on steps 2 to 6 determining the *actual* vulnerability, adaptive capacity, measures and opportunities and giving an advice to the city council. Important in these steps is the involvement of experts with specific knowledge concerning the local situation, transforming theoretical treats and opportunities into actual challenges and chances.

In order to identify the potential vulnerability, the following questionnaire is used. Next, the adaptive capacity is determined in a workshop with various actors and stakeholders, who discuss this topic based on the answers to the questionnaire, the images of the climate effect atlas and their personal expert judgement. In the same workshop, possible measures and opportunities are discussed.

Eventually, all results will be presented to the city council who can than decide whether of not a climate adaptation strategy is considered necessary.

Questionnaire

Water safety
Unembanked areas
1. Do you know which are the unembanked areas?
2. Does the community have any policies in place considering the unembanked areas?
3. Does the community already suffer from high water in the unembanked areas?
4. Do you expect any high water in the future (if so, when)?
5. What damages would be caused by high water in unembanked areas (type plus costs)?
6. Does the city know who is doing what in case of high water in the unembanked areas?
Embanked area / urban water management
7. Do you know the current weak spots in the dykes?
8. Are there any vulnerability maps available (maps concerning inundation depths, vulnerable objects, functions, people etc.)?
9. Are you familiar with, conscious of possible benefits/chances?

10. Do you know how your urban water system works (including the relation with the regional system)?
11. Do you suffer from too much surface water in the current situation (especially in times of heavy precipitation)?
12. Are possible future locations known where excessive surface water might become a problem?
13. Do you know who is responsible for dealing with the results of heavy precipitation?
14. To what extend is the municipality aware of the potential problems and benefits?
Heat
15. What is the ratio between paved and green areas? Where are the paved and green areas situated?
16. Where are the vulnerable groups situated? Do you expect any changes in this situation in the future?
17. Do you know where to look for cooling in times of extreme heat? Does the public know these cool spots?
18. Doe the municipality have some kind of heat plan?
19. Do you know the relation between heat and other topics, like health and air quality?
20. Do you see any benefits regarding the up heating city?
Droughts and salination
21. Where in the city do you suffer from [bodemdaling]?
22. Does the municipality take heat and drought into account when planning green spaces?
23. Do you have any maps regarding relevant information like groundwater levels of foundation materials?
General questions:
24. Do you –in general- know enough about effects of climate change for your community? Dou you know the vulnerability, the benefits and/or the possible measures?
25. Is the municipality aware of potential costs and benefits?
26. Are the politicians sufficiently aware? (do you have evacuation plans, or plans to respond in case of extreme events?
27. Do citizens know whom to call for information? Do you?
28. Is the division of responsibilities clear?
29. Did you take a will-thought decision concerning the balance between problem solving by the municipality and informing the public about how to solve problems on their own?
30. To what extend doe the city already cooperate with other stakeholders? Doe the municipality know its stakeholders?

7. Results from the pilot in the city of Schiedam

1. Collecting information (questionnaire)

First, based on the questionnaire, information was collected. Most of the questions were asked and answered within the organisation of the city of Schiedam. Specific questions concerning the water system were answered by the water board Hoogheemraadschap van Delfland. Specific questions concerning the effects of heat and the safety of the region were answered by the GGD (regional body concerned with public health) and the Veiligheidsegio (regional body concerned with public safety).

All the information was bundled in a document (see illustration) and distributed to all relevant actors within the city of Schiedam and the waterboard.

2. Exchanging knowledge (workshop 1)

The next step was to organise a workshop with different experts from the city in order to:

- Discuss the information that was collected
- Discuss implications for the city in terms of threats and opportunities
- Discuss possible measures
- Discuss what to advice to the city council and deputy mayor

The workshop was held in June 2014 and the following fields of expertise were represented:

- Environmental affairs
- Spatial planning
- Maintenance of public space
- Urban water and sewer system (including a representative of the water board)
- Landscaping [landschapsarchitect]
- Green and ecology [stadsecoloog]
- Economic and juridical affairs

Information bundle for the stress test workshop in Schiedam.

Results of the workshop include:

- **A shared understanding of what we mean by climate adaptation:** Some participants admitted that climate adaptation was not a very appealing subject to them. They thought is was vague, abstract and 'something initiated by the EU'. During the workshop it became clear that climate change:
  - is already happening
  - is already influencing our daily lives
  - is already very relevant for numerous policy areas
  By exchanging knowledge, the group developed a shared image of how climate change affects the city of Schiedam. Moreover, people began to understand that they themselves could do something in order to strengthen the city's ability to adapt to climate change.

- **A clear picture of how climate change links to current activities in the city:** In the city of Schiedam some areas already need to deal with an abundance of water in case of heavy precipitation. In other areas solutions have already been found by creating water storages underneath a road. Dealing with heavy rainfalls is not new to the city. Looking at it as a problem which requires a structural solution is. The long term time frame of climate adaptation as well as the possibility to link this issue to other priorities in the city (like safety and health) offers the change to deal with this issue strategically, improving the quality of both the public and private space in Schiedam.

- **Consciousness among the people present and the motivation to spread the knowledge throughout the organisation:** During the workshop, the people present became more and more aware of the importance of climate change. Meanwhile it was concluded that the rest of the organisation needs to be informed as well. Starting with the deputy mayor and the various 'area managers' (responsible for new developments and restructuring).

- **Clarity about the role citizens can play:** Many policy makers and project leaders were looking for ways to involve citizens in their projects. While talking about climate adaptation, it become clear that citizens can indeed play an important role and that the actions they can take are relatively easy to implement (like using a rain barrel, de-paving the backyard or looking for cool spots during warm summer nights).

- **Better understanding of the knowledge that is still missing:** Not all the questions in de the questionnaire have been answered. Especially questions dealing with drought, salination and ground water remain unanswered. During the workshop these knowledge gaps were discussed as well as ways to bridge this gap.

- **A list of actions (*not measures*) to be taken on the short term:** At the end of the workshop it became clear that one meeting wasn't enough. A large part of the time available was used to exchange knowledge concerning the climate adaptation topics. Too less time was left to define the most important threats and opportunities or to discuss actual measures. So a list of actions was decided upon, including
  - organising a second workshop,
  - Informing colleagues, area managers and politicians by giving several presentations
  - asking experts within and outside the city to answer specific questions
  - reporting to the deputy mayor about this workshop, and suggesting him to advice other cities to do a stress test as well, based on the positive experience of Schiedam.

3. Advising the deputy mayor

This is done by writing a memo and by advising him to promote the stress test to other cities which he actually did during a meeting with all the senior people responsible for Green, Spatial planning and Environment of the region of Rotterdam present.

8. Implications and plans for the future

One week after the workshop in Schiedam was held, a presentation was given to all elderly men responsible for Green, Spatial planning and Environment of the region of Rotterdam. The topic was the stress test, a.k.a. the quickscan climate adaptation, and the offer of the City region of Rotterdam was to support a quickscan in all small and medium sized cities in the region (= all but Rotterdam which already has a climate adaptation strategy). Almost all cities agreed upon doing a stress test and in four cities the test will actually begin before summer!

There are many factors that are expected to have influenced the decision of so many elderly men and women to do the test (like exposure of the topic at a national level, heavy rain showers in the fall of 2013 in the region, the inspiring report on building blocks for climate change adaptation strategies from the City region, the international success of the Rottterdam Adaptation Strategy, the will to co-operate with each-other or a strong personal commitment), but the promising results from the TURAS pilot in Schiedam surely must have had a positive influence!