6 Adaptation to Floods in Riga, Latvia: Historical Experience and Change of Approaches

Laila Kūle, Agrita Briede, Māris Kļaviņš, Guntis Eberhards & Andris Ločmanis[1]

University of Latvia, Faculty of Geography and Earth Sciences, Riga, Latvia
[1]Riga City Council

6.1 Introduction

It is widely acknowledged that coastal areas are among the most vulnerable to climate change impacts and, at the same time, are considerably affected by anthropogenic impacts. Therefore, these areas need particular attention (EEA, 2006). Studies at European level (EEA, 2010) list the following climate change impacts affecting coastal areas: the impacts of sea level rise, increased flooding, more frequent storm surges, changes in temperature, precipitation and ice regime, changes due to increased coastal erosion, increased salt water intrusion in groundwater layers, and changes in coastal ecosystems. In response to extreme weather events and other coastal natural and man-made hazards, inhabitants of coastal areas – urbanised communities in particular – have developed community-based adaptation strategies over the centuries, derived from various types of knowledge (Ensor & Berger, 2009). Floods have been recognized amongst the major natural hazards, causing immense losses every year. Coastal urban territories are particularly vulnerable to flood risks, as is the case with Riga. In Latvia, which is characterized by an excessive moisture regime, rivers can flood due to snow melting and increased precipitation while coastal areas are at risk of storm surges. The 15 km long coastline of Riga City and about 60% of its urban waterline are vulnerable to sea level rise (see Figure 6.1). In the context of climate change, storm surges and flash floods due to intensive precipitation are expected to increase (Avotniece et al., 2010). Outdated technical infrastructure of the urban water supply system is an additional cause of flash floods. The Riga City dominates in many fields in the context of Latvia's development and associated with that, significant human and man-made resources are concentrated in the capital.

The Riga municipality is the largest in the country, with 700 100 inhabitants or 31.4% of the total population of Latvia living in Riga in 2011 and producing 53% of the total GDP in 2009 (CSB, 2011). The average population density is 2303 persons per km^2 (CSB, 2011), but it can range between nine and 15 981 persons per km^2 among its 58 spatial analytical units (Riga City Council, 2012), while especially flood-prone and coastal areas have lower densities. Additionally, 17% of the city is covered by nature reserves which are mainly situated in the coastal and flood-prone areas (Riga City Council, 2012). Daily, many people commute between the suburbs and Riga City so that the population runs up to approximately one million people in the daytime. It is situated in the delta area of the three large rivers: Daugava, Lielupe and Gauja. All three rivers are treated separately in terms of the EU Water Framework Directive and thus three

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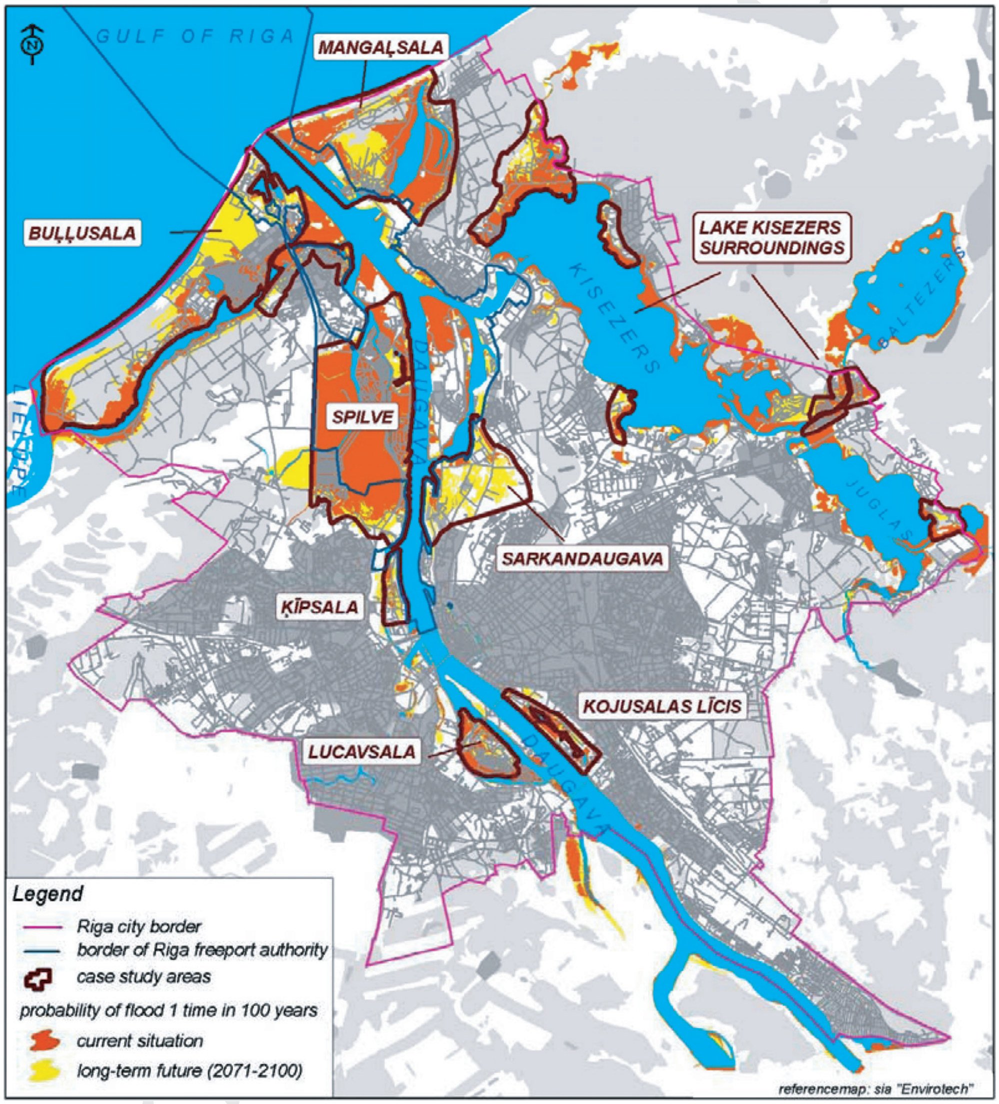

Figure 6.1 Hot spots under discussion that are identified as sites (including technical structures) for climate change adaptation measures, with focus on flood risk management.
Source: prepared by Andris Locmanis, Riga City Council

separate integrated river basin management plans are being prepared in 2009. Beside current water quality and quantity safeguarding, issues of flood prevention and climate change adaptation should be incorporated in these plans in 2015 (European Commission, 2012). As there is a need to coordinate prevention measures against coastal floods in the lower part of three large rivers the case of Riga is particularly challenging with respect to city development and spatial governance.

Directive EC 2007/60 of the European Parliament and of the Council, which specifies the structure and objectives of flood risk management plans and the recommended flood mitigation measures, acknowledges that specific local aspects should be considered in each particular case. Studies at European level do not acknowledge that Latvia in general would be highly vulnerable to flood risks in comparison with other countries (Lugeri et al., 2010) and they also do not record any major flood disasters in the period between 1950 and 2005. Studies at a more detailed level indicate that Riga and other local areas can sustain flood damages and thus flood prevention measures have to be proposed and implemented.

The aim of this study is to look at the historical experience and approaches used to reduce flooding in Riga. This chapter will describe the basic concepts of flood risk management approaches, knowledge types and stakeholder involvement, as well as providing insights into the historical context and current practices of flood prevention management in Riga City. It will also review historical extreme flood events in Riga since the 13th century. To encompass the various types of knowledge relevant for flood risk management, different information sources were examined.

6.2 Relevant aspects for flood risk management

6.2.1 Stakeholder involvement in flood risk management

Adaptation measures to reduce flood risks are basically regulated by Directive EC 2007/60 (Table 6.1). However, the Directive gives little information about the development of flood prevention strategies and implementation of flood management plans on the local level. Nevertheless, the need to find a good governance concept, supporting the implementation process and leading to acceptance and proper application of a flood risk management plan, is obvious. It is of importance to ensure the necessary multi-stakeholder participation in its preparation and decision-making process. A higher quality of the decision-making process and its outcomes can be achieved by considering international success stories and historical experiences with flooding.

Adaptation to flood risks should be a combination of top-down (represented by the EU Flood Directive EC 2007/60 and national governments) and bottom-up processes initiated by interest groups (public and private land developers, entrepreneurs, housing management organizations and citizen groups) or municipalities with flood-prone areas. This concept is stated in Article 10 (2) of the Flood Directive as follows: 'Member States shall encourage active involvement of interested parties in the production, review and updating of the flood risk management plans'. An integrated flood management approach by the World Meteorological Organization (WMO, 2009, p.19) acknowledges that it is important to make use of the strengths of the top-down and bottom-up approaches by determining the appropriate combination of elements from these approaches. It also states that members of as many sectors as possible have to be involved, as they represent different types of knowledge. Coordination and cooperation among institutions affected by flood risks or involved in their management are part of the strategy of how to overcome geographical and functional boundaries and achieve synergy for all the institutions involved (WMO, 2009).

Another key problem in flood risk management is that the Flood Directive replaces traditional flood defence strategies with a risk-based management concept (Samuels et al., 2009). Flood risk management is a part of integrated water resources management, and its systematic actions are divided into groups by the cycle of preparedness for, response to and recovery from a flood event (WMO, 2009). Other aspects of flood risk management are listed in Table 6.1. Again, it is essential for flood risk management to consider stakeholder involvement as manner of a participatory approach and to make sure that stakeholders are well represented in the discussion and decision-making process in relation to flood prevention (WMO, 2009).

Professional and public stakeholders need to build up their capacity of understanding and application of flood risk management (WMO, 2006), which is not a fixed set of tangible measures, but an evolving process of transition to more adaptive flood risk management in order to cope with the emerging uncertainties due to climate change/variability (Tippett & Griffiths, 2007).

The term 'stakeholder', initially used in business management (Freeman, 1984); stakeholder involvement is now broadly applied to different aspects of governance, including environment and resource management (Grimble & Wellard, 1997), coastal management and flood prevention (Heitza, Spaeter, Auzut & Glatrona, 2009; Werff, 2004). This approach is related to the paradigm shift in flood risk management, requiring expert information supply,

Table 6.1 Three dimensions of flood risk management

Context	Process	Content
External: political; legal; social and economical; spatial; and locational. *Internal*: social; cultural; political; institutional; available resources; capabilities; and physical conditions.	*Stages of process:* understanding context; flood-related data collection and monitoring; flood trends and analysis; scenario selection; model creation and assessment; criteria selection; identification of risks, problem areas and hot spots; prioritization; selection of alternative measures; communication and approval of selected measures; creation of organizational and financing structure; implementation; and evaluation. *Planning principles*: sustainability; legitimacy; procedural equality; justice; people first principle; social equity; resources targeted to the most vulnerable; maximisation of utility (greatest risk reduction per unit of resource input); a long-term and visionary approach; proactive, strategic, precautionary approaches; scientific data and evidence-based, ecosystem approach; water-basin approach; the water cycle management approach; multi-hazard approach; risk management approach; community-based approach, multi-scalarity; cost-effectiveness; integration; transdisciplinarity; responsive and participatory processes; openness; public participation; and empowerment. *Governance types*: bottom-up; top-down; subsidiarity; cross-sectoral; short-term; medium-term; long-term; multi-scale; stakeholder involvement. *Organizing strategic planning:* project-based planning; ongoing planning. *Strategic planning mode*: programming; portfolio planning; scenario-based planning. *Learning*: knowledge creation; review and assessment; formal and informal learning; policy transfer; institutional networking; knowledge distribution channels, targeted to specific audiences.	*Goals and specific targets* *System analysis*: controllable; not controllable variables. *Strategic alternatives* as combination of measures. *Structural measures* (flood hazard reduction): barriers; barrages; dams; river regulation and channel improvements; diversion channel creation; dykes, levees and embankments; improved drainage, stormwater and rainwater. networks; flood abatement through forestation; wetland creation and landscaping; improved evacuation network; flood proofing. *Non-structural measures* (flood vulnerability reduction): flood proofing; flood risk identification and assessment; flood forecasting and warning; preparedness, evacuation and post-disaster planning; integration of flood management aspect in regulations of economical activities; regulations of existing property management, land use, and building; flood-sensitive land use; flood prevention integration into sectorial, spatial and development planning; flood warnings and raising public awareness; resilience-building; resistance capacity-building; strengthening local institutions; property purchase and relocation; home owner adaptation; flood aware targeting of public investments, services and infrastructure; flood insurance and other risk sharing mechanisms; compensation.

Source: Modified from Hutter and Schanze, 2008; Parker, 2007; Johnson *et al*., 2007; Tran *et al*., 2008; Neuvel and van den Brink, 2009; Glavovic, 2008; WMO, 2009; Harries and Penning-Rowsell, 2011.

co-thinking, co-design, co-management, consultation, participation and action, and consequently, involving a broad range of stakeholders and practitioners (Werritty, 2006; Tippett & Griffiths, 2007; Mostert et al., 2007). Flood risk management can be implemented if adaptive capacity development, knowledge and adaptive management (Hillman, 2009) are a part of the process. The involvement of stakeholders – that is, all persons, institutions or organizations with an interest in involvement in the issue, either because they will be affected (positively or negatively), or because they can influence (positively and/or negatively) the outcome – is closely linked to social learning (Ridder, Mostert & Wolters, 2005). Stakeholders can be directly or indirectly involved in various stages of different kinds of events and other activities relating to flood risk management and the related decision-making process. But it is always important to inform all stakeholders about the process and the outcomes at each stage. Identification and involvement of a large number of individuals and groups with interest in the issue may encumber the ability to take a decision that would solve the problem (Harrison & Qureshi, 2000). Therefore, stakeholders' assignment in focus groups, as well as the conduct of discussions, expert interviews and workshops, and other means of stakeholder identification and selection are recommended respectively. Studies advise the assignment of stakeholders in terms of the ratio between their interest in the issue and the ability to change the situation, taking into account aspects like authority, finances, knowledge, capabilities, vulnerability and others. The diverse patterns of stakeholder structures will appear if these aspects are referred to flood risk management – for instance, stakeholders who are most vulnerable often lack resources and authority to cope with or prevent flood impacts. Various thematic areas, categories and typologies can be used in order to structure a vast and diverse pattern of stakeholders and their discourses in relation to the issue.

Stakeholder assignment is linked with 'the notion of "interactional field"', a social situation/space defined by its contextualities, a cluster of actors and processes with geographically, socially, economical [*sic*], and politically defined boundaries', and all these factors imply 'a look at social spaces in time/dynamics' (Aligica, 2006, p.85). Harrison and Qureshi (2000) stress that stakeholder identification is a process that needs to be repeated, as discussions will reveal groups and individuals that have not been identified before. Stakeholders can provide information and knowledge not only about the issue, but also on other stakeholders involved. Stakeholder participation process is greatly dependent on institutions responsible for the issue concerned. It is highly important to provide a policy framework and capacity in terms of human, financial and knowledge resources, and time- and place-related aspects for the stakeholder involvement process and its management. Stakeholders have to have the ability and capacity to participate (Weber & Christopherson, 2002). Early involvement of stakeholders is important for a decision-making process with a successful outcome (Reed, 2008).

6.2.2 Social learning as a tool to diminish uncertainties in flood risk management

Social learning is based on a dialogue in which stakeholder independence, the need for interaction, openness, mutual trust and cultural tolerance, common visions, critical self-reflection and strong leadership are recognized. Stakeholder participation ensures that different perspectives on the problem are taken into account whereby ambiguities and uncertainties related to multiple framing of a problem, including the multi-disciplinarity of knowledge (relating to natural, technical and social systems), can be diminished (Raadgever et al., 2011). Face-to-face interaction, communication among stakeholders (knowledge creators, mediators and users), dialogical learning and negotiation are among the uncertainty management strategies proposed for the water management needs (Raadgever et al., 2011). 'Uncertainties about the seriousness of flooding problems, cause-effect relations, or the effects of policy options' can also serve as stimulis for more extended public consultations and other stakeholder involvement activities including 'seeking help from epistemic communities' (Meijerink, 2005, p.1063). Stakeholders can exchange and correct existing knowledge, thus providing additional details related to local specifics. Stakeholder participation adjusts planned decisions to the real situation and to the will of society and its segments, thus contributing to justice. Early stakeholder involvement facilitates the implementation of planned actions, and therefore, is a crucial element of governance aspects. Political commitment, expected and planned organizational changes and the increase of institutional capacity are aspects that also need to be considered in the development of the stakeholder participation process. The other two types of uncertainties beside ambiguity – that is, epistemic (lack of knowledge, information and theoretical understanding) and ontological (unpredictability) uncertainties (Raadgever et al., 2011; Merz & Thieken, 2005) – can be reduced by conducting research and investing in science.

6.2.3 Flood risk management and the relevance of different types of knowledge

Participatory and adaptive flood management strategies are closely linked to knowledge management and integration. As knowledge constitutes a capacity for action and provides tools to comprehend the situation by structuring it and controlling contingent circumstances (Stehr & Ufer, 2009), it is important to be aware of and use all types of knowledge. For the purposes of understanding, there are various approaches to structuring knowledge. Cooperation among natural, technical and social knowledge, implemented through partnerships and coordination across disciplinary boundaries, is crucial for integrated flood risk management (McFadden, Penning-Rowsell & Tapsell, 2009), also indicating a paradigm shift in flood prevention that traditionally has been the responsibility of technical sciences alone (WMO, 2009). The new approach in flood prevention that recognizes the multi-scalarity of water cycle processes does also recognize the importance of embracing local knowledge, community knowledge and place-based approaches, ensuring that these aspects are integrated in the strategy processes. Often, local inhabitants have lived with floods for a long time and consequently, have developed coping strategies which are not always known by the higher levels of administration, experts and academia. It is important not only to access different types of knowledge but also 'to engage diverse ways of knowing within and between scientific and local communities and constituencies of interest' (German, 2010, p.118). When proposing a flood risk management strategy, it has to be communicated effectively to and accepted by local entrepreneurs, employees, residents or visitors to such a degree that it could be successfully implemented as a flood prevention, disaster emergency and recovery tool.

If different types of knowledge management are to be integrated into a flood risk management then not only explicit or codified knowledge that is materialized in scientific literature, factual information, mathematical formulas, databases and documents; but also tacit knowledge (Smith, 2001) that is usually conveyed through face-to-face interaction, conversation, storytelling, observation, imitation, shared experience and practice, should be considered as the latter is relevant for process management and the formation of attitudes and values. Although important, tacit knowledge is difficult to interpret and transfer to other contexts, as well as to capture and to integrate tacit knowledge into formal types of knowledge. Proximity, mutual trust of the people involved, as well as commitment and leadership are crucial factors for the development of tacit knowledge (Holste & Fields, 2010). Another classification of knowledge is used in policymaking. The first type, according to this classification, is traditional 'academic' knowledge which is rooted in past research is based on peer review and is independent; the other two types are 'fiducial' and 'bureaucratic' knowledge (Hunt & Shackley, 1999). Fiducial knowledge is the basis for policymaking. Bureaucratic knowledge is produced jointly by users. Since it is a synthesis for a specific context/use and also often for a specific political situation, it is filtered and judged for particular needs. Both the fiducial and bureaucratic types of knowledge are produced on the basis of contracts and are often validated through the status of authors. All types of knowledge are interlinked and the distribution channels that have a particular bearing on how different knowledge types are interchanged and integrated among involved stakeholders. Haas (2004, p.574) maintains that 'usable knowledge is accurate information that is of use to politicians and policy-makers'. The observations indicate that scientific knowledge is seldom directly transferred to policy documents and their implementation, even if scientific consensus has been accomplished, including flood risk management (Meijerink, 2005). Haas believes that through the process of communicating scientific knowledge to public authorities, knowledge obtains such characteristics as credibility, legitimacy and saliency. 'In practice credibility and legitimacy are mutually reinforcing, as a procedural approach to developing consensual knowledge is likely to generate both accurate and acceptable knowledge' (Haas, 2004, p.574). Four criteria of usable knowledge are identified: adequacy, value, legitimacy and effectiveness (Clark & Majone, 1985). The bridging between knowledge and knowing implies organizational learning and dynamic capabilities of involved institutions. This has not only to focus on internal and external knowledge transfer but also on knowledge integration processes in which the development of understanding and the creation of new knowledge occur through individual interactions and are affected by social contexts (Eisenhardt & Santos, 2001). Equally important are knowledge integration processes as well as interpretation and institutionalization of knowledge. As Albrechts (2001, p.738) notes 'institutionalisation is a process by which ideas and practices become durable reference points for social action. This institution-building (the design of arenas) requires a certain degree of consensus about underlying values' and a commitment to administrative and financial agreements between different levels of government, sectors and private institutions.

Interdisciplinary scientific evidence is applied by downscaling projections to the local level, also included in the area of flood prevention and climate adaptation. Still, there are many pending questions such as the one of how to transfer the results of studies into legitimized and operational activities of local governments. The understanding of and responding to flood processes cover complex issues, different spatial and time scales and, thus, need various academic disciplines and policy fields to be involved in a coordinated manner. Due to uncertainties caused by the irregularity of flood events and insufficient knowledge of flood event prediction, action is often required before a complete understanding of the problem. Flood prevention includes information gathering, knowledge creation, communication and implementation as well as reasonable community actions, taking into account the existing incompatibility between nature and society and the need to overcome physical, administrative, social and political boundaries. All these stages are interlinked in a non-linear manner. They include social learning and new knowledge production processes.

6.3 Historical context of flood risk management approaches in Riga

Various types of knowledge have been used to comprehend the past flood experiences in the Riga City as well as to prepare a cartographic representation of contemporary flood risk management hot spots. The City of Riga has been confronted with the risk of floods since the dawn of settlement. However, the perception of the hazard and actions taken has been quite different. The following account is based on both scientific and historical records of various origins. It also provides an example of how various types of knowledge are utilized for the needs of stakeholders in the current and future flood management setting. The aim of the historical integration is to review information on historical weather events, particularly floods and their characteristics. The frequency of extreme weather events may increase due to climate change. Knowledge of historical weather events can play a critical role in communicating possible future damages caused by climate change. A foundation of trust can be built especially by addressing the people's experiences with or place-based knowledge of such events in former times that are rooted in the natural and cultural context. Social interaction at a closer distance and personal and social memories are particularly important for forming trust (Korczynski, 2000; Swain & Tait, 2007) needed also for action planning, as in the case of flood prevention. The Riga City has got both natural (dunes, beaches and wetlands) and man-made coastal protection structures. Traditionally, Latvian human settlements were not situated in the dunes or flood-prone areas. However, the situation changed when the importance of Riga for trade between East and West as well as its military significance and position as an outpost on the Eastern coast of the Baltic Sea determined a rapid growth of the city. There is evidence that Riga had a protection system on the Daugava River as early as the end of the 13^{th} century (Biedriņš & Ļakmunds, 1990). Two types of constructions were used: (1) coastal wooden stilts to protect the city's fortification wall against ice and foundations against washing-out; and (2) compacted gates for flood protection, although the latter did not function well for the purpose for which they had been built.

Before the construction of hydro power plants (HPP), the causes that determine or facilitate the occurrence of floods in the Daugava River basin were basically of natural origin. The severity of flood depends on rainfall intensity and amount, wind direction and strength, snow melting intensity along with water inflow into the river basin during spring flood, ice and sludge congestions, air temperature in combination with humidity, topography of the area, hydrogeological circumstances as well as morphometric and hydraulic characteristics of the river bed.

Historical records of floods in Riga had already started in the 14th century (Moskovkina, 1960). Historical records of floods in Riga reflected in the following paragraphs are taken from various types of chronicles (including parish chronicles), municipal and state registers, newspapers as well as scientific literature. Several sources reported a catastrophic flood on the Daugava River in 1358. On the basis of annals, the newspaper *Rigasche Stadt-Blätter* wrote that water stood above man's head in the Riga Dome Cathedral's aisle. To keep the memory of this event alive, an iron cross was mounted to the cathedral building's wall, marking the water level of the Daugava River in the year 1358, which is estimated to have risen around 5.5 to 6 metres above the mean summer water level. The spring flood levels in the Daugava basin were also catastrophic in 1578, when vast areas around Riga were submerged and the water level could have possibly risen by 5 or 6 metres, causing huge damage. Great spring floods also occurred in the years 1589, 1597 and 1615 – when water levels possibly rose by 5.5 to 6 metres. In 1615, a huge ice dam formed by the former Bisenieki Isle caused a rapid rise in water levels up the river.

Some major floods were also triggered by storm surges, as was the case after a fierce storm on 30 May 1626. Large masses of sea water were pressed in the Daugava River (presumably with northwest winds) from the Gulf of Riga. These waters, together with the spring flood waters of the Daugava, caused an unusually high water stage. The entire city and surrounding pastures were inundated, many buildings were ruined, the wind downed lots of trees and a lot of people and livestock perished. This natural disaster was caused by the concurrence of two elements: water and storm. Disastrous spring floods with large piles of ice on the Daugava River occurred again in 1649. Then, there were heavy storms on the sea in November and December 1704. Furthermore, in late June 1708, there was heavy rain and subsequent flooding in the Daugava River. The water level in Riga rose by 4.5 metres. In the vicinity of the city, fields and gardens were submerged for four weeks. All plantations and sowings perished.

A particularly harsh winter in 1708/1709 led to a frozen over Baltic Sea and the newspaper *Rigasche Stadt-Blätter* wrote that there was an ice thickness on the Daugava River that reached 1.7 m. On 6 April 1709 the ice started to drift. Since the Gulf of Riga was still covered with thick ice, the ice drifts carried by the river flood waters were piled on the isles and shores of the Daugava River. The water level rose catastrophically, reaching the absolute height mark of 4.68 m on 16 April. Compiling the historical data, Ludvigs (1967, p.231) wrote that

> in November [1708] an exceptionally strong storm raged . . . The storm-blown water flooded the Daugava River banks and isles, washing away houses, livestock and people. Several ships were smashed and cast ashore. The storm was followed by severe frosts, which persisted almost continuously throughout the winter. The ice cover on the Daugava River reached the thickness of 1.5 m. 22 ships were stranded in the ice. . . . When the spring thaw began, the stream brought the ice from the Daugava upriver downwards, while the ice at the downriver did not break, remaining where it was. Consequently, a huge ice dam was formed. The water then broke two new outlets to the sea, flooding Pārdaugava [the left side of the Daugava] and isles of the Daugava. The ice-bound ships could not be salvaged . . . The Zaķusala Island of the Daugava River alone lost 52 houses. . . . . The masses of ice and flood waters broke through the Riga city gates, flooding the streets, buildings and cellars. Water in the Dome Cathedral rose up to the altar.

A cross in the Riga Dome Cathedral's wall is said to act as a reminder of this disastrous flood. The water in the city reached levels similar to human height. All isles and the valley on the left side of the Daugava were flooded, whereas the water on the right side of the river reached Kube Hill and the Citadel.

There were great flood damages in Riga also in the spring of 1783, when dams were washed out and broken on 11 spots. In the same year, the Lakagígar eruption in Iceland occurred and similar flooding events were reported in Europe (Brázdil et al., 2010). Another catastrophic flooding with ice drifts in Riga arose after the harsh winter of 1795. The catastrophic flooding on 12 April 1814 was caused by a thick cover of sludge and ice. Further, a severe flood occurred two years later (in 1816), when large ice jams were deployed opposite Catherine's dam in Riga. In 1829, after a harsh winter without thaws, ice drifts started on 9 April on the Daugava River in Riga. Again, ice piled up on the many low isles and banks. The river bed was obstructed, and the water level rose rapidly upstream of the jam. The low-lying areas of the Daugava valley in Pārdaugava up to Māra's Pond Mills, Catherine's dam, Sarkandaugava and St Petersburg's suburbs were submerged. The old town was saved after much effort.

In 1837, catastrophic spring floods with ice drifts took place on rivers throughout Latvia. The end of 1856 also came with major floods in Latvia. Sharp frost started early in September and continued throughout November, followed by a heavy thaw and major floods at the end of the every month. In Riga many streets and the isles of the Daugava river were flooded, since several dams had been destroyed. Bridges had been carried away. Unprecedented floods struck the city of Riga at the beginning of March 1871. Strong winds from the sea forced large amounts of ice from the Gulf of Riga into the Daugava river mouth, making high ice piles. Their height reached 70 feet (21.35 m) and a width of around 20–30 m. The ice was spread over a length of two to three kilometers (2.12–3.18 km). The ice piles reached the river bottom more than 5 m deep. However, they did not remain for long in the Daugava river, since intense ice drifting started on 17 April. The piles were carried into the sea. Therefore, major flooding failed to appear except for in the low Pārdaugava (Stakle, 1941). At the beginning of the last century, the largest flooding in Riga related to ice jams occurred in 1917. Serious flooding also occurred in the years 1924, 1929, 1932, 1936 and 1937. To sum up, over a period of almost 600 years, from the 14th century until the early 20th century, Riga and its inhabitants endured devastation due to catastrophic flooding caused by ice jams more than 20 times.

Learning from identified and analysed past events can be crucial for public and institutional awareness and for the creation of the most appropriate measures for future flood prevention, taking into account the successes and failures of public responses to historical flood events. The vast majority of the rise of catastrophically high water levels in the period of 1600 to 1700 can be explained by rapid deforestation, land cultivation and reclamation related to population increase, development of agriculture, construction of buildings in towns and countryside, building of ships, also exports of timber, production of coal and extraction of tar. As commonly accepted, snow melts faster and water drains quicker to the rivers in woodless than in wooded areas.

Protective dams were built along the Daugava river bank starting as early as the 17th century. In the middle of that century, the city fortification system was improved and the embankments were also used for flood protection. However, the flood protection systems could not completely protect the city from water inflow. Ice and spring floods also contributed to the risk, changing the water flows which, in turn, transformed the river bed almost every year, so that shipping routes had to be adapted frequently. The main cause of disastrous floods on the Daugava river in Riga over a period of more than 750 years, from the founding of the city until the Ķegums HPP was built in 1939, was the wide and shallow bed of the Daugava river with many larger and smaller isles and sandbars, often changing their location and size. The river washed away some isles during flood and some were formed elsewhere. The sandy, gritty and pebbly material carried from the river sections with rapids from Pļaviņas to the downstream end of the Dole Island accumulated in the river within the city limits of Riga and was partly washed into the sea. During spring floods, drift ice piled up on sandbars and isles, completely damming up the river with huge ice jams. Upstream of the congestion, water levels were rising fast causing flooding of vast areas of the Daugava valley and the City of Riga. In some years, strong north-western storms pressed large masses of ice from the Gulf of Riga into the river mouth, forming large ice piles which also caused flooding in the city. As a consequence of these periodical processes, some 500 to 600 years ago, especially the city centre with its modern multi-storey dwellings, lay about 2–3 m lower. During the last centuries, especially beginning with the demolition of the city ramparts, the territory was banked and elevated up to 5–5.5 m above sea level to avoid flooding. The 5 to 8 meters thick cultural layer serves as evidence for that. The present-day topographic maps of Riga which show those parts of the city that were often inundated during the last centuries, demonstrate effectively the extent of floods (Figure 6.1). If, in some distant future, the sea level in the Gulf of Riga and the coastal areas rises by 4 to 5 metres due to storm surges, the scene would be similar to those 400 to 500 years ago.

In the 1880s, the residents started to canalize the Daugava by deepening the riverbed, straightening the watercourse, removing certain isles and sandbars and building dams. As a result, the risk of ice jams and devastating floods in the city have decreased. Moreover, the situation was improved considerably by building ramparts along the city, shutters at the ends of the streets leading to the river, watergates at both ends of the city canal, as well as by elevating the compound in low-lying built-up areas, using debris as material for banking. In the 19th and 20th centuries, the city started to use icebreakers in the Daugava river before the spring flood season. The construction of Ķegums HPP prevented the formation of ice jams in the city. Nevertheless, the occurrence of disadvantageous wind directions that can lead to severe storms in autumns and winters still threaten the city's low-lying built-up areas situated in the Daugava valley to be flooded in present-day Riga. Such weather conditions are causing water level rises in the Daugava, the Lielupe and the Gauja downstream of about 1.5–1.8 m. During the devastating storms of 1969 and 2005, the water level at the Riga hydrological measurement site at Daugavgriva reached a height mark of 2.1–2.15 m above sea level so that large, vacant and built-up city territories were flooded. As the climate becomes warmer and storms increase in power, water levels rise caused by wind-driven surge into the Gulf of Riga and in such extreme weather events the levels in the City of Riga might reach heights of about 2.5 to 3 metres in the near future. The experiences from previous centuries constitute a valuable source of information on how to adapt to flood risks, while the ongoing global climate change processes bring forward new challenges, requiring new strategies and approaches to reduce flood risks.

6.4 Initiatives of flood risk management in Riga

6.4.1 Flood modelling taking account of climate change

Within the project 'Riga against flood!' (2012), extensive flood modelling works were carried out to give a well-reasoned picture of the current situation as well as possible future consequences of climate change. The time frame was set with three periods: the present, near future (2021–2050) and distant future (2071–2100). According to these, six scenarios were modelled: floods with return periods of one in two, five, 10, 20, 100 and 200 years. All these scenarios were modelled for the main factors that cause flood in Latvia: autumn/winter storm surges, spring meltwater and heavy rain. In total, more than 50 flood scenarios and maps were produced, providing for urban planners with detailed information about flood threats in present times and in the future.

Currently, the national flood prevention legislation contains only one reference to one of the scenarios, that is, the present-day scenario with a probability of occurrence of 1% in 10 years. It is mentioned in the context of a building ban (with the exception of road infrastructure) in flood-prone areas. Such a practice is inherited from the Soviet-era. Nonetheless, this regulation has become a keystone for planners and policy makers, as well as in negotiations between inhabitants and the representatives of the economic sector. Riga city planners have amassed experience through various knowledge exchange trips and interdisciplinary projects (ASTRA, BaltCICA, Riga Against Flood!) by becoming acquainted with other cities' flood prevention practices.

6.4.2 Knowledge transfer in the fields of flood prevention and climate change adaptation

Various types of knowledge and channels have been used to acquire new knowledge in the preparation of flood risk management. The current situation in

Riga is challenging city planners as the urban area is characterized by a great diversity of residential and economic activities, population densities, settlement patterns and land-use types. With the support of the BaltCICA project, the Riga municipality's urban planners and a multidisciplinary group of researchers from the University of Latvia closely cooperated in transferring and integrating the specialized climate change knowledge into regulatory and operational activities of the local government, particularly into the field of spatial planning regulations. Knowledge transfer of new approaches in flood prevention to the municipality of Riga City occurred mainly pioneered by spatial planning as a project team and experts of the project Riga Against Flood! were located in the planning office, supervised by politicians and staff members of the city's Development Department. Community politicians' and experts' project-financed study visits were organized in order to become acquainted with flood prevention, climate change adaptation and spatial planning policies with the aid of concrete example cases, that is, the cities of Antwerp (Belgium), the Hague (the Netherlands) and Hamburg (Germany) in 2010 as well as Rotterdam (the Netherlands) in 2011 (Riga Against Flood!, 2012).

The epistemic community of planners – particularly those with a background in the natural, environmental or geography sciences – plays an important role in transferring scientific knowledge to the applicable policy documents of the Riga municipality. In 2010, the Development Department of the Riga City Council was composed of 80 employees, 12 of whom had a background in the natural sciences. Scientific knowledge transfer is crucial, for instance, for developing the city's adaptive capacity to flood events by determining the appropriate use of the municipality's human, technical and financial resources. Further information sources are research and spatial development projects. The INTERREG III B project 'Developing Policies and Adaptation Strategies to Climate Change in the Baltic Sea Region ASTRA, 2005–2007' initially identified the affected areas in Riga City in case of future sea level rise. Moreover, the Latvian National Research Programme 'Climate Change and Waters' provided a wide range of scientific evidence and financed public awareness activities.

The application of new knowledge obtained resulted in the preparation of cartographic representation of flood risk management hot spots. Mapping was based on a scientific model that took into account the existing data and the predicted future environmental changes up to the year 2100. This knowledge was corrected with regard to other environmental, social and political factors relevant at the local level and through communication with stakeholders who have an interest in these local areas or have tacit knowledge of flood prevention or flood-prone places.

6.4.3 Flood Risk Management Plan – mapping of vulnerable areas of various time frames and flood probabilities

The Flood Risk Management Plan draft for Riga City has been prepared by local planners in 2011 and the strategic environmental impact assessment has been produced in 2012 (Riga Against Flood!, 2012). Acquired knowledge on flood prevention approaches with reference to climate change adaptation is included in the plan draft. It includes the analysis of 22 types of vulnerable areas – recreational areas; natural environments; inner-city areas; residentially, industrially and commercially used areas; areas of mixed use; roads with and without pavement; areas of technical infrastructure and various types of the harbour area – and four types of particular objects – social institutions, cultural heritage sites, natural reserves and industrial sites with permits of integrated pollution prevention and control – in relation to flood risks in the current situation, in the near (2021–50) and distant (2071–2100) future. 0.5%, 1%, 5%, 10%, 20% and 50% probabilities have been used in the spatial analysis. However, in the descriptive part of the Flood Risk Management Plan draft emphasis was given to objects exposed to a current flood probability of 0.5% and 1%, while in the future there are objects which will be exposed to higher flood risks (Table 6.2). The implementation of the Flood Risk Management Plan will include investments in flood prevention structures as well as amendments to the existing long-term development strategies, development programmes, spatial planning documents, building regulations and strategic documents of affected sectors, inclusive of civil defence, public health, transport, culture and social sectors and nature conservation.

Table 6.2 The size of vulnerable areas according to various conditions of probability and climate in Riga city as identified by the draft Flood Risk Management Plan

	Size of vulnerable areas according to various conditions of probability (in 1000 m^2)					
Climate	**0.5%**	**1%**	**5%**	**10%**	**20%**	**50%**
Current	27 005	22 107	10 418	7477	4959	0
Near future (2021–2050)	31 472	26 460	13 833	9742	7489	2880
Distant future (2071–2100)	41 230	34 411	15 004	14 059	11 118	6976

Source: Riga Against Flood!, 2012.

6.4.4 Process of the preparation of the Flood Risk Management Plan

Prior to envisioning the objectives and strategies for flood risk management in the domain of planning, the involved persons should become familiar with the 'Concept of Risk Management' in flood risk mitigation. This phase is particularly relevant as stakeholders have to change their traditional ways of dealing with flood risk issues and have to develop new skills and understanding. The process of acquisition of new knowledge and its implementation in practice needs time and continuous support by stakeholders, researchers in particular. Active cooperation between academics and practitioners in considering international experiences is of utmost importance seen from this perspective. At the end of this process, stakeholders need to be able to demonstrate their acquired knowledge by developing their vision on how to deal with future floods. Therefore, they should consider the current situation (hazard and impact identification and analysis), analyse uncertainties (hydrological, social, economic and political) as well as drivers of future development (risk changes), such as climate change and urbanization. After agreeing on a consensus on flood risk management objectives, the Riga community planners can start the concrete planning phase. At the end of this stage, a set of various flood risk management options should be prepared. This point is the milestone in the management process. In the final phase of flood risk adaptation planning one set of mitigation and adaptation measures has to be agreed on. The assessment of the various options of flood risk management is based on relevant criteria which were defined beforehand (see Chapter 4). Again, it would be favourable if experts coached this process by introducing the approach of Multi-Criteria Decision Analysis (MCDA), by elaborating a decision matrix of the relevant criteria and by providing a decision support tool which all stakeholders could use for weighting the criteria in order to choose the best option that, finally, would serve as the decision (see Chapter 4). Good guidance is necessary in exploring the possibilities to minimize the remaining conflicts of interest between different stakeholder groups. Probably, not all conflicts can be avoided, with the result that the stakeholders have to agree on an 'acceptable level of conflict' by defining priorities. In urban areas like Riga, many stakeholder groups are affected by the actions taken within a flood risk management plan. The stakeholders' analysis should provide the existing political, social and institutional structures with special reference to the organizational structure of flood risk management within the area of interest (Table 6.3) (EC, 2003).

Stakeholder workshops and meetings have been organised by the University of Latvia to broaden the spread of information and consultations outside Riga City's municipal institutions. In the course of this, the University of Latvia transferred the climate change adaptation knowledge of other BaltCICA project partners.

6.4.5 Application of Multi-Criteria Decision Analysis for assessing flood-prone areas in Riga City

Within the BaltCICA project, interdisciplinary seminars on using multi-criteria decision analysis methods for assessing flood-prone areas were organized. In the

Table 6.3 Parameters characterizing stakeholders involved in flood risk adaptation planning and their interrelations

Parameter	Description	Involved stakeholders
Level of impact	Shows to what extent stakeholders are affected by the (non-) implementation of a flood risk management plan	From those being impacted to a higher degree (vulnerable) – residents, employees and visitors at low coastal areas – to ones with low vulnerability
Level of influence	Explains to what extent stakeholders can influence the flood risk adaptation planning and outcomes	From those with high influence, as government and municipal institutions, to residents, particularly vulnerable and with low level of influence
Level of interest	Explains the extent to which stakeholders express their interest to be involved in flood risk adaptation planning	From stakeholders with high interest in environmental, safety and insurance aspects to those with little interest, like many indoor businesses and residents of apartment and rented housing
Level of understanding	Indicates the level of knowledge and awareness of flood risk management (information, methods, legislative framework, including the EU Floods Directive and local practises) and climate change adaptation among various stakeholders	From climate researchers and experts, having a high degree of understanding, to lay persons, local politicians and local mass media that in general have lower understanding
Level of capabilities	Explains physical (technical), financial, social, cultural and political capabilities needed for coping with flood risk and the related social changes.	From state government bodies with high capabilities to lay persons or small businesses with low capabilities
Diverging interests, conflicts and overlapping responsibilities	Explains conflicting interests or ambitions among institutions	Conflicts between organizations acting in one sector, but at different spatial levels or geographical units; conflicts between stakeholders acting in one geographical unit/sector, but at various policy levels

case of Riga City, its specific geographical location in the vicinity of three large river deltas was brought into focus. Although the flood-prone areas are not always directly connected, each of them can affect the development of the respective district in the event of a flood which, in turn, can result in possible impacts on the entire city of Riga and its surroundings. In order to prevent the possibility of flooding, different kinds of flood prevention measures, particularly investments, should be taken in the near and distant future. The city planners should develop a sequential plan on how to protect these areas against flooding. Flood-prone areas in question are very diverse: areas with multi-storey residential buildings (Bolderāja), single-family house estates built at different periods (Mangaļsala, Bukulti, Trīsciems), small river delta areas (Trīsciems by the Langas River and the built-up area around the south-east end of Juglas Lake by the Juglas River), areas located in and around the territory of the Freeport of Riga – subject to special tax and entrepreneurship-related legislation (Spilve, Sarkandaugava), industrial areas (Sarkandaugava), areas within the protected territory of the historic city centre of Riga which is part of the UNESCO World Heritage List (Ķīpsala), as well as areas which are not in active commercial use at the moment but will have potentially developed in the future (Spilve, Lucavsala).

With respect to MCDA, the Multi-Attribute Utility Theory was selected as the most appropriate method. The interdisciplinary group formed within BaltCICA

Table 6.4 Twelve criteria selected for the initial MCDA of the areas that either are flood-prone at present, or may become so in future

	Reference period	
Criteria suggested for MCDA	**Now**	**Changes in the future**
Size of the flood-affected areas	X	X
Population number in flood-affected areas	X	X
Proportion of senior citizens in flood-affected areas	X	
Number of work places (employed) in flood-affected areas	X	X
Economic losses in flood-affected areas	X	X
Number (existence) of high risk objects and critical infrastructure, public infrastructure	X	
Number (existence) of public infrastructure and cultural heritage objects	X	
Existence/non-existence of evacuation routes	X	

evaluated information about the available criteria for analysis. Twelve criteria were selected for the initial analysis that comprises the socio-economic spheres and takes into account the available indicators of the areas that either are flood-prone at present, or may become so in future (Table 6.4).

After a detailed evaluation of the criteria from qualitative and quantitative data aspects, only three criteria were selected for the final analysis: (1) population density in the flood-prone areas, (2) economic losses in the flood-prone areas, (3) changes in economic losses in the future. According to the near-future scenario development prospects for Latvia and Riga (Riga Against Flood!, 2012), the population figure of the flood-prone areas will not change considerably. At the same time, economic losses will significantly increase in many areas. Stakeholder discussions organized in Riga showed that practitioners comprehend the meaning of the near-future scenarios and they see the need to incorporate it in the existing regional planning and flood prevention plans. Economic losses were calculated on the basis of the size of the affected areas, land-use, water depth during floods and duration of flooding (Riga Against Flood!, 2012). During the BaltCICA seminars, the interdisciplinary group of experts proposed that the ranking of the flood-prone areas using MCDA approach should be done in the first place, as the primary task is to determine which of the areas will be worst affected by flooding. Cost-benefit analysis of the implementation of flood prevention measures is a next step, requiring further research.

6.5 Conclusions

The results of modelling revealed that Riga City has a rather high number of flood-prone areas that in most cases are not connected in terms of water management options. Accordingly, for developing flood prevention and climate change adaptation measures, there is a need to define comprehensive and acceptable criteria for planning purposes, including prioritization of the measures in terms of timing and investments needed. In close cooperation between the experts of the Riga municipality and the University of Latvia, possible adaptation options for urban spatial development are being prepared for integration in the comprehensive spatial plan, building and other regulations of the municipality. The Riga Case plays an important role for knowledge and policy transfer in the field of flood prevention and climate change adaptation for other Latvian municipalities and for preparation and improvement of respective national policies.

MCDA has been valued by city planners as a clearly comprehensible support tool for conducting discussions with stakeholders (inhabitants, investors and environmental protection organizations). MCDA can also play a role in knowledge transfer and social learning. Possibility of setting the criteria weights individually allows discussion participants to acquire a better understanding of the causal links between the environmental, economic and social processes. That sort of use, evaluation and sharing of different stakeholders' knowledge can improve common knowledge about flood causes and processes and prevention measures needed. Thus common goals as regards flood prevention in such a complex area as Riga City can be better achieved. Stakeholder involvement and their knowledge management are relevant as a contemporary flood risk management approach involves various dimensions and activities.

New concepts are required to support active participation of stakeholders in developing flood risk management plans in the sense of the EU Flood Directive (2007). Bottom-up approaches are likely to fulfil this requirement. The development of mutual trust and an open atmosphere turned out to be a crucial factor for proceeding with planning. Analysis of the city's sensitivity to floods and economic analysis is a necessary extension of the obligatory flood maps in order to understand the system's limits, enabling stakeholders to assess the risks more realistically. Harmonization with other directives and planning procedures (e.g., the EU Water Framework Directive 2007/60/EC) has to be performed at an early stage, introducing already planned synergetic measures as an element of flood risk management planning. As this is a process that requires extensive knowledge and resources, the expertise of different stakeholder groups and international experiences have to be considered. The Riga City case proves that, in spite of public finance cuts at the national level, the expert community at the local level is capable of attracting EU funding (BaltCICA and Life + project) and is continuing to work towards a safer urban environment. Thus, climate change adaptation measures are included in its everyday tasks and strategic aims.

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