Climate Change Proofing of Infrastructure


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Abstract
Cities – in particular coastal cities – need to adapt their infrastructure to climate change. Climate change will hit first and foremost through the water. Raising sea levels in combination with changes in the precipitation patterns as well as storm patterns will stress the infrastructure not least through increased flooding. There is a need for methods that allow public as well as private organizations to assess the risks and evaluate the cost/benefits (and side effects) of different adaptation measures. Such methods require the linking of GIS with climate model projections and with simulation models capable of simulating the interactions between the different sources of flooding, including tidal and storm surges, river flooding, flooding from local rainfall and potentially flooding from the groundwater.

Introduction
While climate change in general and whether it is man made in particular may still be a controversial topic, few will argue against the need for protecting our properties and infrastructure against the likely impact of climate change.

The global political agenda focuses mostly on climate change mitigation – e.g. through reduced CO₂ emissions. But in parallel with this, local politicians and experts are forced to focus on climate change adaptation – i.e. preparing their cities for the predicted changes – because these changes are bound to happen even if the global community is able to reach agreement on actions to mitigate the changes.

Climate proofing our cities is, in other words, necessary, even though we can’t know for sure exactly how our climate will develop. Taking a wait-and-see attitude may of course be tempting, but the results in terms of damage to property and infrastructure and disruption of our daily lives will, according to all sober assessments, be much worse than the costs associated with timely adaptation to the most likely changes.

Already today and in the years to come, cities are facing the challenges of planning for the climate effects and to assure that they have a relevant basis for decisions on how to prioritize on climate change adaption.

Climate Change Flood proofing
But how do we climate proof our cities? How can we adapt, when we don’t know where the problem areas are?

The short answers to these questions for assissing the likely impacts and to design proper solutions to the problems are:
1) **We do have the know-how** in terms of the predictions from the IPCC, which everyone can download from the IPCC website. The climate models give predictions of changes to precipitation, temperature and sea level change, which are sufficient for a first general assessment of the range of impacts that can be expected at any location – in any city in the world, and

2) **We do have the technology** in terms of modeling tools that can take the predicted changes in precipitation, temperature and sea levels and turn them into predictions of flooding / draught and the associated assessment of capacity problems of the local drainage systems, the safety level of the levees and so forth.

The effects of climate change can be predicted through the use of integrated modeling tools, which make use of the latest results from global and regional research in climate change and combine this with integrated models. Through a scientifically sound downscaling from regional circulations models, local aspects can be considered.

![Figure 1 Climate change proofing using IPCC emission scenarios, Downscaling of Global Circulation Model results and integrated hydrodynamic models.](image)

Furthermore, such integrated models can also be used to assess and optimize the effects of protective measures designed to prevent or mitigate e.g. extreme floods. Models like this are indispensible tools for cost-benefit analyses of proposed climate change adaptation measures.

Without the use of integrated models, adaptive measures may improve conditions at one location at the cost of deteriorating the conditions at other locations. With integrated models, the optimal use of resources for climate change adaptation can be ensured and the level of protection can be assessed and described to local authorities, property owners and to the general public.

In other words: **The city can be climate change proofed.**

The flood oriented modeling tools of DHI (primarily MIKE URBAN and MIKE FLOOD) includes an integrated Climate Change tool which allow the user to define their own climate change scenarios from selection of a Global Circulation model, requested Emission scenario and the desired year of prediction. Outcome of the climate change tool is Delta change coefficients for meteorological model input data and hence, through a seamless creation of climate change adjusted timeseries data, model simulations can be performed for a screening of potential flood related problems.

**A Case Study: Municipality of Greve, Denmark.**

One Danish municipality that has been forced towards early investigation of large scale adaptation measures is Greve (population: 48,000, area: 60 km2 or 14,800 acres). Located on the coast in the southern part of the greater Copenhagen area and situated in lowland terrain, Greve can be said to be one of the most flood-prone areas in Denmark.
Given ongoing climate change patterns, higher rainfall levels will undoubtedly cause more frequent flooding. The municipal council has therefore decided to upgrade the capacity of the existing drainage system to be able to carry 30% more water. The 30% is based on a national recommendations made by the “The Water Pollution Committee of The Society of Danish Engineers”. The 30% increase in a 10 years rainfall, are derived from analyses of Intergovernmental Panel for Climate Change (IPCC) scenarios (scenario A2) and a comparison to rainfall under climate conditions similar to the predicted future climate for Denmark. Hence, the service level is for Greve has been selected to protect the city against flooding from a 10 year rain event under future climate conditions.

Two major flooding events have already occurred in this century, in 2002 and 2007. During the last flooding episode in the summer of 2007 an evacuation was needed in order to protect the inhabitants of the town. The situation put the local rescue services under pressure as flooding temporarily wiped out some of the critical infrastructures while communications and electricity connections were also lost for a while.

In the light of such experiences, Greve is now investing significantly in building capacities to cope with future flooding incidences. Adaptation of the city to climate change is undertaken using a so-called ‘strategy model’ developed by Greve municipality. The model is used to help prioritize those areas of the city to undergo adaptation first.

The strategy model combines a digital terrain model with a hydraulic model. The hydraulic model initially covers the local streams and the drainage systems. Using the future rainfall events (derived from Chicago Design Storms) recommendations and basic flows in the streams, the model simulate which areas will be flooded first. The same model is then used as a tool when investigating and prioritizing the necessary adaptation measures.

Implementation of the model is supported by continuous surveying of the streams and the drainage system to calibrate and validate the model’s performance and to raise the alarm in cases where high water levels are found.

The vision of Greve is to have a model of the total water system. Greve is therefore developing a model for the groundwater system, which will be combined with the strategy model outlined above.

Since Greve is located on the coast, sea level rise will also lead to increased risk of flooding. In order to assess this, a coastal model is currently also being added to the tools used for impact assessment. The goal is to have a fully integrated model complex of all the relevant waters.

All of these actions are coordinated with the implementation of the European Floods Directive in order to predict future flooding and to mitigate the societal impacts of flooding.
The development of the Greve strategy model is perhaps now the trademark of Greve. The model uses a number of technical tools including ArcGIS from ESRI and MIKE modeling tools from DHI to provide a better level of knowledge in respect of the local pre-conditions for flooding, which also leads to a better starting point for the implementation of adaptation measures.

Figure 3 MIKE FLOOD simulation, 10 year rain in 2100. Climate scenario A2 assumed.  
Top: Flood extent for existing situation  
Bottom: Flood mitigation by using a local soccer field for storm water storage

Conclusion

The climate is changing and one of the severe effects is the increased risk of flooding within cities caused from e.g. local rainfall, storm surges, river spilling or raised groundwater. The impact on humans, properties and infrastructures are potentially devastating and methods are required to assess the local impact of climate change scenarios and to quantify the efficiency of flood protection measures if critical events should occur in future.

Through combined use of GIS, mapping, flood simulation models and climate model projections it is possible to determine areas within the cities which are prone to flooding for present or future climate conditions. With flood depths and flood hazard ratings as key output from simulation models, infrastructure elements in risk of becoming either destroyed or inaccessible during a flood event can be identified and such tools therefore serve as invaluable elements for local or
regional authorities in the process of screening a local area for a potential increased risk of flooding due to Climate change effects.

MIKE by DHI flood simulation models (MIKE URBAN and MIKE FLOOD) includes a climate change feature based on the work reported by IPCC in their fourth assessment report. Climate change scenarios are easily defined from user selected Global Circulation models, CO2 emission scenario and scenario year resulting in monthly delta change factors for precipitation and temperature. This methodology is extremely useful in an initial screening of potential, local flooding problems for specific climate change scenarios used as input to the flood simulation models. The model simulation results like maps of flood extent, flood depths or flood hazards can be presented and analyzed further in GIS to present and outline the immediate local effects of climate change and proposed mitigation measures.