May 12
16:30 - 18:00
Meeting Room 18

The role of critical infrastructures in disaster risk mitigation

Session organisers: Elco Koks (*Institute for Environmental Studies*, IVM, Amsterdam) and Lorenzo Carrera (*Fondazione Eni Enrico Mattei*, FEEM, Venice), on behalf of and with the active participation of the ENHANCE project consortium.

Time	Programme
16:30 – 16:45	**Dr. Raghav Pant** **Understanding national scale systemic risks due to critical infrastructure network failures**
16:45 – 16:50	**Q&A**
16:50 – 17:05	**Mr. Robin Nicolai** **Flood risk assessment for the port of Rotterdam infrastructure**
17:05 – 17:10	**Q&A**
17:10 – 17:25	**Dr. Jaroslav Mysiak** **Disruption of a drainage infrastructure system: economic outcomes and risk mitigation policies**
17:25 – 17:30	**Q&A**
17:30 – 17:45	**Mr. Patric Kellermann** **Frequency analysis on critical meteorological conditions in a changing climate - Assessing future implications for railway transportation in Austria**
17:45 – 17:50	**Q&A**
17:50 – 18:05	**Mr. Atte Harjanne** **Potential of intramodal and cross-modal substitution in enhancing the resilience of air transport – Evidence from European airports**
18:05 – 18:10	**Q&A**
18:10 – 18:25	**Mr. Emilio Master Ventura** **A strategy for public infrastructure resilience: Case study of El Salvador in Central America**
18:25 – 18:30	**Q&A and final wrap up by Elco Koks & Lorenzo Carrera**

Poster:

Vulnerability of Mexican critical infrastructure networks in the face of disaster´s risk by the impacts of climate change	Dr. Lopez-Lopez Mr., Victor Manuel, Mexico City
Multi-Scale Criticality Analysis for National Infrastructure Network Systems	Thacker Mr, Scott, Oxford
Climate adaptation engineering: a transport network case study	Pregnolato Ms, Maria, Newcastle
Resilient critical infrastructure at local level	Gebhartova Ms, Jana, Prague
The climate preparedness of Dutch vital network sectors	Dr. LLM Gilissen Mr., Herman Kasper, Utrecht

Annex 1: Selected Abstracts

Dr. Raghav Pant

Understanding national scale systemic risks due to critical infrastructure network failures

National infrastructures such as energy, transport, water, waste and ICT are critical lifeline systems on which society and economy are reliant. These infrastructures are generally built as networks, comprising critical node assets and connecting edge assets, which span the entire national landscape or even traverse beyond national borders. Hence the impacts of any failures to such networks can grow substantially from localized effects towards more global scales. There is enough evidence to support this claim, because there have been major infrastructure failures during extreme events such as hurricanes (Katrina 2005, Sandy 2012), tsunamis (Japan 2011), floods (Great Britain 2013/2014), which have lead to widespread disruptive effects. For risk mitigation and long-term planning for sustainable infrastructure a key research question arises: What are the risks of infrastructure network failures and how can such risks inform resilience planning?

The aim of this research is to address the above research question through a spatial risk assessment framework that incorporates: (i) spatially coherent probabilistic extreme weather events; (ii) interdependent national infrastructure networks; (iii) network demand models; and (iv) macroeconomic linkages. The outcomes of the framework include: (i) spatial estimates of key vulnerabilities in national infrastructure networks; and (ii) demographic and economic consequences of national infrastructure failures.

The risk assessment framework is demonstrated through a flood risk analysis case study of interdependent national-scale networks for Great Britain. For an island like Great Britain, flooding risks are a major cause of concern and are imminent as future climate projections indicate the likely increase in sea levels and frequent extreme rainfall events. We have created detailed spatial networks for the electricity and transport infrastructures and tested their failures when exposed to extreme floods events with 1000-year return periods. The analysis shows that importance of understanding interdependence among infrastructures, which leads to greater failure propagations.

The work presented here makes important contributions to research and practice. The national-scale infrastructure risk perspective provides a useful tool for network operators for analyzing vulnerable points in networks thereby leading towards adaptation planning. Flooding is a major cause of concern in Great Britain, which makes the present research very useful for policy planner and industry stakeholders who are looking for updating the current understanding of large-scale flood risks. In the end we provide a useful tool for infrastructure planners and operators.

Mr. Robin Nicolai

Flood risk assessment for the port of Rotterdam infrastructure

Past floods have shown that critical infrastructure networks are highly vulnerable to floods and when disrupted, the consequences of the flood might increase significantly. The most striking example is the tsunami in Japan in 2011, which led to the meltdown of three nuclear reactors. As a consequence more than 4 million households were left without electricity.

As part of the EC FP7 ENHANCE project (Grant Agreement No. 308438) the case-study “Port of Rotterdam infrastructure” aims to reduce and mitigate the flood risk of Europe’s largest port, now and in the future. The port of Rotterdam is one of the largest logistic, industrial and electricity hubs of Europe. The yearly container throughput is about 450 million TEUs. The industrial cluster contains

amongst others five oil refineries. The productive capacity of the power plants in the port is about 7,000 megawatts, powering a quarter of the industry and homes in The Netherlands.
Currently, the Port of Rotterdam area is considered safe against storm surge floods. The paradox is that the port is located on relatively high grounds, outside of the primary flood defence system of The Netherlands. Climate change (sea-level rise) directly increases the port's flood hazard. The challenge is to develop an adequate adaptation strategy, which minimizes (future) flood risk and enhances society's resilience. To compare strategies and policy measures a risk assessment tool is required that captures the port's flood hazard, exposure and vulnerability under several scenarios. Such a tool must not neglect the presence of the port infrastructure. After all, any substantial disruption of the port infrastructure has a great impact on the Dutch society and possibly on that of North-West-Europe.
We propose an integrated framework for flood risk assessment with societal disruption as the main indicator. Societal disruption is defined as "the extent to which people experience physical, social and emotional hindrance by failure of a function due to a flood". The framework considers business interruption and several 'infrastructure' functions such as electricity and accessibility. Societal disruption is quantified by the number of affected people (inside and outside the vulnerable area), the impact factor and the duration of the disruption. These variables are specified for all functions. Disruption only occurs if the water depth exceeds a certain threshold, specified for each function.
The framework is tested on the port of Rotterdam area. The first results are promising. Wider application to other areas vulnerable to natural hazards is foreseen.

Dr. Jaroslav Mysiak

Disruption of a drainage infrastructure system: economic outcomes and risk mitigation policies

Over the centuries, flood plains have always attracted the development of human activities. This is partly explained by the easiness of waterways transportation, and also by the fertility of soils in alluvial plains and former wetlands. To allow agriculture production and urban development, river diversions and modifications, dams, water reservoirs, dykes, river embankments, and artificial drainage systems have been constructed over time. As a consequence, societies have become more and more dependent on the functioning of their infrastructure systems.
Amongst these areas, one of the most economically productive in Europe is the downstream part of the Padan Plain, in Northern Italy. In particular, under certain meteorological conditions, in the low-altitude zones of this area, the sophisticated system of gravitational water drainage needs to be complemented by water uplifting plants enabling discharge into local rivers. Clearly, this system is extremely vulnerable to external shocks.
Beyond other physical impacts, the devastating earthquake that hit hard the Emilia Romagna region in May 2012 has damaged the water uplifting plants. As a temporary result, flood risk increased dramatically in almost 100 km2 of residential, 85 km2 of industrial and 840 km2 of agricultural land. The event disclosed further vulnerability, generating the need for innovative disaster risk mitigation strategies.
Against this background, this analysis is intended to inform the construction of a multi-stakeholder partnership, rooted in an inter-regional civil protection agreement, and negotiated among a multitude of public and private institutions, for the case of controlled floods and damage reduction by shifting the flood risk and damage from high- to low value land use categories. The analysis ties in with the recent flood risk reduction pursued throughout Italy that aims at flood peak lessening through imposed land easement and servitude.

The research estimates how impairment to drainage infrastructure increased flood risk and amplified the potential economic damage. The flood hazard analysis is based on the observed precipitation applied in 1D hydraulic model Storm Water Management Model. The flood damage is assessed using the stage damage curves transposed into the Italian business and residential wealth context, and regionalised gross added value with variable grid resolution. Impaired infrastructure scenarios are applied.
The results show that the flood risk responses based on controlled flooding on low-value land uses are cost-effective strategies able to reduce the flood damage by a factor 5-6. These results are robust against the uncertainty of flood damage estimation.

Mr. Patric Kellermann

Frequency analysis on critical meteorological conditions in a changing climate - Assessing future implications for railway transportation in Austria

Alpine railway infrastructure is essential for the European transit of passengers and freight as well as for the accessibility of lateral valleys and their economic welfare. Due to limited usable space in alpine regions, railway lines in Austria often follow flood plains or are located along steep unsteady slopes, which considerably expose them to floods and alpine hazards. The majority of alpine hazards are, as a general rule, triggered by extreme (hydro-) meteorological events such as heavy precipitation or extreme temperatures and, thus, are a great issue of concern for risk management for railway infrastructure. Since meteorological hazards cannot be prevented and the implementation of technical protection measures is often not feasible for both financial reasons and aspects of nature and landscape protection, the risk mitigation strategy of the Austrian Federal Railway also puts great emphasis on precautionary and organizational measures as well as preparation tools, i.e. monitoring, warning services, alarm plans and also disruption of traffic if specific thresholds are exceeded. Therefore, a weather information and warning service for railway infrastructure was implemented in 2005.
However, the Alpine region is constantly disclosed as particularly sensitive to climate change. According to recent studies, a significant annual mean temperature rise of approximately 1.6 °C until 2040 as well as potential seasonal changes in precipitation frequencies and intensities is indicated. These changes will presumably have serious implications on the current risk profile of Austria. Hence, providing insights on future trends and frequencies of meteorological extremes with relevance for the railway operation is of utmost importance for a comprehensive and sustainable natural hazard management.
The major objective of this study was to inform the decision makers in the railway sector on possible future changes in hydro-meteorological triggering events for alpine hazards due to climate change. Therefore, frequencies of certain air temperatures as well as liquid and snow precipitation amounts in the periods 1961-1990 and 2011-2040 were analysed on the basis of different regional climate models. Further, the sensitivity of results was tested with varying meteorological thresholds. Finally, the consequences for railway transportation will be discussed.

This case study is part of the ENHANCE-project, funded by the 7th EU Framework Programme (Grant Agreement number 308438).

Mr. Atte Harjanne

Potential of intramodal and cross-modal substitution in enhancing the resilience of air transport – Evidence from European airports

Air transport is a crucial enabler of the modern global economy. Many major international flows of people and high-value goods are almost solely dependent on it. Climate change affects air transport infrastructure and operations due to changing weather patterns and regional increase in some adverse conditions. Because of its critical role in the economy, successful adaptation within the air transport is a necessity. This study analyzes the potential of flexible measures such as intramodal and cross-modal substitution to cope with disruption caused by adverse conditions. Switching passenger flows temporarily to another airports or to rail instead of air could alleviate the delays and costs caused by disruptive weather. Such measures can also yield benefits in current climatic conditions since aviation is already relatively vulnerable to weather in comparison with other transportation modes; weather is the direct cause of at least 10 % of all flight delays. Delays caused by weather also tend to last longer than delays caused by other factors (Perrels et al., 2014).

The study aims to examine the potential implementation of substitution measures in relation to current air transport operations. First, the recent trends and developments in weather related air delays are analyzed based on statistics from Europe, United States and Asia. This is followed by a review of regulatory and operational measures currently in place to manage weather related delays. Finally, using Amsterdam Schiphol and Frankfurt am Main airports as case studies, a new method is developed to calculate the potential impact of intramodal and cross-modal substitution on air transport operations. These airports are selected because such congested hub airports operating on or beyond their airside capacity limit are practical bottlenecks of the European air traffic system.

The results indicate that the impacts of adverse weather conditions on air transport operations can be significantly reduced using new, flexible substitution measures. Based on these analyses, a set of policy suggestions and ideas for future research are formulated. The results of the study can guide further improvements in enhancing the adaptive capacity of air transport in Europe in the face of climate change.

Mr. Emilio Master Ventura

A strategy for public infrastructure resilience: Case study of El Salvador in Central America

El Salvador in Central America was declared in 2010 by United Nations as the most vulnerable country in the world to the impact of natural phenomena, especially those related to climate. In the last six years more than 100 bridges were affected by extreme rainfall, main roads were blocked by landslides and urban flooding impact has increased. The cost of disasters related to rainfall in 2011 came to reach 6"%" of GDP of the country. Given this scenario, a strategy has been implemented by the Ministry of Public Works of El Salvador in order to move the country from a culture of reaction and emergency disaster to a culture of prevention at all levels. Resilience for road infrastructure and for urban and rural settlements is one of the main goals of the strategy; the participation of communities, private companies, universities, local governments, official development assistance agencies and others key stakeholders is included. Significant progress has been done and an important leadership is recognized in Central America for El Salvador related to disaster risk management and climate change adaptation. The strategy, progress, limitations and challenges for the future are presented on the paper.