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Modeling as Knowledge Brokerage Instruments

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Abstract. *The effects of climate change are very uncertain. Very little attention has been paid at the consequences on infrastructure systems of water, energy and transport. While the interconnections and cascade of effects on the economic society are huge. Policy makers have to deal with these uncertainties The unstructured problem of climate change adaptation strategies asks for a productive connection between science and policy. Our research explores the interconnection between climate change, infrastructure systems and governance, from an adaptive management approach and using the policy science interface explicitly. Adaptive management centralizes the concept of and the dealing with uncertainties. The policy science interface starts with the acknowledgement of the necessity of multiple domains and multiples perspectives by solving complex problems. In this perspective a model is an instrument to bridge the gap between science and policy boundaries. By exploring a case study we will bring together and advance knowledge from these multiple domains and multiple stakeholders. We will produce and use a socio-technical qualitative model, and learn how this model will help to structure the complexity and will span boundaries. We use the stakeholders in workshops to sharpen our research, to identify lacking knowledge and to start to bridge the gap between science and policy. Using models as knowledge brokerage instrument in the infrastructure policy decisions is interesting to explore more often.*

Keywords. *Knowledge Brokerage Instruments, Adaptive Management, Climate Change, Infrastructure Systems*

1 Introduction

Many infrastructure providers and administrators are struggling with the issue of climate change: how to deal with the effects, what new investments and maintenance strategies should they decide on, how to keep the network accessible, and what about prevention measures. Especially when several extreme weather events occur more frequently, which effects the functionality of the networks for utilities like drinking water systems, sewage and electricity and the mobility networks like roads, rails and inland waterways. Heavy snow- and rainfalls can disrupt the transportation system totally, like happened last winter in the Netherlands. The interconnection between the infrastructure networks and the cascade of effects leads to economic damage (Veerbeek et al, 2010).

The climate scenario's tend to more, longer and more often these extreme weather types. What exactly the consequences will be for climatologic circumstances and for the weather types, especially on a regional and local scale, is uncertain. The climate conditions during the past decades are most likely no longer a reliable source for future investment decisions considering adaptation strategies (US National Research Council, 2008). Only few studies have researched the effects of climate change to infrastructure and networks. The cluster of Econet, Weather and Ewent are European funded research projects, looking at the effects of climate change on successively the inland waterway networks, regional hazards and the European transportation networks. They all concluded that there are still huge uncertainties in valuing the damages caused by weather extremes to transportation systems, which are determined by system delimitations, consideration of extremes as well as by data uncertainties (TRB, 2012). These huge uncertainties do not facilitate decision making at all. One of the first reports on climate change effects on transportation have already posited that climate change poses a difficult challenge to decision makers (TRB, 2008).

From the climate change perspective infrastructure management is a complex issue because of the interconnection of the infrastructure networks with the economic society and the uncertainties of the effects. INCAH, a research program in the Dutch Knowledge for Climate Innovation Program, aims to develop adaptation strategies for infrastructure and networks, taking into account this complexity. The climate adaptation strategies will be developed on the bases of adaptive management (Holling cs, 1978). This paper describes the system models that are developed in this research, and elaborate their usefulness to describe the infrastructure system, and as new adequate approach to the production of knowledge in an interface between science and policy (Duijn and Rijnveld, 2007). Based on the theory of boundary work (Jasanoff, 1990), we describe how the model can be used as boundary spanning objects.

2 Climate Adaptation Strategies for Policy Makers

Many countries are thinking of adapting to the effects of climate change (US National Research Council, 2010; Dutch Deltaprogramme, UK Climate Change Act, 2008). Only a few countries have issued an adaptation policy for infrastructure, like Germany (Federal Government, 2008).

A common way in policy making is the linear approach for finding solutions. As well in model building it is easier to understand, to research and to measure. A model is by definition a simplification of reality. Many policy problems are perceived to have a linear relationship between problem and solution. In practice, the problem is not solved and unexpected events occur. An example in infrastructure is the problem of congestion. Although all experts agree that building new highways is a short term solution, and does not solve the problem of congestion in the long term, Dutch ministers of Transport have focused on new and extra capacity of highways. More capacity on the roads only attract new traffic; the accessibility increased in relationship with a higher number of cars arriving in a particular time, the individual travel time per car will tend to the old level.

The Dutch Council for transport and networks has published an advice on climate adaptation for infrastructure (Raad voor Verkeer en Waterstaat, 2009), which is built on adaptive governance (Rahmen et al, 2008). This approach is based on adaptive management, which is a structured, iterative process of optimal decision making in the face of uncertainty, aiming to reduce uncertainty over time via system monitoring. Adaptive management should be used not only to change a system, but also to learn about the system (Holling 1978). Because adaptive management is based on a learning process, it improves long - run management outcomes.
According to Allan and Stankey (2009) the challenge in using the adaptive management approach lies in finding the correct balance between a strategic and tactical level; gaining knowledge to improve management in the future and achieving the best short - term outcome based on current knowledge. Adaptive infrastructure management requires a thorough understanding of the infrastructure system and input of a multi-disciplinary and multi-perspective group of stakeholders, enabling policy makers to define productive adaptation strategies and setting up a learning process. Indeed, the mitigation and adaptation measures can be contra productive, and cost effectiveness of decisions asks for windows of opportunity (Kingdon, 1984) in the 'normal' infrastructure management decisions (see figure 1). And planning and policy should be flexible to incorporate uncertainties and unpredictability.

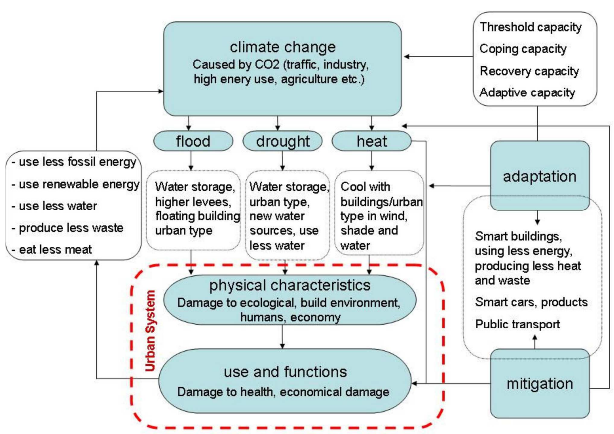

Figure 1: A high-level integrative system diagram for adaptation (source: Dopp, 2011)

The measures can intervene in several ways. They can prevent effects (higher dikes to prevent flooding), decrease negative effects (create alternative routes), take them away or change them (promote teleworking). Each measure is connected with other measures, has secondary effects, and can even influence drivers for climate change.

The infrastructure and mobility system can be regarded as a complex system (Buchs, 2001). It consists of both physical and social-economical parts. The influence of climate change will demand for adaptive capacity of the infrastructure system. Only then the rapid changes, dynamics and unexpected events can be accommodated. The system approach will also help to address the cross sectoral linkages between a problem occurring in one domain and the most effective solution in another.

3 System Approach and the Policy Science Interface

Klir (2001) argued that the aim of system analysis is to use systems thinking and methodology for analyzing complex problem situations that arise in private and public enterprises and organizations as a support for policy and decision making (Klir, 2001). One of the key feature of systems analysis is the recognition that the complexity of the systems that are studied is such, that complete certainty is impossible, and that systems analysis is essentially an art and a craft, based on tacit and informal methods, rather than formal and explicit (Miser & Quade, 1985). They claim that the system analysis is not a scientific discipline or method, but it can be used as an approach for looking at problems and helping policy makers to deal with the 'system'. Dopp used this approach (Berkes and Folke, 1998, Heylighen, 2000) in city planning in relationship with climate change, because there is a mix of elements like urban structures and users that are both part of the problem and part of the solution (Döpp, Hooijmeijer and Maas, 2010). We will use this system approach to understand the infrastructure system and the issues of climate change in relation to each other and to find adaptation strategies to deal with climate change in the context of infrastructure and mobility.

Climate and weather conditions cannot be regarded to be stable, especially when considering long term investment characteristics. It requires a flexible policy and planning, capable of evaluation and midterm changes when circumstances are changing (immediately). It also demands for new approaches to connect short term interventions with long term objectives. Thus, flexibility is not only an attribute of the physical system, but also part of the social and governance system. This implies consequences for policy making and decision making process and for the institutional arrangements of public and private and societal networks.

Hischemöller and Hoppe (2001) describe these type of decision making as an unstructured policy problem, because values are at stake and there is no consensus on the knowledge to be used to solve the problem. A lot of policy problems fall in this category. Cuppen emphasizes the need for a stakeholder dialogue in unstructured problems in order to enrich the policy process with new perspectives, knowledge and values (Cuppen, 2009). She defined this as an organized meeting of stakeholders with different perspectives, knowledge and backgrounds, who would otherwise not meet (or not all together), structured to a greater or lesser extent by means of specific methods, tools or techniques (Cuppen, 2009). Hajer et al instigate a deliberative, collaborative and practice based way of producing knowledge with scientists, policy makers and practitioners. (Hajer and Wagenaar, 2003).

According to the boundary spanning theory (Leifer and Delbecq, 1978), the boundaries between science, policy and practitioners communities hamper the communication. There are three types of boundaries to cross:

1. the science-science boundary: the boundaries between the different scientific disciplines, that are hard to cross as they use different concepts and vocabulary;
2. the policy-policy boundary: the boundaries between the different involved policy domains;
3. the science-policy boundary: the challenge for the involved scientific disciplines is to come up with meaningful results for the policy domains;

Inspired by the concept of boundary spanning, there are three conditions that should be met for a productive connection between science and policy (Duijn et al., 2008):

1. Joint production of documents, models, etc. ('boundary objects')
2. People who can combine different fields of knowledge and can attach to different communities ('boundary spanners')
3. Legitimate and transparent processes to guide boundary spanning activities

The next paragraph describes the INCAH project and elaborates the functioning of the system model as a boundary spanning object. It makes clear how it helped to understand the infrastructure system and to define most urgent and promising research questions within the project. We use examples from the road infrastructure and the interrelationships with the other systems to clarify this function.

4 The System Model for Infrastructure Systems

INCAH (Infrastructure and Networks for Climate Adaptation in Hotspots) is a project in an innovation program on Climate Adaptation (Climate for Knowledge). INCAH focusses on four infrastructure types[1] (drinking water, electricity, rail road, vehicle roads) and their mutual connection and dependencies. Two important elements have been distinguished connecting well to the concepts of the system approach:

- Analysis of stakeholders and their involvement.

  The system can be described from several perspectives, which lead to new insights and new participation of actors. The dialogue about the system is as much important as the accuracy of the system description. This is not only about expert knowledge but about common understanding and creation of new collaborative knowledge to be able to change quickly to dynamic changes.
- Creation of adaptive capacity.

[1] The choice for these four infrastructure systems is mainly practical: the researchers involved has best relationships with these types.

> By realizing learning communities in social actor networks, solving problems will become more flexible. The adaptive capacity of social systems enables themselves to change and to adapt, without decreasing productivity, effectiveness or functionality of the system itself. This capacity prevents from 'lock-ins', because more options will be possible.

Based on Jackson the road infrastructure can be regarded as a socio-technical system when 'work groups or organizations have interactive technological and social aspects and in designing the structure of the group or organization both of these should be considered' (Jackson, 2000). The technological aspects are civil engineering elements like bridges, construction, concrete and asphalt and ICT elements for travel time information and speed measurements. The social aspects are related to traffic behavior of drivers, maintenance organization and road investments decision making.

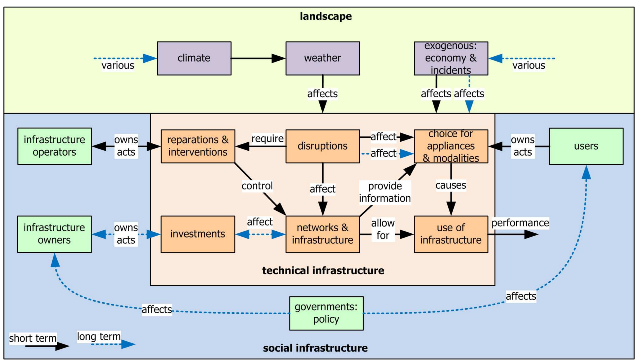

Figure 2: General framework of a socio-technical infrastructure system

Within the INCAH project we have set up a general framework (see figure 2), and adapt it to the road infrastructure system. Adaptations were mainly related to the right verbs and words for physical elements and the correct stakeholders and actors that are dealing with the operation and management in this network (see figure 3)

This system model describes the landscape that influence the socio-technical system, the technical infrastructure and the social infrastructure. The technical infrastructure is basically the physical part and is closely related to the domain of civil engineering and construction and ICT. The social infrastructure is mainly related to governance and consists of the decision making process and the way actors own or act on this technical infrastructure. Effects of climate change, one of the 'events' in the landscape, are related to multiple domains. Groundwater level influences the strength of dikes and embankments. The location and numbers of bridges or tunnels determines the robustness of the road network. And maintenance policy and investment strategies provide the functional quality of the roads and accessibility of destinations. Each domain is represented by its own stake. From the unstructured problem approach the dialogue between these domains, and between policy makers, researchers and practitioners is important to valorize the knowledge developed and to find out realistic solutions. The distinction between short term and long term, conform the adaptive management approach, shows that the effects could have different dynamics, and that possible measures could lead to unexpected or non-wanted consequences.

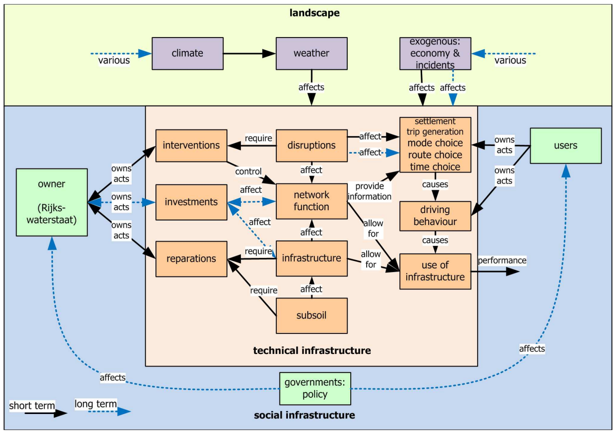

Figure 3: Adapted framework to the socio-technical system of road transport

5 The System Model as Boundary Spanning Object

We have used this qualitative system model in a first interactive project workshop, led by a facilitator which have many qualities of a boundary spanner (Duijn, 2010). Participants of this workshop were researchers of the project and stakeholders with stakes in one of the four infrastructure systems. Stakeholders were both policy makers, decision makers, advisors of the board and civil servants. They did not know each other, strong and trustingly relationships were absent. The workshop have been evaluated by a questionnaire, which we use to underline the conclusions. The workshop was built up by three steps.

The workshop started with the general project description and the more specific work packages descriptions. We asked the stakeholders to raise all the questions they had. Despite the fact the participants did not have strong relationships, many positive and negative critics were spread out by stakeholders. The transparence of the workshop process and the openness of the facilitator were very important in this. Almost all participants felt comfortable and safe to bring up all necessary questions and remarks.

Next we introduced adaptive governance and the system approach as the main concepts of the research for adaptation strategies. This leads to insights on these concepts for stakeholders and researchers and the acknowledgement that not only each own subject counts. These two activities give an overview of the main questions from the perspective of the stakeholders considering climate adaptation strategies for infrastructure. See table 1.

The last step was the explanation of the general framework and the socio-technical system per infrastructure network. It was explicitly introduced as one way of presenting reality, not meant to be the only way. In a process of asking questions and giving answers the intertwined process took place, in which scientists, stakeholders and policy makers are interacting to deal with the policy problem. The connection between these groups and between scientific information and policy making is explicitly rewarded and acknowledged. The discussion in subgroups have led to several observations and remarks in a debate between researchers and practitioners, and it have also led to many new and relevant questions. As said before this type of policy problem shapes the role of science and the use of knowledge. The workshop made quite clear to all participants the relevance of scientific knowledge to the policy decision making. The stakeholder interaction has improved the learning cycle in the policy domain.

The comprehensive discussion with stakeholders completed the adapted framework for road infrastructure systems; not only with facts and relationships, but mainly with comments, suggestions, questions, assumptions. It elaborated the different perspectives of the stakeholders on the road infrastructure network, and expose the interference between the different infrastructure networks. Many of these questions arise because the whole infrastructure system was visible, instead of one part only. See table 1. All questions and remarks have helped the researchers to better understand the point of interest of the stakeholders more thoroughly.

Table 1: Type of questions and remarks in the workshop.

Questions and remarks based on research presentations and perspective from stakeholders	**Questions and remarks based on debate and discussion between stakeholders en researchers**
Effects of climate change and extreme weather on embankments, bridges, asphalt, traffic flows	In sights in critical tipping point for service quality, maintenance costs and their influence on design parameters.
Frequencies of network disturbances	Weather forecasts and their use for dynamic traffic management and incident management
Loss of capacity by traffic behaviour	What about the system robustness in relationship with climate change effects?
Economic effects of unreliability of the network	Coping with incidents by using multimodalities.
	Connection between adaptive policy and adaptive asset management related to signposts

A lot of remarks were related to the interconnection and translatability between the several infrastructure systems. For instance the stakeholders suggested to copy the economic valuation of delay in rail road due to more extreme weather conditions on the delay of roads. The stakeholders have learned from the energy infrastructure, for instance the write-off of investments. This is not practiced in decision making for road infrastructure investments, but is quite common in the energy infrastructure market. Using write-offs could help to save money for asset management, maintenance and replacement.

In the evaluation all participants agreed on the usefulness of the system model. First of all it has structured the discussion and the interrelationship between work packages. Secondly it helped to bridge language gaps and get to know each other's perspectives. Thirdly it contributes to openness and transparency of the process, because it is not presented as 'the truth'. One of the participants could improve or complement the system model, but was still convinced of the appropriate use of the (incomplete) model in the discussion. The workshop facilitator was assessed to fulfill the requirements of a boundary spanner: connecting domains, giving floor to all participants, and positioning neutral towards researchers or stakeholders. As well the process of the workshop was assessed to be transparent.

6 Conclusions

The use of a boundary spanning object like the socio-technical system model has contributed to hamper boundaries between science and policy in finding climate adaptation strategies. First of all it has structured the dialogue. It has helped the policy makers acting in different systems to learn from each other and to translate feasible solutions in one system to other infrastructure systems. It has stimulated the integration and cooperation between the researchers, because there was a common ground to discuss on, to learn from correlation or correspondence of infrastructure systems and to transform existing methodologies in new domains. The boundary between scientists and policy makers has been hampered as well. By discussing and adapting the system models new questions from policy makers have been raised. The perspective of the stakeholders and the background of these questions were more clear and therefor better understandable for the researchers. The researchers have been helped to formulate their research from the bases of the system model, contributing the brightness of the research questions.

These conclusions meet the conditions of Duijn et al (2008) corresponding the boundary spanning objects. The conditions of the boundary spanner and the boundary process are as much as important. Main characteristics of the boundary spanner are enabling the involvement of all participants, appreciating both the knowledge from stakeholders and researchers equally, connecting several domains and facilitating a transparent process. The socio-technical system model has supported both the process and the facilitator.

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