Outline for the case Road maintenance in a changing climate

Introduction

Roads and transport systems are vulnerable to climate change impacts (VTT 2011; Koetse and Rietveld, 2009; Regmi & Hanaoka, 2011; Road ERA-net 2009 & 2010). Furthermore, the future road system will have to provide an adequate service level while accounting also for other long term changes, such as in demography (ageing), in economic structure (possibly reinforced by mitigation policy), and in spatial organization (contrasts between regions, urban sprawl).

The road system is a part of the overall transport system and e.g. for several goods transport categories other modes such as rail and inland/coastal waterway are relevant alternatives. So, as it comes to scenario analysis the road system cannot be assessed in isolation from other transport networks with which it is both competing and co-operating. Yet, it seems that for strategic level adaptation planning the national level road system can be regarded largely as a separate entity, distinct from other modes. Similarly, at regional/local levels mainly links to the neighboring regions count, not so much links to other networks. This delineation is also important in order to keep the adaptation planning and policy cycle manageable, because the road transport sector has many stakeholders with different agendas. Climate change has a large variety of direct and indirect impacts on the transport sector. Table 1 below shows a tentative distribution of activities by different stakeholders and by geographic / administrative aggregation level.

Table 1 – ***Tentative identification of relevant (predominant) operating levels and actors***

	Local		**Regional**		**National***		**International**	
	public	private	public	private	public	private	public	private
Infrastructure planners	X		X		XX		X	
Infrastructure designers			x	x	X	XX		X
Infrastructure builders		x		x		XX		X
Infrastructure operators	x		x	x	X	X		
Transport service operators (freight; passengers)	x	x	X	X	X	X		XX
(holders of) private cars, motor bikes, etc.		XX						
Non-motorised transport		XX						
Freighting clients		X		X		XX		XX
Storage; handling		x		X		XX		X
Tourism		x		X		X		X
Vehicle makers						X		XX
Support services (weather; routing; safety; etc.)					X	X	X	X

XX = clearly dominant; X = important; x = some (limited) role

*) focus area of the case

Red: inside transport system; **blue**: direct impact on size & quality of demand for road vehicle movements; grey: auxiliary services that strongly interact with effects of climate change

Various possible effects of climate change on road infrastructure and its users

The expected effects of a changing climate in Nordic countries imply among others a higher frequency of bad road conditions in winter, a higher frequency of more serious wear and tear of infrastructure and equipment, higher risks for large scale impact events (e.g. inundated tunnels), as well as induced behavioral effects possibly entailing maladaptation[1,2]. According to a review study of the Swedish Road Authority (Vägverket 2008) of all Nordic countries the Norwegian road system seems to be the most exposed to different adverse impacts of climate change, whereas the Finnish and Swedish exposure profiles are very similar[3].

Although a significant share of the weather impacts is already today taken into account in the design, a change in the strength and/or frequency of damaging impacts may cause a need to change road structures (Saarelainen and Makkonen, 2007). For example, trenches and bridges, and culvert structures of smaller roads have not been designed for high precipitation. Climate change will also have an effect on the routine and periodic maintenance of roads (Finnra 2009). In order to keep the present level of service, there are needs for changes in the maintenance guidelines. Further development of warning systems for road users and information in trip planning are important ways to mitigate any negative effects of weather and climate.

Climate change may affect demand of road transport services directly, e.g. climate change may alter the supply chains in forest and food industries. The competitive position of road transport may change for better or worse, depending on how other modes respond to changing circumstances and risks, on the regulatory and costs effects of explicit adaptation policy, on the interaction with other policies (mitigation, clean air, urban zoning, safety etc.), and on the ability of the road transport sector (incl. its infrastructure and supporting services) to co-operate coherently to find efficient and timely answers (Salanne et al, 2010).

All in all there are three main domains of effects, being (1) ***traffic safety***, (2) ***road maintenance***, and (3) ***traffic capacity.***

Effects in the domain of *traffic safety* follow from adverse weather situations, of which the frequency of various types may increase (e.g. freeze-thaw cycles, intensive rainfall, etc.). Without countermeasures the consequence would be more casualties and fatalities, more loss of productive life, and more vehicle damage. It should be realized that when these adverse situations are considered as single events not any societal or technical learning is taken into account, and consequently the estimated incremental impacts tend to be near the upper bound. If over the course of time (i.e. as climate change proceeds) road users and road administrations get convinced that the frequency of some adverse events has increased, adaptation will start to occur, e.g. by using another type of asphalt, favoring cars with more intelligent braking and low resistance detection, etc. These reactive adaptations would mitigate the increase in impacts to some extent. The point is of course to develop proactive adaptation in order to prevent any increase of accidents. In some cases innovations spawn by adaptation plans could even result in a reduction of accidents. For impact assessment and cost-benefit analysis of adaptation alternatives this distinction between short term and long impacts should be kept in mind.

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[1] For example, notwithstanding a long-term downward trend in Finnish road transport casualties the number of fatalities on roads in July 2010 was significantly higher than in previous years' July or in June 2010. Virtually the whole of July 2010 was warm to very warm in most parts of Finland, except Lapland.

[2] For elaborate listings of possible impacts see: Meyer et al 2009.

[3] Interestingly enough, actual cost incurred since 2000 due to effects of extreme weather events are significantly higher in Sweden than in Finland (see: SOU 2007-60, Sweden facing climate change).

The annual costs of accidents in Finland (incl. production loss due to loss of lives and permanently disabled) can be loosely assessed to be of the order of magnitude of 600 million Euro.

As regards *road maintenance* the adverse effects concern especially weather circumstances that increase wear and tear. Freeze-thaw cycles are also in this case relevant, but just as well very low or high temperatures, as well as drought (followed by intense rainfall). It also depends on the technical state of a road, the underlying soil type, and the nearby natural environment whether a significant increase in deterioration will occur.

The task of road maintenance is to ensure a minimum level of service (with traffic flow and traffic safety as principal factors) throughout the road system while keeping current and expected costs manageable, and honoring side conditions, e.g. regarding environmental requirements. Maintenance can encompass smaller repairs due to winter damage, as well as larger refurbishments and adding of lanes. Road clearing (from snow and debris) is usually seen as an operational task, separate from other maintenance. Since implications of climate change may vary across locations the preventive responses need to be flexible in order to enable least cost solutions. As a consequence *asset management tools* (including indicators for the technical state of road sections) will be of great use and need to be adapted to be able to include the implications of climate change (Meyer et al, 2009). In turn the further development of these systems to adequately account for climate change needs often rather detailed technical research (Petkovic et al, 2010; IRWIN 2009). Judgment of effects and prioritization of actions will also depend on the way road and maintenance is funded (from the annual budget; from a fund; through public-private partnership PPP) and whether some kind of lifecycle costing approach is allowed in the evaluation of how to prioritize maintenance needs.

The maintenance task interacts with operational tasks (like snow clearing) and strategic tasks (road planning). Budget pressures in one task group may lead to cost rises in another. For example, some asphalt types may require more often salting against slippery conditions than other ones. On the other hand experiences in each of the task groups could also be used to make activities and choices in another task group more effective. It means that *learning across the entire* road administration is important.

The share of the annual budget of the national road administration attributed to maintenance is about 550 million euro, of which operational tasks may cover up to 10% of that budget. The investment amount for new roads is about the same as the maintenance budget[4]. The relative significance of the maintenance budget will rise as investment in new roads will stagnate of decrease. The total value of the Finnish road system is in the order of magnitude of 36 billion euro (approx. current replacement value; Uimonen 2008).

Last but not least adverse weather causes reduction in *traffic capacity*, as speeds go down. This results in travel time losses, skipping of trips, and delayed delivery of goods (with possible knock-on effects in production). In case of essential trips or deliveries it may also lead to use of extra (back-up) vehicles, whereas also increased cost of overtime work could occur as well (though this is mainly a transfer at the macro-economic level). Even though there is tacit knowledge across transport providers regarding travel demand and driving behavior responses (peer reviewed) literature based on systematic research starts to appear only since recently (Cools et al, 2010;

[4] These figures do not included road expenditures by local authorities and private road owners (forest companies and road co-operates in rural areas). According to Ministry of Transport (2003) municipalities spent about 750 million euro per year on roads.

Sumalee et al, 2011) In Finland there are no very precise estimates available on the costs of weather related delays and interruptions. Leviäkangas (2007) mentions an amount of 20 ~ 30 million euro per year. As mentioned before over time road users will start to adapt if they realize that certain delays occur too frequently. Responses could vary from shifts in departure time to switching to another mode or even relocation of activities.

A note on service levels

In road planning and maintenance service level is an important lead concept, denoting primarily standards for traffic flow, average speed, and safety by road type and segment. Observed traffic flows, speeds and accidents can be compared with minimum target levels. If minimum target levels are too often not fulfilled action should be taken. By means of operational and maintenance services a road administration attempts to manage the road system such that non-target achievement remains a marginal phenomenon, without incurring too much cost. The challenge is to find a robust balance between current quality and cost demands and future quality and cost demands. To this end the road administration is monitoring traffic flows and accidents on its network as well as running an asset management system, which also includes indicators for the technical state of the roads (by segment). It buys weather information to project needs for clearing services and quick repairs, as well as provide services for road users informing them via internet cameras regarding the driving conditions of road segments. It may also operate electronic speed indication systems, e.g. in case of adverse weather conditions, congestion, etc.

Despite these extensive observation systems the experienced service level of drivers may deviate from that defined by the road authority. There may be all kinds of additional features (road side objects, secondary weather aspects (e.g. daylight intensity), personal skills and expectations) that affect the experienced service level of a driver. One way to assess experienced service level is apply personal observation technology (cameras, sensors) or to use a driving simulator. Kita and Kouchi (2011) apply such an approach in conjunction with a postulated utility function. Yet, this approach is mainly useful as input for designing evaluation systems of observed or reported ratings. Another approach is to use feedback surveys among road users (Lodenius, 2011), which are used in almost all Nordic countries. However, these surveys are held at most once a year and often even less frequent. So, these surveys are picturing posterior impressions of states and tendencies in traffic. Furthermore, the surveys may – at least in part – measure acceptability levels instead of potentials for improvement. This still can assist in priority setting of maintenance and correction of some road maintenance practices, but it misses opportunities for improving proactive management.

Technological development

When contemplating effects of climate change it should be kept in mind that technical and social innovations can both reduce and increase the vulnerability of road users. For example, logistic developments, such as ‘just-in-time’ delivery and optimized supply chain management, lead to minimal costs of holding stocks, but boost the sensitivity to disruptions. On the other hand ICT services can help drivers to be up-to-date on expected weather and driving circumstances for the remainder of the trip. ICT in conjunction with smart cars and smart highways could even directly intervene in the driving so as to minimize accident risks. Projections of incremental risks due to climate change effects should factor in the effects of changes in society (e.g. like an ageing population, urban sprawl, etc.) and in technology (such as smart highways and smart cars).

3.Accounting for adaptive management in the adaptation planning cycle

On the basis of the NONAM workshop in Reykjavik an adaptation planning cycle for the road sector was condensed into a flowchart (figure 1).

As stated earlier the process starts with some kind of official mandate. Based on existing legislation or as part of the mandate guidelines for the planning process, including stakeholder involvement, may already be available. Usually this still leaves the core team of internal experts and process managers (usually of the ministry of transport) a lot of leeway how and whom (and when) to invite. The choice of stakeholders should correspond with the (foreseen) framing of the adaptation plan. Therefore it may be necessary to invite additional stakeholders later on. Stakeholders may be granted certain rights, often by law, regarding the course of the planning process, the transparency of choices made, and the evidence of provided input (see also figure 1). Yet, the participation and its procedural rights don't provide any guarantee that provided information, priority settings, etc. of particular parties have noticeable effect on the resulting definition of alternatives, even though participants often develop expectations to that effect. This needs to be clearly communicated in the invitation and throughout the planning process. On the other hand this notion needs to be balanced against the effect that experiences as if participation does not make any difference should be minimized. Lack of participation during decision making may seriously affect later on formal acceptance and also actual policy implementation. Differences in effectiveness of participation are often related to large differences in capacity to grasp the entire theme area and consequences of choices.

Considering the discussion in the previous sections figure 1 should be largely self evident. A special feature is the insertion of a third party peer review of the scenarios and the analyzed dilemmas regarding aspired versus achievable service levels of the road infrastructure. Such a review aims to ensure a solid credibility and authority of the analysis and thereby at keeping the stakeholder deliberations constructive and solution oriented. Figure 1 also allows for the various learning cycles within the same planning cycle as well as in the long term for a new policy cycle.

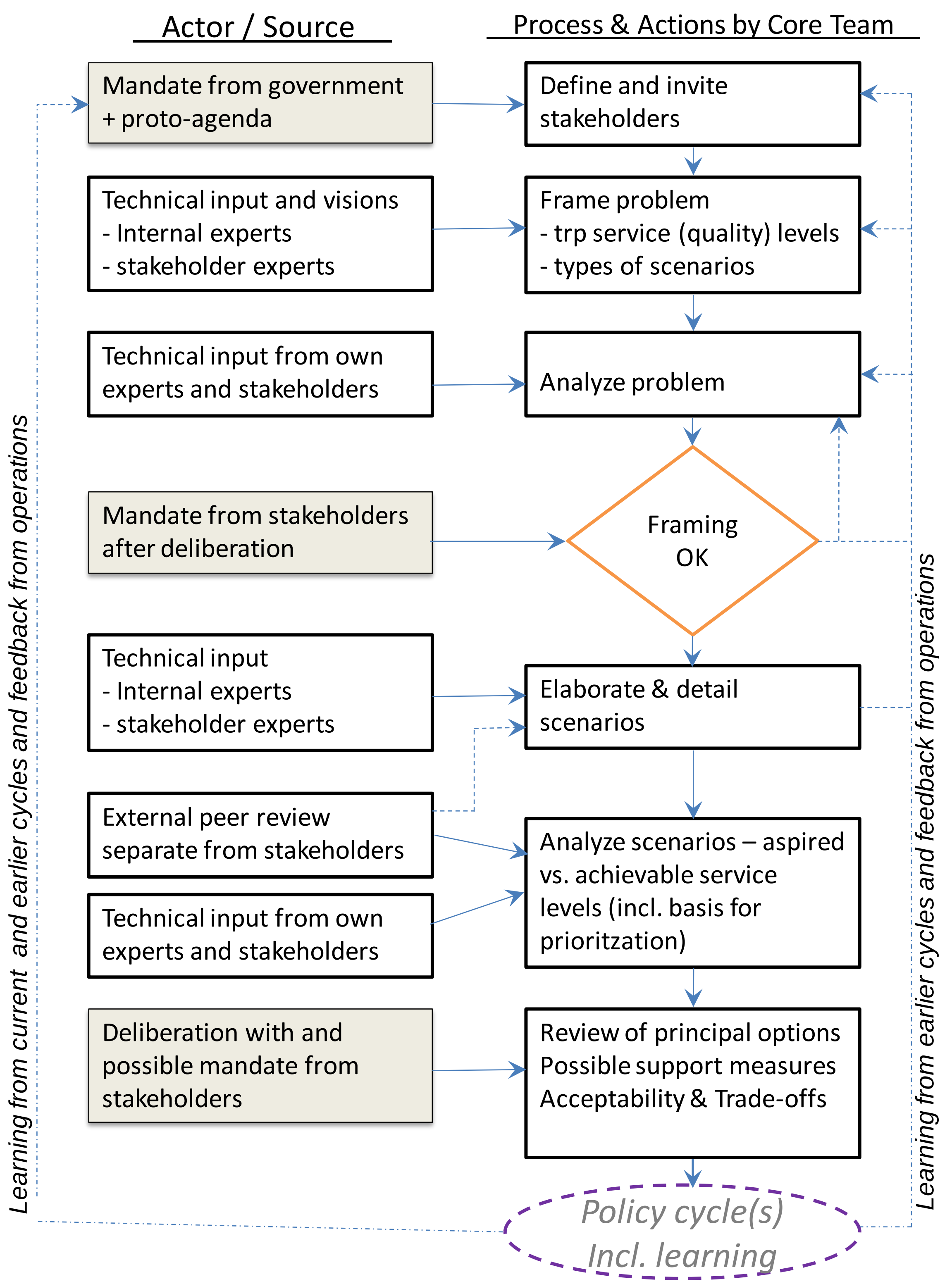

Figure 1. *Flow chart summarizing information and decision flows of an adaptive management inspired adaptation planning cycle for road transport (at national strategic / tactical level)*

Literature:

Andrey, J. (2010), Long-term trends in weather-related crash risks, *Journal of Transport Geography*, Vol. 18, pp. 247-258.

Cools, M., Moons, E., Wets, G. (2010). Assessing the Impact of Weather on Traffic Intensity, *Weather, Climate and Society*, Vol.2, pp.60-68.

The Finnish Road Administration (Finnra) (2009), The effect of climate change on the routine and periodic maintenance of roads, Finnra report 8/2009, (in Finnish, abstract in English)

Haas, R.; Felio, G.; Lounis, Z.; Cowe Falls, L .(2009), *Measurable performance indicators for roads: Canadian and International Practice*, National Research Council Canada, NRCC-52692.

Jaroszweski, D., Chapman, L., Petts, J. (2010), Assessing the potential impact of climate change on transportation: the need for an interdisciplinary approach, *Journal of Transport Geography*, Vol. 18, pp. 331–335.

Kita, H. and Kouchi, A. (2011), Quantifying perceived quality of traffic service and its aggregation structure, *Transportation Research Part C*, Vol. 19, pp.296–306

Koetse, M.J. Rietveld, P. 2009, , The impact of climate change and weather on transport: An overview of empirical findings, *Transportation Research Part D*, Vol.14, pp.205-221.

Klöckner, Ch.A., Friedrichsmeier, Th. (2011), A multi-level approach to travel mode choice – How person characteristics and situation specific aspects determine car use in a student sample, *Transportation Research Part F*, Vol.14, pp.261-277.

Leviäkangas , P., Tuominen, A. , Molarius, R., Kojo H. (eds.), (2011), *Extreme weather impacts on transport systems*, VTT Working Paper 168. http://www.vtt.fi/inf/pdf/workingpapers/2011/W168.pdf

Leviäkangas, P. & Hautala, R. 2009. Benefits and value of meteorological information services – the case of the Finnish Meteorological Institute, *Meteorological Applications*, 16, pp. 369–379.

Meyer, M.D., Amekudzi, A., O'Har, J.P. (2009), *Transportation Asset Management Systems and Climate Change: An Adaptive Systems Management Approach*, paper for Transportation Research Board 2010 Annual Meeting, CD-ROM proceedings.

Mills, B., Tighe, S.L, Andrey, J., Smith, J.T., Huen, K. (2009), Climate Change Implications for Flexible Pavement Design and Performance in Southern Canada, *JOURNAL OF TRANSPORTATION ENGINEERING*, October 2009, pp. 773-782.

Petkovic, G., Humpsted, T., Bjordal, H., Larsen, O., Aursund, P.O. (2010), *Climate and Transport – R&D Programme for Adaptation of Norwegian Roads to Climate Change,* proceedings of Transport Research Arena Europe 2010, Brusssels 7-10 June 2010. http://2010.traconference.eu/

Perrels, A., Simola, A., Rosqvist, T., Virta, H., Molarius, R. (2011), *Quantifying direct and induced economic costs of climate change sensitive natural hazards at regional levels – example Finland*, NCCR Climate Economics and Law Conference, Bern,16-17 June, http://www.nccr-climate.unibe.ch/conferences/climate_economics_law/papers/Perrels_Adriaan.pdf

Saarelainen, S. & Makkonen, L. (2007), *Adaptation to climate change in road management – Pre-study*, Helsinki 2007.

Salanne, i., Byring, B., Valli, R., Tikkanen, R., Peltonen, P., Haapala, J., Jylhä, K., Tolonen-Kivimäki, O., and Tuomenvirta, H., 2010: Climate Change and Freight Transport. Ministry of Transport and Communications – publication 15/2010. 98 pp. (in Finnish, abstract in English)

Sumalee, A., Uchida, K., and Lam, W.H.K. (2011), Stochastic multi-modal transport network under demand uncertainties and adverse weather condition, *Transportation Research Part C*, Vol.19, pp.338-350.

Swedish Government Official Reports, (2007), Sweden facing climate change, Stockholm, SOU-2007-60. http://www.sweden.gov.se/content/1/c6/09/60/02/56302ee7.pdf

Uimonen, S. (2008), The capital stock of Finnish road (in Finnish), in Honkatukia, J. (ed.), *The macro-economic effects of transport (in Finnish)*, Ministry of Transport & Communication, Helsinki, publ.25/2008, pp.75-126.

Venäläinen, A. and Kangas, M. (2003), Estimation of winter road maintenance costs using climate data, *Meteorological Applications*, Vol. 10, pp.69–73

Transport case – questions and tasks

The case concerns the Finnish national road system maintenance planning challenges regarding the inclusion of climate change adaptation measures. The working groups are supposed also to observe other objectives and pressures which affect the decision making.

With reference to adaptation planning cycle two sets of tasks are defined, each capturing a part of the adaptation planning cycle. Each working group is supposed to choose a different task package.

Case task sets (choose either 1 or 2)

1. *Defining and framing the problem, stakeholders involvement, and initial analysis*

Involve and clarify at least the following elements:

1.1. objectives
1.2. objective hierarchy
1.3. stakeholder mapping and involvement plan
1.4. process outline
1.5. expected outcome (what kind of answers, information, report status, etc.)

Questions:

A. Uncertainty

- What climate change effects and other major changes should be considered in this case?
- What are the main uncertainties on climate change effects? .. and other effects?
- Which ambiguities are in play regarding various themes and challenges?
- Prepare a survey of the main uncertainties and ambiguities, their characteristics and describe how to deal with the different sources of uncertainties
- How are you representing and explaining uncertain knowledge to stakeholders?

B. Knowledge and information organization

- What time frame does your project have, both with respect to the project time itself and regarding the envisaged implementation period (horizon)?
- Which information and knowledge is needed regarding climate effects and the involved uncertainties? What are the main knowledge gaps?
- What types of knowledge and information are you eliciting, in what way and from which stakeholders?
- What knowledge and information representations are you using and why?
- Are you supposing equal validity and credibility of acquired knowledge and information? and do others have the same perception?
- How are you integrating knowledge from different stakeholders?
- When you integrate knowledge from different stakeholders, whose knowledge is the integrated knowledge?

C. Prepare a stakeholder involvement plan

- How do you achieve a common understanding among stakeholders?
- What are the overall objectives and principles of the stakeholder involvement?

- What participatory methods are being used with the different types of stakeholder in the stakeholder process, and for what purpose?
- Stakeholder analyses and role of authorities
  - Overall process time schedule
  - How long will the different parts of the stakeholder process last?
- How will you encourage the same stakeholders to keep on participating for the duration of the stakeholder process?
- What are the key milestones of the process?
- What are the criteria of success for the process?
- What are the key challenges to organising a successful stakeholder process that you are trying to overcome, and how?
- What different skills will be needed to successfully realise the process?
- Which group model building and stakeholder engagement tools should be included for dealing with ambiguity/framing of the scenario development and uncertainties?

D. How do you deal with social learning and planning for change in the stakeholder involvement process?

E. What conflicts, if any, are there in trying to support social learning and formal decision-making processes at the same time?

F. How do you test behavioural responses to risk and acceptability of policy through the stakeholder involvement process?

G. How should the scenarios be applied in the stakeholder involvement process?

H. Capacity of policy makers, water managers, researchers

I. What capacity is needed of policy makers and water managers in order to make full use of scenario work

- What are the requirements to research results?
- Can stakeholders and policy makers cope with uncertainty? How?
- Describe the most important assumptions to achieve a fruitful social learning process.

J. Connecting to Policy

- Where is the stakeholder process situated in the formal policy making process?
- How are you to guarantee that the results of the stakeholder process are substantively used to guide final decision-making?

K. Supporting adaptive management

- What parts of the adaptive management process are different parts of the stakeholder process supporting?
- What aspects of adaptive governance are different parts of the stakeholder process supporting?

2. *Scenario building and impact assessment for Finland:*

You are requested to:

- build at least one scenario as a basis for evaluating climate change impacts and adaptation measures;
- to outline what kind of impact assessments and what kind of evaluation methods you would use for the appraisal of (packages of) adaptation measures;
- to carry out some quantitative projections and evaluations where you see fit.

Data are provided regarding:

- length of the national road network, and its distribution by type of highway
- map of the road system
- traffic intensity in different parts of the network
- the vehicle stock
- population and population density by region and for the largest cities
- meteorological data on current and future climate
- expected growth rates of traffic intensities
- expected growth rate of the vehicle stock
- population projections
- committed road plans
- a dataset with collision data combined with weather data and road & traffic features

Tasks – questions to be answered

1. **Knowledge gathering – climate change effects**
   - What time frame (horizon) do you choose for the projections? Please clarify your choice.
   - What information and knowledge is needed regarding climate effects and its implications in this case?
   - What are the involved uncertainties?
   - What are the main knowledge gaps?
     - please describe how you would deal with handling the various uncertainties;
   - How would you preferably acquire the knowledge? (new data, modelling studies, stakeholder processes, research, analogies, etc.)
   - What are the requirements regarding the data?
   - What are the expected main climate change effects for this case?

2. **Identify possible development scenarios**
   - What are the respective key characteristics with respect to climate change, societal development, economics, governance structures, technology, values & norms, and people's behaviour?
   - Describe the selected scenarios (base year, time horizon, time steps, geographic coverage, main themes, major driving forces, considered effects, considered adaptation measures and uncertainties)
   - To what extent and how do you involve stakeholders in the scenario building?
   - What are the adaptation options?

- By what methods and criteria are you evaluating original impacts of climate change and the effectiveness of countermeasures?
- How do you deal with uncertainty in the scenarios? and how with trade-offs?

3. Reflection on the scenario(s)

- What are the critical assumptions regarding risk perceptions and behavioral responses in the different scenarios?
- How should the scenario and its results be positioned and used in the planning process?
- How would you ensure credibility of the scenario and impact evaluation?
- For what reasons and by which groups credibility could be questioned?
- Assuming that credibility is not seriously questioned, what would be the next steps after scenario and impact evaluation?
- What would be a reasonable assumption about the remaining shelf life of the scenario & impact evaluation?
- How to make the most of societal and organizational learning processes with respect to scenario & impact evaluations?