Adapting professional practices to meet the challenges of climate change: a focus on transport systems and infrastructure

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Climate change is a fact of life and will remain so for decades, whatever mitigation measures may be invoked. Transport professionals need to adapt their practices to explicitly include climate considerations, especially with regard to the provision, management and operations of transport facilities, infrastructure and assets that will be in use for many decades. This note uses the example of transport infrastructure to consider how to undertake the explicit inclusion of climate factors in engineering practice, by considering three major themes for climate change adaptation:

1. the options for changing practice, not merely refining or improving current practice
2. risk management and the development of adaptation frameworks and pathways, with appropriate decision support tools, and
3. in terms of the natural phenomena affecting transport systems and themselves affected by climate change, the central role of water, in its many guises, in the degradation and limitation of the performance of transport facilities, assets and systems. Temperature cannot be ignored either, but water in the wrong place or in the wrong amount is always a problem.

Practical examples of the potential need to change design and maintenance practices include the provision of coastal defences and transport infrastructure in coastal zones, noting the importance of ports and airports often located in these zones; the potential impacts of climate change on road pavements and other infrastructure assets (especially bridges), with the potential impacts on railway systems maintenance and operations from thermal buckling of rail tracks, and with the rising needs to focus more on the provision of suitable, safe infrastructure for the active travel modes of walking and cycling, particularly in urban areas.

Risk management and the development and application of adaptation frameworks and pathways provide key principles for the planning and implementation of adaptation programs. Transport infrastructure is but one of many vital infrastructure systems and there are significant interdependencies between these systems, which leads to the necessary identification of critical infrastructure components. Adaptation frameworks and pathways provide the basis for a systematic approach to planning and decision making and are consistent with established procedures in professional practice. Established information and data sources and decision support tools provide the resources available for transport systems management, but need augmentation to include climate parameters, variables and climate change scenarios. The existing tools need refinement or modification to make them climate-sensitive, and there is a need to embrace emerging tools specifically cast at decision making under uncertainty and with consideration of both short-term and long-term issues – the circumstances at the heart of planning for climate change adaptation.

Risk management for climate change adaptation requires consideration of climate stressors and their effects on infrastructure. The role of water as an agent for the degradation or accelerated deterioration of transportation assets is a key consideration. Sea level rise, storm surges, extreme precipitation events, rising groundwater, water penetration into in-ground structures, scour, flash floods and temporary and long-term inundation are issues for concern in transport asset management, and are issues that are exacerbated by climate change. Corrosion and material degradation are further problems directly affected by water, including water vapour and humidity. Rising temperatures also pose problems, indirectly with sea level rise, and directly with degraded performance of road pavements and rail tracks.

The task for transport professionals is to keep their infrastructure and systems climate resilient. This will assist in maintaining efficient and safe transportation operations and reduce future costs such as congestion, delays and severance. The potential for service disruptions will also be reduced. On the demand side, ensuring resilience will require travel behaviour changes by the community, as part of wider climate change mitigation initiatives. On the supply side, climate change adaptation is now an essential concern for transport agencies. Existing infrastructure may require rehabilitation, refurbishment or retrofitting to make it more adaptable. Design methods and maintenance programs will require review and revision. New infrastructure should be planned, designed, constructed, maintained and operated to accommodate the shifts in climate that may occur over the operational lives of the infrastructure assets. Climate-resilient infrastructure should offer improved service reliability, increased asset life and protection for asset returns. Given the uncertainties that surround potential climate change at the local or regional level, flexible and adaptive approaches are required in the provision and operation of infrastructure. The uncertainties – which in the long term include social and technological change as well as climate change – need to be recognised and accepted, even if they cannot be adequately described. This will provide the means to ensure resilience across a range of future climate scenarios. Policy analysts and decision makers require access to high quality information, consistent and expanding databases and suitable analytical techniques to ensure informed planning and decision making. This access to information needs to be complemented by the development of technical and institutional capacities to manage climate-related risks.

One vital aspect of the management of risk and uncertainty in adaptation planning for transport concerns the evaluation methods to be employed in the assessment of risk. For some time the main method for similar evaluations in transport has been benefit-cost analysis, and this technique is well understood and highly developed. However, its application in adaptation planning presents some problems, given the long timespans (the planning horizon) to be accounted for and the high degree of uncertainty about future costs and benefits over that time duration. Conventional benefit-cost analysis may not have the capability to properly account for these concerns, as it tends to place more emphasis on costs and benefits arising in the short- to medium-term. Other established techniques such as cost-effectiveness analysis and multi-criteria analysis may suffer from similar concerns. While multi-criteria analysis offers an approach that could focus on longer-term impacts and differing degrees of uncertainty, it may rely on subjective judgements in this regard. Other methods perhaps more suited to decision making under uncertainty have been promulgated, including real options analysis and robust decision making. More research and development and practical assessment of the utility of these decision support tools is required. In terms of their potential use in climate change adaptation studies in transportation, the following guidance is suggested:

- *Benefit-cost analysis*: this technique values all benefits and costs of all options, and estimates the net present values in monetary terms. It is suitable for identification of low- and no-regret options in the near future. It can be used as a decision support tool in iterative climate risk management. It is most useful when (1) climate probabilities are known, (2) climate sensitivity is small compared to overall costs and benefits, and (3) good data exist for the major cost and benefit components
- *Cost-effectiveness analysis*: compares costs of options against their effectiveness (monetary or non-monetary) to rank the options, and then uses cost curves for targets and resources. Its suitability is as for benefit-cost analysis, but its use is for applications where benefits are not expressed in monetary terms
- *Multi-criteria analysis*: this technique allows consideration of qualitative aspects as well as quantitative data in ranking alternative options. The impacts on each individual criterion can also be seen. Its suitability is as for benefit-cost analysis, and it is best used for scoping options to indicate potential poor performance on individual criteria. It can complement other tools and capture qualitative effects

- *Real options analysis*: this technique allows for economic analysis of future options and accounts for the benefits of delaying a decision on a given option, to gather further information over time and maintain flexibility in planning. It is suitable for economic analysis of major asset investment decisions over the medium term and allows analysis of flexibility in the staging of major projects
- *Robust decision making*: identifies strategies that are robust rather than optimal, by 'stress testing' a number of plausible scenarios for the alternative options. It thus provides for the identification of combinations of strategic (i.e. long-term, scenario-independent) and operational (short-term, scenario-dependent) decisions.

The principles intimated above provide a sound basis for informed adaptation planning, but what is still missing is a properly established analytical methodology designed for use in climate change adaptation studies, which includes environmental and/or climate variables as explicit, required inputs in the models, tools and procedures used in the design and performance assessment of transport systems and infrastructure. A general modelling approach for climate change adaptation in transport engineering is defined and explained in the paper. In this structure the models of asset or system performance take inputs from two separate sources. The first source is the physical and performance data for the object (e.g. infrastructure asset, network or subnetwork) to be modelled, which would include the design loads (including travel demand) to be applied to the object, its physical size and dimensions, component structure, the materials it is composed of and the rules for its operation. The second source is a set of (defined) climate scenarios, downscaled to suit the location of the object, which could apply over the planned or assumed lifetime of the object. Then the performance of the study object under different climate scenarios can be modelled, and vulnerability and risk for the object assessed and compared over the scenarios. Adaptation policy and planning can then be informed by the results of the analysis, allowing for the development and implementation of appropriate planning and works programs with adaptation components. Applications of the methodology are available, including for road pavement performance and for rail track performance. The recommended methodology includes a phase for monitoring, review, learning and model refinement on the basis on experiences gained and observed in earlier cycles of the process. Experience, learning and knowledge development will be vital facets of future engineering practice for climate resilience.

These issues are discussed in depth in Taylor (2021).

Reference

Taylor, M A P (2021). *Climate Change Adaptation for Transportation Systems*. (Elsevier: Oxford).