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Initiatives in climate change impact assessment and adaptation for inland transport

Draft chapter III - Methodologies for assessing impacts of climate change hazards on transport systems

Submitted by Climate Sense

I. Under what circumstances will an assessment of climate change impacts be required?

1. Transport organizations may be motivated to carry out impact assessments related to climate change hazards for a number of reasons. These could stem, for example, from legislative drivers, corporate social responsibility (CSR) pressures, continuing safety and reliability issues, and expert knowledge of future climate trends.

2. As climate hazards can and do cause catastrophic failure of transport infrastructure systems, transport managers are increasingly concerned about the frequency and magnitude of climate events. In the past fifteen years, knowledge about climate hazards has increased, with potential impacts being identified and, in some cases realized. Because of this, international and local guidelines have been published, by overarching organizations like PIANC, PAIRC, the IRF and UIC, and more locally by infrastructure managers such as Network Rail in Britain, *[France, Germany, Spain others…]*. These guidelines can act as a spur to transport managers recognize that climate change needs transport managers to draft and implement adaptation plans, which often call on industrial sectors to develop and report progress on a regular basis.

3. National Adaptation Plans (NAPs) often require transport organisations' input – and NAPs can relate to the 2016 Paris Climate Agreement Clause 7, on adaptation – which requires regular reporting on adaptation progress. Such 'top down' drivers are evident in countries such as the UK, *[other countries to be listed]* often backed up with legislation. Regulators are known to require adaptation plans, and transport operations and maintenance teams – in the front line of response to climate–related extreme weather events – seek ways to make their system more robust in the face of the future climate. Good asset management practice, such as set out in the ISO 55000 series of standards, can be a driver, and ISO 14090

on adaptation planning a useful framework for the entire process of adaptation planning. Assessment of hazards, consequences, vulnerabilities and exposure as well as adaptive capacity feature in ISO 14090, and risk assessment is fundamental to complying with ISO 55001

4. Hence from many perspectives – from a policy, top-down longer-term strategic basis, to the bottom-up, immediate recognition that action is urgently needed the assessment of climate change impacts across a transport system is essential. Such assessment is a vital early stage to addressing current and future climate hazards so as to maintain the safety and reliability of transport, one of the critical infrastructure systems underpinning society. From another angle, directors of organisations have a legal duty of care and as climate risks are foreseeable, most transport managers are aware or becoming aware of the need to assess these hazards and their impacts.

5. So how are impacts assessed?

The word 'Risk'

Note that it is essential to understand the potential misuse/ perceptions of terms such as 'risk' and 'impact': to some, the word risk can mean 'likelihood', to others it could be an annualised average damage expressed in currency. ISO 14090 defines 'risk' as 'the effect of uncertainty', explaining in notes that *an effect is a deviation from the expected. It can be positive, negative or both. An effect can arise as a result of a response, or failure to respond, to an opportunity or to a threat related to objectives.* It goes on to say that *uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood.* ISO defines 'impact' as *effect on natural and human systems.*

II. Impact assessment methods

6. The term 'impact assessment' has been chosen so as to cover various ways of measuring impacts. Risk assessments, vulnerability assessments, threshold analyses are three ways of assessing impacts mentioned in ISO 14090, acknowledging that different organisations use methods as suited to their own needs. Environmental teams tend to look at *hazard x exposure x sensitivity/vulnerability*. IPCC uses such an approach and builds in an *adaptive capacity* quotient over time to demonstrate how risk can change. Engineers often use a *likelihood x consequence* or *probability x cost* method, giving a snapshot in time from which a future risk can be determined after *mitigation measures* are implemented.

7. Adaptive capacity is the ability of systems to adjust to potential damage or to respond to consequences [after ISO 14090]. Adaptive capacity can include physical capacity-building measures such as flood defences or drainage or air-conditioning and cooling, as well as management systems – weather warnings, response plans and the like.

[Diagrams – IPCC/ ISO 14091/ 5x5 Matrix]

[Case study worked example]

III. Typical infrastructure asset classes/ systems/ portfolios

8. Good asset management practice such as that set out in the ISO 55000 series of standards groups assets by asset type, asset class, asset system or asset portfolios. It is useful to think of the latter – portfolios of interconnected assets covered by an asset management system relevant to the purpose of these assets. An asset portfolio is typically established and assigned for managerial control purposes. Portfolios for physical hardware might be defined by category (e.g. plant, equipment, tools, land). Software portfolios might be defined by software publisher, or by platform (e.g. PC, server, mainframe).

9. An asset management system can encompass multiple asset portfolios, and examples can include physical assets, information assets, intangible assets, critical assets, enabling assets, linear assets, information and communications technology (ICT) assets, infrastructure assets, moveable assets.

10. In ports, waterways, roads and railways, Table X shows a list of assets, systems and typical vulnerabilities caused by climate hazards. It elaborates on the kind of data needed to be known by transport entities on their assets for assessing their exposure and sensitivity and in turn their vulnerabilities to climate change. [*a work in progress*]

Table X
Transport Assets, Systems, and Vulnerabilities to Climate Hazards [*A work in progress*]

Infrastructure Type	Typical Assets	Systems	Climate Change Hazards	Typical Vulnerabilities	Climate Data Needed for Assessment
Ports	Terminals	Cargo handling	Sea-level rise	Container handling equipment Roadways	Elevation, flood mapping, coastal erosion data
	Docks, Piers	Vessel scheduling	Storm surge	Docking	Asset age, maintenance data
	Storage facilities	Communication systems	Strong winds	Communication failure	Wind exposure data, asset resilience to wind speeds
	Inland transport links	Rail, road, pipelines	Storms, Heavy Rainfall, Heatwaves	Flooding, loss of onward/ inward supply chain routes	Flood risk maps, foundation elevation data Heat maps
Waterways	Canals	Canal bed	Droughts	Water levels reduced = navigation issues	Water level trends, precipitation records
	Riverbanks	Revetments and bank protection	Heavy rainfall, flood flows	Erosion, sedimentation	Sediment flow models, erosion rates
Roads	Highways	Traffic management	Heatwaves	Pavement deterioration	Pavement material data, thermal stress data
	Bridges	Foundations	Flooding	Scour to foundations	Flood risk maps, foundation elevation data
	Tunnels	Tunnel lining	Heavy rainfall	Structural damage	Geotechnical reports
Railways	Track	Track system	Extreme heat	Track deformation	Heat thresholds
	Lineside signalling	Control systems	Flooding	Equipment immersion	Elevation, flood zones, drainage systems
	Embankments	Track support	Extreme rainfall	Landslip damage to infrastructure	Slope/ geology/ geotechnical assessments

A. Critical Infrastructure Identification for Climate Hazard Adaptation

11. What is Critical Infrastructure? Critical infrastructure in transport refers to assets and systems that, if disrupted, would significantly impact public safety, economic stability, or national security. In the context of climate hazards, identifying and prioritizing these assets helps direct resources for resilience building.

12. Transport infrastructure, including roads, railways, airports, and ports, is vital for both economic growth and human well-being, as it enables people and goods to access markets,

essential services, and leisure destinations. Disruptions or failures in transport infrastructure can have severe consequences, limiting market access and hindering people's ability to reach critical services. Given the range of natural and human-made hazards that can affect transport networks, it is unrealistic and economically unfeasible to maintain all infrastructure resilient to every threat. Therefore, it's essential to prioritize investments in the most critical infrastructure to prevent significant service interruptions.

13. Criticality is a relative measure of the importance of a transport asset or operation, focusing on the consequences of its failure. *[See elsewhere in this paper [the guide*]] which is aimed to help transport professionals identify which components of a transport network—whether linear assets like roads and railways or node assets like ports and airports—are most critical for maintaining service. The process involves evaluating the assets' roles in delivering transport services and its potential impact on, for example, the economy and human well-being if disrupted. Identifying these key assets allows for targeted action to maintain connectivity and performance at acceptable levels.

14. The guide also emphasizes the need to consider economic, social, and environmental factors when assessing criticality. The importance of these aspects will vary depending on the specific function of the asset (e.g. goods movement versus access to healthcare) and the scale of assessment (e.g. local or national). By understanding which infrastructure is most crucial and vulnerable, resources can be directed toward strengthening resilience where it will have the greatest effect on sustaining economic performance and supporting communities.

IV. Impact assessment methodologies

15. Table Y shows a selection of assessment tools that are known and available and an indication of where they are suitable: *[A Work in Progress]*

Tool	**Description**	**Suitability for Surface Transport**
Stress Tests	Stress tests simulate extreme weather conditions and climate impacts (e.g., floods, heatwaves) to test the resilience of transport infrastructure. They assess the performance of assets under adverse scenarios, revealing weaknesses in design and functionality.	Suitable for evaluating road, rail, and bridge infrastructure, providing insights into design improvements and maintenance needs under future climate conditions.
Rapid Adaptation Pathway Analysis	This tool quickly maps out adaptation options by identifying immediate, medium-, and long-term actions required for transport systems to cope with climate change. It focuses on cost-effective and timely interventions.	Ideal for strategic planning and policy development, helping transport authorities prioritize actions across different timeframes for maximum impact.
Vulnerability Assessment	Identifies and analyzes the elements of the transport system that are most vulnerable to climate hazards. It examines infrastructure, services, and users to predict failure points and the consequences of extreme events.	Useful for pinpointing areas of the transport network that need reinforcement or redesign, particularly in regions prone to floods, landslides, or high temperatures.
Risk Assessment	Assesses the probability and impact of climate-related risks on transport infrastructure and operations. Risk assessment tools use climate projections to quantify potential	Appropriate for identifying high-risk transport corridors, helping prioritize resource allocation for climate-resilient

	future hazards and inform risk mitigation strategies.	investments and maintenance strategies.
Criticality Assessment	Identifies transport infrastructure that is critical to the functioning of the wider transport network. It determines which assets, if disrupted, would have the most severe impacts on connectivity, economy, and safety.	Best suited for identifying key transport routes (e.g., major highways, railways) where failure could disrupt essential services, requiring focused adaptation measures.
Threshold Analysis	This method determines the points at which transport systems fail under specific climate conditions (e.g., heat causing rail buckling, or rainfall intensity overwhelming drainage systems). Thresholds guide planning for adaptation measures.	Effective for designing adaptation interventions that are tailored to specific climate thresholds, ensuring infrastructure remains operational within safe limits.

V. Systemic matters (based on and paraphrased from ISO 14090 Annex A)

16. Systems thinking involves understanding the complex, nonlinear, and interconnected systems within which an organization operates. Many large organizations function as complex adaptive systems, meaning their various components, such as emergency response, transportation, supply chain, finance, and procurement, interact in dynamic and often unpredictable ways. To effectively manage these interactions, organizations need strategies that allow them to adapt based on changing needs or circumstances.

17. By applying systems thinking, organizations can better understand the full range of interactions and interdependencies affecting their operations, both internally and externally. This approach helps to set boundaries for adaptation efforts, filtering out less relevant elements while still recognizing their importance. Within these boundaries, organizations can focus on a more manageable set of adaptation activities. The holistic nature of the concept can allow the identification of possible unintended consequences.

18. Systems thinking also aids in identifying positive and negative feedback loops, which can either mitigate or intensify the impacts of change. Additionally, it helps anticipate unintended consequences of decisions or actions before they are executed. Ultimately, organizations can use systems thinking to clarify and refine the activities that truly matter and can be influenced, allowing them to establish realistic boundaries and make adaptation more achievable.

[Introduce diagrams from ISO 14090 or others. Some words on Policies/ Strategies/ Plans as set out in ISO55000 on Asset Management can be useful. Also case studies.]