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Group of Experts on Assessment of Climate Change Impacts and Adaptation for Inland Transport

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Initiatives in climate change impact assessment and adaptation for inland transport

Impacts of Extreme Weather Events on transportation system – Business case for adaptation

Note by the secretariat

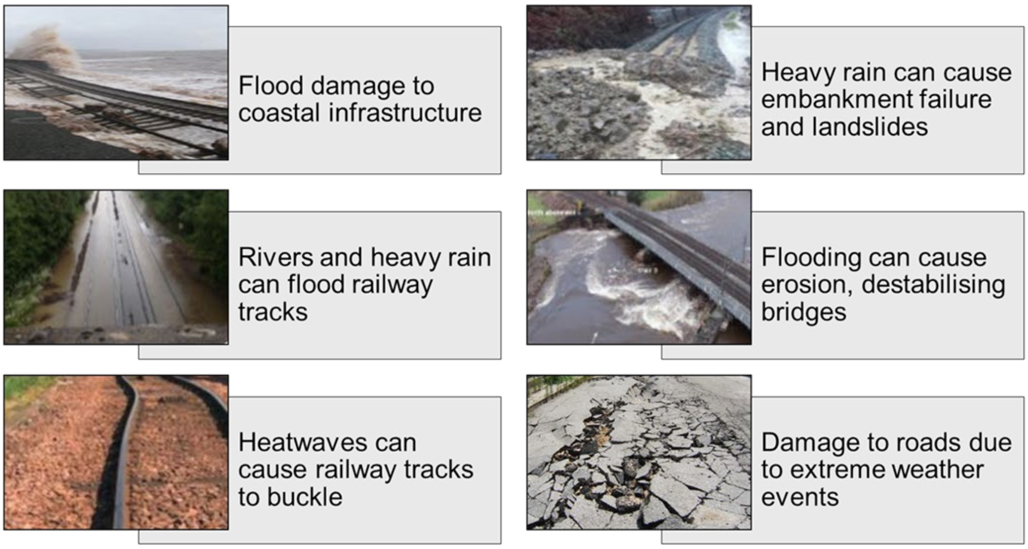
I. Background

1. Climatic changes such as increasing sea levels and temperatures along with growing intensity and frequency of extreme weather events are threatening to compromise European transportation services as well as infrastructure (Nemry and Demirel, 2012). Such impacts on the transportation sector can have destructive consequences, especially for Europe's society and economy (EC, 2013). The current scientific literature shows a growing concern on the effects of climate change to transport infrastructures and transport activities. Transportation of passengers and goods essentially depend on a complex network of land based, maritime, inland water, and air connections as well as infrastructures. Figure 1 demonstrates some key examples of the impacts of weather and longer-term climatic change on different transport assets (Ferranti et al., 2021).

2. Many businesses and industries rely on a functioning and strong supply chain network, which can be put under extreme stress and uncertainties due to unexpected weather conditions and weather events. These threats can impose both short- and long-term disruptions. Companies which are located or primarily have most of their business near high-risk areas are exposed to higher probabilities of disruptions and higher margins of damage. Since transportation is a crucial aspect in the supply chain, any disruption to the transportation sector such as extreme weather disruptions, can have a knock-on effect on every dependent parameter. An obvious long-term implication would be to mobility and development across the globe. Customers and consumers will naturally have concerns about the stability of the system. This will be magnified by the increasing intensity and quantity of these weather events posing a significant risk to infrastructure on all levels. Some of the risks will be short term, however, the long-term risks are expected to drive policies across government and private stakeholders. In the recent years, there has been a shift from

stakeholders to address and tackle these concerns with an increase of resources allocated in terms of knowledge, time and money (Finley and Schuchard, 2011).

Figure
Some key examples of the impacts of weather and longer-term climatic change on different transport assets (Adapted from Ferranti et al., 2021)



II. Floods of 2002 in Eastern Germany – Case study

3. It has been reported that in August 2002, two specific types of flooding were reported; flash flooding in eastern regions of Germany caused overloading ditches and brooks and flowed into the river Elbe which eventually caused further flooding in the northern regions of Czech Republic. The flooding in Germany lasted for a few hours, but had caused significant damages to the various aspects of transport infrastructure such as roads, bridges, energy supply etc. The damage was also extended to various communication assets and unfortunately caused 21 fatalities in Germany and 17 in Czech Republic. As the increased water levels in the river Elbe continued, this went on to cause consequent flooding in Czech Republic. The water levels recorded peaked to levels not observed in the last few centuries. The aftermath of the peak still posed a significant risk, and the large scale of this event was captured and estimated to have caused financial loses of almost 11 billion Euros. The supply chain was disrupted massively, especially the transport sector. Capacity overloads and slower deliveries impacted all levels of business. This included roads, rails, water pathways and railway networks. Approximately 400 km of railway network in Germany was damaged. In Saxony alone, almost 20% of the railway network was damaged along with 466 bridges and 740 km of open roads. These floods had also disrupted the Urban Public Transport network through closures, detours and cancellation in the capital city of Saxony, Dresden. Of the 11 billion Euros in financial damages, 8.6 billion Euros was lost in Saxony (6 billion Euros in direct damages), making it one of the most expensive natural disasters for 2002 and one of the worst in Germany. The traffic sector in Saxony encountered damages of around 2 billion Euros, with road infrastructure (1 billion Euros) and rail infrastructure (0.8 billion Euros) being the largest parts. Table 1 provides a high-level cost breakdown on the damages for urban public transport in Saxony as a result of the flooding events. It seems that Saxony communities were disproportionately affected where roads & bridges underwent more than 450 million Euros of damages. Since roads and bridges were affected as well, this resulted in economic losses shared by all aspects and levels of infrastructure. Dresden also encountered huge economic losses with impacts ranging from roads, urban public transport to different infrastructures. Despite the significant damages, the stakeholders came together, and all modes of transport were brought back to normal operating levels by October 2002. More than 200 projects were commissioned and finished to enable greater use of the most important routes. Total repair took much longer as some jurisdictions have different policies. It is

understood that the costs associated with these 200 projects was around 21 billion Euros and infrastructure recovery took around 4 years (Doll et al., 2011).

Table
Summary of cost estimates for flooding damages to transportation sector in August 2002 (adapted from Doll et al., 2011)

Location	*Impact description*	*Damages (€)*
Saxony,	Roads and bridges	464 million
Communities	Urban Public Transport	69 million
	Thereof district Dresden	66.8 million
Saxony, state	State roads and bridges	113 million
Dresden	Roads	202.8 million
	Urban Public Transport	99.2 million
	Infrastructures	83.8 million
	Vehicles and ferries	13.4 million
	Buildings and others	0.5 million

III. Addressing the scope of the data

4. This case study was chosen because floods are one of the most important extreme weather events for most parts of Europe. The case study reflects the information chain from weather forecast till disaster management. However, in terms of economic losses, it appears that the information available is a summary of the cost estimates of the total damage due to flooding and provides data in terms of infrastructure damage only. Whilst this information allows to quantify the impact of an extreme weather event on the whole, it appears that specific cost data is limited. As discussed earlier, an occurrence of a single weather event may result in several kinds of disruptions to different transport modes. For example, an extreme precipitation event might result in major disruptions to railway operations. This might include implementing measures such as reducing operating speeds of trains, diverting or even cancelling train operations. Such measures can have corresponding consequences where the transport operator may incur economic losses. In addition, the failure of an infrastructure would also mean additional economic losses. Overall, the most common consequences of harmful weather include time delays, accidents, customer dissatisfaction, disturbances to operations and increased maintenance as well as repair requirements. All of these consequences have some direct and/or indirect costs associated with them.

5. It is historically well known that persistent heavy rains, river floods as well as flash floods can lead to immense damages to different transport sectors. Overall, floods amongst different weather-related disasters, generate some of the largest amounts of economic damages and fatalities. Altogether, the frequency of extreme weather events such as river and coastal flooding is likely to increase in most parts of Europe. Therefore, in order to have a better understanding of the impacts of climate change on the transportation sector in terms of the economic losses, it is important to obtain a complete breakdown of the direct and indirect costs arising from a single incident. To do so, a number of past EU projects were reviewed along with other data sources. However, as stated above, a limited amount of information is available. This has been the case for other EU major extreme weather events as well where even less information is available on the economic losses.

6. To address this issue, and as a starting point, a small group of volunteers from the Group of Experts on Assessment of Climate Change Impacts and Adaptation for Inland Transport (Group of Experts) working with UIC developed a questionnaire to be disseminated by UIC (International union of railways) to railway infrastructure managers and

operators. The questionnaire is developed with the aim of obtaining detailed costs on major incidents caused due to precipitation or precipitation combined with other weather event. This questionnaire seeks information on disruption types such as train speed reduction, train diversions and train cancellations along with the internal costs or losses of consequences from a single incident. The questionnaire is also designed to inquire more about the process of categorizing and establishing costs in a typical railway organisation.

IV. Adaptation in transport sector

7. Adaptation in the transport sector refers to the minimization of the potential impacts on transport systems from climatic changes (such as increased intensity of rising sea levels and average temperatures along with increases in overall climatic variability) (Doll et al., 2014). For transportation infrastructure, it has been identified many times that adaptation is particularly difficult as it is a challenging sector to adapt due to its large secondary economic impacts, with regional and global consequences. Nevertheless, adaptation is recognized as a crucial response because even if current agreements to limit emissions are implemented, they will not stabilize atmospheric concentrations of greenhouse gas emissions and climate. Hence, adaptation is considered here as a key component of an integrated and balanced response to climate variability and change.

8. To drive successful adaptations, multiple levels of stakeholders, must agree on polices at the local level and the highest levels of government to sustain both short- and long-term goals. This has been defined clearly by IPCC (2011). Additionally, the adaptation strategies must also demonstrate benefits for both short- and long-term policies. These will be in the form of reducing glaring vulnerabilities. The implementation of these strategies will be dependent on parameters such as the adaptive capacity and the capabilities of the institutions in question.

9. To improve resilience across various levels of the transport sector, it is critically important to carry out timely risk assessments in order to plan for extreme weather event responses which is a key strategy for targeting long-term improvement. Regions that are significantly at higher risks to vulnerabilities and lower capacities to implement adaptations will need to be considered as focus projects. Although more specific information on the costs of adaptation is needed, several studies and research projects have identified that the cost of inaction or delayed policies and strategies is expected to be more costly compared to the cost of actions addressing climate change (including adaptation measures) (Doll et al., 2011). To this end, in order to develop a business-case for adaptation and also effective adaptation strategies, an incident-based approach must be taken which would require analysing in detail several weather-related incidents occurring across the ECE region. This will further allow a closer look of local infrastructure assets that require adapting.

10. The cost benefit analysis can help determine the best strategies to deploy as resources like both time and money are often limited and this additional analysis can help deliver better results. These types of analyses have already been in practice for decades at various organizations, however, have not been adopted yet for exploring adaptation strategies. There remains relatively little research into the costs and benefits of adaptation for transport infrastructure. A cost benefit analysis can help determine the benefit of the upfront or continued investment in an adaptation measure when compared to other initiatives. In fact, it provides a more quantified approach to problem solving. To analyse the data correctly, both costs and benefits need to be defined clearly. Adaptation costs should include the costs for planning and preparation, the cost to execute measures and non-direct and direct transitional costs. The benefits consecutively can be defined as the damage costs reduced or eliminated and other direct and non-direct cost savings realized from these implementations (IPCC, 2011).

11. In line with this, the questionnaire developed herewith as part of this work also enquires about any adaptation measures adopted by the transport organizations following an extreme weather incident. This also includes exploring the success of the measure in terms of preventing any future incidents on the transport network and the cost breakdown of the implemented adaptation measures. The developed questionnaire is provided below

(section 5) for reference purposes. This approach appears to be a creative way of obtaining some useful data on economic losses as well as the costs associated with recovery and adaptation. However, as mentioned earlier, the questionnaire is only designed to take into account incidents due to precipitation or precipitation related events for railway networks. Since by the end of the century, heat waves and droughts will likely account for 90% of the climate hazard damage (Forzieri et al., 2018), it therefore seems that developing a similar questionnaire for other extreme weather events such as heat waves is also important to obtain relevant information on economic losses as well as the costs associated with adaptation compared to inaction costs. The developed questionnaires could also be disseminated beyond the current organisation (UIC) if recommended. This would not only allow for achieving responses for multiple transport infrastructures (roads, bridges, embankments and railways) and services, it will also assist with strategies to prevent future incidents of similar type from causing distribution to the previous ones. Finally, the Group of Experts is invited to advise on the elaboration and dissemination of questionnaires for collection of information regarding economic losses as well as the costs associated with adaptation compared to inaction costs.

V. Questionnaire

(1) Have there been incidents of various severity detected at your network which led to any kind of disruption to train operations due to precipitation or precipitation combined with other weather event? If so, please briefly describe detected disruption, if any, at the following ranges of precipitation, which might have occurred in the last 5 years. It will be appreciated, as far as possible, if at least one incident per given range could be provided.

(a) 10-30 mm/day: ______________________

(b) 30-50 mm/day: ______________________

(c) 50-100 mm/day: ______________________

(d) 100-150 mm/day: ______________________

(e) > 150 mm/day: ______________________

In the description of an incident please indicate as far as possible:

(a) circumstances beyond merely the precipitation, if relevant, which led to the incident, e.g. drought period followed by sudden intensive precipitation.

(b) as type of disruption:

- train speed reduction and resulting delays (over which period) and consequences* if any
- train diversions (how many; over which period) and consequences*
- train cancellations (how many; over which period) and consequences*

**as consequences you may refer to internal costs or losses, e.g. compensation payments for cancelled/delayed service or losses related to loss of traffic, both temporarily or medium to long-term.*

(c) as type of incident: decrease of visibility, drainage failure, track inundation, mud on the track, failure of embankment (cracks, swelling), bridge scouring, etc.

(2) Is your organisation routinely recording the performance-related costs (of delays, line closures affecting the service) or the costs of infrastructure repair following an incident? If so, how are these categorized? If not, how do you establish the costs, if at all?

(3) For the incidents/disruptions described in question 1, could you inform about the recorded performance-related costs and/or the costs of infrastructure repair?

(4) Following any of the incidents/disruptions described in question 1, did you as railways (railway undertaking/rail infrastructure manager) implement any measures to mitigate the consequences of subsequent precipitation events? Have there been measures implemented by

other bodies – e.g. relevant authorities or other sectors – which had a positive effect on the railway? If so, please briefly describe them. Please indicate if the measures led to prevention of incidents on the network (affected section of network) despite precipitation levels of the same ranges which led to disruptions prior to the measure implementation.

(5) Please provide a brief cost breakdown of the implemented adaptation measures by the railways as referred to under question 4.

VI. References

Doll, C., Kühn, A., Peters, S., Juga, J., Kral, S., Ennei, R., Pietroni, F., Mitsakis, E., Stamos, I., Schultmann, F., Wiens, M., Schätter, F., Meng, S., Bartsch, M., Kynnös, K., Hietajärvi, A.-M., Kostioinen, J., Mantsinen, H., Hinkka, V. 2014. Guidebook for Enhancing Resilience of European Road Transport in Extreme Weather Events. The MOWE-IT project.

Doll, C., S. Klug, J. Köhler, I. Partzsch, R. Enei, V. Pelikan, N. Sedlacek, H. Maurer, L. Rudzikaite, A. Papanikolaou, V. Mitsakis (2011): ―Adaptation Strategies in the Transport Sector‖ Deliverable 4 of the research project WEATHER (Weather Extremes: Impacts on Transport Systems and Hazards for European Regions) funded under the 7th framework program of the European Commission. Project coordinator: Fraunhofer ISI, Karlsruhe, 30.9.2010.

EC. 2013. Commission Staff Working Document. Adapting infrastructure to climate change. Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. An EU Strategy on adaptation to climate change. (SWD (2013) 137 (https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:52013SC0137). Accessed 7 January 2022.

Ferranti, E.J.S., Greenham, S.V., Dora, J. Pyatt, N., Quinn, A.D., Reeder, T. 2021. Review of Network Rail's Weather Resilience and Climate Change Adaptation Plans .A report for the Office of Rail and Road. Climate Sense Ltd and Birmingham Centre for Railway Research & Education (BCRRE), University of Birmingham. March 2021.

Finley, T. and Schuchard, R. (2011). Adapting to Climate Change: A Guide for the Transportation Industry. BSR. Available at: http://www.bsr.org/reports/BSR_Climate_Adaptation_Issue_Brief_Transportation.pdf. Accessed on 15th February 2022.

Forzieri, G., Bianchi, A., Silva, F., Marin Herrera, M., Leblois, A., Lavalle, C., Aerts, J. and Feyen, L., 2018. Escalating impacts of climate extremes on critical infrastructures in Europe. Global Environmental Change, 48, pp.97-107.

IPCC (2011): Summary for Policymakers. In: Intergovernmental Panel on Climate Change Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C. B., Barros, V., Stocker, T.F., Qin, D., Dokken, D., Ebi, K.L., Mastrandrea, M. D., Mach, K. J., Plattner, G.-K., Allen, S., Tignor, M. and P. M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York NY, USA.

Nemry, F. and Demirel, H. 2012. Impacts of Climate Change on transport: a focus on road and rail transport infrastructures. EUR 25553 EN. Luxembourg (Luxembourg): Publications Office of the European Union. JRC72217. (https://publications.jrc.ec.europa.eu/repository/handle/JRC72217). Accessed 11 January 2022.