Informal document WP.5/GE.3 (2019) No. 1

Distr.: General
24 January 2019

English only

Economic Commission for Europe

Inland Transport Committee

Working Party on Transport Trends and Economics

Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes

Sixteenth session
Geneva, 29 and 30 January 2019
Item 4 of the provisional agenda
Discussions on the final report of the Group of Experts

Implications for Transport from climate variability and change

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This document provides the draft text for the introduction of the final report. The Group of Experts will be invited to discuss it and make suggestions and give directions for its further elaboration in the final report.

Implications for Transport: A short review

With regard to the sensitivity of transport networks to CV & C, a previous review (ECE, 2013) has found that: (a) transportation assets tend to be more sensitive to extreme events, such as storm surges, heavy precipitation events, heat waves and high wind events than to incremental changes in the mean of the climate variables; (b) maintenance, traffic conveyance and safety are generally more sensitive to climate forcing than physical assets, as thresholds for e.g. delaying/cancelling transport services are generally lower than those for damages to infrastructure and (c) transport assets are sensitive to stressors whose occurrence is relatively unlikely in comparison to typical weather variability. For example, the superstructure of the US Gulf Coast bridges proved to be vulnerable to loading from direct wave impacts due to the unprecedented coastal sea levels induced by the storm surge of the Katrina (2005) hurricane (USDOT, 2012).

Hydro-meteorological extremes, such as heavy rainfall/floods and droughts are already causing substantial damages to transport infrastructure and services. Changes in extreme precipitation may result in river floods that might be particularly costly for inland transport networks (Hooper and Chapman, 2012), as major roadways and railways are located within and/or crossing flood plains (Figs. 12 and 14); they can also have significant effects on bus/coach stations, train terminal facilities and inland waterway operations. There can be direct damages during, and immediately after, a heavy precipitation event that require emergency response as well as measures to support the structural integrity and maintenance of roads, bridges, drainage systems, and tunnels (USDOT, 2012).

Road and railway networks are projected to face significant risks of flooding as well as bridge scouring, whereas the projected increases in downpours/floods will also cause more rain-related road accidents (due to vehicle and road damages and poor visibility), delays, and traffic disruptions (e.g. Hambly et al., 2012). Road networks are expected to be severely affected by the projected increases in heavy downpours and flooding, through diverse impacts on the different types of pavement, asphalt and concrete; these would require adaptive maintenance practices such as construction of adequate drainage and the use of permeable pavements and polymer modified binders (e.g. Willway et al., 2008). Regions where flooding is already common will face more frequent and severe problems. Standing flood waters could have severe impacts and high costs; for example, the costs due to long-term road submersion in Louisiana have been estimated as US$ 50 million for 200 miles of the state highways (Karl et al., 2009). In the USA, adaptation costs for (road and rail) bridges vulnerable to river flooding have been estimated as $ 140 - $ 250 billion through the 21st century (Wright et al., 2012). For the EU27 cost estimations are lower: future costs for bridge protection against flooding have been estimated as up to € 0.54 billion per year (EC, 2012; ECE, 2015).

Railway infrastructure could be also impacted severely, with impacts including track and line side equipment failure, flood scours at bridges and embankments due to high river levels and culvert washouts, landslides, as well as problems associated with personnel safety and the accessibility of fleet and maintenance depots. In the UK, costs related to extreme precipitation/floods and other extreme events, which are already estimated as £ 50 million a year, might increase to up to £ 500 million a year by the 2040s (Rona, 2011). Extreme winds are also projected to be more catastrophic in the future (e.g. Rahmstorf, 2012), particularly at coastal areas where they can cause coastal defense overtopping and flooding of coastal/estuarine railways. Extreme winds could also cause infrastructure failures and service interruptions though wind-generated debris (e.g. (PIARC, 2012; ECE, 2013; 2015).

The projected increase in the frequency of heat waves may also pose substantial challenges in the railway, road (and airport) operations and services, due to rail buckling, road pavement damages and necessary reductions on aircraft payloads. The projected increases in the number of days with temperatures above about 38 ^{0}C (Vogel et al., 2017) can lead to increasing road infrastructure failures. Drier and hotter summers will cause pavement deterioration and/or subsidence, affecting performance and resilience (PIARC, 2012). Model predictions (EC, 2012) have estimated the additional annual costs for the upgrade of asphalt binder for the EU27 under the SRES scenario A1B[1] as € 38.5–135 million in the period 2040 - 2070 and € 65-210 million in 2070 - 2100. Nevertheless, it should be noted that as road surfaces are typically replaced every 20 years, such climate change impacts could be considered at the time of replacement.It should be also noted that heat waves could affect very significantly the transport personnel, passengers and freight, particularly when combined with high relative humidity (Mora et al., 2017; Monioudi et al., 2018).

Arctic warming may lengthen the arctic shipping season and introduce new shipping routes. There may be new economic opportunities for Arctic communities, as reduced ice extent facilitates access to the substantial hydrocarbon deposits (at Beaufort and Chukchi Seas) and international trade. At the same time, Arctic warming will result in (a) greater coastal erosion due to increased wave activity at the polar shorelines of Canada, the Russian Federation and the USA (e.g. Lantuit and Pollard, 2008) and (b) increasing costs in the development and maintenance of transport infrastructure due to thawing permafrost (ECE, 2015). Permafrost thawing (e.g. Streletskiy et al., 2012) presents serious challenges for transportation, such as settling and/or frost heaves that can affect road structural integrity and load-carrying capacity (ECE, 2013). In Arctic areas many highways are located in areas with already discontinuous, patchy permafrost, resulting in substantial maintenance costs as well as usage restrictions (Karl et al., 2009). Such disruptions are projected to increase substantially under the predicted increases in the extent/depth of permafrost thaw (EEA, 2015a).

Inland waterways[2] can also be affected by both floods and droughts. Floods can have major impacts such as suspension of navigation, silting, changes in the river morphology and damage of banks and flood protection works (ECE, 2013). Inland waterways can also be affected by low water levels during droughts, which are considered a greater hazard for inland waterways than than floods (Christodoulou and Demirel, 2018). A research study[3], which has used the Rhine–Main–Danube (RMD) corridor as a case study, has found that over a period of 20 years, average annual losses due to low water levels were about € 28 million (see also Jonkeren et al., 2007). Projections from different climate models, however, do not show significant effects of the low flow conditions on the RMD corridor until 2050; nevertheless, 'dry' years may lead to a 6–7 % increase in total transport costs compared to ''wet'' years.

[1] This scenario is roughly equivalent to the IPCC AR5 scenario RCP6.0.

[2] According to the TRANSTOOLS8 reference scenario, in 2005 approximately 293 million tons of freight was transported among the EU countries (excluding national trade) using IWW, an amount slightly smaller to the amount of freight transported by rail and to the one third of the amount of freight transported by road

[3] EU FP7-ECCONET Project, http://www.tmleuven.be/project/ecconet/home.htm

Impacts of CV & C on the European transport systems were studied in recent European projects[4]. These projects found that there is a lack of reliable information relevant to the vulnerability of the different transport modes. Direct costs borne by the transport sector, such as those from infrastructure repair/maintenance and vehicle damage and increased operational costs, have been estimated for the period 1998-2010 as € 2.5 billion annually, and indirect costs from transport disruptions as €1 billion annually. Rail has been the most affected transport mode, with 'hot spots' in E. Europe and Scandinavia, whereas the effects on roads (mainly from weather related road accidents) have been found to be more evenly distributed.

Coastal transport infrastructure (coastal roads, railways, seaports and airports) will be dis-proportionally impacted by the CV & C as, in addition to the above challenges, they will have to adapt to increasing marine coastal flooding (Asariotis et al., 2017; Christodoulou and Demirel, 2018). In the UNECE region, mean SLR and increasing storm surges and waves, particularly along the NW Europe, the Baltic Sea and the NE Pacific coast the of US and Canada (e.g. Vousdoukas et al., 2016a; Mentaschi et al., 2017), may induce major impacts, including flooding of roads, rail lines and tunnels in coastal areas. Coastal inundation can render transportation systems unusable for the duration of the event and damage terminals, intermodal facilities, freight villages, storage areas and cargo and, thus, disrupt supply chains for longer periods (ECE, 2013; 2015). Pecherin et al. (2010) have estimated that 1 m increase in the extreme sea levels (ESLs) above the inundation level of the current 1-in 100 year-storm event[5], would result in damages and repair costs of up to € 2 billion for mainland French A-roads, excluding operational and connectivity costs. Another study (EC, 2012) has provided an initial estimate of the future risk of the European coastal transport infrastructure due to mean sea level rise-SLR and storm surges on the basis of a comparison between the coastal infrastructure elevation and the combined level of 1 m mean SLR and the 100-year storm surge height; it was found that coastal transport infrastructure (e.g. coastal roads) at risk represents the 4.1 % of the total, with an asset value of about € 18.5 billion. As however, more detailed projections on future extreme sea levels-ESLs and coastal waves are starting to become available (Vousdoukas et al., 2016b; 2017; Mentaschi et al., 2017; Camus et al., 2017) for the UNECE region (and beyond), it is a worthwhile exercise to assess again the potential inundation impacts on the ECE coastal transport infrastructure under different CV & C scenarios.

A recent study focusing on ports (Christodoulou and Demirel, 2018) has found that 64 % of the EU seaports could be inundated under the IPCC (2013) estimated SLR and the projected storm surges and waves (Vousdoukas et al., 2017). Major impacts include disruptions of operations and damages of port infrastructure and vessels, whereas hinterland connections will also be affected. Seaports in Greece (169), the UK (165) and Denmark (90) will be the worse affected by 2080, when the number of EU seaports facing the risk of inundation is expected to increase by 50% relative to 2030 (to 852 ports). This trend is particularly strong along the North Sea coast, where according to the GISCO database over 500 ports are located with traffic accounting for up to 15 % of the worlds cargo transport (EUCC-D, 2013).

[4] The EU-FP7 WEATHER http://www.weather-project.eu and EWENT Projects (http://www.weather-project.eu/weather/inhalte/research-network/ewent.php).

[5] Costs assumed in the study: average linear property cost at €10 million/km of road surface; repair costs at about €250 thousands/km)

Finally, it should be noted that the transport industry is a demand-driven industry. Climate Variability and Change can have significant effects in, almost all, sectors of economy, and thus affect indirectly transport services through e.g. changes in commodity demand and tourism transportation (ECE, 2015).

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