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G7 Transport Academic Workshop

Transport System Resilience: Challenges, Metrics and Policies

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International Transport Forum

Wednesday, 10th April 2024 - Aula Magna “Carassa e Dadda”
Politecnico di Milano, Bovisa Campus, Milan (Italy)

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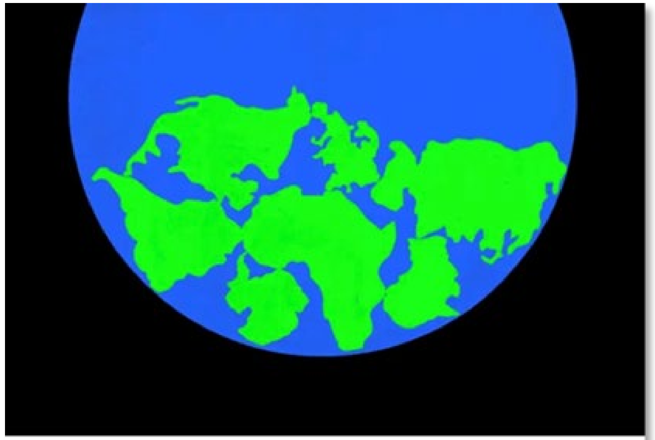
We're on the brink of a 'polycrisis' – how worried should we be?

Jan 13, 2023

weforum.org



Tyler Comrie

OPINION

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Opinion Columnist

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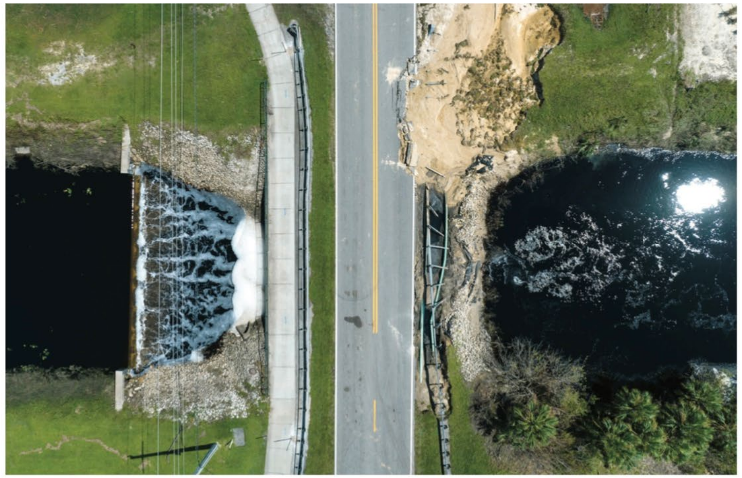
International Transport Forum



Transport System Resilience

Summary and Conclusions

194 Roundtable

Challenges

	Accidental	Intentional
Internal	Technical and operational failure	Strikes
External	Climate events Pandemics	Geopolitical crises Cyber-attacks

Character of system disruptions:

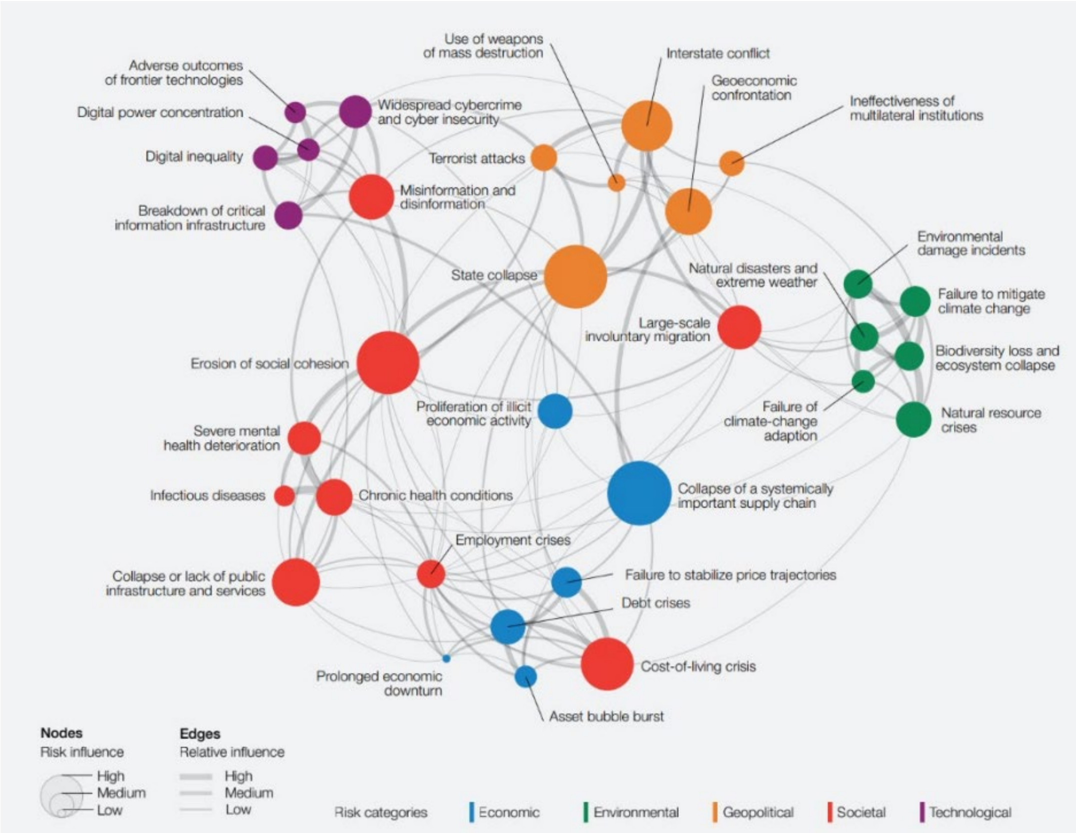
- **Internal**. Coming from inside transport system More leverage for transport sector.
- **External**. Coming from outside transport system. Less leverage for transport sector.

Causes of system disruptions:

- **Accidental**. Impacts are random.
- **Intentional**. Targeted at largest vulnerabilities.

Intentional external disruptions are the most difficult to predict.

Challenges: cascading effects



Source: WEF 2023

Cascading effects:

- "Adding connections between networks diverts load, and that diverted load tends to be absorbed by the neighboring network rather than amplified and returned.
- So, interconnectivity limits cascading effects, but only up to a critical point.
- Introducing too many interconnections is detrimental. Interconnections let diverted load more easily return and with catastrophic effect.
- After the critical point, adding interconnections amplifies large global cascades."

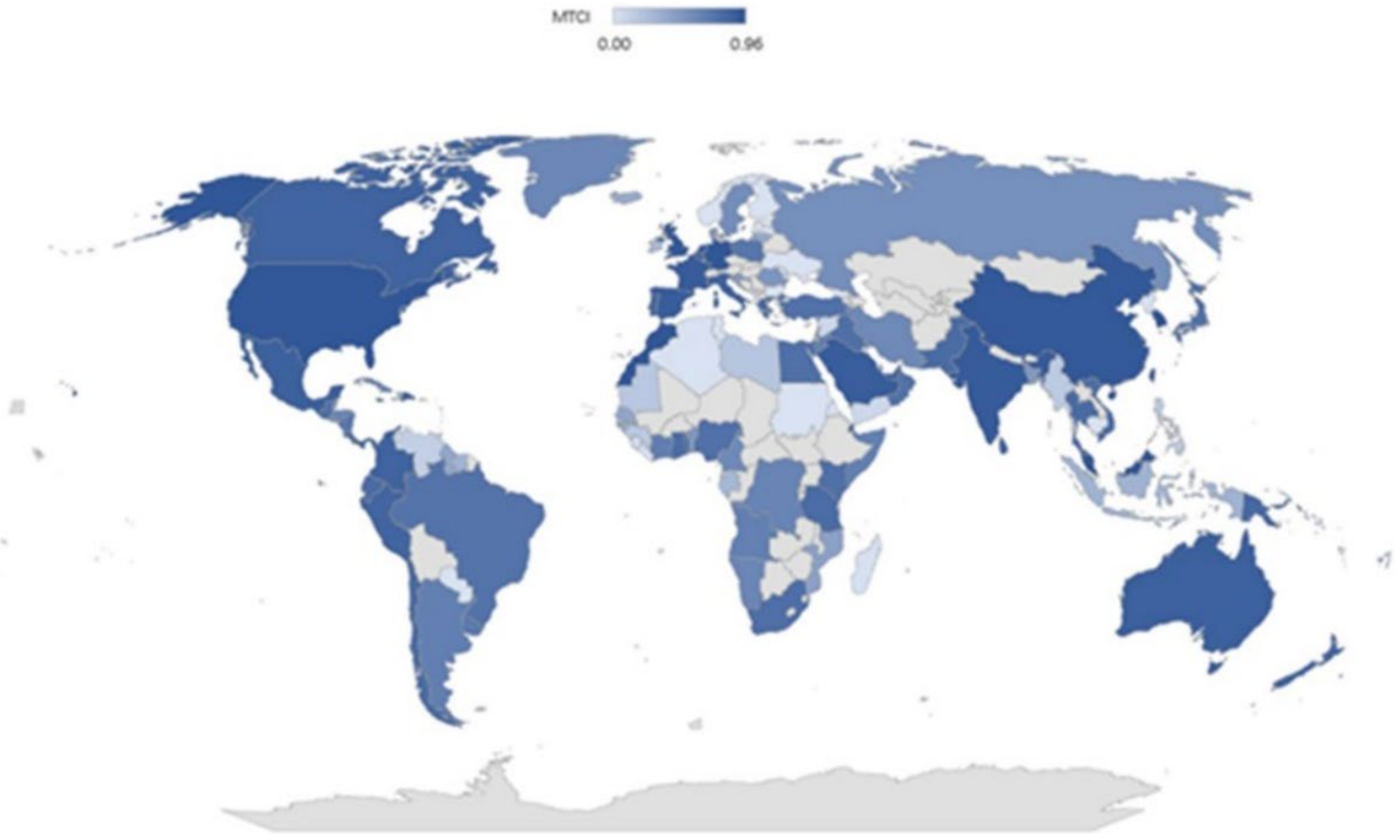
Can we determine where is this critical point in different transport systems?

Source: Brummitt et al 2012

Metrics

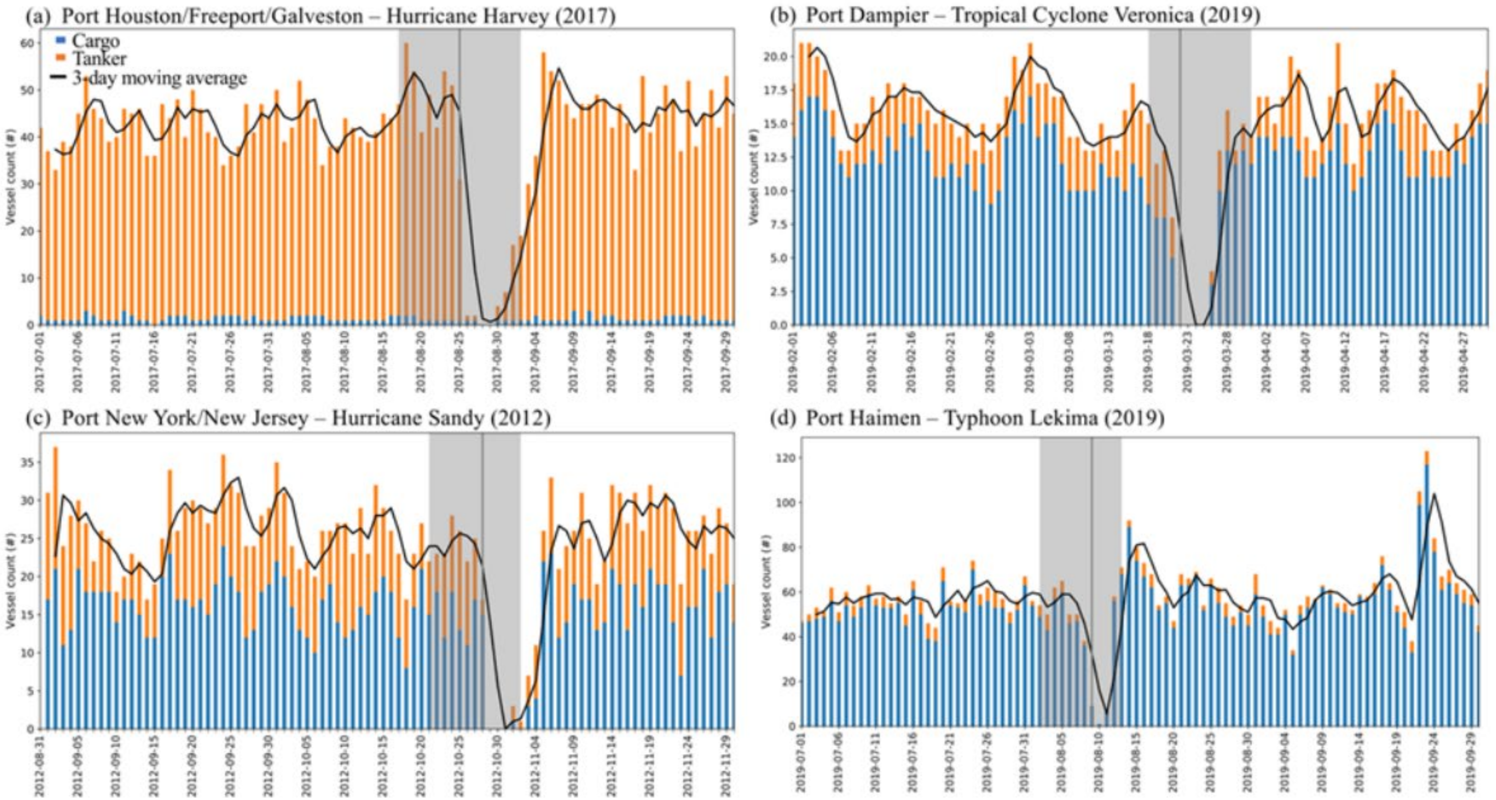
- Performance indicators
- Recovery time
- Network characteristics
- Transport modelling

Metrics: performance indicators



Maritime trade connectivity

Metrics: recovery time



Note: Overview of port disruptions for four ports and events: (a) Port of Houston/Freeport/Galveston (United States) during Hurricane Harvey; (b) Port Dampier (Australia) during Tropical Cyclone Veronica; (c) Port New York/New Jersey (United States) during Hurricane Sandy; and (d) Port Shanghai (China) during Typhoon Lekima. The grey shading represents the formation and dissipation of the event, while the grey vertical line indicates the date on which the weather event made landfall.

Source: Verschuur, Koks and Hall (2020).

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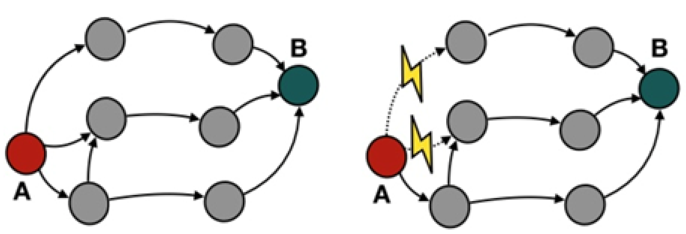
Metrics: network characteristics

Type of network	Examples	Transport system	Extent of preparedness
Highly connected	Grid, matching pairs, complete grid, diamond	Urban street systems of larger cities	Highest preparedness
Centrally connected	Hub and spoke, double tree, diverging tails, crossing paths	Aviation networks Container shipping	Least prepared, but most responsive to adaptation
Circuit-like connections	Central ring, double U, converging tails	Underground transit Urban roadway system	Relatively prepared
Randomly connected	Random, scale-free, small world	Urban transit networks Intercity roadways	Less prepared, but provides some redundancy

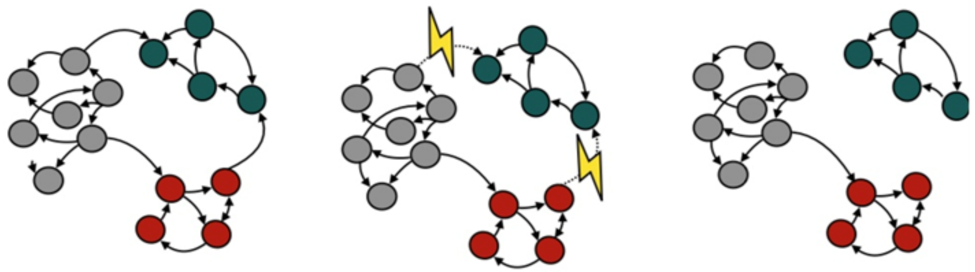
Source: Zhang et al. (2015).



Redundant pathways between A and B

Shock in the system

Perseverance of pathway between A and B



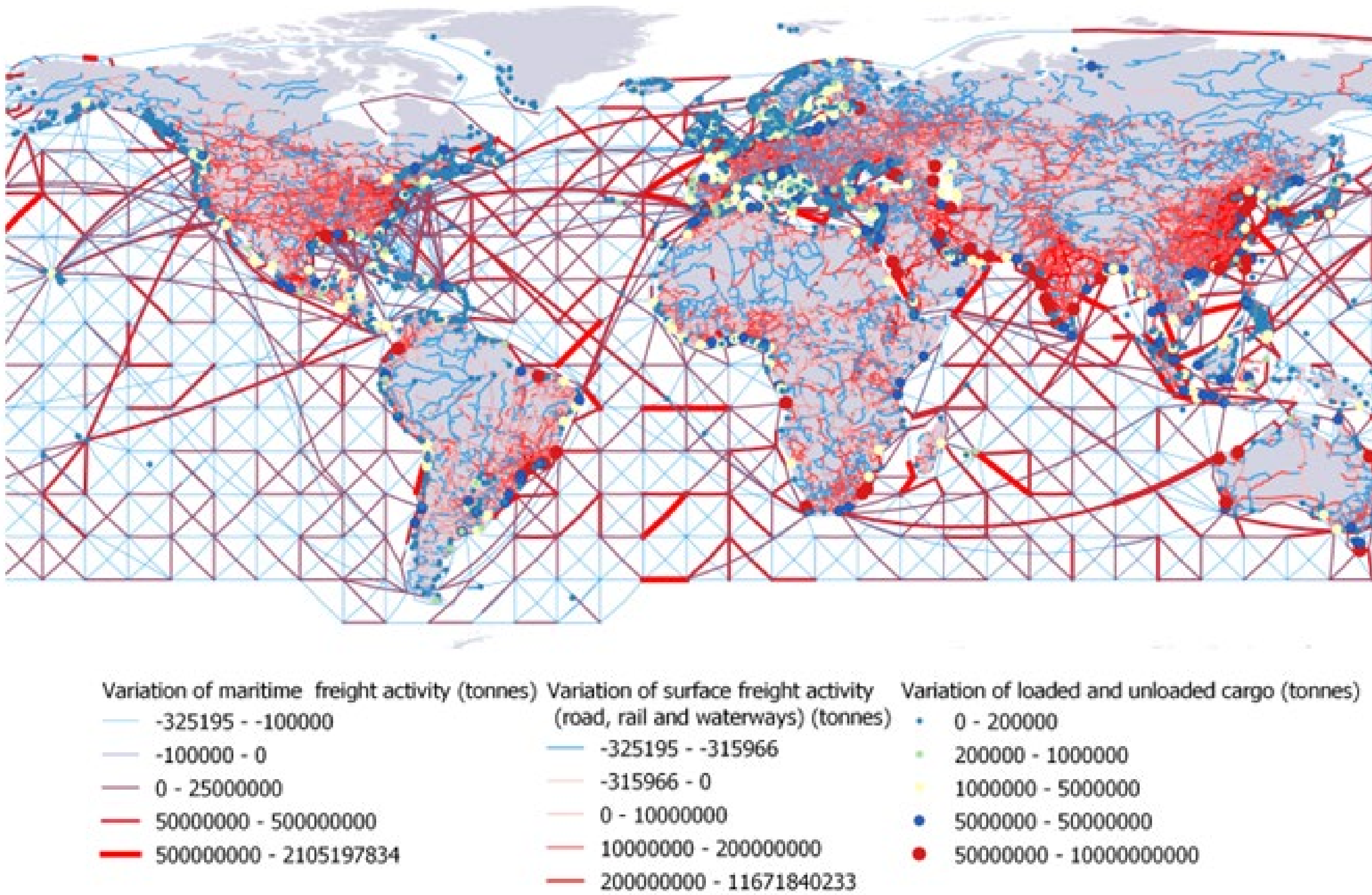
Modular network

Shock in the system

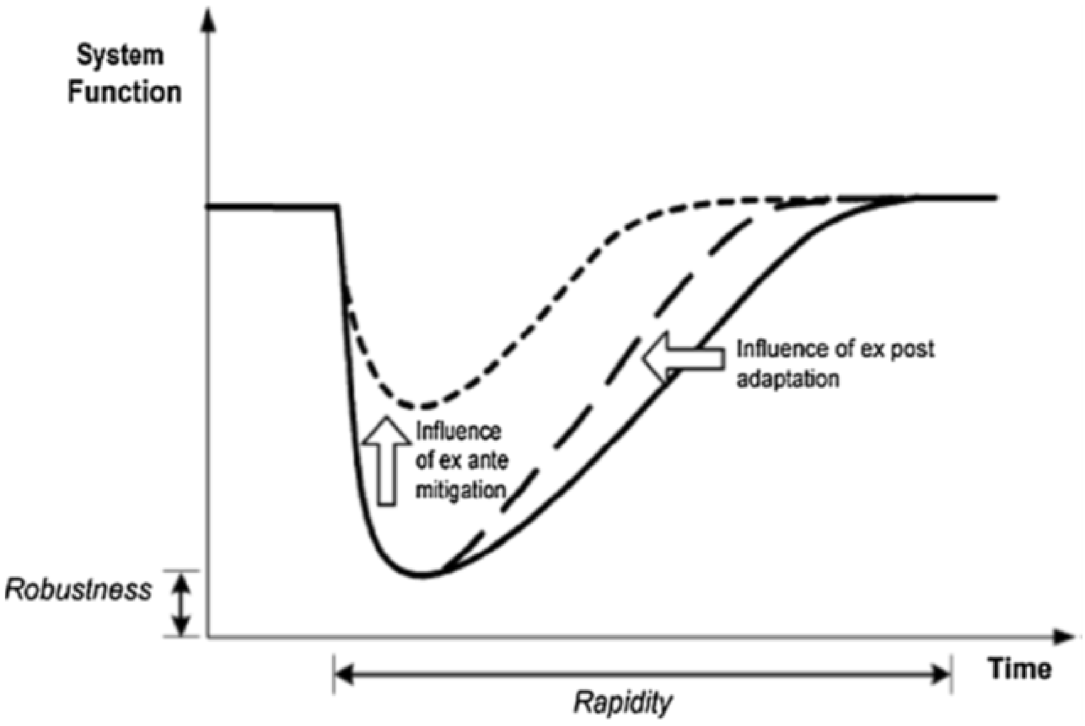
Network fragmentation

Source: Kharrazi et al 2020

Metrics: transport system modelling



Policies



Transport system disruptions:

- **Robustness**. The more robust a system, the less system functions are affected.
- **Rapidity** of recovery. Determines the time a system is disrupted.

Mitigation – robustness – pro-active:

- **Avoid.** Reduce the risk of the disruption.
- **Coping capacity**. How does the system cope with the disruption?
- **Redundancy**. Alternative capacity in case disruptions take place.

Adaptation – rapidity - reactive:

- **Response**. Dealing with immediate impacts.
- **Recovery**. Restore system functions.

Policies for mitigation

Type of measure	What does it aim to do?	Examples of measures
Avoid	Mitigate disruptions (e.g. climate change) Avoid settlement in high-risk areas Produce networks that reduce the risk of cascading	Climate-change mitigation policies Land-use planning, relocation policies Strategic planning (hubs and minor hubs)
Coping capacity	Increase resistance of infrastructure to disruptions Protect critical infrastructure	Infrastructure investment (e.g. in drainage, permeable road surfaces, earthquake-proof construction, and increased pumping capacity in tunnels) Investment in elevated roads, runways, dikes, seawalls and bridges Prioritising maintenance of "critical networks"
Redundancy	Add links to create more alternative routes Provide buffers for crucial inputs (including electricity, workers and equipment)	Infrastructure investment planning Prioritising redundancy budgets for infrastructure managers

Policies for adaptation

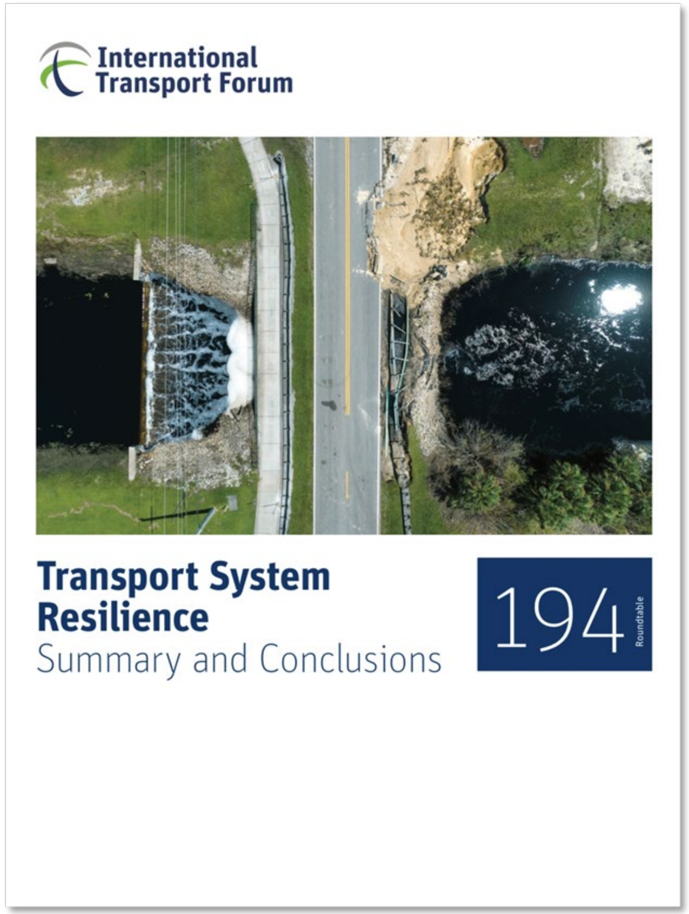
Type of measure	What does it focus on?	Examples of measures
Response	Planning, institutional and legal frameworks Training Optimising existing infrastructure	Contingency plans and timetables User communication plans Information systems for rescue workers Legal and contractual frameworks Support tools on which responses to prioritise Lane reversal and shoulder use (on roads)
Recovery	Clearing obstacles New transport equilibria New societal equilibria (e.g. teleworking, inventories, sourcing)	Plans and resources for clearing debris and conducting urgent repairs Relocation of roads, railways, runways and ports Policies on framework conditions (e.g. labour, trade facilitation, foreign direct investment)

Policies: trade offs

- Mitigation lessens the need for adaptation but could be more expensive in certain circumstances. Which ones? When does mitigation or adaptation make most sense?
- Depends on transport modes and shape of networks.
- E.g. centrally connected networks (hub-and-spoke) are less robust, but most reactive to response actions. So, for sectors with such network structures (aviation, container shipping) disaster preparedness is most critical.
- Certain mitigation measures (e.g. relocation) could be too expensive until the disruption has happened (e.g. when infrastructure in a coastal area is flooded).
- In order to make efficient decisions, insight in costs of disruption and the costs of mitigation and adaptation options is needed.

Policies: our recommendations

- Incorporate resilience into transport policy and planning systematically
- Develop tools that help reduce uncertainty about future disruptions of transport systems
- Develop guidance on which resilience measures for transport systems should be applied when and how
- Improve global co-ordination mechanisms to deal with the impacts of transport system disruptions



Thank you!

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