European Commission

SCIENCE FOR POLICY BRIEF

TRIMIS insights

Research and Innovation in Transport Resilience in Europe

HIGHLIGHTS

→ Resilient mobility is a key objective of the EU Sustainable and Smart Mobility Strategy. Policy priorities include contingency planning and resilience testing, infrastructure climate proofing, Trans-European Transport (TEN-T) Network integration and interoperability between modes, and cyber-security.

→ 50 EU-funded FP7 and H2020 research and innovation projects addressing transport resilience have been selected for analysis. Their total budget is EUR 202 million.

→ Leading research themes include monitoring techniques for infrastructure resilience, Information and Communication technology and Artificial Intelligence enablers for resilience management and timely reaction to disruptions, and decision-making frameworks.

→ Future orientations include climate-proof design and certification of infrastructure and vehicles, data- and AI-driven resilience monitoring and response and virtual resilience testing.

INTRODUCTION

Overall context

Transport is a cornerstone of all human activity, be it supply chains, commute, or recreation. As recent crises highlight, the EU needs to be prepared and absorb disruptions of any kind to avoid long lasting consequences to the economy and quality of life of its people.

The EU transport system will be challenged by climate events of increased intensity and other possible natural or manmade disruptions. **Bolstering transport resilience** therefore is one of the pillars of the **EU Sustainable and Smart Mobility Strategy**.

Resilience for a transport system [1] is its ability to absorb disturbances, maintain its basic structure and function, and recover to a required level of service within an acceptable time and costs after being affected by disruptions.

EU research and innovation (R&I) plays a crucial role. It studies the risks and proposes solutions through durable infrastructure and smart maintenance, schedule re-planning, interoperability and flow redistribution between transport modes, and strategies for emergencies.

Policy overview

The **Sustainable and Smart Mobility Strategy [2]** anticipates disruptions caused by climate change and extreme weather events. Furthermore, the need for cyber security is highlighted with the increasing automation and connectivity. To safeguard transport continuity, policy measures include the upgrade of physical and digital transport infrastructure, to ensure multimodality and interoperability between different modes and the completion of the Single European Transport Area, with an emphasis on the TEN-T network.

The European Commission **Contingency Plan for Transport** strengthens the resilience of EU transport in times of crisis. The plan proposes actions to guide the EU and its Member States. Certain of these actions require technology developments and R&I: ensuring connectivity and passenger protection, efficient border management for freight, sharing transport information, building resilience to cyberattacks, and resilience testing.

The **European Climate Law** (Regulation (EU) 2021/1119) includes stronger provisions on adaptation to climate change. Transport infrastructure must be adapted to climate change and made resilient to disasters, and the Commission is addressing this both in the **TEN-T review** and the **Climate Adaptation Strategy**, including through dedicated guidance on climate proofing.

The **Climate Adaptation Strategy** highlights, among others, the need for smarter adaptation by improving knowledge and managing uncertainty, and the conversion of climate information available into customised, user-friendly tools. Infrastructure investments must be climate resilient, to minimise the risk of disasters. Finally, climate proofing standards are needed in energy, transport and construction sectors.

The European Union Agency for Cybersecurity (ENISA), **Directives on Security of Network and Information Systems** constitute a common baseline to enhance cyber-resilience in all activity domains, including in transport.

Further strategic and policy documents delve into how to reach resilience objectives for each transport mode. All mentioned policy priorities require research and innovation for the development of transport resilience technologies, frameworks, certification and monitoring.

Method

TRIMIS [3] has scanned through its database of EU transport research and innovation projects to identify the challenges, opportunities, and main achievements in transport resilience.

CINEA, the European Climate, Infrastructure and Environment Executive Agency, manages most of the identified projects and contributes towards the EU research and innovation goals through its implementation of relevant EU funding programmes.

This policy brief contains an overview of recent and ongoing R&I activity and a discussion on what should come next in EU transport safety & resilience R&I, based on the Science for Policy report [4]. The dataset of selected projects is available in [5].

FINDINGS

Role of research and innovation

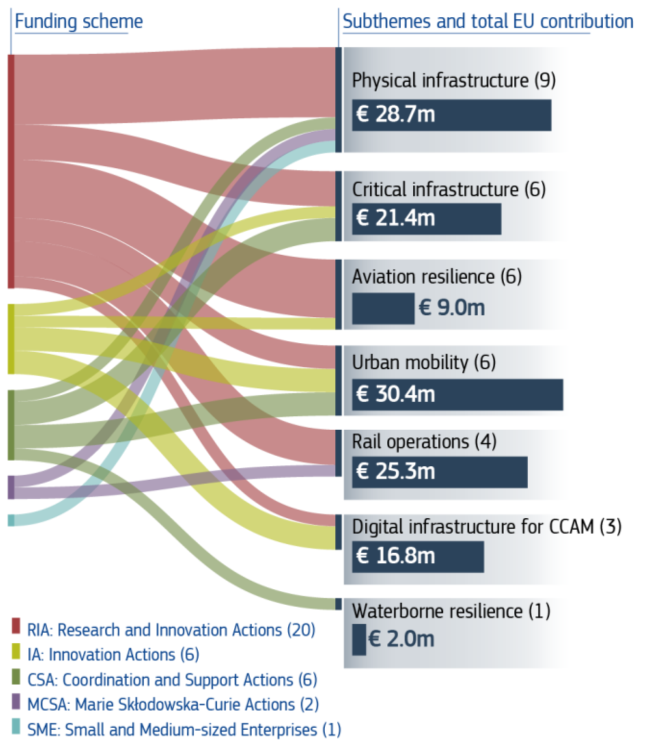
In R&I, the European Framework Programmes treat resilience both in a **transversal approach related to global risks** such as terrorism and cyberattacks, and on the impacts of evolving climate conditions, and as a **transport specific challenge**. In the latter, the focus is on climate-proof physical infrastructure, vehicle technologies and digital infrastructure for increased automation, multi-modality across modes and inter-modality across operators, and resilient aircrafts.

Research efforts

50 EU-funded projects were selected for the analysis of R&I in Transport Resilience. The projects were grouped into seven thematic clusters.

The majority come from the H2020 programme, yet also FP7 projects were included when judged pertinent. The 35 H2020 projects that were reviewed (Figure 1), accounted for EUR 136 million of EU funding for a budget of ca. EUR 145 million. In addition, 15 FP7 projects, accounting for EUR 41 million of funding were included in the project reviews. The total EU contribution in all analysed projects is EUR 186 million for a total budget of EUR 215 million.

Figure 1 – H2020 transport resilience R&I effort repartition [4]



Most projects were funded under Research and Innovation Actions (RIA - 21 projects). RIA actions are generally low technology readiness level (TRL) research, indicating new topics and opportunities under investigation. The few Marie

Skłodowska-Curie Actions (MSCA) projects examined here correspond to basic research. The 6 projects under Coordination and Support Actions (CSA) promote sector-wide collaboration and knowledge management.

Finally, projects funded under Innovation Actions (IA) indicate solutions that are demonstrated in pilot deployments during the project. They mostly address the resilience of urban mobility and urban nodes and the digital infrastructure for Connected, Cooperative and Automated Mobility, solutions that are to be deployed in the coming years.

Globally, infrastructure resilience is the most investigated area, including the surface network, critical infrastructures and digital infrastructure, with 18 projects and an EU funding of EUR 69 million.

Research trends

EU R&I projects engage with transport resilience on the different levels and functions of transport systems. These levels and functions relate transversally to more than one of the clusters presented in Figure 1.

Operational resilience at the vehicle level, for aviation and waterborne transport, ensuring safe operation and mission achievement against individual vehicle-scale disruptions such as weather, malfunction, and traffic. In this sense resilience is very much related to safety, and is investigated through advanced cockpit and bridge design, pilot and crew navigation aids, and early warning and information systems. Effort is directed to transfer knowledge and practice from aviation to waterborne transport in the domains of resilience management and reaction to disruptions such as extreme weather.

Planning and traffic management resilience at the node and network level: for aviation and rail, disruptions can have spiralling effects with delays and cancellations propagating from a node to another. R&I projects engage in using Artificial Intelligence (AI) to anticipate, identify and predict the evolution of disruptions and their impacts, and real-time planning and information systems that allow for minimising impact and faster recovery when disruptions occur. For automated road transport, integrated traffic management is investigated.

Surface physical infrastructure resilience: for rail, waterborne, and road transport, against the effects of aging, use intensification and environmental damage, EU-funded projects engage in advanced sensor and monitoring systems for the infrastructure state of health, to achieve time- and cost-efficient maintenance, warning systems and flow redistribution. Recent calls aim to increase the operational resilience of inland waterborne transport in low-water level conditions.

Digital infrastructure resilience: in all domains of transport, automation requires robust sensor and ICT operations in communications, cloud-computing and human machine interfaces. For automated road transport and rail transport, the effort is directed towards robust telecommunications for integrated traffic management.

Rolling stock and fleet resilience: like for infrastructure, projects propose innovative solutions to detect damage and monitor the state of health of vehicles. Predictive maintenance will benefit transport efficiency, safety, and resilience.

Critical infrastructure resilience and cybersecurity: against human-made threats, both physical and cyber, on transport critical infrastructure and Information and Communication technologies (ICT) infrastructure, R&I actions focus on developing risk assessment and management frameworks, detection techniques, robust ICT systems and reaction strategies when threats materialise.

Urban mobility resilience: at urban scale, resilience encompasses all transport modes involved. Projects that were identified in this topic engage in knowledge management, collaboration, and resilience management framework development. One aspect critical for resilience management is the monitoring of the whole urban mobility transport system and flows.

CONCLUSIONS

Resilience is a major challenge for the EU transport system, considering the rise in complexity and interconnection in transport to address demand, efficiency and sustainability objectives, and the potential increase in frequency and intensity of disruptions.

R&I projects engage in the various aspects of transport resilience. The solutions examined range from technical to strategic, and there are common patterns across transport modes. These common patterns include, for technical solutions, the detection and monitoring techniques, and the use of ICT and AI as enablers for resilience management and timely reaction to disruptions. For strategic and tactical solutions, projects develop resilience management and decision-making frameworks.

Way forward

On the way forward for transport resilience, R&I can benefit by replicating practices from safety R&I, such as safe design, data driven safety and virtual testing, and policy, such as KPIs for measuring progress and virtual certification.

Resilient design and certification: for all modes, vehicles and infrastructure, resilient design should be a requirement. This covers structural resilience (e.g., materials that sustain heat), operational resilience with an increased envelope (e.g., vessels at low water levels, batteries during heatwaves), and passenger health and adequate thermal comfort. Design of passenger space for health preservation and prevention of disease propagation is a prerequisite for modal shift towards mass transit following the COVID crisis.

Resilience virtual testing: at the network and traffic system level, experimental study of transport resilience is impractical. Simulation and virtual testing are tools that can be used to better prepare for disruptive events. Simulation is a means of evaluating scenarios of disruptions of varying nature and amplitude, and predicting how the system responds, and how resilience management measures can preserve and restore operation.

Data driven resilience: transport resilience can be quantified, and KPIs that indicate e.g., transport flows can be used to benchmark both the extent of a disruption and the response efficiency as a tool for resilience policy implementation monitoring. Quantification and data acquisition contribute both in increasing understanding and operationalisation of resilience.

Cross-sector awareness and collaboration can bring mutual benefits and ensure coherence and overall resilience. Transport providers and policy, research, industry stakeholders should jointly address how to best incorporate resilience as a core requirement throughout the transport system, as is the case for safety.

Certain important aspects of transport resilience R&I are suggested to be further considered in the requirements and planning of future work programmes.

EU strategic autonomy: research and policy on increasing EU technology, industrial, material and energy autonomy inherently improve transport resilience.

System complexity: projects showcase that ICT can increase transport resilience by monitoring systems, detecting disruptions, and providing the means to adapt and respond to them. Nevertheless, the increasing interconnection of the transport system and dependency on automation and ICT technology also create vulnerabilities. Therefore, research and innovation must be aware and adequately address resilience trade-offs.

Modal shift: modal shift towards active modes and mass transit has a positive impact on transport resilience, reducing material and energy demand, and road traffic and network complexity. The prerequisite is a robust and resilient public transport system, which will be challenged by the increase in traffic.

Workforce availability: current trends suggest that the availability of qualified transport personnel is declining. R&I in automation is partially addressing this challenge. Adequate training and human-machine interface design are requirements to safeguard transport resilience against overreliance and misuse of automation.

Box 1: Related and future JRC work

Since 2017 TRIMIS reports have covered a wide range of transport topics and presented analyses of relevant research and innovation initiatives in Europe, providing recommendations to policy makers on future initiatives.

Furthermore, the JRC engages in research and policy feedback for overall EU resilience. Among the notable works and outcomes, is the Copernicus Emergency Management Service and the Resilience Dashboards.

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[4] Research and Innovation in Transport Safety and Resilience in Europe, https://europa.eu/!4mjHtX

[5] List of projects dataset https://data.jrc.ec.europa.eu/dataset/fd8c2211-ef60-4843-9ff9-62971f94e109

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