Stress-testing to promote the resilience of EU policies

STUDY

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Stress-testing to promote the resilience of EU policies

Stress-testing is a promising foresight policy tool that can support the design of EU policies able to withstand the shocks and challenges of both the present day and the years to come. This study explores how the European Parliament could use stress-tests to identify weak points in EU legislation and avenues for further EU action.

The study draws on the findings of a stress-test of EU rail transport policy and recommendations from an expert practitioner of foresight and regulatory policy. It finds that stress-tests across different policy areas could boost the European Parliament's role as co-legislator in the European Union, especially in the agenda-setting and law-making phases of the legislative cycle.

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Executive summary

Why this study?

The European Union (EU) has been confronted with a number of shocks and challenges in recent years, including the COVID-19 pandemic, the war in Ukraine and high inflation. There is a growing recognition that **the current approach to policymaking in the EU is not sufficient to confront future shocks and challenges** and an operating environment of polycrisis.[1]

Stress-testing is a promising foresight policy tool that can help to ensure that policies are ready for future shocks and challenges.[2] At present, stress-tests are best known in the banking sector, as a means to promote resilience to financial crises, yet the approach could be more widely applied to other policy areas. Within the context of the European Parliament, **stress-tests can identify weaknesses and shortcomings in existing and proposed EU policies** that could be addressed through amendment of existing legislation and/or proposals for new legislation and other action at the EU level. Moreover, regular stress-test exercises applied to EU policies can help to reduce the need for urgent legislative procedures, which are increasingly used in the context of crises but offer limited opportunity for scrutiny and oversight.[3] Stress-tests can actively encourage consensus-based anticipatory thinking and preparing for alternative futures, especially crises, and can also promote democratic oversight.

This study also explores how **stress-testing could support the European Parliament's strategic contribution to agenda-setting and law-making processes in the EU.** It draws on findings from a stress-test of EU rail transport policy and recommendations from an expert practitioner of foresight and regulatory policy.[4]

Stress-test of EU rail transport policy: Key findings

The stress-test of EU rail transport policy identified several weaknesses.[5] For instance, the **proposal for a revision of the Trans-European Transport Network (TEN-T) Regulation** (COM(2021) 812 final) does not include guidance for Member States on how to implement and finance life-cycle analysis and climate-proofing in rail infrastructure plans. Another example is the fact that the **Combined Transport Directive 92/106/EEC** does not acknowledge barriers in shifting to rail due to congestion around big cities and insufficient cross-border coordination. **Regulation 913/2010/EU concerning a European rail network** for competitive freight is, meanwhile, not ready to ensure continuity of freight operations when unforeseen demand increases rapidly.

The stress-test suggests several EU actions that could reinforce the resilience of rail transport in the EU: boost resilient cross-border EU rail governance including effective coordination; create effective incentives for shifting freight to rail; secure EU railway operations from cyber-attacks, other man-made disasters, as well as from adverse weather effects of climate change; and provide ambitious and long-term tools to supporting investment in EU railways.

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1 European Parliament, Parlemeter Autumn 2022, Eurobarometer 98.1, December 2022, Chapter 2.3.

2 Fernandes M. and Heflich A., 'How to stress-test EU policies - Building a more resilient Europe for tomorrow'', European Parliament Research Service, 2022.

3 Improving urgency procedures and crisis preparedness within the European parliament and EU institutions, European Parliament, March 2022.

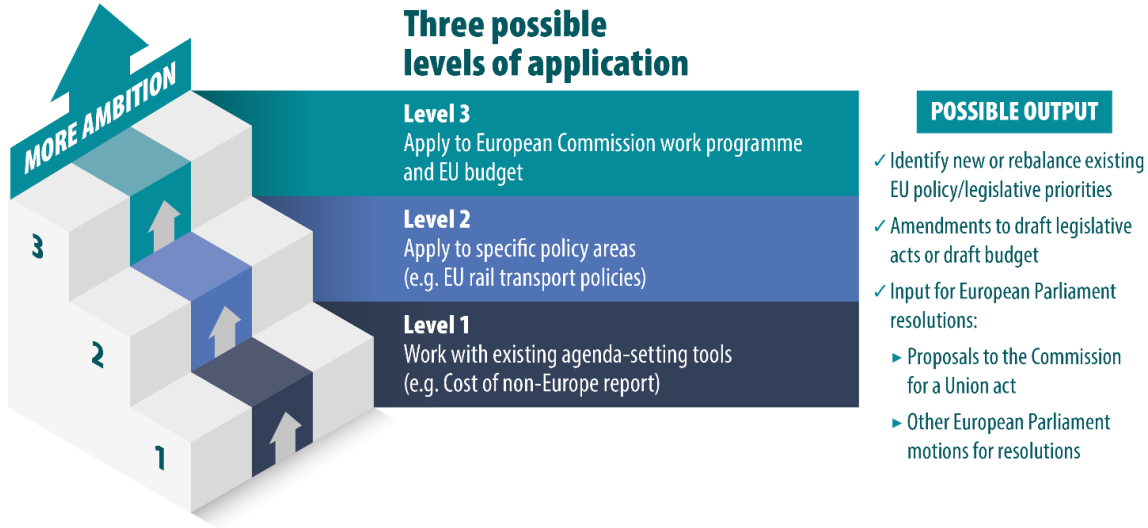
4 The commissioned expertise is reflected in Annex I – DTI Research paper and Annex II - Jackson Briefing note.

5 The stress-test of EU rail transport policy was mainly completed in October 2022 and reflects the state of play of EU legislation at that time. See Annex I - DTI Research paper for more information.

What are the options for stress-testing in the European Parliament?

Stress-tests could be done at different levels in the European Parliament (see Figure 1). At the lowest level of ambition (Level 1), it could build on existing agenda-setting tools, such as **cost of non-Europe reports and European added value assessments** that are prepared by the European Parliamentary Research Service at the request of parliamentary committees. At its highest level of ambition (Level 3), stress-testing could also shed light on **weaknesses in the priorities set in annual and multiannual EU work programming** and complement interinstitutional EU processes such as the European Strategy and Policy Analysis System (ESPAS). The output from stress-test exercises could be reflected in amendments of draft legislative acts or provide input for European Parliament resolutions. Regardless of the level of ambition, **stress-test exercises should consider the implications of high-probability, high-impact shocks** that could occur in the near future, such as a public debt crisis, a China invasion of Taiwan, and deglobalisation.

Figure 1 – Stress-test exercises in the European Parliament



Source: Developed by the authors.

Recommendations

Stress-testing is a promising tool that can support policymakers to consider future shocks and challenges in their work. It is neither desirable nor possible to stress-test all EU policies. Instead, **stress-tests can offer high added value to agenda-setting and law-making tools that are already used in the European Parliament**. The stress-testing tool could be especially valuable in the European Parliament's input to and scrutiny of the forward planning of the Commission's policy priorities and work programmes as well as the EU's multiannual financial framework.

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1. Context and objectives

This section sets out the context and objectives for the study. Section 1.1 reviews the democratic legitimacy and accountability of the EU's response to recent shocks and challenges. Section 1.2 then looks forward to consider how EU law-making practices from the European Parliament perspective could be adapted to respond better to the future shocks and challenges. Section 1.3 then introduces how stress-testing could be used in the European Parliament policymaking process.

1.1. The EU's response to recent shocks and challenges

The EU has faced a number of disruptive shocks and challenges in recent years – including the COVID-19 pandemic, the war in Ukraine and the energy crisis – which have exposed shortcomings and weaknesses in EU policies. The impacts of such shocks have transcended borders and social strata. A survey found that about **half (46 %) of the European population had experienced a fall in their personal living standards due to recent crises**.[6]

The EU's policy response to recent shocks and policies drew in large part from urgent legislative procedures based on Article 122 of the Treaty on the Functioning of the European Union (TFEU). The European Commission invoked Article 122 to set up a framework of crisis-relevant medical countermeasures,[7] to establish the European instrument for temporary support to mitigate unemployment risks in an emergency (SURE),[8] and to accelerate the deployment of renewable energy.[9]

> Article 122 TFEU: Without prejudice to any other procedures provided for in the Treaties, the Council, on a proposal from the Commission, may decide, in a spirit of solidarity between Member States, upon the measures appropriate to the economic situation, in particular if severe difficulties arise in the supply of certain products, notably in the area of energy.

Urgent legislative procedures based on Article 122 TFEU are exempt from standard better law-making procedures such as impact assessments and stakeholder consultations,[10] as well as scrutiny from the European Parliament, which is the only democratically elected EU institution and represents EU citizens. The use of Article 122 procedures raises questions about the quality of the legislation being put forward and the potential democratic deficit.[11] The European Parliament raised these concerns in response to the Commission's proposal for a Council regulation to introduce caps on energy prices in September 2022.[12] In particular, the Parliament 'recall[ed] that this instrument [Article 122] should only be used for emergency situations' and confirmed its readiness 'to act swiftly on this pressing issue if called upon, as it requires full democratic legitimacy and accountability'.[13]

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6 European Parliament, Parlemeter Autumn 2022, Eurobarometer 98.1, December 2022.

7 Council Regulation (EU) 2022/2372 of 24 October 2022 on a framework of measures for ensuring the supply of crisis-relevant medical countermeasures in the event of a public health emergency at Union level.

8 Council Regulation (EU) 2020/672 of 19 May 2020 on the establishment of a European instrument for temporary support to mitigate unemployment risks in an emergency (SURE) following the COVID-19 outbreak.

9 European Commission, Proposal for a Council Regulation laying down a framework to accelerate the deployment of renewable energy, COM(2022) 591 final, 9 November 2022.

10 European Commission, Better Regulation Guidelines, Chapters 2 and 4, SWD(2021) 305 final, 3 November 2021.

11 Improving urgency procedures and crisis preparedness within the European parliament and EU institutions, European Parliament, March 2022. 'The combination of weak Commission competence, strong Council authority and the extensive exclusion Parliament as a potentially co-authorising body leads in the state of emergency situations to a considerable democratic deficit at the European level, which is not compensated for by the control procedures of the national parliaments.'

12 Proposal for a Council regulation on an emergency intervention to address high energy prices (COM/2022/473 final).

13 European Parliament resolution of 5 October 2022 on the EU's response to the increase in energy prices in Europe (2022/2830(RSP)).

These concerns have also been raised in the context of the European Parliament's special committee on the lessons learned and recommendations from the COVID-19 pandemic to strengthen the EU's resilience and preparedness for future health threats. The special committee was established in March 2022 to draw lessons learned and recommendations from the COVID-19 pandemic in relation to four pillars: (1) health, (2) democracy and fundamental rights, (3) societal and economic impact, and (4) the EU and the world. **In its draft report, the special committee voices its concern 'that during the pandemic the executive branch had the upper hand in emergency decision-making, which undermined the role of the European Parliament**. It therefore calls on the Commission and the Council to refrain from using Article 122 TFEU and to increase parliamentary control and co-decision for various instruments so as to bolster the legitimacy of emergency response actions'.[14] The immediate response to the European monetary union crisis was also largely based on Article 122 TFEU.[15]

A similar pattern has emerged at the Member State level. **During the COVID-19 pandemic, national parliaments often delegated legislative powers to the executive branch.** Emergency and fast-track legislative procedures were also widely used. National parliaments however, remained active in their scrutiny and control function even though the passing of emergency legislation was naturally dominated by the executive branch.[16] National parliaments with an in-house budget office, which could provide rapid analysis of policy costs and forecasts, had a notable advantage during the COVID-19 pandemic. Parliaments in countries with a higher quality of democracy also proved to be more resilient in maintaining their oversight function.[17] More recently, in France, the use of Article 49.3 of the national Constitution to pass a pension reform without the involvement of the parliamentary assembly has been likened to Article 122 TFEU.[18]

1.2. How can the EU adjust its law-making practices to ensure more resilience to shocks and challenges?

There is growing recognition that the EU will have to withstand more and more shocks and challenges with cross-border impacts.[19] Yet, the current approach to policymaking does not adequately reflect this reality. The Organisation for Economic Co-operation and Development (OECD) has called on governments to enable the development of more agile and future-proof regulation.[20] The Council has also called for a more proactive crisis response.[21] **Crises offer an opportunity for policymakers to rethink priorities, planning and processes at a level that is not possible during normal times.**[22]

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14 Draft report on the COVID-19 pandemic: lessons learned and recommendations for the future, 13 March 2023, (2022/2076 (INI)).

15 This included decisions related to the European Financial Stabilisation Mechanism (EFSM), the European Financial Stability Facility (EFSF) and the permanent European Stability Mechanism (ESM). Improving urgency procedures and crisis preparedness within the European parliament and EU institutions, European Parliament, March 2022.

16 Parliamentary oversight of governments' response to the COVID-19 pandemic: Literature Review, European Parliamentary Research Service, Ex-Post Evaluation Unit, January 2023.

17 Ibid.

18 Malingre V. L'article 122, le « 49.3 » de l'Union européenne, *Le Monde*, 1 February 2023.

19 European Parliament, Parlemeter Autumn 2022, Eurobarometer 98.1, December 2022.

20 OECD, Recommendation of the Council for Agile Regulatory Governance to Harness Innovation, 2021.

21 European Council, Council conclusions on Disaster Risk Reduction in EU external action, 28 November 2022.

22 Parliamentary oversight of governments' response to the COVID-19 pandemic: Literature Review, European Parliamentary Research Service, Ex-Post Evaluation Unit, January 2023. As noted in the study, 'crises of the magnitude of COVID-19 pandemic offer parliaments the opportunity to think big about structural reforms, national priorities and key directions of policy change'.

The EU's policy-making practices could be adapted to respond to the uncertain context where future shocks and challenges are expected but are presently unknown, as follows.

Step up the use of foresight in agenda-setting and law-making debates. Practical consideration of strategic foresight can help ensure that policies are ready to confront different future risks and challenges, particularly those that are cross-border in nature and span different policy areas with different degrees of Member State competence.

Consider all aspects of risk management. These aspects also known as the '4 R's' include Reduction – taking steps to eliminate the risk or reduce the likelihood and impact of the risk; Readiness – ensuring that there are systems and capabilities which can be brought into action should a disruptive event occur; Response – managing an effective response to a disruptive event; and Recovery – activity to return the area affected to a healthy, stable state.

Improve the EU's emergency governance to respond to crises. Such improvements could include Treaty change, in particular an amendment defining trigger conditions for emergency measures, as well as changes in existing operational procedures and cooperation mechanisms such as interinstitutional agreements. These improvements could enhance the European Parliament's access to classified information relevant to crises and participation in debates concerning the budget and the financial constraints that emerge during crises.

More attention could be given to reducing potential risks in a comprehensive and coordinated way across Member States. Global shocks and challenges and the scale of their negative impacts are often not exogenous, but rather a result, at least partially, of long-standing policies and practices. For example, the COVID-19 pandemic revealed the negative consequences of reducing investment in public health systems, in particular the workforce and medical equipment in recent years.[23] The war in Ukraine revealed the costs of trade relationships with Russia, in particular for natural gas.[24]

1.3. Objectives of this study

A 2021 EPRS study introduced a five-step methodology to stress-test EU policies.[25] The approach could help policymakers adjust their law-making practices and consider future shocks and challenges. This study explains how **stress-testing can boost the European Parliament's contribution to agenda-setting and law-making processes in the EU.** Like other tools, such as cost of non-Europe reports and European added value assessments, stress-tests can help steer debate to define EU policy priorities and achieve consensus.

Stress-testing is a foresight policy method that can: (1) check if a policy action is sufficiently robust, resilient and reactive to future possible shocks and challenges; and (2) identify avenues for further policy action to reinforce the weak points of the policy action. It does not serve to predict the future, but rather to ensure that policy actions are resilient to different, alternative futures.

Section 2 presents findings from an application of stress-testing to EU rail transport policy. It draws from research carried out by the Danish Technological Institute (see Annex I – DTI Study).

Section 3 draws on this experience and others to present a conceptual overview of the possible levels of ambition. It draws from recommendations provided by Andrew Johnson of the Victoria University of Wellington, an expert practitioner of foresight and regulatory policy (see Annex II).

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[23] Lietzmann J. and Lemetayer L., Workshop on COVID-19: EU Crisis Preparedness and Response – Workshop Proceedings, Study requested by COVI Committee, March 2023.

[24] In 2021, the EU imported about 83 % of its natural gas supplies. About half was from Russia.

[25] Fernandes M. and Heflich A., 'How to stress-test EU policies - Building a more resilient Europe for tomorrow', European Parliament Research Service, 2022.

2. Stress-testing EU rail transport policy

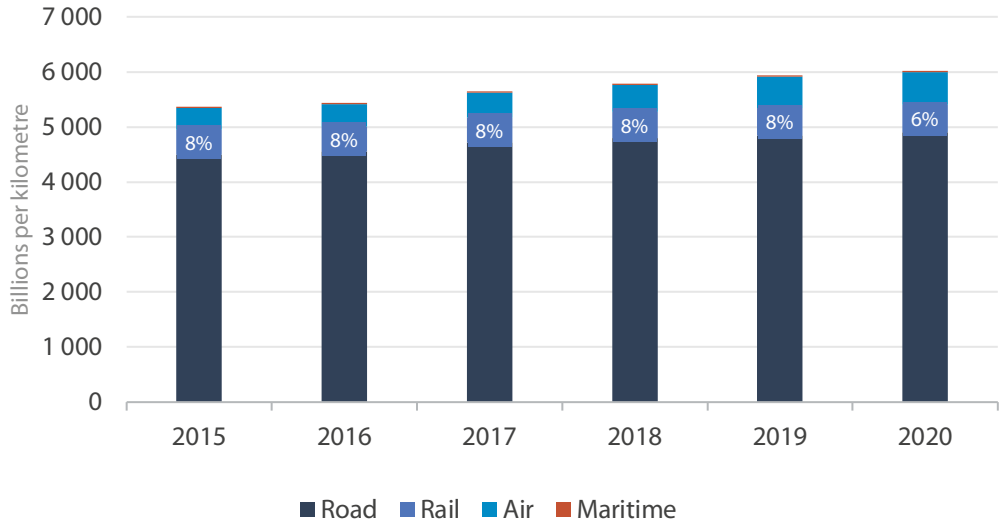
This section presents the key findings from a stress-test of EU rail transport policy. The stress-test was done by assessing the potential impacts of four possible future shocks on a selection of EU rail policies and proposals.

Section 2.1 presents an overview of the EU rail transport sector and the challenges in its future outlook. Section 2.2 presents the selected EU railway laws and proposals for their reform that were subject to the stress-test. Section 2.3 presents the four shocks that serve to test the vulnerabilities of the EU policies, while Section 2.4 presents the key findings of the assessment. More information about the stress-test and its detailed findings are provided in Annex I – DTI Research paper.

2.1. Will the increasing importance of rail transport be accompanied by better preparedness for future shocks and challenges?

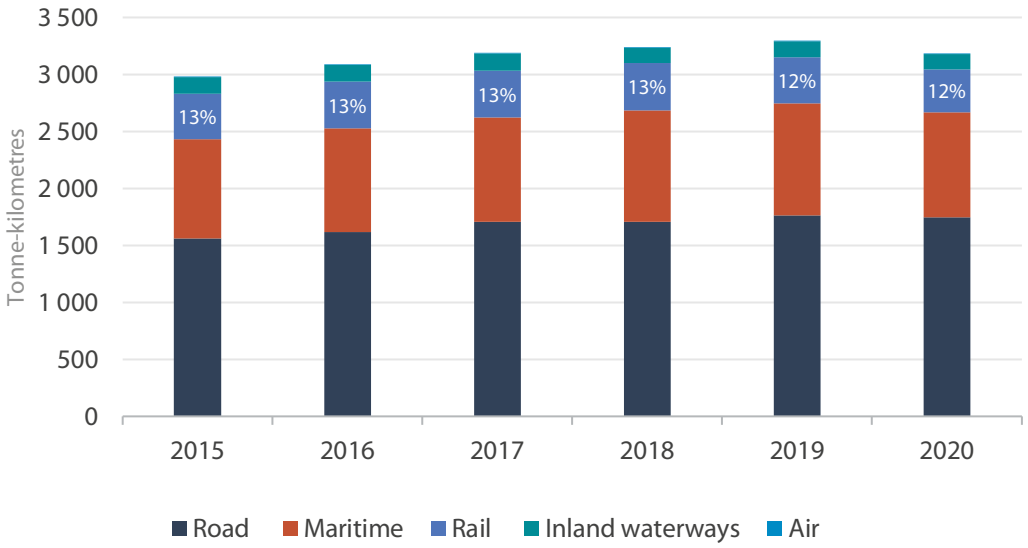
Rail transport is central to supporting the free movement of people in the EU and the movement of goods within countries and across borders. Rail accounts for less than 10 % of all passenger kilometres travelled in 2020 and about 12 % of all tonne-kilometres of freight. These figures have remained quite stable, although there was a drop in passengers in 2020 due to the COVID-19 pandemic (see Figures 2 and 3).

Figure 2 – EU passenger movements by mode of transport (2015-2020)



Source: Developed by the authors, based on the European Commission, Directorate-General for Mobility and Transport, EU transport in figures: statistical pocketbook 2022, Publications Office of the European Union, 2022.

Figure 3 – EU freight movements by mode of transport (2015-2020)



Source: Developed by the authors, based on the European Commission, Directorate-General for Mobility and Transport, EU transport in figures: statistical pocketbook 2022, Publications Office of the European Union, 2022.

The share of greenhouse gas (GHG) emissions attributable to the transport sector has increased over time and reached about a quarter of the EU's total emissions in 2018.[26] Rail transport, whether of passengers or freight, is considered one of the most environmentally friendly modes of transport, producing a relatively low level of GHG emissions.[27] **Shifting passenger and freight transport to rail could help reduce GHG emissions in the European transport sector.**

Rail transport policy is a shared competence between national and EU levels.[28] Action at the latter level aims at creating a single European railway area, which would reduce differences between national railway systems and deliver an efficient and competitive cross-border network of freight and passenger connections, as well as promote other EU goals such as strategic autonomy.[29]

Despite the ongoing transformation of the rail sector, which is supported by EU strategies and policies,[30] progress is slow – especially when it comes to decarbonisation, modernisation, safety, social harmonisation and interoperability. Some operational and technical bottlenecks in cross-border train connections persist.[31] For example, freight operators considering an intermodal shift from road to rail lack sufficient information on intermodal terminals and real-time rail network capacities.[32] Moreover, **rail struggles to be competitive against other modes of transport due**

26 European Environmental Agency, Greenhouse gas emissions from transport in Europe, October 2022.

27 Annex I – DTI research paper, Section 1.1.

28 Article 100(1) of the Treaty on the Functioning of the European Union (TFEU).

29 European Commission, Communication on Sustainable and Smart Mobility Strategy, COM(2020) 789.

30 For a broader overview please see Annex I – DTI Research paper, Section 1.2 and the European Commission website.

31 European Rail Agency, Report Cross-border Rail Transport Potential, 2022; European Court of Auditors, A European high-speed rail network: not a reality but an ineffective patchwork, 2018. European Court of Auditors, Rail freight transport in the EU: still not on the right track, 2016.

32 European Court of Auditors, Intermodal freight transport - EU still far from getting freight off the road, 2023.

to the unequal coverage of external costs (e.g., accidents, air pollution, noise, congestion, and habitat damage). On average, the external costs of high speed trains are more than covered by investment and the price paid by consumers (145 %), while the external costs covered for aircraft and passenger cars is much lower (45 % and 63 % respectively).[33] The level of cross-border rail services – which are in the remit of EU legislation – has been stagnant for almost two decades.[34] About half of all freight moved on rail in the EU is transported across borders, but only about 7 % of passenger rail is international.[35] Meanwhile, new, and even more ambitious goals are being set out for the sector. For example, one of the milestones in the EU sustainable and smart mobility strategy is to increase rail freight traffic by 50 % by 2030 and double it by 2050 as compared to 2015.[36] In the European Green Deal, the EU set out to reduce transport sector GHG emissions by 90 % by 2050.[37] Moreover, the revision of the TEN-T regulation also envisages an acceleration of several goals, such as deployment of a European rail traffic management system (ERTMS) on the TEN-T comprehensive network by 2040.[38]

Recent crises have put EU rail policies to the test.[39] Although there have been positive consequences,[40] the impacts of crises on rail transport have mainly been negative. Research and academic studies have assessed the vulnerabilities of railway systems, but the links to policies and decision-making processes is weak.[41] Policies that draw on practical considerations and scientific evidence could help to promote the resilience of EU rail transport policies against shocks. The European Commission's contingency plan for transport, which presents a toolbox with ten measures to support Member States boost transport sector preparedness and response capacities, appears to be a step in the right direction.[42]

2.2. Scope of stress-test on EU rail transport laws and measures

The scope of the stress-test exercise was defined in relation to the **EU's sustainable and smart mobility strategy**.[43] The strategy, presented at the end of 2020, aims to boost the decarbonisation

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33 European Commission, Directorate-General for Mobility and Transport, Wijngaarden, L., Schroten, A., Essen, H., et al., Sustainable transport infrastructure charging and internalisation of transport externalities, Publications Office, 2019.

34 European Rail Agency, Report Cross-border Rail Transport Potential, 2022

35 Ibid.

36 European Commission, Communication on the Sustainable and Smart Mobility Strategy – putting European Transport on track for the future, COM(2020) 789, December 2020. Goals were previously set out in the European Commission, White Paper – Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system (COM/2011/0144 final).

37 This commitment was reiterated in the sustainable and smart mobility strategy. Whereas the White Paper on Roadmap to a Single European Transport Area published by the Commission in 2011 first set a goal of a 60 % reduction in transport emissions by 2050 compared with 1990 figures. European Commission, Communication on the European Green Deal, COM(2019) 640, December 2019.

38 European Commission, proposal for a regulation on Union guidelines for the development of the trans-European transport network, COM(2021) 812 final.

39 See more in Borca, B., Putz, L.-M., Hofbauer, F., Crises and Their Effects on Freight Transport Modes: A Literature Review and Research Framework. Sustainability 2021, 13, 5740 and European Commission, Communication on A Contingency Plan for Transport, COM(2022) 211, May 2022.

40 For example, the EU Recovery and Resilience Facility that 'offers an unprecedented opportunity for a renaissance of rail and new investments in rail, with almost 50 billion euro of additional funding expected for rail'. European Commission, Communication on action plan to boost long distance and cross-border passenger rail, COM(2021) 810, December 2021.

41 Hong, W-T., Clifton, G., Nelson, J. D., Rail transport system vulnerability analysis and policy implementation: Past progress and future directions, *Transport Policy*, Volume 128, 2022, Pages 299-308.

42 European Commission, Communication on a contingency plan for transport, COM(2022) 211, May 2022.

43 European Commission, Communication on the sustainable and smart mobility strategy - putting European Transport on track for the future, COM(2020) 789, December 2020.

and digitalisation of the transport sector. It set several targets for rail, such as doubling traffic on high-speed passenger rail by 2030 (and tripling it by 2050) and increasing rail freight traffic by 50 % by 2030 (and doubling it by 2050) as compared with 2015. The strategy is organised across three pillars and 10 flagship initiatives. Overall, the strategy looks at over 80 pieces of EU legislation and/or other proposed EU action up to 2024. The stress-test on EU rail transport focused on three flagship initiatives concerning freight and passenger rail transport. Some existing EU legislation as well as recent proposals were selected for the stress-test (see Box 1).

Box 1 – EU sustainable and smart mobility strategy – defining the scope of the stress-test

The stress-test on EU rail transport policy focused on a selection of EU legislation supporting three flagship initiatives of the EU sustainable and smart mobility strategy.

Flagship #4: Greening freight transport aims at increasing the modal share of rail, which has been in decline. Problems identified by policymakers include missing links in multimodal infrastructure, lack of multimodal exchange of data, lack of research and investment, lacking rail freight capacity, bad cross-border coordination and cooperation between rail infrastructure managers, lack of digital coupling, and insufficient automation.

The stress-test focused on the following EU policies: Combined Transport Directive 92/106/EEC; Regulation 1315/2013/EU on the Trans-European Transport Network (TEN-T) and proposal for its revision COM(2021) 812 final; and Regulation 913/2010/EU concerning a European rail network for competitive freight.

Flagship #6: Making connected and automated multimodal mobility a reality aims at building a legal framework to support multimodal travel information, booking and ticketing services, further rolling out the European rail traffic management system (ERTMS), and fostering train/rail automation. Problems identified by policymakers include the lack of an EU-wide framework for multimodal information, ticketing and payment services; an insufficient legal framework at EU-level that would support interoperability across national and private systems; and the need to ensure operational data and personal information against security breaches.

The stress-test focused on the following EU policies: Commission Delegated Regulation 2017/1926/EU on Multimodal Travel Information Services and planned proposal for EU-wide multimodal digital mobility services; Directive 2010/40/EU on Intelligent Transport systems and proposal for a revision COM(2021) 813 final.

Flagship #8: Reinforcing the single market aims to complete the TEN-T core network by 2030 and build it as a truly multimodal system by securing sufficient investment (around €300 billion just to complete the core network). Problems include lack of funding, continuing obstacles to the free movement of goods and services, high entry barriers for new players, and disruptions experienced during the COVID-19 pandemic.

The stress-test focused on the following EU policies: Transport relevant State aid rules (Article 107 TFEU) and 2008 Community guidelines on State aid for railway undertakings (2008/C184/07) and their revision.

Source: Annex I – DTI Research paper based on European Commission, communication on the sustainable and smart mobility strategy – putting European transport on track for the future, COM(2020) 789, December 2020.

2.3. Possible future shocks used in the stress-test

The stress-test on EU rail legislation and measures considered four types of shocks, which could differ in their underlying cause and the resulting impacts. The shocks are possible highly disruptive events that could materialise in the near future. The **four possible future shocks** considered were: (1) a persistent heatwave in Europe; (2) the EU banning the internal combustion engine in new heavy-duty trucks from 2035; (3) a destructive cyber-attack on the European rail traffic management system (ERTMS); and (4) China invading Taiwan.

Each possible future shock and its relevance to rail transport is described below. More information about future shocks and their use in stress-testing can be found in Section 3.2.1.

2.3.1. Possible future shock #1: A persistent heatwave in Europe

The Intergovernmental Panel on Climate Change (IPCC) 6th assessment report confirmed that extreme weather and climate events are increasing and that 'their attribution to human influence, has further strengthened'.[44] The failure to address climate change mitigation and adaptation has been recognised as one of the top global risks, while natural disasters and extreme weather events also present a significant risk.[45] These findings are especially concerning for Europe, which is warming faster than the rest of the world.[46]

Weather phenomena can have adverse effects on railway infrastructure, with some weather events such as storms and floods having potential to impact the whole rail system.[47] High temperatures as well as heatwaves and the fires they can cause can lead to rails buckling and thermal expansion in structures (such as bridges and overhead power lines). Drought, drying soil and landslides can have negative effects on rail infrastructure such as slope failure, and track or poles supporting overhead lines misaligning. Impacts in the rail sector could have significant effects on other systems, namely industries that rely on rail freight transport and other modes of transport that links with rail transport. Rail infrastructure is also often linked to and dependent on other infrastructure namely energy, water, and digital infrastructure that could also be adversely impacted by extreme weather events. A simulation research study of future extreme weather events found that the negative impacts of extreme weather events on rail infrastructure could reach over €300 million per year in Europe.[48]

In this context, **the stress-test developed a scenario of a persistent heatwave in Europe and considered the disruption it would imply for EU passenger and freight railway as well as related EU legislation and measures**. The scenario is based on several assumptions, namely: that in 2030, despite EU being on track to become the first carbon-neutral continent in 2050, global emissions continue to increase because other major CO_2 emitters (China, the US, India and Russia) do not implement equally ambitious policies; adverse heatwave impacts on EU renewable energy supplies, and on EU inland water transport linked with rail and road transport in multimodal transport corridors. Wildfires and the burning of over one million hectares of land, force passengers and businesses to find alternative means of transport. Overall, on the one hand, this scenario increases demand for rail services, as fewer goods can be transported by inland waterways. On the other, rail demand falls, as its infrastructure suffers from disruption on the lines, line closures and deviations caused by the persistent heatwave.[49]

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44 Intergovernmental Panel on Climate Change, Synthesis Report of the IPCC Sixth Assessment Report (AR6). Summary for Policymakers, 2023.

45 World Economic Forum, The Global Risks Report 2023, 18th edition, 2023.

46 European Environment Agency, Global and European temperatures, June 2022.

47 Palin E., Stipanovic Oslakovic I., Gavin K., Quinn A., Implications of climate change for railway infrastructure, WIREs Climate Change, 12(5), 2021.

48 Doll C., Klug S., Enei R., Large and small numbers: options for quantifying the costs of extremes on transport now and in 40 years, Nat. Hazards, 72 (1) (2014), pp. 211-239.

49 See Annex I – DTI Research paper, Section 3.3.1 for more information. The scenario considers that road and ship freight increases by 17 % in the affected area. The scenario also considers geographical differences, namely that while southern Europe would face the highest temperatures during a heat wave, rails in Eastern Europe and the Balkans would be more affected, due to their poorer condition.

2.3.2. Possible future shock #2: The EU banning the internal combustion engine in new heavy-duty trucks from 2035

The EU's shift of freight to rail has been rather ineffective so far, with the percentage of goods transported by rail in the EU stagnating at around 18 % for decades, compared to 75 % transported by road and the remainder by inland waterways.[50] **Heavy-duty vehicles have high GHG emissions, as they are predominantly equipped with combustion engines** – they are responsible for 27 % of all EU road transport emissions as compared with 70 % for cars and vans.[51] Previous emission standards set in the EU for heavy trucks date to 2019,[52] before the EU agreed to raise the ambition of 2030 climate and energy targets to achieve carbon neutrality by 2050 in a more efficient way.[53]

In this context, **the study developed a stress-test potential future shock scenario of an EU decision banning internal combustion engines in new heavy-duty trucks from 2035**.[54] Moreover, this scenario develops a pessimistic vision[55] and assumes that a gap in rapid deployment of zero-emission trucks (e.g. electric or hydrogen-powered) persists in 2040, and the uptake in these technologies is slow and at a low level owing to rising electricity prices, as well as under-developed infrastructure for high-power charging. As a result the EU takes a radical step to ban combustion engines to boost the uptake of zero-emission trucks. This leads to a 'gradual but massive shift of freight away from roads and onto rail'.

2.3.3. Possible future shock #3: A destructive cyber-attack on the European rail traffic management system (ERTMS)

Widespread cybercrime and cyber-insecurity are mentioned as top-10 global risks both in the short- (2 years) and long-term (10 years) by the 2023 World Economic Forum (WEF) Global Risk Report. The report underlines that **cyber-attacks on digitalised critical infrastructure, such as transport, will become more common**. The recent European Union Agency for Cybersecurity (ENISA) report on the cyber-threat landscape in the EU transport sector analyses, among other things, 21 incidents targeting the railway sector out of a total 98 cyber-attacks that occurred in January 2021 to October 2022.[56] The report finds that attacks on the rail sector, mainly ransomware and data-related

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50 See e.g. European Court of Auditors, A European high-speed rail network: not a reality but an ineffective patchwork, 2018 and Eurostat, Freight transport statistics - modal split, data extracted in February 2023.

51 European Environmental Agency, Greenhouse gas emissions from transport in Europe, October 2022.

52 Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO_2 emission performance standards for new passenger cars and for new light commercial vehicles , and repealing Regulations (EC) No 443/2009 and (EU) No 510/2011 (recast – Text with EEA relevance).

53 European Commission, proposal for a regulation of the European Parliament and of the Council amending Regulation (EU) 2019/631 as regards strengthening the CO_2 emission performance standards for new passenger cars and new light commercial vehicles in line with the Union's increased climate ambition, COM(2021)556 final. Recently a political agreement was reached on an EU ban on combustion engines in cars and vans from 2035 onwards. See: Council of the EU, 'Fit for 55': Council adopts regulation on CO2 emissions for new cars and vans, Press release, 28 March 2023.

54 This scenario was developed in April-September 2022. The scenario can be considered less probable due to a February 2023 proposal by the European Commission for a revision of CO_2 standards of heavy-duty trucks, aiming at a 'decrease [in] CO_2 emissions per km from new HDV by 90 % by 2040, as compared to the reference period (1 July 2019-30 June 2020), with intermediate targets for 2030 (45 %) and 2035 (65 %)'. Nonetheless, the scenario still holds value because of the impacts it implies.

55 A study for the European Commission estimates that changes in modal shift between rail and road will depend on 'market readiness of innovation' especially in relation to higher (4/5) levels of automation. It also concludes that considering the complexity of the rail system rail industry innovations related to automation, the change might be slower than those for road transport. See more in: European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Study on the competitiveness of the rail supply industry: final report, Publications Office, 2019.

56 European Union Agency for Cybersecurity, ENISA threat landscape: transport sector. March 2023. The report underlines that these figures might be undervalued because not all attacks are reported.

threats, almost exclusively targeted railway undertakings and infrastructure managers. The main targets were railway 'IT systems like passenger services, ticketing systems, and mobile applications, causing service disruptions'. According to ENISA, there was an increase in 2022, compared to 2021, of 'hacktivist' activity, due to the Russian war of aggression against Ukraine.

Against this background, **this study developed a future scenario of a destructive cyber-attack targeting the ERTMS** as an example of how disruptive an attack could be in 2030, if the EU succeeds in digitalising its rail transport. It assumes impacts on 'positioning, tracking and railway signalling systems underlying the ERTMS over several weeks'. This reinforces opposition to total digitalisation of the signalling system (however adoption is to be completed on the core TEN-T TEN T network in 2030, so ERTMS deployment is at a point of no return) but also increased 'acceptance of tighter cyber and data protection'.

The countries most severely hit by the cyber-attack on the ERTMS were those which had made the most progress in terms of deploying ERTMS on their national rail systems. Citizens in these countries would become more sceptical of the benefits of digitalisation in rail transport and more broadly in society.

2.3.4. Possible future shock #4: China invading Taiwan

A future possible invasion of Taiwan by China would challenge the European rail area and **disrupt supply chains by fundamentally changing international trade flows.** The Economist Intelligence Unit identifies such a conflict, which would force the US to intervene and potentially lead to a global conflict, as one of its top-10 risk scenarios for 2022. Such a conflict could destroy the Taiwanese economy, including its semiconductor industry. The Taiwanese Taiwan Semiconductor Manufacturing Company Limited (TSMC) produced more than half of all the world's semiconductor chips in 2022.[57]

The same source notes a high-probability, high-impact risk that worsening US China ties could **force a decoupling in the global economy**.[58] The World Economic Forum finds that geo-economic confrontation was ranked as having a high severity in the short-term (next two years) and a lower severity over a 10-year horizon.[59] The Atlantic Global Foresight Survey 2023 found that more than half of foresight experts (70.5 %) considered that the risk of China retaking Taiwan by force could materialise within the next 10 years.[60] Moreover, foresight experts are drawing insights from the war in Ukraine for a potential response to this risk.[61]

In this context, **the stress-test developed a scenario of a possible future shock of China invading Taiwan.** Such a shock could impact trade relations and global trade flows significantly. It could be expected that EU companies would move production and assembly facilities closer to home, leading to shorter supply chains, less global shipping and potentially higher prices for consumers. Trade with other regions of the world – South Asia, North Africa and South America – would increase to partially replace China's role in global supply chains. Goods from these regions would primarily be transported by sea. Military spending in Europe would rise and investment would increase to support more dual-use rail for civilian and military needs to and from EU ports.[62]

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57 Chang, E., Taiwan's TSMC still accounts for more than 50% of global chip market share, 16 March 2022.

58 EIU Risk Outlook 2022, 10 scenarios that could impact global growth and inflation, The Economist Intelligence Unit, 2021.

59 World Economic Forum, The Global Risks Report 2023, 18th edition, 2023.

60 Atlantic Council, Global Foresight Survey 2023.

61 Hille K., US military deepens ties with Japan and Philippines to prepare for China threat, 8 January 2023.

62 See Annex I – DTI Research paper, Chapter 3.3.4 for more information. The scenario assumes EU imports from Asia fall 70 % compared to their 2021 levels and that half of these goods are now imported from other regions outside the EU.

2.4. Key findings of stress-testing of EU rail transport policy in the context of recent EU-level action

Table 1 (below) summarises the findings of the stress-testing, i.e. checking the impact of the four hypothetical future shocks on selected EU railway laws and measures related to achievement of the three sustainable and smart mobility strategy (SSMS) flagship initiatives: flagship #4: greening freight transport; flagship #6: making connected and automated multimodal mobility a reality; and flagship #8: reinforcing the single market (see Box 1 above). These objectives mutually reinforce each other, for example improvements in multimodal mobility as well as green freight solutions will have positive impacts on and strengthen the single market.

However, the stress-testing simulation of disruptive event scenarios exposed several weaknesses in EU railway policies, which might hinder achievement of the SSMS's flagship goals.

For example, **achieving the goal of greening freight transport (SSMS flagship #4) could be endangered** by a disruptive event such as Scenario 1's prolonged extreme heatwave in Europe. Two main weaknesses were revealed by the stress-test.[63]

First, to achieve this goal the share of freight transported by rail in Europe needs to radically increase. However, a disruptive heatwave may further increase barriers to shifting to rail.[64] This could be due to infrastructure damage caused by extreme long-lasting temperatures and associated fires, as well as due to lack of an appropriate level of funding for railway freight (assumed not only to decrease, but even be diverted to other emergencies exposed by extreme weather events). This **risk might be especially high if no reform of the 30-year old Combined Transport Directive is undertaken**[65] and if other relevant policy measures to increase the attractiveness of freight transport by rail[66] and EU railways' climate-resilience are not boosted. Moreover, a check of the TEN-T Regulation and its ongoing revision (as of April 2023), also revealed a potential weakness: that in case of a large-scale disruptive event like in Scenario 1, investment in the TEN-T network might no longer be prioritised. The 2021 Commission assessment of TEN-T also mentioned that a majority of the new measures needed to boost the TEN-T network will have to be implemented by 2040 and 2050. This means that the necessary funding is not yet secured, as the current MFF only runs to 2027.[67]

Second, the extreme heatwave stress-test scenario also considers a contrary impact of a potential abrupt increase in railway freight transport demand if waterborne transport becomes impossible due to low inland water levels. However, here again the Combined Transport Directive in its current form would not be able to respond to such an increase in demand, as for the last three decades it has proved an insufficient incentive to shift freight from road transport to rail.

The remaining goods, worth approximately €323 billion, are produced in the EU and transported to consumers using European road and rail.

63 See Annex I – DTI Research paper, Section 4.

64 For details, see Section 2.1 above.

65 The previous attempt to reform the directive failed and the European Commission withdrew the 2017 proposal in 2020. See European Parliament, Legislative train schedule website, Proposal for a directive on common rules for combined transport of goods, updated 20 March 2023.

66 Among the policies that would most impact freight transport by rail competitiveness are effective measures incentivising most sustainable modes of transport.

67 European Commission, Impact assessment accompanying a proposal for a regulation on the development of the TEN-T, SWD(2021) 472 final.

Table 1 – Selection of findings of the stress-test on EU rail transport policy

Stress-tested EU railway laws, proposals and measures	Key vulnerabilities exposed by stress-test scenarios of disruptive events	Relevance for EU goals[i]		
		#4: Greening freight transport	*#6: Connected and automated multimodal mobility*	*#8: Reinforcing the single market*
Combined Transport Directive 92/106/EEC	• Barriers to shift to rail, including congestion around cities and insufficient cross-border coordination	✓		✓
Regulation (EU) 1315/2013 on the trans-European transport network (TEN-T) and proposal for a revised TEN-T Regulation (COM(2021) 812 final)[ii]	• Lack of guidance for Member States on how to implement and finance life-cycle analysis and climate proofing in infrastructure plans • No operational coordinated EU mechanism envisaged for disruptive event impacting TEN-T network[iii] • EU funding up to 2027, whereas TEN-T goals up to 2050 • Passenger and goods capacity if an abrupt increase in demand occurs	✓	✓	✓
Regulation 913/2010/EU concerning a European rail network for competitive freight	• Continuity of freight operations when unforeseen demand quickly increases • Governance mechanisms for rail freight corridors when there is no political consensus on how to react to a crisis are not envisaged	✓		✓
Commission Delegated Regulation 2017/1926 on the provision of EU-wide multimodal travel information services including an expected proposal on EU-wide multimodal digital mobility services[iv]	• No provision on cybersecurity at EU level[v]		✓	✓
EU State aid rules relevant to rail transport	• None	✓	✓	✓

i) See 10 flagship initiatives set out in the European Commission communication on the SSMS, COM(2020) 789.

ii) In the wake of Russia's war of aggression on Ukraine and a real-life stress-test that exposed the vulnerability of the EU transport network, including the issue of different rail track gauges between Ukraine and the EU, the European Commission presented an updated proposal for revision of the TEN-T Regulation. However, the stress-test could not analyse the updated proposal, as the selection of EU laws and proposals to analyse was made prior to the publication of the updated proposal (see Annex I - DTI research paper).

iii) However, the Directive (EU) 2022/2557 on the resilience of critical entities and Directive (EU) 2022/2555 on measures for a high common level of cybersecurity across the Union (NIS2 Directive) should increase critical entities' resilience in times of crisis – including rail infrastructure managers and rail undertakings. Directive (EU) 2022/2557 obliges Member States to cooperate on maintaining resilient shared critical entities and establishes the EU-Cyber Crises Liaison Organisation Network (EU-CyCLONe).

iv) The stress-test analysed an inception impact assessment (European Commission, Inception Impact Assessment for an Initiative on Multimodal Digital Mobility Services, Ares(2021)6062336, 5 October 2021). Meanwhile, according to the 2023 Commission work programme, the Commission will publish a legislative proposal for a common European mobility data space in the second quarter of 2023.

v) The directives mentioned above in note iii should increase critical entities' resilience in times of crisis.

Source: Developed by the authors, based on Annex I – DTI Research paper.

The European Parliament has called for strengthened combined freight transport in the EU.[68] Parliament has acknowledged that there is a need for different policy tools to shift towards the least-polluting and most energy-efficient modes of transport in a cost-efficient manner.[69] Nevertheless, no political agreement has been reached between the Parliament and the Council on the 2017 Commission proposal to reform the Combined Transport Directive.[70] As mentioned above, reform of this directive is key to achieve the EU objective to 'green' freight transport and the European Commission is planning to make a further proposal to revise this important EU law in the second quarter of 2023.[71] During the same period, the Commission also plans to publish a legislative proposal on international freight and passenger transport – increasing the share of rail traffic. This initiative is aimed at improving access to rail infrastructure, especially for international freight with 'measures to better manage, coordinate and thereby increase the capacity of railways'.[72]

Moreover, in view of the vulnerabilities mentioned above and considering that many different tools are needed to stimulate a shift to rail, it is important to mention that in 2021, in the wake of the recovery following the COVID-19 pandemic, the European Investment Bank (EIB) launched a Green Rail Investment Platform,[73] supporting investment in the rail sector. In its resolution of 13 December 2022 on the action plan to boost long-distance and cross-border passenger rail, Parliament called for funds to be secured and better use made of those existing. The European Parliament also strongly supported this EIB initiative.[74]

Another initiative worth mentioning is the EU-funded INFRARISK research project that stress-tested critical infrastructure in different parts of the TEN-T network (both road and rail) against different extreme, low-probability natural hazards. The project also developed quantitative indicators for at-risk infrastructure.[75] Another EU-funded project, FORESEE, developed a toolkit to provide short and long term resilience schemes for rail and road corridors and logistics terminals that are able to reduce the magnitude and/or duration of disruptive events produced by humans or nature.[76] Discussions on proposed EU policies in EU rail transport could adopt these research findings.

Achieving the goal of a connected and automated multimodal mobility (SSMS flagship #6) could be hampered by a crisis such as that given in Scenario 3 – a destructive cyber-attack, targeting the ERTMS. The stress-test revealed that **provisions on cybersecurity are missing** in Commission Delegated Regulation (EU) 2017/1926), and that the inception impact assessment of

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[68] European Parliament, legislative resolution of 27 March 2019 on the proposal for a directive amending Directive 92/106/EEC on the establishment of common rules for certain types of combined transport of goods between Member States.

[69] European Parliament resolution of 9 September 2015 on the implementation of the 2011 White Paper on Transport: taking stock and the way forward towards sustainable mobility (2015/2005(INI)).

[70] European Commission, Proposal for a directive amending Directive 92/106/EEC on the establishment of common rules for certain types of combined transport of goods between Member States, COM(2017) 0648.

[71] European Commission, Annexes to the Communication on the Commission work programme 2023. A Union standing firm and united, COM(2022) 548 final ANNEXES 1 to 5.

[72] European Commission, International freight and passenger transport – increasing the share of rail traffic, accessed on 20 April 2023.

[73] European Investment Bank, Newsroom, EIB launches 'Green Rail investment Platform', 14 December 2021.

[74] European Parliament resolution of 13 December 2022 on the action plan to boost long-distance and cross-border passenger rail (2022/2022(INI)).

[75] The INFRARISK project received funding from the European Union's 7th programme for research, technological development and demonstration under grant agreement No 603960, see website.

[76] The FORESEE project received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769373, see website.

the expected regulation on multimodal digital mobility services, does not mention any measures addressing a severe EU-wide breach of cybersecurity.[77]

However, the European Commission SSMS already proposes that it will address this issue by including a proposal on EU-wide multimodal digital mobility services. A first step in this direction was the publication of a proposal for amending the Intelligent Transport Systems (ITS) Directive.[78] The goal of the amendment is to facilitate the creation of connected and automated multimodal digital mobility services for EU transport and mobility. To achieve this goal, the amendments suggested for the ITS Directive concern offering greater interoperability, cooperation, and data-sharing in ITS services across the EU. According to the 2023 Commission work programme, the Commission will also publish a proposal for a common European mobility data space in the second quarter of 2023.[79] Moreover, the recently adopted Directive (EU) 2022/2557 on the resilience of critical entities and the NIS2 Directive are also meant to address EU railways' cybersecurity gaps.

In the context of the need for adequate digitalisation and cybersecurity, and better coordination, in particular for cross-border rail traffic, the European Parliament's resolution of 13 December 2022 on the action plan to boost long-distance and cross-border passenger rail, demands the Commission 'consider the creation of coordination mechanisms for the better integration of cross-border rail traffic into national traffic and, therefore, for more efficient management of rail capacity for both passenger and freight trains'.[80] In the same resolution, the Parliament highlights 'the vital role that rail transport plays in keeping transport functioning even in crises by accommodating enormous passenger influxes within short periods'.[81]

Nevertheless, it remains to be seen how the recently adopted and upcoming proposals for EU law are implemented and if the identified cybersecurity risks will be effectively addressed across the EU.

Achieving the goal of reinforcing the single market (SSMS flagship #8) could be hampered by a crisis such as hypothetical Scenario 4 – a Chinese invasion of Taiwan. Nevertheless, the stress-test revealed that the **EU State-aid rules for rail transport[82] are robust, resilient and sufficiently flexible in a crisis**.[83] This is mainly due to the emergency clauses they encompass, which allow the Commission to authorise aid during disruptive events,[84] as well as to 'promote the execution of an important project of common European interest or to remedy a serious disturbance in the economy of a Member State'.[85] However, despite the existence of future-shock-proof State-aid rules for rail, a problem of potentially insufficient public funds to further promote and maintain railways may still prevail under this scenario. This is however indirectly related to the EU State-aid regulations and could be a consequence of this scenario if, under the assumptions made, public spending in the

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77 European Commission, Inception Impact Assessment for an Initiative on Multimodal Digital Mobility Services, Ares(2021)6062336, 5 October 2021.

78 See the new Article 7a in the proposal for a Directive of the European Parliament and of the Council amending Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, COM(2021) 813, European Commission, December 2021.

79 European Commission, Annexes to the Communication on the Commission work programme 2023. A Union standing firm and united, COM(2022) 548 final ANNEXES 1 to 5.

80 European Parliament resolution of 13 December 2022 on the action plan to boost long-distance and cross-border passenger rail (2022/2022(INI)).

81 Ibid.

82 The stress-tested EU laws and measures were: Articles 93, 107 and 108 of the Treaty on the Functioning of the European Union (TFEU) and the Commission's 2008 Guidelines on State Aid for Railway Undertakings – European Commission, Communication on Community guidelines on State aid for railway undertakings, (2008/C 184/07).

83 See details of this stress-test in Chapter 4.4 in Annex I – DTI Research paper.

84 Article 107(2)(b) of the TFEU allows 'aid to make good the damage caused by natural disasters or exceptional occurrences.'

85 Article 107(3)(b), TFEU.

railway sector could be redirected to other priorities, such as the military and defence. This could be amplified by a general negative financial impact on railway undertakings due to a contraction in the EU economy. In this regard, the stress-test found that this problem could be addressed by EU instruments promoting funding for dual (civilian and defence) use of railway infrastructure.[86] Moreover, another vulnerability exposed in the stress-test simulation – of a surge in demand for freight transport by rail[87] – could not be easily addressed by legislative measures, as its nature requires time to plan and execute.

In respect of the real-life shock of Russia's full-scale invasion of Ukraine and the transport needs it has exposed (including an increase in demand for rail transport of goods from Ukraine), the European Commission and EU Member States established 'Solidarity Lanes'. These allow passenger and freight transport to operate more effectively, but nonetheless also revealed existing shortcomings. The European Parliament underlined 'the necessity for the EU railway system to accommodate higher volumes of passengers and freight' in its resolution of 5 May 2022.[88] The Parliament also called on the Member States to 'accelerate the standardisation, harmonisation and interoperability of the railway systems across all Member States', as well as demanding the Commission take appropriate action to address remaining shortcomings.[89] The Parliament also supports the Commission's plans to 'assess an EU-wide VAT exemption for international train services and the revision and simplification of State aid rules'.[90] Finally, the **Parliament called for 'massive high-quality investment in sustainable and efficient transport infrastructure, including missing high-speed rail links'**.[91]

Based on the above considerations, **general recommendations for future-proofing EU railway policies** and for action to diminish the impact or eliminate potential disruptive events, can be made:

- boost resilient cross-border EU rail governance including effective coordination;
- create effective incentives for shifting freight to rail;
- secure EU railway operations from cyber-attacks, other man-made disasters, as well as from adverse weather effects of climate change;
- provide ambitious and long-term tools to support investment in EU railways.

86 Such as the 2022 CEF Transport Military Mobility call, European Commission, 4 May 2022.

87 It is assumed that a China invasion of Taiwan will affect maritime shipping rates of goods and shift demand to railway and inland waterway freight transport.

88 European Parliament resolution of 5 May 2022 on the impact of the Russian illegal war of aggression against Ukraine on the EU transport and tourism sectors (2022/2643(RSP)).

89 Ibid.

90 European Parliament resolution of 13 December 2022 on the action plan to boost long-distance and cross-border passenger rail (2022/2022(INI)).

91 Ibid.

3. Stress-testing in the European Parliament: What are the options?

The 2021 study on stress-testing EU policies[92] defined a stress-testing methodology that encompassed five steps. Further research[93] has identified additional insights for each step (see Table 2).

Section 3.1 explains the three ways in which stress-testing can be applied within the European Parliament context and three corresponding levels of ambition. Section 3.2 presents key methodological elements of the stress-testing tool, regardless of whether it is applied at a lower or higher level of ambition. Lastly, Section 3.3 presents key design elements for any stress-testing exercise in the European Parliament.

Table 2 – Stress-testing methodology and additional insights for application in the European Parliament

Stress-testing methodology[1]	Insights for application in the European Parliament[2]
Step 1 – Identify EU legislation	Section 3.1 – Three levels of ambition and Section 3.3.1 – What is the scope?
Step 2 – Invite policymakers and relevant stakeholders	Section 3.2.3 – Gaming to review EU policies and Section 3.3.2 – Who should be involved and when?
Step 3 – Explore future scenarios	Section 3.2.2 – Bow-tie analysis and Section 3.2.3 – Gaming to review EU policies
Step 4 – Review EU legislation	
Step 5 – Summarise and disseminate findings widely	Section 3.3.2 – Who should be involved and Section 3.3.3 – How can the stress-testing exercise be transparent?

Source: EPRS, developed by the authors. [1] M. Fernandes and A. Heflich, 2021. [2] Annex I – DTI research paper and Annex II – Jackson briefing note.

3.1. Three levels of ambition are possible

Figure 4 illustrates the possible levels of application for stress-testing in the European Parliament. Stress-tests at all levels could have added value, depending on its timing in the political and legislative cycle.[94]

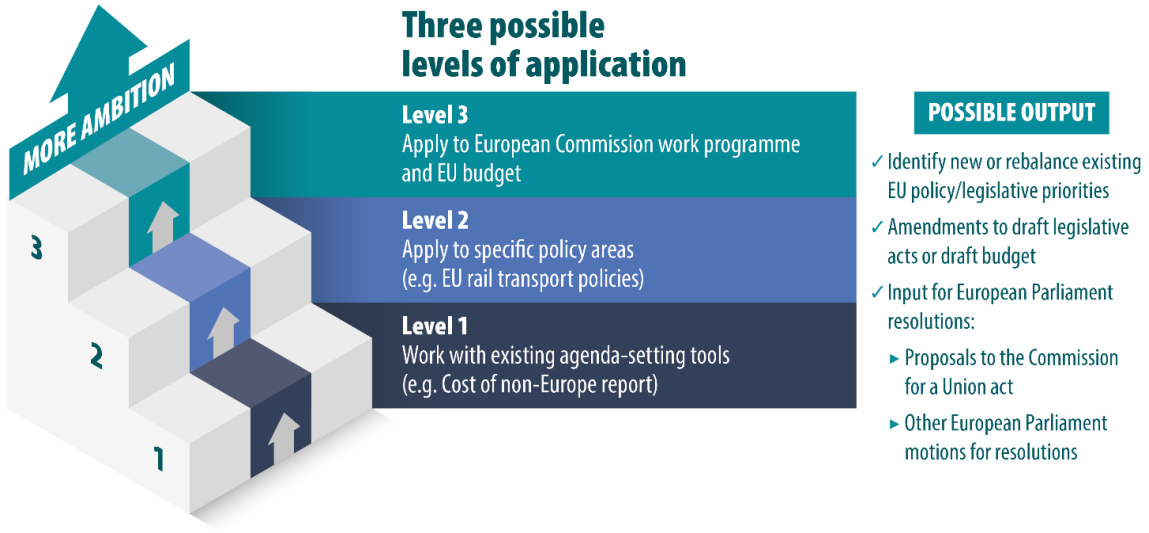
Level 1 stress-testing would build on existing agenda-setting tools, such as: **'cost of non-Europe' reports**, which review the gaps and barriers in the EU legislative framework in specific policy areas, identify broad policy options and assess the potential gains in quantitative terms to the extent possible; and **European added value assessments**, which accompany legislative-initiative reports of the European Parliament. These assessments provide supporting evidence that can support the design of the European Parliament's proposals (both legislative and non-legislative measures), their legal basis, and their potential added value.

92 Fernandes M. and Heflich A., 'How to stress-test EU policies - Building a more resilient Europe for tomorrow', European Parliament Research Service, 2022.

93 The application of the stress-testing methodology to the rail transport sector (see Annex I – DTI research paper) and recommendations provided by an expert practitioner (see Annex II - Jackson briefing note).

94 See Annex II – Jackson briefing note, Section 2.4.

Figure 4 – Stress-test exercises in the European Parliament



Source: Developed by authors.

Both tools review the status quo and use it to assess the potential added value of further action at the EU level. The status quo is typically considered to be fixed or evolving according to expected trends. However, different future scenarios could be considered based on potential shocks. **The policy options in 'cost of non-Europe' reports and European added value assessments could be assessed under varying scenarios, thus providing a richer analysis for policymakers.** With this revised approach, policy options for the EU would be viewed not only in respect of their potential gains, but also the extent to which they could be realised under different future scenarios.

Owing to recent crises and the recognised importance of being ready for future shocks, Level 1 stress-testing is already under way to some extent in the European Parliament. For example, a 'cost of non-Europe' report on energy system transformation considered several extreme scenarios, such as considering the impact on EU energy-related GHG emissions in two (counterfactual) scenarios of: i) no-cooperation at EU level since 1990 to reduce GHGs, and ii) non-cooperative approach of EU Member States on climate policies from 2020 onwards. Both tests revealed that the EU would not be able to reduce its energy-related GHG emissions by 2050 to a level allowing it to achieve carbon neutrality.[95] The European Commission is also taking up stress-testing in its impact assessments. In its impact assessment accompanying the proposal for a revision of the TEN-T Regulation, the European Commission considered the resilience of the TEN-T network due to river flooding.[96]

Level 2 stress-testing would represent a new, agenda-setting tool that could complement 'cost of non-Europe' reports and European added value assessments. It would focus on a selection of EU policy and funding instruments within a policy area similar to the approach for rail transport, which is presented in Annex I and summarised in Section 2.

A more ambitious approach (Level 3) could consider a stress-testing exercise on the annual and multiannual EU work programmes. Under Article 17(1) of the Treaty on European Union, the European Commission should initiate programming with the support of interinstitutional

[95] Heflich A and, Saulnier J., EU energy system transformation – Cost of non-Europe Report, European Parliamentary Research Service, October 2021.

[96] Impact Assessment Report Accompanying the proposal for a regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, SWD(2021) 472, European Commission, December 2021.

agreements with the European Parliament and the Council. Discussions and structured political dialogues on the work programmes can offer opportunities for the European Parliament to call for the inclusion of new legislative initiatives or rebalancing of priorities, for example, in joint declarations on annual interinstitutional programming, or during the hearings of Commissioners.[97] Stress-tests at this level could complement interinstitutional foresight and anticipatory governance processes in the EU, such as the European strategy and policy analysis system.[98]

Stress-testing could also be used to test the resilience of the **multiannual financial framework (MFF)** to future possible shocks. In December 2022, the European Parliament concluded that 'need for an urgent revision of the MFF is beyond any doubt' and that a 'business as usual' approach will not remotely suffice to tackle the array of challenges posed and could thereby undermine confidence in the Union.[99]

Box 2 – Examples of crisis-specific legislation in the EU

In recent years, the EU has introduced a range of legislation to support an EU response to specific crises. Examples are presented below.

- Temporary Protection Directive (2001/55/EC). This directive can provide for an immediate response to displaced persons external to EU borders. It can only be activated by unanimous Member State agreement.
- Contingency plan for transport (COM(2022) 211). This plan presents 10 areas of action to coordinate the introduction of emergency crisis-response measures in the transport sector.
- Proposal for a directive on resilience of critical infrastructure (COM(2020) 829 final). The legislation would creative a framework to support Member States ensure that critical entities in 10 sectors (energy, transport, banking, financial market infrastructures, health, drinking water, waste water, digital infrastructure, public administration and space) can withstand disruptive incidents.
- Directive on measures for a high common level of cybersecurity (2016/1148). This directive, which came into force in 2023, strengthens security requirements, obligations and enforcement across the Member States, and promotes cooperation on cyber-crisis management.
- Communication on disaster resilience goals (COM(2023) 61 final). In February 2023, the Commission announced the setting of common goals to support collective capacity and preparedness for natural disasters. It notes that the Commission will develop Europe-wide, transboundary, cross-sectoral scenarios for 16 main hazards.

Stress-testing can help strengthen the European Parliament's input into the agenda-setting phase while promoting more resilient, robust and future-proof EU policies. Level 1 stress-testing could identify weaknesses in the status quo, new policy options or considerations for European Parliament resolutions with proposals to the Commission for a Union act, as well as other Parliamentary motions for resolutions. Stress-testing of Commission legislative proposals (Level 2) could identify gaps that could be addressed by European Parliament amendments, e.g. of a draft legislative act or on a draft budget. Level 3 stress-testing could identify areas that require more attention in the EU legislative programme or the MFF, or demonstrate the need to rebalance the priorities set by the European Commission.

Stress-testing can raise a fundamental question concerning **the choice of having standalone, crisis-specific legislation** versus legislation that has integrated crisis response considerations. One

[97] Mańko R. Annual legislative planning in the EU, Briefing, European Parliamentary Research Service, February 2023.

[98] ESPAS – at the heart of EU foresight, website.

[99] European Parliament resolution of 15 December 2022 on upscaling the 2021-2027 multiannual financial framework: a resilient EU budget fit for new challenges (2022/2046(INI)).

approach may be preferred to another, depending on the specificity of the shock and the extent to which its impacts touch on different policy areas, EU competences, and EU policies. Box 2 presents a selection of recent examples of standalone, crisis-specific legislation. A stress-testing exercise can also raise fundamental questions about whether **EU policies should promote certainty or flexibility in crisis response.** An EU legislative act could indicate who should act under certain circumstances, thus providing certainty, or it could indicate the goals to be achieved, thus allowing for flexibility in the means.[100] The best approach may depend on the type of shock, the policy area and the institutional set-up at the EU, national, region and local levels.

3.2. Key methodological elements

Stress-testing in the European Parliament could take a similar methodological approach regardless of its level of ambition. Yet, the design of the stress-testing exercise should be tailored to the objectives, the policy area and the political context. Key elements include defining a portfolio of possible future shocks, bow-tie analysis and gaming. Each element is discussed below.

3.2.1. Define a portfolio of possible future shocks

The starting point for stress-test exercises is the review and development of shocks that could occur in the future and would have significant impacts in the EU. The review could draw on a wide range of sources including the **Future Shocks report**, published each year by EPRS, which presents a selection of possible risks and the EU capabilities to respond (see Box 3). Other sources include the annual Strategic Foresight Reports of the European Commission,[101] as well as horizon-scanning reports from international organisations such as the World Economic Forum,[102] think-tanks such as the Atlantic Council,[103] and risk assessments by reinsurance companies.[104] Such shocks – in particular technology-related shocks – may not generate purely negative impacts, but may also be beneficial for some groups. For example, dialogue-based artificial intelligence chatbots such as ChatGPT could offer superior information gathering services, but could also render certain jobs obsolete.

Box 3 – Monitoring future shocks in the European Parliament

In 2022, EPRS initiated an annual 'Future Shocks' series of publications to present a review of global risks and to focus on specific risks for Europe, and on the capabilities and resilience of the EU system in the face of multiple challenges. It seeks to provide up-to-date, objective, and authoritative information on global risks – a 360° survey, based on risk literature from a broad range of sources. The paper includes areas where the EU has primary competence, but is not limited to these areas.

The forthcoming 2023 edition will highlight 15 different risks that could occur in the coming decade (relating to geopolitics, climate change, health, geo-economics, democracy) and 10 policy responses to those risks, each addressing both existing governance capacity and possible ways to enhance capabilities within the EU.

Source: EPRS, Future Shocks 2023, forthcoming.

As noted in Annex II – Jackson, a starting point could be a list of 100 future possible shocks and classify them in terms of type of primary impact (e.g. economic, social, health or environmental) and

[100] See Annex II – Jackson briefing, section 2.2.

[101] European Commission, Communication from the Commission to the European Parliament and the Council, 2022 Strategic Foresight Report: Twinning the green and digital transitions in the new geopolitical context (COM/2022/289 final).

[102] World Economic Forum, The Global Risks Report 2023, 18th edition, 2023.

[103] Atlantic Council, Global Foresight Survey 2023.

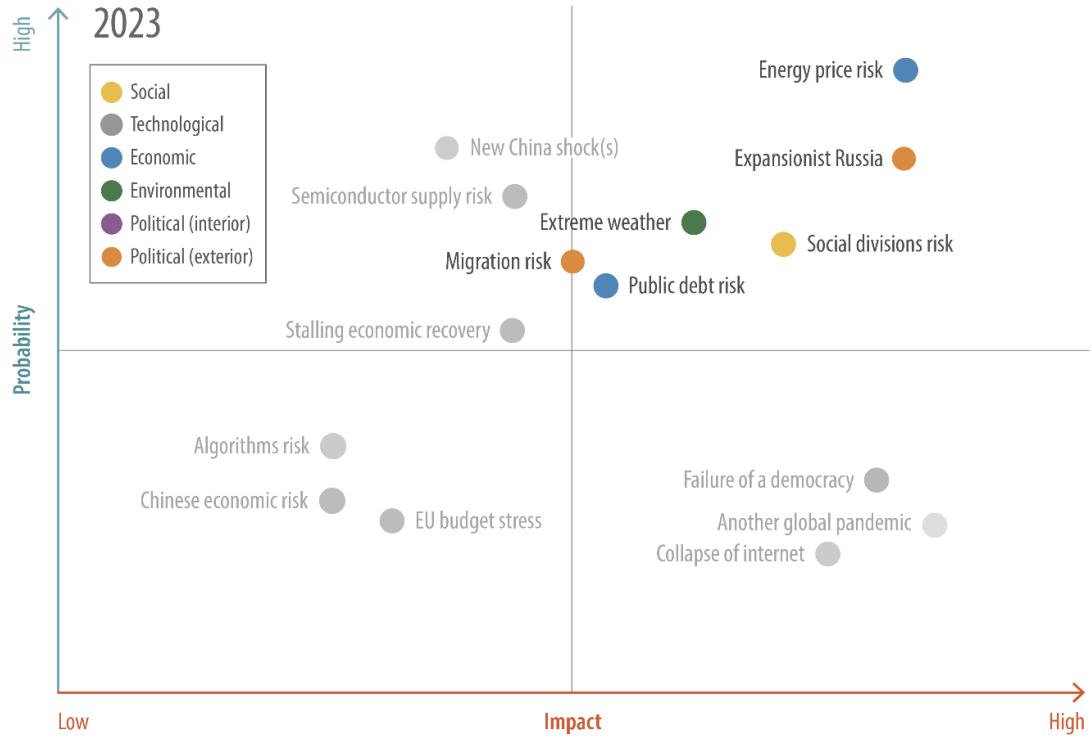
[104] As these companies are typically privately managed and profit-driven, the selection and presentation of risks should be viewed with caution.

the first and second sectors of impact (e.g. transport, energy, employment or agriculture). **The list should then be narrowed down to 20 future shocks that would have the greatest scale of negative impact on the EU either directly or through a chain of events** (e.g. significant casualties, displacements, business closures, or environmental destruction) and other criteria,[105] such as:

- the likelihood of occurrence in the near future;
- the geographical scope (e.g. originating within or outside the EU and with or without transboundary impacts);
- the extent to which national capacities would be unable to respond;
- the complexity of shock in terms of the types of impacts and the sectors affected; and
- the EU's competence to act.

The selection of 20 future shocks could prioritise high-impact, high-probability events such as those in the upper right quadrant of Figure 5, and draw from input from a range of experts covering different policy areas and perspectives. A short narrative could be developed for each possible, future shock, as was done when stress-testing EU rail policy.[106] Some scenarios of disruptive events may be taken from existing sources.[107]

Figure 5 – Identification of possible future shocks for stress-test exercises



Source: EPRS, Future shocks 2022.

[105] This differs from the approach suggested in Annex II. It would be more objective to ignore the likelihood of occurrence.

[106] See Section 2.3 and Annex I – DTI research paper, Section 3.3.

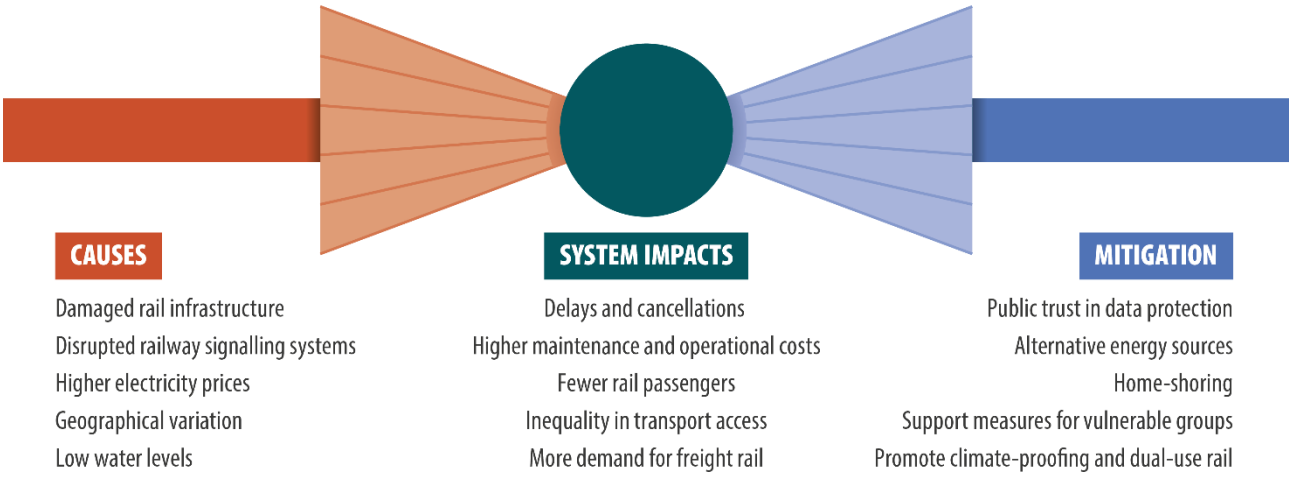
[107] For example, the European Union Institute for Security Studies has published several reports though the Chaillot Paper series. An example includes: Faleg G., African Futures 2030 - Free trade, peace and prosperity, Chaillot Paper, March 2021.

The portfolio of 20 shocks and narratives for stress-test exercises could be prepared ahead of planning for the multiannual legislative programme and updated annually based on the latest horizon-scanning assessments. Expert opinion suggests preparing a systems map of all 20 future shocks together to identify interlinkages and synergies in impacts should more than one disruptive event occur at the same time.[108]

3.2.2. 'Bow-tie' analysis of system impacts

The system effects of the selected shocks would be developed as a paper exercise, using a 'bow-tie' approach. **The 'bow-ties' would illustrate the causes and system impacts of the future shocks, and identify possible ways to mitigate them using EU, national, regional or local capacities.** Figure 6 presents an example of a 'bow-tie' analysis for EU rail transport policy, which was the focus of the stress-test exercise presented in Section 2.

Figure 6 – Illustration of a 'bow-tie' analysis for EU rail transport policy



Source: EPRS based on Annex I - DTI Research paper, Table 3 and Annex II - Jackson - Figure 6.

The stress-test found that the future possible shocks triggered a range of causes that could impact the EU rail system. For example, the persistent heatwave (possible future shock #1, see Section 2.2.1) could lead to rail buckling and sagging power lines, thus damaging the rail infrastructure. A possible invasion by China of Taiwan (possible future shock #4, see Section 2.2.4) could lead to a redirection of public funds from rail transport towards other projects supporting EU defence policy. A cyber-attack (possible future shock #3, see Section 2.2.3) could lead to a disruption of positioning, tracking and railway signalling systems underlying the ERTMS.

The system impacts of possible, future shocks include delays and cancellations for passenger and freight transport, and higher operational and maintenance costs. Nonetheless, the demand for freight rail would increase. The number of rail passengers would fall, while inequality in access to public transport would increase. An estimated six percent of people in the EU cannot afford the regular use of public transport – this share could increase in response to a shock.[109]

The impacts of possible, future shocks on the EU rail system could be mitigated in a number of ways. For example, long-term investment could be reinforced with respect to rail connectivity, climate-proofing and dual-use improvements that can support both civilian and military transport

[108] See Annex II - Jackson briefing note, Section 3.2.

[109] Baptista I. and Marlier E. Access to essential services for people on low incomes in Europe - An analysis of policies in 35 countries. European Social Policy Network, 2020.

needs. Measures could be taken to counteract the fall in demand for passenger rail and ensure access for low-income populations, thus helping to ensure that the EU can remain on track to meet the GHG emission reduction targets set out in the European Green Deal. Measures could also be taken at the EU level to support the upskilling of the rail sector's labour force to meet the demands of a more digital and green rail system, and to draw more workers to the sector, in particular youth and women. An estimated 1 in 5 rail workers is a woman, while only about 1 in 10 rail workers is less than 30 years of age.[110] Best practices to recruit a more diverse workforce may be drawn from the women in transport – platform for change initiative organised by the European Commission.[111]

3.2.3. Reviewing EU policies and measures against system impacts

The findings of the 'bow-tie' analyses would provide the basis for a set of narratives specific to the scope of the stress-testing exercise, which could be limited to a specific EU policy, a policy area or a set of priorities**. Stakeholders, including policymakers, could then be invited to participate in a 'game' to review how the system impacts of the shocks could relate to the EU policies in question.** The stakeholders could first review whether the narratives are complete and/or whether there are other considerations to develop. Experts could be consulted directly or via Delphi panels to clarify certain impacts and pathways. Once the narratives are complete, the game could begin. Each participating stakeholder could be assigned a specific role related to the system impacts and the policies in question. As noted in Annex II, economic entities would primarily be interested in maximising profits, while citizens would be more interested in their income and security. Member States would seek to minimise the risk and the negative impacts to ensure political stability. **The stakeholders should assume the perspective of the assigned role regardless of his or her actual role and views.**

The stress-test game could take the form of a standalone workshop or a workshop organised during the European Parliament's consideration of a draft legislative act (e.g. a shadow meeting), and could be completed within two hours. The participants could come from the committees and Members of the European Parliament, as well as the European Parliament's administration. Other institutions and organisations could also be invited to participate in the 'game'. **A facilitator would guide the exchange, ensure participation from all players and prompt discussion about the extent to which the EU policies in question could withstand the pressures of the shocks and where the gaps and weaknesses appear.** The game would conclude with a discussion about the possible adjustments that could be made to the policies in question to mitigate the weaknesses and gaps, and develop recommendations such as those presented in Section 2.3 for the stress-test of EU rail transport policy. The design of the game should be tailored to the specific stress-testing exercise and could draw on existing approaches, such as the scenario exploration system developed by the European Commission's Joint Research Centre (JRC).[112]

3.3. Key design elements

Three design elements of a stress-testing exercise should be decided beforehand to ensure success in meeting the objectives. These design elements should take full account of the constraints and take care not to sideline policymakers, stakeholders and the public. Time, in particular, is a major constraint for evidence-based policymaking in the European Parliament. The European Parliament must often work quickly to react to actions taken by the European Commission or to flag concerns

[110] European Commission, Report from the European Commission to the European Parliament and the Council, Seventh monitoring report on the development of the rail market under Article 15(4) of Directive 2012/34/EU of the European Parliament and of the Council, COM(2021) 5 final.

[111] European Commission, Women in transport - 2021-2022 activity report, December 2022.

[112] This 'game' has been adapted to different policy areas for example, to explore the future of migration in the EU; see an overview of the game as well as a summary of the outputs.

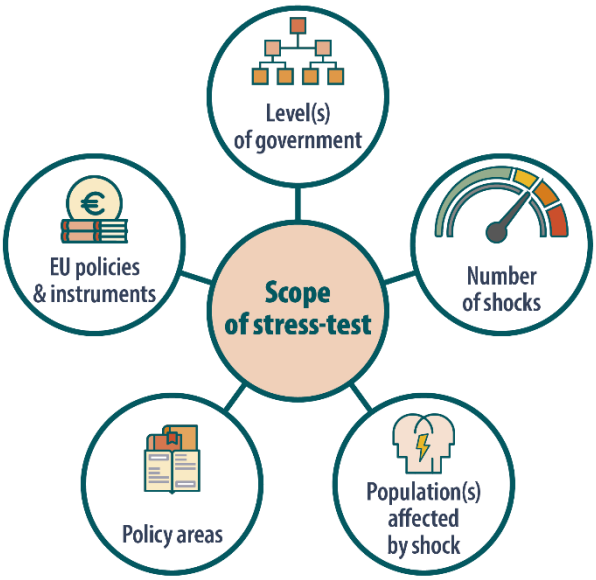
and issues that should be taken into account. To the extent possible, **stress-testing must avoid creating an additional burden or complicating the core work of the European Parliament.**

The three key design elements can be presented as questions. What is the scope of the stress-testing exercise? Who should be involved and when? How can the stress-testing exercise be transparent? Each of these design elements is discussed below.

3.3.1. What is the scope of the stress-testing exercise?

The scope of the stress-testing exercise has several dimensions that should be discussed and defined at the outset (see Figure 7). These dimensions include the relevant pieces of legislation and instruments, the relevant policy areas with regards to impacts, the number and type of shocks taken into consideration. Assuming that the available time is fixed, **defining some dimensions in a broad manner implies that other dimensions should be defined more narrowly.**

Figure 7 – Defining the scope of a stress-testing exercise



Source: EPRS, developed by authors.

The stress-testing exercise on rail transport (see Section 2) had a relatively large scope in terms of the pieces of EU legislation and instruments. However, the affected policy areas (mainly transport, innovation, environment and defence) and the number of shocks (four in total) were more limited. Defining the scope is related to some extent to defining the level of ambition of the stress-testing exercise (see Section 3.1). Considering more shocks and more EU policies and instruments can lead to a more ambitious stress-testing exercise that identifies broad gaps (Ambition level 3). Considering fewer shocks in relation to a smaller number of EU policies and instruments can lead to more specific findings, which could support amendments and trilogue negotiations (Ambition levels 1 or 2). Strategic crisis management or disaster resilience plans could also be fine-tuned by stress-testing. For example, the European Court of Auditors recommends stress-testing the updated pandemic procurement framework to identify and overcome weaknesses such as the limited capacity to overcome supply-chain disruption.[113]

[113] European Court of Auditors, EU COVID-19 vaccine procurement. Sufficient doses secured after initial challenges, but performance of the process not sufficiently assessed, September 2022.

Defining the scope of the stress-testing exercise is also about **prioritisation of the objectives considering the policy and political context**, and the possible levers of action available to the EU. Is it important to take the interlinkages of impacts across policy areas into account, or the severity of impacts on certain groups such as women or small and medium-sized enterprises (SMEs). The **possible levers of EU action** depend on the existing EU legislative framework, EU competences as defined in the Treaties and coordination mechanisms in place with actors at the international, regional and local levels.

3.3.2. Who should be involved and when?

The stress-testing exercise should draw on inputs from policymakers and stakeholders at various points and especially at the outset when defining the scope (see Section 3.3.1). Ensuring the involvement of policymakers and stakeholders can help to ensure the relevance of the exercise, and the take-up of the findings.

An initial core list of participants could be defined prior to commencing the stress-testing exercise. This list should include **a 'champion' from the European Parliament** – one senior person who fully supports the stress-testing exercise and has the power to take or facilitate action based on its findings. The core list could be adapted and expanded over the course of the stress-testing exercise. In addition to elected Members of the European Parliament, the list could include representatives from other EU institutions, stakeholder organisations (EU, international, national, regional and/or local), and experts. **Historians could also provide useful perspectives as they are familiar with past occurrences of shocks.**[114] The list should not be limited to people physically based in Brussels or the EU. Its primary audience is the European Parliament, although there could be value in extending coordination with the Commission, the Council and the Member States. For example, the Council recommends Member States stress-test the resilience of critical infrastructure against antagonistic man-made threats.[115]

In addition to defining the scope, the participants could also be involved in all steps of the stress-testing exercise, including the bow-tie analysis and gaming. **Different levels of involvement could be envisaged for each participant according to their available time, engagement in related activities, and to ensure a balance of interests at each point in the stress-testing exercise**. It is also important to highlight that participants may be requested to represent a viewpoint or perspective that it is not their own. Such role-playing can help identify new insights and build more shared, holistic thinking.

3.3.3. How can the stress-testing exercise be transparent?

The European Parliament is the only democratically-elected European institution and its work and activities are largely transparent to citizens via its communication activities and outreach. **Similarly, the public also have the right to know that the European Parliament is seeking to ensure that EU policies are sufficiently resilient and robust to possible future shocks, and how this process is undertaken.**

Stress-testing exercises should therefore maintain transparency, ensuring the public is aware and informed. For any planned stress-testing exercise, the European Parliament could consider publishing a **roadmap of the objectives and key steps of the stress-testing exercise**, similar to the roadmaps published by the European Commission for impact assessments. These roadmaps

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[114] For example, historians of epidemics and pandemics provided insights into the COVID-19 pandemic. Brown, T., The COVID-19 pandemic in historical perspective: an AJPH dossier, *American Journal of Public Health*, 111(3), 2021, pp. 402-404.

[115] Council of the European Union, Council Recommendation on a Union-wide coordinated approach to strengthen the resilience of critical infrastructure 2022/0338(NLE), 9 December 2022.

could also serve as a **'call for evidence'** to be provided by the public and stakeholders, who could suggest specific shocks, policies, perspectives and other evidence that should not be overlooked.[116]

The organisers of the stress-testing exercise could use **public advertisements to recruit experts or raise awareness about workshops**. Online tools could be used to ensure that participants can engage in the stress-testing exercise regardless of physical location and language. Lastly, the European Parliament could seek to **draw input and disseminate the findings of stress-testing exercises to national parliaments** via the European Centre for Parliamentary Research and Documentation (ECPRD) network. Stress-testing exercises could be carried out in national parliaments and complement EU-level exercises.

[116] The European Commission issues 'calls for evidence' as part of its public consultations.

4. Conclusions

Recent global crises, including the COVID-19 pandemic, the war in Ukraine and soaring consumer prices, underscore the need to adapt policymaking approaches in the EU while ensuring democratic accountability. **Stress-testing is a promising tool that can support the adaptations that policymakers must make in the face of future shocks and challenges.** High-probability, high-impact challenges in the near-term outlook include the risk of a sovereign debt crisis, outbreak of war with China, and deglobalisation. When and where considered relevant, EU policies should be stress-tested to help ensure their readiness, resilience and robustness to face these possible future shocks. Regular stress-testing of EU policies can help to avoid the consideration of ad-hoc, emergency legislation that does not undergo the ordinary legislative procedure and that is not subject to parliamentary oversight.

This study outlines how stress-testing could be carried out in a practical way in the European Parliament and the kind of results it could generate for policymakers.[117] Stress-testing is not a research product, but rather a tool that should be integrated into the policy-making process, particularly at the agenda-setting stage of the legislative cycle. **The added value of stress-testing depends on its timing, and the policy and political context.** Stress-testing exercises should be adapted accordingly and consider the corresponding possible levers for EU action. Nonetheless, stress-testing exercises would maintain some common **methodological and design elements**. One key element is the involvement of policymakers and stakeholders from the outset in defining the scope of the stress-testing exercise, considering the possible gaps in the current EU policy framework, and finally, in adopting the results of the stress-testing exercise in their daily, policymaking activities.

Stress-testing could be done at three levels of ambition. At the lowest level of ambition it could build on existing agenda-setting tools such as '**cost of non-Europe**' **reports and European added value assessments**, which are prepared by the European Parliamentary Research Service at the request of the parliamentary committees. At its highest level of ambition, **stress-testing could uncover weaknesses in the priorities set in annual and multiannual EU policymaking/legislative programming**, complementing interinstitutional EU processes such as the European Strategy and Policy Analysis System. It is neither desirable nor possible to stress-test all EU policies. Instead, stress-testing should be considered where it can offer **high and complementary added value to existing law-making processes.**

[117] This study builds on a 2021 study that identified the need for a stress-testing tool in the European Parliament and outlined five steps for its methodology; Fernandes M. and Heflich A., 'How to stress-test EU policies - Building a more resilient Europe for tomorrow', European Parliament Research Service, 2022.

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Annex I

Stress-testing EU policies on rail transport: Are they on track for the future?

Research paper

The global political landscape is increasingly challenged by crises, and there is a pressing need to develop policies that are both flexible and resilient so they can continue to be effective, not only in the expected future, but also in the face of disruptive changes. Policy stress-testing, where policies and related documents are subjected to theoretical stress can be a useful tool in this respect.

The research paper presents the results of an exercise that stress-tested European rail policies against four scenarios. The scenarios covered a broad range of potential challenges for European rail by considering the impacts of a persistent heatwave, a ban on new heavy goods vehicles with internal combustion engines, a cyber-attack on rail management systems, and an invasion of Taiwan by China. Key legislation and policy documents linked to three selected flagship initiatives of the sustainable and smart mobility strategy (SSMS) were reviewed against the scenarios.

The stress-testing exercise identified several vulnerabilities in the scrutinised legislation which may hamper its successful implementation as well as the achievement of the policy goal of shifting freight and passengers from road to rail within the timelines set. In particular, difficulties to secure adequate funding for infrastructural improvements that would create incentives for such a shift were identified as a challenge. EU legislation under way will address some of the vulnerabilities identified. However, it still remains to be addressed how funding for the development of rail in line with the SSMS can be secured in the long term.

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Executive summary

This research paper is part of the effort of the European Parliament to integrate foresight into the policy design process. It presents outcomes of a stress-testing exercise that was conducted to **investigate the potential value of the Parliament's stress-testing methodology** by applying it to a single policy area to show how it can enhance the resilience of specific EU policies.

The political landscape of Europe is increasingly challenged by crises in the wake of disruptive events, such as the COVID-19 pandemic, extreme weather events caused by climate change, and the 2022 war in Ukraine following the Russian invasion. At the same time, the digital and green transitions – collectively referred to as the 'twin transitions' – become even more urgent in view of these crises. They require not only technological solutions but changes in structures, systems, and mindsets across all sectors and European societies. Hence, there is **a pressing need to develop policies that are both flexible and resilient** so they can continue to be effective, not only in the expected future, but also in the face of disruptive changes.

Policy stress-testing can be a useful tool to achieve this. It is essentially **a simulation exercise, in which policies and related documents are subjected to theoretical stress** in the form of scenarios representing different ways the future may unfold. The assessment of how legislation or policy initiatives (proposed or existing) will perform in the face of different theoretical futures can reveal potential weaknesses in the stress-tested policies, enabling policymakers to consider how to amend and further future-proof them.

To investigate the applicability and value of the European Parliament's stress-testing methodology, the **research focused on the stress-testing of EU rail transport policies (both freight and passenger) as well as related documents** (such as those linked to policy proposals, including impact assessments, implementing studies, and reports by the European Parliament). This research focus was chosen for two main reasons. First, EU action on transport is urgently needed to deliver on strategic targets for the reduction of greenhouse gas emissions. The EU itself, for instance, sees the need to stimulate more sustainable modal choices by transport users and is thus trying to promote a shift from air and road transport onto rail (as well as to inland waterways in the case of freight).[1] Second, in support of a greener and more digitalised mobility system in the EU that is resilient against future crises, the European Commission has recently brought forward a range of proposals to review existing, and introduce new, rail policies.[2] The relatively high level of activity in the policy area of rail transportation thus makes it well-suited for the purposes of this research.

Due to a rapidly evolving policy context in regard to rail, as well as transport in general, it is important to highlight that **the stress-testing exercise conducted for this research paper was concluded at the end of October 2022**. Therefore, the research does not take more recent evidence or developments into account.

Approach and methodology

This research paper applies the stress-testing methodology of the European Parliament to a selection of EU rail transport policies, taking both freight and passenger rail into account.[3] A total of **four stress-tests were conducted** with the help of four individual scenarios. For each stress-test, a set of key legislation was tested against a specific scenario. All stress-tests were carefully planned and designed to maximise the relevance and value of their results. This involved several steps as outlined below.

Limiting the scope of the stress-testing activities: With the help of feedback from consulted rail stakeholder organisations (listed in Annex A), the research team chose to focus the stress-testing exercise on four sets of key legislation linked to three flagship initiatives of the European Commission's Sustainable and Smart Mobility Strategy (SSMS).[4]

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1 In January 2020, the European Parliament expressed its support of a shift to sustainable and smart mobility in its resolution on the European Green Deal (Resolution of 13 November 2020 on the Sustainable Europe Investment Plan — How to finance the Green Deal, European Parliament). The European Commission has defined specific milestones for a modal shift to rail in its Sustainable and Smart Mobility Strategy (Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020).

2 See, for example: New transport proposals target greater efficiency and more sustainable travel, European Commission, 14 December 2021.

3 The stress-testing methodology was developed in a previous pilot study, see Fernandes and Heflich, 2022.

4 Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

Mapping potential policy weaknesses: Rail stakeholders were consulted to identify possible weaknesses in the selected policies, such as underlying assumptions, which may pose a risk because it could mean that a policy following disruptive developments may cease to perform as intended.
Developing targeted scenarios: On the background of steps one and two, four primarily qualitative scenarios – one for each stress-test focusing on a specific set of key legislation – were developed. The scenarios were based on disruptive events taking place in the near future (between 2027 and 2035). These events were chosen according to their expected consequences and potential for exerting significant theoretical stress on the selected rail policies in line with findings from step two. Scenario trajectories and impacts were validated in online workshops with foresight experts and rail experts.
Conducting the stress-tests: The four sets of EU rail policies were each tested against one of the developed scenarios to reveal potential weaknesses.
Presenting lessons learnt: As a final step, the outcomes of the conducted stress-tests were compiled and used to devise recommendations on how the resilience of the scrutinised policies could be enhanced.

Figure 1 on the following page summarises the main outcomes of the four stress-tests conducted for this research paper.

Overview of key findings

Figure 1: Main outcomes of the four conducted stress-tests

Source: Authors' elaboration. Please note that scenarios for each stress-test are presented in chapter 3 and the outcomes in chapter 4.

Lessons learnt

The lessons learnt can be divided into two: lessons regarding the stress-testing methodology, and findings from the conducted stress-tests.

Methodological lessons learnt

Overall, **the methodology – stress-testing against scenarios based on shocks with relevance for transport – proved effective** in identifying vulnerabilities in policies and legislation.

Transport policy in general, and rail policy in particular, must consider the construction, maintenance, management, and operation of large and investment-demanding infrastructures. The research thus found that **the stress-test of EU rail policies requires consideration of the resilience and responsiveness of the rail infrastructure, its management and financing, as well as the available funding instruments and systems**.

On this background, the stress-testing exercise also proved that **the used stress-testing approach is not only applicable to policy initiatives and associated legislation** – it is also well-suited to consider the adequacy of funding instruments and systems designed to facilitate policy implementation, and to identify insufficient coordination between policy silos.

A related **challenge for the method is to avoid a strict focus on the policy area or legislation to be stress-tested**, since any individual policy interacts with policies and developments in other areas or sectors. To understand developments in the rail sector, the research team had to consider developments in the digital field as well as EU energy policies, for example. This underlines **the need for a holistic approach when conducting stress-tests**.

To ensure that the stress-tests lead to valuable outcomes, **scenario development was started with the rail policies as a point of departure**. First, underlying assumptions and objectives of the policies were identified and subsequently shocks that – while plausible given current trends – could conceivably challenge the resilience of the selected policies were defined.

While defining the shocks, it was important for the relevance of the stress-testing outcomes to focus on creating situations that have not been foreseen by policy makers and may potentially complicate or hamper policy implementation. For this purpose, the development of **short, but concrete, scenario narratives with a focus on rail transport and including rough quantitative estimates of key indicators**, proved valuable for the targeted stress-testing of EU rail policies.

Drafts of the scenario narratives were used in **validation workshops attended by foresight experts as well as rail experts familiar with foresight methods**. This proved to be very productive, since the rail experts were able to contribute their insights into aspects of rail infrastructure, management, and technology that proved invaluable in fine-tuning the scenarios.

The involvement of rail stakeholders in the scoping of the stress-testing exercise and in discussions on preliminary findings was generally effective. Contributing stakeholders expressed great interest in being involved in the exercise, indicating that **wider availability of training in the use of foresight methods could promote dialogue about future challenges and opportunities – also in terms of policy development**. The findings from this stress-testing exercise will hopefully contribute to stimulating a broad change of mindset in this direction.

Key findings from the rail transport stress-testing exercise

The stress-testing of selected EU rail policies and related policy documents has revealed some vulnerabilities or weaknesses in most of the scrutinised policies and legislation. **While most of these weaknesses are not critical, taken together, they may prove detrimental to the ability of the EU rail policies to achieve their objectives**.

The most weaknesses in a specific legislative instrument were found with respect to the **Combined Transport Directive**.[5] The market incentives set by the directive, for example, do not pay attention to greenhouse gas efficiency or average external costs of various modes of transport. However, the current review of the TEN-T Regulation[6] may complement the Combined Transport Directive and address some of the identified weaknesses.

Outcomes from three of the four conducted stress-tests point towards **a lack of instruments to ensure the functioning of the rail network during crisis situations** (e.g., extreme climate events or cyberattacks). In a situation where a crisis drags on, this will likely lead passengers as well as logistics operators to seek other means of transport.

Two of the scenarios lead to an increase in the demand for rail freight capacity. While the European rail policies aim at facilitating a shift from other transport modes to rail (and inland waterways in the case of freight), and the scenarios in that sense should be positive, the research indicates that **the capacity of the European rail system to accommodate a sudden increase in the demand for rail freight transport is limited**. A significant increase in capacity cannot be achieved in the short term without difficulties, given the funds currently set aside to expand the network and increase the capacity of the rolling stock.

All stress-tests highlight that it is not fruitful to discuss vulnerabilities in the policies and legislation without considering already existing **vulnerabilities in the physical infrastructure and management of the European rail network** that could be exacerbated in a crisis. With regard to the physical infrastructure, there are evident interoperability problems between national systems that require significant economic resources to be amended. Since cross-border infrastructure management is fragmented and undertaken by a mix of private and public operators, extensive coordination among a wide array of stakeholders is required.

For example, a group of nine European Coordinators has been tasked with coordinating the decisions and actions of Member States and other relevant stakeholders in regard to implementing the nine core network corridors of the Trans-European Transport Network. However, the analysis has found that the **Coordinators are not bestowed with powers that will allow them to secure funding for the network during a crisis, nor do they have enforcement powers in case of disagreements** between Member States or the disengagement of a Member State. This challenge is acknowledged by policy makers, and to some extent, **remedial action has been taken,[7] but the analysis indicates that these actions will not be sufficient in the event of a crisis**.

With respect to the timelines of European rail policies, workshop participants expressed that **the assumptions of much of the legal framework are unrealistic (at least within the next ten years)** given the changes needed to the European rail system to reach strategic targets concerning a modal shift to rail. Delivering on these targets will require EU institutions, as well as national rail authorities and private rail operators, to assume responsibility for implementing relevant policies and securing financing for the improvement of rail infrastructure.

The increased digitalisation of rail is to ensure its competitiveness vis-à-vis other transport forms, while also making rail more vulnerable to cyberattacks. The analysis found that there is **insufficient attention to cyber security** in several policies with relevance for the digitalisation

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5 Directive 92/106/EEC of 7 December 1992 on the establishment of common rules for certain types of combined transport of goods between Member States.

6 Proposal for a regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, COM(2021) 812, European Commission, December 2021.

7 According to Directive 2008/114/EC on the resilience of critical entities, adopted in June 2022, Member States are obliged to cooperate on maintaining the resilience of shared critical entities.

of rail, including the Directive on Intelligent Transport Systems.[8] However, there is legislation underway to amend this apparent gap, such as the NIS II Directive.[9]

The analysis also examined whether the adoption of specific **new technologies for rail** could conceivably contribute to achieving relevant policy objectives by increasing the competitiveness of rail. These technologies included hydrogen propulsion for rolling stock and the introduction of longer freight trains, driverless trains, and digitally enhanced signalling systems. However, **none of these technologies were expected to be fully implemented within the time horizon analysed in the scenarios** (i.e., in the next 10-20 years), and hence, would not contribute significantly to counter their negative impacts.

The analysis has further underlined how **the development of the role of rail in the transport system is closely interwoven with European and national energy systems and energy policies**, as those impact on the availability of fuels and other sources of power for trains. The cost – and possibly use – of rail transport is likely to be affected by energy shortages, while the sustainability of rail transport greatly depends on the European energy mix.

Last but not least, **financing stands out as a key issue**. In all scenarios, there is a risk that national and private funds are channelled away from expansion or even necessary maintenance of the rail network, due to the impact of crisis situations. The prioritisation of investments in rail infrastructure by the EU and Member States is necessary to achieve policy objectives for rail. With respect to EU funding, financial obligations are made only until 2027, whereas much of the necessary improvements will require investment also in the decades after 2030. Uncertainty about financing may prevent railway stakeholders from initiating projects demanding long-term investments. **Achieving the ambitious European goal of a significant modal shift to rail will therefore require continuous political prioritisation and support, even when faced by other important societal demands.**

[8] Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

[9] Commission welcomes political agreement on new rules on cybersecurity of network and information systems, European Commission, 13 May 2022.

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Glossary

This glossary defines key terms and abbreviations as used throughout this research paper.

Term	Definition
Carbon intensity	Measure of how clean electricity is, referring to how many grams of carbon dioxide are released to produce a kilowatt hour of electricity.
Cooperative Intelligent Transport Systems (C-ITS)	These systems are comprised of connected vehicles capable of communicating with each other as well as transport infrastructure with the help of digital technologies, including fully autonomous vehicles.
Core network	The central part of the Trans-European Transport Network (TEN-T), covering the most important connections that link key nodes in the entire network and mainly consisting of nine Core Network Corridors (European Commission, n.d.(a)).
Core network corridors	Nine transport corridors forming the backbone of the TEN-T's core network by connecting key nodes in the network (e.g., the Rhine-Alpine Corridor or the North Sea-Mediterranean Corridor) (ibid.).
Decarbonisation	The process of removal or reduction of carbon dioxide output into the atmosphere.
Electrification of rail	The implementation of systems that supply electric power to rolling stock without an on-board prime mover or local fuel supply.
European Rail Transport Management System (ERTMS)	The system is comprised of different technologies that, together, are being deployed in the EU rail network to create a single, harmonised control, command, signalling, and communication system.
Greenhouse gas efficiency (GHG efficiency)	Refers to the amount of greenhouse gas emissions linked to a specific entity or object. In this research paper, the term is used to compare the average greenhouse gas emissions resulting from the transport of passengers or freight over one kilometre by different transport modes.
High-speed rail	A type of rail running significantly faster than traditional rails, requiring advanced infrastructure (e.g., continuous welded rail lines to reduce track vibrations) and using specialised rolling stock.
Hydrogen-powered	Refers to rolling stock powered by hydrogen, typically using hydrogen fuel cells. Hydrogen-powered rolling stock can operate on non-electrified lines.
Line-kilometre (line-km)	Unit of measurement used to measure the length of railway networks; in the case of multiple-track railway lines, only the distance between origin and destination is counted.
Mobility as a service	A type of service allowing users to plan, book, and pay for different transport options, including journeys involving the seamless transfer from one modal choice to another, by combining all modes of transport in a single, interoperable platform.
Modal choice	The choice between different available transport modes, including transport by air (e.g., planes), road (e.g., cars, busses, heavy-duty vehicles), and water (e.g., marine vessels and passenger ships).
Modal share	The percentage share of each mode of transport within the total use of transport.
Persistent heatwave	One of the scenarios developed for this research paper is based on a 'persistent heatwave'. The phrase is used to describe regularly (i.e., yearly) reoccurring heatwaves (while the scenario also sees a steady increase in average temperatures each year).
Stress-testing	Stress-testing checks the stability, strength, and robustness of policies by analysing how they may perform in the face of scenarios representing different plausible futures. As a policy tool, it can provide guidance on policy areas in need of improvement or rebuilding. (Fernandes and Heflich, 2022)
Rolling stock	Rolling stock refers to powered and unpowered railway vehicles.

Trans-European Transport Network (TEN-T)	The Trans-European Transport Network (TEN-T) refers to the implementation and development of a Europe-wide network of railway lines, roads, inland waterways, maritime shipping routes, ports, airports, and railroad terminals. The TEN-T is comprised of two layers: The Comprehensive Network covers all European regions and is planned to be completed by 2050. The Core Network includes the most important connections that link key nodes in the entire network and mainly consists of nine Core Network Corridors (European Commission, n.d.(a)).
Ton-kilometre (tkm)	Ton-kilometre (tkm) is a unit of measurement that is equivalent to transporting one ton of freight over a distance of one kilometre.
Passenger-kilometre (pkm)	Passenger-kilometre (pkm) is a unit of measurement that is equivalent to transporting a passenger over a distance of one kilometre.
Policy weakness / policy vulnerability	Critical or weak point in a policy, especially assumptions that can be demonstrated to be incorrect in some scenarios and lack alignment with other policy measures.
Scenario	Theoretical description or narrative of a plausible future (Fernandes and Heflich, 2022). The scenarios for this research paper focus on the expected impact of specific shocks (see below) taking place in the near future (2027-2035) on the transport system (rail transport in particular). To illustrate some of the impacts, the scenarios are supplied with quantifications of key indicators.
Shock	A specific disruptive event with a significant impact on different spheres of society and having the potential to bring about significant changes (Ringland, et al., 1999).

1. Introduction

This research presents outcomes of a stress-testing exercise that was conducted to **investigate the potential value of the European Parliament's stress-testing methodology**[10] as a policy tool by applying it to a single policy area and showing how it can enhance the resilience of specific EU policies.

With this background, the research paper can be seen as part of the Parliament's efforts to integrate foresight into the policy design process. **The political landscape of Europe is increasingly challenged by crises** in the wake of disruptive events, such as the COVID-19 pandemic, extreme weather events caused by climate change, and the 2022 war in Ukraine following the Russian invasion. These challenges are all transnational by nature and require transnational solutions. As an international organisation that fosters collaboration and dialogue between European states, the **EU is uniquely positioned to help address these issues** and coordinate the actions of Member States for greater impact in efficiency in a way that would be difficult to accomplish by any individual state.

The digital and green transitions – collectively referred to as the 'twin transitions' – become even more urgent in view of the above crises. They require not only technological solutions but changes in structures, systems, and mindsets across all sectors and European societies. Hence, there is **a pressing need to develop policies that are both flexible and resilient so they can continue to be effective**, not only in the expected future, but also in the face of disruptive changes. Policy stress-testing can be a useful tool to achieve this. It is essentially a simulation exercise, in which policies or concrete legislative documents are subjected to theoretical stress in the form of scenarios representing different ways in which the future may unfold[11]. The assessment of how legislation or policy initiatives (proposed or existing) will perform in the face of different theoretical futures can reveal potential weaknesses in the stress-tested policies, enabling policymakers to consider how to amend and further futureproof them.

The research presented in this paper focuses on the stress-testing of **EU rail transport policies (both freight and passenger) as well as related documents** (such as those linked to policy proposals, including impact assessments, implementing studies, and reports by the European Parliament and the European Commission). There are two main reasons why this policy area was chosen to demonstrate the applicability and value of the Parliament's stress-testing methodology. First, EU action on transport is urgently needed to deliver on strategic targets for the reduction of greenhouse gas emissions. Second, in support of a greener and more digitalised mobility system in the EU that is resilient against future crises, the Commission has recently brought forward a range of proposals to review existing and introduce new rail policies. The relatively high level of activity in the policy area of rail transport thus represents a great opportunity for policy stress-testing in line with the Parliament's functions to help set the legislative agenda and provide legislative scrutiny.

The following sections of this chapter offer an introduction to European rail transport by describing its position in the European transport mix and examining the sustainability of rail transport. Challenges faced by the rail sector are also outlined, followed by an overview of key technologies for the digitalisation and greening of rail transport that are meant to help overcome these challenges. The last two sections of the chapter focus on recent EU actions on rail transport (section 1.2), as well as other EU measures with relevance for the rail sector (section 1.3) to present how policymakers seek to put European rail on track for the future.

[10] Fernandes and Heflich, 2022.

[11] ibid.

1.1. Rail transport

The rail sector is an essential part of the European transport system, playing a key role for socio-economic cohesion in the EU. With a total length of around 201 000 line-kilometres, the EU 27 rail network is used to transport some 1.6 billion tonnes of freight and 7.1 billion passengers each year.[12] These figures underscore the importance of the rail sector for cross-border trade and mobility in the EU.
The following subsections are dedicated to different aspects of the rail sector, looking at the position of rail in the European transport mix, rail's status as a sustainable form of transport, as well as the key-challenges facing the rail sector.

Modal share of passenger and freight rail transport

While the European rail network serves the travel needs of its citizens and the distribution of the goods they buy and use, and despite the long history of rail transport, **rail is far from being the dominant transport mode in Europe**. This is illustrated by the latest statistical data allowing for a comparison of the modal share of all major transport modes.
Rail passenger traffic is mostly domestic: In 2018 only 7 % of rail passenger kilometres (pkm) were linked to rail journeys across borders.[13] In 2019, rail passenger traffic volumes in the 27 EU Member States accounted for nearly 421 billion (pkm) out of around 6 trillion pkm for land transport overall. The modal split of passenger transport for 2019 in the EU demonstrates, likewise, that **citizens travel far more by road than by rail**.[14] It links passenger rail to a modal share of 7 %, while passenger cars had the greatest modal share with 71.5 %, followed by air transport (9.7 % - only national and intra-EU), and busses and coaches (8.1 %). Noticeably, the modal share of intra-European passenger air transport has increased steadily since 2000 (with some minor exceptions, such as a period of stagnation in 2012-2013), while the modal share of rail has been generally stable in this period, fluctuating between 6.5 % and 7.0 % over the two decades.[15] Intra-European air transport is expected to increase further over time,[16] indicating a lower take-up of high-speed and cross-border rail services.
Rail freight transport is mostly transnational.[17] In 2019, rail freight traffic volumes in the 27 EU Member States accounted for nearly 408 billion tonne kilometres (tkm) out of around 3.4 trillion tkm of transport overall (including transport by road, sea, inland waterways, air, and pipelines). **The EU modal split of freight transport for 2019 links rail freight to a modal share of 12 %, while road freight transport had the highest modal share with 52 %**, followed by sea transport (28.8 % - only domestic and intra-EU). The modal share of inland waterways (4.1 %), pipelines (3 %), and air (0.1 %) was significantly lower than that of rail freight in 2019.[18] Historical data reveal that the modal share of rail freight has generally

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12 Seventh monitoring report on the development of the rail market, COM(2021) 5, European Commission, January 2021.

13 This is the latest available data mapping the share of pkm linked to cross-border journeys among all rail pkm. Source: ibid.

14 Data for 2019 are used even though the latest available data covers 2020. This is due to the fact that transport demand across transport modes was significantly and unusually reduced in 2020 due to the Covid-19 pandemic and its impact, including lockdowns and other restrictions. Source: Statistical Pocketbook 2022: EU transport in figures, European Commission, September 2022.

15 Statistical Pocketbook 2022: EU transport in figures, European Commission, September 2022.

16 Air Passenger Numbers to Recover in 2024, IATA, March 2022.

17 In 2018 more than half of total rail freight was across borders. Source: Seventh monitoring report on the development of the rail market, COM(2021) 5, European Commission, January 2021.

18 Statistical Pocketbook 2022: EU transport in figures, European Commission, September 2022. Data for 2019 is used even though the latest available data covers 2020. This is due to the fact that freight transport demand was significantly and

declined in the past two decades, falling from 14.1 % in 2000 to 12 % in 2019. For comparison, the modal share of road freight increased from 46.9 % to 52 % in the same period.[19]
Furthermore, one effect of the COVID-19 pandemic was a decrease of the demand for transport, including rail transport, with passenger transport being particularly affected by restrictions on international and domestic travel.[20] However, statistical data covering the period 2000-2020 clearly show that impacts of the pandemic have not significantly changed the balance between the transport modes, neither in terms of freight nor passenger transport.[21] In contrast, Russia's invasion of Ukraine in 2022 could be seen to have a negative influence on the freight volumes transported by EU rail, while no negative effects on have been registered. Ukrainian goods, which used to be shipped by maritime routes, had to be moved onto rails, which resulted in bottlenecks (this situation is described in more detail in section 3.3.2, as it provides part of the backdrop for the scenario 'EU bans new combustion engines'). Moreover, due to EU sanctions, freight trains operating between China and the EU were no longer able to stop in Russia, while the logistics companies running these trains tried to avoid transit through Russia for security reasons. This contributed to extended use of the 'Middle Corridor'[22] as an alternative route, in part resulting in longer journeys and supplementary costs.[23]

Key challenges for the rail sector

Rail's modal share in transport has remained significantly low in the past two decades (see section 1.1.1), which is a challenge for the EU. **Rail is generally recognised as the most environmentally friendly form of mass passenger transport, and the second most sustainable transport option for freight transport** surpassed only by shipping. This is due to a range of factors, including widespread use of electric traction, relatively low energy consumption, and low levels of atmospheric emissions compared to road and air transport.[24] Therefore, boosting rail freight and passenger transport is seen by EU policymakers as necessary to achieve a more sustainable European transport system.

unusually reduced in 2020 due to the Covid-19 pandemic and its impact, including lockdowns and other restrictions, leading, for example, to the shutdown of production facilities.

19 ibid.

20 Impacts of the COVID-19 crisis and national responses on European railway markets in 2020, IRG – rail, July 2021; Relaunching transport and tourism in the EU after COVID-19 – Part VI: Public Transport, European Parliament, February 2022.

21 Freight transport statistics - modal split, Eurostat, April 2022; Modal split of passenger transport, Eurostat, July 2022; Statistical Pocketbook 2022: EU transport in figures, European Commission, September 2022.

22 From China to Kazakhstan, over the Caspian Sea to Azerbaijan, from there through Georgia to Izmit and eventually Istanbul in Turkey. In Istanbul, the cargo is reloaded onto other vessels to go to Trieste.

23 Russia's war on Ukraine: Implications for transport, Briefing, European Parliament, June 2022.

24 Rail 2050 Vision: Rail - the Backbone of Europe's Mobility, ERRAC, 2017; Transport and environmental report, European Environment Agency, 2022.

Text box 1: Greenhouse gas efficiency of rail for passenger and freight transport

Passenger transport: rail has the greatest greenhouse gas (GHG) efficiency of all motorised passenger travel.[25] The average GHG emission of passenger flights per passenger kilometre (pkm), for instance, is almost five times higher than the equivalent for passenger rail, followed by passenger cars (4.3 times higher), buses and coaches (2.4 times higher), as well as motorised maritime transport (1.8 times higher).[26]

Freight transport: Maritime shipping has the highest GHG efficiency among all motorised freight transport modes with rail (not far behind) in second place. The average GHG emission per tonne kilometre of heavy-goods vehicles is almost six times higher than the equivalent for rail freight, with the respective average for air cargo being more than 43 times higher.[27]

However, the overall picture is more nuanced. A report from 2018 stated that 60 % of the European rail network's main lines, which accommodate 80 % of European rail traffic, are electrified.[28] This means that **the environmental sustainability of rail transport greatly depends on the carbon intensity of the EU's electricity mix**. When comparing the sustainability of different transport modes, it is also relevant to look at the external costs linked to them and to what degree the individual transport modes cover these. While rail has a relative green profile in terms of GHG efficiency, **it tends to be more expensive compared to other transport modes**.

A reason for this is that external costs (e.g., accidents, air pollution, noise, congestion, and habitat damage) are not reflected equally in user costs across transport modes.[29] A study from 2019 presented the infrastructure and external costs linked to different transport modes, while also mapping the extent to which each transport mode internalises external costs.[30] Key indicators are highlighted in the text box below.

Text box 2: Average external costs and coverage ratio - passenger and freight transport

[25] The stated greenhouse gas calculations are based on the well-to-wheel principle, meaning they cover emissions from energy production/transmission/distribution as well as emissions from the driving phase, i.e., fuel combustion in vehicles.

[26] Passenger rail is linked to 33 gCO_2e per pkm (meaning the average emission linked to moving one passenger one kilometre calculated in grams of CO_2 equivalent), passenger flights to 160 gCO_2e per pkm, passenger cars to 143 gCO_2e per pkm, buses and coaches to 80 gCO2e per pkm, and motorised maritime transport to 61 gCO_2e per pkm. Source: Decarbonising road transport — the role of vehicles, fuels and transport demand, Report, European Environment Agency, June 2022.

[27] Maritime freight transport is linked to 7 gCO_2e per tkm (meaning the average emission linked to moving a payload of one tonne a distance of one kilometre), rail freight to 24 gCO_2e per tkm, inland-waterways transport to 33 gCO_2e per tkm, heavy-goods vehicles to 137 gCO_2e per tkm, and air cargo to 1036 gCO_2e per tkm. Source: ibid.

[28] Electrification of the transport system, European Commission, January 2018.

[29] Ruete, Challenges for European Rail - Getting Solutions on Track, Jacques Delors Institute, 29 March 2021.

[30] Sustainable transport infrastructure charging and internalisation of transport externalities, European Commission, 10 July 2019. The study presents data for EU28 covering 2016.

Passenger transport: The average external cost of passenger rail varied from 1.3 EUR-cent per pkm (high-speed trains), to 2.6 EUR-cent/pkm (electric trains), and 3.9 EUR-cent/pkm (diesel trains). In comparison, the average external costs of aircraft (3.4 EUR-cent/pkm) as well as buses and coaches (3.6 EUR-cent/pkm) were lower than those of diesel passenger trains. In contrast, passenger cars were linked to an average external cost of 12 EUR-cent/pkm.[31] There are significant differences regarding the coverage ratio of these transport modes.[32] In 2016, users of electric passenger trains paid for 61 % of the transport mode's external costs through taxes and charges. For diesel passenger trains, the respective share was 91 % and for high-speed trains 145 %. Users of passenger cars (63 %) and aircraft covered external costs to a much smaller degree (45 %).[33]

Freight transport: Electric freight trains were linked to average external costs of 1.1 EUR-cent/tkm and diesel freight trains to 1.8 EUR-cent/tkm. In contrast, heavy goods vehicles stood for significantly higher average external costs with 4.2 EUR-cent/tkm, also when compared to inland-waterways (1.9 EUR-cent/tkm) and maritime (0.7 EUR-cent/tkm) vessels.[34] The coverage ratio of freight rail was between 30 % (electric freight trains) and 55 % (diesel freight trains), while heavy goods vehicles – responsible for more than three quarters of EU road freight in tonne-kilometres[35] – had a coverage ratio of 37 %. The coverage ratio of inland-waterways (12 %) and maritime (4 %) vessels were much lower.[36]

The data presented in the text box above underlines that **the principle of 'polluter pays' – a key basis for EU environmental policy – is not implemented in transport pricing.**

With the European Green Deal, the EU has pledged to reduce its transport-related greenhouse gas (GHG) emissions by 90 % by 2050.[37] To help deliver on this target, the European Commission has defined specific milestones for a **modal shift to rail**, as further outlined in section 1.2. The Commission has likewise underlined the urgent need to increase the number of rail passengers and to shift a substantial amount of freight – today 75 % of inland freight is carried by road[38] – onto rail and inland waterways.[39]

To achieve these strategic goals, the railway sector must become more competitive and undergo a transformation, as underlined in the Multi-annual Work Programme of Europe's Rail Joint Undertaking.[40] One of the requirements is to **increase the capacity for passenger and freight transport**. For passenger rail, boosting the provision of international passenger rail services, could serve to enable more international travellers to take the train.[41] To increase the rail sector's capacity for freight transport, additional issues, such as congested tracks around large

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31 Ibid.

32 The following data refer to the extent to which different transport modes cover their external costs (their coverage ratio). They represent the overall cost coverage excluding fixed infrastructure costs and are derived by comparing revenues from all taxes/charges with all external and variable infrastructure costs.

33 Sustainable transport infrastructure charging and internalisation of transport externalities, European Commission, 10 July 2019.

34 ibid.

35 Goods vehicle stock in reporting countries, 2021 (thousand), Eurostat, n.d.

36 See footnote 31 for an explanation of *coverage ratio.* Source: Sustainable transport infrastructure charging and internalisation of transport externalities, European Commission, July 2019. Data presented refers to EU28, covering 2016. No comparative data available for air freight transport.

37 Communication on the European Green Deal, COM(2019) 640, European Commission, December 2019.

38 Fostering the Railway Sector Through the European Green Deal, Part 2 - Freight, European Union Agency for Railways, May 2021.

39 Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

40 Europe's Rail Joint Undertaking Multi-Work Programme, EU-Rail, March 2022.

41 Witlox et al., Changing tracks: identifying and tackling bottlenecks in European rail passenger transport, 2022.

cities or a lack of coordination regarding track access rights between operators in different countries, must be addressed.[42]

For both international freight and passenger transport, **barriers to interoperability** may cause technical issues at borders. Such barriers include the use of 30 different national rail signalling systems across the EU as well as different rail gauges. To address this issue, the EU and rail stakeholders have been working, for the past thirty years, on the development and deployment of the European Rail Traffic Management System (ERTMS) to implement a single, harmonised control, command, signalling, and communication system that is fully interoperable across borders in the EU rail system.[43] However, progress reports and other assessments by the European Commission highlight that the deployment of the ERTMS is significantly delayed and has to happen at a much faster pace going forward (in 2019, it was deployed on 16 % of the core network corridors only, which is far from the objective of 100 % by 2030). While plans are in place to boost deployment until 2030, slow progress with the ERTMS hinders increases in terms of interoperability and rail capacity.[44]

Another challenge is the use of rail gauges that differ from the UIC Standard adopted by most Member States in seven EU countries.[45] Switching from one gauge to another can be costly in time and infrastructure, as it requires either the transhipping of goods and passengers from one train to another or the repositioning of the train cars' wheels, which requires dedicated machinery.[46] Since passenger and freight trains share much of the same rail network, a **combination of infrastructure investments and advanced technological solutions is needed to accommodate simultaneous growth in passenger and freight rail capacity**. In some areas, the physical expansion of the rail network will be necessary. This also includes the need to enhance the network for better resilience (e.g., by providing redundancy to ensure that there are alternative paths if one rail corridor is closed due to a temporary disruption).[47] However, since the EU already has one of the densest railway networks in the world, part of the solution could be a more efficient use of the existing infrastructure through digitalisation and automation of the rail sector (see section 1.1.3 for examples).[48]

Furthermore, **the services offered by the rail sector must be more customer-oriented,** meaning that they are able to react to demand, adapt to customer requests, and are equally accessible to all customers. The flexibility of rail services is hindered by a long planning horizon. Rail freight operators are particularly affected, having difficulties answering to ad hoc

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42 Florence School of Regulation - Transport Area, The Governance of Rail Freight Corridors, European Transport Regulation Observer, January 2021.

43 ERTMS: Making the railway system work better for society, European Union Agency for Railways, 2016; ERTMS: What is ERTMS about, European Commission, n.d.; History of ERTMS, European Commission, n.d.

44 Impact Assessment Report accompanying the document Proposal for a Regulation of the European Parliament and of the Council on Union Guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, SWD(2021) 472, European Commission, December 2021; Progress report on the implementation of the trans-European transport network in 2018 and 2019, COM(2021) 818, European Commission, December 2021.

45 Finland, Estonia, Latvia, and Lithuania use the 1,520 mm Russian standard; Ireland uses the 1,600 mm standard; and Portugal and Spain use the 1,668 Iberian standard—as opposed to the 1,435 mm international standard used in the rest of Europe, as well as the US, China, and several other regions in the world. Source: Switching to European track gauge would cost €8.7 billion, ERR, September 2022.

46 Digitalisation in railway transport: A lever to improve rail competitiveness, European Parliament, February 2019; de Kemmeter, What are the consequences of Europe's different railway gauges?, 21April 2022.

47 This point was raised by one of the interviewed national rail attachés. See also: Reeves et al., Rail: An industry guide to enhancing resilience - Resilience Primer, May 2019.

48 Digitalisation in railway transport: A lever to improve rail competitiveness, European Parliament, February 2019; Europe's Rail Joint Undertaking Multi-Annual Work Programme, EU-Rail, 1 March 2022.

demands for freight as they must book train paths approximately one year in advance with the infrastructure managers who set the timetable.[49]

There is also a need to **better integrate rail networks and their associated services with other transport modes** if rail is to become a more attractive transport choice for passengers and freight customers. Travelling by rail often entails the use of other modes of transport, such as buses or other forms of public transport to reach train stations or to complete the 'last mile' on a planned journey. However, intermodal transport is often slower and less reliable than unimodal road transport. The differing costs of transport modes discussed above are part of the problem, while the absence of relevant terminal infrastructure and a low level of investment in digital solutions to streamline the management of multimodal transport flows also hinder intermodality and thus the use of rails.[50]

Finally, **the rail sector faces a social challenge**. A large share of its workforce is expected to retire before 2030. At the same time, the sector is experiencing a severe skill shortage, since there is a rising demand for skills that can help drive the technological developments needed for the digital and green transition of European rail. It is thus important to increase the attractiveness of the sector to get young people and those seeking a change in career to join its workforce. Initiatives to get more women to join the rail sector – which has traditionally been very male-dominated – are part of ongoing efforts to bolster the rail sector's workforce. As emphasised by rail stakeholders, such efforts must go together with the upskilling and reskilling of existing human capital to ensure a workforce that can make use of research and innovation to create a more competitive, user-oriented, efficient, and sustainable European rail system.[51]

Technologies for the green and digital transformation of rail

Technological advancements have promise to address many of the rail sector's challenges. The Joint Research Centre (JRC) of the Commission describes in its latest foresight report on the twin transitions, [52] how transport demand and services may change until 2050 and what technologies are expected to play a key role in this context. According to the report, **road passenger transport is expected to grow by roughly 21 % and road freight by 45 % by 2050,** despite ongoing efforts in favour of a modal shift from road to rail and waterborne transport. Other factors expected to impact transport in the coming decades include urbanisation, evolving costs of sustainable transport options, and new business models (particularly in terms of supply chain management). With this in mind, the **digitalisation of the transport sector** is highlighted in the report as an essential step towards greater sustainability. Combining digital technologies with next-generation battery systems, for instance, is foreseen to enable the greater electrification of various modes of transport for both passengers and freight. Pairing digital solutions with artificial intelligence is expected to pave the way for more efficient multimodal mobility solutions. This entails the creation of digital solutions promoting 'mobility as a service' by combining all modes of transport in a single, interoperable platform allowing users to plan, book, and pay for different transport options, including journeys involving the seamless transfer from one modal choice to another.[53]

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49 Rail freight transport in the EU: still not on the right track, European Court of Auditors, May 2016; Europe's Rail Joint Undertaking Multi-Annual Work Programme, EU-Rail, 1 March 2022.

50 ibid.; Future EU transport must tap into the potential of intermodality, European Economic and Social Committee, July 2021.

51 European Erasmus+ project to train skills for the future of railways, Staffer – European Rail Skills Alliance, n.d.; Skills, Unife – The European Rail Industry, n.d.

52 2022 Strategic Foresight Report: Twinning the green and digital transitions in the new geopolitical context, COM(2022) 289, European Commission, June 2022.

53 ibid.

When it comes to more specific rail technologies, a prominent example is the deployment of the aforementioned **European rail traffic management system (ERTMS)**. The major industrial project (with origins in the 1990s) aims to establish a single standard for railway signalling in Europe.[54] EU's ambition is to have ERTMS deployed on the core rail network by 2030 and across the entire EU network by 2050.[55] However, in 2020, the roll-out was roughly 20 % behind schedule. At this pace, the ERTMS will be completely installed in the core network in approximately 2033 and across the entire network by 2058.[56] The widespread deployment of ERTMS promises **several benefits for European rails**: It will increase safety levels; make it possible to reduce the minimum distance or time between trains, thus increasing capacity; make disruptive failures less likely, increasing train punctuality; and lay the foundation for automated train operation.[57] It has also been decided to phase out GSM-R in the next decade and replace it with a new radio transmission subsystem called Future Railway Mobile Communication System (FRMCS).

The **FRMCS** is a 5G-based system that makes it possible to send large volumes of data with significantly faster response times through the network. The FRMCS is, therefore, described as a key-enabler for the digitalisation of rail. It extends possibilities in terms of installing communication devices and sensors on trains, which can provide fast and reliable data to control centres, for example, in connection with the real-time monitoring of all on-board systems. This advanced connectivity is an essential requirement for the safe and efficient operation of driverless trains, with the automated or remote operation of trains being highlighted as part of the answer to the rail sector's challenge of an ageing workforce.[58]

Driverless trains have the potential deliver additional benefits, including a significant boost to network capacity. Since automated trains allow for further reduction of the minimum distance or time between trains, more passengers and freight can be transported by rail at the same time. The concept of **'virtual coupling'**, which is gradually gaining traction within the railway industry, is about maximising this potential. The idea builds on the wireless exchange of information between trains regarding their speed, location, and heading. Thanks to this vehicle-to-vehicle communication, trains could be separated by less than an absolute breaking distance and may even form connected platoons, which could help increase capacity at bottlenecks in the rail network.[59] Another technology that can be mentioned here is **'Digital Automatic Coupling' (DAC)**. It is an innovative approach to the automatic coupling and decoupling of the rolling stock in a freight train, both in a physical sense (i.e., establishing the mechanical connection and air line for braking) as well as digitally (i.e., securing electrical power and data connection). The DAC system is to be installed in all relevant freight wagons by the end of 2030 to replace manual coupling/decoupling and allow for a faster and more efficient creation and modification of freight trains.[60]

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54 ERTMS: What is ERTMS about, European Commission, n.d.; History of ERTMS, European Commission, n.d.; European Rail Traffic Management System (ERTMS), Railway Technology, 28 May 2021.

55 EU Commission: deployment ERTMS is behind on schedule, RailTech.com, 27 January 2021.

56 Calculation based on the delays reported in ibid.

57 What are the benefits?, European Commission, n.d.; Preparing future evolution, European Commission, n.d.

58 Future Railway Mobile Communication System, UIC, 2021; Oberle, K., Building digital railways with 5G and FRMCS, Railway International, 10 June 2021.

59 Driverless Trains: On Track for a Rail Revolution, SNCF, n.d.; Quanglietta et al., Modelling and analysis of Virtual Coupling with dynamic safety margin considering risk factors in railway operations, Journal of Rail Transport Planning & Management, June 2022.

60 Digital Automatic Coupling – Delivery programme, European DAC Delivery Programme, n.d.

Automated train operation is also linked to **greater energy-efficiency**, as the underlying monitoring and control systems, for example, can anticipate upcoming events (such as curves or slow traffic) and adapt train movement and speed accordingly.[61]
The integration of trains into **intelligent energy management systems**, for instance, involving optimised on-board and line-side energy storage, as well as the distribution of energy according to supply and demand, is another technological development, which is expected to increase the energy efficiency of rail in the future.[62] To this end, rolling stock can be introduced or upgraded to recover energy through regenerative breaking, while railway stations and networks can be integrated into the wider energy supply sector for renewable energy.[63]
The **digitalisation of rail is expected to have a positive impact on the transport mode's attractiveness and open it to a wide range of new business models**, thanks to the inherent increase in data production and availability. Relevant technological advancements, such as the FRMCS and its combination with monitoring and other connected devices, for example, are foreseen to lead to better planning, tracking and shipment information capabilities. More real-time data on train position, speed, passenger capacity, and expected times of arrival can feed into applications for mobility as a service, allowing passengers to plan their journeys more accurately. At the same time, rail operators can use remote monitoring and real-time diagnostics for preventive maintenance of rolling stock, while rail freight customers can be provided with insights into the current location of their transported goods and the movements of the freight train carrying them forward.[64]
A final consideration relates to **hydrogen-powered trains**, of which some are already in operation in Germany for **passenger rail**. The technology is also being tested in Austria, the Netherlands, Poland, and Sweden.[65] Hydrogen-powered trains have several advantages. Their energy use does not lead to CO_2 emissions, as the conversion of hydrogen to electricity in the internal fuel cell only has steam and condensed water as biproducts. Additionally, hydrogen-powered trains can be deployed on existing non-electrified rails (these include 40 % of the European rail network's main lines).[66] However, their overall environmental impact depends on the energy sources used to produce the needed hydrogen. Overall, GHG emissions are lower if renewable energy sources, such as solar and wind energy, are used for this purpose.[67] However, so called green hydrogen coming from renewable electricity is still not deployed at scale in Europe and its cost remains high. Whether hydrogen-powered trains will be more economically viable and energy-efficient in the future will partly depend on how the cost of green hydrogen develops and the levels of its production in the overall power supply. Technological advances, such as increases in fuel cell and battery capacities could also be decisive factors.[68] The wider deployment of hydrogen-powered trains, as well as other transport modes using alternative fuels, will also depend on the development of relevant

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61 Vahidi, A. and Sciarretta, A., Energy saving potentials of connected and automated vehicles, Transportation Research Part C: Emerging Technologies, 2018.

62 Feng et al., Electric railway smart microgrid system with integration of multiple energy systems and power-quality improvement, Electric Power Systems Research, 2021.

63 Regenerative braking in trains, UN Climate Technology Centre & Network, n.d.; Kirby, European Trains Go Down Renewable Route, Our World, 16 February 2016.

64 Digitalisation in railway transport, European Parliamentary Research Service, February 2019.

65 Buckley, J., The world's first hydrogen-powered passenger trains are here, CNN travel, August 2022.

66 See footnote 28.

67 Kuta, Hydrogen-Powered Passenger Trains Are Now Running in Germany, Smithsonian Magazine, 7 September 2022.

68 Logan et al., Electric and hydrogen rail: Potential contribution to net zero in the UK, Transportation Research Part D: Transport and Environment, 2020.

infrastructure, such as recharging and refuelling stations.[69] Hydrogen-powered **freight** trains have not yet been implemented. Freight trains are generally much heavier than passenger trains, and this would require more fuel cells on board to propel the train, which would take up more space and thus be less economical.[70] Therefore, in 2022, hydrogen-powered trains are mostly relevant for passenger rail, for example, to link non-electrified lines (in places where rail electrification is very expensive) to the wider rail network.[71] With more and more rails being electrified in the EU, this area of application is shrinking. **Although hydrogen-powered trains are unlikely to play a dominant role in the future European rail network, they are (together with battery-electric) still a viable alternative to diesel-powered trains.**

1.2. Rail transport policies

EU action on rail contributes to the policy objectives for the transport sector overall, which seeks to achieve connected, inclusive, safe, and sustainable mobility within the EU. Since the 1990s, there have been efforts by the EU and its Member States to develop a common rail policy with the goal of creating a **single European railway area**. This is to be achieved by increasing compatibility between Member States' different national railway systems and developing an efficient and competitive European railway network. In support of this overarching goal, **four legislative railway packages were adopted between 2001 and 2016**.[72] They aimed to gradually open rail transport service markets to competition to increase the interoperability of national railway systems, and to define the framework conditions for a single European railway area. The four railway packages covered a wide range of aspects, including the granting of licenses to railway undertakings, charging and capacity allocation rules, the creation of the European Agency for railways and rail regulatory bodies in each Member State, as well as passenger rights and the certification of train crews.[73] Following a Commission proposal in 2017, the legal framework for passenger rights was updated further with a dedicated regulation by the European Parliament and the Council, which came into force in 2021.[74]
As described in section 1.1.2, there continues to be a range of challenges that need to be addressed to ensure the transformation of the rail sector in support of a more efficient and sustainable European transport system. These challenges underline **the need for further EU policy action on rail**, such as initiatives to help promote infrastructure investments and technological solutions that increase rail capacity, or measures to better integrate rail networks and their associated services with other transport modes (e.g., mobility as a service).
At a more general level, there is a need for policy initiatives in support of the overall strategic goal of reducing transport-related greenhouse gas (GHG) emissions in the EU by 90 % by 2050.[75] On this basis, the European Commission under President von der Leyen released its **Sustainable and Smart Mobility Strategy (SSMS)** in December 2020. The strategy is meant to guide the development of the European transport sector and help bring about its green and

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69 See for example, Post et al., A solution approach for deriving alternative fuel station infrastructure requirements, Flexible Services and Manufacturing Journal, 21 April 2017.

70 Gaspar and Esmanhoto, Hydrogen trains – Is it a sustainable option for freight transport?, Shaping Future, 20 December 2021. See also Shirres, Could hydrogen trains be the future of Rail, Institution of Mechanical Engineers, 29 October 2018.

71 ibid.

72 Railway Packages, European Commission, n.d.

73 ibid; Building the single European railway area, European Council, 2021.

74 Regulation (EU) 2021/782 of the European Parliament and of the Council of 29 April 2021 on rail passengers' rights and obligations (recast); A further revision of the framework is set to be adopted by the Commission in the second quarter of 2023.

75 Communication on the European Green Deal, COM(2019) 640, European Commission, December 2019.

digital transformation. As mentioned previously, it sets out specific targets for the boosting of rail transport. They include the doubling of traffic on high-speed passenger rail by 2030 and its tripling by 2050, while the aim is to increase rail freight traffic by 50 % by 2030 and double it by 2050.[76]

The SSMS is structured according to three themes and ten key actions – the so-called 'flagships' – of which seven are related to rail transport. Table 1 offers an overview of these flagships and their key elements with respect to rail transport:

Table 1: Sustainable and Smart Mobility Strategy - overview with flagships and key elements pertaining to rail

	Flagship	Key elements pertaining to rail
Sustainable mobility	#3 Making interurban and urban mobility more sustainable and healthy	**Development of high-speed rail services** on short-haul distances to promote the availability of carbon-neutral choices for scheduled collective travel under 500 km within the EU by 2030. Action to **boost long-distance and cross-border passenger rail** services with the aim of making key connections between cities faster through more efficient use of existing rolling stock, and infrastructure improvements in favour of new train services including at night. Focus on **multimodal and cross-border tickets**: The introduction of innovative and flexible tickets is meant to promote multimodality and provide travellers with easy access to door-to-door travel options. To support multimodal travel, the initiative calls for **new and innovative digital solutions** allowing users to plan, book, and pay for various types of mobility via a single digital channel.
	#4 Greening freight transport	A substantial amount of inland road freight to be shifted to rail and inland waterways. The development of **multimodal logistics for delivery** within, and beyond, urban areas is to support this transformation. **Improving rail freight capacity and management** by strengthening cross-border co-operation between rail infrastructure managers, revising regulation governing Rail Freight Corridors and the TEN-T core network to create 'European Transport Corridors', and deploying new technologies. **Reinforcing economic incentives for transport** users to make more sustainable choices, e.g., carbon pricing and infrastructure charging.
Smart mobility	#6 Making connected and automated multimodal mobility a reality	Realising the potential of **smart digital solutions and intelligent transport systems** (ITS) with a focus on creating a functioning multimodal system. Revision of EU legislation to allow for the development of smart and integrated, multimodal information, ticketing, and payment services. Continued focus on the **deployment of the European Rail Management System** (ERTMS) in favour of efficient capacity

[76] Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

		allocation and traffic management, including the **update of technical specifications** for cross-border interoperability.
	#7 Innovation, data, and artificial intelligence for smarter mobility	Driving the research and development of innovative and sustainable transport technologies, such as hyperloop and autonomous vehicles. Focus on **enhancing the digital infrastructure** (e.g., IoT-technology) to realise the potential of **artificial intelligence** as a key component of a smart transport system. Development of a **European Common Mobility Data Space** to ensure that the data needed to meet EU objectives on transports – from multimodality to sustainability – can be collected, accessed, and exchanged.
Resilient mobility	#8 Reinforcing the single market	Call for **substantial public and private investments in transport infrastructure and vehicles** (such as rolling stock and its modernisation), including the **completion of the TEN-T core network** and its transformation into a truly multimodal system. Ensuring that these investments are coordinated and prioritised within EU funding programs (NextGenerationEU recovery instrument and others). **State aid rules for railways are to be reviewed** to enhance the already flexible framework for public funding of multimodality to address mobility needs and incentivise different multimodal options. Support of **strategic value chains** securing supply of materials and technologies essential for the development of a smart and sustainable mobility system, helping to avoid EU dependency on external suppliers.
	#9 Making mobility fair and just for all	Promote **affordable, accessible, and fair mobility** for passengers and other users of transport services. In support of fair mobility, **passengers (and their rights) are to be better protected** with the Commission considering a simplified and harmonised multimodal framework for passenger rights. Focus on **improving the working conditions of transport workers** (including considerations to introduce measures strengthening the existing legal framework on these conditions and calls for a just transition for transport workers, e.g., in light of growing automation within transport).
	#10 Enhancing transport safety and security	To **upgrade high-risk infrastructure**, measures to **update and improve the existing security framework** (to address risks such as cyberthreats and boost security of network and information systems) will be introduced.

Source: European Commission, 2020a & authors' elaboration.

Table 1 clearly illustrates the EU's intention to implement a wide range of initiatives to address the rail sector's complex challenges (see section 1.1.3). **Rail is to be fully integrated into a smart, efficient, sustainable, and resilient multimodal EU transport system.** The SSMS sets strategic milestones for the boosting of passenger and freight rail transport, as outlined

earlier, while also proposing specific actions on how to reach these.[77] In the Annex to the Sustainable and Smart Mobility Strategy,[78] **the Commission has outlined 82 policy actions to be taken until 2024**, including the revision of existing legislation and the introduction of new legislation to deliver on the strategy's flagship initiatives.

To date, the Von der Leyen Commission has put forward **two packages of proposals in support of the European transport system**. The first one was adopted in April 2020 and covers policy measures aimed to provide relief to aviation, inland navigation, maritime, rail, and road sectors. They were all negatively affected by increased administrative burdens and travel restrictions following the outbreak of COVID-19 in Europe.[79] The second package of proposals, adopted in December 2021, is primarily about rail transport and follows up on a range of proposed actions in the SSMS. It includes a proposal for revising the Union guidelines for the development of the trans-European transport network (TEN-T), a Communication on the new EU urban mobility framework, a proposal for the amendment of the legal framework for the deployment of Intelligent Transport Systems[80], and an Action Plan to boost long-distance and cross-border passenger rail.[81]

A **third package of proposals** was under way at the time of conducting this research. It includes a legislative proposal on international freight and passenger transport (to increase the share of cross-border rail traffic), a revision of the Combined Transport Directive (to support the shift from road freight to lower emission transport modes), a revision of the Train Drivers Directive (to enhance cross-border mobility of train drivers), a proposal promoting multimodal digital mobility services (to integrate public transport and rail services in favour of a multimodal mobility system), as well as a revision of the Directive on Deployment of Alternative Fuels Infrastructure (to ensure swift and coherent deployment of recharging and alternative refuelling stations for transport, including rail).[82] According to the Commission's work programme 2023, the plan is for most of these proposals to be adopted in the second quarter of 2023 – with two exceptions. The Directive on Deployment of Alternative Fuels Infrastructure is listed as a 'priority pending proposal' without a defined date for adoption, while the revision of the Train Drivers Directive is not mentioned at all in the work programme.[83]

1.3. Other EU measures with relevance for the rail sector

[77] Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

[78] Annex to the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

[79] Coronavirus: package of measures to support transport sector, European Commission, April 2020.

[80] Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, COM(2021) 813, European Commission, December 2021.

[81] Proposal for a Regulation on Union guidelines for the development of the trans-European transport network, COM(2021) 812, European Commission, December 2021; Communication on The New EU Urban Mobility Framework, COM(2021) 811, European Commission, December 2021; Communication on Action plan to boost long distance and cross-border passenger rail, COM(2021) 810, European Commission, December 2021.

[82] European Parliament, initiatives on: International freight and passenger transport, n.d.; Sustainable transport – revision of Combined Transport Directive, n.d.; Revision of the Directive on the certification of train drivers, n.d.; Multimodal digital mobility services, n.d.; Regarding the Directive on Deployment of Alternative Fuels Infrastructure, see: Revision of the Directive on Deployment of Alternative Fuels Infrastructure, Legislative Train Schedule, European Parliament, November 2022 and EU Parliament throws weight behind alternative fuels infrastructure for railway, RailTech.com, 20 October 2022.

[83] Annexes to the Communication on the Commission work programme 2023, COM(2022) 584, European Commission, October 2022.

Since the operation of rail infrastructure and rolling stock is not possible without energy supply, it is relevant to highlight **EU climate and energy policies**. These policies generally aim **to diversify Europe's sources of energy and reduce dependency on energy imports** to ensure the functioning of the internal energy market, as well as improve energy efficiency by decarbonising the economy and promoting low-carbon and clean energy technologies.[84] In support of the European Green Deal, the Von der Leyen Commission has presented the 'fit for 55' package[85] in July 2021. Designed to realise EU climate objectives, such as the 55 % reduction of net GHG emissions by 2030 (compared with 1990 levels), it consists of 13 interlinked proposals to revise existing EU climate and energy laws, as well as six proposals for the introduction of new legislation. The package includes, for instance, targeted efforts to include the maritime and road transport sectors in the EU Emissions Trading System, thereby **helping to level the playing field in terms of the coverage of external costs by different transport modes** which was discussed in section 1.1.2.[86] An integral part of the 'fit for 55' package is the proposal to review the Energy Taxation Directive, which partly aims to raise the price of GHG emissions in the transport sector by introducing a new structure of tax rates on fuels and electricity.[87] Given rail's relatively high GHG efficiency (see section 1.1.2), these **measures can be expected to increase the competitiveness of rail** compared to more polluting transport modes.

Also of relevance is the European Commission's proposal for a Revision of the Renewable Energy Directive, which is meant to accelerate the uptake of renewable energy in Europe by **setting a common target of 40 % for the share of renewable energy in the EU's energy consumption by 2030**. The proposed revision also strengthens measures for renewables' uptake in transport and introduces a credit mechanism to promote electromobility.[88]

The Commission sought to increase this target further in March 2022 in light of disruptions of the global energy market following Russia's invasion of Ukraine[89]. However, the Council of the EU adopted an approach, in 2022, that supports the original 40 % share of the renewable energy target. In regard to transport, this approach **would give Member States the option of choosing between a 13 % reduction in the national transport sector's GHG emission intensity or a 29 % share of renewable energy** measured in the final energy consumption by the national transport system by 2030.[90]

In the wake of the COVID-19 pandemic, **the EU adopted a Recovery and Resilience Plan called NextGenerationEU (NGEU)** in February 2021 to aid Member States' recovery from the impact of the pandemic and to stimulate national investments in line with EU policy

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84 Energy policy: general principles, European Parliament, 2022.

85 Fit for 55 Package, European Parliament, June 2022.

86 Fit for 55 Package, European Parliament, June 2022.

87 Proposal for a Council Directive restructuring the Union framework for the taxation of energy products and electricity (recast), COM(2021) 563, European Commission, July 2021. The proposal also aims to ensure that kerosene used as fuel in the aviation industry and heavy oil used in the maritime industry are no longer fully exempt from energy taxation for intra-EU transport.

88 Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652, COM(2021) 557, European Commission, July 2021.

89 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, REPowerEU Plan, COM(2022) 230, European Commission, May 2022. The Commission presented its REPowerEU plan in March 2022, which aims to increase Europe's energy independence from unreliable suppliers and volatile fossil fuels. According to the proposal, this is to be achieved by accelerating the transition to clean energy, and the Commission proposed to increase the EU's 2030 target for renewable energy from 40 % to 45 %.

90 Revision of the Renewable Energy Directive, Legislative Train Schedule, European Parliament, October 2022.

priorities.[91] The Recovery and Resilience Facility (RRF)[92] under the NGEU provides a total allocated amount of €723.8 billion to be dispersed among Member States who are required to dedicate at least 37 % of their allocation from the RRF to measures contributing to EU climate objectives.[93] In its first annual report on the RRF, the Commission highlighted that investments in sustainable mobility accounted for 32 % of the total expenditures under the facility's green transition pillar (a total of €71.3 billion). These measures include large investments to upgrade and extend national railway infrastructure by different Member States, such as France, Italy, and Romania.[94]

Another important funding instrument that can support investments in the rail system is the **Connecting Europe Facility (CEF)**. In its latest iteration, the CEF for the period 2021-2027 was adopted in July 2021 with an overall budget of €33.71 billion and the aim **to support infrastructure investments across the EU in transport, digital, and energy projects**. With €25.81 billion, the largest share of the CEF 2021-2027 is dedicated to the transport sector and earmarked to promote interconnected and multimodal networks by developing and modernising rail, road, inland waterway, and maritime infrastructure. One of the priority areas in this context is the further development of the TEN-T with a focus on implementing missing links and cross-border projects with EU added value.[95] The CEF's energy budget of €5.84 billion is partly dedicated to the implementation of cross-border projects focusing on renewable energy generation, which may contribute to the 'greening' of rail by providing cleaner energy sources for it. Last but not least, the remaining €2.07 billion make up the digital budget earmarked for projects promoting the roll-out of 5G connectivity systems, including support of digital gigabit connectivity across borders. These systems can – among other things – be seen as laying the groundwork for the further digitalisation of rail, for example, as enabling technology for the FRMCS as outlined in section 1.1.3.[96]

Since it has relevance for the financing of rail transport, it can be highlighted once more (as in Table 1) that the **State aid guidelines for railway** are currently in the process of being revised, with Commission adoption indicated for the fourth quarter of 2023[97] (although the revision is not mentioned in the Commission work programme 2023[98]). The overall objective of the revision is to streamline and simplify state aid provisions in support of rail's increased competitiveness through fair competition, for example by easing the market entry of new rail undertakings and ensuring the modernisation of fleets.[99]

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91 Next Generation EU – Make it real, European Union, n.d.

92 Regulation (EU) 2021/241 of the European Parliament and of the Council of 12 February 2021 establishing the Recovery and Resilience Facility.

93 While €385.5 billion are non-repayable support, the remaining €338 billion are loans and other smaller funding programmes.

94 Report from the Commission to the European Parliament and the Council – On the implementation of the Recovery and Resilience Facility, COM(2022) 75, European Commission, March 2022; NextGenEU – Laying the Foundations for Recovery: France, European Commission, June 2021; NextGenEU – Laying the Foundations for Recovery: Italy, European Commission, June 2021; NextGenEU – Laying the Foundations for Recovery: Romania, European Commission, June 2021.

95 Regulation (EU) 2021/1153 of the European Parliament and of the Council of 7 July 2021 establishing the Connecting Europe Facility and repealing Regulations (EU) No 1316/2013 and (EU) No 283/2014.

96 ibid.

97 Rail transport – revision of State aid guidelines: About this initiative, European Commission, n.d.

98 Annexes to the Communication on the Commission work programme 2023, COM(2022) 584, European Commission, October 2022.

99 Revision of the Community Guidelines on State aid for railway undertakings – Impact Assessment, European Commission, October 2021.

2. Objectives and methodology

2.1. Why stress-test?

As concluded in the pilot study preceding this research paper, **stress-testing can be applied in the policy process to enhance the robustness and resilience of policies**.[100] Assessing the performance of proposed or existing policy initiatives against different scenarios can reveal policy weaknesses and allow policymakers to consider possible ways of addressing these.
The EU rail policies to be scrutinised in this study are primarily meant to support the green and digital transformation of the European rail system in favour of a competitive, efficient, secure, and sustainable European transport system. They play an important role in terms of delivering on the strategic targets for the transport sector that the EU has committed to (including specific milestones for the reduction of the sector's GHG emissions and the boosting of rail freight transport and long-distance passenger rail, as outlined in sections 1.1 and 1.2). By stress-testing selected EU rail legislation and policies, **this research paper helps identify weaknesses in the policy framework for the rail sector and, where possible, proposes actions to address the weaknesses and enhance the resilience of policies**.

2.2. Brief overview of the methodology

The research team took a range of steps to prepare and conduct the stress-testing exercise and draw out lessons learnt for the research paper. To limit the scope for this exercise, the research team initially decided to **focus on three selected flagship initiatives** of the Commission's Sustainable and Smart Mobility Strategy (see chapter 3 for more information on the selection process).[101] Following this step, the scope of the stress-testing exercise was defined in consultation with stakeholders from the rail sector.[102] During qualitative interviews, stakeholders were asked to identify which specific rail policies, linked to the chosen flagship initiatives, should be scrutinised. They were likewise encouraged to highlight vulnerabilities in these policies, such as underlying assumptions, which may pose a risk (e.g., because they could mean that the policy, following disruptive developments, may cease to perform as intended or no longer be able to deliver on its objectives in the future). During this process, equal attention was given to policies pertaining to rail passenger and rail freight transport.
Taking the findings from this initial research phase into account, **the research team decided to conduct four stress-tests of key legislation** (some of the policies to be scrutinised are linked to more than one flagship initiative). Each individual stress-test was carefully planned and designed to maximise the relevance and value of outcomes. Results from initial stakeholder consultations during the scoping phase fed into the selection of four disruptive events. These events were chosen by the research team according to their expected consequences and potential for exerting significant theoretical stress on the rail policies to be scrutinised. This aspect was quite important, since the aim for each stress-test was to expose individual rail policies to targeted scenarios that were chosen and developed on the grounds of already known issues or weaknesses linked to the policies in focus.
The research team developed **four different scenarios** with each one to be used in a single stress-test of specific key legislation. Each scenario is based on an individual disruptive shock which, in the theoretical scenarios, occurs in the near future (between 2027-2035). These

[100] Fernandes and Heflich, 2022.

[101] Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

[102] See Annex A for a list of the stakeholder organisations consulted during the research.

shocks are **specific events with widespread and lasting effects on different domains of society**. The scenarios were primarily developed using a qualitative approach, while some quantifications of key indicators for the rail sector were added to illustrate scenario impacts. As presented in section 3.3, the four narrative scenarios contain a brief outline of the developments in the transport sector leading up to the shock at the centre of the scenario, a short description of the shock itself, while also mapping the impact of the shock (i.e., the specific consequences of the event with particular focus on the impact on the rail sector).
The research team organised **two online workshops** to support the validation of the scenario impacts by foresight and rail experts. At the workshops, participants discussed both the immediate and subsequent consequences of the disruptive events characterising the different scenarios, while also discussing and validating drafts of the scenario narratives by the research team. During the workshops some national perspectives were obtained as well.
During the next stage of the research, the actual stress-testing exercise was conducted, and the **selected rail policies were reviewed against the individual scenarios in four different stress-tests**. Stakeholders from the rail sector, as well as national rail attachés were invited to provide feedback on initial findings and any input received was used by the research team to enhance its analysis.
The following chapter 3 offers an **overview of the scope of the stress-testing exercise** by outlining the scenarios and introducing the key legislation that was stress-tested against these. Chapter 4 details the **findings from the stress-tests**, including identified policy weaknesses and relevant review clauses or emergency provisions that could increase policy resilience in the face of relevant disruptive events. The **main outcomes of the stress-testing exercise and lessons learnt** are summarised and presented in chapter 5.

3. Scope of the stress-test

3.1. Selection of three flagship initiatives

Seven of the ten flagship initiatives in the Sustainable and Smart Mobility Strategy have direct relevance to rail. To limit the scope of the stress-testing exercise, it was decided to focus on three of these initiatives.
When making this selection, the following criteria were considered. First, it was noticed that there is **a certain degree of similarity, if not overlap, between some of the initiatives**. For instance, flagship #6: *Making connected and automated multimodal mobility a reality*, #7: *Innovation, data, and artificial intelligence for smarter mobility*, and #10: *Enhancing transport safety and security* all address different aspects of digitalisation of the European transport infrastructure.
Second, the stress-test should include **policies aimed at improving passenger rail transport as well as freight transport**. Some of the flagship initiatives include objectives and legislation targeting both these types of transport (e.g., #8: *Reinforcing the single market*), while others are expressly directed at improving the sustainability and efficiency of either passenger or freight transport.
Taking these criteria into account, the research team proposed to select policies and legislation within three flagship initiatives:

- #4: Greening freight transport
- #6: Making connected and automated multimodal mobility a reality
- #8: Reinforcing the single market.

Flagship initiative #4 aims to increase the modal share of rail, which has been in decline. Problems identified by policymakers include missing links in multimodal infrastructure, lack

of multimodal exchange of data, lack of R&I, too little rail freight capacity, bad cross-border coordination and cooperation between rail infrastructure managers, lack of digital coupling, and insufficient automation.

Flagship initiative #6 aims to build a legal framework to support multimodal travel information, booking and ticketing services, further rolling out the European Rail Traffic Management System (ERMTS), and fostering train/rail automation. Problems identified by policymakers include the lack of an EU-wide framework for multimodal information, ticketing and payment services; an insufficient legal framework at EU-level that would support interoperability across national and private systems, and the need to ensure operational data and personal information against security breaches.

Flagship initiative #8 aims to complete the TEN-T core network by 2030 and build it as a truly multimodal system by securing sufficient investment (around €300 billion to only complete the core network). Problems include lack of funding, continuing obstacles to the free movement of goods and services, high entry barriers for new players, and disruptions experienced during the COVID-19 pandemic.

The relevance of these flagship initiatives was subsequently confirmed in conversations with rail experts and stakeholders[103]. While the stress-testing considered policies and regulation within these three flagship initiatives, it should be noted that the overall objectives of the Smart Mobility Strategy were considered in the stress-testing exercise to the extent that overarching assumptions were challenged by the different scenario shocks. Further, it should be noted that the research team deemed the actions under the flagship initiatives 4 (*Greening freight transport*) and 8 (*Reinforcing the single market)* to be intricately linked, which is why two of the four stress-tests scrutinised legislation linked to both initiatives.

3.2. Shocks that could challenge the selected policies

The stress-testing method used here requires that a limited number of shocks are selected to use as the base for scenarios against which the policy can be tested. **The identification of relevant shocks was done in a bottom-up manner** (rather than applying random shocks, e.g., from a catalogue of wildcards). First, the objectives and assumptions of the policies within each of the selected flagship initiatives were considered with a view to provide a first assessment of their robustness and identify what type of events could be expected to reveal (one or more) vulnerabilities in the policy to potentially prevent it from being effective.

As described in Table 1, **flagship initiative #4, Greening freight transport**, has the following levers of relevance to rail transport:

Shift of inland road freight to rail and inland waterways
The development of multimodal logistics
Improving rail freight capacity and management
Reinforcing economic incentives for transport users to make more sustainable choices

Several events could hamper the shift from road freight to rail freight or prevent a larger role for rail in multimodal freight transport, since the choice of transport mode is made on a case-by-case basis by individual logistics enterprises. Such choices are based on calculations that include, in addition to the end-to-end cost per unit transported, transport time from end to end, access to specialised transport (cooling/freezing), the ability to flexibly arrange transport, and the experienced or perceived reliability of any subcontractors.

If the cost of road freight transport per unit transported is significantly lower than the cost of rail freight transport (as is the case in 2022), and road transport is more flexible, logistics operators lack incentives to shift to rail. Therefore, **the flagship initiative includes an**

[103] See Annex A for a list of consulted stakeholder organisations.

ambition to reinforce economic incentives for the companies to make more sustainable choices by introducing or tightening carbon pricing and infrastructure charging. These policies are key to the success of the flagship initiative, and a stress-test should focus on events that would change the parameters in a way that could potentially undermine their effectiveness.

A climate-related event would most likely affect several parameters, shifting the relative position of road, air, waterways, and rail in the European transport system. In addition to direct impact on the transport infrastructure (both road and rail), the financing of the initiatives, including the implementation of the TEN-T regulation[104], could be jeopardised if funds are needed for climate emergencies.

The key elements with relevance for rail transport of **flagship initiative #6, Making connected and automated multimodal mobility a reality,** are:

- Realising the potential of smart digital solutions and intelligent transport systems (ITS)
- Revision of EU legislation to allow for the development of smart and integrated, multimodal information, ticketing, and payment services
- Continued focus on the deployment of the European Rail Management System (ERTMS)

A main assumption behind this flagship initiative, and the associated policies, is that data can be exchanged securely, and interoperability between national systems achieved. Besides the potential political challenges in implementing EU legislation at the national level, the initiative begs the question of what would happen in the event of a major breach in cybersecurity.

Flagship initiative #8, Reinforcing the single market, has the following key elements with relevance for rail transport:

- Call for public and private investments in transport infrastructure and vehicles
- Ensuring that these investments are coordinated and prioritised within EU funding programmes (NextGeneration EU recovery instrument and others)
- State aid rules for railways are to be reviewed
- Support of strategic value chains

The call for public and private investments is vulnerable in any crisis in which national public and private funds, as well as EU funds are being channelled towards crisis mitigation or reconstruction. The support of strategic value chains may also be jeopardised by actors outside the EU imposing restrictions on trade with EU countries.

The selected shocks

Considering the potential vulnerabilities of the policies described above as well as the intention to test the legislation in scenarios based on a range of different types of shock, it was decided to develop scenarios based on the following four shocks for the stress-test:

A persistent heatwave affecting most of Europe. This is an example of a more widespread and persistent climatic change, and as remarked by experts in a workshop, heatwaves are usually accompanied by drought as well as severe storms. An event of this nature will have an impact not only on the rail infrastructure but may also lead to the need to channel funds away from investments in rail.

EU bans the sales of new heavy goods vehicles with internal combustion engines as of 2035. This event was included as an example of a type of event that would necessitate a planned shift from road to rail and inland waterways.

A destructive cyber-attack targeting the European Rail Traffic Management System. Since digitalisation is a key element in the Sustainable and Smart Mobility

[104] Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the Trans-European Transport Network and repealing Decision No 661/2010/EU.

Strategy, cyber security becomes a key issue, and it is relevant to examine how the policy instruments will stand up to a major attack on the digital rail infrastructure.

China invades Taiwan. The achievement of a single European rail area is dependent on investments in the TEN-T network and the ability of the EU to secure strategic supply chains. An invasion of Taiwan by China would be an example of an event that could trigger impacts that would challenge the European rail area and disrupt supply chains by fundamentally changing the flows of international trade.

Table 2 below offers an overview of the scope of the stress-testing exercise, presenting for each of the four stress-tests, what legislation and focus area (i.e., passenger and/or freight) was subjected to which scenario.

Table 2: Relevant legislation for the stress-tests: key legislation and focus area

	Scenario	Flagship initiative	Legislation to be stress-tested	Focus
Stress-test 1	Persistent heatwave affecting most of Europe	#4 Greening freight transport #8 Reinforcing the single market	Combined Transport Directive Regulation on the Trans-European Transport Network (TEN-T) and revision	Passengers and freight
Stress-test 2	EU bans new internal combustion engine heavy goods vehicles as of 2035	#4 Greening freight transport #8 Reinforcing the single market	Regulation concerning a European rail network for competitive freight EU 2021 Rail Corridor Initiative Rail Freight Corridor Regulation and revision Combined Transport Directive Regulation on the TEN-T and revision	Freight
Stress-test 3	Destructive cyberattack targeting cellular networks	#6 Making connected and automated multimodal mobility a reality	Delegated Regulation on Multimodal Travel Information Services Directive on Intelligent Transport systems and revision, including a multimodal ticketing initiative	Passengers
Stress-test 4	China invades Taiwan	#8 Reinforcing the single market	Transport relevant State aid rules 2008 Guidelines on State aid for railway undertakings and revision	Freight

Source: European Commission, 2020b & authors' elaboration.

3.3. Consequences and impact of the shocks

Disruptive events tend to create difficulties (or opportunities) far beyond their immediate consequences. Based on the shocks described above, four scenarios were developed with input from scenario experts, as well as rail experts and stakeholders. The four scenarios are presented below. Their descriptions include an explanation of the defining shock and discuss multiple consequences derived from it. The scenarios come with comprehensive references, as well as footnotes that explain the underlying facts, assumptions, and calculations behind the figures presented. All scenarios begin with a short section that sets the scene by describing central developments between the time of writing and the point where the scenario takes place.

The scenarios were created by the research team and subsequently presented at two workshops with rail and foresight experts. Feedback from these workshops were implemented, and the following pages present the resulting revised scenarios.

Scenario 1 – Persistent heatwave affecting most of Europe

Setting the scene

Scenario 1 takes place in 2030.
Between 2022 and 2030, the average temperature in Europe gradually increased. While ambitious decarbonisation initiatives were implemented, and the EU was on track to achieve net-zero emissions by 2050,[105] *global CO_2-emissions were still increasing year by year due to the lack of equally ambitious action by major CO_2-emitters, such as China, the United States, India, and Russia.*[106]
EU Member States' investment in transport infrastructure, while increasing in absolute terms, had for the most part gone into maintaining the 2022-level quality of rails and roads in Europe without fundamentally improving or expanding either, with the exception that rail lines were increasingly electrified – especially in Central and Western Europe. By 2030, electric trains accounted for more than 90 % of passenger rail activity and approximately 75 % of freight movements.[107] *While hydrogen-powered trains were operating in a handful of places, especially in Germany, they comprised a small share of the total EU rail system.*[108]
As part of the European Green Deal,[109] *€600 billion from the NextGenerationEU Recovery Plan*[110] *were invested into greening European economies and society. In combination with Member States' own investments in renewable energy, this led to much more wind, solar, and hydro power in the European energy mix. In fact, the EU met its goal of reducing greenhouse gas emission levels by 40 % below 1990 levels before 2030.*[111] *However, this green transition also made the European energy network more susceptible to weather-related disruptions, since an economically viable solution for energy storage has yet to be widely deployed.*[112]

The scenario

The year is 2030, and it is the warmest August on record in Europe. In Germany, the average temperature hits 22 degrees Celsius, 1.7 degrees warmer than in August 2022 and a staggering four degrees warmer than the average temperature from 1991 to 2020. Peak temperatures are well into the 30s Celsius in Northern Europe. Unfortunately, this record seems almost trivial by now, since the past five years of repeated heatwaves have seen consecutive records for warm weather. Indeed, what used to be seen as a heat wave might just be the new

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105 In 2020, the average greenhouse gas emission per capita across the EU amounted to 7 tonnes compared to 8.9 tonnes in 2009. Source: Net greenhouse gas emissions, Eurostat, n.d.

106 In 2020, China was responsible for 30.64 % of global CO_2 emissions, the United States were responsible for 13.53 %, India for 7.02 %, and Russia for 4.53 %. Source: Distribution of fossil fuel CO2 emissions worldwide in 2020, by select country, Statista, n.d.

107 In 2019, electric rail accounted for approx. 80 % of passenger rail activity and half of freight movements. Source: Rail: More efforts needed, IEA, September 2022.

108 Section 1.1.3 offers additional information on hydrogen-powered trains.

109 Communication on the European Green Deal, COM(2019) 640, European Commission, December 2019.

110 NextGenerationEU, European Union, n.d.

111 Climate change mitigation, European Environment Agency, November 2020.

112 Amrouche, et al., Overview of energy storage in renewable energy systems, International Journal of Hydrogen Energy, December 2016; Zantye et al., Optimal design and integration of decentralized electrochemical energy storage with renewables and fossil plants, 2022.

European normal. Nonetheless, the past five years of warm weather have shocked the European transport sector.

The persistent heatwave has massive impact across all of Europe. For instance, firefighters in Southern Europe and much of Central Europe face an ongoing battle against forest fires.[113] Even in cities as far north as Scandinavia, grass fires have led to the destruction of more than 100 houses this year alone.[114] Taken together, **well over one million hectares of land have been burned so far in 2030**.[115] These fires have had dire impact on the rail sector – especially in forested areas in Southern Europe. Rail stretches in Catalonia, Southern France, Austria, Slovenia, and even central Germany[116] are unusable due to surrounding wildfires. This has forced passengers and businesses to find alternative means of transport, and – among other things – has led to an increase in road and ship freight by 17 % in the affected area.

The higher temperatures increase the risk of rail buckling,[117] as steel rails become up to 20 degrees warmer than the ambient temperature in areas affected by the heatwave. This leads rails to become constrained by the anchorage holding them in place. Thus, they are more likely to bend out of shape. Trains must operate at slower speeds to avoid derailment caused by rail buckling, and on rail lines where the rails have been severely deformed, trains are cancelled. **Despite European efforts to climate-proof the rail sector, a functioning way of adapting to the warm weather has yet to be identified**.[118]

Power lines ending at fixed points – as opposed to auto tension power lines – are at risk of sagging and getting in the way of trains. In some areas, the wires holding powerlines in place expand making the lines drop dangerously low.[119] As a result, total rail delays have increased by 15 000 minutes a day.[120] Moreover, the heat-related damage to infrastructure leads to an increased need for rail maintenance, while the workers responsible for this task need protection from heat stress and, therefore, work fewer hours (working at night is no real alternative, since temperatures only fall slightly during the heatwave).[121] This adds to a **significant increase in the cost of maintaining the rail lines** and causes the task of making them usable again to be more challenging. The estimated daily delay caused by buckling-related maintenance alone is approx. 13 000 minutes.[122] The impact of these delays on national and corporate economies is severe.

While Southern Europe has faced the highest temperatures, the rails in Eastern Europe and the Balkans are generally in worse shape and hence far more vulnerable to disruption, be it from

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113 A study found that heatwaves and wildfires have detrimental impact on rail and road infrastructure at similar levels. See Table 1 in Forzieri et al., Escalating impacts of climate extremes on critical infrastructures in Europe, Global Environmental Change, 2018.

114 In 2022, more than 40 houses were destroyed in London after grass fires spread in several areas. Kirk et al., Europe's record summer of heat and fires – visualised, The Guardian, 26 July 2022.

115 In 2022, 515 thousand hectares had been burnt in Europe by 23 July. Source: ibid.

116 Areas chosen based on the density of forest. Source: Forest map of Europe, European Environment Agency, 28 October 2015.; For impacts of wildfires on rail, see for example: Fires near tracks and heat complaints: hot spell shakes up European railways, RailTech.com, 19 July 2022.

117 Sabrina Weiss, How to Prevent Another European Transport Meltdown, Wired, 29 July 2022.

118 Quinn, et. al., Rail Adapt – Adapting the railway for the future, International Union of Railways report, November 2017.

119 Kobie, Sag, buckle and curve: why your trains get cancelled in the heat, Wired, 27 July 2019.

120 Based on calculations from Ferranti et al., The hottest July day on the railway network: insights and thoughts for the future, Meteorological Applications, April 2018.

121 Palin et al., Future projections of temperature-related climate change impacts on the railway network of Great Britain, 28 June 2013.

122 ibid.

rail buckling or other sources.[123] This shock is thus particularly detrimental for transport of freight, as well as passengers in these parts of the EU.

The high temperatures have also led to **lower water levels in European rivers**, including the Danube and the Rhine, the most important European rivers for freight purposes. The low water levels limit the amount of waterborne freight that can be sustained. In 2021, Europe's waterways transported more than one tonne of freight each year for every EU resident (in all 524 million tonnes),[124] contributing roughly €78 billion to the European economy.[125] With low water levels in the Rhine and the Danube as well as other rivers and canals, this number is reduced to some €30 billion in 2030 (meaning approximately 201 million tonnes of freight). The reduction in freight volumes on both rails and rivers is, to some extent, compensated for in road and airborne freight, but this is not always possible, and as a result, bottlenecks emerge leading to an overall slowdown of the economy.

The heat further creates **problems for the European energy supply**. European hydropower generation has been cut in half due to the low water levels.[126] Moreover, nuclear plants have had to reduce their activity due to a lack of river water for cooling.[127] Additionally, solar panels generally run at 10 %-25 % reduced efficiency when they overheat.[128] Finally, a property of heat waves is the lack of wind, meaning reduced energy input from wind turbines.[129] The result of all this is the need to increase the use of gas, coal, and oil to make up for the lost hydro, nuclear, solar, and wind energy, leading to a larger share of fossil fuels in the European energy mix. Although fossil fuel power plants had been shut off by 2030 (as per the EU's climate target), some of this infrastructure can be used to recommence energy production and address the ongoing energy crisis.[130] However, this approach leads to **higher CO_2-emissions from electricity generation** and from the production of hydrogen for the few hydrogen-powered trains.

Regarding passenger transport, **new patterns of tourism have begun to emerge**. The Mediterranean is no longer sought out by north Europeans as a holiday destination to the same degree as before. Instead, there is increasing traffic towards Scandinavia. Moreover, the warm weather threatens public health – it led to 90 000 more heat-related fatalities in 2029 alone[131] – and to escape the heat, more European citizens are travelling north.[132] This has led to changes in consumption levels and goods distribution in Europe, as more consumer goods need to be transported north than before. Already, calls are heard for more EU action to secure the flow of goods.

Finally, the high outdoor temperatures increase the **need to keep temperatures down inside trains** by upgrading air conditioning or developing and installing other technologies.[133] This

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123 Expert comment in workshop 1. See also Ari et al., Infrastructure in Central, Eastern, and Southeastern Europe: Benchmarking, Macroeconomic Impact, and Policy Issues, 2020.

124 Inland waterway transport statistics, Eurostat, 2022.

125 Wilkes, Historic Drought Threatens to Cripple European Trade, *Bloomberg*, 10 August 2022.

126 Expert comment in workshop 1. See also Rossignol, European Hydropower under threat. Energynews, 10 August 2022.

127 Expert comment in workshop 1. See also Beaupuy, EDF Expects Nuclear Output Cuts in Summer on Low River Level, Bloomberg, 5 July 2022.

128 Masterson, Why don't solar panels work as well in heatwaves?, World Economic Forum, 9 August 2022.

129 Heat waves and renewable energies, Univergy Solar, 2022.

130 Similarly to the way the retirement of some coal plants was postponed during the 2022 energy crisis. Source: Schonhardt et al., Coal's on a comeback in energy-desperate Europe, ClimateWire, 3 October 2022.

131 See Naumann et al., Global warming and human impacts of heat and cold extremes in the EU, 2022.

132 Expert comment in workshop 1. See e.g., McClanahan, Stockholm Instead of Rome? October Instead of July? How Heat Waves Are Changing Tourism in Europe, The New York Times, 4 August 2022.

133 See e.g., Lemoine, How record-setting heat waves in cities across UK, US and mainland Europe could punish economies already reeling from inflation, The Conversation, 20 July 2022.

has led to higher ticket prices, negatively impacting passenger numbers. Regarding freight, the warmer weather has increased the demand for refrigerated wagons used to transport heat-sensitive goods.[134]
On a positive note, in the face of higher temperatures, **policymakers and citizens have become more aware of the dire consequences of climate change**, leading to a greater willingness to both use and invest in rail as a greener mode of transport.

Key Impacts

Rail buckling and power line sagging have led to rail delays and increased need for maintenance. This type of impact has been most critical in Eastern European Member States, due to their less developed rail infrastructure.
Rail buckling and power line sagging have led to rail delays and increased need for maintenance. This type of impact has been most critical in Eastern European Member States, due to their less developed rail infrastructure.
Increased expenses for air conditioning of trains have been offloaded on ticket prices.
As a result of delays and rising ticket prices, passengers have increasingly switched from rail transport to using cars for long-distance and cross-border travel.
Low water levels of European rivers have increased the volume of goods that must be transported by road or rail.
Lower energy production levels from sustainable sources led to increased CO_2-emissions from electricity production. north to escape the heat.
New patterns of tourism have emerged, as more people are travelling north to escape the heat.

Scenario 2 – EU bans new internal combustion engine heavy goods vehicles from 2035

Setting the scene

Scenario 2 takes place in 2040.
Throughout the 2020s, rail transport grew its modal share of freight transport vis-à-vis roads in Europe. However, road-based transport remained the dominant form of overland freight, due to its much greater flexibility. By 2023, only a small share of European lorries were not diesel-driven, due to poor implementation of the EU regulation on the deployment of alternative fuels infrastructure[135] and despite the work of the European Battery Alliance since 2017[136] and the presence of more and more electric heavy goods vehicles on the market. Strong headway was being made within battery-driven lorries, but they remained a more expensive option for long-distance transport – especially following the massive increase in electricity prices in 2022, which severely hurt the competitiveness of electric lorries.[137]
As in scenario 1, EU Member States' investment in transport infrastructure, while increasing in absolute size, had for the most part maintained the 2022-level quality of rails and roads in Europe without fundamentally expanding either, although rail lines were increasingly electrified – especially in Western Europe. Part of the €600 billion coming from the Recovery

[134] Expert comment in workshop 1. See e.g., Kulikowska, Increase in demand for refrigerated transport in Germany due to warm spring, Trans.info, 12 July 2018.

[135] Proposal for a regulation on the deployment of alternative fuels infrastructure, , European Commission, July 2021.

[136] European Battery Alliance, European Commission, n.d.

[137] Earl et al., Analysis of long haul battery electric trucks in EU, Marketplace and technology, economic, environmental, and policy perspectives, August 2018.

and Resilience Fund was invested in rails, but this had mostly supported the electrification and modernisation of rails rather than an expansion of the rail network.[138]

The scenario

In 2022, the EU approved a ban on new light-duty vehicles with internal combustion engines from 2035.[139] The following year, **the EU decided to expand this ban to cover new heavy goods vehicles (HGVs) with internal combustion engines** as well. In the European Commission's Smart and Sustainable Mobility Strategy of 2020,[140] revised targets had been set for the reduction of CO_2 emissions from cars and vans, and emission targets for HGVs had already been defined in 2019.[141] To reach these targets, the EU introduced mechanisms to incentivise the uptake of zero- and low-emission HGVs and set requirements for the establishment of recharging points along the TEN-T core network (at least one 1 400 kW recharging pool dedicated to HGVs deployed in each direction of travel with a maximum distance of 60 km in-between them by 2025 and at least one 3 500 kW recharging pool every 60 km by 2030).[142]

The emission standards implemented in 2019 had been up for review by the end of 2022. However, at the time of the revision, the energy crisis and resulting high electricity prices meant that it was deemed unrealistic to increase the targets. Furthermore, **the uptake of electric lorries for long-distance freight transport was hindered not only by rising energy prices, but also a lack of infrastructure for high-powered fast charging.**[143] While some Member States had made progress in terms of implementing public charging stations for fast stops as well as overnight charging of lorries, most had failed to do so.[144] This resulted in a fragmented charging network, causing reluctance among road freight service providers to make the switch from diesel to electric driven HGVs.[145]

Therefore, to accelerate the move towards more climate-friendly freight, the EU decided to ban the selling of new HGVs with internal combustion engines along with their light-duty counterparts. The average life span of HGVs is approximately 15 years[146], and policymakers expect there will hardly be any fossil-driven HGVs on EU roads by 2050. Consequently, logistics providers have been scrambling to adapt to this prospect.

The year is now 2040, and **there are still relatively few electric or hydrogen powered lorries on the European roads.** Despite technological and infrastructural progress being

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138 See for example: Recovery and resilience plans for Austria, Denmark, Bulgaria, France, and Ireland available at Recovery and Resilience Facility, European Commission website, n.d.

139 Fit for 55: MEPs back objective of zero emissions for cars and vans in 2035, European Parliament, 6 August 2022.

140 Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

141 Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC.

142 These requirements for recharging pools are in line with the Proposal for a Regulation on the deployment of alternative fuels infrastructure, COM(2021) 559, European Commission, July 2021. See also: Reducing CO2 emissions from heavy-duty vehicles, European Commission, n.d.

143 Electric trucks: new study pinpoints precise locations for charging infrastructure across EU, ACEA, 9 June 2021; Alternative Fuels Infrastructure Regulation Heavy-Duty Vehicles, ACEA, n.d.

144 Volvo opened its first electric truck charging facilities in Sweden in 2021, and BP in Germany in 2022. Source: Den publika laddplatsen, som är placerad på Falutorget, är den första i sitt slag och kan även användas för laddning av personbilar, Gothenburg Energy, n.d.; BP opens its first electric truck charging facilities to support the decarbonization of transport, BP, 27 July 2022.

145 For an overview of the required number of charging points for electric trucks in Europe, see Interactive map – Truck charging points needed in Europe by 2025 and 2030, per country, ACEA, 25 May 2021.

146 Average service life of trucks in Japan from 2012 to 2021, Statista, 2022.

made, there is still a limited supply of electric- or hydrogen-powered lorries, a patchy charging infrastructure, a lack of technological advancements in terms of battery and fuel cell technology, ongoing difficulties to produce green hydrogen, and a shortage of lithium for electric batteries.[147] Hence, the result has been a gradual but massive move of freight away from roads and onto trains.

With limited advances in electric HGVs, the ban on combustion-powered HGVs meant that two trillion tonne-km of goods a year needed to be moved from the road onto the European rail system or to inland waterways during the 2030s,[148] an increase of approximately 26 % over the 2019 volume for a total of almost four trillion tonne-km of rail freight.[149] Action was taken by both national governments and the EU throughout the period to address bottleneck issues. This was done in much the same way that action was taken during the Ukraine War to help Ukrainian grain exports reach the European market i.e., by making more rolling stock available, increasing the capacity of transport networks and transhipment terminals, encouraging flexibility among customs operations, and increasing available storage of goods.[150] Nonetheless, **the rail network was unable to handle the additional goods, and the overall freight volumes have dropped**, leading to higher freight rates on rail, an economic downturn, and industries redesigning their entire supply line, including a renewed focus on local production to minimise transport.

The shift from road to rail has further been slowed down, as **train stations were initially unable to handle the increased freight volumes, and thus became logistical bottlenecks**. More goods needed to be transhipped between trains and lorries closer to the destination, and only a few European train stations were able (or sufficiently large) to handle the goods transfer, which again led to substantial train delays. Moreover, the parking facilities near the train stations were often vastly inadequate for the increased handling of goods, resulting in traffic jams in city centres. The same issue applied to logistics terminals near ports, albeit to a smaller extent, since these facilities were already geared to handle larger volumes of goods. As a result, by the mid-2030s, national and local governments began rethinking fundamental urban design principles to accommodate the importance of rail for freight to and from cities.

In addition, the increasing number of trains led to **key stretches of rail on the European network acting as bottlenecks.** Such stretches include the tunnels under the Alps and rail corridors between major European cities that are key nodes in the network.[151]

In 2033, the **European Investment Bank planned to invest more than €100 billion between 2035 and 2045** in the expansion of rail infrastructure and capacity to accommodate the new demand.[152] National funds were also directed at research and development related to rail technology, starting with funds from the Recovery and Resilience Facility.[153] The shared

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147 The shift from internal combustion engine to electric personal vehicles is in itself expected to require 15 times more lithium than is the case for the 2022 car production in Europe. Source: Vela, J. H., Brussels Playbook: Breton wants to save Das Auto — Carbon levy — Mellow Meloni, 4 November 2022.

148 Estimate based on the annual tonne-kilometre of freight transport in 2018 and assuming the total volume of long-distance road freight is slightly more than the total amount of international road freight, given that some international transport will be short-distance, some national transport will be long-distance, and some long-distance transport will be moved to sea or air transport rather than rail. Source: Smedt and Wispelaere, Road freight transport in the EU, 2020, p. 35.

149 Carlier, M., Rail freight industry in Europe - statistics & facts, 2022.

150 European Commission to establish Solidarity Lanes to help Ukraine export agricultural goods, European Commission, 12 May 2022.

151 Expert comment in workshop 1. See also Mitusch, et al., The structure of freight flows in Europe and its implications for EU railway freight policy, 2014.

152 Compared to €39 billion of investment between 2011 and 2020. Source: Rail transport, European Investment Bank, n.d.; See also Transport infrastructure: EU invests EUR 5.4 billion to support key projects across the continent, European Commission, 29 June 2022.

153 See section 1.3 for an explanation of the Recovery and Resilience Facility.

ambition was to have **more rail tracks, more rolling stock, faster trains, more electrification, and more out-of-city logistics hubs for handling freight trains**. Most of this R&D has long term prospects. By 2040, approximately €60 billion had been invested by the European Investment Bank's and was resulting in new rail stretches through some of Europe's main logistical arteries. The first new stretch of rail through southern Germany is expected to be ready for use in 2042. Meanwhile, in the shorter run, some Member States invested in retrofitting existing fleets of lorries and high-capacity vehicles to turn them into electric or hydrogen-powered lorries using conversion kits. This was done to meet some of the demand for zero-emission transport at lower costs.[154]

At the same time, **funds have been pouring into electrification of HGVs**. The immediate goal is to make electric HGVs viable for short-distance transport between rails and producer/seller. In the longer run, electric HGVs may, in part, resume the long-distance transport function they had prior to 2035.

The ban has already resulted in layoffs in the transport sector and is expected to continue to do so in the years to come. In 2020, there were approximately 3.8 million heavy lorry and bus drivers in the EU. Roughly a third of these, 1.3 million people, are expected to have lost their jobs by 2045.[155] One can add to this the 600 000 people otherwise employed in road-based logistics.[156] **Re-skilling efforts have been initiated in several Member States to train lorry drivers for other sectors**, including rail, where new investments have been accompanied by a renewed demand for skilled labour. The former lorry drivers have, all along, been considered a potential resource in meeting a changed European logistics demand – but the transition has required substantial re-skilling efforts at both the national and the EU level.

In terms of CO_2-emissions, the ban has had some effect. **Emissions from road transport has fallen** by approximately 115 million tonnes CO_2[157] and, though emissions from air transport and shipping have increased, the overall result is a greener European transport sector.

The increased pressure on the European rail system has led to a greater demand for coordination among Member States. Especially in border regions, coordination of rail policies and placement of logistics facilities have seen renewed interest.

Some European stakeholders lament the perceived breach of technology neutrality by the EU in banning a certain form of vehicle. This has caused increased political tension among Member States, especially in countries that have been unable to find new jobs for the laid-off.

Key impacts:

- Logistics companies were pressed to rearrange their modes of long-distance transport from roads to rivers, rails, and sea.
- Logistics companies were pressed to rearrange their modes of long-distance transport from roads to rivers, rails, and sea.
- Rail terminals become logistical bottlenecks, as they must handle far more goods.at both national and EU levels) was taken to address bottlenecks.
- Urgent political action (at both national and EU levels) was taken to address bottlenecks.

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154 Retrofitting à la française to decarbonize diesel-powered commercial vehicles, buses, and trucks, La French Fab, 12 May 2022.

155 Almost 29 transport workers per 1 000 people in the EU, Eurostat, 2021.

156 For an impression of the size of the sector as a whole, see Number of employees in the transport industry in the European Union (EU-27) in 2018, by sector, Statista, n.d.; see also Vela, J. H., Brussels Playbook: Breton wants to save Das Auto — Carbon levy — Mellow Meloni, 4 November 2022.

157 Road transport fuel combustion emitted around 888 million tonnes of CO_2 in 2018. Heavy duty trucks and buses accounted for 26 % and light duty trucks for a further 13 %. If roughly half of the 26 % is comprised of long-distance freight, the ban would result in a 13 % reduction or ca. 115 million tonnes CO_2. Source: DeStatis, Road transport: EU-wide carbon dioxide emissions have increased by 24% since 1990, n.d.

Demand for rail freight has increased leading to higher freight rates on rail, an economic downturn in Europe, and to industries redesigning their entire supply line with greater focus on local produce.
There was an increase in European investments in improved rail connectivity and electric HGVs from 2035 and onwards. to help accommodate the increased freight demand.
Existing lorries were retrofitted and turned into electric or hydrogen-powered lorries to help accommodate the increased freight demand.
Massive layoffs in road transportation sector and demand for re-skilling for rail. has been significantly reduced.
CO_2-emissions from the European transport sector has been significantly reduced.
Through the 2030s, Member States voiced a need for coordination of rail policies.

Scenario 3 – Destructive cyberattack targeting the European Rail Traffic Management System

Setting the scene

Scenario 3 takes place in 2030.
Between 2026 and 2029, the European Rail Traffic Management System (ERTMS)[158] *was rolled out to most of the European core rail network, despite delays. The system was expected to be completely deployed in the EU core network by 2033.*[159] *ERTMS allowed for an increase of the speed of trains and the capacity of rail infrastructure, while also enhancing rail safety.*
During this period, the digital transformation of society continued. As part of the transformation, more and more appliances and tools were digitally connected via the Internet of Things (IoT). The increased use of digital tools has been accompanied by the implementation of the EU's Cybersecurity Strategy[160] *under the Digital Europe Programme,*[161] *which strengthened the resilience of critical infrastructure, built operational capacity to prevent, deter, and respond to cyberthreats, and advanced cooperation between Member States on cybersecurity. Throughout the 2020s, efforts under the Cybersecurity Strategy helped defend Member States against a growing number of potentially destructive cyberattacks.*[162]
The growing cyberthreat has also nurtured a political discussion in the EU about data security and digital innovation. Already in 2019, it was evident that a strict data security regulation could both stimulate and constrain digital innovation.[163] *This tension was still visible in politics as the division grew wider between groups who called for tighter data restrictions to protect citizens' data, and those who believed that regulations mainly serve to constrain European businesses and stifle innovation.*

The scenario

In the summer of 2029, a massive cyber-attack wreaked havoc on the European Rail Traffic Management System (ERTMS), the single European signalling and speed control system

158 European Rail Traffic Management System (ERTMS), European Union Agency for Railways, n.d.

159 This scenario assumes that ERTMS will be completed on time, despite studies arguing this is unlikely to be the case – source: CCS TSI Revision –revised ERTMS deployment requirements (Impact Assessment), European Commission, 2021. This is done to focus the stress-test on the impact of such as attack, rather than on whether the development of ERTMS has happened according to plan or not.

160 The Cybersecurity Strategy, European Commission, n.d.

161 The Digital Europe Programme, European Commission, n.d.

162 Threat Landscape 2021, ENISA, 27 October 2021.

163 Martin et al, How Data Protection Regulation Affects Startup Innovation, 18 November 2019.

ensuring the interoperability of national railway systems across much of the EU. The attack disrupted positioning, tracking, and railway signalling systems underlying the ERTMS over several weeks. As many of the system's functions failed following the cyber-attack, trains had to stop all over the EU and travellers were unable to obtain travel information via their usual digital channels.[164]

This was not the first cyberattack against a rail network. In January 2022, hackers attacked the Belarusian railways demanding that trains stop transporting Russian troops.[165] This was described as a serious blow, which affected automated systems from payroll to cargo manifests and timetables, and compromised data security.

Although the failsafe systems immediately kicked in after the 2029-attack to prevent train collisions,[166] material damage, and human casualties, the immediate consequences were still massive delays and cancellations.[167] Most of the network has been restored since then, and analogue systems have been improvised and implemented. Nonetheless, passenger numbers have never fully recovered and remain 30 % lower than before the attacks, as users choose other modes of transport. This has led to a decrease in rail revenues of €21 billion.[168]

For five months after the attack, trains could no longer be run as closely together as normally possible, due to the failure of the affected signalling and positioning systems. To compensate, experiments were made with fewer but longer trains, and these experiments turned out to be successful. The **longer trains have now become the norm**.

Following the disturbance of the train schedules, **a sizable share of regular train commuters opted to work more from home instead of relying on the train to get to work**. This has meant an increase in remote work (similar to after the COVID-19 shutdowns) and a reduction in rail use during weekdays specifically.[169] As a result, the infrastructure is able to accommodate more long-distance and cross-border trains, both for passengers and freight.

The countries most severely hit by the cyberattack on the ERTMS were the ones who had made the most progress in terms of deploying the system on their national rail systems. At a fundamental level, the attack reignited scepticism towards digitalisation among groups of citizens. This scepticism has made it even harder to implement new comprehensive digital systems relating to rail infrastructure. Digital initiatives that were meant to build on ERTMS-deployment, such as the automation of train operations, suddenly faced stark opposition.

The cyber-attack further led to the **revival of older rail management and signalling systems** as a backup precaution for future incidents. Though the newest rolling stock were only equipped with the ERTMS-system, older stock had both ERTMS and legacy systems installed. After the cyberattack, the ambition was to have redundant systems in place in all rolling stock for similar attacks in the future. This would allow some level of train activity to continue.

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164 This scenario is similar to the first scenario presented by ENISA; however, the scope is much greater here as the attack does not only cause a single train collision but indeed disruptions in the entire European network. Source: Railway Cybersecurity - Good Practices in Cyber Risk Management, ENISA, 25 November 2021.

165 Roth, 'Cyberpartisans' hack Belarusian railway to disrupt Russian buildup, The Guardian, 25 January 2022.

166 As discussed in Chen et al., Security Analysis of Urban Railway Systems: The Need for a Cyber-Physical Perspective, 2015.

167 For a list of hazards or probable failures resulting from cyber-attacks and a list of cyber-attacks on railways, see Thaduri et al., Cybersecurity for eMaintenance in railway infrastructure: risks and consequences, 15 March 2019; Kour et al., Railway Defender Kill Chain to Predict and Detect Cyber-Attacks, January 2020.

168 In 2020, passenger operators fell by 42 % as a result of Covid-19, equivalent to a reduction in total sector revenue of approx. €24 billion. Assuming a 25 % increase in overall passengers between 2019 and 2029 and a similar relationship between revenue and passenger operators, a decline of 30 % in 2029 would be equivalent to approx. 21 billion. Source: European rail sector revenues fall €26bn in 2020, IRJ, 4 February 2021.

169 European public transport recovers, but commuting has changed, ING, 15 July 2022.

However, this was costlier, required more maintenance, and put extra strain on the training of operators (who now had to be able to operate both the old and the new systems).[170]
The cyber-attack also revealed a significant weakness at the heart of the EU's efforts to digitalise its common rail system. Although the Directive on the resilience of critical entities had required Member States since 2023 to ensure the resilience of rail infrastructure and rail undertakings, the directive's poor implementation has left the EU rail system vulnerable to cyber threats.[171] The immediate political reaction was to call for tighter regulations on cyber and data security to protect critical infrastructure as well as personal data. These security precautions may slow future efforts to digitalise the rail sector and make them more costly. At the same time, new technologies and digital features, namely associated with the Internet of Things (IoT), have created a significant increase in the possible entry points into the digital systems of the rail sector and thus increased cyber vulnerability.[172] These are often based on wireless communication, which further exacerbates the issue because it enables entry into a network without a physical connection.[173] As a whole, the cyberattack has shifted the public opinion towards acceptance of tighter cyber- and data protection, even if it may constrain European digital innovation – in rail and other areas.

Key impacts

Immediate disruption of positioning, tracking, and railway signalling systems underlying the ERTMS over several weeks causing massive delays and cancellations.
Immediate disruption of positioning, tracking, and railway signalling systems underlying the ERTMS over several weeks causing massive delays and cancellations.
Passenger numbers have been reduced. Some chose other means of transport, while a share of regular commuters opted to work more from home.
Fewer but larger trains have been put into operation.
There has been an increase in public scepticism towards digitalisation.
Infrastructure operators reimplemented previously retired systems as a backup precaution, despite the costs associated with retrofitting some rolling stock (including additional needs for maintenance of the redundant systems).

Scenario 4 – China invades Taiwan

Setting the scene

Scenario 4 takes place in 2030.
Through most of the 2020s, EU-China relations were ambivalent to say the least. On one hand, trade ties continued to grow stronger. EU imports from China were expected to reach €870 billion in 2032 (compared to €472 billion in 2021), and exports to China were expected to reach €393 billion in 2032 (compared to €223 billion in 2021).[174] There were already signs, however, that these estimates would probably prove too high. Higher wages in China made

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170 CCS TSI Revision –revised ERTMS deployment requirements (Impact Assessment), European Commission, 2021.

171 The scenario assumes that the EU has adapted the Proposal for a Directive on the Resilience of Critical Entities, COM(2022) 829, European Commission, December 2022. The Council presidency and the European Parliament reached political agreement on the directive in June 2022, see: EU resilience: Council presidency and European Parliament reach political agreement to strengthen the resilience of critical entities, European Council, June 2022.

172 Cyber risk in an Internet of Things world. Flashpoint edition 4: More data, more opportunity, more risk, Deloitte, 2015.

173 Kapoor, Understanding Railway Cybersecurity, Global Cybersecurity Alliance, 2022.

174 Estimates based on the 2011-2021 growth in EU imports from and exports to China. Source: China-EU - international trade in goods statistics, Eurostat, February 2022.

Chinese production of low-skill products less competitive,[175] and advances in automation made it cheaper to produce goods in Europe, as wage levels became less of an issue for businesses.[176] Nonetheless, trade ties to China were still important to the European economy by 2027.
At the same time, political tensions between the EU and China were also increasing through the 2010s and 2020s for several reasons including: Chinese violations of human rights,[177] Chinese IP theft from European companies,[178] the persistent European trade deficit vis-á-vis China (projected to hit €477 billion in 2032),[179] and China's aggressive behaviour towards Taiwan. At the structural level, the continuing growth of China's economic and military power made Beijing act more assertively[180] and placed it on a political collision course with the United States and, per extension, many of the US' allies in Europe.[181] Meanwhile, China maintained its ambition to reunite Taiwan with the Chinese mainland, causing unease in Taipei as well as Washington and Brussels.[182] By 2025, China had strong enough military capabilities to mount a full-scale invasion of Taiwan and was still regularly violating the Taiwanese air defence identification zone with warplanes, including nuclear-capable bombers.[183]
With this ambivalent relationship to Beijing, the EU enacted the European Chips Act to reduce European dependency on Chinese and Taiwanese microchips and semiconductors. By 2026, the EU produced 15 % of the world's microchips and was on track to achieving its 2030 goal of 20 %.[184] Similarly, while the European Battery Alliance, launched in 2017, strengthened EU's global position on the battery market, the market continues to be dominated by China.[185]

The scenario

In 2027, **the People's Republic of China acted on its long-term ambition to reunite The Republic of China – Taiwan – with the Chinese mainland**, even if it required military means. The invasion[186] itself went more smoothly for the Chinese forces than anyone had foreseen, and the island was under Chinese control before any outside power could intervene.[187] The

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175 The average wage in China more than doubled from 2012 to 2021. Source: China Average Yearly Wages, Trading Economics, n.d.

176 On the move: manufacturing's return to the developed world, FDI Intelligence, 2019.

177 China; Events of 2021, Human Rights Watch, 2022.

178 Chinese hackers took trillions in intellectual property from about 30 multinational companies, CBS News, 2022; Countering Unfair Chinese Economic Practices and Intellectual Property Theft, Carnegie Endowment for International Peace, 2022.

179 Estimate based on China-EU - international trade in goods statistics, Eurostat, February 2022.

180 Sørensen, C. T. N., The Significance of Xi Jinping's 'Chinese Dream' for Chinese Foreign Policy: From 'Tao Guang Yang Hui' to 'Fen Fa You Wei', 29 May 2015 and Chang-Liao, N.-C., China's New Foreign Policy under Xi Jinping, 2016.

181 Tunsjø, Ø., The Return of Bipolarity in World Politics, 2018; Layne, C., The US–Chinese Power Shift and the End of the Pax Americana, 2018.

182 Davidson and Graham-Harrison, Xi Jinping opens Chinese Communist party congress with warning for Taiwan, The Guardian, 16 October 2022.

183 Recommendation of 21 October 2021 to the Vice-President of the Commission / High Representative of the Union for Foreign Affairs and Security Policy on EU-Taiwan political relations and cooperation, 2021/2041 (INI), European Parliament.

184 European Chips Act, European Commission, n.d.; see also: The European Chips Act: A Strategy to Expand Semiconductor Production Resiliency, CSIS, 7 March 2022.

185 Share of the global lithium-ion battery manufacturing capacity in 2021 with a forecast for 2025, by country, Statista, 9 March 2022.

186 The term 'invasion' is used throughout this report to denote the forceful reunification of Taiwan (the Republic of China) with mainland China (The People's Republic of China), since this would be the most widely shared perception of such an event, even if proponents of the People's Republic of China would object to the characterisation.

187 A Chinese invasion of Taiwan would probably not be as smooth as assumed here. This decision is made to focus on the political and economic consequences of the invasion and their impact on the rail sector, rather than focus on the military

invasion was immediately followed by massive US and EU sanctions against China, leading to a complete breakdown in trade relations. Now, three years later, global trade flows are fundamentally changed. Both European and American companies have moved production and assembly facilities closer to home, resulting in shorter supply chains and a reduction in global shipping.

A large share of global manufacturing, both in terms of volume and in terms of value, is still handled outside of Europe**. Trade with South Asia, Northern Africa, and South America has increased** to supplant China's role in the European supply chains.[188] Products from these parts of the world are for the most part still shipped to Europe by sea. Turkey has also become an important country for manufacturing and assembly, and products from Turkey frequently find their way to European markets by rail. Nonetheless, most extra-regional trade continues to use the European ports and the rail lines that connect the ports to the European hinterlands.

While the global flows of trade to Europe require the same types of transport infrastructure as before the shock, **transport infrastructure demands in Europe have changed**. With more production taking place within Europe, the demand for land-based freight has increased, while inter-regional shipping has declined.[189] EU imports from Asia have fallen by 70 % compared to their 2021 levels.[190] Half of these goods are now imported from other regions outside the EU, but the remaining goods, worth approximately €323 billion, are now being produced and sold within the EU. These goods are for the most part transported on European roads and rails. The result is a demand for improved rail infrastructure in continental Europe.

As shipping between Europe and China has all but disappeared, **shipping rates have plummeted.** This in turn has made trans-Atlantic and inter-European trade via ocean ports cheaper. The result is that EU-USA trade has increased substantially, and more inter-European cargo is being handled by ship than ever before. These shorter shipping routes are generally serviced by smaller freight vessels than the large vessels that used to sail between Europe and East Asia.

The invasion has also caused **severe disruption to the availability of electronic chips in the EU**. The Taiwanese company TSMC produced more than half of all the world's chips in 2022.[191] Though some new supplies have emerged, and existing suppliers have increased their production since then, the price of new chips has increased drastically, and companies face long waiting times. This in turn has led to a shortage of machinery and appliances needed to modernise, extend, digitise, and automate the rail sector in the EU. The cost of the chip shortage is expected to exceed €600 billion,[192] forcing the EU to accelerate its efforts to build a native chip industry. In time, this native industry is expected to become a global competitor in the chip market. The battery industry is in a similar situation, as four of the world's ten largest battery manufacturers for electric vehicles were headquartered in China before the conflict broke out, forcing European companies to search for new suppliers.[193]

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dynamics of the invasion itself. For such a war game simulation, see e.g., War Game Simulates Chinese Invasion of Taiwan, Wall Street Journal Podcasts, 11 August 2022.

188 Andersen, N. K., The Road to Empire? Assessing the Emergence of a China-Centric Geoeconomic Order, 2021.

189 Shehadi, A. I.-H. S., On the move: manufacturing's return to the developed world, 18 April 2019.

190 Extra-EU trade in goods, Eurostat, March 2022.

191 Chang, E., Taiwan's TSMC still accounts for more than 50% of global chip market share, 16 March 2022.

192 The 2022 chip shortage costs the US economy approx. €240 billion in 2021 alone. Given the comparable sizes of the economies of the US and the EU today, growth in chip demand from 2022 to 2030, and the assumption that a chip shortage would be much more sever in case of a de facto removal of TSMC from the global chip market, an expected shortage price of €600 billion seems a very defensive estimate. Source: Rowsell, J., How much has the semiconductor shortage cost?, 5 May 2022.

193 Bhutada, G., Mapped: EV Battery Manufacturing Capacity, by region, 28 February 2022.

Finally, the invasion of Taiwan has **fostered closer military relations between Europe and the US, as well as increased military spending**. With average Member State military expenditure rising from 1.6 % of GDP in 2020[194] to an expected 2 % of GDP in 2031.[195] This will ultimately lead to approximately an extra €154 billion in military expenditure across the EU.[196] This substantial rearmament has also increased demand for the infrastructure to move troops around Europe. Hence, military experts are calling for more rail investments to support troop mobility and the transport of heavy military equipment on the continent and to the major ports. Consequently, increased military spending led to more dual-use rail improvements that can service civilian and military transport needs to and from European ports (as well as to the Eastern border of the EU).[197]

Key impacts

Fundamental changes to global trade flows as European and American companies move production and assembly facilities closer to home, resulting in shorter supply chains, a reduction in global shipping, and greater demand for European rail transport.
Extra-regional trade continues to use the European ports and the rails that connect to the European hinterlands.
A reduction in shipping rates, due to reduced demand, makes trans-Atlantic and seaborne inter-European trade cheaper, resulting in the movement of some goods from rail to ship.
The shift to shorter shipping routes increases demand for smaller freight ships. shortage detrimental to businesses and further electrification of European rails.
Europe suffers a massive microchip and battery shortage detrimental to businesses and further electrification of European rails.
Part of the increased military spending goes to improving Europe's rail infrastructure for dual-use purposes.

3.4. Summary of scenarios and impacts

Table 3: Scenarios and impacts, summarised

Scenario	Type of shock	Impact on rail demand	Impact on rail infrastructure
Persistent heatwave affecting most	Environmental	Passengers are switching from rail to road for long-distance travel due to unreliability of railway services.	Rail buckling and power line sagging leads to delays and increased maintenance needs.

194 Military expenditure (% of GDP) - European Union, World Bank, 2022.

195 Different EU countries are on different trajectories in terms of military spending, with countries like Poland already spending more than 2 % of GDP and others, like Denmark, expecting to hit 2 % by 2033. Source: Hutt, D., How European countries stand on 2% of GDP defence spending, 22 July 2022.

196 Calculation based on the estimate that the EU will have a GDP in 2027 of €22 045.94 billion, and that the EU's GDP will not grow between 2027 and 2030 due to the global trade disruption of the invasion of Taiwan. Source: European Union: Gross domestic product (GDP) from 2017 to 2027, Statista, n.d.

197 EU digs out millions to prepare rail for military use, RailFreight.com, 14 April 2022.

of Europe		Low water levels lead to increased freight volumes in rail transport. New patterns of tourism are emerging as more people choose to travel towards the north of Europe. Increased awareness of climate change and support for sustainable solutions, including rail.	Lower energy production from sustainable sources leads to increased CO_2-emissions from electricity production.
EU bans internal combustion engines in new heavy goods vehicles as of 2035	Political	Logistics companies seek to shift long-distance freight transport from road to rivers, rail, and sea. Fewer road transport options for freight leads higher demand for rail freight.	Urgent political action needed to address bottlenecks. Massive layoffs in the road transport sector and increased demand for reskilling for rail. Larger investments in rail connectivity and electric HGVs. Lorry fleets are retrofitted into electric or hydrogen-powered lorries.
Destructive cyberattack targeting cellular networks	Technological	Reduction in rail passengers, as some former rail passengers are moving towards other means of transport, while others opt to work more from home.	Disruption of positioning, tracking, and railway signalling systems underlying the ERTMS, causing delays and cancellations. Fewer but larger trains in operation Reimplementation of backup systems by rail operators.
China invades Taiwan	Geopolitical	Shorter supply chains, less global shipping, and greater demand for intra-EU rail transport. Rail lines connecting European ports to the hinterlands are kept in use for extra-regional trade.	Digitalisation of the rail network is slowed down due to shortage of microchips and batteries. Increased military spending, part of which goes to improving Europe's rails for dual-use purposes.

Source: Authors' elaboration.

4. Findings from the stress-tests

This chapter presents the outcomes from the four conducted stress-tests. Key legislation and policy documents linked to three selected flagship initiatives of the SSMS[198] were reviewed against the scenarios presented in sections 3.3.1-3.3.4. This was done to identify policy weaknesses that could be related to one or more of the shocks that the scenarios are based on, as well as the impacts of these shocks. In addition, information was sought about the flexibility of the policies and legislation, embodied as review clauses and/or emergency clauses, since the existence of such provisions allow policymakers more space to act in a crisis, regardless of whether the circumstances of the crisis has been foreseen by the legislation or not.
The sections below detail the findings of this analysis.

4.1. Findings from the first stress-test: Persistent heatwave affecting most of Europe

The research found that the assumptions behind policies belonging to flagships #4 – *Greening freight transport* and #8 – *Reinforcing the single market* indicated that these policies could potentially be vulnerable in the event of a persistent heatwave in Europe.
A persistent heatwave will have significant negative impact on the physical rail infrastructure and as a consequence, the regularity of trains. Further, a heatwave accompanied by widespread drought would lead to a significant decrease in renewable energy production as well as rising energy prices, which will negatively affect the electrified parts of the rail network and lead to increasing prices. In such a situation, there will be fewer incentives for logistic operators to move from road to rail, or to consider multimodal solutions involving rail, and a move of freight away from rail towards road may even be the result. A resulting decrease in demand for rail freight may be offset to a certain extent by the need to move goods that used to be transported by waterways no longer available due to low water tables. Hence, **there are significant uncertainties attached to the demand for rail freight transport in the situation described in the heatwave-scenario**.
With regard to the policy goal to extend and improve the rail infrastructure, in this scenario **it may be a challenge to secure sufficient funds for necessary investments**. In the countries hardest hit, operational costs of rail will increase, and national funds may need to be channelled into emergency measures. This may in turn challenge the ability of states and private rail operators to secure sufficient investments for extending and improving the rail network to comply with the plans for the TEN-T core network.

Findings with respect to the Combined Transport Directive

The Combined Transport Directive 92/106/EEC supports the shift from road freight to lower emission transport modes such as inland waterways, maritime transport, and rail.[199] The preparation of a proposal for a revision of the directive is underway as of November 2022.[200]

[198] The selected flagship initiatives are: #4 – Greening freight transport, #6 – Making connected and automated multimodal mobility a reality, and #8 – Reinforcing the single market. Section 3.1 outlines the selection process.

[199] Directive 92/106/EEC of 7 December 1992 on the establishment of common rules for certain types of combined transport of goods between Member States.

[200] European Commission, Have your say - Sustainable transport - revision of Combined Transport Directive.

Review clauses or plans for review

There is no formal review clause in the directive, but the Commission is required to submit a report every two years. These reports have documented the **ineffectiveness of the Directive when it comes to increasing rail's share of freight transport**.[201]

Emergency clauses

There are no emergency clauses in Combined Transport Directive 92/106/EEC. However, emergency clauses in this context do not make much sense. The entire framework is about liberalising the rail sector and reducing taxes for multimodal transport to increase its share – which has not been effective so far.

Vulnerabilities of the legislation in this scenario

The Combined Transport Directive 92/106/EEC relies on market incentives for a shift to rail. In the scenario where Europe is plagued by a persistent heatwave, it is assumed that EU Member States' investment in rail infrastructure between 2022 and 2030 has, for the most part, gone into maintaining the quality of rails and for rail electrification (rather than for extending capacity). This would all in all still be a best-case scenario, as financing of rail project has been a long-standing problem in the EU and is not an issue that is addressed by the directive. Furthermore, the heatwave would have a negative impact on the physical infrastructure. **The impact would pose significant barriers to a shift to rail**. At the same time, in this scenario, the demand for rail capacity may well increase for reasons directly linked to the heat. For example, a persistent heatwave may cause rivers to dry up, making it impossible to use them for waterway freight. A possible consequence could be increased demand for intra-European rail freight transport. This would not be a result of the policy, but rather the effects of such a scenario aiding the achievement of policy objectives.

The **main weakness of the Combined Transport Directive appears, however, not to be linked to environmental impact, but rather to the main assumption of the directive**: that liberalisation of the transport sector would lead to long-haul freight transport by road being shifted to a combination of short transport by road (e.g., from the point where goods are loaded and transported to the nearest railway station, or from a railway station to the destination) and long-haul or cross-border transport by rail. So far, this shift has failed to materialise.

Overall, the directive does not motivate shifts of freight transport from road to rail and waterways by reference to environmental reasons, but by reference to problems with road congestion.[202] The directive therefore does not necessarily incentivise a shift to the most greenhouse gas efficient form of transport or rank the most desirable forms of transport and what to do if those (in this case, inland waterways) would become unavailable due to changes in the climate. The **market incentives set by the directive do not take into consideration the greenhouse gas efficiency or average external costs of various modes of transport**.[203] To set market incentives right, the respective greenhouse gas efficiencies of various modes of transport, their average external costs, and their coverage ratios of external costs should be

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201 Impact assessment accompanying the Proposal for a Directive of the European Parliament and of the Council amending Directive 92/106/EEC on the establishment of common rules for certain types of combined transport of goods between Member States, SWD(2017) 362, European Commission, November 2017.

202 See recitals of Directive 92/106/EEC on the establishment of common rules for certain types of combined transport of goods between Member States.

203 See section 1.1.2 on the respective greenhouse gas efficiencies of various modes of transport and their average external costs and coverage ratios.

included. This might warrant, for example, more than only tax reductions for rail and waterway transport to achieve a level playing field between road and rail transport.

Adjustments in the "Fit for 55" package to include maritime and road transport sectors in the EU Emission's trading system could be a complementary policy that would set market incentives in a way that a shift to rail is made attractive.[204] At the same time, it is assumed that electricity generation from renewable sources may face difficulties during an extreme heat wave. If the electricity for rail were to come from GHG-inefficient electricity generation, this would need to be reflected in the way GHG and average external costs from various modes of transport would be calculated under a future Combined Transport Directive. This would ensure that shifts to more environmentally friendly modes of transport are encouraged.

Findings with respect to the TEN-T Regulation and revision

The Trans-European Transport Network (TEN-T) policy addresses the implementation and development of a Europe-wide transport network including all transport forms and terminals. The ultimate objective is '…to close gaps, remove bottlenecks and technical barriers, as well as to strengthen social, economic and territorial cohesion in the EU'.[205] The policies build on Regulation No. 1315/2013/EU.[206]

Review clauses or plans for review

Article 54 of Regulation 1315/2013/EU foresees a review by 31 December 2023 of various aspects of the TEN-T Regulation. A revision has been ongoing since 2021. The European Commission has drafted a proposal for a revised regulation.[207] There are four aims of the revision: to increase the share of greener transport (in particular rail), to foster multimodality and interoperability of TEN-T transport modes, to increase the resilience of the TEN-T network to climate change, and to improve TEN-T governance tools.

Emergency clauses

In Regulation 1315/2013/EU, Article 5 (g) **requires that planning of the TEN-T network considers the vulnerability of transport infrastructure regarding a changing climate, as well as natural or man-made disasters**, with a view to addressing those challenges – so there is already a requirement for the network to be climate crisis proof to the extent possible.

Article 10 (e) of this TEN-T Regulation requires priority to be given to measures in the development of the network for 'improving or maintaining the quality of infrastructure in terms of safety, security, efficiency, climate and, where appropriate, disaster resilience, environmental performance, social conditions, accessibility for all users, including elderly people, persons with reduced mobility and disabled passengers, and the quality of services and continuity of traffic flows'.

Article 35 says that 'During infrastructure planning, Member States shall give due consideration to improving resilience to climate change and to environmental disasters.'

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204 See also section 1.3.

205 Quoted from Trans-European Transport Network (TEN-T), European Commission, n.d.

206 Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the Trans-European Transport Network and repealing Decision No 661/2010/EU.

207 Proposal for a Regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, COM(2021) 812, European Commission, December 2021.

The objectives of the proposal for a revised TEN-T Regulation[208] now also include in Article 4 (d) (iv) 'supporting **mobility that is fit for the changing climate and resilient to natural hazards and human-made disasters** and ensures efficient and fast deployment of emergency and rescue services, including for persons with disabilities or reduced mobility'.
New Article 5 (g) to (h) of the proposal now addresses disruptions in further detail, but without specifying concrete action plans for climate resilient infrastructure in case of disaster and traffic disruption.
New Article 46 specifies how Member States should plan infrastructure to ensure security and resilience in light of climate change, including life-cycle analysis and climate proofing.
New Article 47 deals with risks to security and public order and requires Member States and the European Commission to exchange information about security risks. This includes giving some powers to the Commission to act and issue opinions in case third-country nationals or undertakings participate in a project of common interest within the TEN-T framework. The idea behind this provision is to allow the Commission to review decisions by Member States on foreign direct investment related to critical infrastructure within TEN-T network, which are not already covered by Regulation (EU) 2019/452.[209]

Vulnerabilities of the legislation in this scenario

TEN-T Regulation 1315/2013/EU contains provisions to make sure that projects for rail corridors are planned in a manner that considers natural disasters and climate change, and the proposal for a revised TEN-T Regulation[210] adds further details to existing provisions on making and building resilient rail infrastructure. **While the proposal for the revised TEN-T Regulation would require Member States to include life-cycle analysis and climate proofing in their infrastructure plans, no further guidance is given as to how such analysis should be implemented**. There is also no specific legal basis given for the Commission or expert bodies, such as the European Rail Agency or IRG-Rail, to draw up binding best practices to ensure that life-cycle analysis and climate-proofing are carried out in an effective manner. As the Commission notes in its impact assessment accompanying the proposal for a revised TEN-T Regulation, there were no dedicated studies of the resilience of the TEN-T network when it comes to extreme weather conditions.[211]
A further vulnerability of TEN-T Regulation 1315/2013/EU and the proposal for amending it is that **neither have legislative provisions indicating how infrastructure should be made climate resilient, and how this should be financed**. During a heat crisis, securing financing for infrastructure expansion may present a problem, since funds are channelled into amelioration of the effects of drought and wildfires described in the narrative of the heatwave scenario. The original regulation refers to a variety of funds to align and combine to fund the building of the TEN-T core network,[212] e.g., structural and cohesion funds, the Neighbourhood

208 ibid.

209 Regulation (EU) 2019/452 of the European Parliament and of the Council of 19 March 2019 establishing a framework for the screening of foreign direct investments into the Union.

210 Proposal for a regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, COM(2021) 812, European Commission, December 2021.

211 The EU Commission undertakes an analysis of the resilience of the TEN-T network when it comes to river flooding, in particular ports. 6% of the TEN-T rail network would be affected by flooding. Source: Impact Assessment Report Accompanying the document Proposal for a Regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, SWD(2021) 472, European Commission, December 2021.

212 Recital 47 in the Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU.

Investment Facility (NIF), the Instrument for Pre-Accession Assistance (IPA), and financing from the European Investment Bank, and the European Bank for Reconstruction and Development.

The proposal for a revised TEN-T regulation refers to InvestEU; the Recovery and Resilience Facility; Cohesion Policy; Horizon Europe; and 'other financing instruments established by the European Investment Bank'.[213] These funding institutions and instruments, however, would likely be the same called upon to avoid other devastating effects of a persistent heat wave, and it is not clear how priorities for these funds would be set in such a situation, potentially leaving initiated TEN-T corridor projects stranded. According to the proposal for a revised TEN-T Regulation, **the European Coordinators for Transport Corridors shall identify and prioritize investment needs in rail,**[214] **but the coordinators do not have enforcement powers to secure that funding is not diverted to other projects from the European rail corridors**.

As shown in the scenario focusing on the impacts of a persistent heatwave (see section 3.3.1), Member States and their rail infrastructure could be affected differently, which may require an adaptation as to how cross-border coordination of rail transport works. **There appears to be no provision in the regulation that guarantees the maintenance of proper cross-border management in times of crisis where political forces might pull their attention away from the TEN-T project** (also noted as a problem in stakeholder consultation for the revision of TEN-T Regulation and addressed e.g., in Article 51 of the revised TEN-T Regulation[215]).

The TEN-T Regulation envisages a position of European Coordinators that should support the implementation of the core network corridors and report on any impediments.[216] **While the European Coordinators could exert soft pressure through reporting to the European Commission, Member States, and other stakeholders,**[217] **they have no enforcement powers in case of disagreements between Member States, or if disengagement of a Member State would occur**. At the same time, however, under the Directive on the resilience of critical entities,[218] agreed on in June 2022, Member States would be obliged to cooperate on maintaining the resilience of shared critical entities. Both rail infrastructure managers and rail undertakings are classified as critical infrastructure in the Annex to the Directive. This Directive could thus compensate the lack of hard mechanisms to ensure coordination in the case of a massive heat wave under the TEN-T Regulation.

No concrete harmonised measures for increasing the share of rail in multimodal transport are given in the TEN-T Regulation in its current form. Such measures are however introduced in the revised TENT-T proposal, e.g., by allowing freight trains with a length of at least 740 m to travel without special permission in the comprehensive network during specific time frames. Articles 15 and 16 of the proposal push for longer trains, running with higher frequency and at higher speed in the core and extended network.[219] In periods of persistent drought, however, problems, faster trains running at higher frequencies could

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213 Recital 72 in the Proposal for a regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, COM(2021) 812, European Commission, December 2021.

214 Article 51 (6) and (7) of the proposal for a revised TEN-T Regulation, source: ibid.

215 Article 51, COM(2021) 812.

216 Article 45, Regulation (EU) No 1315/2013 on Union guidelines for the development of the TEN-T

217 See Article 45 (5)(d), ibid.

218 See Proposal for a Directive on the Resilience of Critical Entities, COM(2020) 829 final, European Commission, December 2020. The Council presidency and the European Parliament reached political agreement on the directive in June 2022, see: EU resilience: Council presidency and European Parliament reach political agreement to strengthen the resilience of critical entities, European Council, June 2022.

219 Article 15 and 16, COM(2021) 812.

exacerbate the risk of sparks from friction igniting wildfires. If this turned out to be the case, the European Commission could grant individual exemptions under Article 16 (5) (b) of the proposal, which could allow for a reduction of speed and frequencies in 'duly justified cases' after 'a socio-economic cost-benefit analysis and an assessment of the impact on interoperability'. Those exemptions, however, might jeopardise the attainment of the milestones in freight and passenger rail travel for 2040 and 2050 envisaged in the revised TEN-T proposal.[220]

While the proposal for a revised TEN-T Regulation remedies some of the vulnerabilities, the issue of financing of the core network remains. The funds within the EU Recovery and Resilience Facility, for example, are committed to dedicate significant parts to transport. However, it is not clear whether these commitments can be kept (or legally enforced). **There are also significant mismatches between funding timelines and the timeline for the improvements of the TEN-T network.** The new timeline for completing the implementation of the improvements to the TEN-T network now also includes milestones for 2040 (completion of extended core network, which is fully electrified and allows for rail transport of longer, heavier and more frequent train travel, and deployment of ERTMS as the only signalling system on the entire core network). This is in addition to the milestones for 2050 (extending all 2040 goals to the comprehensive network, increase of the market share of rail freight by 100 %) – while, for example, funding from the Recovery and Resilience Facility is granted until 2027 only, and there are no commitments beyond 2027.[221]

Finally, the proposal for a revised TEN-T regulation will create an even larger regulatory framework than the existing TEN-T Regulation 1315/2013/EU. In the Commission's impact assessment of the TEN-T Regulation, problems in the governance structure of the TEN-T network were already noted.[222] **The enhanced role of the European Coordinators could be an avenue to allow for better coordination, as well as to ensure efficient administration, but the revised TEN-T proposal does not really specify their mandate**.[223] The problem of ensuring good governance in moments of crisis, thus, would not fully be addressed by the revised TEN-T Regulation.

220 COM(2021) 812.

221 Article 7, Regulation (EU) 2021/241 of 12 February 2021 establishing the Recovery and Resilience Facility.

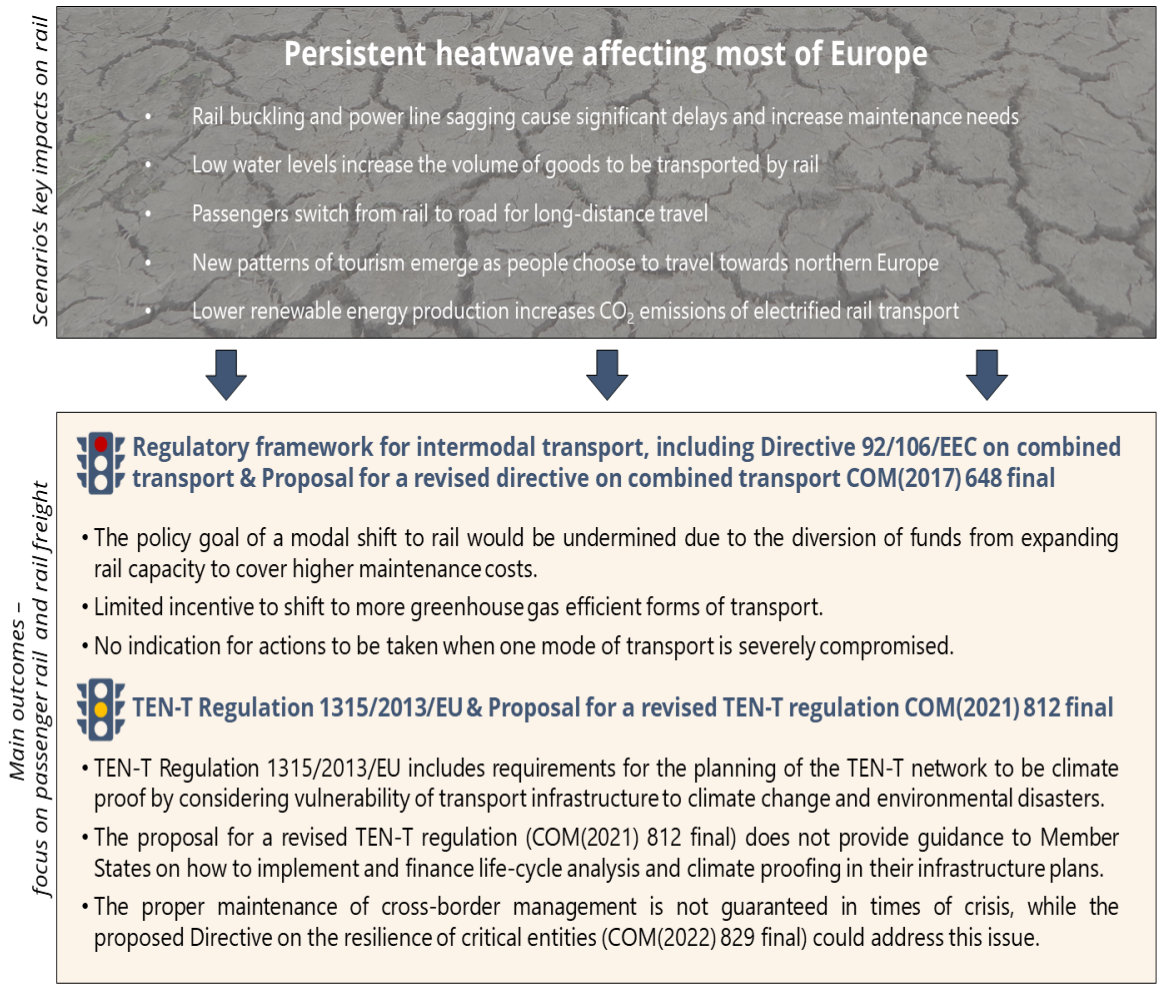
222 Impact Assessment Report Accompanying the document Proposal for a Regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, SWD(2021) 472, European Commission, December 2021.

223 As noted, for example, by EIM position paper on the revised TEN-T Regulation proposal, 27 June 2022.

Overview of main outcomes

The figure below summarises the main findings from the first stress-test:

Figure 2: Main outcomes of the first stress-test



Source: Authors' elaboration.

4.2. Findings from the second stress-test: EU bans new internal combustion engine heavy goods vehicles from 2035

During the scoping exercise, the research found indications that policies within flagship initiative #4 – *Greening freight transport* and #8 – *Reinforcing the single market* could potentially be vulnerable to a situation where a sudden change in the mix of transport modes would create a rapid increase in the demand for rail transport. As an event that could create such a situation, the team proposed a scenario where the EU, to reach the CO_2-emission targets for 2030 would ban the selling of new heavy goods vehicles with internal combustion engines as of 2035 (alongside the already scheduled ban of petrol and diesel cars).

At a first glance, the ban would be supportive of EU rail policies since it would increase the price of road freight and limit road freight capacity by forcing logistics companies to invest in electric or hydrogen-driven lorries rather than the cheaper diesel lorries. The increased price of

road freight would improve the competitiveness of rail freight. However, the ban would also create challenges to EU rail policies, the main challenge pertaining to **the capacity of the rail network and rolling stock to accommodate a swift increase in the demand for rail freight.** Not only are there issues concerning different gauge widths, but also, there are some nodes which are limiting the capacity of other parts of the rails (the example of the tunnels through the Alps was offered here).

Findings with respect to the EU Regulation concerning a European rail network for competitive freight

Review clauses or plans for review

The Commission is to report on the application of the Regulation 913/2010/EU concerning a European rail network for competitive freight every three years.[224] The 'EU 2021 Rail Corridor Initiative' includes a revision of the Rail Freight Corridor Regulation but has not been published to date.[225]

Emergency clauses

Article 17 of the Regulation on a European rail network for competitive freight[226] provides for traffic management in case of disturbance, but only seems to be tailored to ordinary disturbances, not major shocks. The exact rules are adopted by the management board of the respective rail freight corridor. No clear rules for coordination between the various management boards appears to be envisaged.

Vulnerabilities of the legislation in this scenario

Regulation 913/2010/EU only establishes freight corridors but does not account for any situations where the resilience of the freight corridors might be at stake, e.g., due to climate change, a disruption (e.g., Rastatt accident), or radical increase in demand for rail freight services as in this scenario.

At the same time, coordination mechanisms between EU Member States, when it comes to ensuring continuing rail freight operations, have been shown to be successful before. As the Commission mentions in its Contingency Plan for Transport, the Commission and Member States were able to establish a Network of National Transport Contact points during Covid 19, which enabled the establishment of Green Lanes to keep cross-border rail transport flowing.[227] The same is now happening in the context of the Russian invasion of Ukraine where so-called Solidarity Lanes have been established. This shows that the Commission and Member States have been able to agree on crisis measures to make passenger and freight transport more effective and to ensure better cooperation between Member States. The question might then rather be whether EU legislation should be adapted to put a legislative framework around the European Commission's powers to react during crises to hedge against any potential negative consequences from allowing it to act without or with little oversight by other EU institutions.

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224 Article 23, Regulation (EU) No 913/2010 of 22 September 2010 concerning a European rail network for competitive freight.

225 EU 2021 rail corridor initiative, including the revision of the rail freight corridor Regulation and actions to boost passenger rail, Legislative Train Schedule, European Parliament, October 2022.

226 Article 17, Regulation (EU) No 913/2010 of 22 September 2010 concerning a European rail network for competitive freight.

227 Communication on A Contingency Plan for Transport, COM(2022) 211, European Commission, May 2022.

It is not clear what would happen when there is no political consensus on how to react in exceptional circumstances when it comes to coordinating and reacting to any shocks regarding rail freight. The scenario used in the second stress-test describes how certain Member States lament the EU decision to ban new internal combustion engine HGVs. At the same time, the scenario makes clear that Member States have been willing to invest in rail infrastructure in the meantime, just like they have worked on relieving bottlenecks and making multimodal terminals apt for increased freight loads. The mechanisms under Regulation 913/2010/EU foresee cooperation mechanisms in the planning and allocation of capacity to freight trains[228] and when it comes to investment planning of the freight corridors.[229] These provisions would appear to be apt to ensure a satisfactory level of coordination through the management board composed of infrastructure manager representatives and Member States' representatives.

Overall, Regulation 913/2010/EU does not foresee governance mechanisms for rail freight corridors in moments of crisis or shocks. The scenario on the ban of new internal combustion engine HGVs does not involve a shock in the proper sense of the word, but rather a gradual development towards a shift from road to rail announced in advance. Still, it may be worthwhile reflecting whether to include considerations in relation to exceptional circumstances in the governance framework of the rail freight corridors. This would be particularly important where there might be obstacles to a consensus regarding how to react to a shock among Member States, national regulators, infrastructure managers, and the Commission.

Findings with respect to Review of the regulatory framework for intermodal transport, including the Combined Transport Directive

Review clauses, plans for review and emergency clauses

As described in section 4.1.1.

Vulnerabilities of the legislation in this scenario

The complete ban of new internal combustion engine HGVs for long distance road freight transport could radically increase the demand for rail freight capacity. This would likely make some of the provisions providing economic incentives for shifting to multimodal transport (like tax exemptions or reductions) redundant, as market incentives would already be there due to a lack of alternatives. **Probably an entirely new and different regulatory framework, e.g., on fair allocation of rail freight capacity would be necessary to keep competition on the market fair and to avoid disruptions/congestion**.

As explained in Section 1.1.2., a fundamental transformation of the railway sector is necessary to significantly increase the share of freight transported by rail. In order **to increase the capacity of the European rail network for freight, barriers to interoperability (gauges and signalling), problems with congestion around large cities, and insufficient cross-border coordination would need to be remedied**. As explained in section 4.1.2, the revised TEN-T Regulation[230] would have as its goals to enhance interoperability of the core and the comprehensive TEN-T network and could thus complement the Combined Transport Directive.

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228 Article 14, Regulation (EU) 913/2010 of 22 September 2010 concerning a European rail network for competitive freight.

229 Article 11, ibid.

230 Proposal for a regulation on Union guidelines for the development of the trans-European transport network, amending Regulation (EU) 2021/1153 and Regulation (EU) No 913/2010 and repealing Regulation (EU) 1315/2013, COM(2021) 812, European Commission, December 2021.

Furthermore, if there is a situation, as in this scenario, where Member States have been willing and able to commit considerable funds to improving rail infrastructure (€60 billion by 2040), at least problems from lack of investment, which jeopardise the achievement of the goals under the Combined Transport Directive, as well as the TEN-T Regulation, would not materialise.

Findings with respect to the TEN-T Regulation and revision

Review clauses, plans for review and emergency clauses

As described in section 4.1.2

Vulnerabilities of the legislation in this scenario

The TEN-T Revision[231] does not foresee a situation where there is a severe supply shock in one mode of transport (road) that would radically increase demand in another modality (rail). **While the legislation aims to increase capacity of rail freight, it does not foresee that the demand could increase radically at relatively short notice.** As the workshop participants noted and exemplified, the European rail system is unable to respond to short-notice requests for service from freight customers because schedules often need to be set months or years in advance.[232] Existing infrastructure improvement projects have also shown extreme delays, as for example the roll-out of the deployment of the ERMTS across all core network corridors, which continues to be far from the goal of 100% deployment on all corridors by 2030.[233] Extending the capacity of the rail network by improving or expanding the physical rail infrastructure equally requires decades of planning and construction work.

The successful NRLA project in Switzerland, for example, substantially increased the number of freight trains able to cross the Alps, while taking more than 20 years to complete.[234] Even though the NRLA project was particularly ambitious, also less ambitious projects would likely have a time horizon of at least 10 years. Overall, it would be extremely difficult to respond quickly to an increase in demand by initiating an expansion and improvement of the physical infrastructure. Therefore, other less demanding measures, which also entail important trade-offs, could be contemplated. One example would be to eliminate the night-time ban for freight trains, which would increase capacity, but would also lead to increased noise levels.

Finally, capacity increases could also be achieved by accelerating the implementation of innovative technologies such as automatic coupling, faster data exchange, and driverless trains. These technologies can potentially already be in place by 2035. In addition, **there is an idea in the framework of the TEN-T Regulation to establish connections with R&D centres in favour of new technologies that can make the construction and maintenance of rail infrastructure faster and cheaper, and, ultimately, more responsive to changes in demand**. Developing this idea further – and provide funding for the establishment of a dedicated R&I network – could prove a key opportunity for EU to create added value in the field of rail policy.

231 ibid.

232 See section 1.1.2.

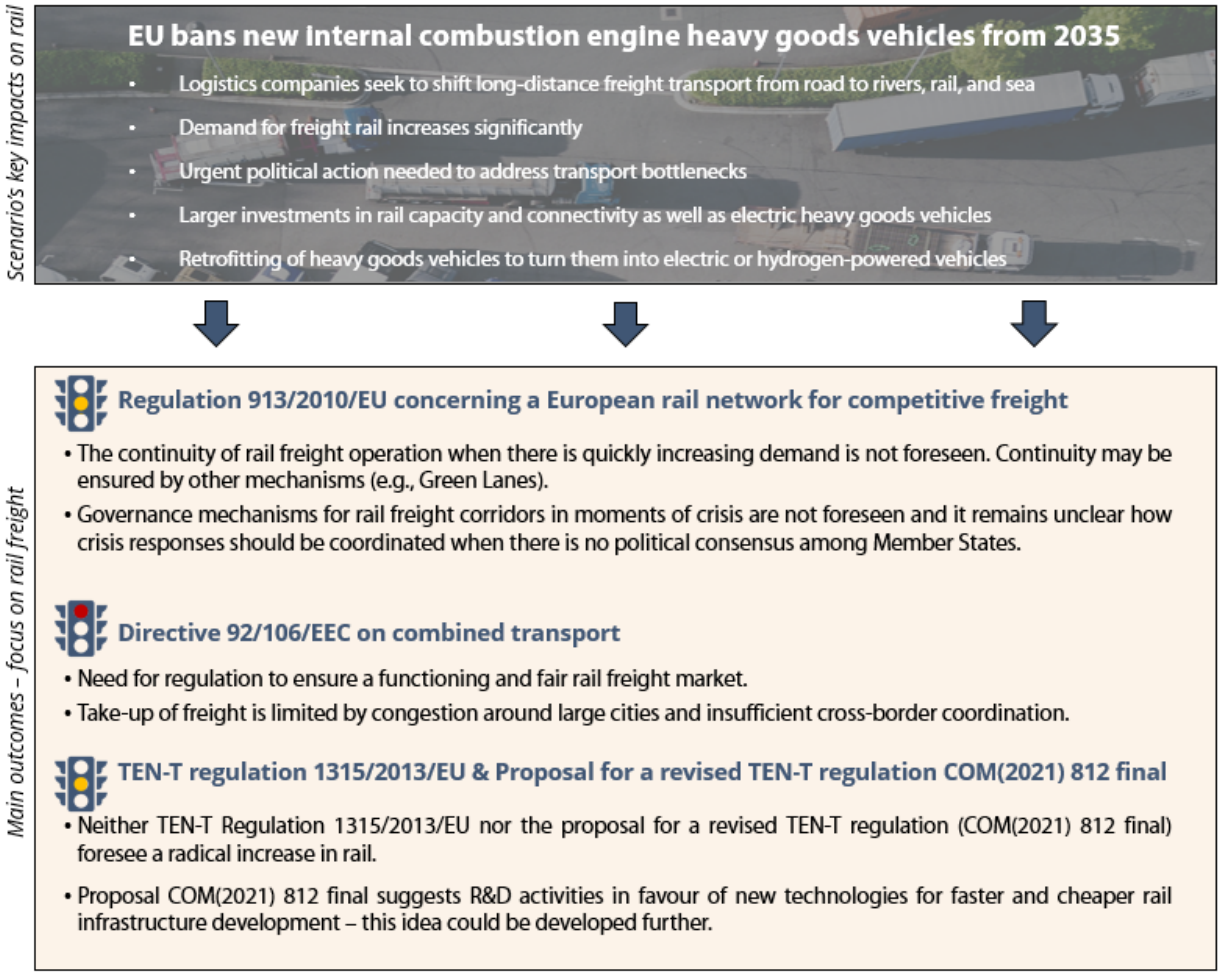
233 In 2019, roll-out stood at 16% of all core network corridors, see also section 1.1.2. above.

234 Overview, Alptransit Portal, n.d.

Overview of main outcomes

The figure below summarises the main findings from the second stress-test:

Figure 3: Main outcomes of the second stress-test



Source: Authors' elaboration.

4.3. Findings from third stress-test: Destructive cyberattack targeting the ERTMS

Flagship initiative #6 – *Making connected and automated multimodal mobility a reality* concerns digital aspects of (rail) transport. It was therefore assumed that these policies would be vulnerable to cyber threats regardless of the origin or purpose of such threats.

Policies within Flagship #6 aim at building a legal framework that supports multimodal travel information, booking, and ticketing services, further rolling out the European Rail Traffic Management System (ERMTS), and fostering train/rail automation. Hence, the policies target both passenger and freight transport. As indicated in the scenario, such advances in the ERMTS and automation might be put in danger by a large-scale cyberattack. The following thus reviews Directive 2010/40/EU on Intelligent Transport Systems (ITS) and assesses how its

vulnerabilities vis-à-vis the threat of a large-scale cyber-attack, the Delegated Regulation 2017/1926 on the provision of EU-wide multi-modal travel information services, and the ambitions of the EU Commission regarding multi-modal digital mobility services under the SSMS.

Findings regarding the Directive on Intelligent Transport Systems

Review clauses or plans for review

The Commission may adopt delegated acts under Article 7 of the ITS Directive 2010/40/EU[235] regarding specifications (which would likely also include cybersecurity aspects).
In addition, Member States must report every three years on the progress made on ITS actions, and the Commission must report every three years on the implementation of the ITS Directive to Parliament and Council (Article 17).
In 2021, the Commission tabled a proposal for amending the ITS Directive based on the SSMS.[236] The goal of the amendment is to facilitate the creation of connected and automated multimodal digital mobility services in the EU. In order to achieve this goal, the amendments suggested for the ITS Directive concern offering more interoperability, cooperation, and data sharing of ITS services across the EU.

Emergency clauses

The proposal for a revised ITS Directive would empower the Commission to adopt interim measures in the event of an emergency.[237] These new interim powers would allow the Commission to adopt immediately applicable implementing acts suspending or establishing obligations in regard to ITS services. The Commission's powers under this provision would be governed by regulation 182/2011[238] laying down the rules and principles concerning mechanisms for control by Member States of the Commission's exercise of implementing powers.

Vulnerabilities of the legislation in this scenario

The ITS Directive mostly addresses road mobility. It contains little information about resilience or risk assessment of data and digital infrastructure, except Article 10 which covers measures to protect personal data (which would by now likely be covered by GDPR in any case). There are no provisions on cybersecurity. This would change with the European Commission's 2021 Proposal for amending the ITS Directive, which would allow under new Article 7a to authorise the Commission to adopt interim measures in an emergency with severe direct impact on cyber security.[239] In its comments on the Commission proposal, Transport and Tourism Committee of the European Parliament proposed to narrow the scope of the

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235 Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

236 See new Article 7a in Proposal for a Directive of the European Parliament and of the Council amending Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, COM(2021) 813, European Commission, December 2021.

237 ibid.

238 Regulation (EU) No 182/2011 of the European Parliament and of the Council of 16 February 2011 laying down the rules and general principles concerning mechanisms for control by Member States of the Commission's exercise of implementing powers.

239 Article 7a, COM(2021) 813.

Commission's emergency powers by stating that they should 'only be used in emergency situations when other forms of remediation by other authorities have not been successful.'[240] At the same time, **the scenario based on a destructive cyberattack describes how infrastructure operators revive old systems as a backup precaution. The revised TEN-T Regulation, however, specifically requires abandoning the predecessor systems to the ERTMS**.[241] A move back towards old technology might create new problems from a cybersecurity perspective, and is something that neither the amendment to the ITS nor the revised TEN-T Regulation take into account. The viability and costs and benefits from reverting to old systems in case of a break-down of the ERTMS, and how multimodal IT systems could or should react to it, is not considered in the proposed pieces of legislation. This being said, there already exists a security and trust standard that is mostly deployed in the context of road safety in connection with Cooperative Intelligent Transport Systems (C-ITS).[242] These systems are comprised of connected vehicles capable of communicating with each other and the transport infrastructure trough digital technologies, including fully autonomous vehicles.[243] It could be worth exploring whether C-ITS standards could offer a blueprint for cybersecurity in the railway sector as well. This seems particularly relevant in the context of emerging digital technologies, such as the FRMCS (see section 1.3), that allow for the operation of automated trains.

Findings with respect to the Commission Delegated Regulation on the provision of EU-wide multimodal travel information services

Review clauses or plans for review

Delegated Regulation 2017/1926 on the provision of EU-wide multimodal travel information services[244] contains no review clauses, but a reporting obligation was imposed on Member States. In the European Commission's SSMS, a revision of the Delegated Regulation 2017/1926 is included to provide for dynamic data exchange and interoperable payment solutions.[245]

Emergency clauses

None.

Vulnerabilities of the legislation in this scenario

There are no provisions on cybersecurity or other means of ensuring accuracy and data integrity in the Delegated Regulation. These could potentially be required in the standards and technical specifications of multimodal travel information services. At the same time, as

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240 Draft report on the proposal for a directive of the European Parliament and of the Council Amending Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, TRAN Committee, European Parliament, 24 May 2022.

241 e.g., Article 17 (1), COM(2021) 812.

242 Report on the Implementation of Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport, COM(2019) 464, European Commission, October 2019.

243 Inception Impact Assessment for an Initiative on Specifications for the provision of cooperative intelligent transport systems (C-ITS), Ares(2017)2592333, European Commission, 22 May 2017.

244 Commission Delegated Regulation (EU) 2017/1926 of 21 May 2017 supplementing Directive 2010/40/EU of the European Parliament and of the Council with regard to the provision of EU-wide multimodal travel information services.

245 Communication on the Sustainable and Smart Mobility Strategy - putting European Transport on track for the future, COM(2020) 789, European Commission, December 2020.

noted by the European Commission in its contingency plan for transport[246], **there is legislation underway to raise cybersecurity levels in the EU in general via the NIS II Directive[247] and for critical entities, including rail infrastructure, in particular**.[248]
These new pieces of legislation would require transport providers to take measures to become more resilient to threats to cybersecurity. Also, ENISA has released guidelines to increase railway cybersecurity.[249] All these initiatives might close the gap in legislation relating to protecting European rail networks from cyber threats.

Findings regarding EU-wide multimodal digital mobility services

This is proposed by the European Commission as an element of the SSMS.[250]

Review clauses, plans for review or emergency clauses

These are not specified yet.

Vulnerabilities of the legislation in this scenario

The inception impact assessment suggests a review of Delegated Regulation 2017/1926 to also provide for dynamic data exchange and interoperable payment solutions.[251] **The inception impact assessment does not mention any measures targeting increased risk of exposure to cyberattacks. Given that other legislative instruments are under way, at least references to them could be included in any possible future legislation**.

246 Communication on A Contingency Plan for Transport, COM(2022) 211, European Commission, May 2022.

247 In May 2022 the European Parliament and European Council reached an agreement on the text of the NIS II Directive. Source: Commission welcomes political agreement on new rules on cybersecurity of network and information systems, European Commission, 13 May 2022. (The political agreement is based on the Proposal for a Directive on measures for a high common level of cybersecurity across the Union, repealing Directive (EU) 2016/1148, COM(2020) 823, European Commission, December 2020).

248 Proposal for a Directive on the resilience of critical entities, COM(2020) 829, European Commission, December 2020. The Council presidency and the European Parliament reached political agreement on the directive in June 2022. Source: EU resilience: Council presidency and European Parliament reach political agreement to strengthen the resilience of critical entities, Council of the European Union, 28 June 2022.

249 Railway Cybersecurity – Good Practices in Cyber Risk Management, ENISA, 25 November 2021.

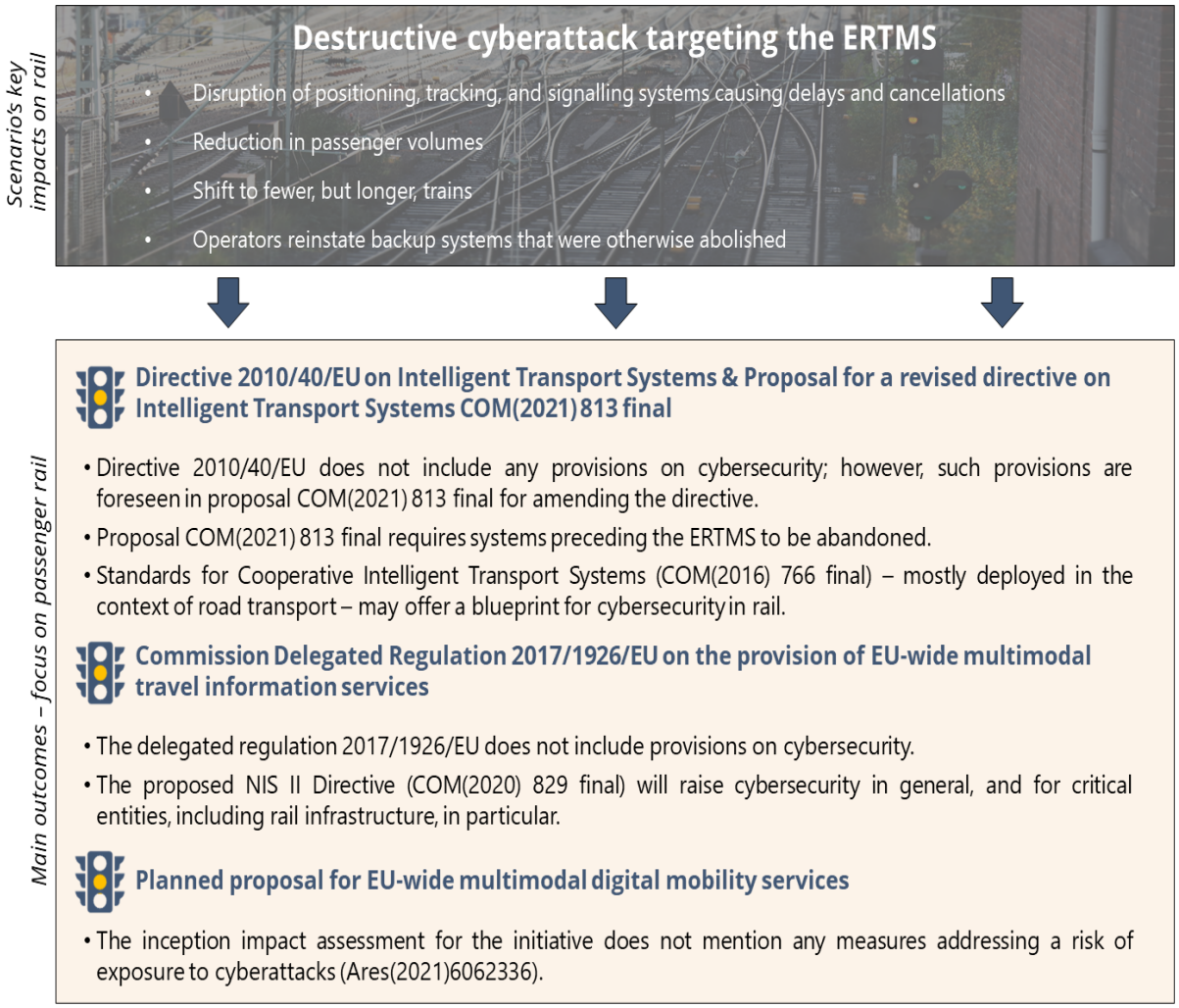
250 An inception impact assessment was published on 5 October 2021. Source: Inception Impact Assessment for an Initiative on Multimodal Digital Mobility Services, Ares(2021)6062336, European Commission, 5 October 2021.

251 Ares(2021)6062336, European Commission, 5 October 2021.

Overview of main outcomes

The figure below summarises the main findings from the third stress-test:

Figure 4: Main outcomes of the third stress-test



Source: Authors' elaboration.

4.4. Findings from fourth stress-test: China invades Taiwan

Policies within flagship #8 – *Reinforcing the single market* were found to be potentially vulnerable to events that could channel funds away from investment in rail. A geopolitical scenario was therefore proposed in which China has invaded Taiwan, resulting in international economic sanctions and a changed landscape for European extra-regional trading – especially regarding electronic chips, telecommunications devices, and batteries.

The impact on the scenario on rail pulls into two directions: on the one hand, as more production shifts from China to the EU the demand for European rail transport increases. On the other hand, an expected reduction in shipping rates would move some amount of goods from rail transport to waterborne transport modes. Furthermore, a contraction of the European economy is expected, and overall public spending has increased for military and defence

activities. This begs the question whether the EU's State aid rules are sufficient to help in managing such a crisis and its impact on the transport sector.

Findings with respect to transport-relevant State aid rules

Review clauses or plans for review

The transport-relevant State aid rules in the context of this study consist of Article 107 of the Treaty on the Functioning of the European Union (TFEU) together with the Commission's 2008 Guidelines on State Aid for Railway Undertakings.[252] The European Commission is required to report on the application of the Guidelines (at the latest) five years after their date of publication. As of November 2022, the Commission is in the process of reviewing its Guidelines. It published an inception impact assessment on 1 October 2021, and updated Guidelines should be adopted within Q4/2023.[253]
In addition, the Commission has proposed a block exemption regulation for certain categories of State aid in the rail, inland waterway and multimodal transport sectors in July 2022.[254]

Emergency clauses

Article 107(2)(b) of the TFEU allows 'aid to make good the damage caused by natural disasters or exceptional occurrences.'
Under Article 107 (3) (b), the European Commission can authorise 'aid to promote the execution of an important project of common European interest or to remedy a serious disturbance in the economy of a Member State'.
There is no mention of emergencies or crisis situations in the guidelines themselves, but the Commission's Contingency Plan for Transport mentions that **the experience with adopting guidelines on the application of the state aid rules during the Covid 19 pandemic showed that the EU state aid regime was flexible and could be effectively deployed in times of crisis**.[255] This is not only true for crises caused by internal factors, like Covid 19, but also for crises caused by external factors. As a response to the Russian invasion of Ukraine, for example, The European Commission adopted a new Temporary Crisis Framework to allow Member States to support their economy under Article 107 (3) (b) TFEU.[256] Member States, for example, are able to support companies that are struggling due to the EU sanctions package against Russia. A similar framework could be adopted to help struggling EU companies after an attack of China in Taiwan.

Vulnerabilities of the legislation in this scenario

The relevant State aid guidelines do not specifically address situations where aid is to be given to the rail sector in cases of crises. Nonetheless, the Commission found flexible solutions to support struggling rail companies during Covid 19. State aid law thus seems to provide a

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252 Sources: Articles 93 and 107 of the Consolidated Version of the Treaty on the Functioning of the European Union, Official Journal of the European Union, 26 October 2012; Communication on Community guidelines on State aid for railway undertakings, (2008/C 184/07), European Commission, July 2008.

253 Inception Impact Assessment on the Revision of the Community Guidelines on State Aid for Railway Undertakings, Ares(2021)597518, European Commission, 1 October 2021.

254 Proposal for a Council Regulation on the application of Articles 93, 107 and 108 of the Treaty on the Functioning of the European Union to certain categories of State aid in the rail, inland waterway and multimodal transport sector, COM(2022) 327, European Commission, July 2022.

255 Communication on A Contingency Plan for Transport, COM(2022) 211, European Commission, May 2022.

256 Article 107 (3) (b), Consolidated Version of the Treaty on the Functioning of the European Union, Official Journal of the European Union, 26 October 2012.

flexible solution for providing financial support during crises, but it **does not provide solutions for situations in which public funds might be insufficient to provide aid in the first place. In this case, however, military spending might be aligned with increased spending in rail infrastructure, thus aligning both defence and transport policies**.[257] This is already being fostered by the 2022 CEF Transport Military Mobility call, which makes €330 million available from the CEF funding to adapt the TEN-T network for dual civilian and defence use.[258] This entails upgrading rail infrastructure to allow for the movements of military troops and assets, for example by adapting rail lines for the circulation of larger and heavier trains.[259]
However, the surge in demand for rail to transport freight might create a bottleneck, as it takes a long time to plan and execute capacity increases of rail infrastructure for freight. It would thus seem that while the state aid regime is flexible to allow for financing of rail projects, it might nonetheless be difficult to react to a positive demand shock in the short term. The European Parliament has stated that 'the State aid rules relevant to transport should be revised to enable more public support to develop and deploy clean and smart mobility technologies and their related industries'.[260] To some extent, **the Parliament's call for such a revision could actually be understood as incentivising the investment in innovation for scaling and rolling out rail freight projects more quickly and maybe even flexibly** to absorb demand shocks in either direction in order to remedy this inherent vulnerability in situations where rail would need to respond in a shorter term to emergencies.
In this context, **vulnerabilities already identified in the process of setting up Solidarity Lanes to allow trade between the EU and Ukraine to shift more to rail should be tackled already now**. These vulnerabilities include different gauge width in countries to the East and external to EU borders, insufficient transhipment capacity, and lots of red tape at EU's external borders.[261]

Findings with respect to Review of 2008 Community Guidelines on State aid for railway undertakings

Review clauses or plans for review

The 2008 Community Guidelines on State aid for railway undertakings[262] do not contain formal review clauses, but the process to amend the guidelines offers much greater flexibility than a proper legislative amendment needed in the case of Directives or Regulations.

Emergency clauses

The inception impact assessment on the revision of the Community Guidelines[263] does not refer to emergency or crisis situations, but given the flexibility of State aid rules, this might not be

[257] This is noted by the European Parliament in relation to the revision of the TEN-T Regulation, see Resolution of 20 January 2021 on the revision of the Trans-European Transport Network (TEN-T) guidelines, 2019/2192 (INI), European Parliament, pt. 49.

[258] The call closed in September 2022. Source: 2022 CEF Transport Military Mobility call, European Commission, 4 May 2022.

[259] EU transport infrastructure: speeding-up investments in dual civil/defence use and energy efficiency, European Commission, 8 April 2022.

[260] Draft report on the sustainable and smart mobility strategy, TRAN Committee, European Parliament, 22 March 2021.

[261] Communication on an Action Plan for EU-Ukraine Solidarity Lanes to facilitate Ukraine's agricultural export and bilateral trade with the EU, COM(2022) 217, May 2022.

[262] Communication on Community guidelines on State aid for railway undertakings, (2008/C 184/07), European Commission, July 2008.

[263] The EU Commission published the Inception Impact Assessment on the Revision of the Community Guidelines on State Aid for Railway Undertakings (Ares(2021)597518) on 1 October 2021.

necessary. At the same time, **it would seem natural to include the experiences from adapting State aid rules with the help of the 2008 Community Guidelines to negative demand shocks in transport during Covid 19 in a more generalised fashion when drafting new guidelines**.

Vulnerabilities of the legislation in this scenario

As described above, in section 4.4.1.

Overview of main outcomes

The figure below summarises the main findings from the fourth stress-test:

Figure 5: Main outcomes of the fourth stress-test

Source: Authors' elaboration.

5. Lessons learned and key findings

Below, the lessons learned and conclusions on the stress-testing of EU rail policies are presented. The lessons learned can be divided into two: lessons regarding the stress-testing methodology, and findings from the stress-test itself.

5.1. Methodological lessons learned

Overall, the methodology – stress-testing against scenarios based on shocks with relevance for transport – proved effective in identifying vulnerabilities and gaps in policies and legislation. Stress-testing policies against scenarios combining high impact

events with existing trends has been shown to be efficient in discovering weak points in policies and regulation that may impede the attainment of policy goals.

The research focused on rail policies. Transport policy in general, and rail policy in particular, deals with the construction, maintenance, management, and operation of large and investment-demanding infrastructures. The research thus found that **stress-testing of EU rail policies required consideration of the resilience and responsiveness of the rail infrastructure, its management and financing, as well as the available funding instruments and systems**.

The exercise further demonstrated that **the stress-testing method is not only applicable to policy initiatives and associated legislation** – it is also well-suited to consider the adequacy of funding instruments and systems that are designed to facilitate policy implementation, and to identify insufficient coordination between policy silos.

A challenge for the method is **to keep focus strictly on the policy area or legislation to be stress-tested**, since any individual policy interacts with policies and developments in other areas or sectors. This challenge can only be overcome by considering those other policy areas in the analysis – otherwise, crucial interactions may be overlooked. For example, in this research, it quickly became clear that the research team needed to consider policies and developments in the digital field, as well as energy policies and the European energy supply system, to understand the developments in the railway sector. It illustrates that foresight – and hence, stress-testing – is always holistic in nature, working from a 'what if' question and considering impact and interactions between them that create wholly new situations and interrelationships.

The pilot study on the development of the European Parliament's stress-testing methodology[264] and the research presented here have illustrated that **stress-testing can be carried out at different levels of detail**:

A **broad approach** would consider broad scenarios (possibly already existing ones) and test policy assumptions in these scenarios. The main drawback of this approach is that scenarios not developed specifically with the policy area to be stress-tested in mind will include topics and issues with low immediate relevance for the policy area being tested (in the case of rail policy stress testing, the population's future food choices may serve as an example of one such topic that could be prominent in a scenario but have little or no relevance for rail policy).

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A **narrow approach** would look at one type of future event, seeking, as far as possible, to quantify its impact, and test against that type.[265] While being very concrete, this approach risks overlooking events in other spheres of society, which may potentially have huge impact on the

[264] Fernandes and Heflich, 2022.

[265] An example of a detailed approach to stress-testing can be found in the Netherlands, where municipalities are required to perform a stress-test against forecast climate data, see e.g., Instructions for the standardised stress test Spatial Adaptation, Kennisportaal Klimaadaptatie, n.d.

policies being stress-tested (in the case of rail policies. Not considering e.g., technological change could easily lead to overlooking risks as well as opportunities).
It proved surprisingly difficult, however, to identify unexpected shocks which could also be considered relevant for stress-testing.

> First, the 'unexpected' is more often than not expected or predicted by someone – by a think tank, by the foresight community, or by experts in a field.[266]
> Second, the borderline between a shock and a trend is not always clear, as evident from the scenario involving a persistent heatwave.

Compared to the methods used in the stress-testing exercise for the aforementioned pilot study,[267] the scenarios used for this research paper were further developed. In the pilot exercise, legislation was tested against impacts described in 'futures wheels'[268] validated by foresight experts. The exercise exposed that many of the impacts identified in the futures wheels proved irrelevant to the stress test. As a result of this observation, the research team made the choice to develop **short, but concrete, scenario narratives with a focus on rail transport and included rough quantitative estimates of key indicators**, for the stress-testing of EU rail policies.
Like in the stress-testing exercise for the pilot study, the scenarios were validated in two online workshops that each looked at two of the four scenarios. In the validation workshops for this research, **the narratives proved more effective in eliciting relevant observations from the participants than the futures wheels had been**.
Also, while the participants in the pilot study workshops were foresight experts alone, for the validation workshops feeding into this research paper, **it was decided to include rail experts with some experience with foresight methods in addition to foresight experts.** This proved to be very productive, since the rail experts were able to contribute insights into aspects of rail infrastructure, rail management and travel patterns that proved invaluable in fine-tuning the scenarios.
The rail sector is characterised by a **rich stakeholder landscape**, and the involvement of these stakeholders was sought in the scoping of the exercise, as well as in a discussion of preliminary findings. The input from the stakeholders was invaluable in scoping the research and validating scenarios, and the stakeholders have expressed great interest in being involved in this exercise, although it required from them that they should depart from thinking about today's facts and political configurations and engage with uncertainty and the 'what if' question. The experience indicates that making training in the use of foresight available for stakeholders as well could promote the dialogue about future challenges and opportunities. Meanwhile, the findings from this stress-testing exercise will hopefully contribute to stimulating a broad change in mindset.

5.2. Key findings from the rail transport stress-testing exercise

The stress-testing exercise 'exposed' a selection of EU rail policies to four scenarios, each developed from a shock or disruptive event with significant impacts in either an environmental, political, or technological domain. The stress-testing of selected EU rail policies and related policy documents has revealed some vulnerabilities or weaknesses in most of the policies and legislation exposed to the scenarios. While most of these weaknesses are not critical, taken together, they may prove detrimental to the ability of the EU rail policies to achieve their objectives.

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266 While, for example, the Covid-19 pandemic would appear to have been unexpected, a pandemic of approximately this nature had been predicted by medical experts for several years. See e.g., Completed Projects: SPARS Pandemic Scenario, Johns Hopkins Bloomberg School of Public Health, 2017.

267 Fernandes and Heflich, 2022.

268 For an explanation of this methodology, please refer to the annex to the pilot study (Andersen, et al., 2022).

The most weaknesses in a specific legislative instrument were found with respect to the **Combined Transport Directive,** which is far from achieving its objectives, and its revision has been stunted by political disagreements. The analysis found that the market incentives set by the directive do not pay attention to greenhouse gas efficiency or average external costs of various modes of transport. At the same time, the analysis also found that the revised TEN-T Regulation would have as its goal to enhance interoperability of the TEN-T network and could thus complement the Combined Transport Directive.

Whereas the critical role of rail networks and rail infrastructure is recognised in the proposal for a directive on the resilience of critical entities as well as the Commission's contingency plan for transport, the research points to **a lack of instruments to ensure the functioning of the network during a crisis**, as demonstrated in three of four stress-tests (excluding the stress-test based on the ban of new internal combustion engine HGVs by the EU). In the scenarios linked to these three stress-tests, the ability to uphold regular rail services across Europe are challenged. In a situation where a crisis drags on, this will likely lead passengers as well as logistics operators to seek other means of transport. Since the policy ambition is to move passengers and freight from road (and air and sea) towards rail and inland waterways, a crisis may well produce a context where there is an increasing gap between the political ambitions and the instruments required to make this ambition a reality.

All stress-tests have pointed out that it is not fruitful to discuss vulnerabilities in the policies and legislation without discussing already existing **vulnerabilities in the physical infrastructure and management of the European rail network** that could be exacerbated in a crisis. With regard to the physical infrastructure, there are evident interoperability problems between national systems requiring significant economic resources to be amended. Since cross-border infrastructure management is fragmented and undertaken by a mix of private and public operators, extensive coordination among a wide array of stakeholders is called for.

Furthermore, the climate-related scenario (a persistent heatwave) pointed to the **need for a physical rail infrastructure that is better able to withstand extreme climate events**. While the **TEN-T regulation and proposal for revision** hold provisions that call for actions to climate-proof transport infrastructure, neither give concrete instructions as to *how* infrastructure should be made climate resilient. The proposal for revision refers to funding institutions and instruments that could be utilised for the expansion and improvement of the network, but these institutions and instruments would likely be the same called upon to ameliorate the effects of a climate-related crisis, such as a persistent heat wave.

In the implementation of the TEN-T network, including its climate-proofing, **coordination between rail operators and managers is crucial**. To facilitate coordination, it is proposed to appoint European Coordinators to support the implementation of the core network corridors. However, it is not envisaged that these coordinators will have any enforcement powers in case of disagreements between Member States. Coordination may however be safeguarded by the directive on the resilience of critical entities that obliges Member States to cooperate to maintain the resilience of shared critical entities, among them rail infrastructure managers and rail undertakings.

This challenge is acknowledged by policymakers, and, **to some extent, remedial action has been taken.** However, the analysis indicates that **these actions will not be sufficient in the event of a crisis**. For example, to support and solidify the implementation of the TEN-T network, a group of nine European Coordinators have been tasked with coordinating the decisions and actions of Member States and other relevant stakeholders in support of this goal. The Coordinators are however not bestowed with powers that will allow them to secure funding for the network during a crisis, nor do they have enforcement powers in cases of disagreements between Member States or disengagement of a Member State occurs.

With respect to the timelines of European rail policies, workshop participants expressed that **the assumptions of much of the legal framework are unrealistic (at least within the next ten years)** given the changes needed in the European rail system to reach the targets. Reaching the targets will require not only the EU institutions, but also national rail authorities and private rail operators, to assume responsibility for implementing the policies and – not least important – securing financing for improving the physical and digital infrastructure.

One of the instruments envisaged in the policy framework to ensure the competitiveness of rail vis-à-vis other transport forms **is increased digitalisation** of the infrastructure itself, as well as of journey planning and ticketing. A general observation is that the more digitalised and interconnected the rail system becomes, and the more its elements (signalling systems, route planning, ticketing, signposting etc.) are connected via the internet of things (IoT), the greater its vulnerability to cyberattacks – regardless of the motivation of such attacks.

In the event of a large-scale cyberattack, a situation can arise that puts a brake on regarding the digital transformation of rail, due to **insufficient attention to cyber security in the legislation within Flagship Initiative #6, Making connected and automated multimodal mobility a reality.** However, there is legislation underway to amend this apparent gap, in particular, for critical infrastructure which will require transport providers to take measures to become more resilient to threats to cybersecurity (the NIS II Directive), just like support is provided in the shape of guidelines to increase railway cybersecurity provided by ENISA.

The analysis has further illustrated how **the development of the role of rail in the transport system is closely interwoven with European and national energy systems and energy policies**, as those impact on the availability of fuels and other sources of power for trains. Electrification of the European rail system to move away from polluting diesel engines and to improve interoperability is a key objective of rail policies at EU as well as national level. However, the heatwave scenario demonstrated how electrified stretches of rail can be quite vulnerable to climate-related events as well as geopolitical events, to the extent that these events impact electricity generation, as has already been the case during the drought throughout Europe in the summer of 2022 and the gas shortage that was one result of the sanctions on Russia following its invasion of Ukraine. Since supply chains for fossil fuels are also vulnerable to extreme climate events, general energy shortages may ensue, leading to higher prices for electricity and increased prices for rail operation – and possibly use.

The analysis also looked at whether the adoption of **new technologies** in a broad sense could conceivably contribute to achieving the policy objectives in the scenarios analysed. The technologies considered included propulsion technologies (hydrogen trains) as well as innovations like the introduction of longer freight trains, driverless trains, and digitally enhanced signalling and route and time planning (the European Rail Traffic Management System, ERTMS). Once these technologies are fully implemented, they will contribute to more efficient and safe rail operation, and hence, increase the competitiveness of rail over the competing transport modes (provided that those modes have not made similar technological advances). However, none of these technologies can be expected to be fully implemented within the time horizon analysed in the scenarios, and hence, would not contribute to counter the negative impacts in the four scenarios. **With respect to the ERTMS and other digital solutions for rail, their implementation would even increase the vulnerability of the system** to malevolent actions, and redundancy in the systems is not planned. However, the analysis suggests that redundancy in the shape of systems that are disconnected from the public internet appears to be the only way to prevent the impact of a local breakdown from spreading throughout the system.

Two of the scenarios (a ban on new heavy goods vehicles with internal combustion engines as of 2035, and a scenario where China invades Taiwan) create an increase in the demand for rail freight capacity. While the European rail policies aim at facilitating a shift from other transport

modes to rail (and inland waterways), and the scenarios in that sense should be positive, the research indicates that **the capacity of the European rail system to accommodate a sudden increase in the demand for rail freight transport is limited**, and that a significant increase in capacity cannot be achieved in the short term without difficulties, given the funds currently set aside to expand the network and increase the capacity of the rolling stock.

Overall, **financing stands out as a key issue**. To achieve policy objectives set for 2040 and 2050, substantial investment in rail infrastructure, rail management, and implementation of new technologies is required over the entire period. When policymakers are tasked with addressing the impact of an external shock, they will most likely face pressure from stakeholders and populations to focus on different kinds of impacts. In all scenarios, there is a risk that national and private funds are channelled away from expansion (or even necessary maintenance) of the rail network in a crisis situation. The extent of this risk depends on political priorities in the Member States and cannot readily be estimated. With respect to EU funding, financial obligations are made only until 2027. Uncertainty about financing may prevent railway stakeholders from initiating projects demanding long-term investments.

The research has highlighted that the prioritisation of investments in rail infrastructure by the EU and Member States is necessary to achieve policy objectives for rail (and in the wider sense, for the green and digital transformation), no matter how the future unfolds. There is hardly any scenario in which policymakers will not be tempted to divert funds away from rail to other salient issues. **Achieving the ambitious European goal of a significant modal shift to rail will therefore require continuous political prioritisation and support, even when faced with other important societal demands.**

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Annex A. List of stakeholder organisations consulted

The following stakeholder organisations contributed to the research presented in this report, either by granting interviews, through participating in scenario validation workshops, or by providing written feedback to research questions and content. The research team would therefore like to extend its gratitude to the organisations listed below:

Organisation	Passenger / freight rail
ITF, The International Transport Forum, OECD	Passengers and freight
EIM, European Rail Infrastructure Managers	Passengers and freight
ETF, European Transport Worker's Federation	Passengers and freight
ERFA, European Rail Freight Association	Freight
EU-Rail, Europe's Rail Joint Undertaking	Passengers and freight
UITP, The International Association of Public Transport	Passengers
UIRR, the International Union for Road-Rail Combined Transport	Freight

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Annex II

Recommendations for the design of a stress-testing tool for the European Parliament

Briefing note

This briefing note proposes a process to identify the priority disruptive events that could have a significant impact on the European Union. The process could help to ensure that the programme of legislative reform takes account of those events. New legislation considered by Parliament could also be tested for its robustness to such disruptive events.

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Executive summary

The European Union (EU) has to respond to many and various types of disruptive events. Where the scale of impact is small, these are dealt with effectively by individual Member States within the existing legislation and associated policy settings. However, more recent disruptive events, such as COVID-19 and the war in the Ukraine, have shown that additional rapid action, beyond that allowed for under existing legislation is sometimes necessary.

The challenge though, is designing and allowing for the appropriate democratic processes to occur in a timely fashion in response to such disruptive events. It has been necessary for the European Commission to take emergency action in response to recent events, without the normal democratic process associated with the introduction of EU legislation. This briefing note builds from previous work, which explored futures approaches which could be used to increase the robustness of legislation.

This paper first considers the levers that the European Parliament has to improve the robustness of EU legislation to disruptive events then proposes a process to gain a better understanding of the potential risks and impacts of disruptive events; help prioritise which legislation is developed; and ensure that the legislation and consequent regulatory systems are more robust to disruptive events.

The process involves four stages:

- a meta scan to create a database of disruptive events;
- prioritisation of the top-20 disruptive events;
- a comparison of the forward EU legislative programme with that prioritised list to ensure that there is opportunity to improve the robustness of the relevant legislation;
- testing the robustness of draft legislation to disruptive events by engaging with stakeholders in the foresight process of systems analysis and gaming.

It is recommended that this process is trialled so it can be refined and enable the skills of those involved in the process to be developed before being applied in practice in the European Parliament.

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1. Introduction

The European Parliament is seeking recommendations for the design of a stress-testing tool and how it could be used in the context of the European Parliament. This briefing note proposes the design for a stress-testing approach which complements other products and processes within the institution. The analysis and recommendations take into account the unique institutional setting of the European Parliament, as well as its existing processes and anticipatory policy-making tools.

This note considers how foresight techniques could be used to increase the robustness of the European legislation to disruptive events. Before considering the appropriate foresight tools it is essential to first consider what the foresight activities will be seeking to influence. The foresight tools have to be designed to be able to inform the design of the legislative levers that the European Parliament holds.

As a consequence, this note starts by considering when and how the European Parliament can influence European legislation. Then it considers the risks of making changes to the legislation to deal with disruptive events, noting the care which must be taken in allocating powers to deal with disruptive events before they have materialised. This provides the target and the context for the proposed methodology to stress test legislation for robustness to cope with disruptive events.

The briefing note will seek to answer the following questions in order to recommend a practical approach to stress-testing European legislation:

- What should the goal and objectives be for stress-testing?
- What are the broad forms of legislative response to manage uncertainty?
- What are the risks associated with legislation designed to manage uncertainty?
- What should the scope for the stress-testing process?
- What are the options for the processes and approaches to stress test policy and legislation by European Parliament
- How to identify the disruptive events and system impacts?
- What we can learn from the previous trial of a stress-testing approach?
- What skills are needed by those involved in stress-testing?
- What are the options for the form of the output from stress-testing?

2. Analysis

2.1. What should the goals and objectives be for stress-testing?

2.1.1. Goal

It is proposed that the goal for the stress-testing method should be to build legislation that is more responsive and better able to deal with disruptive events, without undermining its core purpose or acceptability. This should be based on a transparent, democratic process that allows stakeholders' views to be considered.

This recognises that it will be possible in some instances to build the necessary powers into legislation to deal with a range of disruptive events. But it also balances this goal with a recognition that the prime aims when designing legislation must remain dealing with existing risks and doing so in a way that is acceptable to citizens and organisations.

The stress-testing method should consider the 4 'Rs'[1] of managing risks associated with disruptive events:

- **Reduction** – taking steps to eliminate the risk or reduce the likelihood and impact of the risk;
- **Readiness** – ensuring that there are systems and capabilities which can be brought into action should a disruptive event occur;
- **Response** – managing an effective response to a disruptive event;
- **Recovery** – activity to return the area affected to a healthy, stable state.

2.1.2. Objectives

The list below is a proposed starting point for the objectives and should be developed to include a date by which each of the objectives would be delivered, to ensure that these are SMART objectives (specific, measurable, achievable, relevant and timebound). The objectives of the method should be to:

- create a prioritised list of disruptive events for the European Union;
- understand and quantify the type and impacts of the disruptive events;
- test the European Commission's proposed legislative programme for completeness against those events;
- ensure that in the process of legislative design, evidence on disruptive events is provided and considered by the European Parliament; and
- ensure that the robustness of regulatory systems is considered, not just individual pieces of legislation.

A 'disruptive event' is considered to be a risk that materialises that has a significant effect on economic, social, health or environmental outcomes of the European Union. Disruptive events can be either known possible risks, such as the eruption of a volcano or risks which have not yet been identified. The stress test will not assess the robustness and preparedness of regulatory systems[2] to trends which will overtime create challenges in Europe, such as falling fish stocks or demographic change.

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1 The 4 Rs, National Emergency Management Agency of New Zealand website.

2 Regulatory systems and stewardship, Ministry of Business, Innovation & Employment website, New Zealand.

A 'regulatory system' includes all legislative acts[3] relating to the management of a sector or area of risk; along with the associated policies and organisations put in place under that body of law to set standards, deliver services, educate, provide information, ensure compliance and monitor and evaluate the outcomes.[4]

A 'legal power' is the right or authority to command action of others contained in a legislative act.

The 'legislator' is the body or bodies responsible for making law.

2.2. What are the broad forms of legislative response to manage disruptive events?

The purpose of the method is to identify possible disruptive events that the EU will face and to ensure that the legal powers to respond to those events have been well scrutinised before they are brought into force and are available when they are needed.

Significant legal powers are typically needed to respond effectively to disruptive events. These legal powers would not be helpful or appropriate in normal times. This suggests that the extra-legal powers should only put in place or become effective if an event occurs. However, it is likely that if there is a disruptive event, then a rapid response is needed to minimise harms. This allows little time or opportunity for the appropriate scrutiny of the new legal powers before those powers are put in place through new legislation. This creates social and political challenges when seeking to respond to a disruptive event and at the same time maintain social trust.

When the European Parliament identifies a disruptive event that will need to be managed there are several ways in which the legislation could be designed to ensure the European Union can cope well with disruptive events. It could:

- Recommend stand-alone emergency legislation is put in place legislation to deal with specific events or shocks. For example, Directive 2001/55EC provides the rules on temporary protection in the event of a mass influx of displaced persons to promote a balanced response from EU Member States. This could either be as a separate piece of legislation or it could be embedded within normal legislation to be activated if the disruptive event materialises;
- Include in the new EU legislative act specific powers to respond to particular types of disruptive events. For example – if there were an event which significantly restricted air travel, specific legal powers could be provided to enable the European Commission or other EU level executive agency to manage a co-ordinated response;
- Include in the design of the EU legislative act performance based rather than prescriptive rules to respond to particular types of event. For example, if an event restricts air travel allow National Aviation Authorities to decide on proportionate steps to keep citizens safe; and
- Ensure that the legislation requires the creation of strong institutions. Irrespective of having the right law in place also need institutions with people, resources and flexibility to be to respond to a crisis – whatever the nature of the crisis. This is a necessary rather than a sufficient condition to be effective in a response to a disruptive event.

There are advantages and disadvantages with each of these approaches. Tables 1 and 2 consider each of the legislative approaches which could be employed to deal with disruptive events against

[3] Types of EU law, European Commission website.

[4] Regulatory systems and stewardship, Ministry of Business, Innovation & Employment website, New Zealand.

5 criteria. Table 1 is a high-level summary of the assessment and Table 2 provides an explanation of the ratings provided in Table 1.

- Practicality – considers whether the approach is a practical approach that the European Parliament can take.
- Big change - disruptive events will often need significant new powers to be given to the regulator[5] affecting the operations of organisations and the rights of citizens. Will the option provide powers necessary to respond to a disruptive event.
- Meets the need – will the EU legislation provide the necessary legal powers to respond to the particular disruptive event.
- Scrutiny - the extent to which adequate scrutiny could be given before the new powers are put in place to ensure that the voices of citizens and stakeholders are heard to ensure social trust is maintained.
- Quick - the extent to which the remedy be in place with the speed needed for the EU to be able to respond quickly and effectively to the disruptive event.

Table 1: Overview of the advantages and disadvantages of the different regulatory responses

	Practicality	Big change	Meets need	Scrutiny	Quick
Emergency legislation					
Specific power to respond to an event					
Performance based power to respond to an event					
Strong institutions					

Source: Author elaboration

Note: green means the approach would achieve the outcome, orange it may achieve the outcome and red means it will not achieve the outcome at the top of the column.

[5] The regulator could be an EU level regulator or a Member State regulator.

Table 2: Explanation of the ratings in *Table 1*

Approach	Advantages	Disadvantages
Emergency legislation to deal with specific disruptive events, or include clauses to deal with a disruptive event in the legislation which can be activated should that event occur	Allows a thorough review of the approach by the European Parliament to ensure that the necessary balances and checks are in place. Allows the necessary institutional arrangements and associated practical steps to be put in place so that the European Union can respond quickly should the event materialise. Allows the European Parliament to agree the conditions under which the emergency legislation comes into effect.	The emergency legislation may not cover the disruptive event which materialises, whether in scale or type. It is unrealistic to have legislation in place to cover every possible type of disruptive event. Social expectations and institutional arrangements may change between the time the legislation is created and the occurrence of the event. The powers may not be sufficient when the legislation is designed based on possible rather than real challenges. The key is including the necessary checks and balances before the emergency legislation is activated.
Include the necessary legal powers in legislation when it is drafted	Allows a thorough review of the approach by the European Parliament to ensure that the necessary balances and checks are in place. May allow the necessary institutional arrangements and associated practical steps to be put in place so that the EU can respond quickly should the event materialise. This is the main difference with the previous option as the first option is a single piece of legislation dedicated to dealing with a disruptive event, while this option is embedded within legislation which will have wider goals. Allows the European Parliament to agree the conditions under which any extra emergency powers are activated.	The legislation may not cover the disruptive event which materialises, whether in scale or type. It is unrealistic to cover every possible type of disruptive event. Social expectations and institutional arrangements may change between the time the legislation is created and the event occurs. The powers may not be sufficient when the legislation is designed based on possible rather than real challenges. The key is including the necessary checks and balances before any extra powers to deal with a disruptive event are activated.

Approach	Advantages	Disadvantages
Have performance-based legislation.	May allow sufficient flexibility to respond to some aspects of a disruptive event. Allows for flexibility for the institutions to decide how best to respond to the particular challenges of a disruptive event.	Can create uncertainty for investors as they do not know whether they will meet the requirements of the law. Can create uncertainty for citizens and for the regulator as it may be difficult to check whether their actions or approach comply with the legislation.
Strong institutions with the capability to effectively manage the disruptive event	Strong institutions are a necessary condition for the regulatory system to be effective. But they are not a sufficient condition, as they can only deal with the disruptive event if they are given the powers and resources to respond effectively	Strong institutions with wide ranging powers may overstep what is expected of them. Legislation is usually designed so that the regulators has powers proportionate to the risks that they are managing, with the associated expectations of transparency of decision making and appeal procedures. So, a strong legislator is unlikely to be sufficient to deal with a disruptive event

Source: Author elaboration.

Another approach, which is taken in New Zealand, is to draft legislation to deal with a type of disruptive event which is held ready to be finalised (see Box 1). This allows legislation to be quickly adapted to deal with the specific challenges of a disruptive event. While there is no specific provision for this in the EU Treaties, it could be considered in the longer term in the EU. Another approach would be for the European Parliament to develop an example of the process it would expect to be followed for emergency powers to be turned on if included in a piece of legislation.

'National secondary legislation'[6] is also used to 'switch on' the legal powers necessary to respond to a particular disruptive event in New Zealand. The national secondary legislation can be in several forms which can be broadly categorised as affirmative or negative resolution. The affirmative resolution regulation is debated, typically in a parliamentary select committee, before it comes into power and the negative resolution will come into effect unless Parliament negates the regulation within a specified time. This allows rapid change, within bounds previously agreed by Parliament and for there to be the minimum Parliamentary scrutiny before the new law is brought into force. It might be possible for the EU to consider using such an approach though it is unclear whether this would be possible through delegating legislation.

Box 1 – New Zealand's approach to providing the necessary powers in response to COVID-19 while maintaining social license

New Zealand has generic legislation in the Civil Defence Emergency Management Act to allow it to respond to emergencies, as well as legislation to deal with particular types of emergencies, such as the Epidemic Preparedness Act.

New Zealand responded to the outbreak of COVID-19 by putting in place a 'lockdown' asking citizens to stay at home for a period to limit the spread of COVID-19. New Zealand's Health Act provides the Director General of Health with the legal power to require individuals to isolate, but it does not provide the legal power to require widespread isolation or isolation of specific groups of people.

New Zealand responded to this by putting in place the Public Health Response Act to create the necessary legal powers to implement national and regional lock downs. This needed to be put in place rapidly. A small core team was set up to produce the legislation which included an expert in regulatory policy with many years of experience developing the policy for legislation; a senior Parliamentary Counsel, two representatives of Crown Law and two other legal experts.

The legislation went through Parliament under urgency so there was no usual opportunity for scrutiny through select committees. To balance this, the legislation was only in force for 90 days (with the possibility of extension), it was designed to be proportionate to the risks, enhanced transparency and accountability by requiring all Orders made under the act to be published and subject to affirmative resolution by Parliament and set out the prerequisites for the Minister to make an Order. A formal Parliamentary Enquiry[1] run by a select committee was established as the legislation was brought into force to allow for external challenge[1]. The approach was designed to deliver the necessary rapid response, whilst also providing for the appropriate checks and balances to maintain the social licence to support the legislation.

A small expert legal team was maintained beyond the enactment of the initial legislation to allow for the ongoing capability to respond to the changing context and needs of the legislation as the crisis evolved.

2.3. What are the risks associated with legislation designed to manage uncertainty?

Before any consideration is given to designing in robustness for future shocks the legislator must deal with the challenges of finding a good and acceptable balance between the restrictions it imposes on the various parties affected by the legislation. The legislator also has to do so without creating unintended harm and decide the fine balance between introducing rules that minimise risk without causing undue restrictions. Designing legislation is a difficult task and is becoming more so as those involved in creating the legislation also wrestle with demands to respond to

[6] Glossary, New Zealand Legislation website, and What is Secondary Legislation?, UK Parliament website.

intergenerational issues – considering the consequences of the legislative design on future citizens in addition to the many interested parties of today.

And while the purpose and the theoretical design of legislation may be clear, the many processes legislation goes through means that the output is about finding the best compromise to balance these many interests, which will improve the existing situation. The stress-testing tool will add value to that process, but also add complexity, as it is another perspective to consider amidst the various interests and goals the legislators need to consider.

Given this context, it remains essential that the primary lens that is applied to the design of legislation is that it seeks to deliver the best regulatory system to achieve its stated purpose. So, unless it is emergency legislation with a purpose of responding to possible shocks, the priority should be creating good legislation for the current risks which it is managing. Robustness to shocks is the icing to make the perfect legislative cake.

There are two risks, the first is that no or little thought is given to dealing with disruptive events in the design of the legislation. If this happens then the European Union will have poorly prepared legislation to respond to the next disruptive event and risk bypassing democratic processes to be able respond quickly.

The second risk is that too much thought is given to dealing with disruptive events in the design of the legislation. If this happens it could detract from the time available to design legislation that is well balanced for existing risks and lead to legislation which includes unnecessary and undue restrictions on citizens or businesses in normal times. In both cases, it could undermine trust in the European Institutions and associated willingness to accept and follow the rules which are put in place.

It is therefore important to get the right balance and stress test European Legislation in a way which is proportionate, transparent and provides evidence to support consideration of the trade-offs between managing existing risks and disruptive events.

It is not practical to run a stress-testing process for all EU legislation. That would be a enormous task. A proportionate approach is proposed below, which provides input on which legislation should be on the legislative programme to deal with disruptive events.

2.4. What should the scope be for the proposed stress-testing approach

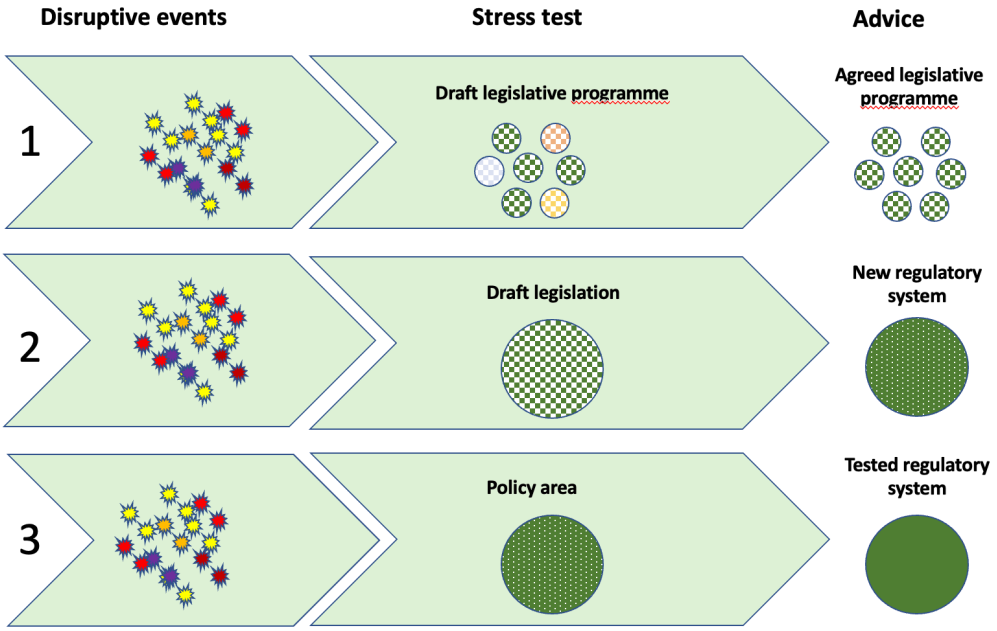
Ideally stress-testing would be used by the European Parliament at three points to ensure that European legislation and the associated regulatory systems will respond well to disruptive events, whilst also maintaining social capital and be subject to the appropriate democratic scrutiny. In order to maintain social capital, the process must also be transparent, provide for democratic accountability and be inclusive – allowing stakeholders' views to be considered in the process.

Under the proposed approach stress-testing would be used in three different ways, to:

- support the European Parliament's contribution to the five-year political cycle which includes the priorities expressed by the heads of state and government in the European Council and the European Commission's legislative programme;
- review individual draft pieces of legislation; and
- review overall policy, and regulatory systems.

Figure 1 provides a diagrammatic representation of the three stages at which stress-testing can be used. The first arrow for each type of stress-testing illustrating that the same meta scan of disruptive events can be used in all instances. The second arrow for each type of stress-testing explains what the disruptive events are being testing on. The final column indicates the scope of the advice that will be provided by each type of stress test. A 'regulatory system' includes broader policies and the capacity and capabilities of institutions established to monitor, provide guidance and enforce the law and overlapping or associated law which works alongside the specific legislation in question. For example, when considering management of movement of people, privacy law and health and safety legislation may need to be considered alongside immigration law.

Figure 1: Illustration of the relationship between the three types of stress-testing



Source: Author elaboration

The proposed approach assesses the overall robustness and preparedness of regulatory systems to disruptive events. It goes beyond the question of whether a new piece of legislation will be robust. The approach seeks to ensure that the whole regulatory system has the necessary capability and capacity to respond should a disruptive event. The framework included in Table 1 should be used alongside each of these processes to consider the appropriate response to the findings of the stress-testing.

A disruptive event is a risk that materialises that has a significant effect on economic, social, health or environmental outcomes of the European Union. This includes both known possible risks, such as the eruption of a volcano and risks which have not yet been identified. It does not cover the assessment of and advice on the robustness and preparedness of the regulatory system[7] to emerging challenges such as mitigating carbon or demographic change.

EU Treaties would be outside the scope of the first two types of stress-testing, but could be considered under the third stream where the overall regulatory system is considered. While EU Treaties would not be the focus, it would be unwise to exclude these fully from testing of an overall regulatory system in case a Treaty includes conditions critical to an effective European level response to a disruptive event.

[7] Regulatory systems and stewardship, Ministry of Business, Innovation & Employment website, New Zealand.

2.5. What are the options for processes and approaches to stress test policy and legislation by the European Parliament

The suggested processes below would be highly dependent on the existing anticipatory tools and capability of the European Parliament. Where there is a 'foresight' component in a process, the expectation is that it would build on existing material and rely on the existing analytical capabilities of the European Parliament's, including its foresight team, anticipatory policy team or ex-ante impact assessment experts. The processes below seek to ensure that the existing anticipatory analysis brings the most benefit to the development of EU's regulatory systems.

Box 2 – Foresight and policy

This briefing note builds from the experiences using strategic foresight to inform policy in the UK and New Zealand. The key aspects of how to ensure that strategic foresight work is effective at informing general policy, rather than legislative design are captured in various guidance notes such as on the Observatory of Public Sector Innovation's pages on 'Futures and Foresight'.

Much futures and foresight work is carried out internationally, but little of it has significant impact. The challenge is using the insights to inform policy settings and legislative design. The countries known to have a closer connection between their Foresight work and government policy include Singapore which has established the Centre for Strategic Futures in its Prime Minister's Office, and the United Kingdom's Foresight Directorate within the Government Office for Science. Both have influence as they are located within the public sector and have a dedicated role to progress Foresight thinking for their nations. Japan has a long history of using a Delphi based approach for its foresight activities which it runs every five years. The focus in Japan initially was to inform public sector research investment, though more recently it is being used to inform wider policies. The UK foresight process initially followed the Japanese approach, using Delphi to inform investment in science. The UK's foresight process was changed in 2004 to inform long term policy issues.

The UK and Japanese examples highlight the connection between good foresight and academic research. This is a logical connection, given that the technology of the future will be built from the successes in the science laboratories of today. And the academic community brings with it an understanding of how people, societies and environmental systems react and respond to change. The importance of this connection is recognised in the UK's Parliament through support of the Parliamentary Office of Science and Technology which provides impartial, accessible science reviews to the UK's parliament, including organising horizon scanning activities.

Sources:

OECD website, Observatory of Public Sector Innovation - Futures & Foresight

CSF, Centre for Strategic Futures - a Singapore Government Agency website

UK Government website, Foresight Projects

UK Parliament website, The Parliamentary Office of Science and Technology

3. Testing the proposed legislative programme for future years

3.1. Proposed process

It is not possible, on an annual or five-year basis, to test all existing European legislation for resilience to shocks. Instead, it is proposed that the forward legislative programme proposed by the European Commission (both at the beginning of the five-year cycle and for each year afterwards) is tested to see whether it covers the areas where there is greatest risk from disruptive events.

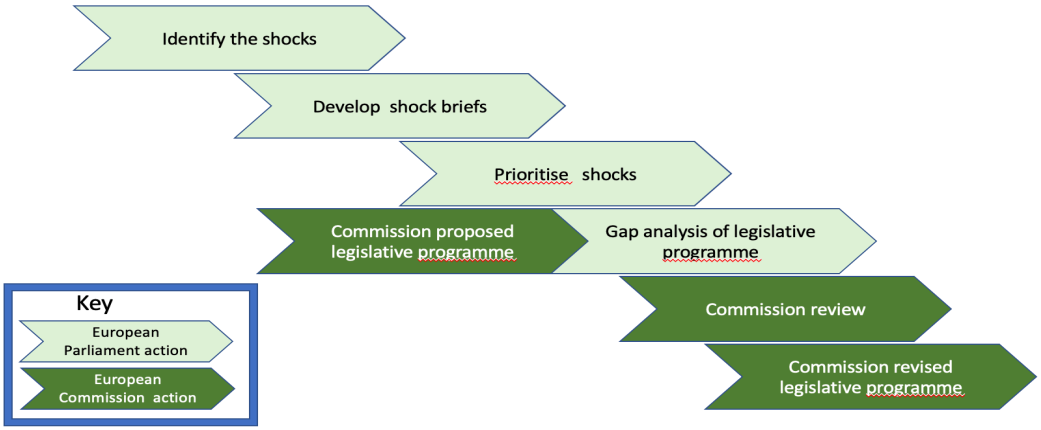
The first step in this process is the creation of a database of disruptive events. The list of shocks would be prioritised and used to test whether the proposed programme matches the list of future shocks. If there is a match, no further work is needed at that stage as the impact of those shocks can be considered when the draft legislation is reviewed by the European Parliament. Figure 2 provides an illustration of the sequence of the steps in this process.

If there are exceptions (that is, there are areas of law which are not in the programme, but which would be affected should the shock materialise) the European Commission could be asked to consider whether they have confidence that either:

- The existing legislation has the right balance of emphasis between managing existing risks with the risks posed by the shock; or
- That, while the legislation could be improved to deal with possible disruptive events updating the legislation is of a lower priority than the legislation which is currently on the five-year plan.

If either of these conditions are met, then no further action is needed. If neither of these conditions is met a recommendation could be made to the European Commission to adjust the forward programme of legislation to improve the robustness of that legislation to future shocks. The European Commission could progress this through amendments to the existing legislation or through a proposal to create emergency legislation to deal with the disruptive event (see *Table 1*).

Figure 2: Illustration of the process to review the proposed forward legislative programme



Source: Author elaboration

The level of evidence that the European Commission provides to support its answers should ultimately meet the expectations of the overall process, that is it should be a transparent exchange with opportunity for the views of stakeholders to be sought. While this would be the ultimate aim for this process, a relational approach would be the right approach when the stress-testing approach is first used to allow for process improvements, learning on both sides and to build trust in the value of the process.

3.2 How to identify the disruptive events (shocks) and system impacts

There are many existing reports which identify possible future shocks. Some of these reports look across all areas and others seek to identify shocks which will affect a particular area – for example economic shocks, shocks which affect social cohesion, or the range of shocks which will be the result of the changing climate. The European Parliament's Think Tank has developed some good quality material which provide a good starting point for this work.[8]

It is recommended that a meta scan is conducted of existing literature to identify shocks and that the scan is used to create information on a set of shocks. This scan should draw from the existing material produced by the European Parliament and the European Commission, but also seek to draw from a wider range of sources. Examples of the sources include the broad Davos annual risk report,[9] reports on global drivers of trends,[10] reports on specific risks by professional organisations[11] and views in general publications.[12]

When a broad list of disruptive events has been developed, it should be tested with a small group of those who seek to identify the weak signals and future risks. Ideally this should provide a global perspective with a representative from each continent. The list should then be prioritised to those disruptive events that would have a significant effect on the EU, whether directly or through a chain of events. For example, a climate event outside of the EU could either have little direct effect on Europe or have a significant effect on a supply chain critical to Europe.

The information for each disruptive event should include:

- a short descriptions of the shock;
- the system effects of the shock;
- the consequential nature of the impacts;
- an assessment of the scale of the impact of the shock on the European Union;
- the likelihood of the risk materialising;
- references to allow for a deeper understanding of the shock and verification of impacts.

At least 100 potential shocks should be identified. Shocks should be categorised according to the nature of the impact and the sector that the shock would affect to allow for easy selection of the disruptive events. It would be possible to include both primary and secondary impacts of each of

[8] Directorate-General for Parliamentary Research Services (DG EPRS) with the Directorates-General for Internal Polices (IPOL) and External Policies (EXPO), European Parliament, Future Shocks 2022 - Monitoring risks and addressing capabilities for Europe in a contested world, April 2022.

[9] Global Risks Report 2022, World Economic Forum website.

[10] Driving forces cards 2035, CSF - Centre for Strategic Futures, Singapore website.

[11] Six key trends impacting global supply chains in 2022, KPMG website.

[12] The Top 10 Global Risks of 2023, Time website.

the disruptive events. Table 3 illustrates how various disruptive events might be categorised according to their primary impact and the main sector affected.

This list would then need to be prioritised to select the top 20 disruptive events to use as the basis for the assessment of the European Commission's proposed legislative programme. The initial prioritisation should be based on the scale of the impact of the disruptive event. Likelihood should not be considered in this initial prioritisation.

Table 3: Illustration of the matrix of categorisation of disruptive events

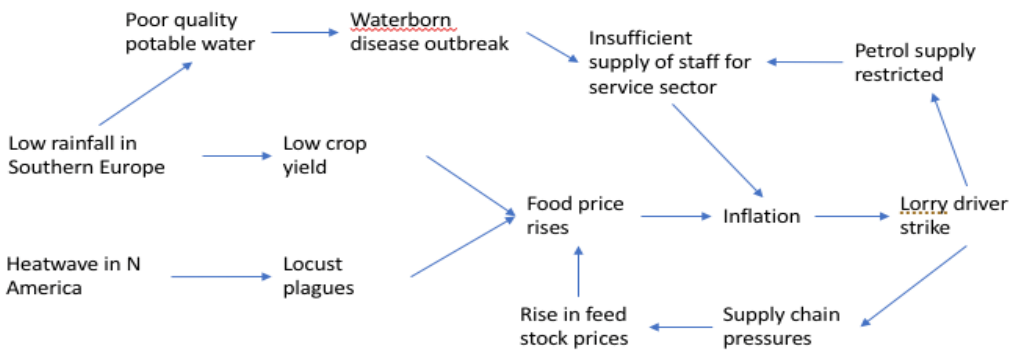
Disruptive event	Primary Impact	Sector
Global Financial Crisis	Economic	Financial
Volcano cloud restricts flights	Economic	Aviation
Self-driving vehicles approved for road use – improving access but leading to unemployment	Social	Transport
Cereal blight	Social	Primary industry
Nuclear meltdown	Health	Energy
Contaminated potable water	Health	Local Government
Major oil spill at sea	Environmental	Shipping
Sea lice deplete fish stocks	Environmental	Fishing and Food
Breakthrough in fusion technology	Environmental	Energy

Source: Author elaboration

The prioritised list should include disruptive events to represent each of the categories of Primary Impact. The number in each of the categories of Primary Impact would not need to be equal, but there should be at least three from each category.

It would also be possible to develop a disruptive events 'systems map' of the interplay between different disruptive events based on their primary and secondary effects. This brings with it the advantage of developing a wider understanding of the system impacts of each disruptive events and the potential positive or negative synergistic effects of the impacts if more than one disruptive event is felt at the same time. Figure 3 illustrates of a small part of a potential disruptive events systems map. It shows possible related disruptive events and the flow on consequences of the events and possible reinforcing loops.

Figure 3: Example of a disruptive events systems map



Source: Author elaboration

An Advisory Group should be established to review the proposed top 20 disruptive events. There are many forms that the Advisory Group could take. Initially it is recommended that a small Advisory Group is created which includes an expert from each of the areas of primary impact chaired by a member of the European Parliament's secretariat. This is a pragmatic and low-cost approach to take while the method establishes credibility. The primary role of this Advisory Group is technical – to ensure the quality of the information on disruptive events.

The Advisory Group may decide to have two prioritised lists – the initial list based on scale, plus a second list which is based on multi criteria analysis of scale, likelihood, social imperative, need for an EU level intervention and competence of the EU to act. The first list would allow a test of the proposed legislative programme against an assessment for protection against the greatest harm, the second an assessment to protect for the more imminent risks.

It would be possible to develop from this initial group a Futures Committee for the European Parliament as is already seen in some other countries and is reviewed in the European Report on How to stress test EU policies.[13] Though if the group were to be developed to create a Futures Committee the role of the group would change. A European Futures Committee is likely to have a wider role, beyond disruptive events considering the implications of emerging trends on the long-term goals and priorities of the European Union. As such it would need to have representation of the different political parties.

Box 3 – Composition of expert advisory groups

Expert advisory groups are a common part of good quality foresight processes to ensure that any proposals are based on expert knowledge. Three very different examples of the make-up of such an advisory group can be seen in three projects on future flood risks, future capital markets and future transport demand. In each case the work was overseen by people with significant practical expertise and reputation as leading thinking in the sector being considered.

[13] Fernandes M, Heflich A. How to stress-test EU policies - Building a more resilient Europe for tomorrow, 2022.

4. Testing individual pieces of legislation

4.1. Options to stress test individual pieces of legislation

4.1.1. Option 1 – stakeholders using gaming to identify the system impacts

A portfolio of 20 disruptive events would be the starting point for the stress-testing exercise to ensure that the legislation is tested against a wide range of events. The portfolio of disruptive events could be the same as the one used to test the proposed legislative programme. Or it could be modified using the wider data base of disruptive shocks to be a closer match to the area of the legislation being considered. For example, if looking at aviation legislation, it would be valuable to include all shocks classified as having a primary or secondary impact on aviation.

The chosen portfolio of shocks would be used as the basis of a gaming exercise with stakeholders to understand the nature of the effects of a disruptive event on the sector. Specific examples of the disruptive events would be developed to be used in the gaming exercise. For example – rather than using the generic risk of a volcanic eruption affecting air travel it would consider a specific event such as the eruption of Eyjafjallajökull with 100 thousand flights cancelled.

Subsections of the disruptive events systems map might be used as inputs for the gaming exercise, to ensure that both primary and secondary impacts are considered as well as testing for robustness to multiple reinforcing disruptive events.

Gaming has been used for many years, particularly by the military to understand how an opponent might respond to a particular strategy. More recently the European Commission has developed a gaming approach to explore broad policy areas through a gaming approach.[14] Other examples include the work of RAND supporting the UK's Foresight analysis of the future of Cybertrust.[15] A different gaming approach is suggested here to allow time to look at 20 disruptive events.

The stress-testing gaming exercise would involve stakeholders representing the relevant authorities, regulators, organisations and citizens. The session would start with a short briefing for all attendees. Then each group would be asked to consider:

- What they think the impact would be on the sector and them from the suite of disruptive events;
- How they would respond to each of the events.

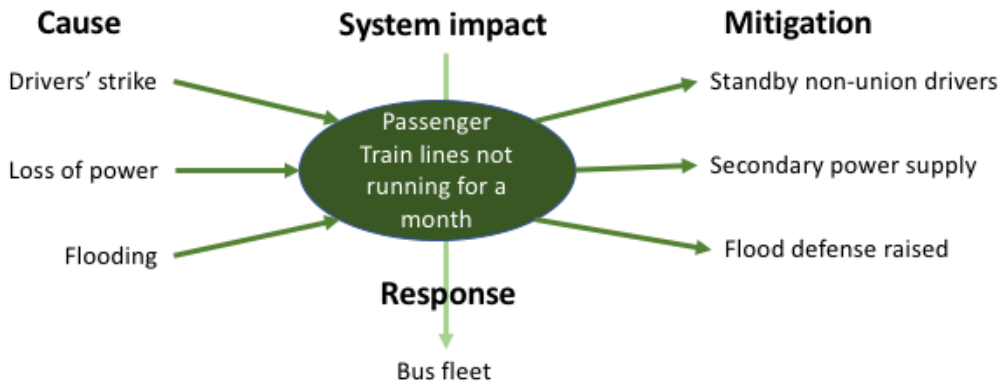
The responses would be shared with the other groups to test whether it changed the way they would respond to the situation.

The output from the conversations would be an understanding of the system impacts of a variety of disruptive events. For example, for rail a number of different disruptive events could lead to the situation where part of the network is no longer operational. The causes could be different. While the system impact is the same the mitigation might be different, but the response to remedy the system impact might be the same. This is captured in Figure 4 which provides an example of the possible outputs from an exploration of the system impacts of a range of disruptive events.

[14] FuturGov Game, European Commission website.

[15] Cyber Trust and Crime Prevention: Gaining Insight from Three Different Futures, UK Government, Office of Science and Technology, April 2004.

Figure 4: Illustration/Example of how the causes, system impacts, mitigations and responses would be captured from the gaming exercise.



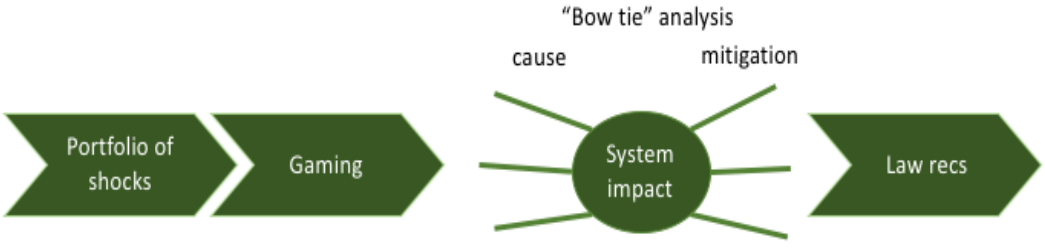
Source: Author elaboration

The information captured in the 'bow tie' would then be used as the basis of the review of the proposed legislation. The outputs from the bow tie analysis allow legislation to be developed against the 4 Rs mentioned in paragraph 2.1.1. The information on causes helps to test for how to reduce the likelihood and impact of the risk, mitigation informs the readiness and the response. The system impact allows consideration of what will be needed for recovery.

Table 1 above could be used to consider what the appropriate level of regulatory response would be to the risk. Figure 5 illustrates the flow of these activities, with the list of shocks as the input to a gaming exercise – the impact assessment as the output from the gaming exercise and the basis for recommendations to ensure that the associated legislation is robust.

If the response involves a small adjustment to the legal powers of a regulator this could be provided for within the Legislative Act. For example, the level of risk for flood defence for critical rail tracks might be set to maintain the risk at a one in a 200-year event rather than at a one in 100-year event.

Figure 5: Illustration of the overall process that would be followed under Option 1



Source: Author elaboration

On the other hand, if the legal power needed to respond to the shock would have a significant effect on citizens or commercial organisations, then the regulatory response would either need to be captured in a piece of emergency. Raising issues such as this at the stage of development of new

legislation would mean that the European Parliament would have an opportunity to influence the legislative approach to dealing with disruptive events. It would reduce the chance of surprises.

The output from this process would be recommendations of issues to be considered when the draft legislation is reviewed by the European Parliament. It would be supported with information on the scale of impact for specific examples of the disruptive event, together with options to manage this risk.

4.1.2. Option 2 – stakeholders using gaming to test system impacts on draft legislation

A second option would allow the European Parliament to apply the gaming approach to the system impacts of the portfolio of shocks directly on the draft legislation.

Instead of engaging stakeholders to explore the system effects of shocks, the system effects would be developed as a paper exercise by a small group of experts. Again, the system effects would be captured using the 'bow tie' approach.

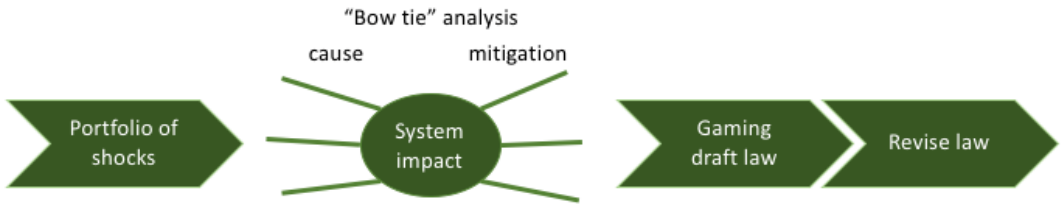
The composites of the bow ties from all of the disruptive events would be used to create a set of narratives of the challenges that could affect the system. Stakeholders would then play the various roles in the system given the new legal framework. They would be given clear aims – for example economic entities would be tasked with maximising profit, citizens with maximising their benefits, regulators with minimising risks and Member States with achieving political success. Over the course of a morning, constraints would be imposed on the situation to reflect the effect of a disruptive event or series of disruptive events.

The game would be monitored for:

- success of the regulatory framework to respond to the pressures; and
- negative unintended consequences of the regulatory system.

At the end of the game the players would be asked to reflect on: 'what changes to the law could have been made in advance to mitigate the effects of the disruptive event'. The output from this exercise would be a report with options to strengthen the draft law to deal with the system level shocks. *Figure 6* illustrates the different sequence of the activities under option 2. The initial input would be the portfolio of shocks, a paper exercise would assess the system impacts as inputs to a gaming exercise where the draft law is tested for robustness to the consequential challenges.

Figure 6: Illustration of the high-level flow of the process for Option 2



Source: Author elaboration

4.1.3. Advantages and disadvantages of Options 1 and 2

It would be valuable to trial both Option 1 and 2 to see which produces the most useful insights. However, the *Table 4* below explores the advantages and disadvantages of each of the options.

Table 4 considers the advantages and disadvantages of options 1 and 2 to test draft legislation against a portfolio of shocks using system impact analysis and gaming

Option 1		**Option 2**	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
It allows for a practical assessment of the system impacts of a range of disruptive events.	The system impacts are identified as the basis for recommendations of issues to be considered in legislative design. As such it is not a direct test of disruptive events on the draft legislation	It allows direct testing of a range of disruptive events on the draft law	The aspects of the law to be tested would have to be simplified to be able to run this as a gaming exercise. There is a risk in doing so it would undermine the coherence of the framework
	The recommendations could again be seen as generic and as a consequence of less value than the effort to create the insights	The recommendations are more likely to be specific	It could be hard for stakeholders to learn the rules for the game for the exercise to be realistic
			It relies on expert assessment of the impact of the disruptive events. This might miss some of the practical real-life challenges
			There is a risk that the outputs will be skewed towards responses rather than reduction, as those involved are gaming the events happening. This could be mitigated in the design of the engagement with the stakeholders, providing opportunity after the gaming for the stakeholders to discuss what could have been put in place in advance to reduce the likelihood the event would occur.

Source: Author elaboration.

5. Testing policies

To ensure the best preparation for a disruptive event it is essential that the wider policy context and the associated regulatory system are tested to see how it will respond if a disruptive event occurs. A mock disruptive event is the best way to provide that learning experience. In addition to testing how robust the overall regulatory system is, it allows key players to: establish the networks they need to respond to an event; learn how to prioritise the actions they take and the actions they ask other to take; get a better idea of the level of resources needed to respond to a crisis; and the practicality of getting those extra resources in place.

It also has the benefit of seeing whether additional legal powers would be needed to deliver the best outcome in a disruptive event.

Many nations hold emergency drills. If it does not occur already it would be helpful to:

- share with Member States the prioritised list of disruptive events, to inform the events chosen for national emergency management exercises;
- agree an approach to capture lessons learned from those exercises that can be fed into the development of new legislation.

5.1. What skills are needed by those involved in stress-testing?

A range of skills is needed to ensure that the stress-testing exercises add the greatest value. The development of the database of disruptive events, needs to bring together those with experience scanning for future disruptive events who will think laterally, with experts in the relevant areas who are able to advise on likelihood and scale of impact. This includes academics, modellers, policy analysts and legal experts from the relevant areas.

The gaming exercises should involve expert facilitators but also people who are experts in designing the sessions and writing the underlying narratives. Stakeholders invited need to bring with them practical experience working in the field and also a willingness to accept the future might not be the same as today. It is essential to include an expert in synthesis – who is able to listen to the conversation and make the connections and see the insights that arise during the gaming sessions. In addition to these core skills a project leader will be needed who can win the engagement of those involved even when they are being taken out of their comfort zone.

In addition to inclusion of people with the right skills it is essential that sufficient resource is provided to deliver a high-quality piece of work. This may mean having a small team dedicated to deliver this process. The quality and impact of foresight type activities is often weakened when those asked to deliver the work, also have significant separate roles to fill. As a consequence, the foresight work, plays second fiddle to their core roles.

5.2. Governing the process

There must be effective governance of the process for it to have impact. In my experience establishing and running the Foresight Directorate in the UK and experience working on long term strategic issues in New Zealand, I found that futures work remained only an interesting intellectual exercise if we did not win the support of a senior champion at the outset. Winning the support of a senior champion ensured that we were considering the issues which were of greatest importance to them and that we had engaged the people with the power to take action based on the findings of the report. The best way to achieve that was to create a governance group chaired by someone who will champion the process and has senior level influence in the advice that is provided. To add greatest value, consideration will need to be given to how to ensure that stress-testing in the European Parliament has the same level of connection to ensure it is considering the most important issues and has support for its findings. Along the same lines the process will also need to include people with the power to influence the acceptance of the new process, such as a representative of the European Commission and representative of the Council. This also might be through inclusion in a governance group to guide and advise on the stress-testing work.

It is important that the roles of the different groups involved in this work is clear and well-integrated. For example, the Advisory Group mentioned in Section 4.2 is a technical group ensuring the quality of the assessment of the relative importance of the list of disruptive events. The role of the Governance group is to ensure that the process is applied to the most important issues, that it is well run, well resourced, lessons are learned from experience and delivers valuable outcomes.

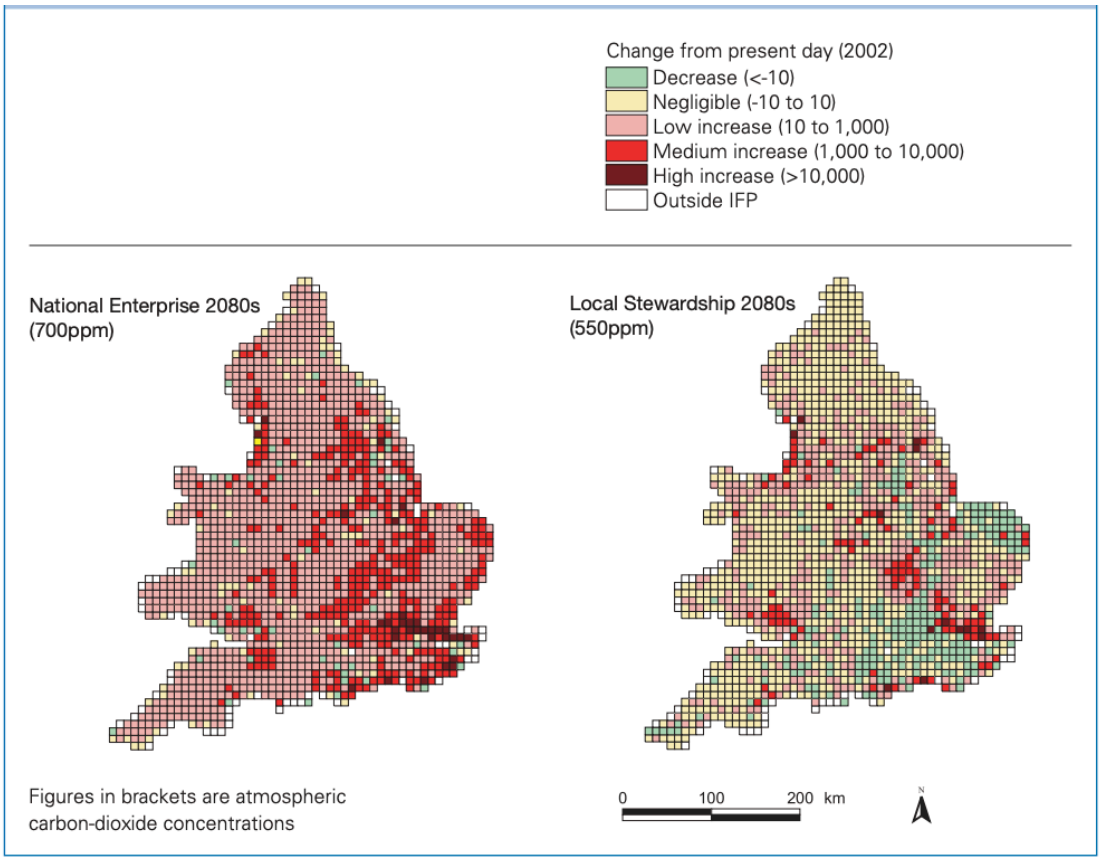
5.3. What are the options for the form of the output from stress-testing?

One of the problems with foresight work, is that if it simply confirms the expected challenges that we will need to respond to in the future, stakeholders will consider that the futures work is a waste of time. On the other hand, if the foresight work says that the future will be different it is hard to convince anyone to take action because it is not possible to provide evidence.

There are two ways that it is possible to overcome this. The first is to create persuasive artefacts which demonstrate the consequences of not acting. The second is to ensure that those with the power to act are involved in the process, so that they own the conclusions as well as the people running the exercise. In the European Parliament, it might be possible to involve the 'shadow meeting' that includes one representative from each political group in the process, whether in the review of the disruptive events list and evidence or in the gaming exercise.

A good example of creating persuasive artefacts is Figure 7, which is an artefact from the UK's Foresight flood defence project which created a map of the UK showing how flood risk would change under four scenarios if left unattended. It showed an increase in risk even in the most favourable situations. The map was published in the UK's national papers and led to strong support from Members of Parliament for action as the Members of Parliament could identify the changes in flood risk in their own constituency.

Figure 7: A picture used in the Foresight flood defence project to effectively communicate the risks if no further action was taken to manage long-term flood risks in the UK



Source:

Foresight flood defence project, Office of Science and Technology, UK Government.

It is not always possible to create artefacts, particularly in the short amount of time that is likely to be available as legislation passes through Parliament. It is therefore better to rely on the second option and include those with the power to influence change in the stress-testing exercise.

6. Recommendations

It is recommended that the European Parliament:

1) Trial the proposed method:

- Develop a prioritised list of disruptive events with associated information on those events;
- Develop a template to capture the information on those disruptive events in a common form;
- Trial the use of that list to review the existing forward plan of legislative reform;
- Include in that trial, those with a deep understanding of the evidence necessary to Influence decisions on the forward programme of legislative reform;
- Trial the use of the prioritised list of disruptive events on a current piece of draft legislation.

2) Develop the advisory and governance arrangements for the process:

- A senior level champion is identified to oversee the trial;
- Representatives from the European Commission and Council are included in the governance group for the trial;
- There is further work to explore the value of having a Futures Committee for the European Parliament and if so the appropriate form for that Committee.

3) Staff the process:

- The staff who will run the process are directly engaged in the trial to allow the development of skills before deployment of the process;
- An expert in policy and foresight plays an advisory role for the trial with a commitment to providing ongoing mentoring and advice when the new process is introduced.

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Stress-testing is a promising foresight policy tool that can support the design of EU policies able to withstand the shocks and challenges of both the present day and the years to come. This study explores how the European Parliament could use stress-tests to identify weak points in EU legislation and avenues for further EU action.

The study draws on the findings of a stress-test of EU rail transport policy and recommendations from an expert practitioner of foresight and regulatory policy. It finds that stress-tests across different policy areas could boost the European Parliament's role as co-legislator in the European Union, especially in the agenda-setting and law-making phases of the legislative cycle.

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