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**Authors:**
**Angela Stefania Bergantino, Alessandro Gardelli**

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Title: A summary of the empirical transport resilience literature and a review of a case study.
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This study defines the concept of resilience of a mobility system as “the ability of a transport system to resist external shocks, maintain its functions, and return to full service as quickly as possible.” Through an in-depth recognition of the literature, it discusses the components that jointly characterize the resilience of a mobility system, namely robustness, redundancy, resourcefulness, and rapidity, as well as the factors that influence them. Finally, it presents one case study, e-scooters rental in Turin, showing how redundancy and thereby resilience can be positively affected by the integration between the standard public transportation system and forms of sharing mobility.

# A summary of the empirical transport resilience literature and a review of a case study

Angela Stefania. Bergantino[1,2], Alessandro. Gardelli[1,2]

[1] *University of Bari "Aldo Moro", Department of Economics, Management and Business Law*

[2]*Laboratory of Applied Economics, University of Bari "Aldo Moro"*

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**Abstract**

This study defines the concept of resilience of a mobility system as "*the ability of a transport system to resist external shocks, maintain its functions, and return to full service as quickly as possible.*" Through an in-depth recognition of the literature, it discusses the components that jointly characterize the resilience of a mobility system, namely robustness, redundancy, resourcefulness, and rapidity, as well as the factors that influence them. Finally, it presents one case study, e-scooters rental in Turin, showing how redundancy and thereby resilience can be positively affected by the integration between the standard public transportation system and forms of sharing mobility.

**Keywords:** Transport resilience; Shared mobility; Public transport integration; E-scooters
**JEL codes:** R41; R42; L91

## 1. Introduction

Transport resilience refers to the ability of transport networks (both at an infrastructure and a service level) to resist external disruption, maintaining functions as much as possible and return to a full level of service in a short time. This summary, based on the paper published in Transport Reviews (Bergantino et al., 2024), reviews the relevant empirical literature on transport resilience, categorizing the various factors influencing resilience and identifying the spatial patterns commonly found across case studies. These factors and patterns are contextualized within a typical resilience assessment framework to provide insights for improvement and suggest future research directions for transport scholars. Although several reviews on transport resilience have been published in recent years, limited work has focused on classifying empirical findings or, more broadly, on understanding the role of real-world data in resilience assessments. The main innovation of this study lies in its review of the use of empirical data in transport resilience assessment, its classification of analytical results, and the insights and recommendations derived from this analysis. Under the GRINS topic, the review addresses the need for supporting resilience assessment metrics, particularly focusing on transport networks and their impact on the resilience of territories. To achieve this, the paper collects a set of 127 relevant transport resilience studies, subsetting it down to the 53 that utilize real-world data for analysis. The empirical findings are classified within the 4R framework supporting the resilience triangle (Bruneau et al., 2003; Tierney & Bruneau, 2007), which is the most widely adopted framework in the literature. The paper's key objective, based on this contextualization, is to test this standard framework over several case studies, offering insights for its improvement, and highlight topics worth of further investigation.

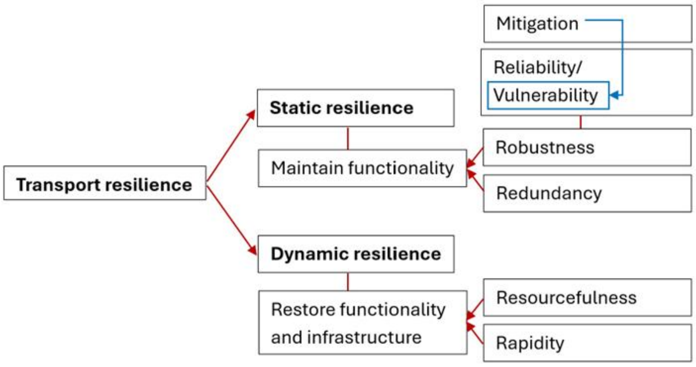
# 2. Outline of literature background

## 2.1 Methodology of the review

As anticipated, several review papers have explored the conceptualization of transport resilience, elaborating on its related attributes and the interconnections between them. The literature also overviews in detail assessment metrics. Below, a brief summary of the key insights on both the concepts and the metrics is presented. Transport resilience refers to the ability of a transport system to resist external shocks, maintain its functions, and return to full service as quickly as possible. At the moment of disruption, the concepts of robustness and redundancy are used to describe the extent to which service is maintained (robustness) and the availability of alternative options to offset the disutility of the performance loss (redundancy). Once the disruption is over, the concepts of rapidity and resourcefulness define how quickly, and by what means (in terms of resources deployed), the system's performance returns to its normal operating state.

These four main attributes—robustness, redundancy, resourcefulness, and rapidity—are the 4 ”R”s that form the 4R framework (Bruneau et al., 2003). They define resilience in different stages: static resilience, measured by robustness and redundancy during the disruption, and dynamic resilience, measured by resourcefulness and rapidity during recovery (see Figure 1.1). Several other concepts complement this framework. Vulnerability, the opposite of robustness, defines the amount of performance degradation experienced during the shock. Reliability measures the likelihood of successful functionality under various operational conditions. Mitigation strategies, aimed at strengthening critical infrastructure, focus on enhancing robustness and reducing the risk of performance degradation during future disruptions.

Figure 1.1. Resilience concepts interconnections based on Bergantino et al. (2024)




Regarding assessment metrics, there are generally two types: topological and performance based. Topological metrics assess resilience by examining the static structure of the network (nodes and edges), focusing on changes in network topology (i.e., the connections between nodes). Performance based metrics, on the other hand, include the dynamic aspects of the network, such as flows, speed, and time, providing a quantitative assessment of resilience by measuring lost performance rather than focusing exclusively on changes in connectivity.
A literature keyword search was conducted to identify the most relevant studies on transport resilience. From an initial general search on Scopus, combined with additional papers identified through snowballing, 127 studies were retrieved. After reviewing the abstracts, 53 papers that utilize real-world data were selected for further analysis. Of these, 38 papers use flow data, 30 use on travel time, 7 coordinate tracking, 5 transport costs and 2 use accident data. 17 papers study road networks, 11 railways, 10 metro services, 10 bicycles, 6 airways, 5 bus services, 5 multimodal networks, 2 walking and 1 waterway. These 53 papers were thoroughly reviewed and qualitatively assessed to summarize their main findings and methodologies.

## 2.2 Main insights

Several spatial patterns and influential factors of transport resilience are found across the set of reviewed papers. As regards the spatial patterns:

1. Central areas vs peripheral areas: central areas are vulnerable to disruptions due to dense passenger flows and infrastructure, but they often recover more quickly thanks to higher redundancy and prioritization in recovery. Conversely, peripheral areas tend to be less vulnerable due to lighter flows but lack of redundancy (few transport options)
2. High vs low accessibility: areas with lower accessibility are generally less vulnerable to disruptions due to lighter gravity, but tend to lack of redundancy, with few alternatives and main corridors that, If disconnected, heavily impacts performance.
3. Distance decay from alternative modes: when connecting alternative modes within a buffer, users disutility from disruption is partially offset. For example, when bike sharing services are located inside a 1km buffer from public transport stops, system resilience is increased.
4. Location of the hazard: When natural hazards like hurricanes hit, regions close to the coastline tend to be more impacted. However, there are countertrend, like local changes in demand and disruption spillovers.

As regards influential factors:

1. Redundancy: as expected, redundancy, both infrastructural and between modes, is associated with higher level of resilience. Infrastructural redundancy refers to the density of infrastructure and consequently all the different paths that can be taken to reach a destination. Between-modes redundancy refers to the quantity of different transport options to be taken by individuals.
2. Provision of real-time information: Effective communication from transport practitioners regarding real-time conditions is associated with higher level of resilience, allowing users to change behavior and find alternative solutions.
3. Institutional plans and management: Pre-, during and post-disruptions institutional actions help the transport system overcome the shock more smoothly. In particular, critical infrastructure identification, mitigation strategies and post-emergencies plans are found to be positive across case-studies.
4. Climate change and intensity of disruption: As expected, the stronger the disruption impact, the worse the drop in performance. As climate change is expected to exacerbate the impact of hazards, severity of disruptions effects are expected to rise.
5. Strengthening of the infrastructure: Improvements on the physical robustness of the infrastructure and on its connectivity (also in terms of integration and compatibility between types of infrastructure) mitigates performance degradation and increases redundancy.
6. Congestion: systematic congestions, also in terms of pre-existing bottlenecks, further strengthens the negative effects of disruptions.

7. Increase in socio-economic indicators: Increase in socio-economic indicators, like GDP growth, does not always automatically associate with increase in transport resilience. Side effects like increased pressure from urbanization can lead to offsets to transport resilience.

The papers found that both spatial pattern and influential factors fit into the 4R framework, meaning that all items identified have some type of effect on the 4 resilience attributes. It is worth noting that some have negative effects (e.g., congestion on rapidity), some have positive ones (e.g. central area on redundancy) and some have effects on more than one attribute (e.g. strengthening of infrastructure on robustness and redundancy). Because of this, multiple attribute resilience metrics should be preferred to single attribute ones. Table 1.1 below categorizes the effects of the identified items on the attributes of the 4R framework.

Table 1.0. Summary of positive and negative effects of the identified empirical factors

| | **Positive Effect** | **Negative Effect** |
|---|---|---|
| **Robustness** | • Institutional plans and management<br>• Strengthening of infrastructure | • Central area<br>• High accessibility<br>• Location of the hazard<br>• Climate change and intensity of disruption<br>• Congestion |
| **Redundancy** | • Central area<br>• High accessibility<br>• Distance decay from alternative modes<br>• Institutional plans and management<br>• Strengthening of infrastructure | |
| **Resourcefulness** | • Central area<br>• Institutional plans and management | |
| **Rapidity** | • Central area<br>• Institutional plans and management<br>• Provision of real-time information | • Congestion |

It is also possible to see from the table above that, if practitioners are interested in a specific attribute of resilience, they can leverage on specific factors. For example, policymakers willing to increase rapidity of recovery may consider tackling systematic congestion while making real-time information available during shocks.

## 2.3 Research gaps

Despite fitting the results into the 4R framework, we identified some issues related to its graphical representation. The first concern regards the definition of the pre-disruption level, which is difficult to ideally identify. In some cases, the pre-disruption reference value is set as the last observation before the shock, which might not be ideal as it could be affected by random operational fluctuations and may not represent the true 100% operational level. The same issue applies to the recovery target, that is often set as the pre-disruption level. Further investigation into these methodological challenges is of utmost importance to improve the framework's real-world applicability. Long-term historical data, for example, could help setting a more ideal standard reference level for pre-disruption performance.
Furthermore, 4 relevant research strands have been identified to be further investigated. Specifically:

- How can disruptive events be categorized for empirical analysis?
- How do different types of disruptions impact various transport modes?
- Is there an association between long-term economic growth and growth in transport resilience?
- Multimodal networks remain underexplored, causing gaps in our understanding of resilience and disruption impacts within networks of networks.

We believe that the research on these underexplored topics will increase our knowledge on transport resilience while helping the adoption of resilience frameworks of assessment based on real data collection.

# 3. Case study: the contribution of e-scooter services to the resilience of urban transport [1]

## 3.1 Framework

The aim of this case study is to understand to what extent a greater supply of transport alternatives favors individuals during a disruption in an urban setting. A key concept central to this work is redundancy. Redundancy is the ability of a transport network to offer several alternatives that can support each other in the event of an external shock (Bergantino et al.,

[1] This chapter summarizes the content of the article: Bergantino, A. S., & Gardelli, A. (2024). The contribution of e-scooters services to urban transport resilience. Journal of Transport Geography, 118, 103869.

2024). How is the complementarity/substitution between modes evolving during such events? To answer this question, we take advantage of the natural experiment context of 7 local public transport (PT) strikes in Turin, Italy, between October 2021 and October 2022. During this time span, we observe the hourly number of e-scooters' rents and the length of the rents' trips. We aim to address two research questions:

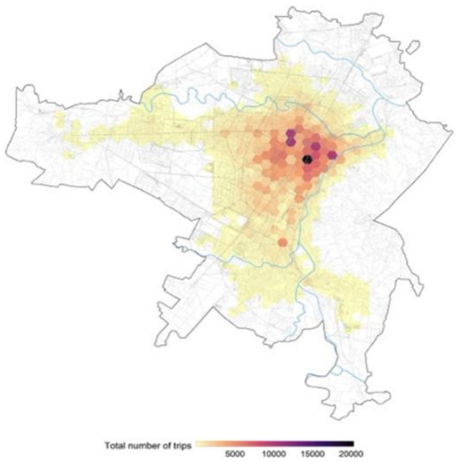
1. Does e-scooter sharing offer redundancy to PT when the latter is disrupted?
2. Does a spatial pattern of proximity to disruption exist?

### 3.2 Data

For this analysis, three main datasets[2] have been used. The following subsections will briefly discuss the three datasets.

Data of individual e-scooters Origin-Destination (OD) tracks aggregated at different levels, is used in the analysis. Figure 1.2 displays the concentration of starting trips inside a 500m × 500m grid.

Figure 1.2. Density of started trips on a 500m × 500m grid




In the same year window, 7 strike events are identified and double-checked both with the National Strike Authority and the local public transport operator, which provided us with the average participation of drivers to the strike (data available form the Authority).

Transit stop data is downloaded to investigate the spatial patterns. Relevant literature on the topic finds a distance decay pattern on the effect starting from the disruption site. Translated and applied to our case study, that would suggest that the closer the start of the trip is to a

[2] Authors did not have the permission to share data openly but eventually and upon requests in an aggregate form.

transit stop (disruption site), the stronger the effect of the disruption (strike) in terms of e-scooters trips counts and length increase.

### 3.3 Methodology

To answer the first research question, we observe the number of e-scooter trips and their lengths during a strike day, comparing them to a baseline scenario through econometric modeling. As regards the second research question, we include in the modeling an interaction term of proximity to transit stops to analyze if the strike effect on the e-scooter trips is larger in the vicinity of the disruption sites, i.e., the transit stops. Combining the two aspects, to study the effect the following negative binomial regression model is proposed:

$$E[trips_{it}] = exp(\beta_0 + \beta_1 \times strike_t + \beta_2 \times strike_t \times prox_{it} + \gamma \times X_{it})$$

where:

- $trips_{it}$ the hourly count of e-scooter trips for neighbourhood i,
- $strike_t$ is a dummy variable for the strike event at hour t,
- $prox_{it}$ is a dummy variable that controls proximity of transit stops via buffers,
- $X_{it}$ is a vector of control variables, including weather, special events and fixed effects,
- $\gamma$ is a vector of coefficients for the control variables.

As regards the length of trips, the following OLS model is proposed to study the effect of strike, interacted with proximity to transit stops:

$$triplength_{it} = \beta_0 + \beta_1 \times strike_t + \beta_2 \times strike_t \times prox_{it} + \gamma \times X_{it} + \varepsilon_{it}$$

### 3.4 Results

The results of the modeling show that there is a redundancy effect of e-scooters to PT, which is stronger when reaching proximity to the transit stops. During a strike event, on average the e-scooter trips are 89% more than during a regular day within a 50m buffer to transit stops, ceteris paribus. The average length of an e-scooter trip confirms a possible substitution pattern, considering that, during a strike day, the average length is around 9 transit stops. The analysis found temporal heterogeneity, as the effect is stronger closer to the weekends, while it is totally inhibited in the hour window 9am-12am. In terms of complementarity/substitutability, the redundancy effect is likely to be in between the two concepts. On the one hand, there is a substitution effect, as part of the undone PT rides is absorbed by the e-scooter rents. On the other hand, it may also be seen as a support to PT (and ideally a complement to it) when the latter is not able to perform to its operative regime. As regards the spatial pattern of proximity, which is in line with the relevant micromobility literature, such phenomenon may be explained through the so-called ”announcement effect” (Adler & van Ommeren, 2016), which found that the effect of the strike is influential only when the strike is actually in place, while no effect is observed when the strike is announced but canceled. According to this evidence, it may be that the individuals are not aware of the strike, and part of them decide to look for the closest e-scooter while being at the transit stop. The analysis found a temporal heterogeneity as well. We hypothesize that the reason why the effect is stronger on the weekend and inhibited in the mornings might be because of the user class. Several evidence reports that the typical user class is young males, which use more the e-scooter on weekend days for recreational purposes while use them less during school hours.

To summarize, during disruption events, e-scooters support the PT by absorbing part of the undone transit trips, offering a viable alternative to perform them. The effect is spatially and temporally heterogeneous, being stronger reaching proximity to the transit stops (spatially), being stronger closer to the weekends and weaker in the week morning (temporal). The temporal heterogeneity, being possibly explained by the typical user class - young males - might mean heterogeneity in the redundancy effect as well. The analysis highlights the existence value of e-scooters, that only by being present offers an alternative mode to at least a part of the individuals. However, the benefit, and so this piece of resilience, is class-specific. For this reason, we recommend it to be only a piece in a bigger puzzle of policies to make urban transport network more resilient to all.

# 4. Key references


[1] Adler, M. W., & van Ommeren, J. N. (2016). Does public transit reduce car travel externalities? Quasi-natural experiments' evidence from transit strikes. Journal of Urban Economics, 92, 106-119.

[2] Auad, R., Dalmeijer, K., Riley, C., Santanam, T., Trasatti, A., Van Hentenryck, P., & Zhang, H. (2021). Resiliency of on-demand multimodal transit systems during a pandemic. Transportation Research Part C: Emerging Technologies, 133, 103418.

[3] Azolin, L. G., da Silva, A. N. R., & Pinto, N. (2020). Incorporating public transport in a methodology for assessing resilience in urban mobility. Transportation Research Part D: Transport and Environment, 85, 102386.

[4] Baroud, H., Barker, K., & Ramirez-Marquez, J. E. (2014). Importance measures for inland waterway network resilience. Transportation Research Part E: Logistics and Transportation Review, 62, 55-67.

[5] Bergantino, A. S., & Gardelli, A. (2022). Il contributo dei monopattini alla resilienza del trasporto urbano: una analisi empirica su dati innovativi. Contributo in Rivista. Economia e Politica dei Trasporti, SIET (sietitalia.org).

[6] Bergantino, A. S., & Gardelli, A. (2024). The contribution of e-scooters services to urban transport resilience. Journal of Transport Geography, 118, 103869.

[7] Bergantino, A. S., Gardelli, A., & Rotaris, L. (2024). Assessing transport network resilience: Empirical insights from real-world data studies. Transport Reviews, 44(4), 834-857.

[8] Bergantino, A. S., Intini, M., & Tangari, L. (2021). Influencing factors for potential bike-sharing users: An empirical analysis during the COVID-19 pandemic. Research in Transportation Economics, 86, 101028.

[9] Bešinovi?, N. (2020). Resilience in railway transport systems: A literature review and research agenda. Transport Reviews, 40(4), 457-478.

[10] Brazil, W., White, A., Nogal, M., Caulfield, B., O'Connor, A., & Morton, C. (2017). Weather and rail delays: Analysis of metropolitan rail in Dublin. Journal of Transport Geography, 59, 69-76.

[11] Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., Shinozuka, M., Tierney, K., Wallace, W. A., & Von Winterfeldt, D. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. Earthquake Spectra, 19(4), 733-752.

[12] Büchel, B., Spanninger, T., & Corman, F. (2020). Empirical dynamics of railway delay propagation identified during the large-scale Rastatt disruption. Scientific Reports, 10(1), 1-13.

[13] Campisi, T., Basbas, S., Skoufas, A., Akgu¨n, N., Ticali, D., & Tesoriere, G. (2020). The impact of COVID-19 pandemic on the resilience of sustainable mobility in Sicily. Sustainability, 12(21), 8829.

[14] Chang, S. E., & Nojima, N. (2001). Measuring post-disaster transportation system performance: The 1995 Kobe earthquake in comparative perspective. Transportation Research Part A: Policy and Practice, 35(6), 475-494.

[15] Chen, Y., Fuellhart, K., Grubesic, T. H., Zhang, S., & Witlox, F. (2024). An analysis of the context factors influencing the diverse response of airports to COVID-19 using panel and group regression. Transportation Research Part A: Policy and Practice, 179, 103925.

[16] Chen, Z., & Wang, Y. (2019). Impacts of severe weather events on high-speed rail and aviation delays. Transportation Research Part D: Transport and Environment, 69, 168-183.

[17] Cheng, L., Mi, Z., Coffman, D. M., Meng, J., Liu, D., & Chang, D. (2021). The role of bike sharing in promoting transport resilience. Networks and Spatial Economics, 1-19.

[18] Cox, A., Prager, F., & Rose, A. (2011). Transportation security and the role of resilience: A foundation for operational metrics. Transport Policy, 18(2), 307-317.

[19] da Mata Martins, M. C., da Silva, A. N. R., & Pinto, N. (2019). An indicator-based methodology for assessing resilience in urban mobility. Transportation Research Part D: Transport and Environment, 77, 352-363.

[20] Dawson, D., & Marsden, G. (2019). Disruption and resilience: New realities? Transport Matters, 303-326.

[21] Dawson, D., Shaw, J., & Gehrels, W. R. (2016). Sea-level rise impacts on transport infrastructure: The notorious case of the coastal railway line at Dawlish, England. Journal of Transport Geography, 51, 97-109.

[22] de' Donato, F., & Michelozzi, P. (2014). Climate change, extreme weather events and health effects. The Mediterranean Sea, 617-624. https://doi.org/10.1007/978-94-007-6704-1 38

[23] de Jong, G., & Lieshout, R. (2021). Disruption in the air: The impact of flight rerouting due to air traffic control strikes. Transportation Research Part D: Transport and Environment, 90, 102665.

[24] D'Lima, M., & Medda, F. (2015). A new measure of resilience: An application to the London Underground. Transportation Research Part A: Policy and Practice, 81, 35-46.

[25] Donovan, B., & Work, D. B. (2017). Empirically quantifying city-scale transportation system resilience to extreme events. Transportation Research Part C: Emerging Technologies, 79, 333-346.

[26] Fabella, V. M., & Szymczak, S. (2021). Resilience of railway transport to four types of natural hazards: An analysis of daily train volumes. Infrastructures, 6(12), 174.

[27] Fernandes, V. A., Rothfuss, R., Hochschild, V., Silva, M. A. V., Silva, W. R., Steiniger, S., & Santos, T. F. (2019). Urban resilience in the face of fossil fuel dependency: The case of Rio de Janeiro's urban mobility. Urbe. Revista Brasileira de Gest˜ao Urbana, 11).

[28] Ferranti, E., Chapman, L., Lowe, C., McCulloch, S., Jaroszweski, D., & Quinn, A. (2016). Heatrelated failures on southeast England's railway network: Insights and implications for heat risk management. Weather, Climate, and Society, 8(2), 177-191.

[29] Fikar, C., Hirsch, P., Posset, M., & Gronalt, M. (2016). Impact of transalpine rail network disruptions: A study of the Brenner Pass. Journal of Transport Geography, 54, 122-131.

[30] Fuller, D., Sahlqvist, S., Cummins, S., & Ogilvie, D. (2012). The impact of public transportation strikes on use of a bicycle share program in London: Interrupted time series design. Preventive Medicine, 54(1), 74-76.

[31] Ganin, A. A., Kitsak, M., Marchese, D., Keisler, J. M., Seager, T., & Linkov, I. (2017). Resilience and efficiency in transportation networks. Science Advances, 3(12), e1701079.

[32] Ganin, A. A., Mersky, A. C., Jin, A. S., Kitsak, M., Keisler, J. M., & Linkov, I. (2019). Resilience in intelligent transportation systems (ITS). Transportation Research Part C: Emerging Technologies, 100, 318-329.

[33] Gao, Y., & Wang, J. W. (2021). A resilience assessment framework for urban transportation systems. International Journal of Production Research, 59(7), 2177-2192.

[34] Gonçalves, L. A. P. J., & Ribeiro, P. J. G. (2020). Resilience of urban transportation systems. concept, characteristics, and methods. Journal of Transport Geography, 85, 102727.

[35] Gu, Y., Fu, X., Liu, Z., Xu, X., & Chen, A. (2020). Performance of transportation network under perturbations: Reliability, vulnerability, and resilience. Transportation Research Part E: Logistics and Transportation Review, 133, 101809.

[36] Hara, Y., & Kuwahara, M. (2015). Traffic Monitoring immediately after a major natural disaster as revealed by probe data - A case in Ishinomaki after the Great East Japan Earthquake. Transportation Research Part A: Policy and Practice, 75, 1-15.

[37] Jani?, M. (2015). Reprint of "Modelling the resilience, friability and costs of an air transport network affected by a large-scale disruptive event". Transportation Research Part A: Policy and Practice, 81, 77-92.

[38] Jani?, M. (2018). Modelling the resilience of rail passenger transport networks affected by largescale disruptive events: The case of HSR (high speed rail). Transportation, 45(4), 1101-1137.

[39] Jaroszweski, D., Hooper, E., & Chapman, L. (2014). The impact of climate change on urban transport resilience in a changing world. Progress in Physical Geography: Earth and Environment, 38(4), 448-463.

[40] Jiang, R., Lu, Q. C., & Peng, Z. R. (2018). A station-based rail transit network vulnerability measure considering land use dependency. Journal of Transport Geography, 66, 10-18.

[41] Jin, J. G., Tang, L. C., Sun, L., & Lee, D. H. (2014). Enhancing metro network resilience via localized integration with bus services. Transportation Research Part E: Logistics and Transportation Review, 63, 17-30.

[42] Loo, B. P., & Leung, K. Y. (2017). Transport resilience: The occupy central movement in Hong Kong from another perspective. Transportation Research Part A: Policy and Practice, 106, 100-115.

[43] Lu, Q. C. (2018). Modeling network resilience of rail transit under operational incidents. Transportation Research Part A: Policy and Practice, 117, 227-237.

[44] Matisziw, T. C., Ritchey, M., & MacKenzie, R. (2020). Change of scene: The geographic dynamics of resilience to vehicular accidents. Networks and Spatial Economics, 1-20.

[45] Mattsson, L. G., & Jenelius, E. (2015). Vulnerability and resilience of transport systems - A discussion of recent research. Transportation Research Part A: Policy and Practice, 81, 16-34.

[46] Mudigonda, S., Ozbay, K., & Bartin, B. (2019). Evaluating the resilience and recovery of public transit system using big data: Case study from New Jersey. Journal of Transportation Safety & Security, 11(5), 491-519.

[47] Niu, C., Zhang, T., Nair, D. J., Dixit, V., & Murray-Tuite, P. (2022). Link-level resilience analysis for real-world networks using crowd-sourced data. International Journal of Disaster Risk Reduction, 73, 102893.

[48] Otuoze, S. H., Hunt, D. V., & Jefferson, I. (2021). Neural network approach to modelling transport system resilience for major cities: Case studies of Lagos and Kano (Nigeria). Sustainability, 13(3), 1371.

[49] Pan, S., Yan, H., He, J., & He, Z. (2021). Vulnerability and resilience of transportation systems: A recent literature review. Physica A: Statistical Mechanics and its Applications, 581, 126235.

[50] Poulin, C., & Kane, B. M. (2021). Infrastructure resilience curves: Performance measures and summary metrics. Reliability Engineering & System Safety, 216, 107926.

[51] Reggiani, A., Nijkamp, P., & Lanzi, D. (2015). Transport resilience and vulnerability: The role of connectivity. Transportation Research Part A: Policy and Practice, 81, 4-15.

[52] Saberi, M., Ghamami, M., Gu, Y., Shojaei, M. H. S., & Fishman, E. (2018). Understanding the impacts of a public transit disruption on bicycle sharing mobility patterns: A case of Tube strike in London. Journal of Transport Geography, 66, 154-166.

[53] Safitri, N. D., & Chikaraishi, M. (2022). Impact of transport network disruption on travel demand: A case study of the July 2018 heavy rain disaster in Japan. Asian Transport Studies, 8, 100057.

[54] Santos, L. J., Oliveira, A. V., & Aldrighi, D. M. (2021). Testing the differentiated impact of the COVID-19 pandemic on air travel demand considering social inclusion. Journal of Air Transport Management, 94, 102082.

[55] Serulle, N. U., Heaslip, K., Brady, B., Louisell, W. C., & Collura, J. (2011). Resiliency of transportation network of Santo Domingo, Dominican Republic: Case study. Transportation Research Record: Journal of the Transportation Research Board, 2234(1), 22-30.

[56] Spyropoulou, I. (2020). Impact of public transport strikes on the road network: The case of Athens. Transportation Research Part A: Policy and Practice, 132, 651-665.

[57] Stott, P. (2016). How climate change affects extreme weather events. Science, 352(6293), 1517-1518.

[58] Sun, H., Wu, J., Wu, L., Yan, X., & Gao, Z. (2016). Estimating the influence of common disruptions on urban rail transit networks. Transportation Research Part A: Policy and Practice, 94, 62-75.

[59] Sun, J., Chow, A. C., & Madanat, S. M. (2020). Multimodal transportation system protection against sea level rise. Transportation Research Part D: Transport and Environment, 88, 102568.

[60] Sun, X., & Wandelt, S. (2021). Robustness of Air transportation as complex networks: Systematic review of 15 years of research and outlook into the future. Sustainability, 13(11), 6446.

[61] Tang, J., Heinimann, H., Han, K., Luo, H., & Zhong, B. (2020). Evaluating resilience in urban transportation systems for sustainability: A systems-based Bayesian network model. Transportation Research Part C: Emerging Technologies, 121, 102840.

[62] Teixeira, J. F., & Lopes, M. (2020). The link between bike sharing and subway use during the COVID-19 pandemic: The case-study of New York's Citi Bike. Transportation Research Interdisciplinary Perspectives, 6, 100166.

[63] Tierney, K., & Bruneau, M. (2007). Conceptualizing and measuring resilience: A key to disaster loss reduction. TR news, (250).

[64] Tsapakis, I., Turner, J., Cheng, T., Heydecker, B. G., Emmonds, A., & Bolbol, A. (2012). Effects of tube strikes on journey times in transport network of London. Transportation Research Record: Journal of the Transportation Research Board, 2274(1), 84-92.

[65] van Cranenburgh, S., Chorus, C., & Van Wee, B. (2012). Substantial changes and their impact on mobility: A typology and an overview of the literature. Transport Reviews, 32(5), 569-597.

[66] van Exel, N. J. A., & Rietveld, P. (2001). Public transport strikes and traveller behaviour. Transport Policy, 8(4), 237-246.

[67] van Exel, N. J. A., & Rietveld, P. (2009). When strike comes to town...anticipated and actual behavioural reactions to a one-day, pre-announced, complete rail strike in The Netherlands. Transportation Research Part A: Policy and Practice, 43(5), 526-535.

[68] Vickerman, R. (2021). Will Covid-19 put the public back in public transport? A UK perspective. Transport Policy, 103, 95-102.

[69] Wan, C., Yang, Z., Zhang, D., Yan, X., & Fan, S. (2018). Resilience in transportation systems: A systematic review and future directions. Transport Reviews, 38(4), 479-498.

[70] Wang, H. W., Peng, Z. R., Wang, D., Meng, Y., Wu, T., Sun, W., & Lu, Q. C. (2020). Evaluation and prediction of transportation resilience under extreme weather events: A diffusion graph convolutional approach. Transportation Research Part C: Emerging Technologies, 115, 102619.

[71] Wang, Y., Zhan, J., Xu, X., Li, L., Chen, P., & Hansen, M. (2019). Measuring the resilience of an airport network. Chinese Journal of Aeronautics, 32(12), 2694-2705.

[72] Woodburn, A. (2019). Rail network resilience and operational responsiveness during unplanned disruption: A rail freight case study. Journal of Transport Geography, 77, 59-69.

[73] Yang, Y., Beecham, R., Heppenstall, A., Turner, A., & Comber, A. (2022). Understanding the impacts of public transit disruptions on bikeshare schemes and cycling behaviours using spatiotemporal and graph-based analysis: A case study of four London Tube strikes. Journal of Transport Geography, 98, 103255.

[74] Younes, H., Nasri, A., Baiocchi, G., & Zhang, L. (2019). How transit service closures influence bikesharing demand; lessons learned from SafeTrack project in Washington, D.C. metropolitan area. Journal of Transport Geography, 76, 83-92.

[75] Zhang, J., Hayashi, Y., & Frank, L. D. (2021). COVID-19 and transport: Findings from a world-wide expert survey. Transport Policy, 103, 68-85.

[76] Zhang, S., & Witlox, F. (2020). Analyzing the impact of different transport governance strategies on climate change. Sustainability, 12(1), 200.

[77] Zhou, L., & Chen, Z. (2020). Measuring the performance of airport resilience to severe weather events. Transportation Research Part D: Transport and Environment, 83, 102362.

[78] Zhou, Y., Wang, J., & Yang, H. (2019). Resilience of transportation systems: Concepts and comprehensive review. IEEE Transactions on Intelligent Transportation Systems, 20(12), 4262-4276.

[79] Zhu, Y., Ozbay, K., Xie, K., & Yang, H. (2016). Using big data to study resilience of taxi and subway trips for hurricanes Sandy and Irene. Transportation Research Record: Journal of the Transportation Research Board, 2599(1), 70-80.

[80] Zhu, Y., Xie, K., Ozbay, K., Zuo, F., & Yang, H. (2017). Data-driven spatial modeling for quantifying networkwide resilience in the aftermath of hurricanes Irene and Sandy. Transportation Research Record: Journal of the Transportation Research Board, 2604(1), 9-18.