Considerations of Resilience Management in Transportation

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Keywords: Resilience, transportation, system, network, performance

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Introduction

The aim of transportation systems is to enable movement of people and goods and to guarantee supply chain, in terms of safety and security at the core level, in terms of reliability and sustainability at an intermediate level, and in terms of efficiency at an outer level (Nogal & O'Connor, 2017).

Traditionally, transportation systems have been designed and managed under a risk-based perspective, where serviceability level of the system should be guaranteed under any likely circumstance. In that way, the service offered by the transportation system was established as the input of the problem, and as a result of a number of engineering, social and economic considerations, the infrastructure was designed or the services programmed.

The present transportation is characterized by its complexity and high interconnection with other systems, such as information and communications technology systems (ICTs) (Roege et al., 2017). Dependencies among systems imply that a perturbation in another system is likely to cause stress in the transportation system, and vice versa, triggering sometimes an uncontrolled feedback process. Thus, analyzing transportation systems without considering the relation with other systems would lead to underestimating both risks and consequences. In addition, ageing of the existing infrastructure that requires important investments to maintain acceptable service conditions, worsened by an increasing transport demand during a time period characterized by emerging threats, such as climate change and cyber-attacks, poses a special challenge to decision-makers when trying to allocate scarce resources competing with the needs of other critical infrastructures. Practitioners and managers have realized that the risk-based approach can be improved by a resilience perspective, whose aim is to guarantee the critical functions associated with a given level of disruption (Nogal & O'Connor, forthcoming), whereby the threshold relates to the tipping point where the required services cannot be provided anymore, and might vary over time with the improvement or worsening of the situation. For instance, it is a waste of resources to design a railway that provides the same level of reliability in normal situations as under an extreme (though statistically probable) snowstorm.

Resilience management of transportation systems might be defined as the culture, processes and structures directed towards the effective management of passenger demand, goods supply, and services under different internal and external shocks and stresses, compatible with the resilience of

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other related systems.

This chapter is focused on resilience management applied to transportation systems, where the user-oriented perspective is a key aspect to establish the role of the transportation system within a larger system consisting of many other systems, such as health, finance, and power. In other words, society is the guiding thread connecting them (Allen, Angeler, Garmestani, Gunderson & Holling, 2014).

Resilience management in transportation networks following Hurricane Irma

In September 2017, Florida suffered Hurricane Irma, which impacted with maintained 298 km/h winds for 37 hours in total, the longest period at this speed ever recorded, causing 84 fatalities. Under the threat of Hurricane Irma, 6.5 million people were evacuated from Florida to head north using land-based transport networks. To allow such a massive evacuation, tolls were suspended and the left shoulder of I-75 (northbound) and I-4 (eastbound) were opened to traffic.

The shoulder-use plan for evacuations was put in place for the first time by the Florida Department of Transportation. Supported by theoretical studies, in comparison with the traditional contraflow plan, the new plan would provide similar evacuation capacity, reducing the personnel, resources (e.g., highway patrol cars, orange cones) and time required to implement, and avoiding the head-on collisions between confused drivers. Despite these measures, important traffic congestion in major roads (e.g., northbound I-95, I-75, and Turnpike) was registered, exacerbated by the long lines at fuel stations, which, in turn, suffered from fuel shortage as a consequence of Hurricane Harvey (September 2017).

For the case presented, traffic jams, hours to obtain fuel and free toll-roads might be understood as a clear failure of the transport system under a risk-based perspective, where a fixed threshold related to a well-functioning system may be assumed. Indeed, the concept of system failure is a key aspect to understand the transition from the risk-centered vision to a resilience-centered vision. Under a resilience perspective, the main function of the transport system in this case was the safe evacuation of the population. Thus, the evacuation of 6.5 million people in less than five days cannot be considered as a failure. Nevertheless, there is room for improvement, e.g., four fatalities were registered due to car crashes. If a fixed threshold in terms of mobility conditions were established under any possible situation, the required effort and cost to guarantee that the system is always above this threshold would be absolutely disproportionate. Therefore, it is crucial to prioritize objectives and accept some non-optimal states compatible with the intensity of the hazardous event.

A distinguishing characteristic of the Resilience Management is the inclusion of a feedback process, which allows the improvement of the system to future events, sometimes materialized by adaptation plans (Florin & Linkov, 2016). In the aftermath of the hurricane, a Committee on Hurricane Response and Preparedness was created to analyze the response and take advantage of the lessons learned from the experience. Among the several themes discussed, some recommendations were identified in terms of evacuation to improve the preparedness level to future events. They can be summarized in (a) to extend the evacuation road networks, (b) to include contraflow lanes were appropriate, (c) to use rail transport to evacuate people and meet fuel demands, (d) to provide Floridians with real-time information regarding the evacuation choices, and (e) community education (Florida House of Representatives, 2018).

Among these recommendations to improve the resilience of the system, the last two points are highlighted. Risk management commonly focuses on the physical aspects of the system. The social aspects and how information is created, shared and understood, if considered, are assumed as secondary aspects. In the case of Hurricane Irma, the relevance of the social, the information and the cognitive domains to improve the response of the system was identified by the Committee. They are aspects that make a difference between a safe infrastructure system and a resilient one. Besides, the coordinated response is crucial between different decision-makers, infrastructure managers and operators, emergency responders, and other stakeholders. Given the short time to coordinate the operations, an established protocol with clear objectives and hierarchies is mandatory. Florida, an area commonly affected by hurricanes, has improved its resilience to hurricanes over time through a loop process of preparedness, response, recovery and learning with each event (Wood, Wells, Rice & Linkov, 2018) (Nogal, 2018).

As indicated, a few days before Hurricane Irma occurred, Hurricane Harvey had impacted the area, causing fuel shortage, among other issues. The relevance of a recovery plan, strategically designed prioritizing on key aspects, e.g., fuel supply, is here observed. Resilience management extends the classical risk management by including this post-event layer. In terms of transportation, one of the reasons to implement the shoulder-use plan is that allows a natural, smoother transition to normal operation by drivers.

Hurricane Irma case has evidenced how transport systems are at the service of the overall society, therefore, the needs of the society at each time should define the functions to be developed by transport systems with an integrative vision that includes all other systems (e.g., health, power, financial, etc.).

Building a resilient future

Let's imagine that a practitioner designs a wall to avoid potential landslides affecting a road. Because climate change might increase the risk of landslides in the area, the engineer, following his/her risk-based perspective, thinks that a bigger wall should be built to guarantee the safety level. Nevertheless, the combination of a smaller wall designed to resist the probable landslides, with a number of soft measures, such as use of vegetation and surface drainage techniques (e.g., buried drains) (Gavin & Djidara, 2015), and monitoring and warning systems for very low-probability events, might be a more inexpensive solution, which is also safer, not only in relation to landslides, but to a wider range of threats. This simple example of a resilient solution is presented to show that resilience-building is not about accepting a certain degree of risk but modifies the point of how to deal with risk. Note that the core functions of the transportation system are safety and security, and they should be always guaranteed.

Different performance of the transportation system is then expected under different disturbing scenarios, e.g., a hurricane or a strike. Therefore, when a hazardous event occurs, it might be expected that the system performance fulfils a series of functions (those identified as more relevant) but not others, causing that some actors, such as some users, might feel not entirely satisfied, if not negatively affected. The Florida case presented before shows that there is a number of actors involved, from transportation authorities to rescue services, politicians and social media. To avoid misunderstanding and even misuse of the decisions taken under a resilience umbrella, resilience-based decisions should be backed by programs and protocols defined in advance seeking consensus with stakeholders. To develop a well-defined resilient transportation system, it is

important to build on the social responsibility and awareness of the different stakeholders.

We claim that transitions to a resilient future require the definition of cross-sectorial visions and feasible action pathways to achieve such visions. With that aim, a map of the desirable resilient future considering a holistic perspective of the transport system as a part of a bigger system, should be envisaged. Then, the feasibility should be assessed through backcasting, where policies and programs connecting the future and present are identified. Here the main actors and their roles within the process have to be clearly identified. Special attention has to be paid to coordination among agencies, coordination among transport modes, cross-border governance arrangements, adequate communication tools and social education to engage users.

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