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AN EXPLORATORY ANALYSIS OF RISK, RESILIENCE, AND SUSTAINABILITY MANAGEMENT OF TRANSPORT INFRASTRUCTURE SYSTEMS

Transport infrastructures have a wide range of beneficial impacts on economic welfare and equity, as well as on reducing prices and boosting levels of investment, trade, and productivity. It is estimated that low and middle-income countries will need to invest in new transport infrastructure between 0.5% and 3.3% of their gross domestic product (GDP) annually (US$157 billion to US$1 trillion) by 2030, plus an additional 1.1% to 2.1% of GDP annually for maintenance of existing and new transport infrastructure. Maintenance costs are even more relevant than new investment costs for countries with large transportation networks, such as European countries, with the aggravating fact that failing to perform routine maintenance will result in poor service and will cost 50% more overall because of additional rehabilitation needs.

Transportation networks have a wide geographical extension, exposing each infrastructure asset to stressors such as floods, earthquakes, tsunamis, landslides, hurricanes, wildfires, or extreme temperatures. This exposure, in combination with the inherent vulnerability of transportation assets, have led to huge economic losses in past. Global Expected Annual Damages (EAD) due to direct damage from natural hazards to road and railway assets range from US$3.1 to US$22 billion, and approximately 73% is caused by surface and river flooding. Fig. 1 illustrates these interrelations between risk, resilience, and sustainability in the context of decision support for resilient and sustainable societal developments. It can be observed that a resilient infrastructure system provides benefits to society in terms of economy, livelihoods, safety, and health, but, at the same time, imposes resource consumption and emissions to the environment. Thus, these trade-offs must be well understood when deciding how to optimize the resilience of infrastructure systems while guaranteeing long-term sustainability. These interrelations and conflicts between resilient and sustainable infrastructure systems have been recognized over the past years and have received increased attention. Based on the foregoing outlined challenges, the present study aims to establish a better understanding of the current state of the art in the domain of risk, resilience, and sustainability management, with a focus on flood hazards. This focus is given the challenges posed by climate change effects and the fact that floods generate the largest amount of economic damage for the transport sector among weather-related disasters.

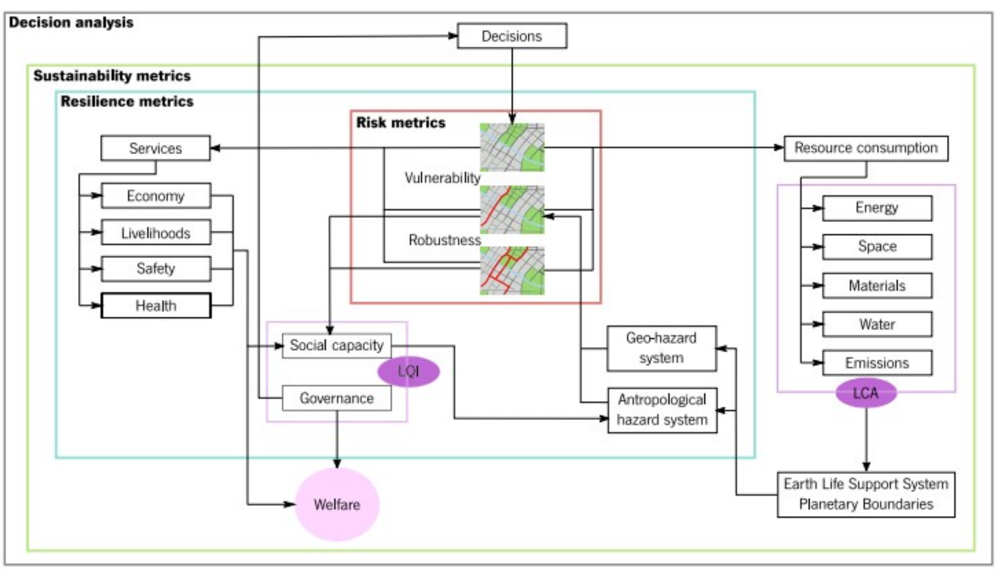

Fig. 1. Connections between risk, resilience, and sustainability with assessment metrics and techniques

This step sets the baseline for conducting analysis, which is a quantitative method for exploring and analyzing large volumes of scientific data, along with science mapping, that can facilitate deciphering and mapping a particular knowledge domain. Two quantitative techniques, namely by terms co-occurrence and coupling networks, were employed to analyze the scientific literature from the emergence of the field in 1990 until 2022. The Scopus database was selected due to its extensive publication coverage within the research domain under study. The term co-occurrence technique is useful for identifying patterns and trends in the research field, studying how different sub-fields are interconnected, finding potential opportunities for bridging the gaps between sub-fields, and searching for approaches in other research domains which can be imported. As depicted in Fig. 2, the relation between exposure or hazard events and the direct consequences is termed vulnerability, and the link between the direct consequences and the indirect consequences is related to the concept of robustness. Essentially, the vulnerability of a system indicates the degree to which exposures generate direct consequences, while robustness characterizes the degree to which a system is able to contain or limit indirect consequences associated with a hazard event. If the indirect consequences of a scenario outweigh the direct consequences, then the system lacks robustness with respect to this scenario. The other two system characteristics which are crucial for the management are resilience and sustainability. When modeling these system characteristics, not only the losses but the capacity of the system (economic, social, and/or environmental) to sustain, adapt, and recover from adverse effects should be considered.

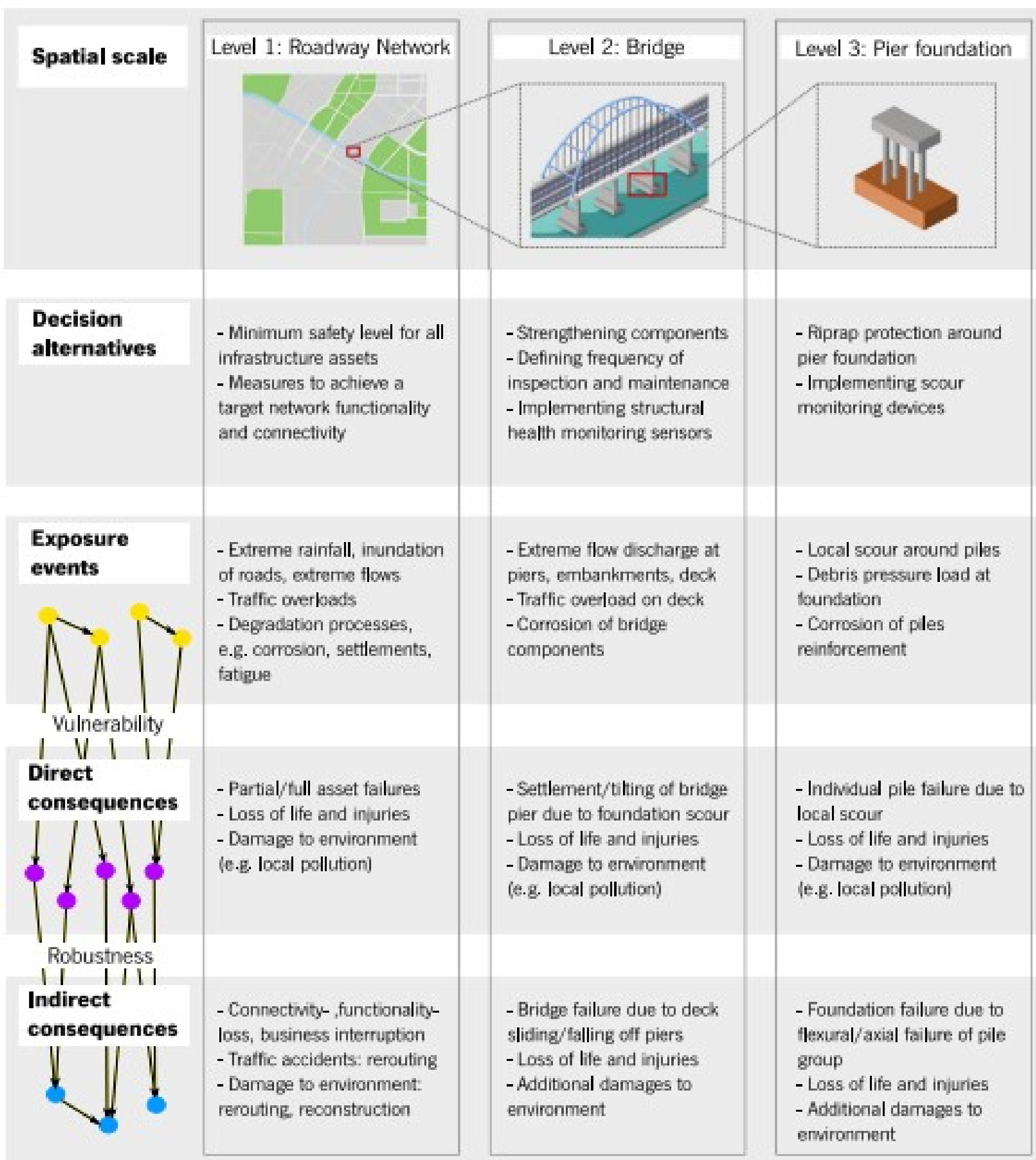

Fig. 2. System representation at different spatial scales

The economic capacity is based on the benefits generates through the provision of services, i.e., mobility for people and goods through taxes or toll roads. In some cases, infrastructure assets such as bridges or viaducts may also provide a cultural and historical value that is transformed into economical service related to tourism.

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ANALYSIS OF THE IMPACT OF INDUSTRIAL GLOVES ON THE PERCEPTION OF HAND DEXTERITY, FUNCTION AND STRENGTH OF HANDS BY THE EXAMPLE OF THE US CONSTRUCTION INDUSTRY

Work-related hand injuries can have significant functional implications. If a worker sustains amputations to all five digits of one hand, this injury represents an overall impairment of 90% of the upper extremity and, thus, 54% of the whole person. In 2020, over 102,000 workers sustained hand injuries resulting in days away from work, according to the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2021). A systematic review calculated the total costs of acute hand and wrist injuries consisting of direct costs (healthcare costs, worker's compensation payments) and indirect expenses (lost productivity, accident investigation) could range from $3257 to $169,408. As such, glove wear is a critical component of personal protective equipment (PPE), and the type of glove utilized must be based on the nature of the exposure.

Among those in the building industries, exposure to awkward postures and confined spaces lead to musculoskeletal disorders, which decrease efficiency and increase the risk of injury. The most severe hand injuries in the building industry have been associated with maintenance tasks, roof bolters, and equipment operations. These hand injuries are attributed to exposure to metal parts (e.g., pipe, wire, and nails), metal covers and guards, inserting roof bolts, drilling steel, and maintaining belt conveyors. Injuries to the hands occur almost evenly to both the right hand (48%) and left hand (52%).

To mitigate the direct and indirect injury costs, workers in industrial settings such building and extraction are often required to wear industrial metacarpal gloves as PPE. In some situations, employers provide or mandate PPE gloves to be worn without assessing the glove's impact on the worker's effectiveness in completing various tasks required for the job. Workers wear those gloves to complete various occupation specific tasks, including manipulating tools and equipment. However, if the gloves do not fit well or limit their dexterity, workers may be non-compliant with glove-wearing requirements, thus increasing the risk of severe injuries. Researchers recently identified 16 factors that contribute to PPE non-compliance in the construction industry, including poor risk perception and safety supervision.

Previous studies focused on evaluating the level of mechanical protection offered by metacarpal gloves , but there is limited research examining the impact of metacarpal gloves on manual hand dexterity, strength, and perception of exertion, within heavy-duty industries. Prior pilot research on metacarpal gloves was conducted with a small-sized subject pool (Fig. 1). In this previous pilot study, the participants were predominately student younger females who were asked to complete dexterity tests