# TEACHING MATERIAL GUIDANCE

## 1) Title of the material

***Rehak, D.; Senovsky, P.; Slivkova, S. Resilience of Critical Infrastructure Elements and Its Main Factors. Systems 2018, 6, 21. https://doi.org/10.3390/systems6020021***

*https://www.mdpi.com/2079-8954/6/2/21*

## 2) Which section of the SUMP it is relevant to?

This article defines the initial and functional conditions for building and strengthening the resilience of critical infrastructure elements, i.e., the resilience concept in a critical infrastructure system. Therefore, the article can be linked to the third, fourth and fifth sections of the SUMP circle related respectively to the determination of planning framework, analysis of the mobility situation (in particular the analysis of problems and opportunities for all modes of transport - **subsection 3.2**.), scenario building and joint evaluation (development of scenarios of possible futures - **subsection 4.1**.) and vision and strategy development (arguments for stakeholders – **subsection 5.1**).

## 3) Which Mobility Manager knowledge this material is the most relevant to?

It is related to Transport and mobility planning (section 1 of the Mobility Manager competencies) especially 1b (employment of ITS/ICT and smart measures) and Data analysis for mobility planning (section 5 of the Mobility Manager competencies) especially 5a (data collection and analysis) as well as Stakeholder involvement tools (section 7 of the Mobility Manager competencies).

## 4) Problem approached and content overview

Problem approach – general understanding of how to manage the resilience of urban transport systems. The resilience of a critical infrastructure system can be seen as a characteristic that reduces vulnerability to threats, minimizes their consequences, accelerates response and recovery, and facilitates adaptation to a disruptive event. In this context, it can be said that comprehensive knowledge of the environment and the main factors that determine the limit, and influence resilience is a fundamental prerequisite for strengthening the resilience of critical infrastructure elements. Based on this idea, the article defines the initial and functional conditions for building and strengthening the resilience of critical infrastructure elements, that is, the concept of resilience in the critical infrastructure system. Then, factors determining the resilience of these elements were identified, both in terms of technical resilience (i.e. resilience and reproducibility) and organisational resilience (i.e. adaptability). In the final part of the article, these factors are presented in more detail in the context of case studies focused on the electricity, gas, information and communication technology and road transport sectors. The determination of these factors is examined concerning the intensity of the disruptive event and the performance of the critical infrastructure element in question.

The literature review presented in this paper has shown that while the general concept of resilience as such is usually common, ideas about the grouping of individual measurable elements and their content vary considerably depending on both the topic being addressed (e.g. reliability theory, ecology, governance, etc.) and the depth of research on CI (critical infrastructure) systems (i.e. sectors, subsectors, elements, components). However, these discrepancies need to be reconciled for the sake of evaluation.

Based on the data collected, the research team identified three core components of resilience, that is, resilience and recovery in terms of technical resilience and adaptability in terms of organisational resilience. Then, variables (12 in total) for these components and measurable items (167 in total) for each variable were derived. The purpose of the selection was to combine the components and variables in a way that would facilitate the assessment of the resilience of the individual elements of the critical infrastructure. Factors limiting the selection were the need to focus on individual components (rather than the sector as a whole) and the requirement that the selected items could be used as a basis for managing the resilience of the components over the long term. Therefore, the issue is considered primarily from a management perspective.

The factors determining the resilience of critical infrastructure were characterised in the article as regards robustness, recoverability, and adaptability. Furthermore, graphical representations of resilience-determining factors for technical resilience were presented in the electricity sector, the gas sector, the ICT sector and the road transport sector.

## 5) Who could be interested in this material?

The article is aimed at students and those looking for inspiration in strengthening system resilience in smart cities to manage the resilience of urban transport systems when such measures are applied in SUMP.

## 6) What is worth mentioning as an innovative factor for the reader?

The resilience of a critical infrastructure system is defined as the ability to absorb, adapt, and/or quickly recover from a potentially disruptive event. In this context, it can be understood as a state closely related to the utility function of individual subsystems. During disruptive events, resilient subsystems show less performance degradation and the time required to return to the required level is significantly shorter. The main driver of developing and enhancing resilience is the establishment of functional conditions, which in turn allows the concept of resilience to be explicitly formulated for those subsystems within the critical infrastructure system. Strengthening resilience is about continually improving the level of factors that determine it. These factors should be given constant attention both in the area of technical resilience (i.e. resilience and recoverability) and organisational resilience (i.e. adaptability). It is equally important to reflect on factors that hinder resilience (e.g. statutory regulation of infrastructure operations or availability of financial resources) and factors that influence it (e.g. threats or instruments that enhance resilience). These principles are generally acceptable in individual sectors of critical infrastructure. However, for the successful implementation of an assessment system, this compatibility must also be manifested at deeper levels, such as the level of individual resilience factors whose performance varies significantly between critical infrastructure sectors. This article presents one way to standardise the perception of these factors while maintaining sector specificity, particularly with regard to the electricity, gas, information and communication technology and transport sectors.

## 7) Limitations

The problem was analysed at a high level of generality, but the presented idea and examples could support integration processes within new technologies to support mobility management, especially in crisis events and also in day-to-day mobility management. The conclusions presented may serve as inspiration for Polish cities regarding the problems that may occur during the implementation of shared mobility services.