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# Developing an IT-Tool for Resilience Assessment

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**Abstract**

Dealing with disruptive events is a major challenge for road infrastructure managers and owners. This research project builds on the methodological approach and considerations from Deublein et al. (2021) by addressing the identified need for research and further development. An implementation-oriented methodology was developed in order to ensure the functionality of the road infrastructure during and after disruptive events. In order to establish the usability of the methodology, a software tool as well as an implementation concept were developed.



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*Keywords:* Resilience assessment; road infrastracture; web-based software tool; disruptive events; extreme weather

## 1. Overview and Motivation

A reliable transport infrastructure makes a significant contribution to social prosperity by ensuring security of supply and meeting the mobility needs of the population and the economy.

Failures of the transport infrastructure caused, for example, by natural events, human intervention or technical failure can lead to high economic costs if they result in prolonged interruptions of critical route elements. A growing need for mobility, aging infrastructures, and the increase in external stress factors such as climate change pose additional challenges for transport infrastructure operators. At the same time, it is important to recognize the opportunities, risks, and challenges of digitization and to integrate them into infrastructure management. Comprehensive infrastructure management is therefore indispensable for high availability and maintaining functionality in the event of an incident. Today, infrastructure managers use a wide variety of management systems for this purpose, such as building management, maintenance management or incident management. What is still lacking today is a holistic, systematic management system that assesses the overall system resilience and enables the

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evaluation of measures with regard to their contribution to maintaining the functionality of the transport infrastructure. In this way, existing approaches could be linked, which would facilitate the management of an increasing number of external stress factors and make it possible to keep the economic costs low.

This research project builds on the methodological approach and considerations from Deublein et al. (2021) by optimizing and further developing the existing approach to assessing the resilience of road infrastructures in terms of methodology and content. Another focus is on the transfer into practice. For this purpose, a web-based IT tool is being developed that can be used to assess the resilience of road infrastructure and the resilience effect of measures. To facilitate the use of the IT tool, a user guide is developed. An implementation concept shows how the methodology and IT tool are to be applied in Practice.

This way, an important milestone for the integration of resilience assessment as an integral part of transport infrastructure management will be reached and the basis for a transfer of theoretical concepts from research to practice, so that decisions in infrastructure management to maintain the functionality of roads can be better prepared and measures or investments better justified in the future.

## 2. Methodology, results and main contributions

A technical concept was developed in which the concrete, overriding requirements for the methodology, the web-based IT tool, the user guide and the implementation concept are defined and documented in the form of a specification sheet. The technical concept represents the starting point for the optimization and further development of the content of the methodology and the implementation. The technical concept ensures that the development and implementation of the methodology can be carried out in a targeted manner.

### *2.1. Methodological concept for resilience assessment*

Fig. 1 below schematically shows the resilience assessment process as it presents itself to the user.

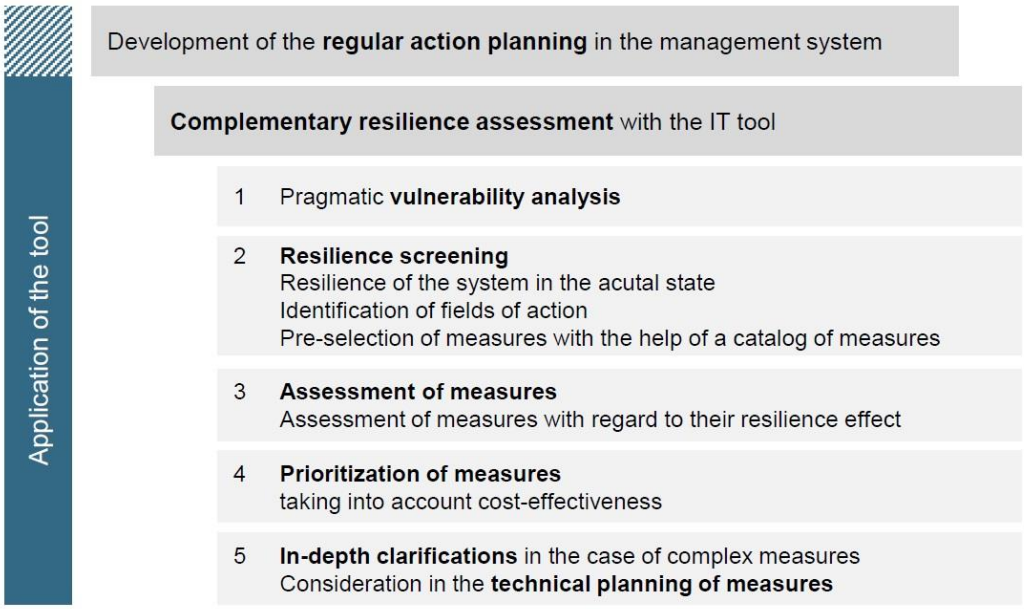


Figure 1: Schematic representation of the resilience assessment process.

The user works out the regular planning of measures in his field of expertise (e.g., construction management, maintenance management or traffic management) for a network element or a road section and/or for specific infrastructure elements of such. Thus, the goal is that no separate investigation is required for the resilience assessment, but that it is embedded in existing management systems and their processes.

If a network element or a road section is assessed from the perspective of the department, a supplementary resilience assessment is carried out with the help of the tool:

1. Vulnerability analysis: The first step is to make a pragmatic assessment of the vulnerability of the road section and/or for specific infrastructure elements. This is based on an assessment of route-specific characteristics (e.g., traffic volume, capacity utilization, alternative access options, etc.) and an assessment of the exposure to hazards with regard to the guarantee of functionality (e.g., natural hazards, technical hazards, etc.).

2. Resilience screening: The aim of the second step is the overall examination of the resilience of a system in its current state, considering any measures already planned in the department, as well as the identification of potential fields of action in which the system performance should be improved with regard to its resilience. Specifically
   - the resilience of the system is to be checked on the basis of a catalog of overarching questions, using resilience criteria that cover all aspects / functionalities relevant to the resilience of the network element belonging to the network,
   - the focus of action identification to individual, currently least resilient fields of action shall be narrowed, and
   - based on the identified fields of action, a pre-selection of potential measures is made, which are then assessed and prioritized in the next step with regard to their resilience effect. In this way, the investigations of the effect of the measures can be carried out in a more targeted and efficient manner.

3. Assessment of measures: The identified potential measures are then assessed in terms of their resilience effect. The resilience effect of a measure can be determined by its influence on the course of the resilience curve. Measures change either the frequency of occurrence of disruptive events or the course of the functionality curve after a disruptive event and thus also the resilience of the system by reducing the absolute (vertical) loss of functionality on the one hand and the du-ration of impact (horizontal) on the other. To assess the resilience effect of a measure on the vulnerable object, the following estimates must thus be made for each measure:
   - Change in the frequency of occurrence of a hazard due to the measure; to be determined separately per hazard (hydrological hazard, gravitational hazard, etc.)
   - Change in the duration of the interruption of operation or loss of functionality due to the measure; to be determined separately per hazard (hydrological hazard, gravitational hazard, etc.)
   - Change in the extent of the loss of functionality due to the measure; to be determined separately per functionality (travel time, operating costs, etc.)

4. Resilience optimization: Based on the determined resilience effect and considering a cost-effectiveness analysis of the individual measures, a ranking list of prioritized measures or combinations of measures is drawn up that is optimal for the resilience of the system. This prioritized ranking list serves as an aid to the decision maker in selecting the most efficient resilience measures and in implementing consistent resilience management.

As a result, the resilience assessments yield a list of supplemental or adapted departmental measures that could be considered from the perspective of maintaining the function of the roadway segment and/or infra-structure elements and an associated pragmatic rating. Additional measures that are judged to be expedient, which on the one hand are relatively simple to implement and do not entail any significant cost consequences, and on the other hand lie within the area of responsibility of the respective department, are to be included directly in the planning of measures wherever possible. In addition, the analysis results in potentially suitable measures for improving resilience. The appropriateness and proportionality of these measures should be analyzed in greater depth in a further step. These are typically cost-

intensive measures or those that are very time-consuming to implement, for example, due to the need for approvals or coordination with different responsible parties.

### *2.2. 5 IT tool and user guide*

The developed methodology concept was implemented in an IT tool. The tool allows users to pragmatically assess additional measures from a resilience perspective. It also allows for an assessment or ranking of their appropriateness in terms of an initial assessment.

By implementing the elaborated methodology in the form of a web-based IT tool, a comprehensive integration of the resilience approach in practice should be facilitated. In addition, the IT tool should enable users to recognize the added value of the resilience assessment for their daily work and to develop an interest in the topic of resilience.

In order to show the user, the functionalities and the handling of the tool, a user guide was created. The user guide explains the most important functionalities of the tool by means of a short description and corresponding screenshots and illustrations and shows step by step how to use the IT tool. The language, scope and level of detail are aimed at these users and should make it easier for them to use the IT tool in practice.

The following technical requirements for the IT tool were defined during interviews with experts and stakeholders:

- Simple and pragmatic use: The methodology should be easy to use (e.g., selecting a route element to calculate the impact of a closure on secondary routes).
- Usability: The tool should be easy to use and self-explanatory. The technical design should be as simple as possible, for example regarding data entry or an automatic check of the completeness of the data required. An assisted application would also be desirable, guiding users step by step and briefly explaining the required entries and selections.
- Compatibility and interfaces: The tool should be compatible with widely used systems/databases and interfaces. Existing data should be easy to import or export (e.g. road traffic data).

Usability as well as performance checks were part of the development process.

### *2.3. Implementation concept*

With the implementation of the methodology in an application-oriented IT tool, the foundations are laid to be able to consider the issue of resilience of road sections or network elements of the road network in existing management systems and action planning in the future. However, this also requires a concept that supports the implementation of the developed resilience approach and the IT tool in practice. Ultimately, the concept and the tool will only add value and increase the resilience of transport systems if they are accepted and applied in practice. The implementation concept is based on the three pillars shown in Fig. 2.

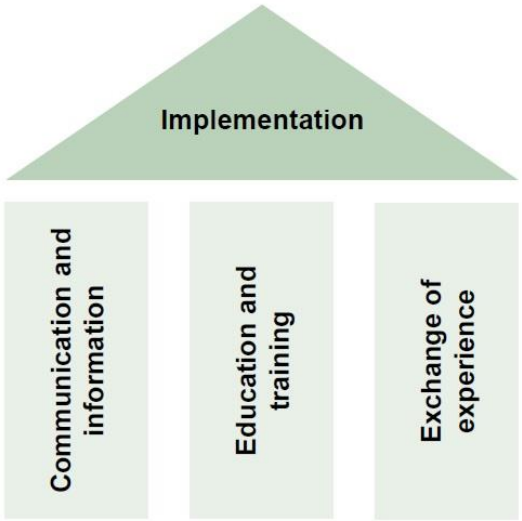


Fig. 2. Three pillars of the implementation concept.

The three pillars include the following activities:

- Communication and information: Information through existing websites, sending newsletters, information through networks, working groups and associations, and information to a wide audience through contributions at professional meetings and conferences. A good coordination of the activities is crucial.
- Education and training: The user should be answered "How is the concept or the IT tool embedded?" and "How do I apply the concept or the IT tool?". For this purpose, it is recommended to provide offers (tutorials, webinars, day courses, etc.). Individualized on-site trainings complement the training of the users. It is recommended to choose a pragmatic and easy-to-implement approach and to build on experience.
- Exchange of experience: Short term, the aim should be to increase awareness of the concept and the IT tool, to demonstrate its benefits and to provide assistance to interested users. Medium term, the experience gained should be compiled and the findings incorporated into further development.

## 3. Conclusion and future works

With this research, an important milestone for the integration of resilience assessment as a component of transport infrastructure management has been achieved and the foundation laid for transferring theoretical concepts from research to practice, so that decisions in infrastructure management to maintain the functionality of roads can be better prepared and measures or investments better justified in the future.

In addition to the further development of the methodology, a web-based IT tool was developed. The IT tool is intended to help managers and owners of transport infrastructure to assess the resilience of their infrastructure. The definition of the system to be assessed, the netscreening and the hazard analysis serve as essential fundament for the resilience screening, the evaluation of resilience improving measures and the resilience optimization. Different infrastructure elements can be assessed on object level (e.g. bridges, tunnels). As s result an overview of possible resilience measures and their impact on the system's resilience is given (Anastassiadou et al., 2020).

To facilitate the use of the IT tool, a user guide as well as an implementation concept were developed showing how the methodology and IT tool are to be applied in practice. For the future, the focus is on the development of the implementation concept and the transfer of the IT tool to other modes of transport.

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