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Sensors and Simulations for Transport Resilience

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Abstract

With the aim of enhancing resilience, the need for method of its measurement arises. To apply the method, resilience indicators must be identified and collected. In this paper we deal with questions of acquisition of indicators, needed to assess resilience of the transport system of the city. More specifically, we will look at the sensors and simulation and their possibilities in this task. That is why the first part of the paper will start with introduction of the Laboratory of Simulation and Modelling of Crisis Phenomena in Transport, and of the simulation program VR®Forces, that we plan to use for application of this paper´s outcomes and for further research of resilience. In second part of this article, we will briefly guide the reader through our view on resilience with focus on transport system of the city. Next, we will move to identification of transport resilience indicators, that could be obtained by the use of sensors within the traffic network and its vehicles or devices, and also indicators, that we can obtain by the use of simulation. Identification of sensors, usable for this task will follow. Finally, the possible use of modelling and simulation in collection of resilience indicators will be explained.

Keywords: Resilience, Sensors, Simulations, Transport, Safe City.

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1. Introduction

In the field of resilience, our focus so far was mostly oriented towards understanding resilience, defining risks and aims of resilience [1]. The goal of our ongoing research efforts is to propose complex view on measurement of resilience in transport system of the city, and in this paper we decided to address the first part of measurement, that comes before actual process of evaluation. This part is gathering of information and indicators from the transport network of the city.

To present complete list of resilience indicators is a task we aim to achieve in our following publications. In this article we decided to summarize, what needed indicators we can get out of the transport network by the use of various sensors and devices, either embedded in the infrastructure, vehicles, or worn by traffic participants.

Questions to answer are as follows:

- what indicators of transport resilience are we able to obtain by the use of sensors?
- What kind of sensors do we need to get desired indicators?
- What indicators of transport resilience are we able to obtain by the use of simulation?
- How can we use simulation to obtain needed indicators?

With this work, we want to prepare the stakeholders and researchers, interested in measuring resilience for the technological needs, that arise from such attempt.

Concerning technology, needed for simulations, we will start with presentation of a program for modelling and simulation of crisis phenomena, developed with focus on transport system, that is currently a part of a laboratory within University Science Park in Žilina.

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2. The Laboratory of Simulation and Modelling of Crisis Phenomena in Transport

In our attempt to enhance the understanding of the resilience within the city, we decided to make use of the Laboratory of Modelling and Simulation of Crisis Phenomena in Transport and in different environments, which is a part of University Science Park. This laboratory is equipped with VR-Forces® simulation program, that enables the simulation of various types of crisis phenomena in different environments.

The VR-Forces® program is shown in figure 1.

Figure 1. Visualization of the simulation in map background in program VR-Forces [2]

Program VR-Forces is a comprehensive simulation tool that allows us to simulate different situations in real or fictional map background. It contains a vast set of features and models, in attempt to provide as realistic output as possible. It uses the OpenFlight format of the digitized terrain, which enables 3D modelling in real time. Simulated environment can therefore be displayed in 2D and 3D formats as well as in real-time and non-real-time. Outputs from the program are displayed in the map background, chosen from the included library. It is also possible to export our outputs into external map backgrounds, such as those of GIS and Google maps [3].

For constructive simulation, the laboratory has four modules for creating crisis scenarios at its disposal at the moment:

- mass traffic accident,
- dissemination and detection of chemical agents,
- chemical fields (consequences of the use of chemical weapons, contamination and decontamination),
- the leakage of radioactive substances.

Within these modules, it is possible to simulate actions like medical treatment, contamination and decontamination of the territory, vehicles, and people. It is also possible to measure contamination and radioactive radiation, to build a dry line, a wet line or decontamination tent etc.

One of the basic possibilities of this program is to address the crisis phenomena of a natural, social and economic nature. The usage is mainly oriented towards the transport system, where it is possible to create simulations of mass traffic accidents or accidents that involve the leakage of hazardous chemical agents, including radioactive substances.

For our ambition to use this program in our resilience research, we aim to widen its use to enable collection and visualization of transport data from around the city. In collecting said transport data, we should focus on those, that will allow us to acquire values of resilience indicators.

3. Resilience

In our previous work, we dealt with the questions of defining resilience. We concluded that resilient city design should result in city systems, that are prepared to adapt to external changes in such a way, that causes minimal changes in system operation and functionality. It should be among today’s goals to utilize the ability of modern technologies to ensure systems functionality through different, mutually independent channels. This way, mainly the critical infrastructure should be backed up, so that failure of some channels would not mean the failure of the whole system.

Based on studied definitions [4,5…], we build our understanding of resilience around keywords in figure 2:

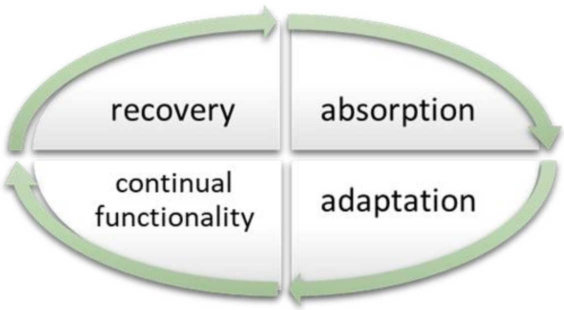

Figure 2. Keywords for resilience understanding

These keywords helped us shape the definitions of resilience and its variations. For our work, we consider resilience as an ability to absorb crisis phenomena of various kinds with non-existent or minimal restriction of the subject´s functioning, allowing adaptation of subject´s resources, skills, and infrastructure to restore its compromised functionalities as fast as possible.

When we focus on the resilience of transport system of the city, it may be defined in a similar way. Transport resilience is an ability of transport system to absorb crisis phenomena of various kinds with non-existent or minimal restriction of traffic speed, possibilities, and safety, allowing adaptation of traffic routes and means, resources, skills, and infrastructure to minimalize the time, needed for restoration of suffered traffic restrictions and for recovery of compromised features of transport system.

In order to prepare a methodological procedure for measurement of transport resilience levels, a list of indicators was created. These indicators should give us overview, complex enough to numerically express the level of resilience of transport system in measured city.

4. Available sensors for pernancy of resilience indicators

Concerning sensors, many authors in current state of art are focusing on creation of smart mobility and autonomy of vehicles, where communication between vehicles and infrastructure is discussed [6,7].

Our focus being resilience measurement, we will comment only on the sensors, that can deliver indicators, needed for our specified task. In the next part, we will identify these indicators and we will present, how the sensors and simulation can deliver data, transferable to the values of individual indicators. From the indicators, needed for resilience measurement procedure, we aimed at two types:

- indicators, that can be obtained by sensors, embedded in the infrastructure, vehicles, wearables…
- indicators, that can be obtained using simulation.

In the first type, we identified following indicators:

a) daily travelled distance of citizens,
b) redundancy for personal vehicles, trucks, and mass transport vehicles,
c) clarity of the traffic net labelling,
d) serviceability of the road,
e) carbon neutrality.

Aforementioned indicators can be obtained by the use of following types of sensoric tools:

a) monitoring of movement, based on wearable devices,
b) sensors, able to count the traffic demand – the indicator is represented by the ratio between number of vehicles, that use measured line per day and available road capacity (maximal number of vehicles, that can get through the measured line per day),
c) camera and program for video analysis, aimed at identification of traffic labelling,
d) camera and program for video analysis, aimed at identification of structural flaws in traffic infrastructure,
e) CO2e as difference between emissions generated and absorbed by city transport system components.

The question of data gathering is a sensitive topic, often associated with network spyware and social media, gathering information about users with rarely giving them the service for control over what data are being held about the users [8]

In the second type, following indicators were identified:

- promptness to act,
- preparedness,
- speed of recovery,
- failure consequences.

To create simulation, that will be able to provide adequate perspective on needed indicators, the simulation program should be able to visualize the situation within the city with as much accuracy, as possible. This goal coincides with the idea of virtual twin of the city, the draft of which is visualised in figure 3.

With this in mind, we are getting back to sensors, that would provide simulation program with information about the city. Information includes:

- meteorological information,
- flood risk information,
- information about dangerous substances leakage and air pollution,
- information from video surveillance and other traffic-measuring sensors,
- GPS tracking of IRS units.

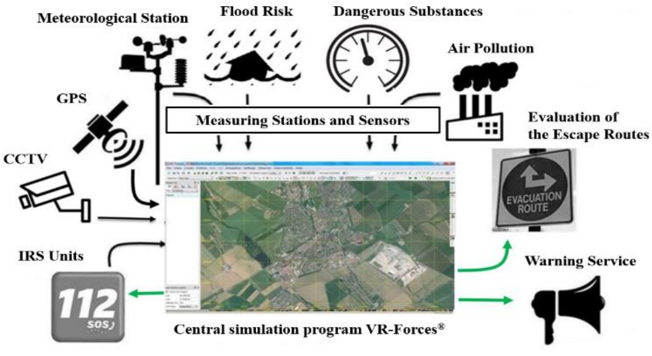

Figure 3. Draft of informational sources for complex city simulation – virtual city twin [9]

Meteorological information serves to assess the weather conditions in real time. Based on these, we can realistically forecast the development of situation, for example in the case of dangerous material leakage.

Flood risk information is important for many areas of Slovakia. Measuring the water level, the speed of its rise, amount of precipitation (current and expected forecast) and other information can give us enough warning signals about incoming crisis phenomena. In countries, threatened by earthquakes, tsunamis etc., those shall be monitored as well.

Information about dangerous substances (such as type of substance, amount, characteristics, behaviour…) should be collected mainly from factories and industry buildings, and other buildings, that store such substances in an amount, that is not negligible.

Air pollution can be calculated as an average value, taken from selected places around the city.

Information from video surveillance and other traffic-measuring sensors, able to count the traffic demand would help with collecting the data for resilience indicators.

GPS tracking of IRS units would help with overview on where the units are currently stationed. This could help mainly in crisis phenomena of bigger scale, where numerous units are needed to cope with the situation and the inevitable level of chaos will obstruct smoothness of processes.

Next, we will describe, how the system works in strengthening resilience indicators.

Promptness to act can be enhanced by warning signals about incoming crisis phenomena or leakage of dangerous materials. Such warnings in advance can help minimize the loss of lives and reduction of material damages, and also, we have better chances at preparing the functionality of city systems to withstand the crisis. If the digital twin of the city knows, what kinds and amounts of substances are stored in which buildings, and if it can simulate the leakage in a real time, right after the sensors, monitoring such industry buildings and factories will pick up and report the actual leakage, then IRS units can go into action with a good idea about the situation. Evaluation of the most suitable escape route in given meteorological situation can be automatic. In the case of air pollution, monitoring its values can let us see the need for corrective measures before it means serious health problems for citizens. Finally, by the use of simulation, exercises can be made for responsible members of crisis teams and IRS units to train and enhance their abilities. These exercises are aimed at enhancing preparedness, promptness to act in the face of crisis phenomena and they can also display most probable consequences of the crisis. Speed of recovery can be measured as well. Expected outcome is, that with more experience in real life scenarios as well as in exercised simulations, the speed of recovery will rise, decreasing the amount of time needed for restoration of effective level of functionality. The use of simulation technologies could make planning of emergency measures more effective, identification of forces and resources, needed to cope with the situation more precise and it could also verify whether the planned resources are sufficient or not, thus enhancing the preparedness [10]. More about exercises for crisis teams can be found in Janosikova et al. [11], in Ristvej, J. et al. [12], in Titko, M. and Ristvej, J. [13] and in Titko, M. et al. [14].

Failure consequences can be visualised in simulation if the failure is set into the simulation of “normal day”. Simulation of normal day is a simulation, where movement habits of citizens and city visitors is simulated. Simulation of habits should be based on average countings of transport flow in individual days of week. All participants of transport system are included: cars, pedestrians, bicycles etc. Then, if we place a crisis scenario in the simulation, we will see all entities, that will have to react to a given failure. This is especially important if we want to deal with the disruptions on transport network of the city. Without the simulation of normal day, simulation of crisis phenomena would seem to occur in empty streets, where only entities we created for the sake of exercise will be affected. This could lead to less precise view on the situation, letting the trainees believe, that there is just a limited amount of people, they will need to deal with during a real crisis.

5. Conclusion

To assess the resilience of transport system of the city, we need to collect information for resilience indicators. In this article we identified indicators, that can be gained by sensors and simulation. We abstained from presentation of the full list of indicators, because not all indicators can be achieved by deployment of sensors of by the simulation. We described the information, needed to create simulations, that can help us identify and strengthen resilience indicators. Our ongoing effort aims to gradually build depicted scheme of simulation. As the first sensor, we picked the temperature sensor, as a part of meteorological information source. The main challenge is expected in creating a communicational link between the sensor and simulation program, so that the program can automatically adjust weather settings, based on the data, received from the sensor. When this link is established, we can continue with adding another sensors and information into the program, creating a tool for measuring and strengthening the resilience of city transport system.

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