Category: paper

The potentials of urban design for a seismic resilient city

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Cities are complex technological, social and spatial systems, providing interactions between different components at different levels. Physical components (buildings, open space, infrastructure) act as the body of the system, its skeleton, lifeblood and muscles. Social components (social community), on the other hand, act as the brain of the city, directing its activities, responding to its needs and learning from their experiences (Godschalk 2003, Desouza and Flanery 2013). Functionality of an urban system depends on a design, diversity, density and quality of individual elements of its components, their interaction, morphology and topology of a city as a whole. These quantitative and qualitative city's properties create a variety of urban functions, and the way of connecting and intertwining elements determines the accessibility of the offer and choice (Norberg-Schulz 1984).

However, due to various dangers that threaten the functionality of an urban system and its cultural sustainability (heritage, morphology of built pattern, social structure, etc.), lasting prosperity cannot be fully guaranteed without enhancing urban resilience. Although the global probability of earthquakes is much lower than extreme weather events, the consequences of an earthquake can be more expansive, both in terms of casualties and economic losses. As earthquake is a rare event, society is unable to develop an adequate perception of seismic risk before a strong earthquake occurs (Shrestha et al. 2018). In order to avoid the worst-case scenarios and limit the extent of damage, more attention needs to be paid to raising public awareness of the importance of reducing risk and increasing the resilience of urban systems.

A resilient city is a sustainable network of physical systems and social community capable of coping with extreme events. During an accident, this network is able to survive and operate in a stressful situation, and after an accident, despite possible altered relationships between individual elements, it is able to recover quickly and efficiently and re-establish impaired urban functions. Highly resilient urban systems are able to adapt, upgrade, and even improve the performance of the entire system compared to the pre-disaster situation.

The subject of the research is the seismic resilience assessment of an urban system, taking into account the interactions of its basic urban components (buildings, open space, infrastructure and social community) and the overall time dimension (before, during and after the disaster). The work focuses on the analysis of the impacts of open space for the recovery of the urban system after an earthquake. Urban resilience is assessed from an urban design point of view, so we are interested in the configuration of an urban landscape, the relationships between individual components of a system and various urban processes. The focus is not on the structural resistance of an individual building, but on the resilience of an urban structure as a whole. The research deals in depth with the analysis of the potentials of open space for seismic resilience of an urban system, especially during the response and recovery after an earthquake. We investigate the relationship between built and open space. An earthquake only affects buildings and infrastructure facilities, which causes victims among the population, disruptions of infrastructure networks and various social organizations, while open spaces remain largely intact. The latter offer the potential for disaster recovery of an urban system and its transformation into a more resilient urban form. The current usability of open spaces as well as their flexibility to take on new tasks in stressful situations was recognized as important facts (Allan et al. 2013).

The research thesis has been set, that the seismic resilience of an urban system depends on the characteristics of the basic urban components and the configuration and topology of the urban landscape, which can be evaluated by assessing its functionality before, during and after the accident. Moreover, city can be modeled as a socio-spatial network system and its functionality can be evaluated both qualitatively and quantitatively using urban-design and graph theory indicators. The proposed model of the urban system assessment enables the identification of weak points such as hubs with high centrality, poor accessibility and resistance of critical facilities (e.g. hospitals, civil protection facilities, emergency care, etc.) and vital infrastructure (e.g. bridges), which represents basis for proposing measures and strategies for seismic resilient design of urban systems. It is possible to analyze the less explored potentials of an urban system, such as potentials of open spaces, which has a positive impact on the resilience of a city, especially during evacuation and recovery after earthquakes.

In the initial phase of the research descriptive method was used, which includes the technique of studying and analyzing the existing literature in order to propose a city model for a comprehensive resilience evaluation. The study continue with experimental method which is used to create a network model of an urban system (graph from points, connections and patches), which is formed from various networks of basic urban components based on geospatial data. An individual network is formed from elements that could be separately evaluated using quantitative and qualitative parameters (various engineering and urban-design indicators). The overall assessment of an individual element is thus multi-layered consisting of its essential properties, which can be shown in the form of graphical diagrams. Afterwards, interactions between individual components and the functionality of the urban system as a whole are going to be analyzed. Simulations of different seismic scenarios are planned as well as the analysis of effects on the built environment, analysis of interactions (impact radius of buildings on transport infrastructure and open spaces, affected residents living in damaged buildings and impaired functioning of organizations in damaged buildings) and impacts on the functionality of the entire urban system. Threat to cultural sustainability and the impact of urban design on the resilience of the city (topology and morphology of the urban landscape) will be observed. Different scenarios of system recovery is planned to be analyzed by taking advantage of open spaces to replace disturbed urban functions. The potential of urban design for seismic resilience enhancement should be evaluated and included in the proposal of measures and guidelines for strengthening the resilience of cities.

In the thesis we want to provide new fundamental knowledge about the functioning of cities in stressful situations and offer directions for seismic resilient urban design. The main expected result of the research is the design of a model for evaluating the seismic resilience of the urban system and its potentials with emphasis on the analysis of the effects of open space on urban resilience, especially in the phase of evacuation, reconstruction and post-earthquake adaptation.

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Design Driven Research

The issue of urban resilience is approached from an urban-design point of view, as the main focus of the research is on the design of urban system, both in terms of morphology of individual elements and topology of the whole urban system. Based on the literature, a model for a comprehensive evaluation of the seismic resilience of an urban system is proposed. Topologically arranged network model consist of different networks of basic urban components. An individual network is built from elements that can be individually evaluated, based on their qualitative and quantitative properties. For example, open spaces can be assessed on the basis of their capacities (size, shape, flexibility, composition, ecosystem services, etc.), spatial distribution and strategic location (proximity to critical urban functions). The model allows the analysis of interactions between individual components and functionality of the urban system as a whole using indicators and algorithms of graph theory. The analyze is going to be performed using GIS tools and computational software (e.g. Wolfram Mathematica). Beside functionality of the whole system, cultural sustainability, accessibility to important urban functions, critical points and bottlenecks of system will be observed. In the analysis of resilience in the phase of evacuation and recovery after an earthquake, the focus is on the potentials of open space for the needs of the affected population and disrupted urban functions. Different scenarios of system recovery is planned to be analyzed by using open spaces to replace truncated urban functions and create more resilient urban form.

Keywords: seismic resilient design, complex urban system, open space

Bio

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I was born on June 22, 1988 in Ljubljana. After high school graduating with honors, I continued with the study of architecture at University of Ljubljana. I completed my master study in 2016. In the same year, I accepted the work of a young researcher under supervision of Assist. Prof. David Koren and enrolled in the PhD study of architecture University of Ljubljana, where I participate in the research program Sustainable Design of Quality Living Environment. During the study, I have presented my current findings in several scientific papers* for which I have already achieved more than 30 citations.

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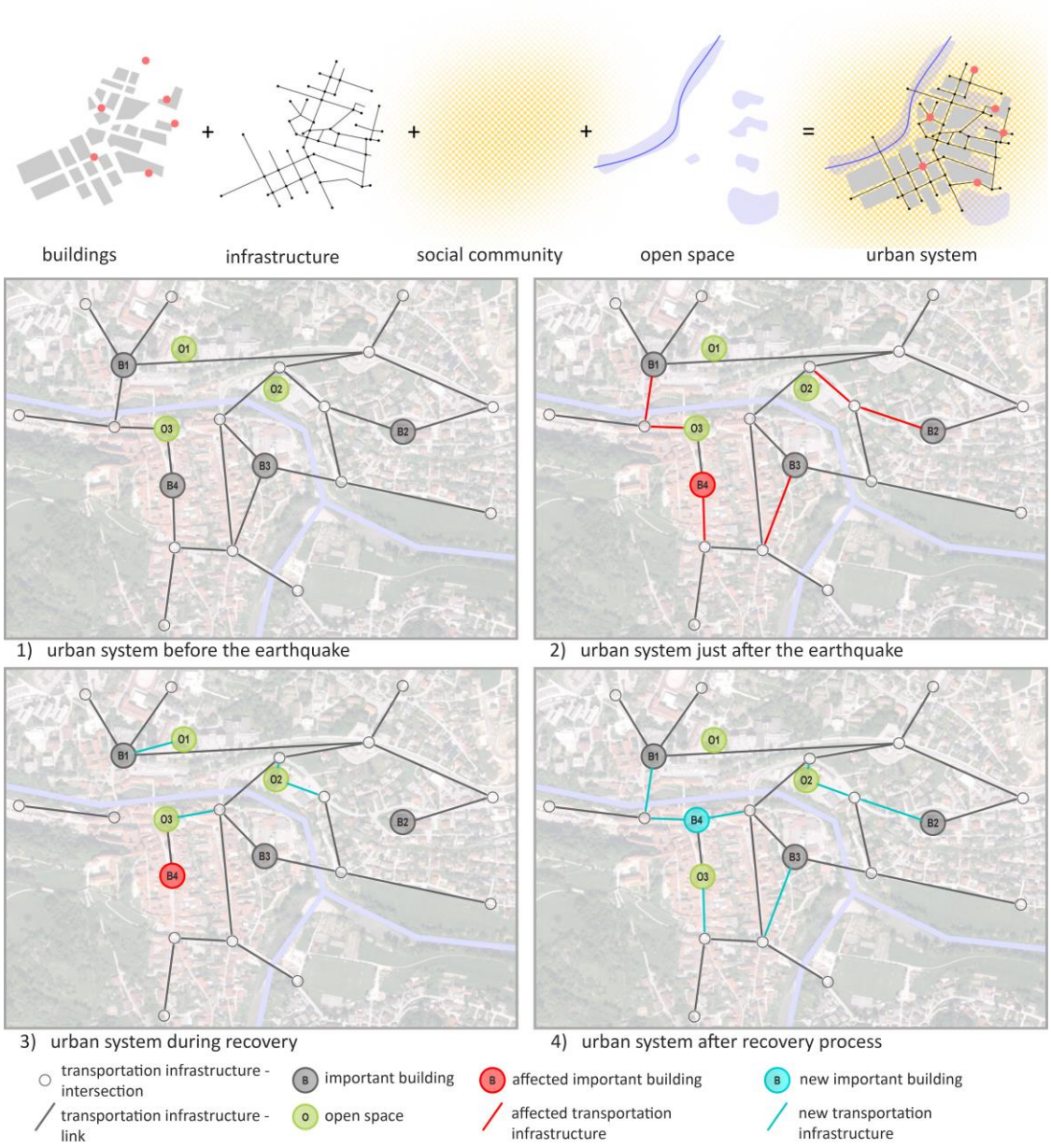

Conceptual presentation of the proposed network model of the urban system and its seismic resilience assessment. (Author's work)