CRITERIA FOR EVALUATION OF RESILIENCE OF RESIDENTIAL BUILDINGS IN CENTRAL EUROPE

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The main objective of the present research was to develop a methodology for assessment of resilience of residential buildings in Central Europe. The main purpose of the methodology is to enable to set performance levels in terms of resilience for new multifamily residential buildings. The paper describes a method of selection and development of the assessment criteria and the final structure of whole assessment scheme and presents examples of detailed evaluation using selected criteria.

Keywords: resilience, residential building, criteria, assessment, multicriteria

1. Introduction

The term resilience comes from a Latin word *resilio* meaning “to bounce back” [1]. It came from the ecological science and in its original meaning it stood for the capacity of an ecosystem to absorb shocks and still maintain function [2, 3]. From the ecological science it spread to other disciplines and started to be used also in architecture. Meerow et al. [4] made a broad review of various papers and definitions and proposed an integrative definition of urban resilience:

Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.

In this paper, we consider resilience of a single building similarly: building resilience is the ability of a building and its systems to maintain or rapidly return to desired functions in the face of disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity.

The main purpose of this paper is to present an approach we have chosen in our research project to define the main resilience-related areas appropriate for development of a system for evaluation of resilience of typical new residential buildings in Central Europe.

2. Methods

The methods used in the research presented in this paper comprised the process of compilation of a short list of potential threats for a typical multifamily residential building located in Central Europe.

In order to make a selection of areas of concerns relevant for Central European multifamily residential buildings in context of resilience, we have used a long list of potential threats to buildings that was compiled in diploma thesis by Paulechová [5] extended by additional items from national policy documents like Climate Change Adaptation Strategy in the Conditions of the Czech Republic [6], National Climate Change Adaptation Action Plan [7], Climate Protection Policy of the Czech Republic [8] and further literature, especially Urban Adaptation to Climate Change in Europe [9]. After that in 2017 we organized 4 meetings of experts

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Fig. 1. Typical contemporary multifamily residential building for which the lists of criteria were developed [10]

on architecture and building engineering experts in order to derive from the long list a short list of threats to work with further.

As a typical representative building of the typology for which the set of criteria was developed is a multifamily residential building for 60 occupants (see Fig. 1).

In the first meeting we introduced the overall long list of possible threats and the experts were asked to prepare their individual evaluations of these threats by using a qualitative risk analysis method using judgment of experts (Delphi Technique). The expert team assessed the vulnerability of a typical residential building to threats from the long list and evaluated the societal significance of each threat.

The second meeting consisted of presentations of outcomes of the individual evaluations, group discussion that lead to a consensual compilation of a short list of the most significant threats.

In the third meeting the long list was used again and the probability of occurrence of each threat was evaluated and combined with estimation of potential economic damage that the event causes. Products of multiplication of probabilities and estimated costs of damage provide weights for sorting the long list and selecting the top-ranked items for further work. In the last meeting, the two short lists were compared and compiled into one final list by overtaking the items that occurred in both lists. Decision on the residual items' inclusion or exclusion was made based on a consensual discussion.

3. Results

The long list of potential threats that has been compiled from the literature review is listed in the following Table 1.

Table 1. The long list of potential threats for building operation

Phenomenon	Potential threats
<i>Climatic and atmospheric threats</i>	
Heat	Longer periods of tropical days Extreme summer temperatures Increased yearly average temperatures Heat islands
Cold	Longer periods of cold days Extreme winter temperatures
Water	Longer periods of drought Dropped levels of underground water

Table 1. (cont'd)

Phenomenon	Potential threats
Extreme climatic conditions	Strong winds and windstorms Hailstorms Torrential rains Avalanches Floods
Air pollution	Dust particles in outdoor air Dust particles indoors Smog

Table 1. (cont'd)

Phenomenon	Potential threats
<i>Geophysical hazards</i>	
Natural	Earthquakes Landslides
Manmade	Settlement of building's structures Settlement of ground soils Land slumps in undermined areas Traffic-induced building vibrations
<i>Fire</i>	
External fire	Effects of external fire Toxic emissions from external fire
Indoor fire	Effects of indoor fire Toxic emissions from indoor fire
<i>Noise</i>	
External sources of noise	Noise from transportation Noise from external technological sources
<i>Social threats</i>	
Unexpected events	Migration waves Social riots Terrorism Wartime period
Long-term development	Increased demand on daily commuting Ageing population Energy poverty Limited technical skills of occupants

The short list resulting from the risk analysis is presented in the Table 2 together with their scores

Table 2. The short list of potential threats after risk evaluation. The significance ranged from 1 to 15, the table presents only items scored 8 and higher

Threat	Significance
Floods	15
Longer periods of drought	15
Torrential rains	15
Dust particles in outdoor air	12
Interruptions of fuel supplies for more weeks	12
Effects of external fire	10
Effects of indoor fire	10
Terrorism	10
Traffic-induced building vibrations	9
Noise from transportation	9
Noise from external technological sources	9
Ageing population	9

Table 1. (cont'd)

Phenomenon	Potential threats
Hazards from location in socially disadvantaged community	Crime Disorderly conduct
<i>Infrastructural failures</i>	
Failures of essential infrastructures	Interruptions of electricity supply for more than several hours Interruptions of supply of heat or gas for heating for more than several hours
Failures of important infrastructures	Interruptions of fresh water supply for more days Interruptions of fuel supplies for more weeks Interruption of data connectivity
Failure of building services	Inability to disconnect failed subsystem Water supply failures and its consequences of leakages Sewage system failures Rain drainage system failures Failures of indoor comfort control systems Security systems failures Failures of indoor transportation systems

coming from a risk assessment matrix that was used for an evaluation of each threat. One axis represent-

Table 2. (cont'd)

Threat	Significance
Disorderly conduct	8
Dust particles indoors	8
Landslides	8
Land slumps in undermined areas	8
Toxic emissions from indoor fire	8
Social riots	8
Increased demand on daily commuting	8
Crime	8
Interruptions of supply of heat or gas for heating for more than several hours	8
Interruptions of fresh water supply for more days	8
Security system failures	8

ed probability of the threat occurrence and the second significance of impacts caused. Scores on both axes ranged from 1 to 5 and the product of multiplication of the assigned values represents the final score for each threat. Table 2 shows just the threats that scored with 8 points or more (the higher, the more significant).

The short list of threats resulting from the estimation of probability of occurrence and from estimation of induced costs of the event is in Table 3. The reference period was 50 years and the reference building was a generic multifamily residential building with 60 occupants in 24 flats. The following rough costs were considered (in Czech crowns, CZK): life threat 50,000,000; health damage with long-term consequences 2,000,000; short-term deterioration of one person's health 50,000; permanent or high frequency repeated restraint of comfort for one person 100,000; one-time comfort limitation for one person 10,000; damage to property – estimated cost of repair; increase in operating costs – estimated increase in operating costs for the whole building.

Table 3. The short list of potential threats coming from estimation of probability of occurrence and from estimation of induced costs of the event. Only threats with combined cost and probability estimation above 500,000 CZK are listed

Threat	Probability × cost in thousands of CZK
Noise from transportation	547,500
Noise from external technological sources	420,000
Smog	120,000
Effects of indoor fire	53,180
Ageing population	28,600
Floods	27,000
Longer periods of tropical days	14,400
Effects of external fire	10,636
Crime	5,000
Migration waves	3,000
Increased yearly average temperatures	2,400
Dust particles in outdoor air	1,500
Disorderly conduct	1,500
Longer periods of drought	1,200
Security systems failures	1,000
Energy poverty	1,000
Extreme summer temperatures	900
Traffic-induced building vibrations	800
Earthquakes	765
Social riots	500
Settlement of building's structures	500
Settlement of ground soils	500

Table 4. Final set of criteria for assessment of resilience of multifamily residential buildings in Central Europe

Category	Threat
Climatic and atmospheric threats	Torrential rains
	Floods
	Extreme summer and winter temperatures
	Longer periods of drought
	Heat islands
Fire	Dust particles in outdoor air
	Effects of external fire
	Effects of indoor fire
Noise	Noise from transportation
	Noise from external technological sources
Social threats	Ageing population
	Low architectural and operating quality, low variability
	Energy poverty
	Disorderly conduct, Social riots and Crime
Infrastructural failures	Interruptions of electricity supply for more than several hours
	Interruptions of supply of heat or gas for heating for more than several hours
	Interruptions of fresh water supply for more days
	Interruptions of fuel supplies for more weeks
Risk of failures of building services	Unreliability or overcomplexity of building services

The two shortlists from Tables 2 and 3 were compared and thoroughly discussed. Most of the items that were included in both tables were included in a final set of criteria summarized in Table 4 above. Some of the threats were merged into a single one, such as *Disorderly conduct*, *Social riots* and *Crime*. Also, wording of some criteria's titles was improved to be clearer.

4. Discussion

In the first short list were noticeable threats whose effects are rather of one-shot catastrophic or emotional character, like floods, droughts or torrential rains related to flash floods. On the other hand, in the second short list scored the threats that present not so visible epic damages, but they are characteristic by small doses of effects over long periods of time and their cumulative effects on human health can be significant. The reason for these winners in the second short list also

lies in the fact that the probability of occurrence of extreme external noise is in present urban conditions very high. It seems that the combining of the two lists thus secured that both rare but powerful events and frequent but weak events are covered by the resulting set of criteria.

The authors are aware of a potential for deeper and more thorough analyses that would incorporate inputs from a variety of disciplines ranging from health-care to insurance business to climatology, however, such outreach has been out of the project scope and budget so far.

5. Conclusion and future work

Through the process of expert discussions and two approaches to evaluation of potential threats for residential multifamily buildings in the conditions of Central Europe we have come up with a set of 18 criteria that will be in the course of project developed into an assessment method that would provide descriptions of indicators, procedures for calculation of their values and benchmarks for calculations of scores in each criterion.

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