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.
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.

| Phenomenon | Potential threats |
|------------|------------------|
| **Climatic and atmospheric threats** | |
| 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 |

Air pollution | Dust particles in outdoor air, Dust particles indoors, Smog |

Table 1. (cont'd)
CRITERIA FOR EVALUATION OF RESILIENCE OF RESIDENTIAL BUILDINGS IN CENTRAL EUROPE

Table 1. (cont’d)

| Phenomenon                | Potential threats                                                                 |
|---------------------------|-----------------------------------------------------------------------------------|
| Natural                   | Earthquakes, Landslides                                                           |
| Manmade                   | Settlement of building’s structures, Settlement of ground soils, Land slumps in undermined areas, Traffic-induced building vibrations |
| External fire             | Effects of external fire, Toxic emissions from external fire                      |
| Indoor fire               | Effects of indoor fire, Toxic emissions from indoor fire                          |
| Noise                     | Noise from transportation, Noise from external technological sources              |
| 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 |
| Infrastructural failures  | Intermittences of electricity supply for more than several hours, Intermittences of supply of heat or gas for heating for more than several hours |
| Failures of important infrastructures | Intermittences of fresh water supply for more days, Intermittences 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 |

The short list coming from a risk assessment matrix that was used for an evaluation of each threat. One axis represent-
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 |
| | Dust particles in outdoor air |
| Fire | 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 healthcare 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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