DELIVERABLE REPORT

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TITLE:	BUILDING MANAGEMENT SYSTEM WITH EVACUATION MODEL-LING -- **SUMMARY**

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Executive Summary

According to various sources (for example the report of the intergovernmental panel on climate change(1), or the Munich Re NatCatService(2)), the chance for climate-induced manifestation of natural hazards (like flooding, storms and droughts) has dramatically increased during the last decades and there is strong evidence for this trend to be continued. In addition, parts of Europe are also exposed to hazards based on geophysical events like earthquakes and volcanic eruptions (for example the earthquake around L'Aquila, Italy, 2009). Apart from natural disasters, Europe has also faced terroristic attacks like bombing or arson (for example train bombings in Madrid, Spain, 2004(3)).

The loss generated by the events was always a combination of damages to persons, buildings and infrastructures. In most cases it can be shown that damages are mitigated if critical infrastructure is rendered resilient regarding the corresponding hazards (fewer fatalities in earthquake-resistant buildings, less damage to buildings with smoke sensors and a proper fire alarming system, prevention of terroristic attacks by intensified security inspections etc.) Therefore, the overall aim of this work is to describe hazards and possible countermeasures and how these measures can be integrated into a best practice approach for the erection of new buildings and infrastructures. To do so, the consideration of hazards should already be integrated into early stages of planning. A result of this project will be the provision of tools to assist this process, in particular, the integration of hazards and their counter-measures into pan-European planning standards like an enhanced BIM (building information modelling) and the development of a hazard-aware building management system (BMS).

In order to prepare the implementation of tools and the codification of new standards, we model and simulate in this report hazards, which are significantly relevant for the construction and operation of larger building complexes embedded into an urban infrastructure. While the results in this report are valid for a variety of buildings, the consortium has agreed upon a specific showcase (multifunctional office complex in the city centre of The Hague), which we bear in mind when looking closer at some specific aspects of the hazards. The overall objective of our work is to identify and standardize measures, which allow us to maintain the building or urban infrastructure (at least as long as required to ensure safe evacuation of all occupants).

We evaluate how down-time after disasters in urban and building infrastructures can be minimized through increased resilience or means of fast recovery (cf. Figure 1). We propose different simulation models, as part of a building management system (BMS), which allows the simulation and therefore the analysis of disaster impacts (by category) and thus provides basis for recommendations on how to improve resilience sensor-based building management systems. This new type of virtual vBMS will be used for an experimental performance analysis of multifunctional sensing elements regarding relevant loading scenarios (defined by the consortium).

WP3: Design for safe operations:

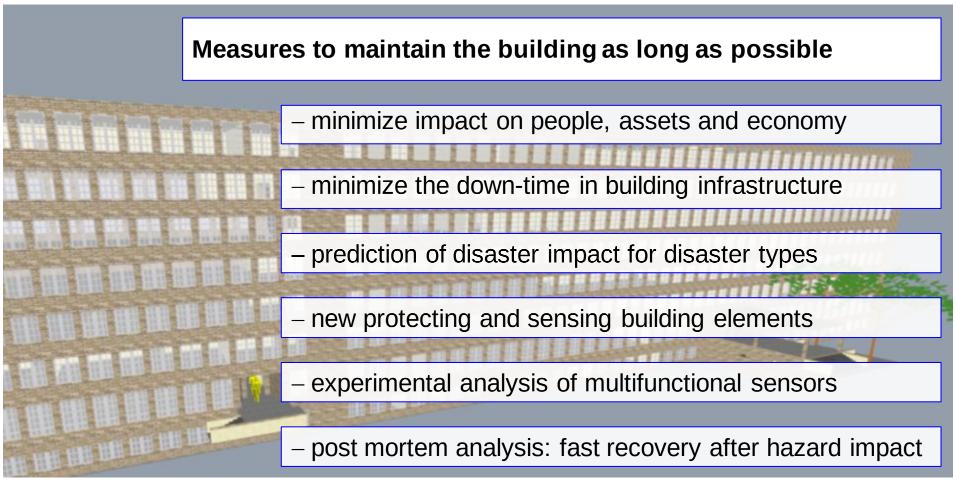

Figure 1: Overview on the main activities in work package 3

Concerning work package 3, we generate a solid base for the top-level activities (like the development of the BMS). We modelled and simulated each of the four hazards (earthquake, flood, fire and emissions, as well as explosion scenarios) relevant for the BMS in detail. Each of the following sections will describe one of the mentioned hazards in detail, based on the description of the hazard itself as outcome of deliverable 3.1 and subdivided here in this report into a simulation model of the hazard itself as well as of the corresponding person behaviour during occurrence of that hazard. Corresponding simulation results for each of the hazards will be shown in this paper. One essential part of a BMS system is the use of sensors within the building. Their utilization and corresponding simulation models will be discussed prior to the integration of all of the mentioned hazard simulation models and sensor models into a new concept for an extended virtual BMS (vBMS) as discussed at the end of this paper.

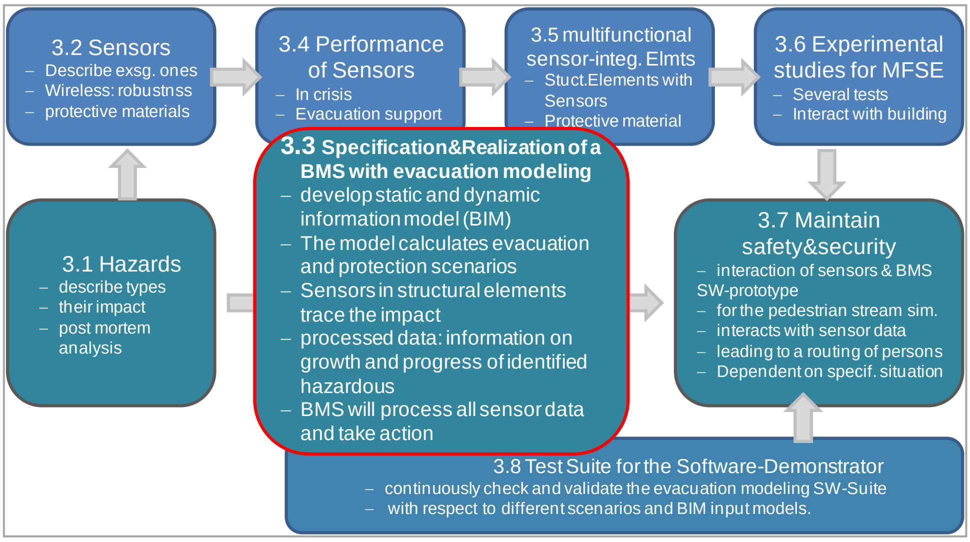

Figure 2: Figure of tasks in work package 3, highlighted is the current task 3.3

(BMS: Building management system, BIM: *Building Information Modelling*, MFSE: Manufacturing Systems Engineering, SW: Software)

Apart from this introductive chapter about work package WP3, this report consists of five parts:

- In the **first part**, simulation models for four types of hazards will be discussed in detail followed by a discussion on several simulation results in a **second part**: The aim of this hazard simulation is the computation of effects of
    - flooding, fire/smoke, virtual explosives, and earthquakes scenarios on the evacuation of buildings. Buildings together with their internal structures like walls, rooms, levels and stairs will be influenced by these hazardous events.

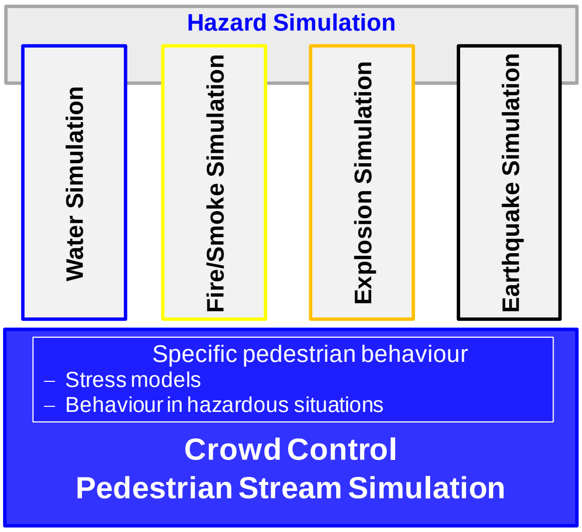

Figure 3: Coupling of Modules for Hazard Simulations and Pedestrian Stream Simulation

    - in addition to this report, deliverable 3.5 requires a "demonstration" of the realization of different hazard scenarios and of the vBMS: on the one hand, this demonstration was shown in different ELASSTIC meetings (Munich Oct. 2014: fire simulation, Amersfoort March 2015: water simulation). On the other hand, a specific demonstration report will be written showing the SW-Demo as a sequence of several screen shots of the SW GUI. Therefore, only very first simulation results are shown in this report.
    - moreover, the specification of three evacuation and protection scenarios as well as the corresponding simulation results are required in Deliverable 3.5: these results are proposed in a third, additional document linked to the scenarios of the MCA analysis (Deliverable 4.2): for a virtual building defined in the previous work packages ("Ribbon 1"), the use of an occupant evacuation for the mentioned three scenarios is demonstrated. The procedure is integrated into the new vBMS model and based on either real or simulated input sensor data for smoke, building conditions and number/position of occupants: Depending on the actual input information / scenario / type of hazard, the pedestrian stream simulation will guide the occupants via the best way out of the complex.

- In a **third part**, virtual sensors as well as the connectivity to real sensors in structural elements will be developed, which will demonstrate the impact on the building structure and its current condition under usual operation or after an extreme event like an earthquake or a blast. The processed data (time depending sensor values (S_Values(t), Figure 4) provides dynamic information on the growth and progress of the identified hazardous condition throughout the building and enable therefore a detailed hazard analysis.

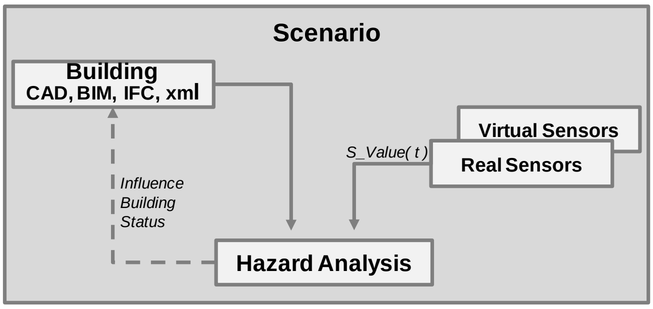

Figure 4: coupling of modules for static building data and dynamic sensor data

– The integration of this sensor information (Figure 4) and the hazard simulations mentioned above (Figure 3) will be used in the **fourth part** of this document (Figure 5), and will lead to a new approach for a virtual Building Management System (vBMS): A static and dynamic information model of the building, its occupants and its assets will be developed and implemented in the vBMS. The model will calculate evacuation and protection scenarios not only based on static inputs (e.g. room layout), but also based on dynamic inputs provided by installed sensors, e.g. smoke and occupancy detectors. The vBMS will process all sensor readings and take appropriate actions. This tactical information will be used to guide the people out of the complex and to improve the effectiveness of first responders and guide incident managers to maximum success – cf. “Intelligent Response”.

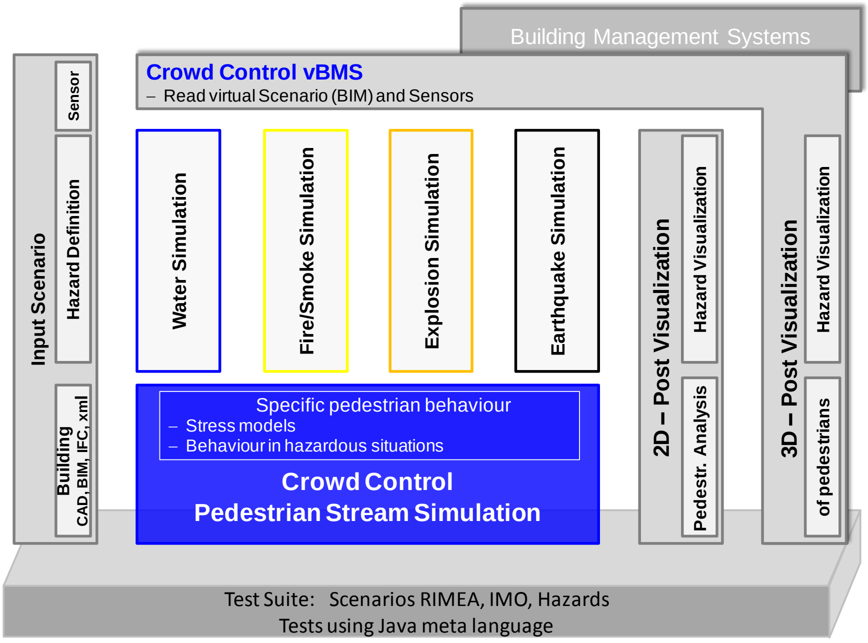

Figure 5: Software Architecture of the „Crowd Control“ Modules

The corresponding 2D and 3D post visualization as mentioned in Figure 5 enables the possibilities of detailed scenario analysis (see Figure 6). Moreover, all simulations are based on a detailed test suite guarantying continuously calibrated and tested simulation results (see Figure 5 and Deliv. 3.8 in Figure 2).

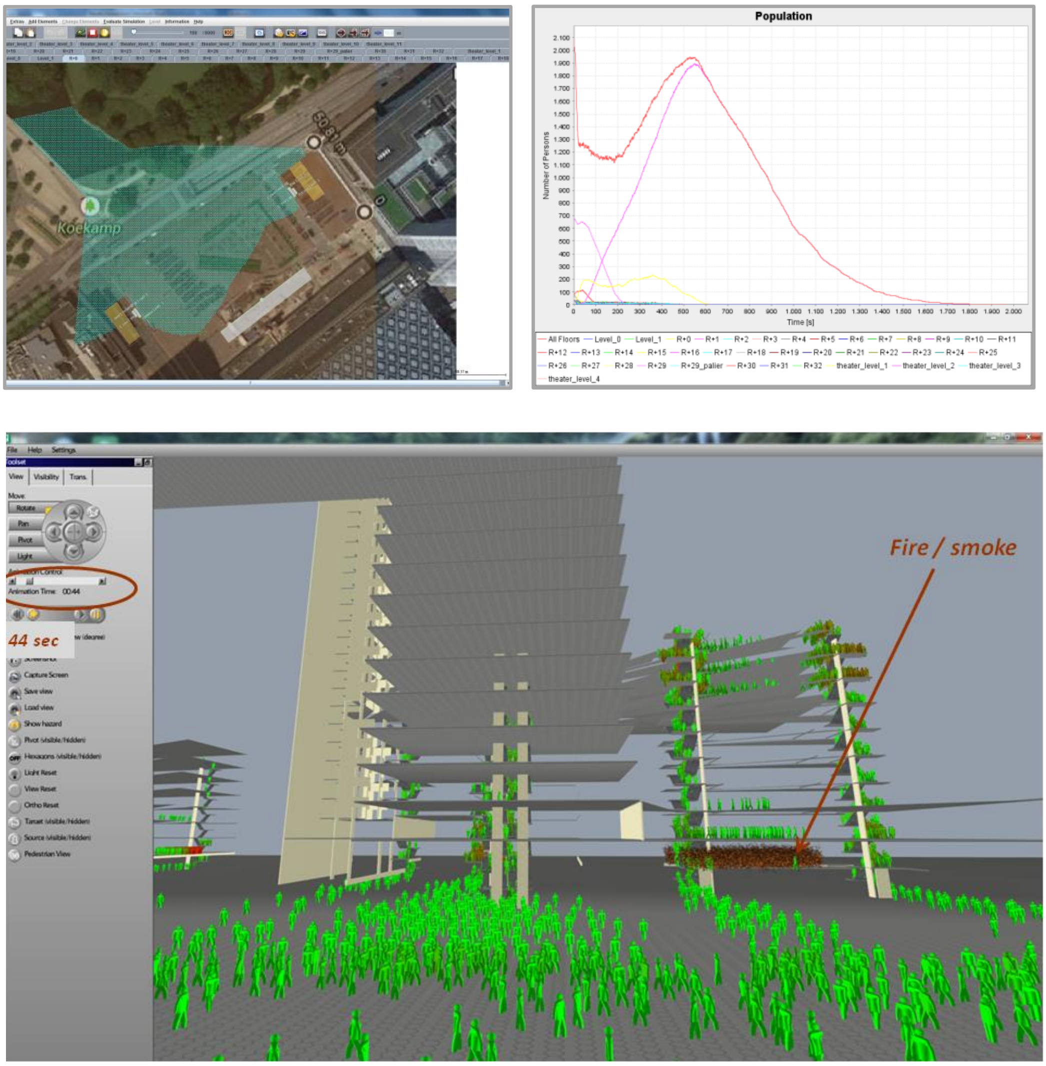

Figure 6: 2D and 3D post visualization for water and fire scenarios

Most of the pages contribute to the first and second part, the modelling and simulation of hazards and their corresponding simulation results. The third part, the sensor definition is an extension of the results of these first parts. An important link to the work package on multi criteria analysis (MCA) constitutes the last part on the employed data model for the BIM part of the BMS as well as the simulation of three different realistic hazard evacuation scenarios (see additional document). This data model will be used as an output format of the vBMS, particularly of the pedestrian stream simulation. Later on, MCA can be performed on the stored data.

This delivered report 3.5 is classified as “confidential” within the ELASSTIC *Grant Agreement* and *Description of work*. Therefore, the reduced version of the report shows only parts of the original deliverable. If there is a specific interest in the complete report, please contact:

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Disclaimer

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