Vulnerability Identification and Resilience Enhancements of Urban Environments

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Abstract

A steadily increasing number of the world's population is living in urban centres. The issue of security and citizen safety in densely populated areas is of paramount importance and a growing concern. In view of the growing sensitivity to terrorism and large scale accident scenarios, natural disasters and crime, urban planning practice must incorporate appropriate security measures for vulnerability identification and resilience enhancements.

In this paper the project VITRUV will be presented. The aim is the development of software tools for the consideration of extraordinary threats in the range of urban planning. For the long and complex development process of urban planning the tools moves across three levels from concept to plan and detail design, compatible with existing planning formats and software solutions. The qualitative or quantitative hazard and risk analysis of single buildings of infrastructure forms the basis. It consists of the analysis of events, scenarios, hazards, damage, frequency of event, exposure of personnel and risk including options for risk visualization and risk assessment. Based on an all hazard risk approach, the tools will enable planners,

- to make well-considered systematic qualitative decisions (concept level)
- to analyse the susceptibility of urban spaces with respect to new threats (plan level), and
- to perform vulnerability analysis of urban spaces by computing the likely damage on humans, buildings and traffic infrastructure (detail level).

The VITRUV project, funded by the European Commission under its FP7 Research & Technical Development Programme, is carried out by a consortium of 12 industry partners, public end-users and research institutions drawn from 8 European countries.

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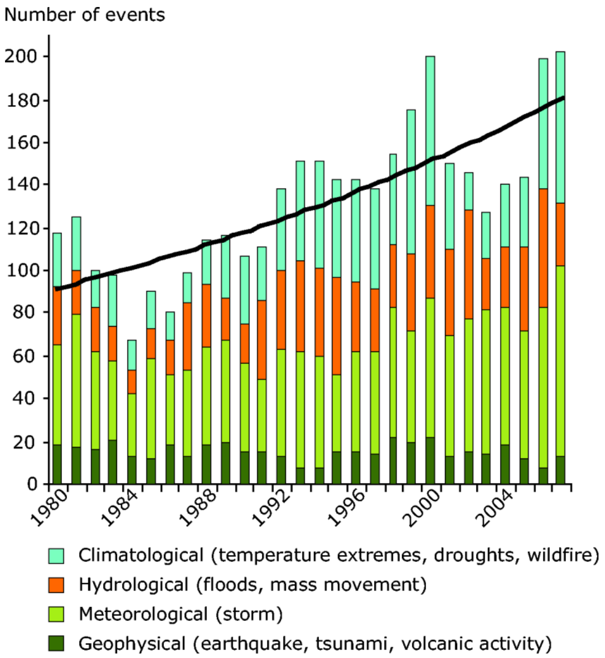
1 Introduction

Security aspects in urban planning processes are a topic with growing interest. There are several aspects which are emphasizes this trend: In relation to the world's population more and more people are living in urban areas. In 2008 first time more people lived in cities than in rural areas. In 2030 approximately 5 billion people will live in urban areas [1]. In Europe there are living 73% in cities. Furthermore it can be seen that there is a need to create security measures against new threats. New threats could be terrorism or the climate change, for example. Such unusual loading cases are mostly not considered on existing buildings.



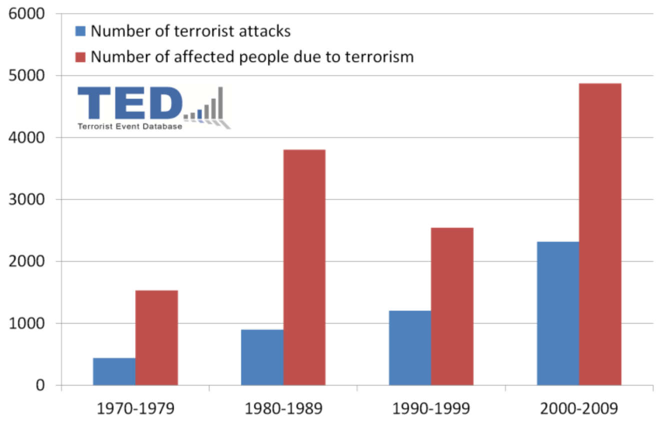


Figure 1: Number of natural disasters (left [2]) and number of terrorist attacks and consequences (right) over time for Western Europe.

Urban planners need support to make decisions concerning the aspects of security and safety planning. This decision support will be made with user-friendly software tools in the EU-project VITRUV [3]. All three stages (see Figure 2) will contribute to enable the development of more robust and resilient structures with respect to urban (re)planning, (re)design and/or (re)engineering. Planners who use VITRUV's tools will be able to deliver urban space less prone to and less affected by attacks and disasters, sustainably improving the security of citizens. Figure 2 gives an overview of the operational stages of urban planning and the connection of each level to the software tools of the VITRUV-project.

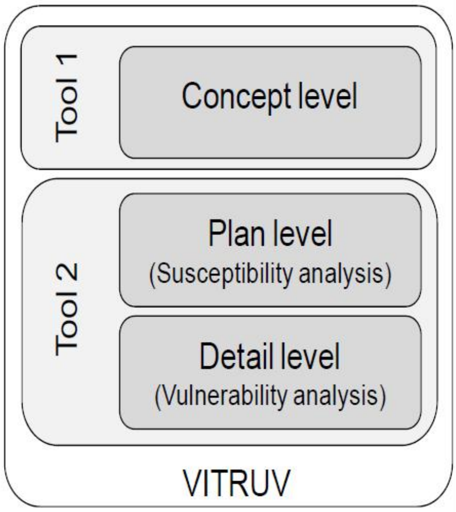
Concept	Strategic Conceptual Policies Qualitative		
Plan	Tactical Modeling Function Empirical		
Detail	Operational Design Details Quantitative		

Figure 2: Operational stages of urban planning (left) and tools overview of the VITRUV project (right).

This paper will present the scopes of the VITRUV project. Furthermore a short introduction in the different tools is given. The focus in this paper will be the presentation of the plan level tool.

2 Overview of the tools

This section gives a overview of the three stages of urban planning and the associated tools, which will be developed during the VITRUV project. The first two sections show the background of each tool for concept, plan and detail level and the last section presents the implementation and visualization of the tools. For plan level a simplified calculation example is given.

2.1 Concept level tool

The aim of the concept level tool is to provide easy-to-use, computer assisted support for urban planners in a systematic, qualitative way that will enable them to integrate security considerations into their plans from an early stage. Although the tools will specifically focus on the issue of security, it recognizes the fact that urban planners work in a holistic environment, i.e. that they have to consider a widely varied range of aspects and interests from a multitude of parties.

This is why the tool places its security information and advice within this context: it will not only further the knowledge of urban planners in security related issues, but will also place these in context with the other aspects of the urban planners' decision space, which will encompass among others the economic, social, ethical, safety and mobility dimensions.

The concept tool is composed of two inter-related components: the Knowledge Base (Securipedia) and the Risk Assessment (SecuRbAn). These components work closely together in supporting the urban planner: the risk assessment components guide the urban planner via a short questionnaire as quickly as possible to potential security issues that might by associated with his particular plan and refer to pages in the Securipedia where more information and advise can be found on these issues.

The SecuRbAn component is designed to provide the Urban Planner with the insight of the main security issues in a simple, intuitive and relatively time-efficient way. To this end, the urban planner is presented a series of questions about his or her project. Questions that are no longer relevant after previous answers have been given are skipped to prevent unnecessary input from the user. The assessment can be interrupted, saved and loaded at any time, which enables the user to get more information and continue his assessment at a later time. It also enables him to load previous assessments, edit only the changes and save it as a new assessment, thereby providing a very efficient way to assess several slightly different alternatives.

In the output of the SecuRbAn tool there are direct links to the Securipedia. Here these security issues are explained and more background information can be found about these issues and possible measures to mitigate the risk. Furthermore, the relations between the various aspects of urban planning and the security issue and its possible solutions are illuminated, such as the impact they can have on economy, mobility, social life, safety or ethics. The use of the two tools in the urban planning process and the interrelation of the two tools is graphically depicted in Figure 3.

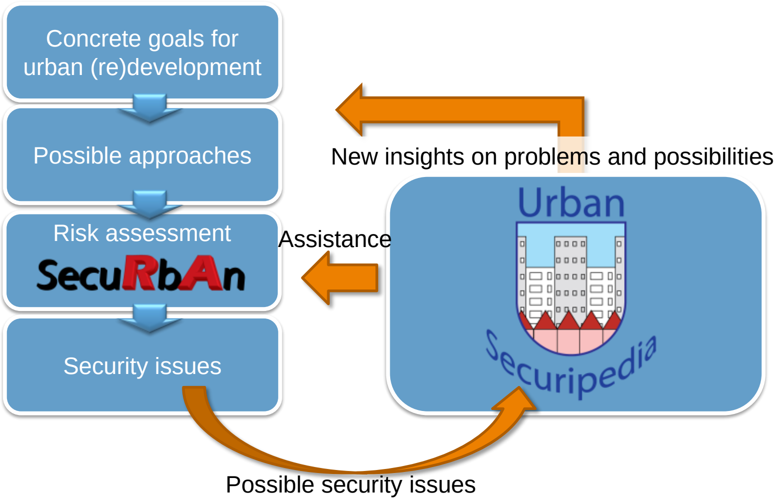


Figure 3: Overview of the concept level tool and the interaction between the two components.

2.2 Plan and detail level tool

On the plan level of an urban planning process a susceptibility analysis is carried out. This includes measures for frequency or probability of events based on specific infrastructure types, such as building, streets and public spaces. The susceptibility can be related to different quantities such as the frequency of (all/ selected) threat types for the considered building/ infrastructure types for example.

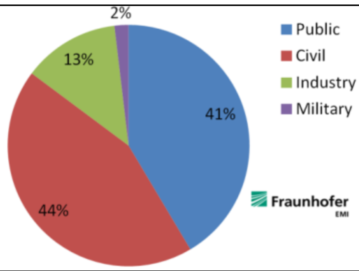
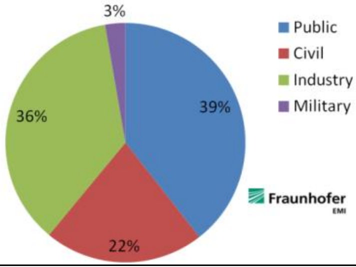
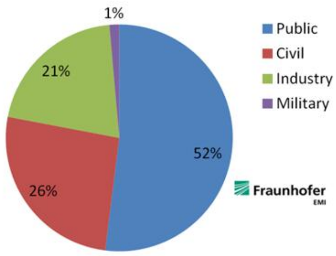
To calculate the empirical risk for items of an urban area the frequency of events must be determined. Currently general crime and terrorist attacks are considered in this project. Further threats, like environmental disasters for example could be considered in future. In this paper examples concerning terrorist attacks using explosives are presented.

To get empirical data of terrorist events the Fraunhofer EMI in-house database TED (Terrorist Event Database [4]) is used. The information of TED builds the calculation basis of the empirical risk assessment for urban areas concerning terrorism. The frequency and the extent of losses are the result of this analysis. Furthermore most common tactics (e.g. a car bomb) are also determined and the empirical values are assigned to the building use. A worldwide database analysis proved in a first extended analysis not to be representative for every country [5]. Major differences were found between types of areas, for example:

- Crisis areas (e.g. Near and Middle East),
- Industrial areas (e.g. Western Europe) or
- Emerging areas (e.g. Africa)

The differences become apparent in the frequency of attacks, the extent of losses, and the distribution to the target buildings. Table 1 highlights the major differences of the three above-named regions. As expected urban areas in Near and Middle East have a very high frequency and also result in large numbers of damage and losses. Cities in Western Europe have a medium number of attacks per year and the resulting extents of losses are very low. Table 1 shows furthermore the distribution of terrorist attacks on targets in the public, civil, industrial and military sector. The large number of attacks on housing estates in West Bank can be seen in the diagram of Near and Middle East. Hence the percentage in the civil range is much higher than for other regions on the world. The diagram of Western Europe is reflecting the results of a 1^{st} world industrial society. Therefore the proportion of target in the industrial sector is higher compared to other regions.

Table 1: Comparison of the empirical frequency, the extent of losses, and the distribution on the targets of terrorist attacks in urban areas for three exemplary regions.

<table>
<tr><th></th><th>Near and Middle East</th><th>Western Europe</th><th>Africa</th></tr>
<tr><td>Attacks per year</td><td>++</td><td>+</td><td>-</td></tr>
<tr><td>Casualties per attack</td><td>++</td><td>-</td><td>++</td></tr>
<tr><td></td><td>
</td><td>
</td><td>
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Beside a regional also a finer database analysis for subcategories of the four basis categories was carried out. An exemplary result of cities in Western Europe is shown in Figure 4. These diagrams show that most terrorist attacks in the public area are directed to agencies, ministries and embassies. Also targets of traffic sector (e.g. public transport terminal or underground) are more endangered. Decisive for industrial countries are also a lot of terrorist attacks directed to targets in the industrial sector. In the subcategories of this sector the numbers of attacks are roughly uniform distributed.

The empirical risk dependening on the target (e.g. embassy or public place) is the result of this analysis. Hence on plan level the new tool can be used to analyse which parts of a city are mostly endangered. A detection of hotspots and an optional subsequent consideration of safety and security measurements will be the benefits for urban planner when using the VITRUV tool on plan level.

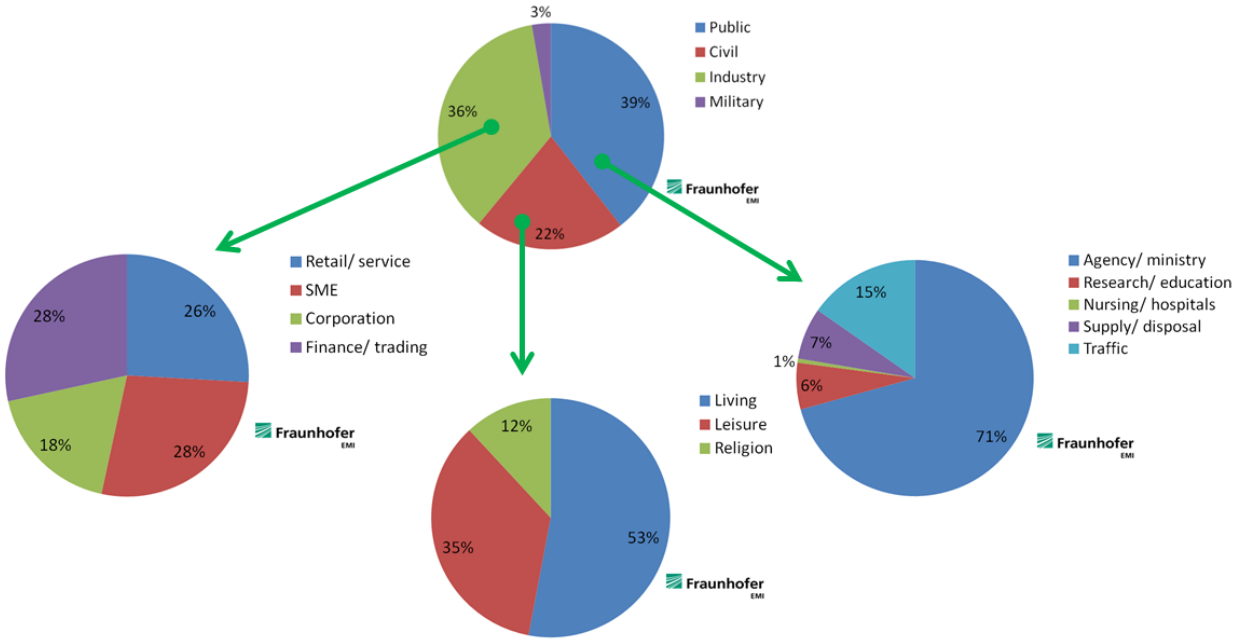

Figure 4: Target dependent distribution of terrorist attacks in European Urban areas.

In a next step the results of the database analysis are used to calculate the empirical risk of an urban object in dependency of the target, like a public place or an embassy, for example. Within the approach the classic definition of risk computation is used. Therefore the empirical risk R for a single building is defined as a product of the susceptibility of a target S and the consequence C.

$$R = S \cdot C \quad (1)$$

The susceptibility can be subdivided in the frequency F and the product of all scaling factors w. The latter are used to consider urban security or other factors, like a high crime rate or increased video or police surveillance which could increase or decrease the probability of an event. Therefore the scaling factors are used to produce more realistic results.

$$S = F \cdot w$$
$$w = \prod_{i=0}^{n} w_i \quad (2)$$

The concept and plan level includes results for the guidance concerning risk assessment and an analysis concerning the susceptibility of targets in an urban area. In a next step the detail level is used to examine what are the effects of the threats that are identified during the plan level analysis. This examination will be carried out with a vulnerability analysis.

After the empirical risk analysis in the plan level the detail level tool includes algorithms for a quantitative risk assessment. The vulnerability is a measure for consequences raised from possible events. The vulnerability can be related to the local measures of

- average physical hazard in case of an attack,
- average damage in case of an attack, and
- average risk.

The threats and the involved scenarios are determined during the plan level analysis. The consequences of considered threats can be calculated for persons and buildings. For the prediction of injury to humans simplified injury models are used. An example for consideration of blast induced injuries can be found in [6] or [7] depending on the pressure and the duration of loading. For the assessment of building damage, in a first step the response of structural members due to external loading is evaluated. The VITRUV tool has the criterion to be a fast running PC based application. Hence for the assessment of the structural response simplified engineering models are used. Single degree of freedom (SDOF) models are common practice to evaluate such nonlinear loading cases [8], [9], [10]. After the assessment of the initial failure the overall structural response of the building is evaluated with a progressive collapse analysis.

For this structural damage assessment more detailed information of the components are used, which are only available on detail level. Building costs and personal density are implemented to calculate lethality respectively structural damage and hence the derived risk for persons and buildings. The definition of the risk assessment on plan and detail level is precisely described and defined in [11].

These results are used for mapping the risks in a 3D visualisation of the urban area. In a next step security measures can be used to minimize the risk. The visualisation of plan and detail level occurs with a user-friendly Graphical User Interface (GUI) which is shown in the following section.

2.3 Implementation and visualization

In this section the implementation and the visualization of the VITRUV tools are presented. The concept level tool and the tool for plan and detail level are two separate but interlinked applications.

The Securipedia is built on the MediaWiki platform, which for example also support wikis like Wikipedia. Figure 5 shows an example of an information page from Securipedia . Because they use the same platform, the user interaction and functionalities of Wikipedia and Securipedia are very alike, or even the same. This means that functionalities that users are already familiar with, such as an index for fast page navigation, internal clickable links and the inclusion of media, are all available and working exactly as would be expected.

The SecuRbAn component is a window application. It runs stand-alone and for security reasons, will not send out any input information over the network. Entered information is stored locally, ensuring the security of the information is entirely manageable by the user. The application includes direct links to Securipedia. SecuRbAn guides the user through a questionnaire and at the end the tool will output potential security issues that are associated with the urban plan. The application is under development and the graphical layout of the component has not yet been designed.

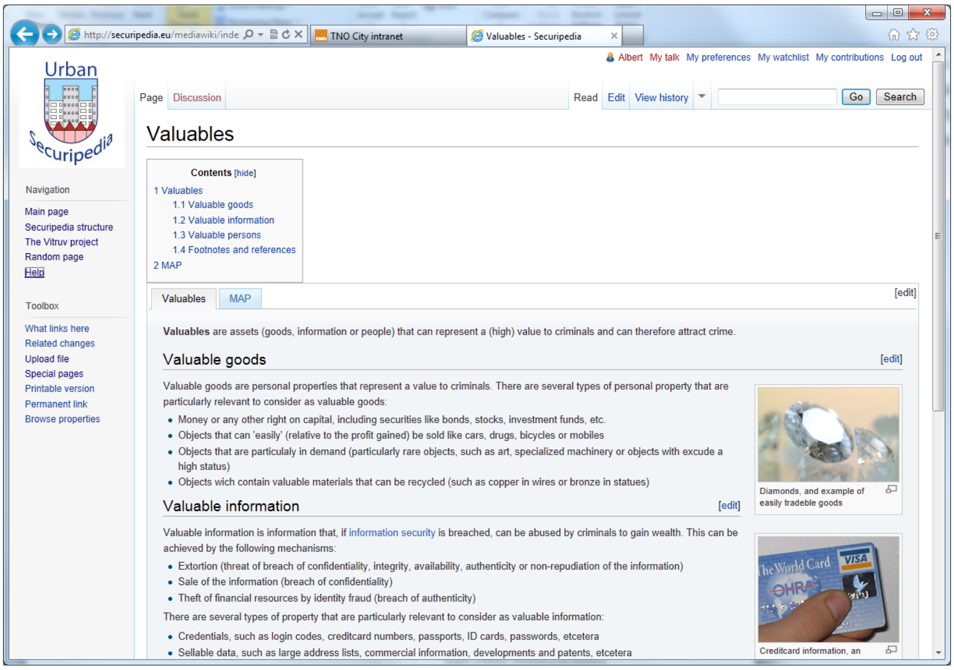

Figure 5: Example page from Securipedia.

Figure 6 shows the window application of the VITRUV tool for plan and detail level. The upper part of this Graphical User Interface (GUI) includes three tabs to switch between concept, plan and detail level. On concept level exists a button to start over a link the separate concept level tool.

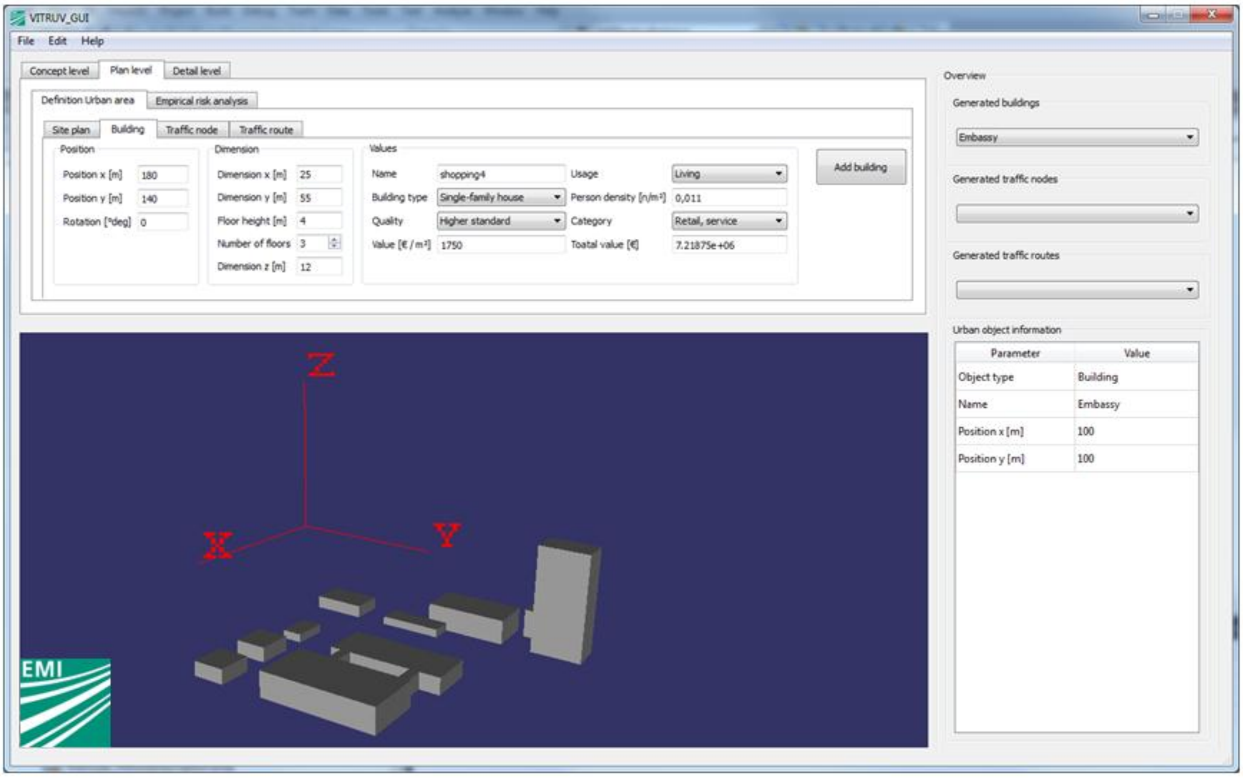

Figure 6: Window application of the VITRUV tool for plan and detail level.

Figure 7 shows the results of a calculation example of the plan and detail level visualisation. In this fictitious urban area several buildings was defined. The urban objects differ by physical parameter like the position and the dimension but also by the building use which is essential for the empirical risk analysis. In this example the empirical data of Western Europe was used. The left picture of Figure 7 shows the susceptibility in the form of attacks per year. The results showing that the embassy got the highest susceptibility. Also the university and the office tower are attributed to higher empirical values. The consequences showing the sum of fatalities and injuries per attack and are illustrated in the mid picture of Figure 7. Here the different protection level of the different building types and uses becomes apparent. Finally the right picture of Figure 7 displays the visualization of the empirical risk defined by equation (1) as the product of susceptibility and the consequences. The result shows that the embassy got the highest risk and the hotel the lowest. Comparing the susceptibility and the risk for the embassy highlights the effect of increased protection measures. In a further step the consideration of scaling factors could represent security measures (e.g. surveillance staff or CCTV monitoring) to decrease the risk value for the embassy.

Figure 7: Visualization of a calculation example. Susceptibility (left), consequences (middle), and empirical risk (right) for a building configuration.

3 Conclusions

In this paper the aims and the contents of the EU-project VITRUV are presented. This project starts in May 2011 and will be finished in May 2014. During this project different risk assessment tools for urban planners are developed. The development of the software allows an identification, detailed analysis and resilience enhancement of "weak points" in urban areas. The tools can be used for planning and (re)design of urban areas to make them less prone for and less affected by terrorist attacks and crime.

The aim of each tool following each level of a urban planning process was presented. For concept level tool knowledge base Securipedia and the risk assessment tool SecuRbAn were shown. Currently the content of the database for Securipedia is being built. On plan level an empirical risk analysis was carried out to get a basis for risk assessment. This paper showed some results of the event analysis and how these data are used to calculate the risk for urban objects. The last part of this paper has shown the implementation of the tools for concept, plan, and detail level. A small calculation example gives an introduction in the user-friendly tool and the easy handling of the results with a 3D visualization.

Acknowledgements

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