テロリズムに対する脆弱性の空間分析 ― 東京都都心を事例として
Spatial Analysis of Terrorism Vulnerability: A Case Study of Tokyo, Japan

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(1) Motivation: A lot of research has been performed on the topic of terrorism risk assessment from financial, sociological, and also spatial perspectives. Yet, risk-based terrorism analysis revealed several shortcomings, such as a lack of spatially explicit data of past events. Also, risk-based analysis can only elaborate reactively on events that have either occurred in the real world in the past, or are the outcome of simulated models.

(2) Originality: This fact can be ameliorated by employing a proactive bottom-up approach based on vulnerability instead of risk. While the latter is the active aspect of any threat, the former can be perceived as a passive attribute of the objects or people at risk. Hence vulnerability analysis focuses on the geography instead of the event. Thereby spatial terrorism vulnerability analysis can be understood as a methodology to evaluate possible targets on a micro scale, in the case of this research on building level within a study area in the Tokyo metropolitan area. We postulate that vulnerability is not distributed equally in space and attributes of objects can be identified that affect their vulnerability, both positively and negatively.

(3) Approach: In our research framework vulnerability is based on two components: *susceptibility*, i.e. factors and attributes that make an asset more or less susceptible to become the target of a terrorist attack, and *disutility*, which describes the value (worth) of the consequences a successful attack has to the stakeholders. This paper focuses exclusively on the susceptibility component.

As a first step, factors were identified that contribute to the susceptibility of buildings to terrorist attacks. The number of people in a building, its usage, the volume of public traffic both inside and outside, the existence of (public) underground parking garages, as well as the percentage of window area, and the symbolic value can make one building more attractive to an attack than others. Therefore, as a next step, these factors were operationalized and transformed to normalized nominal scales to be used in a numeric analysis framework.

Our analysis focuses on the effect that the susceptibility factors have on the object's surroundings, i.e. their *spatial influence* (SI). Generally we were using two types of operationalization for this spatial influence, one being *spatial proximity* to account for the fact that each object affects the space surrounding itself by its attributes, the other one being *spatial concentration* (Fig. 1) to identify hotspots, i.e. spatial agglomerations of similar attributes.

(4) Results: For each of those susceptibility factors, factor maps were generated, which were then combined into an overall susceptibility map (Fig. 2) using map algebra (i.e. raster combinations). In this process it is also possible to assign different weights to the single factor maps to raise or lower the importance of the corresponding factor. Once this is done, vulnerability maps for all attack scenarios of interest can be calculated and, together with a terrorism disutility map, combined into one micro-scale multi-threat terrorism vulnerability map. This map can be useful both to raise awareness for and easily communicate the concept of terrorism vulnerability to the public, and to assist stakeholders (e.g. police, government, city planners, building owners) in identifying areas that are in need of action towards mitigation against becoming target of a terrorist attack.

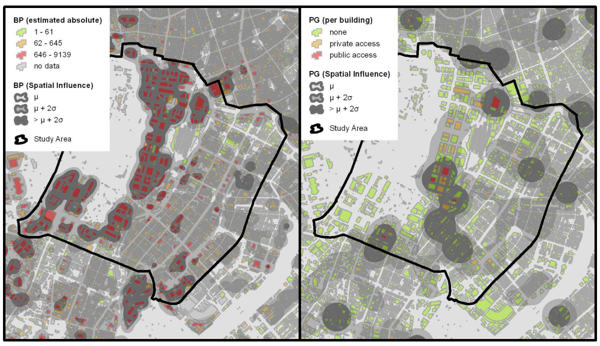

Fig. 1 - Susceptibility factor maps for "building population" (BP; left) and "parking garage" (PG; right). The kernel density distribution has a bandwidth of 150m (BP) and 250m (PG). The output raster cell size is 1m.

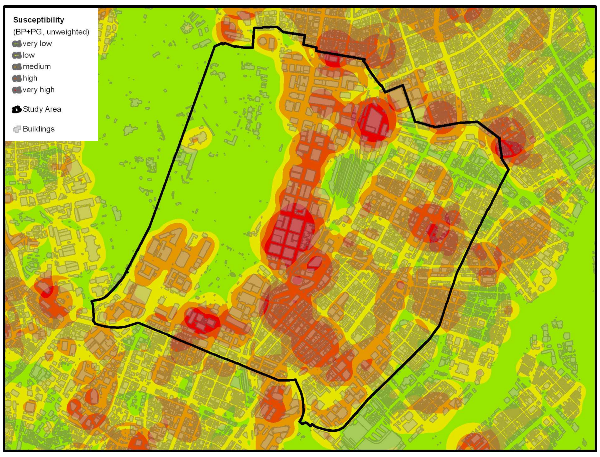

Fig. 2 - Combined unweighted susceptibility map of the two susceptibility factors shown in Fig. 1 (BP + PG)