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

コンスタンティン・グレーガー

Spatial Analysis of Terrorism Vulnerability: A Case Study of Tokyo, Japan

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Abstract: In this paper we present a spatial framework for the analysis of terrorism vulnerability. We outline the benefits that vulnerability-based analysis has over the more traditional risk-based approach and explain our conceptual understanding of vulnerability and its two components: susceptibility and disutility. To provide an overview of the steps within the susceptibility research framework, we describe the selection of appropriate factors, introduce the concept of "spatial influence" of object attributes and explain the process of creating (weighted) factor maps and ultimately a vulnerability map. We then go on to demonstrate the use of our framework in the context of a case study for an urban area in Tokyo, Japan, before ending the paper with a summary of the findings the framework provided and its usefulness.

Keywords: テロリズム（terrorism）, 脆弱性（vulnerability）, 空間的な分析（spatial analysis）, 東京都（Tokyo）

1. Introduction

Looking at risk from a quantitative point of view inevitably brings to focus the risk triplet, formulated by Kaplan and Garrick (1981) as long as 30 years ago. It asks three elementary questions:

1. *What can go wrong?*
2. *How likely is it to go wrong?*
3. *What are the consequences if it does go wrong?*

For the case of terrorism this definition requires some adjustments to be able to give a good representation of the real-world processes involved. Firstly, the scenarios should rather be defined by the question *"What can be made to go wrong?"* in order to incorporate the malevolent aspect, which is intrinsic to all terrorist attacks, and distinguishes the terrorism threat from natural hazards and man-made disasters.

Secondly, occurrence probabilities cannot be given for terrorist attacks without introducing a considerable level of uncertainty. Hence it makes sense to look at the *susceptibility* of the assets of interest towards terrorism, instead. The degree of susceptibility of an asset for becoming an attack target depends on the attack scenario under evaluation and multiple factors, which can be perceived and represented as attributes of the objects under consideration.

Lastly, the consequences have to be understood as the *disutility* a terrorist attack on a certain asset causes. This disutility can be manifold: death and injuries; property damage; or business interruption, amongst others. Another way to enunciate this is to evaluate the value an asset has for a certain stakeholder (e.g. monetary interests, symbolical meaning, etc.). Those values can be assessed using a value tree and can also

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be represented as attributes of the study objects.

The two components of disutility and susceptibility combined represent what can be understood as the *vulnerability* to a certain risk scenario. Both have to be determined for every object of interest. This introduces the need to define a spatial scale that the vulnerability analysis will be performed on. It can range from macro scale, such as the global (Kennedy et al. 2012) or national level (Piegorsch et al. 2007), to micro scale, examining cities or neighborhoods within urban areas (Caplan & Kennedy 2010).

As outlined above, the probability of a terrorist attack occurring cannot be determined with sufficient certainty. Hence, as Caplan and Kennedy stated in the context of crime risk, "[t]he unit of analysis is the geography, not the event." (Caplan & Kennedy 2010) In an urban environment, such as the case study presented in this paper, a micro scale analysis on the level of buildings and infrastructural elements (e.g. roads, railroad lines, electricity networks, water or gas pipes, etc.) is indicated. This paper focuses on the susceptibility component of buildings only.

2. Research Framework

2.1 Susceptibility Factors

As a first step, we identified factors that contribute to the susceptibility of buildings to terrorist attacks, both positively and negatively. The selection of appropriate factors is crucial and will determine the meaningfulness of the assessment (Caplan & Kennedy 2010).

These susceptibility factors were then operationalized to map the abstract factors to concrete real-world features (attributes) of the objects under analysis. In order to use those attributes in a numerical analysis framework they needed to be transformed to normalized nominal or dichotomic scales.

2.2 Spatial Influence

Our analysis focuses on the effect that the susceptibility factors have not only on the objects themselves, but rather on their surroundings, i.e. the space they define and which they exist in. We are employing the concept of *spatial influence*, which has been coined by Caplan and Kennedy (2010) based on the theory of *environmental backcloths*, introduced by Brantingham and Brantingham (1981).

We have been using two types of operationalization for this spatial influence. The first, *spatial proximity*, accounts for the fact that objects affect the space immediately surrounding them within a certain radius by their attributes. The other one, *spatial concentration*, allows to identify spatial agglomerations of objects with identical or similar attributes.

2.3 Mapping Process

Next, we generated separate factor maps for each of the susceptibility factors, which show the spatial influence of the respective factor as a continuous raster surface. Those maps can then be combined into an overall susceptibility map 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 towards the overall susceptibility assessment.

Our analysis framework is geared towards a multi-scenario analysis, in order to provide an overall view on the terrorism vulnerability of the respective study area. As the susceptibility of a certain possible target object varies for different attack scenarios, the susceptibility analysis has to be performed separately for each scenario of interest, which results in multiple susceptibility maps. Those maps can then be combined into a multi-threat susceptibility map using the same map algebra methodology as before. This again allows to assign weights to the individual scenarios, to tailor the analysis towards an estimated threat potential. In this paper we performed the analysis only for the scenario of an attack using explosives.

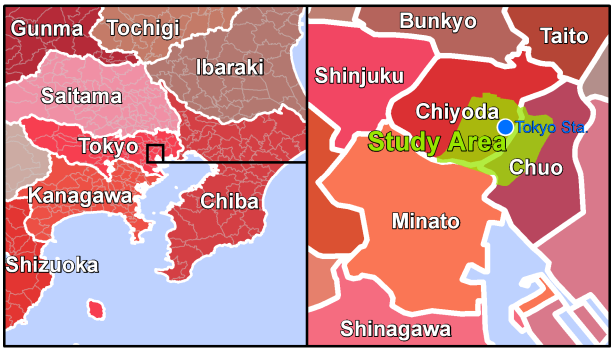

Fig. 1 - Study area in Tokyo, Japan

3. Case Study of Tokyo, Japan

3.1 Study Area

The study area for this case study (Fig. 1) comprises an area of roughly 6 km^2 around Tokyo Station. It contains more than 6,500 buildings and is characterized by diverse land uses (e.g. residential, office, commercial, etc.), building types (e.g. high rise office towers and smaller buildings) and building densities. It furthermore contains several landmarks and critical infrastructures (e.g. Tokyo Station, Tokyo Stock Exchange and several governmental buildings).

3.2 Susceptibility Factors

One of the foremost intentions of most terrorists is to affect a maximum number of people with a single attack. Therefore highly populated places have a higher inherent susceptibility of becoming the target of an attack. Hence we operationalized the susceptibility factor "populated place" by the number of people inside each building. We approximated the building population (BP) using an algorithm introduced by Lwin and Murayama (2009), which allowed us to determine the "fixed population" (i.e. residents or employees). It was then transformed to a nominal scale using the standard deviations from the mean, e.g. $>+2\sigma$ became "very high" (Fig. 2 left).

Second, we were interested in the amount of public traffic (PT) within the buildings, as this will not only determine if it is possible for a perpetrator to enter the targeted object at all, but also how easy it is to "blend in" without his malevolent intentions being recognizable. We created a nominal scale of the amount of publicly accessible features (e.g. shops, restaurants, e.g.) within each building, ranging from "very high" to "none", based on the total number of such features, and an additional category "off-limits" for buildings which are not accessible by the public. While this is a rough approximation, it allows not only for the identification of public traffic, but can also represent a building's "temporary population", i.e. customers.

An underground parking garage (PG) is the easiest way to physically introduce large amounts of explosives into a building. Hence, we were interested in the existence of parking garages and the mode of access. As a result we created a nominal scale of "none", "limited access", and "public access" (Fig. 2 right).

While a detailed analysis of the buildings' engineering features would provide a greater insight into the structural susceptibility towards an attack, this falls outside the focus of our research. It can also not be assumed, in contrary to all other factors used in this case study, that such information is readily available to the perpetrators. Hence we were interested in easily visible building envelope features, more precisely the amount of fenestration (BF). In accordance with screening methodologies by the FEMA (2003) we applied a five step nominal scale.

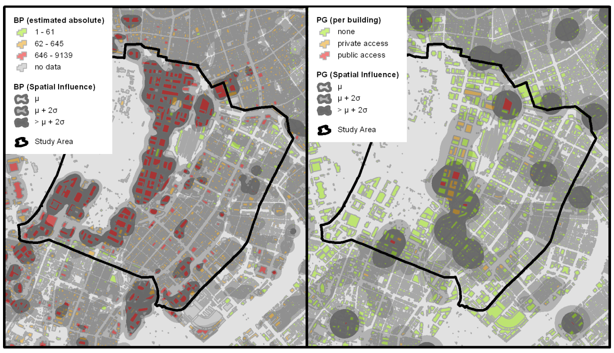

Fig. 2 - Susceptibility factor maps for "building population" (BP; left) and "parking garage" (PG; right)

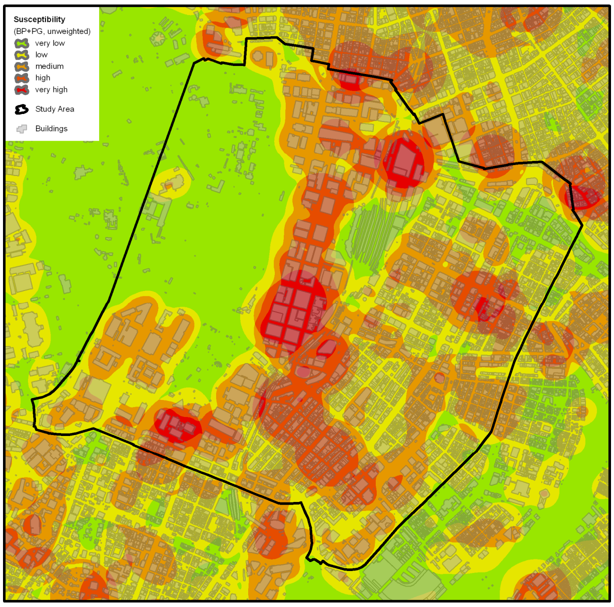

Fig. 3 - Combined unweighted susceptibility map of two susceptibility factors (BP + PG)

Lastly, terrorists are not only interested in creating maximum damage or injuring a large number of people, but they will always want to make sure their deeds attract maximum attention of the intended audience (Savitch and Ardashev 2001). Therefore we were interested in the locations of buildings which have a certain symbolic value (SV), which we represented as a dichotomic "yes"/"no" scale.

We then created the factor maps by evaluating the spatial agglomeration of each susceptibility factor using kernel density distributions. Figure 3 shows the unweighted combination of two susceptibility factors (BP+PG) into a terrorism susceptibility map.

4. Summary

The steps outlined in this paper are part of a greater, overall spatial terrorism vulnerability analysis framework. Here we provided a short overview of the general analysis approach and applied the framework on a case study in Tokyo, Japan.

The maps created in the course of the single processes within our analysis framework 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.

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