

Spatio-Temporal Analysis of Terrorism Vulnerability: A Case Study of Central Tokyo, Japan

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Abstract

Terrorism has become and continues to be one of the biggest threats of our time. Large-scale attacks like 1995 in Tokyo, 2001 in New York City, Washington DC, and Pennsylvania, 2004 in Madrid, and 2005 in London are tragic proofs that this is especially true for highly urbanized areas all over the world. The more prevalent such terrorist attacks happen the more scientific papers are written about them. Yet, this increased number of scientific engagement has not lead to more detailed insights into the underpinnings of terrorism. Instead there are many complaints in the terrorism research community about a lack of quantitative data to corroborate the theories made by scholars from various engaged disciplines like the political sciences, psychology, peace and conflict studies, economy, engineering, urban planning, and also geography.

In this study I introduce methodologies for the spatio-temporal micro-scale analysis of terrorism vulnerability in highly urbanized areas to help overcome this limitation. The underlying conceptual framework is based on the selection of appropriate vulnerability factors, their operationalization in measurable real-world phenomena, the calculation of their spatial influence, and finally their weighted combination into an overall vulnerability index. I also present an exemplar application of this framework in a case study for an actual scenario in Tokyo, Japan. Furthermore I provide an interpretation of the empirical results of the case study, and finally discuss the usefulness of the framework and its operationalization as well as opportunities for possible further studies.

The Human Activity Based Vulnerability Concept I developed is based on the activities of people and how these shape the environment into places of different value to them. I argue that these values are what generates disasters from the threats to these places. This concept represents the theoretical foundation for the analysis framework, which consists of a number of components: multiple sources of “hard”, quantitative data, carefully selected vulnerability factors, the factors’ spatial influence, an important concept that allows for the analysis of the impact an object’s vulnerability has on its surroundings, and finally the factors’ weights among themselves.

In a case study for the central part of Tokyo, Japan, the Special 23 Wards, I show the application of the aforementioned framework in a real-world example. The vulnerability factors I employed in this case study are the stationary building population, the pedestrian volumes on the streets, the passenger volumes of train stations and trains, and the symbolic value of places. I used a number of micro-scale datasets to operationalize these vulnerability factors, among them population, employment, and school census data, train passenger volumes, building data, and

data of the road and railway networks of the study area. Furthermore, the inclusion of a micro-scale dataset of people's movements in 1-minute intervals allowed me to enrich the analysis by the introduction of the temporal dimension. In the course of the study I developed a number of novel methodologies for the quantification of vulnerability. These involve the spatio-temporal categorical estimation of building populations, the use of network analysis methods for the estimation of pedestrian flows, and the operationalization of the objects' spatial influence using kernel density estimation and a linear function of the weighted inverse distance.

To my best knowledge this is the first time that such an approach has been developed. It combines traditional terrorism research with a bottom-up vulnerability-based focus using spatially grounded analytic tools. The output of the model introduced here are micro-scale maps of the spatial distribution and agglomeration of vulnerability in highly urbanized areas. These can help with communicating the abstract concept of vulnerability to the broad public, and also provide the hitherto missing quantitative data about vulnerability, which can help governments, municipalities and other involved stakeholders in making educated decisions about the use of limited fundings for the mitigation of vulnerability and other counterterrorism measure.

The interpretation of the case study's empirical results revealed several interesting insights into the connection between the urban spatial structure of Central Tokyo and its terrorism vulnerability and the spatio-temporal constraints involved. First and foremost the commuting movements from the suburban belt into the city center lead to a dramatically higher overall day-time population. This results in larger areas of higher vulnerability during the day than at night. Over the course of the day clusters of highest vulnerability develop in areas with many large office buildings. Second, the concentrated morning commuting period has a strong impact on the vulnerability levels surrounding the railway transportation network. This effect together with the generally high building populations and pedestrian volumes around larger train station hubs create the overall highest vulnerability index values. Furthermore, the monocentric urban spatial structure of Tokyo manifests itself in the agglomeration of most of the places with high symbolic relevance on the one hand, and most of the office districts with high daytime populations on the other hand. Based on these observations the conclusions can be made that from a terrorist's perspective the most attractive location for an attack would be in the city center, preferably inside or near a major train station or near railway tracks. The most attractive time would be during the day, preferably the morning commute.

Keywords: GIS, micro-scale, spatial analysis, terrorism, Tokyo, urban areas, vulnerability

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