CHAPTER 16

GEOGRAPHIC APPROACHES IN THE STUDY OF TERRORISM

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Overview

Over the course of four days in November 2008, ten Pakistani men associated with the terrorist group Lashkar-e-Taiba carried out attacks in Mumbai, killing 164 people and injuring more than 200 others. The group used automatic weapons and grenades and targeted several highly populated areas, including hotels, a railway station, and a movie theater.[1] In the course of their investigation, Mumbai authorities found that the attackers used satellite maps from the public domain to plan the attacks and escape routes.[2] Far from indiscriminate, these attacks were planned using geographical data to inflict the maximum amount of casualties and provide the best chance of escape. What can this case and other similar events demonstrate about the relationship between geography and terrorism? Further, given the prevalence of increasingly precise geographical data, how can researchers leverage knowledge about geographical factors to better understand, predict, and prevent terrorism?

The widespread popularity of geographic information systems (GIS) in international relations research (see Gleditsch and Ward 2001; Starr 2002) has by no means bypassed the subfield of terrorism studies. Especially since 2000, there has been a wave of research taking advantage of new GIS techniques and enhanced computing power that seeks to identify trends in terrorism, with units of analysis ranging from individual streets (Kwan and Lee 2005) all the way up to cross-national studies (Findley and Young 2012b). In several instances, this research cuts across fields to include geography, criminal justice, and international relations. The precision of GIS data and its ability to provide finer-grain measurements of often used characteristics in terrorism research such as

population, ethnicity, and economic resources open up new possibilities in the field of terrorism research.

This chapter provides an overview of the extant literature, explains the most widely used GIS techniques in the field, discusses how different research questions are best answered using specific techniques and units of analysis, explores areas of further research, and then closes with a brief discussion of the technical requirements for carrying out GIS research. While we do provide a thorough overview of the state of GIS terrorism research, we spend the majority of the chapter covering the technical and conceptual details of GIS and then exploring new avenues of research that we believe provide exciting opportunities to formulate and test hypotheses from theories of political violence and terrorism.

Extant Literature

Terrorism research that utilizes GIS data and methods can largely be divided into two types: (1) small N, country- or even city-specific studies that attempt to identify micro-level trends of terrorism attacks, and (2) large N, cross-national studies that seek to find commonalities in attacks across time and space. Although not a perfect match, this divide often mirrors the larger debate amongst comparative and international relations scholars regarding the utility of small N versus large N studies. We do not purport to provide an exhaustive examination of all studies that fit into one of these two broad categories, but use the following literature to demonstrate this conceptual divide and analyze the strengths and weaknesses of each approach.

Country-Specific Studies

The first major type of terrorism research that uses GIS data employs subnational units of analysis. That is to say, the researchers are looking at city-level, district-level, or departmental-level trends within a single country. These studies leverage the precision of GIS data to analyze patterns in terrorist attacks across time and space at the micro level, meaning trends of terrorism within a single state, district, or even city.

Since 2003, Iraq and Afghanistan have received disproportionate attention from scholars. The presence of US troops and sectarian cleavages have provided both the motive and the opportunity for a large number of terrorist attacks since 2003. Occupation has also meant, however, that because of the desire of US policy-makers to have reliable insurgency data, the reporting of terrorist events is much more widespread and well-documented than may be the case in other situations. A number of studies (Braithwaite and Johnson 2012; Johnson and Braithwaite 2009; Townsley et al. 2008; Medina et al. 2011) have examined the spatio-temporal patterns of insurgent attacks in Iraq since 2003.

Braithwaite and Johnson (2012) examine the variation from January 1, 2005 to June 30, 2005 in improvised explosive devices (IEDs) set by insurgent forces and their relationship with coalition counter-insurgency activity. They divide Iraq into 5 km × 5 km grids and code attacks by week, giving them a unit of analysis of a grid-week. Their findings include a clear spatio-temporal clustering of IED events and statistical evidence that IEDs do not tend to follow recent coalition activity. Similarly Medina et al. (2011) utilize GIS data from January 2004 to December 2009 and find that terrorist events are more likely to occur in highly populated areas but that their frequency and intensity vary widely over time. They also identify several social, political, and cultural triggers that affect the incidence of terrorist attacks, including the celebration of Islamic holy days. Though they focus only on the Iraqi case, Medina et al. argue that policy-makers can use the trends identified in their study to help combat terrorism and insurgency in other states such as Yemen and Somalia, where branches of Al Qaeda carry out terrorist attacks. They contend that Yemen and Somalia are similar enough cases to have their findings be relevant but do not go so far as to say that the trends are similar in other regions or with other terrorist groups.

Researchers have leveraged GIS data to examine terrorism in other states, as well. Given events within the United States in the past twenty years, such as 9/11 or the Oklahoma City bombing, it is unsurprising that several studies (Cothren et al. 2008; Webb and Cutter 2009; Nunn 2007) have looked at terrorism trends on American soil. Webb and Cutter (2009) and Nunn (2007) investigate spatio-temporal factors of terrorist attacks in the United States while Cothren uses geographical data to look for patterns in the *preparation* for terrorist attacks. These articles largely find that terrorism attacks cluster in geographically populated areas but that the means and targets vary according to the type of group (i.e. religious, right-wing, environmental extremists, etc.) carrying out the attack. Israel and Spain, two other states with histories of domestic terrorism, have also been the focus of research using GIS research. In the case of Israel, Berrebi and Lakdawalla (2007) use geocoded data ranging from 1949 to 2004 to examine the characteristics of the location of terrorist attacks, such as distance from international borders, proximity to centers of government administration, and ethnic homogeneity. Also studying Israel, Kliot (2006) focuses specifically on suicide terrorism and, like Berrebi and Lakdawalla, zeroes in on the importance of geography and the location of terrorist attacks relative to other important factors, such as Israeli checkpoints. Lastly, LaFree et al. examine spatio-temporal patterns of ETA terrorist attacks in Spain from 1970 to 2007 (LaFree et al. 2012). They draw from the Global Terrorism Database (GTD) and using the geographical information from the database are able to look at trends as local as district-level.

This discussion does not provide an exhaustive list of every study that uses GIS to examine terrorism trends within a single state, but instead highlights a few illustrative cases. One takeaway from these studies is that their unit of analysis is, at its largest, a state. They focus on a singular case and although some mention the possibility of drawing general lessons to be applied to terrorism studies as a whole, they typically maintain that the trends examined pertain only to their specific spatio-temporal instance. Scholars in

this tradition tend to ask more focused questions, such how does a new cellphone tower lead to future terrorist attacks (Shapiro and Weidmann, 2015). By contrast, a more general question, which is more difficult to isolate a direct causal effect for a particular variable, might be: how do changes in technology lead to increases in terrorist attacks? Scholars are interested in both questions, but the first is more amenable to a clean test that can identify a causal effect. These types of studies might also have more direct albeit limited policy implications.

Cross-National Studies

Beyond more focused, local studies, GIS research on terrorism seeks to use the specificity of spatial data to parse out broader trends that transcend borders. This tool can be used to examine attacks across borders including those that cluster along borders, which was impossible in early studies of conflict. Providing more precise geographic information allows, for example, for examinations of such factors as whether a militarized dispute at a border has the same effect as the same dispute internally or at sea.

A major focus of study within this vein of research is the search for the *typical* or *average* terror venue. Part of the goal of much of this research is an attempt to identify similarities in the location of terrorist attacks across countries and across time to provide better explanation and prediction of the locations for this violence. Although the authors do not employ GIS, a good example of this is the Drakos and Gofas (2006) study of terrorist attacks from 1985–98 in which they find several factors that contribute to attacks, namely low economic openness and high levels of international disputes. They also provide evidence of a regional component, meaning that terrorism seems to have a learning or diffusion quality. That is, within regions groups may learn from each other and the tactics may be adopted by socially or geographically proximate organizations. Tracking the movement of minority groups specifically, Arva and Piazza (2016) find the transnational dispersion of kin minority communities to be a robust predictor of terrorism incidents.

Using geo-referenced data from the Global Terrorism Database (GTD) and geolocated data for civil war zones, Findley and Young (2012b) find that terrorism often occurs in the context of civil war. Additionally, they show there is a strong relationship between civil conflict and terrorism, namely that terrorism is most prevalent *during* war. In their examination of six countries they find that in the post-Cold War period, post-war terrorism attacks are more likely than pre-conflict attacks, lending support for previous arguments for terrorism as a tool of spoiling the peace (Kydd and Walter 2002; Findley and Young 2015), though not necessarily for outbidding (Findley and Young 2012a).

Zeroing in on the spatial dimension, Nemeth et al. (2014) set out to identify terrorist *hotspots*, meaning areas in the world that are more prone to experiencing attacks. The authors merged a geocoded GTD dataset onto the PRIO-GRID[3] cell structure and use a hotspot analysis to see which areas are most likely to suffer from domestic terrorism.

Beyond hotspots for terrorist attacks, GIS can be further utilized to identify movement of the terrorist actors themselves. For example, Eisman et al. (2017) use geographically weighted regressions to highlight the areas most attractive to terrorists as a safe haven. From these safe havens, over one-third of attackers live and planned their activity within 30 miles of the attack location (Smith et al. 2017).

Including a temporal dimension alongside the spatial dimension, Kluch and Vauz (2016) use data on all attacks from 1970 to 2013 to analyze the levels of terrorism within over 200 countries. They find the majority of countries experience no or low-level spans of terrorism that last over long periods of time. Very few countries ever experience "elevated," long-term campaigns.

In line with much of the research just described, Nemeth et al. show that large populations and poor economic conditions make terrorism more likely, but they also show that mountainous terrain, proximity to a national capital, and population density also affect the likelihood of terrorism. The work of Findley et al. (2018) corroborates these findings. Findley and his coauthors use the ITERATE (International Terrorism: Attributes of Terrorist Events) dataset along with the PRIO-GRID dataset to show that transnational terror attacks are most likely to occur in areas of recent civil violence, locations close to capital cities and international borders, regions with low forest cover but mountainous terrain, and centers with higher populations and population densities. In sum, the cross-national GIS studies of terrorism have established a consensus that, worldwide, the areas most likely to experience terrorist attacks are heavily populated areas close to country capitals or international borders, war-affected, poor economic development, and mountainous terrain.

Both domestic and transnational terrorism and the diffusion therein are being analyzed using these tools, yet much work is left to do. Does domestic terrorism encourage transnational attacks? Is the reverse true? Do domestic attacks in border areas have a more profound effect than those in the capital or far from borders? These questions have clear policy implications and are far from resolved in the academic community. While we do not suggest this is the only tool to address such questions, GIS is a powerful instrument for addressing these and related questions.

Additional Applications of Geography in Terrorism Research

Much of the geographic study of terrorism fits into the two major categories described, but it bears mentioning that there are other ways in which the broader field has considered the relationship of geography and terrorism. By mapping data GTD to the subnational level, Findley and Young (2015) are able to evaluate the empirical evidence for spoiling logic in peace negotiations during civil wars. Geocoding the data within battle zones allows them to more accurately differentiate between terrorism violence and military and government violence that are a regular part of civil war.

These lines of study tap into an ongoing question in the civil conflict literature. Is terrorism different than other types of violence carried out by entities such as rebel groups,

militias, or gangs? Scholars have begun to tackle this question at higher levels of a political violence typology, as evidenced by Findley and Young (2015) and studies such as Findley et al. (2012b), in which they overlay terrorist attacks in civil war zones and find a high level of overlap. However, GIS provides the technology to begin to dive into these questions with an even finer grain. For example, attack types and specific targets can be used to help differentiate among political violence types. Are attack types typically used by insurgents against military targets, such as armed assaults, different from those used indiscriminately against civilian populations, such as an IED attack? Examining the target locations of these attacks at a more micro level can illuminate these differences in attack types. For example, was the attack location a military base or a refugee camp? Overlaid with data on locations of actors and incidents known to be rebels, militias, or gangs, GIS offers promising insight into the question of political violence typologies.

Other research seeks to model the location of the terrorist groups themselves. Bennell and Corey (2007) investigate whether criminal profiling, particularly that pertaining to serial criminals, is useful in discovering the whereabouts of terrorist cells. That is, do terrorist groups, like serial criminals, engage in the sorts of behavior that would help law enforcement predict where they might be? Because of the obvious trouble with getting accurate data of terrorist locations, they are only able to examine two cases. However, they give reason to believe that criminal profiling may be useful in finding terrorist locations.

Techniques of GIS

Many scholars of political violence and terrorism are not trained in geography or GIS. To make the maps that are created and analyzed when using GIS applications, a researcher builds them through a series of spatial data layers. These individual layers generally represent different units of analysis, from continent to country to city to specific event. For example, a world map with the seven continents may be the base layer of a map, with subsequent countries, administrative levels, and cities layered on top of it to create a more comprehensive map that can be analyzed at multiple levels.

There are two main types of spatial data: raster and vector. Raster data represent continuous features as individual pixels, or cells, in a grid. The map or representation space is usually made up of a grid of square cells, but they can be rectangular as well. Each cell has a value corresponding to some spatial attribute or multiple layered attributes. Examples of raster data include slope or elevation, changes in land features, or ethnicity of a group. To represent these data visually, each cell could be a different color, depending on its slope or some other attribute which would be explained in a legend. Raster data are limited by the fact that all information inside the cell is the same. In short, a single value is attributed to all space in the cell (Longley et al. 2015). As precision in the cell size increases, this is less of an issue. Other issues, such as how to assign a value for a cell when the cell has multiple values come to the fore. For example, if the cell

has to be assigned a certain ethnic group, should it be coded a 1 if that group is present in the cell? Or only if it is the dominant group?

Vector data, on the other hand, represent discrete features. These features have clearly defined names or boundaries. There are three types of vector data: points, lines, and polygons. Points represent a single pair of geographic coordinates, such as a building, or an event, such as a terrorist attack. Lines represent features that have length but not width, such as a river or a road. Polygons are areas often with boundaries that do not fit neatly into a standardized grid, such as a state, country, or lake. All points can be connected by lines. These lines build polygons rather than grid cells like the raster method.

Both raster and vector data can have associated attributes that are stored in a table linked to each feature. These attributes are non-spatial data that give further information about each feature. For example, for point data where each point represents the coordinates of a terrorist attack, each point could have further information associated with it, such as date of attack and group responsible. These attributes may come with the spatial data or they can be tables, such as an Excel file, which can be joined with an existing spatial layer, as long as a common unique identifier exists.

Vector data are frequently used in terrorism studies. Scholars such as Findley and Young (2012b) and Marineau et al. (2018) utilize point data in the form of geocoded terrorism attacks on all countries in the world; Berrebi (2008) utilize point data to analyze the spatial and temporal trends of terrorist attacks in Israel. They integrate polygon data to further analyze each point, or specific attack, in relation to line and polygon features. In looking at distance from international borders, they use line features. In looking at the relationship between point location and ethnic homogeneity, they are utilizing the attributes of a polygon (the density of a particular ethnicity within a set of boundaries). Medina et al. (2011) use point data from every geocoded terrorist attack in Iraq to perform a similar analysis. The aggregation of spatial vector data and associated attributes has proven to be a powerful tool in GIS analysis.

Chloropleth maps, in which areas are shaded in proportion to the measurement of the statistical variable being displayed on the map, such as attacks per region, are the most often used map tool in GIS applications. These maps supply a quick visual reference that allow readers to better understand existing patterns. Dot density maps are another way to convey the intensity of an attribute. These quantitative, thematic maps place dots of the same size in an area based on the proportion to a numeric attribute associated with this area, such as the number of terrorist attacks that have occurred. Findley and Young use this technique in their contribution to a forum on thinking about acts of terrorism versus terrorists (Asal et al. 2012). A dot distribution map follows the same concept, but uses one dot per area, with its size being in proportion to the numeric attribute of that area.

More nuanced techniques can be utilized in GIS analysis as well. Hotspot analysis uses density of points to analyze where clusters exist (or don't exist) and tells the user if these clusters are statistically significant. Nemeth (2014) used hotspot analysis to find local areas prone to domestic terrorism. Once these areas were defined, they analyzed attributes of each polygon to see which increase the likelihood of terrorist attacks (e.g. proximity to state capital or mountainous terrain).

Geographically weighted regression (GWR) concerns whether an estimated coefficient, fitted to the entire sample (such as every country in the world), adequately represents detailed local variations (such as individual countries). It assesses whether global models follow local regression implementations. These variations do not occur in the typical data space, however, but by moving a weighted window over the data, estimating one set of coefficient values at every chosen point (Bivand et al. 2008). Looking at patterns of terrorist attacks in Turkey, Yildirim and Calb (2013) utilize GWR to investigate the determinants of provincial terrorism and determine why most attacks occur in the south and east of Turkey. Spatial econometrics estimation methods can be used to resolve spatial dependence between observations, such as spatial autocorrelation, such as spillover-effects, neighborhood effects, or state dependence. Spatial autocorrelation occurs when similar values are disproportionately clustered or dispersed on the map, violating the assumption of independence. Variogram tables can be created to allow users to further explore these patterns and adjust if needed.

Areas of Further Research

The fine-grain spatio-temporal characteristics of GIS data open up many exciting areas in terrorism research, of which we discuss three. Scholars could effectively bring together GIS data and quasi-experimental survey analysis. Surveys and quasi-experiments have become increasingly common in the field of international relations but a constant difficulty in these research designs is how to choose a sample. GIS data can help more accurately identify the desired sample group. For instance, if a researcher is interested in how terrorism affects public perception of the government, he or she can leverage GIS spatial data to find the hotspot areas most directly affected by attacks. This would ensure that the researcher is conducting surveys with the desired treatment group.

Another useful application of GIS would be more accurate observational matching. By establishing matching estimates, such as through propensity scores, one can look at cross-national variation to examine systematic variation in the covariates of interest across like cases. In essence, GIS data massively increase the number of possible N upon which to match because no longer would comparisons be constrained to a national level. While on the aggregate Somalia and Colombia, or Somalia and Pakistan, do not line up well for matching, it may very well be the case that certain districts *do.* Matching on a smaller observational unit can allow researchers to more precisely choose their sampling for quasi-experiments and thus provide more possible cases and look for variation across cases.

Secondly, GIS analysis could be used within quasi-experiments themselves. Does the presentation of how data are displayed change the actions of policy-makers? One advantage of GIS data is that it can easily be presented in visual forms, such as heat maps showing the regions, cities, or even roads with the most terrorist attacks. When mapped along with important factors like natural resources, infrastructure, or topography, these visuals can

serve as powerful representations of relationships. But are these sorts of representations more impactful than a typical spreadsheet or a list of terrorist attacks? And do GIS data help to fashion more effective counter-terrorism policies? In this case, GIS analysis can be useful within quasi-experiments to measure the reactions of policy-makers to different types of data representation. While some policy-makers would receive simple spreadsheets or lists of attacks, others would be given more visual representations of terrorist attacks, deaths, and means.

Lastly, researchers could use both the spatial and temporal nature of GIS data to investigate at the subnational level how terrorism affects local issues, such as regional trade, public health, or voting behavior. An attack hotspot may very well see dramatic reductions in trade, a decline in public health indices, or altered voting behavior as a result of terrorist activity, but these effects may be washed out in datasets in which the state is the smallest unit of analysis. Along these lines, terrorism's effect on local elections provides a promising avenue for future studies. Research finds that terrorism has effects on national elections (Montalvo 2011; Getmansky and Zeitzoff 2014), but research looking at subnational effects is sparse (Kibris 2011; Berrebi and Klor 2008). It may very well be that when it is localized to only a few areas of a state, terrorism has little effect on national elections but very large effects on *municipal* elections. Kibris looks at the effect of terrorism on voting in Turkish elections, but only indirectly, using the number of police deaths as a proxy for terrorist attacks. Berrebi's investigation (2008) of Israeli elections at the district level provides compelling evidence that local electorates are, indeed, sensitive to terror attacks and this sensitivity is reflected in their voting patterns. This begs the question of whether this phenomenon is specific to the Israeli case or if it can be generalized to other nation states as well. Similarly, is the magnitude of the effect on voters similar across different types of elections (federal versus local) and attacks (suicide, chemical, etc.)? GIS data allow researchers to analyze the district or municipality as the unit of analysis as opposed to the nation state and can thereby capture variation that previously went unnoticed when aggregated to the national level.

Technical Needs

The most widely used software for GIS analysis is the ArcGIS suite. This program must be run on a Windows machine (or on a Mac utilizing a virtual machine like Bootcamp or Windows Parallels). Developed by ESRI, ArcGIS is made up of several distinct applications which are integrated to allow users to aggregate data sources, build spatial models and maps, analyze them, and produce readable output. ArcCatalog, for example, provides an interface to organize and navigate data while ArcMap allows users to create, interact, and analyze features on an actual map.

A specific type of data is needed in order for ArcGIS to function. Vector spatial data (points, lines, and polygons) must have shape files. These files are available through ESRI, government websites such as census.gov or open source, such as divagis.com.

Depending on the specificity of the feature, data may need to be geocoded (recording the latitude and longitude coordinates). Points, such as specific terrorist attacks, would be an example. Geocoded data allows ArcGIS to transform information into a location on a map. Geographical coordinates (latitude, longitude) provide the most specific geolocation. However, ArcGIS has location finding services which can translate information, such as a zip code, into a general location on a map.

Attributes can be included in the base shape files that are used to build a map. If not, tables containing attributes can be joined with a shape file to supply information about each individual feature. Tables must be in .xls, .mdb, .txt, or .csv form in order to be successfully joined. The text type must match the shape files exactly, and there must be a unique identifier in order for attributes to join features (e.g. country code or date).

While it is certainly widely used, there are several alternatives to ArcGIS. R Maptools allows for the statistical program R to create simple maps. It is fundamentally different than ArcGIS because of its command line interface, in which users type commands rather than the visual interaction of pointing and clicking to select and modify features. The Rgeos and Rgdal packages of this free program can perform many of the same analytic techniques, such as geographically weighted regression and spatial interaction models and produce maps to visualize the data. R is an integrative program, because users have more freedom and ability to edit, analyze, and visualize the data all in one interface.

The spmap, shp2dta, and mif2dta commands in Stata also allow for the use of GIS techniques. Much like ArcGIS, users merge a .shp (shape) file and a .dbf (attribute table) to visually display data. The .shp file must be an ESRI or MapInfoInterchange file. Users can create various types of maps using the command line interface of Stata, such as dot density and chloropleth, and perform spatially weighted analyses, such as spatial autocorrelation and regression.

QGIS and WorldMap are free, open source options. GeoCommons is another online program that has many features similar to ArcGIS. However, ArcGIS remains the most user friendly and comprehensive software for both building and analyzing maps.

Conclusion

The first law of geography or what is called Tobler's law suggests that, "Everything is related to everything else, but near things are more related than distant things." Judging from initial inquiries reviewed here, there appears to be considerable evidence that incidents of terrorism follow this law. We don't yet fully understand these relationships, however. While scholarly research has made significant strides in identifying and examining these effects, especially at the national level, there is much that remains to be learned about how geographic factors affect terrorism. GIS is gaining popularity in the terrorism studies field, with scholars utilizing GIS techniques to determine and explore patterns and trends in terrorism at both local and global levels, and this work is being published in some of the top outlets in the field. Whether the question is why terrorists

choose targets near bus stops in a local capital or which global regions experience disproportionately high rates of terrorist attacks, GIS provides a method for investigation. The spatial and temporal analysis that GIS provides opens up a new window into the field, through which both old and new questions can be explored and answered in a more precise manner.

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Notes

1. *CNN* (2015).
2. *Telegraph* (2008).
3. Released by the Peace Research Institute of Oslo, the PRIO-GRID database is a spatio-temporal grid structure that divides the globe into small quadratic cells. The cells contain basic static in- formation, such as terrain, and can be coupled with more advanced time-varying variables such as population or natural resources.

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