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Predicting Suicide Attacks

Integrating Spatial, Temporal, and Social Features of Terrorist Attack Targets

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Summary

The threat of suicide bombings in the United States and elsewhere prompted the Department of Homeland Security to commission the Naval Research Laboratory (NRL) to develop a method for predicting the determinants of suicide bombing attacks. As a test case, NRL chose to study suicide bombings in four Israeli cities: Jerusalem, Haifa, Tel Aviv, and Netanya. They focused on three terrorist groups: Hamas, Al-Aqsa Martyrs' Brigade, and the Palestinian Islamic Jihad.

NRL designed a two-part study aimed at discovering terrorist group target preferences in suicide terrorism. The first part focused on examining spatial preference patterns: how the different terrorist groups develop target preferences and how these preference patterns can be transferred. Part 2 of the study focused on the sociocultural, socioeconomic, demographic, and political aspects of the suicide bomber attacks. The rationale is that looking at purely spatial attributes ignores the broader social context in which the attack occurred and that proper analysis of this social context can provide additional clues about the risk of future attacks. This monograph documents the results of incorporating these sociocultural, demographic, and political features in the analysis. This work should be considered an exploratory pilot study, designed simply to examine whether sociocultural features of the environment can add explanatory power to models and data sets that focus more on geospatial features.

RAND was asked to explore the ability of sociocultural, political, economic, and demographic variables to add value to the prediction of the timing and locations of suicide attacks in Israel. We did this in two ways. First, we conducted a quantitative analysis using socio-

cultural, economic, and political variables to model areas at increased risk, then examined the value this added to NRL's geospatial predictive techniques. Second, we drilled down more deeply into qualitative data on known attack sites to identify specific types and attributes of locations that may put them at increased risk. These efforts were designed to develop a methodology that could be used to create a short list of at-risk areas for future attacks. NRL's end goal was to produce such a list for the U.S. environment, drawing on the most useful aspects of the methodological and analytic work from this test case.

Quantitative Methodology and Data

The data we analyzed came from multiple sources. Our basic unit of analysis was the statistical area defined by the Israeli Central Bureau of Statistics, which we refer to as "neighborhoods." The analysis included the following categories of data:

- **Socioeconomic characteristics.** We conjectured that it is possible for the socioeconomic characteristics of Israeli neighborhoods to make them more or less attractive as suicide bombing targets. The Israeli census collects detailed socioeconomic information by statistical areas that have roughly the size and population of a U.S. census tract. The Israeli Central Bureau of Statistics collects multiple socioeconomic indicators (average income, high school graduation rate, unemployment, housing density, etc.) for every neighborhood in Israel.
- **Demographic characteristics.** The key targets of suicide bombing in Israel are people (rather than, for example, infrastructure), so it is important to examine whether population variation in the religious, racial-ethnic, and other demographic features of a neighborhood affects suicide bombing targeting preferences.
- **Electoral data.** Past research has shown that political leanings of the Israeli electorate are responsive to terror attacks and that the reigning political party has an effect on the expected number and frequency of attacks. As a result, we expected that terrorist plan-

ners might be attuned to the political leanings of neighborhoods and might select targets based on perceived Israeli partisanship. We obtained 1999 voting data for the Knesset by polling station and aggregated the data to the neighborhood level.

- **Proximity to terrorist safe houses.** We collected coordinates for all known Palestinian Islamic Jihad, Hamas, and Al-Aqsa terrorist safe houses in the region. We calculated both Euclidean and driving distances to the nearest terrorist safe house, as well as the number of safe houses in close proximity to each neighborhood centroid.
- **Sociocultural precipitants.** We compiled a list of precipitants that have been theorized to be associated with the timing of suicide bombing attacks. Existing research has identified religious holidays, political events, and other occurrences as potential precipitants that trigger suicide bombing attacks. Martyrdom videos made by suicide bombers have explicitly referred to political negotiations and high-profile meetings, such as the Arab League Summit. We created temporal variables from information on Jewish religious holidays, political negotiations, and Israeli Defense Force (IDF) operations.

Principal Component Analysis Results

Having collected a large data set, our first task was to narrow the list of variables and create a series of scales. We performed separate principal component analyses for socioeconomic, demographic, and electoral data. The objective was to account for the maximum portion of the variance present in the original set of variables with a minimum number of composite variables. Throughout the analysis, we considered components until they no longer contributed more than 10 percent of the total variance or once the cumulative proportion of variance was 80 percent or more.

- **Socioeconomic Variables.** Analysis yielded two indices that collectively accounted for 69 percent of the variance: Low Income

accounted for 54 percent, and High Wealth accounted for 15 percent.

- **Demographic variables.** Our analysis yielded four indices that accounted for 85 percent of the variance: Aging accounted for 30 percent; Jewish accounted for 23 percent; Asia/Africa Origin accounted for 22 percent; and Nonimmigrant accounted for 10 percent.
- **Political variables.** Analysis of political variables yielded two indices that collectively accounted for 82 percent of the variance: Orthodox accounted for 58 percent, and Non-Arab accounted for 24 percent.
- **All variables.** Using variables from all three domains, we constructed six indices representing 85 percent of the variance.

Logistic Regression Results

We used binomial logistic regression to test the association of indices from each category of variables (socioeconomic, demographic, political) with the probability of attack in particular neighborhoods. In each case, we examined the added value of these indices for predicting attack site probability by neighborhood in addition to NRL's geospatial predictors.

Socioeconomic, Demographic, and Political Model Regression Results

According to the two socioeconomic indices, lower-income neighborhoods were at higher risk, while neighborhoods with higher material wealth were at higher risk than those with lower. The demographic scales indicated neighborhoods with more immigrants of Asian or African origin were at higher risk of attack. Neither political index was significant, but both Orthodox and non-Arab were associated with decreased likelihood of attack.

Socioeconomic, Demographic, and Political Models with NRL Risk Index Regression Results

When the indices from each of the domains were combined with the NRL Risk Index, the index that was trained off of the attack data

absorbs the predictive ability from the other indices. However, the combined models yielded better false positive and false negative rates.

All-Variable Logistic Regression

Next, we used the six indices from the principal components analysis that employed all the variables across the three categories (socioeconomic, demographic, and political). All indices are associated with slightly higher odds of attack. Most notable are the Older/Non-Jewish index and Educated Israeli/Non–Right Wing voters.

Proximity to Terrorist Safe Houses

To test whether tactical accessibility to target sites might affect the strategic planning and operational activity of terrorist groups, we calculated both Euclidean and driving distances (Manhattan[1]) between known terrorist safe houses for Hamas, the Al-Aqsa Martyrs' Brigade, and Palestinian Islamic Jihad and all neighborhood centroids. The models did not reach significance, either for Jerusalem alone or for all cities combined. However, a model examining the number of terrorist safe houses in close proximity (below the median distance) to the neighborhood was marginally significant (p-value < 0.1)

Classification and Regression Trees (CART)

We generated a decision tree that categorized neighborhoods in Jerusalem by risk level. The classification tree model used 12 socioeconomic, 11 demographic, and five political variables to create hierarchical trees generating the most efficient categorization of neighborhoods by risk level while minimizing the variance in each category. This produced four neighborhood profiles, two of which were low risk (0–17 percent probability of attack), one was categorized as moderate risk (55 percent probability of attack), and one was high risk (67 percent probability of attack). The two low-risk profiles contained most of the neighbor-

[1] The Manhattan distance is the distance between two points in a grid based a strictly on vertical and/or horizontal path (that is, along the grid lines), as opposed to the diagonal or "as the crow flies" distance. The Manhattan distance is the simple sum of the horizontal and vertical components, whereas the diagonal distance might be computed by applying the Pythagorean theorem.

hoods in Jerusalem (104 out of 129 neighborhoods). Thus, there was considerable specificity for the remaining neighborhoods categorized as moderate to high risk.

Sociocultural Precipitants

We assigned temporal variables to all neighborhoods in Jerusalem for Jewish religious holidays, political negotiations, and IDF operations. We examined the association between the occurrence of a sociocultural precipitant and attack frequency. Results indicated that the political variable was most important; that is, there was an association between the proximity of political negotiations and the expected frequency of attack.

Qualitative Analysis

We conducted a qualitative analysis to identify and code *themes* common to suicide bombing sites in Israel. The themes reflected both target location types and attributes. The concept was to use the hybrid NRL-RAND model to identify areas at increased risk of attack, then use the themes we had identified to identify specific locations at increased risk of attack. This approach was intended to reduce areas treated as high risk from city regions to more manageable lists of sites.

Methodology

The first step was to review open-source articles about the attacks and target sites. We specifically considered articles on suicide bombings in the four study cities (Jerusalem, Tel Aviv, Haifa, and Netanya). We identified key words and phrases stating target characteristics (the themes) in attack descriptions, target descriptions, and descriptions of areas with visually apparent bombing clusters. The second step was to look for similarities in target characteristics across the events, identifying commonality.

The themes are captured through *codes*—a standard set of labels identifying whether the target site possesses that theme. The codes were derived from observations of the data and reflect both target *types* and

attributes. The presence or absence of the codes can be treated as 0–1 indicator variables, which in turn permit various types of statistical analyses.

The third step was to assess the numbers and timing of attacks having the codes in common. We identified patterns in the codes, including discernible clusters, correlations, and trends. For codes that larger numbers of cases shared, the analysis identified statistically significant findings about target characteristics.

Hypotheses

First, we hypothesized the existence of certain targets that a would-be terrorist would think of attacking. These would be places where it is commonly known that crowds of Jewish Israelis congregate and/or have some special meaning to Jewish Israelis.

Second, we hypothesized that suicide bombing plotters are fairly rational and will select targets that provide reasonably easy access to crowds of people to attack. However, we further hypothesized that, in doing so, would-be terrorists are simply seeking "satisfactory" attacks—identifying "obvious" targets that, at first thought, seem to offer a "good-enough" combination of crowds and easy access.

Since the qualitative methodology was intended to infer the attacking organizations' underlying targeting preferences, we analyzed a location only if a suicide bomber reached his or her intended target. They need not have fully reached their target, but the location they were trying to strike had to be clear. Our research yielded 55 attack cases that were independent and had a clear target.

Results

Codes

Using qualitative data analysis, we identified 12 codes that appeared in at least two cases each: disco or club, hotel, main street, main shopping, alternative, beachfront, children or youth, crowded, easy access, iconic, Jewish and/or Arab, and military.

Distribution of the Codes

The most frequent code, crowded, applied to all cases. This code does not refer strictly to a large crowd, tens of hundreds of people. It means that there was a fairly large group of people at the scene, who were reasonably accessible to the bomber. The frequency of this code implies that the notion that suicide bombers attack targets featuring groups of people that are readily accessible is accurate. Of the remaining 11 codes, the top three were main shopping, iconic, and main street. Almost 70 percent of the cases had at least one of these three codes. The prevalence of these codes is consistent with both a crime pattern theory hypothesis on choosing "obvious" places and a choice to target locations with accessible crowds

Retargeting

Terrorist organizations were very conservative in attacking targets with suicide bombers; targets hit once were at extremely high risk to be struck again. Over one-third (36 percent) of suicide bombings were restrikes of prior targets. Once an organization finds a site that meets its criteria and has attacked it successfully, the site becomes an easy choice for additional attacks. Sites attacked more than once include the following:

- **in Jerusalem:** central bus station, the Jaffa Road–King George Street intersection, Mahane Yehuda market, Ben Yehuda street (pedestrian mall), and the French Hill bus junction
- **in Tel Aviv:** Neve Sha'ana market and shopping areas near the central bus station
- **in Netanya:** Hasharon Mall entrances and immediately surrounding areas, such as nearby bus stops.

Dispersion of Attacks over Time

From reviewing attack descriptions and point maps showing attack locations, we found that target selection migrated from iconic and centrally located targets over time. Such a migration would be consistent with the notion that terrorist organizations choose alternative sites in response to increased security at preferred sites. We assessed whether

this initial impression was quantitatively justified. Our approach was to group the attack sites into clusters by similarities in their codes.

We found two clusters that were highly meaningful, dividing targets that were iconic and/or on a main street from other types of targets. In particular, in the iconic–main street cluster, 82 percent of sites had the iconic code, and 73 percent of sites had the main street code; in the other cluster, zero sites had either of these two codes. The data show a strong migration away from iconic and main street targets over time.

Assessment of Transportation Targets

Twenty-three suicide bombings in the Suicide Terrorism Database were attacks on transportation (bus lines or bus stops). We identified three types of transportation targets within these cases:

- **on-target direct:** These included seven attacks on the transportation system itself.
- **on-target indirect:** These included 13 attacks on a specific location that indirectly involved transportation.
- **not on target:** These included three attacks that were premature detonations while on bus lines.

Conclusions

Quantitative analysis established that socioeconomic, demographic, and political variables have meaningful relationships with the odds of attack within specific neighborhoods and that this added to the explanatory power of geospatial variables.

Demographically, both having a heavily Jewish population and a large number of immigrants (particularly from Asia and Africa) were related to greater risk of attack. Voting for right-wing or Orthodox parties in 1999 was related to lower neighborhood risk of attack.

The relationships between socioeconomic, demographic, and political variables and attack probability held even when controlling for geospatial factors, so they seem to confer risk for reasons beyond their association with geospatial features of neighborhoods.

Perhaps the most striking finding was the robust relationship between multiple types of sociocultural precipitants and attack frequency in Jerusalem. Jewish religious holidays, political negotiations, and IDF operations were all associated with a greater likelihood of attack within the time windows specified for each type of event.

Attackers would trade off between risk (carrying out the attack) and reward (numbers of casualties). Suicide bombers targeted *accessible crowds*.

However, attackers were not simply targeting groups of people at random. First, they were very repetitive in making target decisions. Over one-third of attacks were repeat strikes on locations attacked previously. Locations that have been targeted need to be considered very high risk for future attacks.

Next, attacks most often targeted not just places where people congregate but places that were *well known*. The three most frequent characteristics of attacked sites were that they were the city's principal shopping locations, on one of a city's main streets for shopping and entertainment, and/or were iconic locations in the city.

Recommendations

The study documented here was essentially a proof of principle aimed at suggesting that sociocultural, economic, and political factors have a role in predicting suicide attacks by providing the needed context for NRL's geospatial analyses. We have indeed demonstrated that these factors enhance our ability to predict these attacks. However, there are several ways to further improve our results.

Regression Analyses

The regression analyses we performed were all cross-sectional. However, sociocultural, geospatial, and even precipitant event determinants of suicide bomb attack sites likely change over time. Multiple years of data exist for voting patterns (1996, 1999, and 2003), and the Israeli census has 2008 data available in addition to the 1995 census data used in our analyses. Furthermore, geospatial data are available in specific

years, which would enable modeling of changing road networks and other geospatial features. A panel regression using multiple years of data would allow us to model the influence of changes in the social and geospatial context relative to patterns of suicide bombing attacks over time.

Neighborhoods are also likely to be spatially correlated. The regression models presented in the quantitative analyses did not examine or account for this correlation. Future analysis should consider the spatially correlated regression residuals and apply a spatial smoothing variable to the regression models. This would spatially smooth the estimates and adjust for spatial correlation, providing the ability to reduce the residuals, which would result in smaller prediction errors and ultimately improve model fits.

For the quantitative analyses in this monograph, we focused on attacks in the city of Jerusalem. Further analyses could make use of attack data not only from all four cities, Jerusalem, Haifa, Netanya, and Tel Aviv, but also data on suicide bombing attacks beyond these cities. Furthermore, analyses could model other types of terrorism, such as shooting attacks and nonsuicide bomb attacks.

Sociocultural Precipitants

We specified the relevant time window for sociocultural precipitants a priori, rather than using an infinite time window or developing a set of models to pinpoint the most optimal or influential time window of influence. Future analytic efforts could focus on taking a more-flexible approach to the proximity of sociocultural precipitants to attacks in time and could also consider additional precipitants.

Furthermore, future analyses could take a "neighborhood free" time series approach to all suicide bombing attacks in the region (or even nonsuicide terrorism) to determine how sociocultural precipitants influence terrorism more broadly.

Finally, future analyses could take a more-nuanced approach to linking sociocultural precipitants to types of neighborhoods. For example, one could hypothesize that Jewish religious holidays would be a more relevant precipitant for heavily religious neighborhoods, where

the target population will congregate in greater numbers to prepare for and observe the holiday.

Transferability

The analysis in this report, and in other NRL and University of Oklahoma research, is limited to preferences of Palestinian suicide bombers in Israel. There is some evidence to suggest that there may be a great deal of similarity between attacked sites in Israel and elsewhere. In brief, the suicide bombings in Israel took place during open hostilities between Israel and Palestinians, and the Palestinian terrorist organizations have long espoused ideologies that glorify suicide operations. Neither condition is likely to apply to plots in the United States and other Western countries. Therefore, we believe that directly transferring the target preference results from Israel to other countries has limited value.

However, the methods used to assess target preferences in Israel could be transferred to the United States and other countries. Qualitative data analysis can be applied directly to data for the United States and other countries; the quantitative techniques need to be restructured slightly, but the underlying methods and theory will still apply. We recommend applying the methods that NRL, RAND, and the University of Oklahoma have developed to targeted sites in the United States and other Western countries. Results, if proven to be robust, could be used to develop recommendations for heightened public awareness or preparedness drills in certain areas.