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ORIGINAL PAPER

The Application of the "Law of Crime Concentration" to Terrorism: The Jerusalem Case Study

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Abstract
Objectives One of the areas in terrorism that has not been adequately examined, is the geographic concentration of terror attacks in a city's micro places. The literature related to the geographical distribution of terror generally focuses on macro places: continents, countries, and regions. In contrast, in the study of ordinary crime, significant studies have been conducted on the distribution of crime in micro-places "hot spots". The findings of these studies have great significance when adopting models of law enforcement. This study examines whether there is a concentration of terror attacks in a limited number of hot spots that are stable over time.
Methods This study examines the entire population of terror attacks in the city of Jerusalem between 2000 and 2017 (249 attacks involving explosives, shootings, stabbings, attacks with a deadly weapon, and run over attacks) as a case study. We investigated and mapped each attack's exact location (for the majority of attacks) and characterized the particular micro places of these terror attacks, as well as the attacks themselves.
Results The research revealed that there is a higher frequency of terror attacks concentrated in specific hot spots and that they are stable over time.
Conclusions The concentration of terror attacks calls for a specialized counterterrorism response equivalent to "hot spots policing" based on the characteristics of the potential terrorist hot spots.

Keywords Terrorism hot spots · Geographical concentration of terror · Counter terrorism · Situational prevention of terror · Target hardening

Introduction

In recent years the study of terrorism has benefited greatly from the increasingly frequent application of established theoretical and methodological frameworks from criminology. Indeed, as Clarke and Newman 2006 define it, "Terrorism is a form of crime in all essential respects." (Clarke and Newman 2006, p. 7). Utilizing criminological theories and practices

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which deal with regular crime has the potential to greatly contribute to the understanding of the phenomenon as well as to put in place effective police crime prevention tactics and counter-terrorism measures (Dugan et al. 2005; Perry et al. 2016).

In recent decades, one of criminology's most developing fields has been the study of crime and place (Brantingham 2011). The focus on place was in part encouraged by the great difficulties in identifying unique profiles of offenders. To date, tens of high-quality studies have identified that crime is concentrated at a few places (Eck et al. 2017; Lee et al. 2017). This has enabled the identification and characterization of hot spots of crime. On this basis, new policies such as hot spots policing and focused deterrence strategies have been successfully employed to prevent and reduce crime. Given the great difficulty in identifying profiles of terrorists (Victoroff 2005; Silke 1998), profiling is not an effective prevention strategy (Silke 2003). Based on what we have learned from criminology, a greater focus on place rather than the offender could be of significant benefit (Clarke and Newman 2006). Certain studies explore the geographical distributions of terrorism at more macro-level units of analysis, internationally, regionally, nationally and even locally (e.g. LaFree et al. 2006, 2013; Braithwaite and Li 2007), however, few if any studies have followed the trend of the criminological literature to examine the phenomenon at the micro-level; the street segment.

The street-segment has consistently been identified as the unit of analysis which can best contribute to our understanding of crime and place related phenomena, and which is also most useful for informing the development of enforcement models. Examining crime at the street segment level has consistently found that a majority of crimes are concentrated in an exceptionally small number of street segments. Given the recurrent nature of the empirical observations across a wide variety of contexts, Weisburd (2015) declared that there exists a "law of crime concentration". According to Weisburd: "for a defined measure of crime at a specific micro geographic unit, the concentration of crime will fall within a narrow bandwidth of percentages for a defined cumulative proportion of crime." (Weisburd 2015:138). While what constitutes a narrow bandwidth has not been defined, studies have generally found that approximately 1% of street segments witness 25% of crime, and 5% witness 50% of the crime. Crime prevention strategies that focus on these chronic hot spots, known as "hot spots policing", have been found to be highly effective in preventing and reducing crime (Braga and Weisburd 2012).

Examining whether terrorism operates according to the law of crime concentration could have potentially important policy implications. For example, if terrorism is as highly concentrated as other types of violent offences, prevention strategies such as "hot spots policing" could be an effective counter-terrorism approach. Especially in the case of lone-terrorists, who generally lack traditional infrastructure and communication channels that increase opportunities for detection and prevention (in comparison to organizational terrorism) (Perry 2014; Perry et al. 2019; Spaaij and Hamm 2015), place-based strategies may be quite useful. Increasing random police patrols alone is unlikely to prevent terrorism. In a situation in which terrorism may be found to concentrate in hot spots, hot spot policing approaches could be effective in foiling the types of lone terrorist attacks which have increasingly become more common (Perry et al. 2019).

While prior research has already identified the existence of terrorism hot spots at the global, regional, national, and even local level, there has been little done to examine terrorism within the framework of the law of crime concentration and at more micro-geographic units of analysis. One of the main impediments to this type of research is that like all terrorism research, there is an issue of low base-rates and long observation periods (Gill et al. 2016). Studies of crime often involve thousands of incidents over relatively short

observation periods. Most countries, let alone cities, thankfully do not have enough terror attacks in order to make for a reasonable analysis. However, of all democratic, western style countries, Israel has the largest volume and greatest frequency of attacks (Freilich 2017); enough to enable a meaningful analysis. In this study we rely on official data of all terrorism events in Jerusalem, Israel, and examine the applicability of the law of crime concentration by analysis at the street-segment level. The study also attempts to identify and characterize hot spots of terror attacks at the street-segment level over time. Finally, we consider whether the concentration of terror attacks allows for a specialized counterterrorism response equivalent to "hot spots policing."

Concentration of Terror Attacks at "Terror Hot Spots"

Numerous studies in various cities have established that a large proportion of the total number of crimes are concentrated in a small number of micro geographic places, such as street segments. (Braga et al. 2011; Brantingham and Brantingham 1999; Pierce et al. 1988; Roncek 2000; Sherman et al. 1989; Weisburd and Amram 2014; Weisburd et al. 2012). A comparison study by Weisburd (2015) found that crime concentration had high spatial–temporal stability. In larger cities, approximately 50% of crime incidents were concentrated in between 4.2 and 6% of street segments, whereas 25% of incidents were concentrated in between 0.8 and 1.6%. In addition, it is not only that large proportions of crime are concentrated in a small number of places but that concentrations remain relatively stable over time, with only minor variation from year to year (Braga et al. 2017; Gill et al. 2017).

As Song et al. (2017) contend, the spatial–temporal stability of crime concentration is mostly the result of the spatial characteristics of criminal offences. They explain that a number of different theories from environmental criminology contribute to various elements of the overall explanation of the observed phenomenon. Similarly, in referring to the law of crime concentration as having become a "criminological axiom", Braga, et al. (2017) states that this phenomenon is "completely consistent with our existing spatial theories of crime: motivated offenders and suitable targets converge at specific (micro) place… and rational choice are situationally (spatially and temporarily) specific."

According to rational choice theory, offenders weigh and calculate the potential rewards of an offence against the chances of success or getting caught. Ultimately, criminal acts are therefore the outcome of a series of choices and decisions having been made prior to the crime. Offenders balance opportunities, risks and rewards in determining not only whether to offend, but where to offend, since different places offer different levels of these components (Cornish and Clarke 1987). There is therefore an inherent connection with routine activities theory (Felson 2017) which states that in addition to a motivated offender, a suitable victim (opportunity) and the lack of appropriate guardianship are necessary in order for a crime to take place (Clarke and Cornish 1985). Different places will afford different opportunities in terms of whether or not suitable victims are present there, and whether they exist in the absence of an appropriate guardian or level of guardianship.

According to Crime Pattern Theory, the elements of the physical environment, namely nodes, paths and edges, determine its level of opportunity and whether it will be a crime generator and, or attractor, and to what extent. The makeup of a particular physical space impacts on whether an offense may or may not be committed there. Certain places attract and, or generate offences because motivated offenders are also rational and will seek the most appropriate targets and offending opportunities (Brantingham and Brantingham

1993). Since offenders become familiar with potential opportunities through their routine activities, they also become familiar with the surroundings and the different elements of the environment, including paths. As such, a potential offender may choose to offend in a place with easy access or transportation, even if it exists outside of the primary activity space (Groff et al. 2014).

The Theoretical Applicability of the Law of Crime Concentration to Terrorism

Research has increasingly identified that there exists significant overlap between ordinary criminals and terrorist offenders, especially with regards to their rational choice making (Clarke and Newman 2006; Perry and Hasisi 2015; Dugan et al. 2005; Newman and Hsu 2012). Since the course of every act of crime, or terrorist attack is determined by the direct circumstances of the situation (Clarke 1997), spatial circumstances directly impact terrorists' target selections (Gruenewald et al. 2013; Gill and Corner 2016). As Clarke and Newman (2006) explain, terrorist activities are restricted by the same types of geographical constraints that exist for regular criminal activities. As such, opportunity is coupled to the circumstances of an attack in what Clarke and Newman (2006) call the "four pillars of opportunity." The four pillars include weapon(s), tools/training, facilitating conditions, and importantly, the target (Bakker and De Graaf 2011; Clarke and Newman 2006; Fahey et al. 2012; Perry et al. 2019). While a potentially unlimited number of possible targets exist, various essential characteristics make certain targets more attractive for terrorist's attacks (Clarke and Newman 2006; Newman and Hsu 2012).

The geographical and spatial characteristics of a target play a fundamental role in shaping its attractiveness as a potential site for a terrorist attack (Gill et al. 2017; Griffiths et al. 2017; Newman and Hsu 2012; Rossmo and Harries 2011; Perry et al. 2019). Much like ordinary criminal offenders, terrorists consider a range of factors such as accessibility, distance and the complexity of the journey when selecting a target. The terrorist's familiarity with the routes and paths to and from the target (including escape routes), the target area, as well as opportunities for acquiring and transporting and bring a weapon to the target—also play an important role in selecting a target to increase utility (Clarke and Newman 2006; Gill et al. 2017; Perry et al. 2019; Spaaij 2010, 2012).

These are the primary mechanisms by which criminal offences ultimately concentrate in specific places. Given that such geographical and spatial characteristics play a similar role in the selection of a target for a terror attack, it is reasonable to expect that terrorist attacks will follow similar patterns as regular crime and concentrate in a small number of places and types of places. Indeed, there is good evidence to suggest that terrorism does concentrate in hot spots much the same way as ordinary crime (Yang and Jen 2017).

However, terror attacks are likely to be unique in terms of how they are affected by the different elements from crime pattern theory. According to a study by Song et al. (2017), crime is twice as likely to occur on edges as it is in the interior of local neighborhoods. Additionally, the nature of the offence may require offenders to travel beyond the local neighborhood in order to converge with a suitable target (Bernasco 2014). Prior studies have found that ethnic composition and segregation of places is related to proximity to pathways. Both the demographic and spatial aspects of a place influence offenders' decision making about where to offend (McCutcheon et al. 2016; Brantingham and Brantingham 1995; Rattner and Portnov 2007; Bernasco et al. 2015). Additionally, emotionally motivated offences often include the targeting of specific places or individuals, especially when the offender believes that the target victims are more

likely to be found at a particular place over another (Brantingham and Brantingham 2003; Bernasco 2014; Groff and McEwen 2006; Tita and Griffiths 2005). In examining conflict related deaths in Ireland, Mesev et al. (2009) found that the highest intensity hot spots were those where ethnic segregation was greatest.

According to crime pattern theory, 'insiders' are more likely to offend within their local and immediate activity spaces, whereas outsiders are more likely to feel safer in offending near edges, leaving open the opportunity to flee back to their local areas (Felson and Clarke 1998). Given that terrorists seek to attack members of an outsider group, they may need to travel to edges in order to converge with suitable targets in time and space (Gill et al. 2017; Bakker and De Graaf 2011; Clarke and Newman 2006; Fahey et al. 2012; Kliot and Charney 2006). As such, the particular context and the spatial characteristics of place have an interactive effect in determining the potential locations of attacks (Gill et al. 2017). Perhaps more than ordinary crime, terrorism events are therefore likely to cluster along edges and pathways that denote areas of ethnic segregation or homogeneity, where the targeted victims are more likely to be found.

The Current Study

While analyses of hot spots of terrorism have been conducted at various levels, including global, regional, national, and even local, little has been published regarding the applicability of the "law of crime concentration" to terrorism at micro geographical places such as street segments in a city. One of the major limitations when studying the applicability of the law of crime concentration to terrorism is that terrorism research in general suffers from issues relating to the relatively low number of events spread over short periods of time. (Gill et al. 2016). However, Israel, and Jerusalem in particular, has witnessed an unfortunately large number of terrorism events in a relatively small geographic area and time-span.

The main goal of this study is to examine whether terrorism follows the law of crime concentration in a major city, analyzing the concentration of terrorism at the street-segment level. We draw on established criminological perspectives and methodologies to explain the concentrations of terror attacks in order to further our understanding of the phenomenon.

Research Questions

Based on the above-mentioned literature, this study aims to examine whether the "law of crime concentration" applies to terror attacks at the street-segment level, or whether they are distributed randomly in a city. Specifically, with Jerusalem as a case study:

1. Did a significant number of terror attacks cluster at hot spot street segments?
2. Did the same hot spots suffer from a significant proportion of terrorist attacks repeatedly over time?
3. Additionally, when focusing on the characteristics of the spatial elements of the hot spots, are there identifiable characteristics which are conducive to terror attacks occurring at that particular location?

The Study Population and Research Design

This study explores whether terror attack hot spots exist in micro places in the city of Jerusalem. The case study examines the entire population of terror attacks[1] (explosives, shooting, stabbing, attacks with a deadly weapon, and vehicle borne attacks) in the commercial centers of Jerusalem and in the Jewish and mixed Arab/Jewish population residential sectors of Jerusalem.[2] In order to examine the entire population of terror attacks, a unique database was constructed using Israel Security Agency (ISA) records. Due to the high level of reporting of terror incidents in Israel, official data about terrorist attacks are considered accurate (Perry et al. 2017). The data from the ISA was cross-sampled with data from open sources (such as: news sites and other media publications about the attacks and the attackers, public databases, and some clips of the attacks). The database of this study includes the entire population of terror attacks between January 2000 and December 2017. Data collection for this study consisted of a number of variables related to each attack: coordinates of the attack location; date and time of the attack; type of attack/weapon; number of wounded and killed; type of target (i.e. bus station, intersection); type of victim targeted (whether it was directed against civilian, policeman, security guard, tourist, youth, identifiably-orthodox Jew); personal information about the attacker (name, age, his/her place of residence, marital status, association with a terrorist organization); a short summery of the attack.

During the period from January 2000 and December 2017 there were 249 attacks in Jerusalem targeting Jews,[3] counting only those attacks which occurred in the commercial centers of Jerusalem and in the Jewish and mixed Arab/Jewish population residential sectors of Jerusalem. We excluded hundreds of shooting incidents that occurred in the beginning of the second Intifada where the shooting was directed from within Palestinian Authority (PA)-controlled territories adjacent of Jerusalem towards the southern Jewish neighborhoods of Jerusalem. While certainly important, these types of attacks are more closely related to the activities of guerilla forces[4] that shoot across the border at civilians,

[1] As mentioned, "Facilitating conditions" are one of the 'four pillars of opportunity' necessary for a terrorist attack (Clarke and Newman 2006; Fahey et al. 2012; Perry et al. 2019). According to Eck and Madensen (2009) the opportunity component includes the convergence of physical and social circumstances in time and space to influence the attackers' perception when deciding to carry out the attack. Since the social circumstances of Jewish terrorists are considerably different from those of Palestinians, the two cases of Jewish terrorism were excluded from the analysis.

[2] There are Palestinian villages (for example: the Kafr Aqab area in the north, Shuafat refugee camp in the north-east, Arab al- Swachra, Um Lyson and Umm Tuba in southeast of Jerusalem) that were annexed to the city of Jerusalem after the Six-Day War. Although they are technically within the municipal jurisdiction of Jerusalem, in many respects they are not an integral part of the city of Jerusalem and therefore they were not included in the study. It is also important to note that Jewish citizens rarely enter these locations and therefore there is an absence of potential victims. The study also did not include the areas adjacent to the security checkpoints on the city's boundaries which border the Palestinian Authority, since they are also not an integral part of the city. See: The Jerusalem Institute for Policy Research—http://en.jerusaleminstitute.org.il/.

[3] Most of the attackers who carried out the 249 attacks were killed or arrested (and then interrogated) following their attacks. As such, their identity is known. In a few cases, the attackers were not apprehended but the investigation following the attack clearly determined that the attack was carried out by Arabs targeting Jews. Not included in this study were attacks where there was uncertainty regarding whether they involved an Arab terrorist targeting Jews.

[4] A form of irregular warfare in which a small group of paramilitary combatants use the classic strategy of hit and run warfare while taking advantage of some form of sovereignty or control over a defined geographical area and its population (Martin 2016).

and differ significantly from the more classic terrorist activity which are analyzed in this study. Hundreds of additional 'security events', such as Molotov cocktails and rock throwing were also excluded from the analysis since the vast majority of these events could be classified as civil unrest, which also differ substantially in the four pillars of the opportunity from classic terrorist attacks.

In line with the existing literature on crime and place, we constructed street segments as being those sections of road that exist between two intersections on the street grid, including both sides of the street (Groff et al. 2010; Weisburd and Amram 2014; Weisburd et al. 2012). Within the Municipal jurisdiction of Jerusalem, there are 22,512 street segments, with a total length of 1516 km. In the area selected for the study there are 16,864 street segments totaling a length of 1061 km.[5] The exact location within the borders of the street segments was found in 196 out of 249 attacks and was geo-coded to the precise location of the attack. In 45 of the attacks only the location of the street, but not the exact location of the attack was found. In these cases, we geo-coded the event to the mid-point of the street length. Since the vast majority of those particular streets were not long, the presumed point marked as the attack location, is either inside the street segment where the attack actually took place or directly adjacent to it. For the remaining 8 terror attacks, we were only able to identify the neighborhood where the attack took place. While these cases were not mapped, there was enough information to determine that none of these 8 events occurred in close proximity to any of the other attacks. The significance of this being that they occurred in a street segment in which there were no other attacks. Hence, it was still possible to include these events in calculating the distribution and concentration of attacks in street segments.

Research Method

All of the 241 of the 249 attacks for which sufficient data existed were geo-coded and mapped on street maps of Jerusalem using in ArcGis 10.2 software. Although the number of terror attacks represent an extremely large number of attacks for one city, it is still a very small number relative to other studies of more high-volume crime, or general crime, which may include tens of thousands of events. As Braga et al. (2010) explain, in situations where the number of incidents is smaller than the number of street segments, even random distribution will produce a false perception of concentration and clustering. In the current case, with the integral part of the city of Jerusalem being comprised of 16,864 street segments, even if each of the 249 attacks occurred in a unique location, the maximum possible distribution of attacks theoretically possible (249/16,864) would mean that 100% of the attacks would occur in 1.5 percent of the street segments. In other words, even if each attack were to occur in a different location, all events would occur in only 1.5% of the street segments, giving a misleading impression of a large concentration.

The issue of having fewer incidents than street segments has already been dealt with in prior studies. While a number of suggestions have been made as to how to deal with such a situation, it remains that there is no preferred approach (Curiel and Bishop 2016; Curiel et al. 2018; Lee 2017). While we could simply state that 'all events were concentrated in X street segments out of a possible Y street segments', this would be overly descriptive and would fail to help us to understand and appreciate the actual levels of concentration.

[5] Not including those Arab villages annexed to Jerusalem (see footnote 2 page 11).

One approach would be to compare the minimal concentration which is the number of the attack locations, assuming each attack occurred in a different location, divided by the total number of street segments (in our study dividing 249 by 16,864 = 1.48%) to the observed concentration, which is the number of street segments that had one or more attacks, divided by the total number of street segments. The larger the gap between the minimal possible concentration and the observed concentration, the greater the concentration would be. However, this approach still does not accurately describe the observed concentration, only the difference between the observed and minimal concentration. Another approach would be to represent the number of events (N = 249) as 100%, and calculate the accumulative distribution over the percentage of street segments up to 100%. Given that the maximum distribution would be 249 streets segments, in order to calculate the concentration, we would divide the actual number of street segments that had one or more attacks by the maximum distribution (249). Again, this approach remains highly descriptive.

In a recent article, Bernasco and Steenbeek (2017) proposed an alternative approach which incorporates the basic ideas of those noted above but neatly summarizes the observed concentrations into a summary statistic; a generalized Gini coefficient. The Gini coefficient is a conventional measure of concentration that varies from 0 to 1. As the Gini coefficient is traditionally used to examine inequality, in the context of spatial concentration a Gini of 0 would indicate that all events have a distribution of perfect equality, whereas a Gini of 1 would indicate that all events were limited to one, single place. However, relative to other crimes, terror attacks (c) are rare events, and represent a much smaller number than the number of places (n) where an attack could potentially occur. Therefore, most of the street segments have no attacks and that in itself increases concentration. In any situation where the number of places is larger than the number of events, the Gini coefficient would be biased. Taking this issue into consideration, Bernasco and Steenbeek (2017) detail the approach to calculating the generalized Gini coefficient that accounts for the fact that a large number of street segments have zero attacks. The generalized Gini (G') corrects for the overestimation that appears as a result of there being fewer attacks (C) than the number of street segments (N) by adding this factor into the equation.

$$G' = MAX\left(\frac{n}{c}, 1\right)(G - 1) + 1$$

When plotting the accumulative distribution with a Lorenz curve, this approach replaces the line of perfect equality—which is not achievable—with a line of maximal equality, which has a slope of n/c making a downward correction to the original Gini. Since this study aims to test the applicability of the "law of crime concentration" to terrorism, we evaluate the concentration of terrorism utilizing a traditional and more narrative approach complemented by this statistical approach.

Findings

Did Terror Attacks Concentrate at Street Segment Hot Spots?

The 249 attacks took place at 152 street segments. While nineteen street segments had two or more attacks, 133 street segments had one attack. The Damascus Gate hot spot was the

Table 1 Attack hot spots

The hot spot	Cumulative street segments	Cumulative% street segments	Number of attacks	Cumulative # of attacks	Cumulative % of # attacks
Damascus gate	1	0.40	31	31	12.450
French hill junction	2	0.80	14	45	18.072
HaNeviim St.	3	1.20	11	56	22.490
Hagai St.	4	1.61	7	63	25.301
Lions' Gate	5	2.01	7	70	28.112
Promenade Armon Ha Naziv	6	2.41	6	76	30.522
IDF square	7	2.81	5	81	32.530
Hospice junction	8	3.21	4	85	34.137
Temple mount	9	3.61	4	89	35.743
Herod's gate	10	4.02	4	93	37.349
Shimon Ha tzadik	11	4.42	4	97	38.956
Bar-Lev avenue	12	4.82	3	100	40.161
Liberty bell garden	13	5.22	3	103	41.365
Central bus station	14	5.62	3	106	42.570
Pat junction	15	6.02	2	108	43.373
The new gate	16	6.43	2	110	44.177
The Russian compound	17	6.83	2	112	44.980
Jaffa Heshin junction	18	7.23	2	114	45.783
Samuel Ha tzadik	19	7.63	2	116	46.586
other locations with 1 attack	152	61.04	133	249	100

sight of the largest number of attacks and totaled 31 events. At the French Hill Junction, there were 14 attacks, and 11 attacks occurred at HaNeviim Street, located adjacent to the Damascus Gate. Another hot spot located adjacent to Damascus gate, Hagai Street, witnessed 7 attacks, while not far away at the Lion's gate there were another 7 attacks (see Table 1).

Following the Lorenz curve, a total of 25% (N = 63) of the attacks occurred in just 4 hot spots, representing 1.6% of the maximum number of street segments, while 43.4% (N = 108) of the attacks occurred in just 15 hot spots, representing 6% of the maximum number of street segments. The generalized Gini coefficient for the concentration of all terror attacks at street segments in Jerusalem was $G' = .61$ (See Fig. 1), indicating that the concentration is more than double that of pure randomness.

Another way to describe this finding is that 100% of all attacks (249) occurred at only 152 attack spots which are 61.04% of 249 (maximum possible number of places).

Did the Attacks Concentrate at the Same Hot Spots Repeatedly over Time?

When looking at the hot spots that suffered from three or more attacks during the 18-year observation period, we see that the attacks repeatedly occurred at the same hot spots. At the Hagai Street hot spot, 7 attacks occurred over 17 years; at the Damascus Gate there were 31 attacks spread over 16 years; at the French Hill Junction there were 14 attacks over a period of 16 years. Also, at HaNeviim St. and Armon Hanatziv promenade hot spots, 11

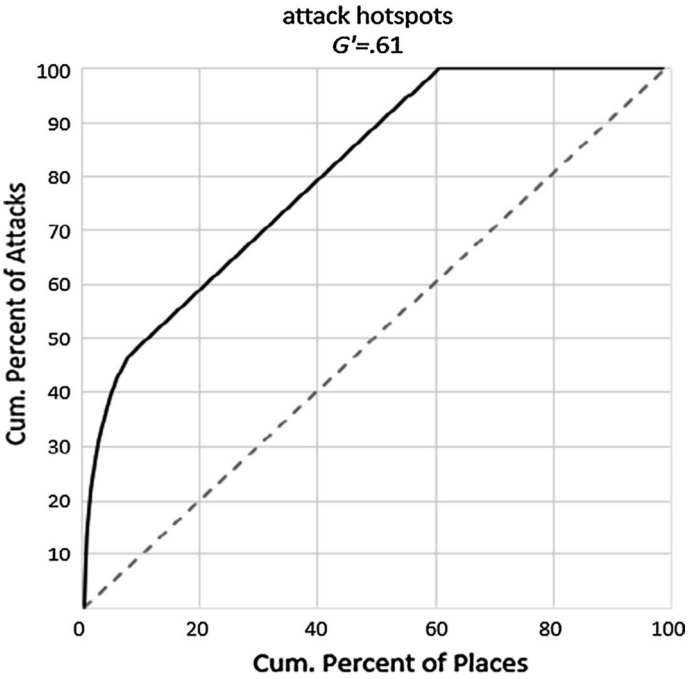

Fig. 1 Generalized Gini Coefficient and lorenz curve for attacks in Jerusalem 2000–2017

and 6 attacks were respectively spread over 16 years. An additional seven hot spots suffered from attacks that were spread over a period of 10 to 15 years. The Central Bus Station hot spot suffered from 3 attacks over 7 years, and the Hospice Junction hot spot witnessed 4 attacks over a 2-year period. This finding that the attacks distributed over years, reveals that the concentration of terror attacks in a limited number of street segments is stable over time and is not a sporadic episode (Table 2).

Are There Certain Identifiable Characteristics of Terror Hot Spots and do These Hot Spots Attract Particular Types of Attacks?

When focusing on the characteristics of the sites of the attacks, certain characteristics related to situational opportunities can be identified. Many of the hot spots are located near bus stops and public facilities, along or in close proximity to the "seam line" represented by the north–south major road #60 known as Route 1 that runs along the pre-1967 border between the eastern and western parts of Jerusalem. The seam line path functions as both an edge which separates between two distinct social conceptual and perceptual spaces–Jewish and Arab homogeneous neighborhoods—and a pathway, given its function as a main travel artery. As can be seen from Fig. 2 (below) the geographical distribution of attacks is significantly concentrated on the seam between the Jewish and Arab neighborhoods. The four most chronic hot spots are located along the path of Route 1, and three of them are clustered in very close proximity to one another (see Fig. 3). This area represents an edge in which the two populations meet on their way to and from significant locations in the Old City of Jerusalem.

Table 2 The number of attacks per year and the total number of wounded and killed at the Jerusalem terror hot spots

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Attacks	Wounded	Killed
Damascus Gate	0	0	2	0	3	0	1	0	1	0	0	0	1	1	2	6	10	4	31	40	4
French Hill Junction	1	4	4	1	3	0	0	0	0	0	0	0	0	0	0	1	0	0	14	182	20
HaNeviim St.	0	1	2	0	0	0	1	0	0	0	0	0	1	0	2	3	1	0	11	26	1
Hagai St.	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	0	2	1	7	7	0
Lions' Gate	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	1	2	7	10	3
Armon HaNaziv Promenade	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	6	20	5
IDF Square	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	2	0	1	5	18	1
Hospice Junction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	4	6	2
Temple Mount	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0	0	0	4	2	0
Herod's Gate	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	4	4	2
Shimon HaTzadik	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	4	18	2
Bar-Lev Ave.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	7	2
Liberty Bell Garden	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	3	62	8
Central Bus Station	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	3	67	1
Pat Junction	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	51	19
The New Gate	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	0
Russian Compound	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	0
Jaffa Heshin Junction	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	32	0
Samuel HaTzadik	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	6	1
Total	1	8	15	1	11	4	5	0	4	1	1	1	3	2	9	20	19	11	116	564	71

Table 3 The average number of wounded and killed at the hot spots in comparison to the other 133 locations which had only 1 attack each

The hot spot	Wounded	Killed	Average # of wounded	Average # of killed
Damascus gate	40	4	1.29	0.13
French hill junction	182	20	13.00	1.43
HaNeviim St.	26	1	2.36	0.09
Hagai St.	7	0	1.00	0.00
Lions' Gate	10	3	1.43	0.43
Promenade Armon Ha Naziv	20	5	3.33	0.83
IDF square	18	1	3.60	0.20
Hospice junction	6	2	1.50	0.50
Temple mount	2	0	0.50	0.00
Herod's gate	4	2	1.00	0.50
Shimon Ha tzadik	18	2	4.50	0.50
Bar-Lev avenue	7	2	2.33	0.66
Liberty bell garden	62	8	20.66	2.66
Central bus station	67	1	22.33	0.33
Pat junction	51	19	25.50	9.50
The new gate	1	0	0.50	0.00
The Russian compound	5	0	2.50	0.00
Jaffa Heshin junction	32	0	16.00	0.00
Samuel Ha tzadik	6	1	3.00	0.50
116 attacks at the 19 hot spots	564	71	4.86	0.61
133 locations with 1 attack each	1442	170	10.84	1.28

One characteristic that differentiates between the different types of hot spots is lethality. Among street segments with two or more attacks, the average number of individuals who were killed was 0.61, and the average number of individuals injured was 4.86. On average, the 116 attacks that occurred in the 19 hot spots with 2 or more attacks were approximately 50% less lethal. The number of individuals who were injured in the 133 attacks that occurred in unique street segments that were not hot spots was 10.84 and the average number of the people that were killed was 1.28 (see Table 3).

Lethality appears to be related to the type of attack, weapons used, and whether the attacker acted alone. Among the 249 attacks, 122 attacks were carried out with tools (such as knives, axes etc.) which were used as weapons (Table 3). For all but one of the attacks the attackers' identities are known and they are classified as having been lone-attackers without organizational affiliation.[6] Indeed, the ratio of lone attackers using tools as weapons is much higher at hot spots—67% (78 out of 116)—than at street segments with only one incident (33%) (Table 4).

For attacks involving explosives (N = 71), an attack type more characteristic of organizational-led attacks, this trend is reversed. The ratio of explosive attacks at the hot spots is

[6] These attackers did not belong to any of the known local organizations and are therefore believed to have lacked formal infrastructure supporting the attack.

Table 4 The weapon used in the Jerusalem terror attacks

Weapon	Stabbing/assault	Explosive	Shooting	Run over	Total
Damascus gate	24	2	5	0	31
French hill junction	2	6	5	1	14
HaNeviim St.	8	3	0	0	11
Hagai St.	7	0	0	0	7
Lions' Gate	5	0	2	0	7
Armon HaNaziv Promenade	5	0	0	1	6
IDF Square	3	1	0	1	5
Hospice Junction	4	0	0	0	4
Temple Mount	4	0	0	0	4
Herod's Gate	3	0	1	0	4
Shimon HaTzadik	2	0	0	2	4
Bar-Lev Ave.	2	0	1	0	3
Liberty Bell Garden	2	1	0	0	3
Central Bus Station	2	1	0	0	3
Pat Junction	1	1	0	0	2
The New Gate	2	0	0	0	2
Russian Compound	0	2	0	0	2
Jaffa Heshin Junction	1	1	0	0	2
Samuel HaTzadik	1	0	0	1	2
Total for the 116 hot spot attacks	78	18	14	6	116
Total for the 133 other attacks	44	53	25	11	133
Total	122	71	39	17	249

only 16% (18 out of 116) in comparison to the ratio of explosive attacks at the other street segments in which only one attack occurred, being 40% (53 out of 133).

Discussion

To the best of our knowledge, this study is the first to examine whether terror attacks in a single city follow the law of crime concentration at the street segment level. As has previously been noted, such analyses have been hindered by the issue of low base-rates and short observation periods. The case of Jerusalem, with 249 attacks over an 18-year period, which included a wide variety of terror attack types and offender types, presented a unique opportunity to test the theory. Following the Lorenz curve, the difference between the observed concentration of attacks in Jerusalem which occurred at 0.9% of the street segments (152 attack spots out of a 16,864 street segments) compared to the maximum possible concentration of 1.48% of the street segments, illustrates that the observed concentration is greater than double that of pure randomness. In this regard, our analysis found that 63 (25.3%) attacks, occurred in just 4 hot spots (1.6% of 249 possible attacks locations), while 43.4% of the attacks occurred in just 15 hot spots, or 6.2% of the possible number of attack locations. The observed concentrations at both the 25% and 50% cutoff demonstrate

great consistency with the findings of Weisburd (2015) regarding the accumulative distributions of crime in major U.S. cities.

The use of the generalized Gini coefficient enabled us to summarize the overall concentration in a situation in which the number of events was smaller than the number of street segments. The identification of a $G' = .61$ denotes a modest degree of concentration. While studies of general crime have found Gini coefficients ranging from .70 to .80 (Bernasco and Steenbeek 2017; Schnell et al. 2017; Steenbeek and Weisburd 2016; Eck et al. 2017; Hardyns et al. 2018; Favarin 2018), research suggests that the level of aggregation matters. For example, De Moor et al. (2018) found Ginis of .43, .54, .55 and .70 for individual crime types, compared to a .56 for all crime types combined. In another study, Vandeviver and Steenbeek (2017) found Ginis ranging between .50 and .65 when limiting their analysis to residential burglaries in Antwerp, Belgium between 2005 and 2016. The implications of the Gini coefficient is that it can be compared to other concentrations for other types of crimes or even other types of phenomena, even where the number of events is equal to or greater than the number of places. That is, the standardization of the generalized Gini coefficient enables us to compare the concentration of terror attacks in Jerusalem with the concentration of other types of offences in other places. For example, our Gini of .61 shows that terror attacks in Jerusalem are slightly less concentrated than robberies in the Hague (G = .72) (Bernasco and Steenbeek (2017), but more concentrated than lethal violence in Belgium (De Moor, et al. 2018).

In examining stability over time, a significant proportion of terrorist attacks in Jerusalem occurred repeatedly at the same small number of street segments. Similar to previous studies of crime, it was found that the concentration of terror attacks in a small number of street segments is relatively stable over time and not randomly distributed. According to rational choice perspectives of terror, which find there to be no fundamental differences in the decision-making processes and basic motivations of regular criminals and terrorists, (Clarke and Newman 2006; Perry and Hasisi 2015; Perry et al. 2019), the spatial circumstances of a particular place increase the likelihood that it will be chosen as a target. Like regular criminals, terrorists evaluate the opportunity structures of specific places, weighing the circumstances in light of the expected outcomes and rewards. As such, the identification of spatial–temporal stability confirms what could be hypothesized; that while Jerusalem includes many potential targets, various essential characteristics increase the opportunities at specific places.

For example, edges and pathways, especially when a street segment can be characterized as serving both populations (such as the Damascus Gate), are more attractive for terrorist attacks. Indeed, this study presents several hot spot characteristics, which most likely have been part of the attackers' considerations when choosing these street segments for repeated attacks. When one tries to understand why terrorists repeatedly select certain locations to carry out their attacks, it might be reasonable to assume that these particular hot spots provide the attacker with the opportunity to cause maximum harm to human life and injure as many people as possible (Clarke and Newman 2006). According to the findings of this study, the attacks that took place in the 19-street segment hot spots were about half as lethal as the other 133 attacks that occurred.

These findings suggest that while causing maximum harm is likely to be an important objective at least for some of the attackers, it might not be their primary consideration when choosing a specific place to carry out their attack (Perry et al. 2017). Lone actors may prefer a target with which they are more familiar, compared to those who have more resources and an organization infrastructure backing them (Perry et al. 2019). Prior studies

have found that lone-actor terrorists are overall less lethal than organizational based attackers. The lack of resources has generally been viewed as a contributing factor to this observation. As such, familiar locations that present better opportunities to attack are very often chosen by lone attackers and since they represent a large number of attackers, these places become hot spots.

This assumption is also in line with previous studies that demonstrated the preference of many criminals and terrorists to work with what they know and operate in familiar locations (Farrell and Pease 2001; Perry et al. 2017, 2019; Weisburd and Telep 2012). Indeed, the findings of this study demonstrate that most of the attacks that were carried out at the identified hot spots were less complex and not as lethal as attacks in other street segments. Due to limited resources and the difficulties in obtaining firearms and explosives, tools used as weapons, including bladed weapons and vehicles, are more characteristic of lone actor attacks. Firearms and explosives are more typical of organizational led terrorist attacks (Clarke and Newman 2006; Gill et al. 2014; Perry et al. 2019) and this is especially true for all suicide bombings attacks.[7]

Attacks using firearms and explosives, while more lethal, were less likely to occur in hot spots than attacks utilizing tools as weapons. These findings can explain why the typical attack at hot spots is significantly less lethal than the typical attack at the other street segments. The one significant exception is the French Hill Junction, which is located on the traffic route a path between the Palestinian Authority and Jerusalem. This hot spot is easily accessible to Palestinians and is a location frequented by a large number of Jews and a few Arabs during many hours of the day. Apparently for these reasons, this hot spot was frequently used by terrorist organizations as a target for carrying out firearm and suicide bombing attacks. Between December 2000 and September 2004, terrorist organizations carried out six suicide bombings and five shooting attacks at the French Hill Junction hot spot. Consequently, although hot spots are more frequently used by the lone attackers, in certain places they can offer a good situational opportunity for organizational terrorist attacks as well.

The findings raise the question regarding which situational opportunities characterize these hot spots and could explain why they were chosen for attacks. Previous studies argue that the situational opportunities that facilitate lone actor attacks are different from those that facilitate attacks carried out by terrorist organizations (Freilich and Chermak 2009; Gill 2015; Kennedy 2010; Spaaij 2012; Perry et al. 2019). The more limited resources available to lone attackers—including weapons and transportation—have a direct effect on the selection of targets (Clarke and Newman 2006). As Song et al. (2017) detail, edges are more likely to experience crime than general nodes. Edges are more likely to be characterized by well-known crime generators and attractors such as bus stops and public facilities. These edges are generally quite familiar to offenders as part of their routine activities. In Jerusalem, these edges are often pathways as well, and denote main thoroughfares, as well as edges between residential areas characterized by ethnic segregation. As Brantingham and Brantingham (1993) find, high crime places are often locations that provide special opportunities for offending across time, where offenders' routines bring them to converge with potential targets in time and space. Given the nature of terrorism, and its general focus on targeting members of specific groups, offenders may need to travel to edges in order to find suitable targets.

[7] See the Israeli Security Agency (ISA) site at https://www.shabak.gov.il/publications.

An additional feasible explanation as to the significantly lower lethality of attacks at hot spots, is connected with the characteristics of the counter measures. Procedures adopted by the police and private security, as well as vigilance and precautions taken by the population who adapted their behavior in response to the attacks which occurred at the hot spots might help explain this phenomenon. An example of this can be seen, at the Damascus Gate where 31 of the attacks took place. The police have a constant presence there and have adopted counter measures that significantly reduce the harm. The average number of individuals who were injured in the 31 attacks at the Damascus Gate was 1.29 and the average number of the people killed was 0.13. In comparison, in the 133 attacks that did not occur at hot spots and did not receive special treatment from the police, the average number of individuals injured was (10.84) and killed (1.28). Another example is that of the French Hill intersection, whose characteristics and location make protection complex. Located near a main hospital, university, and on and off ramps from a major highway, the junction also represents an edge between predominantly Arab and Jewish neighborhoods. After some initial failures, Israeli security tactics managed to secure the area and drastically reduce the number of attacks (See Table 2). While lower lethality might be related to the measures adopted by security forces, it is important to consider that it may also be related to extra precautions taken by the population at known hot spots and the fact that hot spots are more likely to witness the already less lethal attacks of lone actors.

Our findings suggest that the spatial characteristics of most of the terror hot spots in Jerusalem offer specific situational opportunities conducive to terror attacks. As per previous studies, additional situational opportunities that may act as attracters to potential attackers could be: the accessibility of the location, presence of potential victims, familiarity with the area, possible escape routes, hiding places, potential collaborators, and the lack of suitable guardianship (Brantingham and Brantingham 1993; Becker 2014; Gill et al. 2014; Perry et al. 2019). The majority of the hot spots identified can be seen as displaying such characteristics. This demonstrates the important of applying lessons from environmental criminology to terrorism.[8]

Policy Implications

Just as certain spatial characteristics of hot spots increase the situational opportunities for attacks, changes to these characteristics could contribute to prevention and reduction of future events. As Clarke and Newman (2006) detail, counter-terrorism through situational prevention is one of the most effective preventative measures. The effectiveness of place-based interventions has been studied extensively and generally speaking, there is robust evidence that place-based interventions can be effective without displacing crime to nearby areas (Braga et al. 2010). Among the few studies that examined the effectiveness of place-based interventions in counter terrorism, in addition to overall effectiveness (Lum et al. 2006), displacement of attacks was not found. These

[8] This is especially noticeable at the bottleneck passages on the way and inside the Old City where many of the attacks have been carried out. The Damascus Gate for example is used for passage between the Old City and the East Jerusalem neighborhoods adjacent to it and is open for pedestrians only. Tens of thousands of Palestinians from the West Bank pass through the Damascus Gate in order to pray at the Al-Aqsa mosque. This gate is also the entrance which is used by many Jews on their way to the Western Wall and the Old City. https://he.wikipedia.org/wiki/%D7%A9%D7%A2%D7%A8_%D7%A9%D7%9B%D7%9D.

studies conclude that the situational opportunities that exist in alternative, untreated locations were already perceived as being less favorable (Hsu and Apel 2015; Perry et al. 2017). The situational approach does not overlook offenders or their motivations (Braga et al. 2017), and it is certainly vital in reducing terrorist motivations in the long run. Yet, it is more feasible to minimize the opportunities for attacks by implementing situational prevention methods such as hot spot policing (Perry and Hasisi 2015; Perry et al. 2017). The integration of different strategies, namely by minimizing opportunities via problem-oriented policing in hot spots, has been shown to be highly effective in crime prevention.

Applying a problem-solving approach in such instances can help law enforcement to understand the particular situational and social factors that result in these attack concentrations. An in-depth analysis of these factors and the development of a creative response (as well as precautions taken by the population) helped the security forces in Jerusalem to prevent, or at least to minimize the damage of terror attacks. This study's findings reveal that police activity in Jerusalem was effective in preventing attacks at some of the hot spots (the French Hill Junction, for example) and reducing the damage (at the Damascus Gate, where many terrorists continue to attack and did not displace their attacks to other locations). Effective situational crime prevention measures of target hardening of public transportation have also been found to be effective in preventing run over attacks in Jerusalem (Perry et al. 2019).

Based on the findings of the current study, the implemention of prevention measures focusing on just four chronic hot spots can have an impact on the sites where 25% of the attacks took place. As opposed to random patrol strategies, hot spot policing approaches have been found to be highly effective in reducing ordinary crime, with little to no displacement. In the context of terrorism prevention, in Jerusalem, placing a constant presence at a few specific points, together with other situational prevention methods such as private security, the creation of fortifications, obstacles, and barriers, as well as increasing lighting, surveillance, and access control have been proven to be quite valuable. Terror attacks, especially those carried out by lone-actors have been successfully prevented or otherwise had their lethality mitigated by the integration of such methods.

Limitations

While this study has provided important insights into the spatial characteristics of terror attacks at the local, street-segment level, there are some inherent limitations to the generalizability of the findings. Firstly, while the Israeli case has often been referred to as a case study, or natural "laboratory" from which to draw lessons, it is still unknown as to how applicable findings such as the ones from the current study would be to other western, democratic contexts. Among other elements, the geo-demographics of Jerusalem are certainly unique. Nevertheless, as previous studies have pointed out, law enforcement in Israel is sufficiently similar to that of other democracies in the realms of legal practices and supervision to warrant attempts to draw lessons from it (Perry and Jonathan-Zamir 2014; Weisburd et al. 2009).

Secondly, as noted above, our data still suffers from the issue of low base-rates and short observation periods that characterizes and limits terrorism research. It is

important to bear in mind that while Jerusalem has witnessed a relatively large number of terror attacks compared to other Western cities (Frielich 2017), the number of such attacks in Jerusalem is still relatively small when compared to traditional studies of crime and place that may include many thousands of incidents. While we acknowledge that this is an issue that exists in our study, our analytic strategy was specifically selected in order to account for this.

Conclusions

Like many terrorism studies, we examined terrorism as representing a single category of crime (Gill et al. 2017; Perry et al. 2019). However, we did attempt to take into consideration the differences between the various types of attacks while scrutinizing the various hot spots. Future research should seek to deepen the analysis of terrorism and place by examining individual types of attacks and the characteristics of the different hot spots that typify them. Such research should also seek to investigate the characteristics that provide favorable opportunities and make the hot spots more attractive than other street segments for terrorist attacks. Further exploration of terror hot spots will help obtain a better understanding of the situational and environment opportunities of these locations, so that more effective prevention strategies can be implemented. It would be beneficial if future studies attempt to deepen the understanding regarding concentrations of terrorism by studying the geometry of crime, analyzing activity nodes, paths and edges as well as by examining terror generators and attractors.

Appendix

See Figs. 2 and 3.

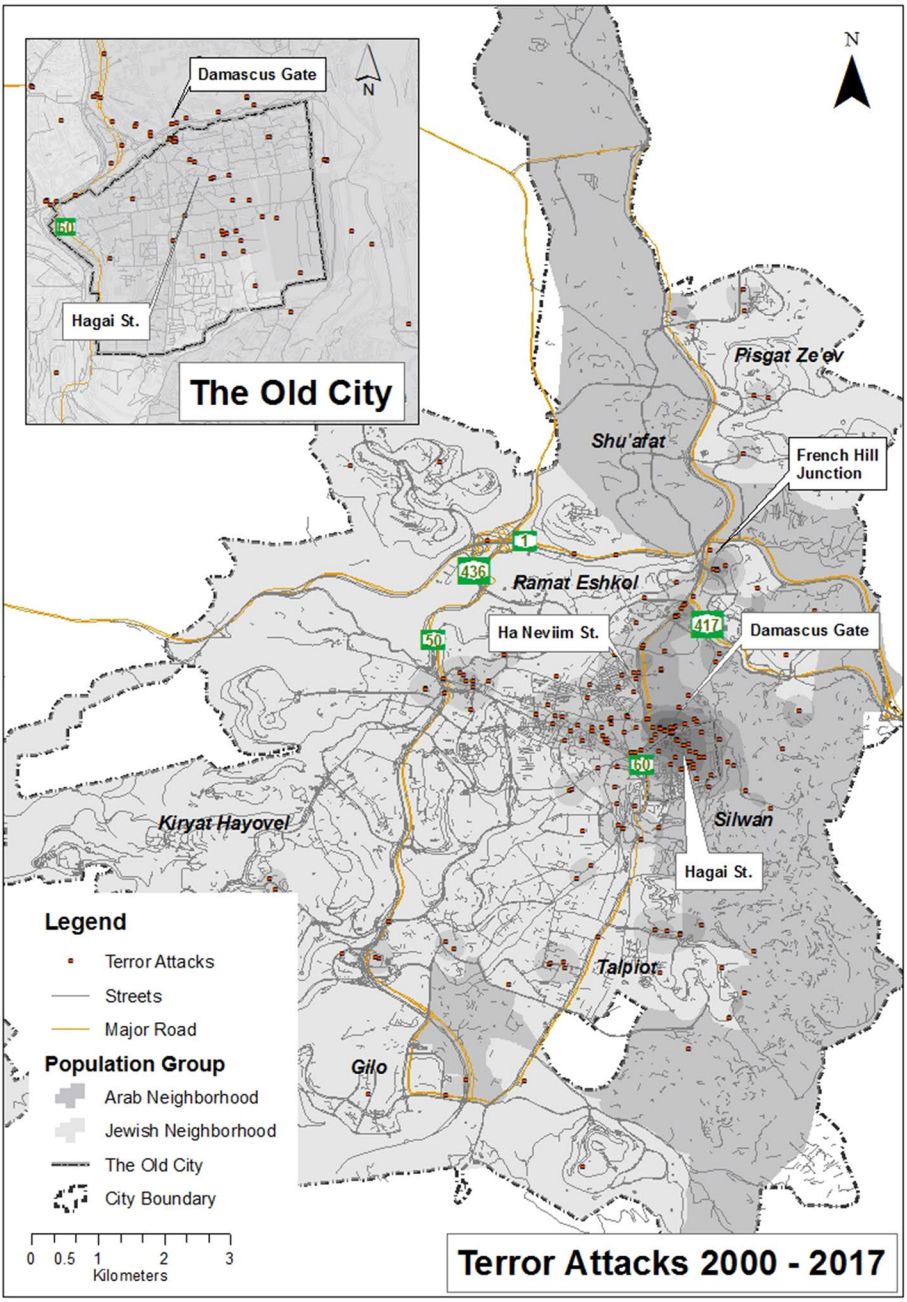

Fig. 2 Terror hot spots in Jerusalem

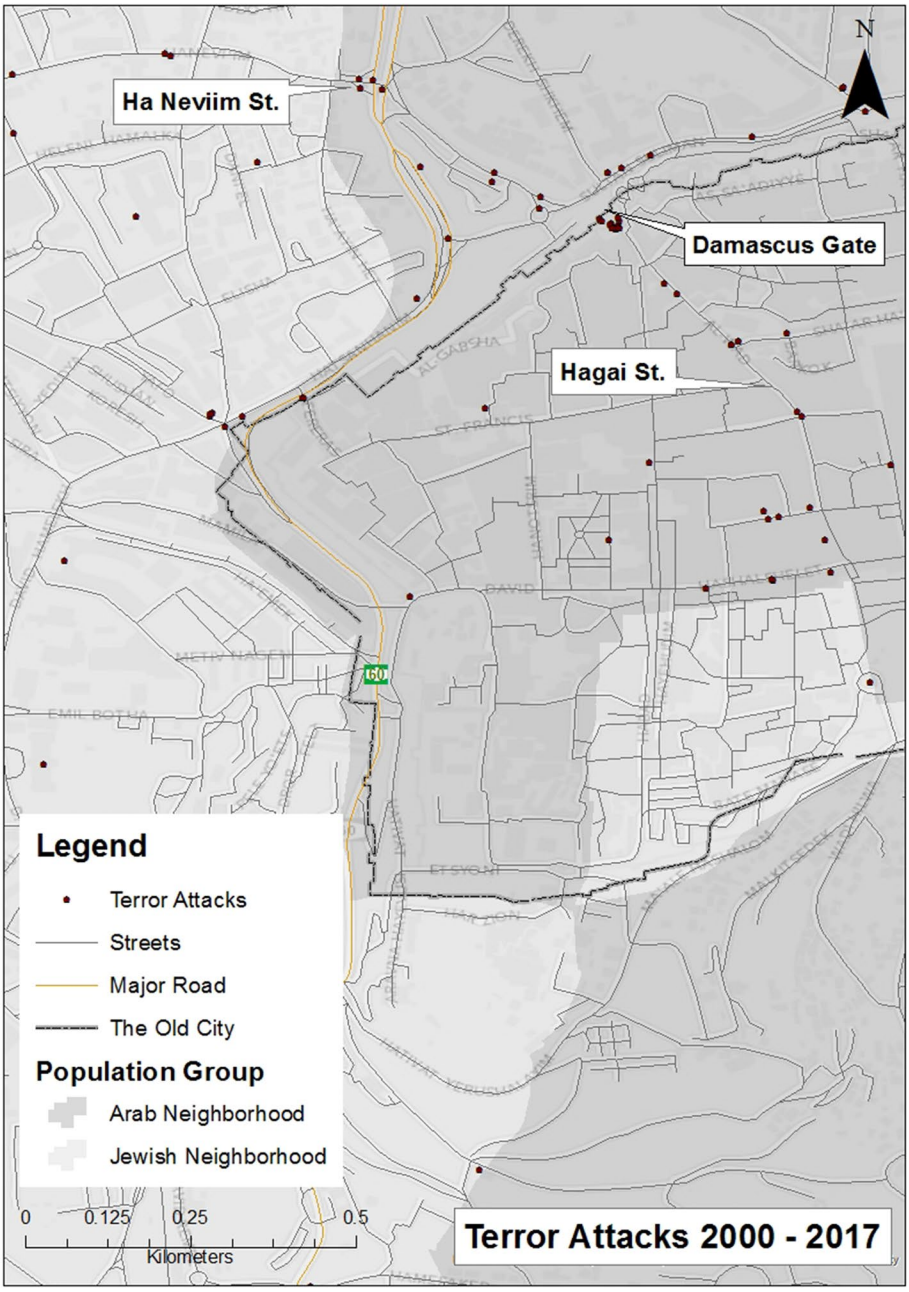

Fig. 3 The proximity of three of the four main terror hot spots in Jerusalem

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