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Modelling the spatial decision making of terrorists: The discrete choice approach

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ABSTRACT

This is the first study to apply a discrete choice model to understand terrorist spatial decision making. The findings support the proposition that terrorists make decisions that are guided by rationality and act in a similar way to urban criminals. A conditional logistic regression ascertained which characteristics increased the likelihood that an area would be selected as a target, using a dataset of attacks carried out by the Provisional Irish Republican Army in Belfast over a twenty-year period. An increase in distance from the terrorist's home to the attack site decreased the likelihood that an area would be chosen and an area was more likely to be chosen if it contained a major road, police station or military base.

1. Introduction

A full understanding of terrorism[1] involves not only examining *why* perpetrators commit such violence but also *how*. Increasingly, studies examine the behaviours underpinning a terrorist attack using approaches developed for the study of the ordinary criminal (Marchment & Gill, 2018). Rather than dramatically depicting perpetrators as irrational and blood thirsty, studies depict them as rational and calculating decision makers seeking political, social and religious change (Clarke & Newman, 2006). Much like ordinary criminals, they make a series of cost-benefit analyses to judge whether a particular offence is worth committing. Unlike ordinary criminals, their decision also has to fit their overarching ideological goals. Their rationality is bounded by a number of individual factors such as risk sensitivity, group guidance, prior experience, and personality (Gill, Marchment, Corner, & Bouhana, 2018). Geographical proximity is an additional factor which has received some empirical support lately (Gill, Horgan, & Corner, 2017; Marchment, Bouhana, & Gill, 2018). In treating distance as a dependent variable however, such studies are limited. They assume targets are spatially uniformly distributed. They also overlook potential targets that could have been chosen, but were not. Ideally, distance should be treated as an explanatory variable, rather than the dependent variable (Kleemans, 1996) and should be used alongside other choice criteria, such as the connectedness of the area, to determine why the chosen target was selected above other similar targets (Bernasco & Block, 2009).

To overcome similar limitations of volume crime research, Bernasco and Nieuwbeerta (2005) applied McFadden's (1974) discrete choice model to the spatial-decision making of urban burglars. Stemming from the field of economics, this approach allows target selection analyses to simultaneously consider multiple factors including the chosen target destination, areas that could have been chosen but were not, the likely origin of offenders and their perceptions that affect decision making. This approach is now well-established in the study of a variety of urban crimes (see Bernasco, Ruiter, and Block (2017); Bernasco, 2006; Bernasco & Block, 2009; Bernasco, 2010a,b; Bernasco and Kooistra, 2010; Bernasco, Block, & Ruiter, 2012; Bernasco, Block, & Ruiter, 2013; Baudains, Braithwaite, & Johnson, 2013; Townsley et al., 2015; Townsley, Birks, Ruiter, Bernasco, & White, 2016; Johnson & Summers,

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[1] Terrorism is a hugely contested concept with diverging opinions across academia, government and the general public. The term has been applied to many manifestations of violence and this has changed drastically over the course of the last 200 years. Academic terrorism definitions differ on issues concerned with who the perpetrator is (state vs. non-state actor) who the target of violence is (non-combatants only vs. broader boundaries), ideological motivations (political vs. non-political), and a number of other criteria (Schmid, 2004). Furthermore, the public's perception of whether an attack is deemed terrorism or not is impacted by attributes of the incident including the type and severity of the violence, motive and the social categorization of the perpetrator(s) (Huff & Kertzer, 2018; D'Orazio & Salehyan, 2018). A consensus definition is non-existent. For the purposes of this paper we define terrorism as using the same criteria as the Global Terrorism Database. A terrorist attack is the *"actual use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation"* (LaFree & Dugan, 2007). Multiple criteria must therefore be present: the attack must be intentional, involve some level of violence and perpetrator by a non-state actor, aim to attain a political, economic, religious or social goal, and occur outside the context of legitimate warfare activities. For a full elaboration of the history and debates in defining terrorism, see Schmid (2004). For the purpose of this study, we narrow our focus to bombings and shootings conducted by the Provisional Irish Republican Army.

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2015; Vandeviver, Neutens, Van Daele, Geurts, & Vander Beken, 2015; Menting, Lammers, Ruiter, & Bernasco, 2016; Bernasco et al. (2017) Frith, Johnson, & Fry, 2017; Lammers, 2017), however is yet to be applied to terrorist acts.

This study applies the discrete choice model to 150 attacks committed by core members of the Provisional Irish Republican Army (hereafter, PIRA). PIRA's attacks were often dependent on the decision making of the individual, operating with a degree of autonomy and were not carried out unless there was a high probability of success (Horgan & Taylor, 1997). The longevity of their campaign, and the variety of attacks incorporated throughout, also provides a wide scope for data. The results suggest that terrorists are similar to traditional criminals in their decision making and they are influenced by spatial context, such as the distance from their home location to the attack location, or the presence of a premises relevant to their ideology.

1.1. Theory

The rational choice perspective of crime, as proposed by Cornish and Clarke in 1986,[2] assumes offenders are rational and purposeful in their decision making. An offender acts in their own self-interest while calculating the costs and benefits of each possible alternative, before making a choice that offers the greatest benefit and lowest cost (Cornish & Clarke, 1986). Full rationality models are unrealistic, as rationality is subject to limits and is guided by time, effort, experience and knowledge (Beauregard, Proulx, & Rossmo, 2005; Clarke & Felson, 1993). Bounded rationality posits that crime is influenced by opportunities, and that the opportunities are dependent on the individual's environment (Simon, 1957, 1986). Although their knowledge of the associated effort, rewards and risks is imperfect, an offender will still attempt to maximise utility based on what they do know. The rational choice perspective has been useful in understanding political violence including terrorism (Clarke & Newman, 2006; Pape, 2005). Committing an act of terrorism, whether under the guidance of a wider network or as a lone attacker, is a purposeful behaviour that is guided by a rational of risk and reward (Crenshaw, 1981; Silke, 2001; Taylor and Horgan, 2006; Marchment et al., 2018; Gill et al., 2018).

The routine activities perspective describes the circumstances in which crime will occur (Cohen, Felson, & Felson, 1979). It extends the idea of bounded rationality into the physical world and suggests crime occurs when a motivated *offender,* a suitable *target* and a lack of a capable *guardian*, coalesce in time and space as individuals undertake their daily routines. Initially, this perspective examined traditional crimes such as burglary (e.g. Wright, Logie, & Decker, 1995), and shoplifting (e.g. Schlueter, O'Neal, Hickey, & Seiler, 1989) and later extended into other volume crimes such as drug dealing (e.g. Jacobs, 1996), white-collar crime (e.g. Paternoster & Simpson, 1993; Simpson, Paternoster, & Piquero, 1998), gang membership and violence (e.g. Spano, Freilich, & Bolland, 2008), organised crime (e.g. Kleemans, Soudijn, & Weenink, 2012), and carjacking (Jacobs, Topalli, & Wright, 2003). Further, it has been applied to non-acquisitive offences such as sex offending (e.g. Beauregard & Leclerc, 2007; Deslauriers-Varin and Beauregard, 2010) and violent offences (Topalli, 2005). The consensus is that offenders 'read' their immediate environment to guide their decisions in the commission of their offence.

Crime pattern theory builds upon both the rational choice and routine activities approaches by looking at crime events via a spatio-temporal lens (Brantingham & Brantingham, 1981). As an individual navigates their city or town on their journeys to and from their daily activity nodes (including places such as their home, places of work and/or education, leisure and recreation venues) they become more familiar with certain areas than others. Over time, this increased knowledge and familiarity become part of an individual's *awareness space*. If the individual has a criminal propensity, offences will occur when this awareness space overlaps with an opportunity for criminal activity. This leads to clear and consistent patterns in which individuals commit crime in areas that are known to them. To travel further beyond their awareness space to commit an offence would mean increased time and effort, as well as an increased level of perceived risk due to their unfamiliarity with the area. Offending in areas they are familiar with reduces the individual's risk of detection and interception. Like urban criminals, terrorists are limited by geographical constraints and keep the distances they travel to commit an attack minimal. Proximity to the target can been considered a key feature of target selection for both group and lone terrorists (Becker, 2014; Clarke & Newman, 2006; Cothren, Smith, Roberts, & Damphousse, 2008; Eby, 2012; Gill et al., 2017; LaFree, Yang, & Crenshaw, 2009).

1.2. The discrete choice approach

Collectively, rational choice perspectives, routine activity theory and crime pattern theory suggest offenders actively select areas and targets in a way that minimises effort and risks and maximises rewards (Johnson & Bowers, 2004; Felson, 2006). Research suggests that a multistage hierarchical process in decision making occurs, whereby offenders select an area that is deemed suitable for the offence, before selecting the specific target (Brantingham, 1978; Brown & Altman, 1981; Bernasco & Nieuwbeerta, 2005). The discrete choice approach (McFadden, 1974) can appropriately model between a set of two or more discrete alternatives, based on the utility the offender expects to derive from each alternative (Train, 2003). It is assumed the offender chooses the alternative that offers the best perceived utility, based on expected rewards, risks and effort. The discrete choice approach models target selection by considering multiple factors at the same time, and enables an impedance measure of distance to be treated as an explanatory variable. As well as the location that was selected for an attack, the model also allows for areas that were not chosen to be examined simultaneously, as well as also considering the origin of offender, and other defined factors that may affect decision making (Bernasco & Nieuwbeerta, 2005).

Bernasco and Nieuwbeerta (2005) first applied discrete choice modelling in the study of criminals by looking at residential burglaries. As well as confirming the importance of proximity in target selection, the study was the first step in establishing risk factors for burglary that were reliant on specific offender characteristics. Subsequent studies replicated these findings with different cities, sample sizes, areal units and independent variables for residential burglaries (Bernasco, 2006; Bernasco, 2010a,b; Frith et al., 2017; Townsley et al., 2015, 2016; Vandeviver et al., 2015). Since its introduction into the study of crime, the discrete choice model has also identified factors (including crime generators and crime attractors) that increase the likelihood of an area being chosen for street robberies (Bernasco & Block, 2009; Bernasco et al., 2012, 2013), commercial robberies (Bernasco and Kooistra, 2010) and thefts from vehicles (Johnson & Summers, 2015).

Clare, Fernandez, and Morgan (2009) expanded on previous studies by exploring the role of natural barriers and connectors on location choice for residential burglaries in Perth. They found the presence of physical barriers such as rivers and roads between the home and target locations significantly reduced the likelihood that the area would be chosen. Connectors, such as the presence of a train line in both the home and target location, increased the likelihood an area would be chosen. Johnson and Summers (2015) also found that areas more connected by major roads were favoured by adult offenders for thefts from vehicles. Similarly, Bernasco et al. (2013) found offenders committing street robbery were more likely to attack in easily accessible and those containing legal or illegal cash economies.

More recently, Menting et al. (2016) used the discrete choice model to examine the effects of the offenders' family members' homes on crime location choice. They found the residential areas of the offender's family

[2] This work stemmed from economist Gary Becker's 1968 paper, in which he argued that choices regarding crime are not dissimilar to other non-crime related decisions. Cornish and Clarke's model differs from Becker's economic model as it emphasises that utility is not always dictated by monetary gain.

members were more likely to be targeted, most likely due to the increased familiarity with the area as it becomes part of their awareness space. Bernasco et al. (2017) added a temporal element by using separate discrete choice models for every 2-h time block per day, for every day of the week, to examine street robbery in Chicago. They concluded that the time of day or week does not affect the importance of defined attributes. For example, robbers preferred to operate in areas close to transit hubs and cash economies, regardless of population density at the time. Lammers (2017) examined the influence of co-offending on crime location choice in The Hague, with results indicating a preference for areas known to multiple members of the group (a shared awareness space). This framework is now well established in studies pertaining to traditional urban crimes. It has also been applied to infrequent events such as rioting (Baudains et al., 2013). There, the presence of an underground train station increased the likelihood the area would be chosen as well as the volume of retail outlets (and therefore number of potential targets). However, to the best of our knowledge, the discrete choice model is yet to be applied to terrorism.

1.3. The Provisional Irish Republican Army (PIRA)

Northern Ireland has been the setting for political violence from different Irish republican paramilitaries, with the mutual aim of removing British rule, since the partitioning of the island of Ireland in the 1920s. The most violent and heavily researched period of the Northern Ireland conflict has been 'The Troubles'. From 1970 until the signing of the Good Friday Agreement in 1998, PIRA led a violent ethno-nationalist campaign. The main targets were the police and the British Army. The threat was not contained to Northern Ireland, with attacks occurring in parts of the Republic of Ireland, England, and mainland Europe.[3] Several studies produced descriptive statistics on the spatial and temporal distribution of attacks in Northern Ireland (including O'Duffy, 1995; Poole, 1995; McKittrick, Kelters, Feeney, & Thornton, 2004; Morrisey & Smith, 2002; O'Leary, 2005). However, research has neglected to include the alternatives that could have been chosen but were not. For example, when examining the distribution of attacks in Belfast it is evident that deaths were higher in extremely divided parts of the city, however there were many other areas that were equally as divided that experienced very few attacks (Mesev, Shirlow, & Downs, 2009).

It is evident that PIRA target selection was guided by the decision making of individuals living within the locality, due to their increased familiarity with the operational area (Horgan & Taylor, 1997; Gill & Horgan, 2013; Asal et al., 2009; Gill, Piazza, & Horgan, 2016; Gill et al, 2018). PIRA members often operated with a high degree of autonomy. Even when high-profile operations were ordered from the top-down, the precise target selection was likely to have been dependent on the attackers' original intelligence-gathering on that target (Horgan & Taylor, 1997). PIRA member Eamon Collins reported that he "*never stopped looking for military targets.*" Gerry Bradley's account of life in PIRA describes attacks as "*pure spur-of-the-moment … target of opportunity.*" Brendan Hughes recalls noticing a British Army jeep: "*We were so confident and in such control of the area at that time that instinct took over: 'There's a target' and 'Hit it.'*" PIRA attacks were also only carried out if there was a high probability that the attack would be a success (Horgan & Taylor, 1997).

As this model of target selection is a model of choice, the decision criteria that shape the choices of offenders should be defined, as well as the specification of the set of alternatives that the offenders can choose from. Terrorist decision-making process is bounded by incomplete information. Although their knowledge is bounded, they are essentially choosing between every premise and person in the city, presenting an enormous choice set. However, the idea there is a hierarchical process in decision making, as mentioned above, suggests the choice set for any offender is a limited number of areas. These can be defined using spatial units such as suburbs, wards or output areas. In this case, the set of alternatives takes the form of output areas called 'small areas' in Belfast, Northern Ireland and the expected utility of each potential target area is assumed to be evaluated according to the decision criteria presented below.

1.4. Decision criteria

The following subsections encompass three primary criteria a terrorist may consider when selecting a target for an attack: a) distance; b) natural barriers and c) ideology. These criteria are based on the theories presented above and related empirical research. In a broad sense, they are based on the assumption that the offender will act rationally in spatial decision making, considering the associated risks, rewards and efforts when selecting areas to target.

1.5. Distance

The least effort principle (Zipf, 1965) assumes that when considering a "number of identical alternatives for action, an offender selects the one closest to him in order to minimize the effort involved" (Lundrigan & Czarnomski, 2006, p. 220). Typically, an offender's journey to crime demonstrates the distance decay function, whereby chances of offending and frequency of offences decrease as distance from their home increases (Bernasco & Block, 2009; Wiles & Costello, 2000). To increase the utility of their attack the offender would aim to keep the distance travelled minimal (Clarke & Newman, 2006). As well as considering effort, the risk of interception before an attack should also be considered (Townsley & Oliveira, 2012). A recent study of the antecedent behaviours of UK-based terrorists concluded that they exhibited similar spatial behaviours to urban criminals and the wider population. They stayed close to their homes or safe houses when preparing for an attack and there was a clear pattern of distance decay (Griffiths, Johnson, & Chetty, 2017). The distance decay pattern has been empirically supported when examining the activities of PIRA (Gill et al., 2016), and lone-actor terrorists (Marchment et al., 2018). Due to their familiarity with the area, members of PIRA often operated within their own 'locality' (Horgan & Taylor, 1997). Further, members of PIRA were often under time constraints, for example due to work and/or family commitments, and as such they would limit the distance they would travel when offending (Gill et al., 2016). As such, it is hypothesized:

Hypothesis 1. The closer a potential target area to a perpetrator's home, the more likely it is that it will be selected.

Similarly, it is also likely that areas in the individual's awareness space identified through their daily routines will be targeted. It is likely that the city centre will be more familiar to the offender than other areas of the city, as they are more likely to be regularly frequented due to the amount of facilities available (i.e. transport, entertainment, retail establishments) (Bernasco & Block, 2009; Bernasco & Nieuwbeerta, 2005). Johnson and Summers (2015) found that adult offenders exhibited a preference of offending close to the city centre when considering thefts from vehicles. It is therefore hypothesized:

Hypothesis 2. The closer a potential target area to the city centre, the more likely it is that it will be selected.

1.6. Natural barriers

The movement of an individual is not random and can be bounded by physical and social constraints. Brantingham and Brantingham (2003; 2008) propose that features such as rivers and forests act as natural 'barriers'. These barriers restrict the movements of offenders and the resulting effort required to offend beyond them is increased. When examining effects of the physical environment on burglary locations, Clare et al. (2009) found a decreased likelihood that a potential

[3] For a detailed history of 'The Troubles' see English. R. (2003). Armed Struggle: The History of the IRA. London: Pan.

target area beyond a natural barrier would be selected. When examining target choices of the t 2011 London riots, Baudains et al. (2013) found that individuals were up to five times more likely to select an area that was on the same side of the river Thames as their home. When taking into consideration that the city of Belfast is split by the River Lagan, and that this will impede the movement of the offenders, it can be suggested that:

Hypothesis 3. The presence of a water body between the perpetrator's home and a target area will reduce the likelihood that the area will be targeted.

A logical suggestion for why one area is chosen over another is accessibility. It is likely that areas more connected to other parts of the city will experience more attacks than those that are not. For example, the existence of a major thoroughfare in the area may influence the likelihood of it being chosen. As major roads facilitate travel around the city, they are likely to be travelled on more often than other smaller streets, such as cul-de-sacs. Thus, an individual's familiarity with the area surrounding major thoroughfares is increased (Armitage, 2007). Research into burglaries suggests the risk is higher in more connected places (Johnson & Bowers, 2010; Armitage, 2007). Similarly, Ozer and Akbas (2011) suggest the reason one of the major police stations in Istanbul is targeted by terrorists is because this station is connected by major streets. More connected areas also potentially offer easier escape routes. Relevantly, Horgan and Taylor (1997) note “escape route accessibility” as one of the key considerations during the planning stage of PIRA attacks.

Hypothesis 4. The presence of a major thoroughfare in an area will increase the likelihood it will be targeted.

1.7. Ideology

Since terrorist attacks are “designed to communicate a message” (Hoffman, 2006), it should be assumed that the spatial decision making of an individual regarding target selection will be influenced by interpretation of ideology[4] in some way. Despite operating in the same social and geographical environment, PIRA's target patterning differed greatly from their loyalist opposition This demonstrates the significance of ideology in shaping targeting strategy. (Drake, 1998). Target choices should be governed by ideology and reflective of the greatest benefit for the cause (Drake, 1998) and to maintain support from those sympathetic to the cause (Hoffman, 2006).

Rewards may be dependent on the availability of suitable victims. Specific structures will increase the attractiveness of an area, as the likelihood that a suitable target is present will increase. PIRA's ultimate aim of ending British rule in Northern Ireland by inflicting enough casualties on British forces that they would be forced to withdraw meant that any member of the security forces was seen as a legitimate target (Drake, 1998). We expect that buildings representative of a British presence in Belfast will act as crime attractors, due to the availability of suitable targets (e.g. individuals entering and leaving the premises, as well as the premises themselves). We also suggest that those chosen will be in the awareness space of the individual perpetrator (Baudains et al., 2013). When considering traditional crimes, it is likely the presence of a police station would act as a crime detractor and an offender would avoid that area to reduce the risk of detection. However, when considering PIRA's ideology, it can be argued that the opposite may be true, due to the availability of targets. As such we formulate:

Hypothesis 5. The presence of a military base or a police station will increase the likelihood that the area will be targeted.

[4] Defined as “beliefs, values, principles, and objectives – however ill-defined or tenuous - by which a group defines its distinctive political identity and aims … and provides a motive and framework for action” (Drake, 1998, pp. 2–3).

2. Data and analytical strategy

2.1. Geographical domain

To test the hypotheses, we collected attacks by members of PIRA, living in the city of Belfast, Northern Ireland, in the period 1969–1989. This period encompasses the first three of five distinct phases of PIRA activity before the slow march toward the Peace Process began in 1990 (Gill, Lee, Rethemeyer, Horgan, & Asal, 2014). Belfast is the capital and largest city of Northern Ireland and is on the flood plain of the River Lagan. The Belfast Brigade was the largest of PIRA's command areas, and as such a substantial amount of PIRA activity occurred in the city.

Since 2011, Northern Ireland has been divided into 4537 ‘Small Areas’ (hereafter, SAs), which are currently the smallest areal unit.[5] SAs were designed specifically for statistical purposes and follow physical features of the environment such as roads and rivers (NISRA). As no sociodemographic variables were included in the analysis, it was deemed that SAs would be appropriate to use, and they therefore formed the choice set of alternatives for this study (a total of 890 for Belfast). The geographical boundary data for the SAs was obtained from the Northern Ireland Statistics and Research Agency (NISRA).

2.2. Case selection

The final offence and offender datasets comprised 150 attacks by 127 PIRA members within Belfast.[6] The datasets were created using parts of an existing dataset previously used for a social network analysis of PIRA's active core members (Gill et al., 2014), as well as additional data obtained from The Irish Times newspaper archives. By core members, we mean those individuals who conducted attacks on behalf of PIRA whilst also holding central positions within the organisation, or at one point in time, co-offended alongside those who held central positions within PIRA. To qualify for inclusion in the offence dataset, the attack had to be attempted or committed by one member of PIRA residing in Belfast, between 1970 and 1989. The location of each attack was geocoded to the corresponding SA. A direct link had to be made with the member of PIRA who committed the attack, whose home address at the time of the attack was known, to qualify for inclusion. The offender dataset contained information on the offender's home location (also geocoded to SA). Cases were removed from the dataset if an accurate home location could not be ascertained. Cases were also removed if the home location of the perpetrator was outside of the study area, in line with previous studies (Bernasco & Luykx, 2003; Bernasco, 2006, 2010b; Bernasco & Block, 2009, 2011; Clare et al., 2009; Bernasco et al., 2013), as the model requires all alternatives in the choice set to be computed (Figs. 1 and 2).

2.3. SA characteristics

Various sources were used to operationalize the characteristics of each SA as well as other decision criteria. The geographical SA data was obtained from NISRA. Binary indicator variables were used to identify the presence of major thoroughfares (A-roads - as according to the Ordnance Survey of Northern Ireland), military bases and police stations (both identified using the Conflict and Politics in Northern Ireland

[5] Wards were the smallest geographical unit in Northern Ireland during the period studied (and were revised twice during this time). However, the area that each ward covered was quite large (mean area 2.25 km^2) and as such it was likely that the effects of some of the variables may be wrongly estimated. For example, most of the wards in Belfast contained a major road and/or a police station, and the effect of distance was one of the key variables to be examined.

[6] Multiple attacks by the same offender may not represent independent observations. Robust standard errors (SE) were used to correct for offender clusters and avoid disproportionate influence on parameter estimation (Bernasco & Nieuwbeerta, 2005; Johnson and Summers, 2015).

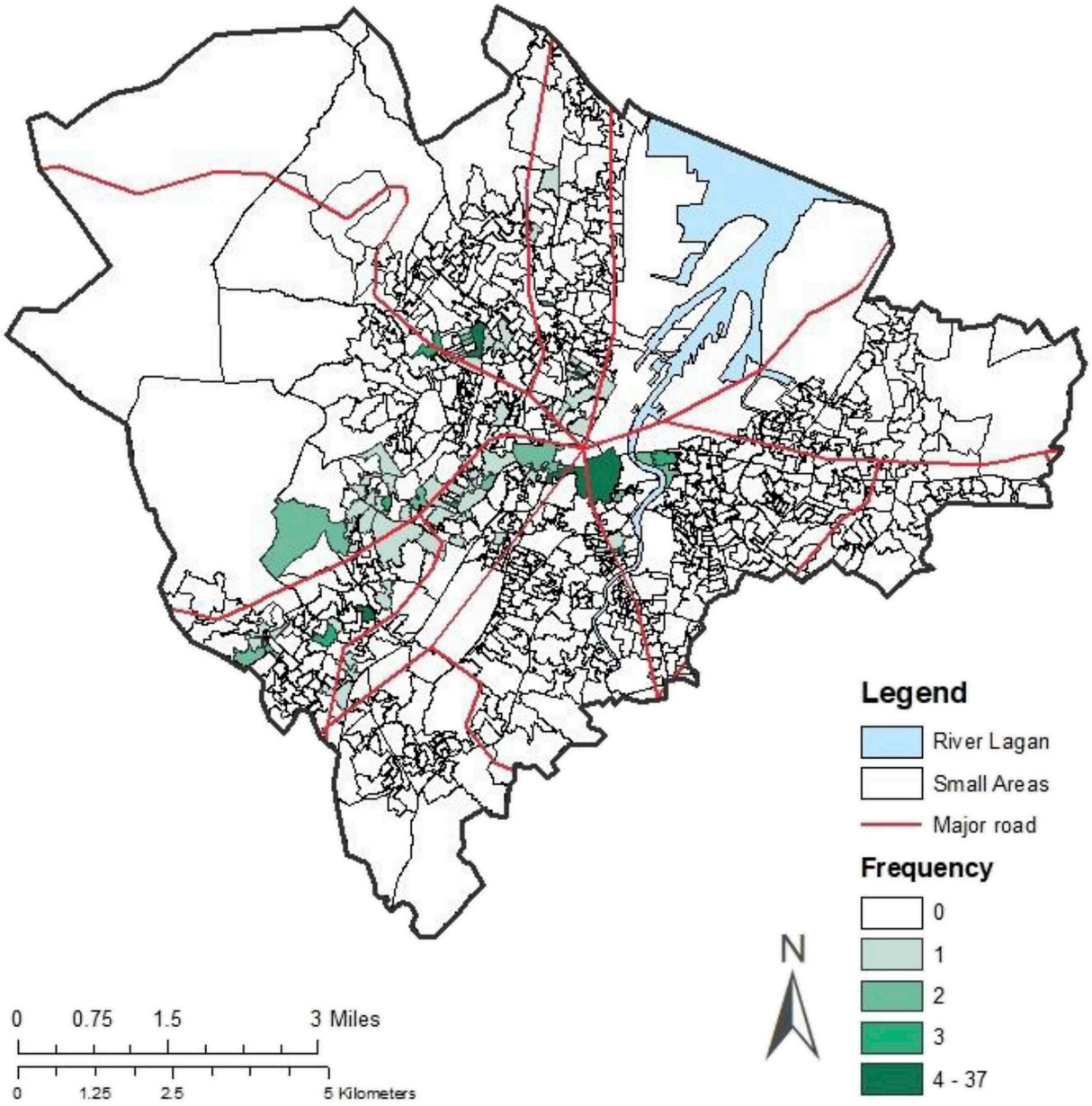

Fig. 1. Thematic map of home locations of offenders for SA in Belfast (1969–89).

web service (CAIN) during the period studied. Distance from the city centre was calculated as the distance from each centroid to the centre of Belfast (measured as a *point* in the Central Business District, adjacent to the City Hall) in kilometres, and Ghosh distance was used in cases where the city centre was located in the same SA as the home SA (please see below for a more thorough explanation of these measures).

Attacks were clustered at SA level: 7 SAs (out of 890) accounted for a third of all attacks for this period (Table 1).

2.4. Small area to small area characteristics

These dyad level measures reflect the relationship between the home location of the perpetrator and the target location of the attack and are used to measure impedance and barrier variables between two SAs.

2.4.1. Distance measures

In line with previous research, the Euclidean distance was computed between the offender's home location and each potential target area. Although the exact home and target locations of each attack were known, the model requires the distance to all non-selected areas to be calculated as well as the ones that were chosen as targets. Consequently, to keep measurement errors consistent, the distances to selected and non-selected SAs were calculated in the same way, using the geometrical centroids of each SA (Bernasco, 2006). An origin-destination distance matrix was created which defined the distance between the geometrical centroids of each SA and the city centre. In line with previous studies, in cases where the origin and destination were located in the same SA (and therefore representing a zero value on the diagonal of the distance matrix) the Ghosh (1951) distance was used. This distance measure calculates the average distance between two random points in a polygon using the formula $D_{ii} = \frac{1}{2}\sqrt{O}$, where O is the area of the SA in square kilometres (Bernasco, 2006; Bernasco & Nieuwbeerta, 2005; Ghosh, 1951).[7] Consistent with previous studies, the distance decay function of crime trips is clear.

[7] This formula is derived for a rectangle and its application for other polygons is an approximation.

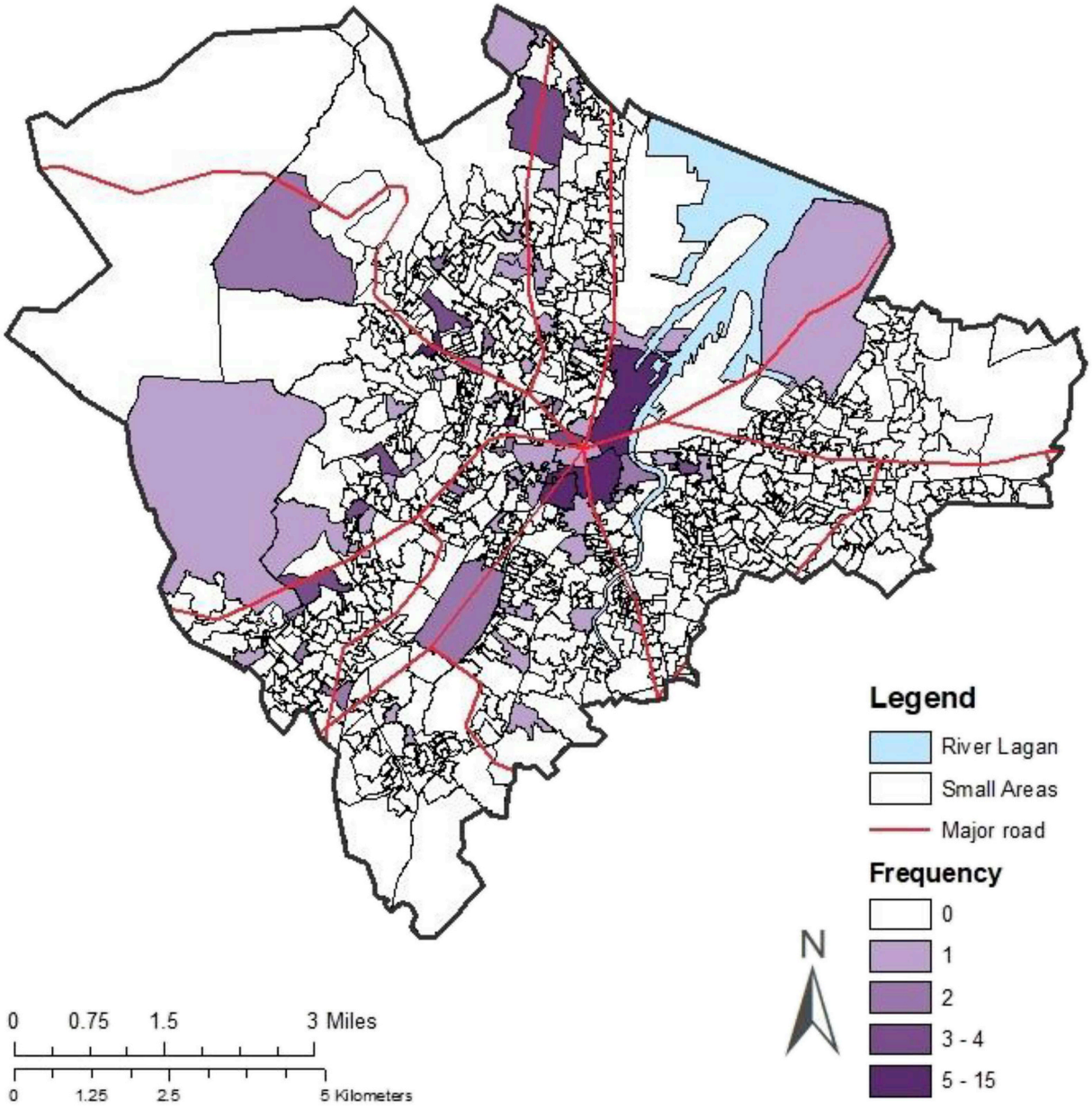

Fig. 2. Thematic map of attacks for SA in Belfast (1969–89).

Table 1
Summary statistics of the independent variables used to characterise the SAs.

Variable	Description	Mean	Standard Deviation	Minimum	Maximum
Distance to the city centre	Measured in km	3.88	1.97	0.28	10.37
River Lagan	Binary indicator for whether the SA is the same or opposite side to the home SA	0.73	0.45	0	1
Major roads	Binary indicator for whether there is a major road in an area	0.27	0.57	0	1
Military base/police station	Binary indicator for whether there is a military base or a police station in an area	0.03	0.16	0	1

2.4.2. Binary variables

Binary indicator variables were used to identify the presence of the following: a) the river Lagan, and as such determining a natural division between the offender's home SA and target SA); b) a British army base, Irish army base or police station; and c) a major thoroughfare.

2.5. Discrete choice model

The discrete spatial choice approach concerns an individual's choice between a set of two or more discrete alternatives, based on the utility they expect to derive from each alternative (Train, 2003). In this case, the set of alternatives takes the form of SAs in Belfast, Northern Ireland and the expected utility of each potential target area is assumed to be evaluated according to the decision criteria presented above. It is assumed that the alternative the terrorist chooses is the one that offers the best perceived utility, based on expected rewards, risks and effort.

This is specified as:

$$U_{ij} = \beta Z_{ij} + e_{ij}$$

whereby Z_{ij} is representative of the perceived utility of the individual i

from choosing alternative j. β is the attribute coefficient that is empirically estimated from patterns in the data. As the information for the observer is limited e_{ij} is a random error term representative of any unobserved additional factors (i.e. personal preferences and other idiosyncrasies of the terrorist) that are not included in the model but may affect perceived utility.

It is assumed the offender (i) will choose the alternative (j) if it gives them more utility than the others (k):

$$Z_i = j \text{ if } U_{ij} > U_{ik}, \forall \ k \neq j$$

where Z_i represents the choice made by individual i. Under the assumption that the j disturbances are independently and identically distributed with type 1 extreme Gumbel distributions, the appropriate statistical analysis to test the hypotheses of this study is the conditional logit model,[8] which takes the form of:

$$Z_{ij} = \sum_{m=1}^{M} \beta_m X_{mij}$$

where M is the number of characteristics associated with the utility, corresponding to the total number of variables captured at the area level. X_{mij} is the value measured for attribute m for the individual i choosing to select a target in area j.

The probability that the individual will choose area j is given by:

$$P(Y_i = j) = \frac{\exp(Z_{ij})}{\sum_{k=1}^{J} \exp(Z_{ik})}$$

$$= \frac{\exp(\beta_1 X_{1ij} + \beta_2 X_{2ij} + ... + \beta_M X_{Mij})}{\sum_{k=1}^{J} \exp(\beta_1 X_{1ik} + \beta_2 X_{2ik} + ... + \beta_M X_{Mik})}$$

where J is the number of areas for the individual to choose between.

The values of βm are estimated using maximum likelihood estimation and are interpreted as the multiplicative effects of a one unit increase in a SA's attribute on its probability of being selected by individual i. A βm value equal to 1 is representative of no association between the variable and the decision making of the individual, with values above 1 suggesting that the variable is positively associated with the likelihood of a SA being chosen.

2.6. Conditional logit

The conditional logit model tested the hypotheses. All models were estimated using STATA (StataCorp, 2001). To implement the model a final working dataset was created in which every possible alternative SA (N = 890) was listed for every individual attack (N = 150), resulting in a 133,500-record matrix. The dependent variable for the conditional logit estimation procedure takes the form of an indicator variable, used in this study to identify the chosen target SA of each offender for each attack. A value of 1 is representative of the chosen SA, values of 0 used for the other 889 SAs that were not chosen. Model fits were assessed and compared using McFadden's Adjusted Pseudo-R^2 (McFadden, 1976): those with large R^2 values were considered better fitting. Pseudo R^2 values are typically much lower than those of ordinary regression analyses: values of 0.2–0.4 are considered extremely good for a conditional logit model (Domencich and McFadden, 1975; McFadden, 1976; Louviere, Hensher, & Swait, 2000).

3. Results

Table 2 presents the conditional logit model results. The $e\beta$ parameters in all results tables are representative of the multiplicative odds ratio of a target SA being selected, following an increase of one unit in the relevant variable.

[8] The conditional logit model is used as it incorporates attributes of both the alternatives and the individual perpetrator. This is opposed to the multinomial logit model which only considers the perpetrator attributes.

Table 2
Estimates of the conditional logit model.

Variable	$e\beta$	z
Distance (km)	0.61***	−7.5
Distance to City Centre (km)	1.02	0.21
River (Barrier)	0.72	−1.16
Major Road (Connectivity)	1.77***	8.95
Military Bases/Police stations	13.78***	15
McFadden's Adjusted Pseudo- R^2	0.143	

*p < 0.05 for $e\beta = 1$, one-tailed, **p < 0.01 for $e\beta = 1$, one-tailed, ***p < 0.001 for $e\beta = 1$, one-tailed.

3.1. Overall model fits

The model provided a satisfactory level of fit, with a McFadden pseudo-R^2 value of 0.178. The likelihood-ratio test ($p < 0.001$) of the model demonstrates that it fits the data better than the null model. Three of the parameters significantly contributed to the predictive capacity of the model.

The coefficient of the first distance parameter is in line with Hypothesis 1. The results show that an increase in distance to the target SA from the home location will decrease the likelihood that this SA will be chosen as a target ($e^{\beta} = 0.61$, $p < 0.001$). However, against the expectation of Hypothesis 2, no significant effect was found for the distance from the city centre.

The estimated effects of a river acting as a natural barrier (Hypothesis 3) were in the right direction, but not statistically significant ($e^{\beta} = 0.72$, $p = 0.25$). In line with Hypothesis 4, the presence of a major road was associated with target choice, increasing the likelihood of the SA being chosen as a target by a factor of 1.77 ($p < 0.001$). As predicted, the presence of a military base or police station increased the likelihood that the area would be chosen as a target ($e^{\beta} = 13.78$, $p < 0.001$).

4. Discussion

Whilst there are some associated unavoidable caveats, this analysis provides a good starting point for further applications of the discrete choice approach to terrorist activity. The findings are very promising and provide further support that terrorists behave similarly to 'traditional' criminals in terms of spatial decision making when selecting targets. The results demonstrate the characteristics of the target SAs as well as the properties of their likely journey to the target influenced the location of PIRA attacks. The model indicated that three of the variables affected the likelihood of a SA being chosen as a target. An increase in distance from the home location decreased the likelihood that the SA would be chosen. The presence of a major road in the SA also increased the likelihood that the SA would be selected. The same was true for the presence of a military base or police station.

Distance is highlighted as an important factor in target selection, which is consistent with previous studies of terrorist activity (Clarke & Newman, 2006; Gill et al., 2017; Marchment et al., 2018) and traditional criminological studies (Bernasco & Block, 2009; Wiles & Costello, 2000). The results illustrate the impact of distance decay, with perpetrators less likely to select an area as distance from the home increases, most likely due to the changes in required effort. This provides further empirical evidence that the target location choice of terrorists is affected by required effort, and that, like traditional criminals, terrorists are limited by geographical constraints. The identifiable effects of the distance variables could be extremely beneficial for investigative techniques, especially when a threat is made against a specific target (Gill et al., 2017; Marchment et al., 2018).

Something that could be taken into consideration in future analyses is the mode of transport to and from each attack. Travelling on foot yields higher risk than by car and it is likely that the perpetrators would

stay closer to home. Travelling to more distant areas on foot would also be much more time consuming, and could increase the risk of identification and apprehension (Bernasco & Block, 2009). It is likely that the perpetrators would have travelled by car when attacking premises as the majority of these attacks were bombings and arson attacks; in particular the use of car bombs during the mid 1970s was extremely high (Horgan & Taylor, 1997).

Contrary to expectations, an association between target selection and distance from the city centre was not supported. This goes against previous research and the suggestion that SAs closer to the city centre will be selected due to a perpetrator's familiarity with the area (Bernasco & Block, 2009; Bernasco & Nieuwbeerta, 2005). However, as highlighted by Johnson and Summers (2015), it should be noted that the distance of the target location from the city centre is analysed independently of how far the attacker's home location is from the city centre. It is likely that their homes were in residential areas away from the city centre and the results confirm that the perpetrators were more likely to commit attacks very close to their homes. The mean distance between home addresses and the city centre was 3.08 km.

No support was found for the idea that rivers can act as physical 'barriers', which contrasts with previous research in the study of urban crimes (Brantingham & Brantingham, 2003; Clare et al., 2009). Future research should explore this further to see if this result is replicated for different locations. A street network approach to the analyses could also be used, which would add depth to the analyses and may affect results.

The presence of a military base or police station increased the likelihood of an SA being targeted. This is in line with optimal foraging theory, and the hypothesis that certain premises would increase the likelihood of an attack due to the availability of targets in the surrounding areas (e.g. officers travelling to and from work). However, caution must be taken when considering this outcome. It may be that attacks near to police stations or military bases were more likely to have been detected, and as such the identity of the offender is more likely to be known. When a sample of attacks is used where it is necessary to have both the home and attack locations, this may be over-represented in the data. However, after plotting a dataset of all attacks where a street address could be found (regardless of whether the home location was known), it was found that SAs experienced similar proportions of attacks.

Regarding connectivity, and consistent with the findings of Ozer and Akbas (2011), the presence of a major thoroughfare increased the likelihood of an area being chosen. This suggests that ease of access and escape are important when selecting targets (Stohl, 1988). These variables are also analogous with the offender's likely familiarity of the area (Armitage, 2007; Johnson and Bowers, 2010) which further highlights the importance of an individual's awareness space (Bernasco & Nieuwbeerta, 2005).

As with many quantitative studies of terrorism and political violence there are a number of constraints associated with the data used in this study. Some difficulties were encountered due to the historical nature of the records used. Typically, similar studies that implement this model to traditional crimes also analyse social context factors in order to further examine environmental criminological theories. For example, levels of social disorganisation (Shaw and McKay, 1942) can be used to assess the degree to which residents of an area can affect informal social control (Bernasco & Nieuwbeerta, 2005; Clare et al., 2009). It was not possible to test the function of such factors and others (e.g. affluence levels), as appropriate figures were unavailable.

The authors initially wanted to consider the residential segregation of Catholics and Protestants in Northern Ireland. The physical separation of the two religious communities is a key characteristic of Northern Irish society (Cairns, 1982; Hewstone, Cairns, Voci, Hamberger, & Niens, 2006). When optimal foraging theory is taken into consideration it is unlikely that members of the predominantly Catholic PIRA would have frequented areas dominated by the Protestant opposition (Hughes, Hewstone, Campbell, & Cairns, 2008). These areas would not be in the offender's cognitive awareness space and as such they would have limited knowledge about the inhabitants (Brantingham & Brantingham, 1981) and physical infrastructure (Bernasco & Nieuwbeerta, 2005). Such dynamics have been suggested elsewhere in both the terrorism and crime literature. For example, Bloom (2005) proposes that Palestinian terrorist groups chose individuals to carry out attacks who had features that would fit in with Israeli society. Gill's (2012) analysis of Palestinian suicide bombers provided some support for this hypothesis. Carter and Hill (1979) found that, in the case of extremely segregated cities, an individual's mental image of their city is often incomplete and strongly influenced by their racial background, due to the dangers of offending where they cannot blend in easily. Bernasco et al. (2013) found that street robbers preferred areas where the majority of residents matched their own racial or ethnic background. Although this concept of 'standing out' in unknown territory is most obvious when considering race, the same affects may be reflected when considering religion. PIRA members would be easily identifiable as the opposite side of the religious divide (Gill et al., 2017) and could be recognized as strangers to the area (Bernasco & Block, 2009; Brown & Altman, 1981). However, due to the retrospective nature of this study it was not possible to get this information for the period studied at small areas level. Some information was available at ward level, however the extent to which analyses at this level can provide meaningful information is limited, and we considered level of aggregation to be too large. As a result, the decision was made to exclude potential social context variables. This meant that it was possible to use a smaller areal unit and therefore increase the potential utility for practitioners.

This is a complete analysis of core Belfast PIRA members convicted of an attack where both the home and attack locations are known. It is a comprehensive dataset for the city with respect to the most important and highly connected members of PIRA (Gill et al., 2014). However, it is not a complete dataset of all PIRA activity in Belfast during this period as several attacks that were identified from the Irish Times archive had to be excluded from the dataset. The main reason for this was because they could not be directly attributed to a specific individual. Also, due to the underlying mechanisms of this model, the data had to be restricted to one city. It was also necessary to omit attacks in Belfast committed by non-residents and incidents outside of Belfast committed by Belfast residents from the sample, thus the effects of the distance variables may be underestimated. This dataset is a slightly smaller sample in comparison to most previous similar studies of crime. There may be some parameter inflation and there is the possibility of skewing of distributions to values higher than the true odds ratio. However, Baudains et al. (2013) used a similar sample size in one of their models examining the London riot. They also noted that although they excluded two of the days (with sample sizes of 54 and 90) the parameter estimates were consistent with the other three days that were examined. Although the sample used in this study was deemed sufficient for the implementation of the model (Greenland, Schwartzbaum, & Finkle, 2000), utilisation of a larger sample size would have been preferable. As well as improving the power and reliability of the model, a larger dataset would have enabled further hypothesis testing.

Areal unit boundaries are arbitrary and lack ecological meaning (Bursik, 1986) and the characteristic data used may not be an accurate representation of the perceptions of those living in the areas (Coulton, Korbin, Chan, & Su, 2001). Smaller units would enable factors such as the effects of social disorganisation to be touched upon, if the data was available. The theoretical notions apply to much smaller units and the street block is the most appropriate unit for analysis (Taylor, 1997). However, larger areal units such as small areas relax the effects of independence of irrelevant alternatives (IIA) which is a consideration of the conditional logit estimation. The IIA assumption expresses that if someone is choosing among a set of alternatives, their odds of choosing *A* over *B* should not be affected by the presence or absence of an alternative *C*. When using larger units preferences for a choice will be less influenced by the inclusion or exclusion of other alternatives, thus

affecting the ratios of β[9] estimates (Greene, 1997).

As well as the necessity of replicating this study using other cities in Northern Ireland where PIRA were in operation, further studies should examine different terrorist groups to identify how transferable the effects are to different contexts. A good comparison would be another organisation with similar targeting patterns, for example Euskadi Ta Askatasuna (ETA). ETA has repeatedly targeted the Guardia Civil (Civil Guard) and the majority of attacks are focused on military and police personnel as well as political and economic targets (Barros, 2003; Drake, 1998). Groups with different ideologies should also be studied, to increase the model's generalisability.

There are several ways this study could be improved and expanded on through the further disaggregation of data. Initially, we aimed to distinguish between different types of targets (i.e. attacks on premises and attacks on individuals), as different types of crimes tend to exhibit different spatial patterns (Andresen & Linning, 2012). However, there was insufficient data to do so. Differences between males and females could be examined as well as modes of attack (bombings, shootings, arson etc.) and types of human target, i.e. military/government/civilian. Other models, such as a mixed logit (McFadden & Train, 2000) or latent class model, could be considered in future studies. The mixed logit also accounts for idiosyncratic variations as it is likely that individuals place different emphases on certain attributes, for example distance (Robinson, 1950). Disparities in the attacks of different terrorists could be looked at, in particular for PIRA where there were variations in the skill sets of members. Gill et al. (2017) found differences between different roles in the group (in this case shooters and IED planters), i.e. IED planters travelled longer distances to attacks. The use of a mixed logit or latent class model would also relax the effects of IIA.

Temporal variations are often neglected in criminological research (Ratcliffe, 2006). Using a model of spatiotemporal choice as opposed to spatial choice may demonstrate that certain types of attacks were more likely to occur on certain days of the week, or certain times of day (included in the set of alternatives), and improve the understanding of target selection. For example, PIRA tended to avoid attacks on Saturdays as fewer people would hear about it on the news on a Sunday, and attacks were often tailored to fit in with the working and social schedules of members (Collins, 1998). Terrorism is not static (Drake, 1998), and PIRA's structure and strategy underwent many changes throughout their campaign (Asal, Gill, Rethemeyer, & Horgan, 2015; Gill & Horgan, 2013). Future research could incorporate distinctions between the different phases of PIRA activity, to see if changes in strategy were reflected in variations in target patterning. It may also be interesting to examine differences between different groups in the same conflict.

The effects of repeat and near repeat victimisation could also be taken into consideration. Studies of traditional crimes tell us that a crime event at one location increases the risk of a further event in the immediate vicinity and within a short time span (Johnson et al., 2007). This pattern has also been found when examining insurgent activity in Iraq (Townsley & Oliveira, 2012). Taking the discrete choice approach, Bernasco, Johnson, and Ruiter (2015) and Lammers, Menting, Ruiter, and Bernasco (2015) found that offenders were more likely to offend in areas they had previously targeted than other areas they had not targeted before. Using this approach to identify the effects of repeat and near-repeat patterns in terrorist attacks could be extremely useful for prevention and disruption strategies in the anticipation of further attacks.

In summary, this study provides a very promising starting point for further applications of the discrete choice approach in terrorism studies. The results provide support that decisions made by terrorists are guided by rationality, are similar to those made by traditional criminals, and are affected by associated risks and rewards. Future use of this model could play a key role in developing and implementing successful prevention and disruption measures.

[9] The attribute coefficient that is empirically estimated from patterns in the data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apgeog.2019.01.009.

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