APPLICATION OF GIS CRIMINALISTICS TECHNIQUES IN THE ANALYSIS OF URBAN TERRORISM

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Abstract: A common myth about terrorist attacks is that they are random incidents that can occur anywhere in the world. While it is true that such attacks can happen globally, they usually exhibit discernible spatiotemporal patterns that could be analysed using criminalistics techniques, methods, and analytic tools. Numerous studies have shown that analysing the spatial and temporal patterns of terrorist attacks can uncover the *modus operandi* of terrorist organisations and shed light on their strategic objectives. By identifying the operational methods of specific terrorist groups, it becomes theoretically possible to create models that predict the spatiotemporal dispersion of their movements and actions. Such models can potentially indicate sites of future attacks, including bombings, arsons,

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assassinations, hijackings, abductions, sabotage, kidnappings, and more.
The paper aims to examine and provide a concise explanation of why the application of criminalistic techniques is possible in the prediction of distinct aspects of urban terrorism.

Keywords: terrorism, cities, geography, hotspot, geographic profiling, GIS

Introduction

The possibility of terrorist attacks occurring across the globe defines terrorism as a subject of geography. The emergence of terrorism and geography as a science are inextricably linked due to the significant sociocultural characteristics of the population that inhabits a specific geographical region. For example, terrorist movements and associated crimes, such as weapons proliferation, money laundering, smuggling, etc., possess spatial and temporal dimensions. These dimensions are manifest in the physical or cyber domain, or both. Such phenomena may be more or less emphasised in different settings, which depend on a multitude of factors. By following the unwritten rule, the world's largest urban centres come to be first on the list. Studies on terrorism reveal that the frequency of terrorist attacks in urban settings obeys a power-law distribution, whether in spatial or temporal dimensions (Guo, 2019; Smith et al., 2008).

Therefore, terrorism as a political phenomenon characterised by pronounced spatial and temporal elements can be studied by using computerised geospatial analytical techniques, while the observed patterns of terrorist activities and spatial behaviour become a subject of criminalistics or intelligence analysis. This is supported by ESRI's (2008) statement that analysts can use geographic information system /GIS/ to understand the geography of crime and make bright decisions about it. As a system used to store, handle, evaluate, record, and visualise data, GIS allows criminalistics and intelligence analysts to observe a crime in the spatiotemporal context in a much more dynamic way than traditional criminalistics used to practice.

Geographic approach in the analysis of urban terrorism

The geographic approach in the analysis of urban terrorist attacks is characterised by a comprehensive and unique understanding of socio-political relations in the observed environment, which contributes to the development of novel methodological views for researching the origins of urban terrorism. Geographical research on terrorism range from examining specific types of terrorist attacks /e.g., suicide bombings/ to analysing the organisational structure of a particular terrorist group. Understanding the spatiotemporal aspects of urban terrorism provides intelligence on terrorist movements, support of the local population, and data on the strengths and weaknesses of terrorist systems. The geographic approach to studying urban terrorism contributes to the investigation of the geospatial dispersion of terrorist cells, their movements, and activities over the spatiotemporal continuum.

This is particularly crucial in studying urban terrorist attacks in large city areas, where terrorist cells can easily blend into the local population and operate covertly, unexpectedly, and unpredictably, resulting in highly effective attacks with significant loss of human life and material damage. According to geospatial studies, more than 60% of terrorist attacks worldwide occur in urban areas, leading up to 90% of fatalities (Python et al., 2018; TC 2-91.4, 2015; Bahgat & Medina, 2013; Krueger, 2010; Berrebi & Lakdawalla, 2007; Glaeser & Shapiro, 2001; Savitch & Ardashev, 2001). Studying the spatial aspects of urban terrorism enhances the identification of the level of radicalisation within the local population and facilitates the observation of patterns in terrorist activity. This study approach helps in locating terrorist hideouts, recruitment centres, and training facilities, including their tactics, and can aid in predicting the locations of the next attacks (Medina et al., 2011, p. 864).

The availability of spatial data on terrorist networks and incidents is crucial for conducting empirical research into the geographical aspects of terrorist movements and actions, as well as the structure of terrorist organisations. In this respect, larger datasets increase the probability of obtaining relevant and reliable spatial information about the observed area. Data on the spatial distribution of terrorists' behaviour, that is, movements and activities over specific periods and its translation into intelligence, can be fully facilitated by applying GIS as a counter-terrorism intelligence cycle's supporting analytics platform.

Terrorist group strategies and tactics hinge on spatial considerations, with movements often shaped by specific geographical contexts. Given that terrorist attacks are heavily influenced by their spatial surroundings, spatial data can reveal patterns that yield intelligence-worthy insights into the spatial distribution of terrorism. The use of GIS to display geographically referenced terrorism and terrorism-related information has proven invaluable for visualising geospatial patterns of terrorist activities and movements (Milojević & Dulović, 2018). GIS's ability to observe disparate dataset types with common geography and to correlate georeferenced data with other pertinent information about terrorist activities provides insight into the spatial and temporal dynamics of terrorist movements within a specific region, as well as potential groupings of terrorists in precise locations, according to the specified criteria. The structure of terrorist groupings depends significantly on the geospatial organisation of urbanised environments, facilitating the application of GIS at both, the macro and micro-level of urban terrorism analysis.

At the macro-level, terrorist organisations direct actions through a decentralised chain of command, adopting a cellular organisational structure that is tailored to each geographic area (ATP 2-01.3, 2019, p. 5-6). Cells, that is, terrorist organisation branches are formed based on the territorial principle, as their members are linked by their residence (Mijalković, 2010, p. 104). The organisational leadership, which sits at the centre of the group's cellular structure, is surrounded by multiple smaller groups, i.e., cells that represent the basic building blocks of a terrorist group. Cells typically consist of three to five members. While some organisations establish multifunctional cells capable of merging into a unified tactical unit - a cell with diverse operational methods, others may create separate cells specialised for conducting specific and improvised operations. Specialised cells emerge when the cellular organisational model of the terrorist structure evolves into the so-called 'column type' model. Such a model is characterised by numerous groups of cells organised into autonomous conglomerates with distinct specialties and unique command structures (Milkovski, 2016, p. 213).

At the same time, terrorist organisations with a large number of members typically feature a central command-and-control unit overseeing one or multiple subordinate cells. Spatial boundaries often form the basis for establishing these command-and-control units, which has been seen in the example of the *Italian Red Brigades*. Regional commands are established to direct terrorist operations and provide support to cells within their designated area. Opposite to, smaller terrorist groups may operate with a single command-and-control unit that directly supervises subordinate cells, regardless of their locations (FM 100-20/AFP 3-20, 1990, p. 3-5). In addition to the macro-level analysis, the study of the terrorist group organisational model can be performed at the micro-level as well.

At the micro-level of the organisation, the structure of a terrorist group is established as a network of nodes with minimal dependence on the leadership. Analysing hubs and connections within a terrorist network could unveil the organisational patterns of terrorist connectivity based on the geospatial principle (Medina & Hepner, 2008). Investigating spatial and organisational links provide an overview of the terrorist movement patterns (Moon & Carley, 2007). Network hubs represent tangible elements within the terrorist group /e.g., members and structures/ that can be the subject of geospatial analysis. Depending on the type of the hub's connectivity model /functional, operational, independent, or network model/, identifying the 'centre of gravity' of a terrorist group is more or less challenging. The connections among network nodes can be classified as 'behavioural' links /e.g., those between superior and subordinate members/ or 'functional' links /e.g., ideology which share propagandists and terrorists/ (Boudreaux & DoA, 2022, p. 18). Despite being the most challenging to integrate, terrorist groups aim for a network mode connectivity because it is the most difficult for counter-terrorism identification. This model may take the form of: /1/ chain network; /2/ circular network; /3/ star network; /4/ multi-channel network; or /5/ hybrid network. This approach provides greater flexibility and multi-layered protection for the terrorist group and its members (Talijan, 2016).

By calculating and analysing the distances between the locations of cells and the locations of attacks, as well as the distances among the cells, the cellular structure of a terrorist group becomes the subject of geospatial analysis (Rossmo & Harries, 2011). Georeferenced data on cell locations, provided in the form of geographic coordinates at the city level, is an essential component for identifying and monitoring patterns of terrorist behaviours in urban areas (Medina et al, 2011). Based on georeferenced data of urban spatial entities, GIS generates an interactive 3D or 4D-real-time map depicting geospatial relationships among elements within observed urbanised regions. For instance, analysing the spatial patterns of terrorist actions and movements over the space-time continuum reveal that during the initial stages of attack planning, terrorists approach the target and, after conducting surveillance, they withdraw. As the attack execution date approaches, terrorists progressively move closer to the target (Bahgat & Medina, 2013). Therefore, geospatial pattern analysis can lead to the prediction of urban terrorist attacks along the space-time continuum, particularly in those city areas with heightened levels of terrorist activity (Python et al., 2021). However, in cases when multiple terrorist groups with varying territorial dispersion and objectives operate in a particular geospace, the resulting pattern of attacks becomes overly complex. A complicating factor is that terrorist groups generally adopt similar planning tactics. For instance, following the adoption of new tactics by the *Liberation Tigers of Tamil Eelam* against different state authorities, terrorist groups in the Middle East such as Al-Qaeda and Hezbollah promptly began employing similar attack tactics. LTTE commanders even travelled to the Middle East to teach these tactics and ensure effective implementation in attack planning (Hoffman, 2006). Besides facilitating the terrorist organisations' ability to learn from each other, the 4th Industrial Revolution and get along globalisation have contributed to the evolution of terrorism threat and its closer ties to organised crime. This has led to the emergence of new threats to national and human security (Mitrović, 2020). Accordingly, the terrorist attack patterns analysis relies on data on the groups' responsibility for conducted attacks. In terms of that, spatiotemporal investigation involves comparing the *modus operandi* patterns of known terrorist groups with the pattern of currently executed attacks. Spatiotemporal mapping of terrorist activities and movements, including location of the future attacks, heavily relies on geospatial criminalistics techniques.

Application of geospatial criminalistics methodology in the spatial investigation and mapping of urban terrorism

The functional relationship between terrorism and crime /when organised crime finances and arms terrorists/ and an instrumental relationship /where terrorists engage in organised crime and *vice versa*/ indicates that terrorist attacks can be considered crimes (Mijalković et al., 2011). Additionally, the methods used by terrorists to achieve their goals, such as assassinations, bombings /e.g., car bombs, letter bombs, suicide bombers, etc./, diversions, public transport hijacking, kidnapping, taking hostages, arsons, ambushes, armed assaults on security forces, etc., classify terrorist deeds as acts of violent crime (Stajić, 2021; Popović & Stupar, 2021). Therefore, besides being acts of a political nature, terrorist attacks are also criminal acts, whether they occur during times of peace or wartime (FM 100-20/AFP 3-20, 1990, p. 3-5). Similarities in the crime and terrorism conceptualisation understanding, information gathering, and investigation approach, indicate that criminology and criminalistics knowledge can be applied in the research of patterns of terrorist attacks (Stevanović, 2021; Stanar, 2020; ATP 2-01.3, 2019; Marchment, 2019; Strider, 2017; Crosby & Fox, 2017; Talijan, 2016; TC 2-91.4, 2015; JP 3-07.2, 2010; Townsley et al, 2008; Forest, 2007; UNODC, 2004; LaFree & Dugan, 2004).

According to this, the GIS-based spatial crime investigation methodology can be applied in the spatial mapping of terrorist actions. The comprehensive study conducted on the spatiotemporal distribution of terrorist attacks in Iraq from 2004 to 2006 provides sufficient evidence of the feasibility of applying a geoinformation system in spatial research of urban terrorism (Siebeneck et al, 2009). GIS can be utilised for crime mapping, criminal analytics, and investigative and pre-investigative purposes (Budimlić et al., 2017, p. 14). GIS-based crime investigative techniques established on geospatial methodology which can be employed in the prediction of terrorist attacks include the hotspot analysis of attacks and geographic profiling of individual(s) who committed attacks. Although these techniques do not directly solve crimes, they can ensure that investigative resources are applied rationally and appropriately to the point of assisting in predicting the locations of future attacks.

Hotspot analysis of terrorist attacks

A crime mapping technique used in the investigation of the spatial dispersion of criminal activities, i.e., hotspots, is a popular method for analysing terrorism events. The term 'hotspot' refers to areas with a higher frequency of crime incidents compared to the average (Eck et al., 2005, p. 2), indicating a greater risk of victimisation than the state-wide average risk. Hotspots are identified based on: /1/ attack frequency; /2/ attack location; and /3/ time of attack (Harries, 1999, p. 112). Several GIS methods can be used for hotspot analysis: /1/ point mapping; /2/ spatial ellipses; /3/ thematic mapping; /4/ GRID mapping; and /5/ surface smoothing method (Gorr & Lee, 2014, p. 28). Among these techniques, the GRID matrix is the most commonly utilised mapping tool for displaying criminal dispersion over space-time, such as terrorist activity and movements. The GRID analytical matrix is based on a geo-informational 3D view of the real world, while a 4D view can be implemented to display terrorism dispersions in real-time mode. While the visualisation of the crime sites demands the scale of 3D, real-time crime prediction depends on 4D modelling.

By analysing the terrorist attack hotspots, mapping them according to specific criteria /e.g., geographic area/, and grouping them into trends by using GIS techniques, the terrorism development patterns could be effectively monitored (Alharith & Samak, 2018). GIS-based spatial analysis of these hotspots can identify areas with a high concentration of criminal and terrorist movements and activities. Investigation of hotspots results in classifying incidents and identifying regions that require increased application of counter-terrorism measures and activities, such as surveillance, reconnaissance, or covert activities (Budimlić et al., 2017). In summary, geospatial hotspot analysis could enhance the prediction of future terrorist attacks over time and space, according to studies (Hajela et al., 2020). During hotspot investigation, statistically prediction-worthy spatial data are identified. These data can be clusterised according to their spatial, temporal, or spatiotemporal attributes. Hotspot analysis uses real-time georeferenced data over terrorist activities to indicate the terrorism risk levels in the observed region (Bowers & Johnson, 2005). Geospatial analysis of terrorism hotspots can be conducted at both, the micro-level and macro-level (VanHorn & Mosurinjohn, 2010, p. 485).

Criminalistics analysts combine various GIS-based analytical tools to visualise surroundings and conduct micro and macro-level terrorism analysis. The micro-level analysis focuses on using quantitative dot pattern heuristics during the investigation of terrorism hotspots. However, most of the terrorism investigations occur at the macro-level, such as the city or neighbourhood level (Harries, 1999, p. 155). Through macro-level analysis, criminalistics analysts can identify terrorist and terrorist-related behaviour patterns.

Just as crime impacts certain neighbourhoods more than others, GIS-based hotspot investigation can be applied to various spatial units - community-level areas, city blocks, streets, or buildings. The study on the spatial distribution of crime incidents in Rio de Janeiro (Miranda & Ferreira, 2008) supports the aforementioned. Due to a specific urban city structure dominated by favelas and natural landscapes, Rio de Janeiro may be seen as a perfect GIS test site in urban settings. The study approach involves the space-time monitoring of Rio de Janeiro's region divided into 300 by 300 metres geographical cells based on a GRID matrix and georeferenced crime incidents. The research findings imply that GIS can be a useful tool in supporting crime mapping in urbanised areas. GIS is highly applicable in the exploring of spatial dispersion and frequency of urban crimes, as well as in indicating a risk of victimisation. As the study stated, the scope of GIS utilisation in the analysis of urban crime patterns depends on the comprehensiveness of crime records and spatial data.

Similar to crimes, terrorist attacks can be analysed at the city or neighbourhood levels, where sufficient spatial and temporal data is available (Medina et al., 2011). A much more comprehensive study than that one conducted in Rio de Janeiro about the spatiotemporal dispersion of urban terrorism confirms that. The analysis of terrorist attack patterns in the cities of New York, London, Paris, Madrid, Istanbul, Jerusalem, and Moscow has revealed that terrorism gravitates toward the urban core or other critical city points according to the principle of repeated concentric attacks (Savitch, 2008). Based on this type of terrorism analysis, counter-terrorism activities could be effectively planned. Considering that the possibility of conducting terrorist attacks depends on the target's strategic and symbolic signific which fluctuates over time, some cities suffer disproportionately more attacks than others. As a result, each city centre requires unique city-scale modelling. City-scale modelling is important as counter-terrorism policies are usually adopted at the level of the city (Graham, 2004). Due to its ability to integrate gathered clusters of data into 3D and 4D models, GIS represents an essential tool in the city-scale modelling and visualisation of future attack sites.

Geographic profiling of terrorists

Opposite to the hotspot investigative method, geographic profiling methodology aims to pinpoint the most likely location of the offender. Geoprofiling implements the sites of serial crimes to determine the most probable area of offender residence or another spatial location of offender detention, such as the workplace (Rossmo, 2000). Geoprofiling technique creates spatial profiles of serial offenders, i.e., a 2D digital map of their most likely spatial detention based on the structured patterns of their behaviour in geographical space (Lundrigan & Canter, 2001). Given that terrorist attacks are cyclical, highly organised, and well-planned actions, there is potential for using geographic profiling in counter-terrorism efforts (Qian et al., 2011). While the hotspot analysis aims to identify the location of the future crime, geographic profiling seeks to identify the individual who committed the offence (Budimlić et al., 2017, p. 19).

According to the research, geographic profiling analytics can effectively assist in investigating acts of domestic terrorism (Bennell & Corey, 2008). Namely, for a crime to occur there must be a time and location intersection between offender and victim. In this respect, multiple studies indicate a connection between the terrorist attack locations, the behaviour of terrorists during attacks, and the locations of group members (Smith et al., 2008, p. 18). Geographic profiling method can assist in detecting terrorism by recognising consistent spatial patterns in the planning and execution of terrorist attacks (Marchment, 2019; Crosby & Fox, 2017; JP 3-07.2, 2010; Freeman et al., 2010; Wang, 2005; Rossmo, 2000).

For instance, a comparative analysis of personality profiles of terrorist and criminal group members reveals that both, terrorist and criminal groups prefer the so-called ‘soft targets’, seek ethical justification for their beliefs and actions, and recruit members from marginalised groups prone to social or political frustrations (Schurman-Kauflin, 2008; UNODC, 2004). The mathematically also statistically supported procedure of geographic profiling in criminal activity investigation relies on analysing the extensive big data clusters of multiple criminal acts, reflecting the distance distribution between the perpetrator's residence and the crime scene. As an illustration, social media platforms /e.g., YouTube, Meta, X, Instagram, etc./ provide valuable sets of data for monitoring potential criminals and terrorists, offering a massive amount of big data that can be both, visual and contextual analysed. Simultaneously, the size of data clusters ranges from several hundred to several million entries, which can be correlated with specific variables, such as telephone numbers or IP addresses, providing quick insights into the individuals under analysis (Milojević & Dulović, 2018).

Major topics or concepts discussed over social media platforms concerning locations, individuals, and groups can be geospatially tracked and investigated. These discussions yield valuable data about individual's profiles and behaviours, offering significant intelligence value (Haridas, 2015, p. 75). Consequently, the analysis of big data has demonstrated that terrorists use the Internet in attack planning, whether within the physical or cyber domain, or both (Alharith & Samak, 2018, p. 15). The analysis of the terrorist attacks planning cycle aims to discover spatiotemporal trends among terrorists' spatial movements across the space-time continuum concerning the location and time of the conducted attack. In terms of this, the success of the implementation of the geographic profiling approach in predictive counter-terrorism analysis depends on available intelligence on the behaviour patterns of terrorists during the planning phase of attacks.

By relying on the structured behaviour patterns of serial perpetrators in space-time, the geographic profiling tool creates spatial profiles of suspected criminals to identify the offender(s) who committed the crime. To construct an offender's geospatial profile, the crime scene location coordinates /e.g., of committed terrorist attack/ and data on suspected perpetrators are inputted into a geographic profiling software containing the 'criminal geographic targeting' algorithms /e.g., Rigel or CrimeStat/. Since perpetrators often commit crimes near, but not too close to their residences due to a desire for anonymity, it is feasible to discover the most probable residence of the perpetrator by using the 'criminal geographic targeting' methodology (Bennell & Corey, 2008). Considering this, Rossmo (2000) advises a minimum of five crime sites to generate valid and reliable datasets on the offender's potential anchor point.

The application of CGT results in a dataset that outlines the most likely area of the spatial detention of offenders. Each output data cluster contains attributes corresponding to the number of geographical features in the real world. Each record includes a unique identifier used to detect and link it /e.g., a crime report/ to its associated geospace, that is, the crime location. A crime report encompasses extensive sets of data related to the offense, such as the type of crime /e.g., assault, murder, terrorism, etc./, victim(s) details /e.g., name and surname, telephone number, address of residence, etc./, applicable characteristics of arrested perpetrator, data on the perpetrator's previous crimes or suspected cases, the presence of an extremist-oriented personality profile, known associates, and other data concerning criminal, terrorist, or subversive groups with which the suspect is or was affiliated. By linking the spatial coordinates of potentially suspected offenders' residences and crime-related data, checklists of suspects can be compiled. In a nutshell, the main function of the geographic profiling method is to prioritise suspects based on defined lists. It is worth noting that the comprehensiveness of checklists depends on the reliability, validity, as well as volume of available or entered data into the information system database.

Given that, the findings of two case studies on terrorism conducted by Bennell & Corey (2008) are presented. The groups that were the object of geographic profiling are *Action Directe* and *the Revolutionary People's Struggle*. The studies used data relating to the history of given terrorist groups, general philosophy, target preferences, and typical actions taken, including data on specific series of terrorist attacks linked to a member of each group. The investigation was carried out by using the geographic profiling software known as DragNet. The key results of Action Directe's attacks patterns analysis have shown that the terrorist's anchor point was not located in any part of the prioritised area, indicating that the offender did have other anchor points, such as a residence or place of work, in closer proximity to the attack sites. However, in the case of geoprofiling of the Revolutionary People's Struggle's members, authors undouble identified the location of the anchor point with a reasonable degree of accuracy. The study finding has affirmed the aforementioned statement on the importance of reliability, validity, and volume of available or entered data, which in the case of Action Directe was lacking /the cause of the data lack was the fact that the offender travelled far distances to carry out his attacks, which has not been predicted by the authors/.

Data on crime location, inserted into geographic profiling software, provides the input and is entered by the optional means of street address, or latitude and longitude. Based on the likelihood of specific crime types, each location is assigned a corresponding feature resulting in a profile of potential offenders that assists in identifying perpetrators of attack. The interception of patterns data on conducted crime and trends in geospatial behaviour of offenders during the planning phase of previous attacks, i.e. *modus operandi*, within GIS may lead to the identification of probable future attack locations. The GIS-based analysis uses information held about offender home addresses to anchor the data about risk factors and propensities of perpetrators in a spatial context (Ottiwell, 2008, p. 86). By leveraging GIS functionalities in data visualisation, it becomes feasible to delineate zones around locations of attack and ascertain whether suspected terrorists were present in, or near the attack site before it occurred. However, an additional analysis is required to interpret the spatial profile so that it can be applied for predictive purposes. Extensive counter-terrorism analysis includes demographic and socio-political investigations of attack areas, alongside distances from institutional and critical infrastructure centres and terrorist-relevant entities (Can & Leipnik, 2010, p. 41). Due to the enormous volume of datasets generated during predictive counter-terrorism analysis, sophisticated GIS software is an essential tool for drawing conclusions about acts of terrorism.

Contribution of GIS in the prediction of urban terrorism

The importance of urban terrorism data is that it can be analysed by different levels of geography /city blocks, streets, or buildings/, and by other variables. Complex phenomena with a multitude of causal factors, such as urban terrorism, can exhibit common statistical patterns that aid prediction. Statistical analysis of urban terrorist attacks has value in data-driven prediction (Guo, 2019), as has been seen in the examples of hotspot mapping and geographic profiling. These methodologies heavily rely on GIS. GIS can assist in the prediction of terrorism by accelerating the intelligence cycle through analysing multiple types of data clusters generated using varieties intelligence disciplines, e.g., GEOINT, OSINT, IMINT, MASINT, SIGINT, TECHINT, HUMINT, etc. (ATP 3-06/MCTP 12-10B, 2022; JP 3-07.2, 2010; ESRI, 2005). In other words, GIS integrates different types of data clusters gathered from multiple sources into a high-value intelligence.

Combining law enforcement data /e.g., field interview information, offense reports, arrests, accidents, domestic violence, confidential informant intelligence, hate crimes, etc./ with non-traditional types of data often available at the city level /e.g., financial records, home ownership information, liquor licenses, tax and license information, geographic data such as aerial photographs, floor plans, buildings drawing, sewer/water system, and parcel information, etc./ helps to examine crime in greater depth (Chapman et al., 2002, p. 4).

For example, the value of using non-law enforcement data at the city level is tracking the amount of explosive raw materials, such as ammonium nitrate, which could serve as an indicator of a potential bombing attack. As can be seen, much of the data is already being stored in different law and non-law enforcement databases. All that is left is to link it to the geographical entities in the real world by using GIS. This means that data can be collected once and utilised many times, reducing redundancy (Lamb & Hough, 2002), and accelerating the intelligence cycle for the second time. Collected data GIS can present in the form of 3D or 4D models of the real world, e.g., terrorist attack sites.

The possibility of GIS application in the terrorist attack sites investigation in urban operating settings has been confirmed by the 3D sniper rifle fire test modelling. The research conducted by VanHorn & Mosurinjohn (2010) adopted a methodology of using the idea of a viewshed and line of sight. A viewshed is created with GIS for a line such as a path along which a target could walk or drive. Differing from the studies' approach conducted by Savitch (2008) and Bennell & Corey (2008) which has considered a 2D view focusing on hotspot identification or mapping trends in specific urban geographic regions, the sniper rifle fire analysis has been examined in the 3D perspective. According to these authors, the viewshed analysis could show every possible location a potential assassin can effectively see the target, both on the ground, in the air, and in or on buildings in the surrounding area (VanHorn & Mosurinjohn, 2010, p. 492). This 3D test model could be upgraded into a 4D model by adding the fourth space-time component, i.e., time (*t*) along with the three spatial coordinates (*x*, *y*, *z*).

The methodology of the 4D modelling is of especially importance in counter-terrorism efforts due to its ability to visualise information in real-time, conduct terrorism risk assessments during specific periods, give possible end-scenarios of terrorist attacks, and suggest effective countermeasures entrenched on available information. According to ESRI (2018), GIS gives crime analysts a major technique to add crime data to perform analysis for crime scene investigation purposes. Multiple spatial and crime datasets could be scored and combined into a single layer to ensure high standards in the visualisation of crime scenes. Information such as area geography, road networks, and other infrastructure data takes on a novel dimension when integrated with crime records and research on the spatial behaviour of offenders (Rossmo, 1995). The biggest advantage of GIS usage in crime scene investigation is its upgradability with additional analytics tools, such as photogrammetry (Mokwena & Makola, 2023). Accordingly, GIS pretends to become a leading data gathering and analytics tool in conducting real-time counter-terrorism analyses.

Big data analytics of terrorism-related data

Alongside the hardware, software, and people, the data is the central element of GIS. Predictive counter-terrorism analysis heavily depends on big data, gathered by using technologies based on remote sensing. Remote sensing data gathering results in raw terrorism-related datasets which require to be defragmentated before the big data analytics become even possible. By applying big data analytics on defragmented terrorism-related datasets, counter-terrorism-worthy information can be made. For instance, one-third of location information is generated through big data analytics (Labrinidis & Jagadish, 2012). The generated information could be utised in the city-level modelling (Pfoser, 2016). Different remote sensing data integration, defragmentation, and analysis, including its 3D or 4D modelling, are supported by GIS.

Big data analytics results in predicting the behaviours of observed entities or spotting trends based on clusters of collected data. Big data analytics enables automatic detection and reporting of anomalies across all domains - land, sea, air, space, and cyberspace (Thiele, 2014, p. 5). For example, big data collected by city optoelectronic and geolocation systems can provide real-time data on the frequency of traffic flows. Based on collected data a GIS-based road-mapping network for responding to the next terrorist attacks can be produced (Sangasumana et al., 2020). The study proved that big data analytics improve the effectiveness of battle engagement by 37% (Milojević & Dulović, 2018, p. 243). Such a possibility exists due to the operational concept of big data analytics to include artificial intelligence and machine learning algorithms in the prediction of future actions. By integrating machine learning with artificial intelligence algorithms by using GIS, terrorist attacks can be fully anticipated (Krieg et al., 2022). As an illustration, the daily personality habits of one group's members may be analysed by employing big data analytic method over HUMINT data gathered from the arrested member(s) of the same terrorist group, while spatial habits can be investigated by applying big data analytics methodology on GEOINT data collected during the surveillance and reconnaissance of the intelligence-interesting member. Briefly, GIS-based big data analytics converts data into counter-terrorism-worthy information by giving them a specific spatial meaning. Accordingly, big data analytics contribution to the hotspots mapping of the attack(s) and geographic profiling of the offender(s) who committed the attack(s) is more than evident.

Conclusion remarks

Basing its internal structure on a unique organisational model, criminal and terrorist groups can adapt activities and *modus operandi* to current geospatial circumstances. Updating *modus operandi* results in ongoing spatial and temporal changes across domains of their movements and actions, such as socio-political, economic, technological, etc. By monitoring spatiotemporal changes and grouping them into terrorist and related security-threatening trends, conditions for creating a comprehensive criminogenic overview are established. These tendencies assist in the prediction of future terrorist and criminal dynamics in the urban environment. Identifying spatiotemporal changes directly impacts risk assessments and the vulnerability analysis validity of terrorist attacks. Through the use of GIS, criminalistics and intelligence analysts can easily investigate spatiotemporal activities, track movements within areas of interest, and identify emerging trends relevant to security interests.

There is no doubt that the cellular organisation approach to modelling terrorist group structure maximally protects its members and leadership from intelligence measures and actions to the extent that even group members often remain unknown to each other. However, to maintain the conspiratorial nature of their activities, cellular structure manages group nodes to operate locally within narrowly defined spatial and temporal operational zones, exposing them to easier spatial identification. Activities of group elements usually vary in start, duration, and termination. Despite the usually obscure behavioural, functional, and instrumental links between nodes or cells of a terrorist group, identifying the activity of one node suggests the existence of multiple collaborating /engaged or passive/ nodes nearby. Combining the spatial knowledge about at least one node's activity with the assumptions on existing additional elements provides enough raw data for the initialise of GIS criminalistics over security-threatening phenomena, events, and processes.

In other words, recent studies on terrorism indicate that applying GIS criminalistics techniques in studying urban terrorism trends and identifying attackers is scientifically justified. Moreover, these studies suggest that answers to fundamental questions crucial for the fruitful prediction of urban terrorist attacks - WHO?, WHAT?, WHEN?, WHERE?, and HOW MUCH? - could be facilitated by implementing GIS across the counter-terrorism domain, which is confirmed by this paper's highlights. However, while the GIS development in policing regarding crimes such as rape or robbery is more than evident, there has been insufficient research on the possibility of projection of urban terrorist pre-attack movements in a space-time trajectory by using GIS in recent years. Accordingly, the effectiveness of GIS-based prediction of future terrorist attacks lacks strong empirical evidence.

The key reason for empirical evidence lacking about the GIS application in urban terrorism prediction lies in the deficiency of technological cooperation and differences in methodological views on the fight against terrorism threat among sovereign states. In terms of technological cooperation within the domains of counter-terrorism, working together is of especially importance due to limitations in the technological capabilities of each state. As an illustration, the global navigation satellite systems, such as the USA's *GPS Navstar*, Russia's *Glonass*, China's *BeiDou*, and EU's *Galileo*, represent the leading technology in geospatial data gathering and continuous real-time global positioning of movements within city environments. This is necessary for conducting the GIS-based predictions of sites of future terrorist attacks, i.e., 4D city-modelling. Nevertheless, to ensure continuous real-time positioning in urban settings, it is required to form a constellation of at least fifty networked satellites. None of the considered satellite systems, that is, states have a sufficient number of satellites currently.

In addition to the lack of cooperation in the technological sphere, the effective response to terrorism depends on a unified methodological approach to the fight against terrorism at the global level. However, methodological distinctions in the fight against terrorism exist and they are caused by different political and legal views of terrorism as a security threat. Accordingly, how states interpret terrorism shapes the fight against it. While the USA sees terrorism as a military threat to its national security, EU member states consider terrorism as an act of criminality, that is, a non-military threat. Different views on terrorism outcomes in different responses to terrorism. If there is no consensus about the way how to behave towards terrorism at the international level, it becomes impossible to establish a coordinated and joint response from states. The absence of a stance on terrorism at the global level impedes the progress in national policies and frameworks for counter-terrorism actions, while terrorist strategies evolve encouraged by globalisation.

A unified and coordinated methodological response at the global level is crucial for protecting against terrorism. For instance, categorising terrorism into transnational and internal forms implies a disparity between international strategy and national counter-terrorism policies - which is mistaken. The methodology for combating terrorism should be uniform regardless of the operational scope of the terrorist group /international, regional, or national/ because terrorism as a security threat is a global security issue. Distinguishing domestic from transnational terrorism is important for criminal /pre-/investigations, that is, hotspot mapping of attacks and geographic profiling of offenders who committed terrorist attacks, as well as for setting up repressive measures against terrorists at the tactical level. Achieving a consensus on terrorism at the global level should be the primary goal in formulating counter-terrorism strategies at the level of the state. Effective national-level counter-terrorism policies require a worldwide legal framework for defining terrorism deeds and sanctions commensurate to the severity of the committed acts.

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