Analysing the Role of “Urban” in Urban Warfare through Paris and Mumbai

by

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Analysing the Role of **“Urban”** in Urban Warfare

through

Paris and Mumbai

ABSTRACT

This thesis is an exploratory research into the intricate spatial attributes that shape patterns of violence in urban environments which have been prone to frequent terrorism. Through Paris and Mumbai, referred to as contested cities, the central question addressed is whether there exists a spatial logic between urban configurations and the patterns of warfare and terrorism. To investigate this, the study takes a holistic approach, employing Bill Hillier's Space Syntax framework as a pivotal analytical tool. The paper initially studies the urban layout of Paris, a city marred by the 2015 attacks, using Angular Segment Analysis. Route analysis reveals that attackers predominantly targeted streets highly integrated into the urban fabric, emphasising the influence of spatial configuration on their route selection. Further, the research introduces a multifaceted analysis comprising three risk layers: A) Explores the spatial distribution of attack points, uncovering a strategic preference for targeting the uppermost integrated street; B) Focuses on visibility, highlighting the significance of local and global integration in attack point selection; C) Examines the proximity of attack points to landmarks, revealing correlations that suggest a targeting strategy around prominent buildings. The Risk Layers combine to develop a Location Quotient for each point of attack and measure their vulnerability to terrorism. Transitioning to Mumbai, a city marked by the infamous 26/11 attacks, the study adapts a different approach due to a lack of detailed route information. It concentrates on spatial integration. Visual Graph and Agent-Based Analysis unveil the pivotal role of visual integration in guiding agent movement and potentially influencing attack patterns, aligning with Paris's findings.

In conclusion, this thesis underlines the importance of spatial attributes in determining violence patterns in contested cities. The synergy between integration, visibility, and proximity to landmarks emerges as a crucial determinant. Ultimately, it enhances the comprehension of the interplay between spatial attributes and urban warfare, underlining how multiple factors contribute towards it.

KEYWORDS

Space Syntax, Urban Warfare, Urban Configuration, Risk Layer, Vulnerability, Point of Attack

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1. INTRODUCTION

"Warfare, like everything else, is being urbanised."
(Graham, 2011, p. 47)

Urban areas are essential in providing homes and improving people's lives. Bill Hillier and Julienne Hanson, in 1984, described urban centres as dynamic hubs that facilitate and shape a wide range of activities in society. However, this centrality makes them prone to unwelcome focus (Glaeser and Shapiro, 2002; Svitková, 2016). Terrorism and violence are complications that cities never anticipated. For instance, the Intifada Campaigns that unfolded within the urban tapestry of Jerusalem, the recurrent spectre of bombings that have cast their shadows over cities like Beirut and Somalia, and the enduring series of attacks that have persisted in the urban landscape of Kabul. Incidents like these collectively share two fundamental attributes: an urban milieu within which they transpire and the manifestation of terrorist activities. This juxtaposition of urban environments with terrorism renders it a paradox. The attributes that define cities as liveable can create an atmosphere of vulnerability.

This thesis considers two tragic and internationally renowned instances – The 2015 Paris attacks *(Fig. 1)* and The Mumbai Taj Attacks of 2008 *(Fig. 2)*, known as 26/11. These incidents epitomise the harrowing consequences of violent intrusion into urban spaces. Cities have never been designed to confront such dire threats. *Mumbai*, a port city in India, has witnessed terror attacks since 1995, meticulously documented in the Global Terrorism Database[1] (LaFree and Dugan, 2007). Similarly, *Paris* has been an open ground for warfare since 1972.[2] Cities that stand vulnerable to the spectre of urban war are known as Contested Cities, as Pullan and Baillie (2013) described.

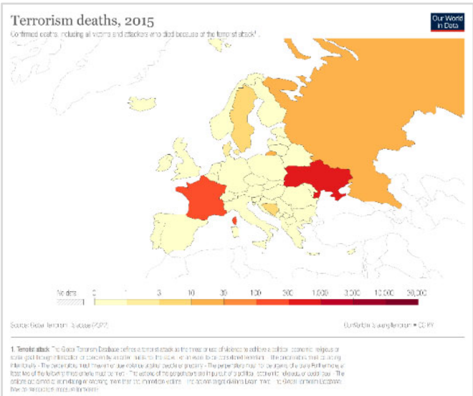

Figure 1- Map of France showing terrorism activities in 2015
Source – Generated by the author using https://ourworldindata.org/terrorism

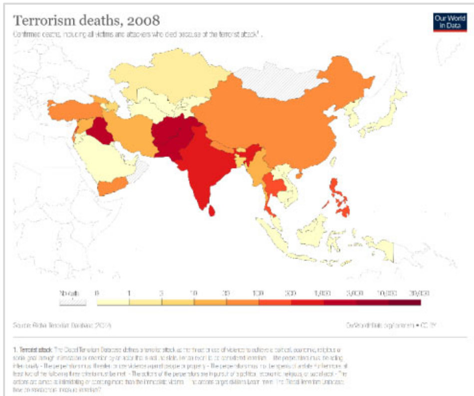

Figure 2 - Map of India showing terrorism activities in 2008
Source - Generated by the author using https://ourworldindata.org/terrorism

Such disheartening stories unfold in cities characterised by political or social instability, one shadowed by terrorism. Amidst the bustling urban realms of Mumbai and Paris, innocent lives were tragically caught and lost in the crossfire. In a recent publication, Ritchie *et al.* (2013) issued an updated data report for 2022 based on the Global Terrorism Database. The report highlights that within the past decade, an average of 26,000 lives have been lost yearly due to terrorism. This data underscores a pronounced concern that resonates within humankind. As the urban realm evolves and thrives, it prioritises functionality, social interaction, and civic vibrancy. However, as terrorism disrupts this harmony, it necessitates a recalibration of our understanding of urban spaces.

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[1] The Global Terrorism Database™ (GTD) is an open-source database including information on terrorist events around the world from 1970 through 2020 (with annual updates planned for the future).
[2] *Ibid.*

This research aims to delve into the intricate dynamics underpinning acts of violence, specifically focusing on the spatial logic using Space Syntax techniques that may drive such occurrences. As Savitch (2005) and Rokem, Weiss & Miodownik (2018) suggest, there is a need to describe the logic behind violence. The complex interplay of spatial configurations and urban environments within contested cities underscores the urgency of determining the multifaceted factors contributing to such distressing occurrences (O'Loughlin *et al.*, 2010). Likewise, the United Nations recognised the need for more effective and evidence-based interventions at the urban level to strengthen resilience against unrest activities. Aligning with the analytical approaches of these scholars, this study seeks to elucidate the spatial dynamics that intersect with instances of unrest.

This thesis sheds light on the profound impact of terrorism on the urban realm and how the layout of cities might make them vulnerable. As Hillier and Hanson described in 1984, there is a need to establish a framework to define the problem of urban space. Further, this thesis considers the problem of space as the breakdown of social order in urban space via terrorism. Hence, to identify the susceptible areas in the spatial arrangement of cities, the overarching research question of this paper is to determine:

Is there a spatial logic between Urban Configuration and the Pattern of War in Contested Cities?

In a broader context, and as a foundational premise for this research paper, it becomes pertinent to hypothesise that the areas within cities with high connectivity and visibility often emerge as easy targets for individuals carrying out foul activities. These individuals are referred to as "perpetrators" in this thesis. In the case of the Paris attacks, the exact points of targets and the routes taken by the perpetrators are identifiable. For Mumbai, the precise locations of targets are determined, however, the route information is not explicitly available.

Consequently, this investigation initially embarks upon exploring the city of Paris. A spatial inquiry is conducted and comprehended using the DepthmapX and QGIS software tools. The subsequent analysis encompasses the pivotal concepts of integration and visibility, which will be further explained in the following sections of this paper. These concepts are systematically examined to determine the spatial attributes that outline the city of Paris.

As Savitch (2005) and Robinson (2016) contend, within the urban-level research domain, including a comparative analysis is an advantageous approach. By adopting this methodological approach, the study extends beyond the confines of Paris. A parallel investigation is conducted involving the city of Mumbai, aligning with the same analytical framework as employed for Paris. However, an agent-based modelling system is used due to Mumbai's unavailability of route information. This system is meticulously configured to simulate movement from the starting points of attack, thereby generating plausible routes or directions that could have been undertaken. This approach, although adapted to Mumbai's context, serves to bolster the investigation of Paris.

An additional hypothesis driving this research delves into the significance and consequences associated with historical landmarks, often viewed as attractors for unrest activities. Frank (2011) and Pullan & Baillie (2013) propose that landmarks are innate to draw crowds, thereby emerging as focal points for orchestrated attacks strategically aimed at densely populated areas to maximise infrastructure and human casualties. This proposition is rigorously examined as well.

The subsequent chapter underlines the theoretical framework. Chapter 3 provides comprehensive insights into the urban fabric of both Paris and Mumbai, providing readers with a visual comprehension of their distinct urban realities. Elaboration on the datasets employed in this study, primarily encompassing the spatial coordinates of the points of attack and the directional routes undertaken in the context of Paris, forms the content of Chapter 4. The ensuing chapter, Chapter 5, delves into the articulated methodology, shedding light on the strategies employed to derive the study's outcomes. The limitations of the data used in the analysis are described in Chapter 6. Chapter 7 describes the analysis of the two cases. Chapter 8 discusses and compares the findings from both Mumbai and Paris while also laying out the conclusions drawn from the research relating these to the literature reviewed at the start.

2. LITERATURE REVIEW

This section theoretically explores the relationship between urban warfare and urban spatial configurations. It draws on the insights of scholars and researchers to understand the impact of urban form on war, spatial vulnerabilities of significant places and methods of warfare. In doing so, this literature review intends to assess the significance of the term "urban" in urban warfare and determine its complexities. Analysing past incidents in multiple cities will assist in comprehending the contribution of urban environments to war. These studies will, thereby, help to undergo an empirical investigation of the two cases studied in this report: Paris and Mumbai.

Urban warfare is a complex form of combat that presents obstacles for military forces. As Svitková (2015) noted, the spatial dynamics of cities, intricate layouts, and narrow streets make manoeuvring and coordinating troops difficult. Densely populated urban areas pose challenges such as minimising civilian casualties and collateral damage. Built environments in cities complicate matters, as soldiers must adapt to varying terrain and structures. According to Keogh (2020), military forces need specialised tactics and strategies for urban warfare. Close-quarters combat, technology, and intelligence make adaptability essential in urban warfare.

Urban warfare dramatically depends on the configuration of a city and cannot be disregarded. The city's layout and composition impact the tactics and strategies forces employ to uphold security measures. Military operations face challenges when dealing with intricate urban structures (Konaev, 2019). The organisation and design of cities impact military strategies, tactics, and the results of conflicts. Springer and Le Billon (2016) argue that cities featuring congested street networks, tall buildings, and narrow alleys act as obstacles towards violence. This enables them to create defensive positions and obstruct enemy movement. It becomes further challenging for attackers to navigate personnel and vehicles through urban terrain, thereby making the achievement of their malicious objectives difficult. The presence of infrastructure and strategic locations in urban areas affect human behaviour, interactions, and movement due to the social logic of space, as Hillier and Hanson (1984) argue. They maintain that the spatial arrangement of a city shapes how people move around and engage with their environments. Hence, effective city planning and design require understanding an urban space and its social dimensions.

Studying city structure and organisation can give insight into the complexities of urban warfare. Expanding knowledge in this area facilitates the comprehension of urban warfare's obstacles and opportunities. Glaeser & Shapiro (2002) and Rokem et al. (2018) examine the relationship between terrorism and urban structure. They emphasise the transformation and adaptation of cities to threats, particularly security measures, through urban design and architecture modifications. The authors investigate how cities respond to terrorist threats. Glaeser and Shapiro's (2002) research analyses the impact of terrorism on urban landscapes. Similarly, Rokem's study of 2018 suggests that geographies of urban violence are recognised as an issue of mobility and that spatial configurations shape and transform urban violence. Both studies examine the relationship between terrorism and urbanisation. In summary, it can be affirmed that urban form and organisation affect urban warfare.

City layout and characteristics determine vulnerability during the war. The construction and layout of a city affect its vulnerability to assault (Pullan and Baillie, 2013). Population density, infrastructure, and the layout of buildings and streets impact susceptibility. High population densities increase the danger of injury and fatalities. Cities might be a desired military target due to the prevalence of power plants and transportation hubs. Hegazi et al. (2022) investigated the use of space syntax in determining historic structures' societal and geographical susceptibility. Researchers got insights into potential targets and vulnerabilities in metropolitan areas using this analytical approach.

Additionally, highlighting their role as central attractions within the urban contexts, landmarks or buildings with historical importance play a significant role in terrorism activities. This role is briefly acknowledged by Frank (2011), where he interpreted the attacks on landmark buildings as acts of war, validating their significance as targets. Similarly, other scholars concisely discussed that "conflicts may form new urban topographies where certain quarters or landmarks are repeatedly threatened whilst other parts of the city may be rarely affected and relatively calm" (Pullan and Baillie, 2013, p.6). These papers signify that the existing literature fails to thoroughly explore the essence of landmarks and their broader influence on the urban realm. It is, however, essential to note that neither of these papers delve deeply into the comprehensive understanding of the intricate impact of buildings, which hold importance on the surroundings. While recognising landmarks as focal points for terrorist activities due to their capacity to draw crowds (Frank, 2011), these papers lay a foundational groundwork in acknowledging the centrality of landmarks in acts of terrorism, yet leave room for further investigations into the dynamics that characterise their relationship with the spatial context of cities.

While studying Turkish Cities, Lum and Kennedy (2012) asses the terrorism risk surrounding religious or political establishments. Their study concluded_"that terrorist incidents within Turkey are not randomly distributed throughout the landscape but rather are concentrated in a statistically significant way" (Lum and Kennedy, 2012, p. 179). It is, thus, essential to identify vulnerable areas to encourage preventative measures for these high-risk historic structures, assuring their survival for future generations and shielding them from danger. Using space syntax analysis, Hegazi et al. (2022) substantiate Lum and Kennedy's (2012) study by investigating the connection between spatial vulnerability and urban heritage conservation. These studies, together, recognise the implicit risks associated with buildings that come with authority and prominence.

Having established that cities are susceptible to violence, it is crucial to comprehend the causes and patterns of conflict. Rokem, Weiss, and Miodownik (2018) studied the spatial logic of intergroup conflict in Jerusalem. The authors investigated the phenomenon to understand the spatial dynamics and symbolic territoriality that drive acts of violence. Their research aims to analyse the factors causing conflict between two groups and find solutions to reduce violence in the divided city. Hence, they provide a layout of methods used to recognise the patterns of violence. Savitch (2005) performed a similar study on London, Moscow and Istanbul, with an extended focus on Jerusalem. He underlined precisely four patterns that terrorists or perpetrators follow to inflict urban terror. His findings on Jerusalem state how the city found a necessity in formerly enclosing open spaces due to urban terror, thereby disrupting urban life. His conclusions are justified by Rokem, Weiss, and Miodownik (2018) several years later, with a similar analysis for Jerusalem. Studying spatial aspects of violence aids researchers in comprehending conflict dynamics and eventually determining why some spaces are more prone to violence. With this logic, it is reasonable to expect that spatial analysis is crucial for examining conflict distribution and understanding its causes.

Following the exploration of the underlying factors contributing to spatial violence, this section of the literature review examines the precedence of various methods of warfare. These methods are strategies the perpetrators use during a conflict to engage with an adversary (Miles, 1999). They can either be the weapons used or the tactics employed. With its history of urban intergroup conflict, Jerusalem demonstrated how a city's spatial layout can influence acts of violence (Savitch, 2005; Rokem, Weiss and Miodownik, 2018). The violence often manifested in Jerusalem is through clashes and confrontations between ethnic and religious groups. These conflicts were characterised by localised, sometimes spontaneous, fights rather than coordinated large-scale attacks.

Alternatively, Belfast's experience with the Shankill-Falls divides highlights the role of urban planning in fostering or mitigating conflict (Boal, 1969; Rifai and Emekci, 2022). This city witnessed a prolonged sectarian violence, with clashes occurring in segregated neighbourhoods. Territorial disputes and tensions between Catholic and Protestant communities often triggered the violence. In contrast, Shenyang's historical experience revealed the long-lasting impact of urban planning decisions on urban vulnerabilities. Although not marked by a specific attack, the city's history, particularly during the late 19th and mid-20th centuries, illustrated how the city's urban design and its extension were influenced by war (Wang, Newman and Wang, 2019).

The Mumbai Terror Attacks[3] occurred in Maharashtra, India, in 2008. A group of 10 gunmen in three groups executed the attacks over four days (Azad and Gupta, 2011). There were suspicions of their ties with Lashkar-e-Taiba[4] (LeT), a terrorist group in Pakistan. The terrorist attack incident was very revealing, considering that the perpetrators carried automatic firearms and hand grenades. The attackers concentrated specifically on innocent individuals at various locations in the southern region of Mumbai (Rabasa, Blackwill and Chalk, 2009). The attack represented an instance of terrorism arising from animosity and a longstanding history of rivalry between India and Pakistan (Azad and Gupta, 2011). Another evident case Ray (2022)

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[3] Mumbai Terrorist Attacks (November 26-29,2008), see in references.
[4] Sisson, M. (2023, June 17). Lashkar-e-Taiba. Encyclopaedia Britannica. https://www.britannica.com/topic/Lashkar-e-Taiba, see in references.

described is the Paris Attacks of 2015, similar to Mumbai, a coordinated set of attacks on the evening of 30 November. The Islamic State in Iraq and the Levant [5] (ISIL) claimed responsibility for the bloodshed. Cities like Jerusalem, Belfast, Shenyang, Mumbai and Paris collectively underscore the intricate relationship between urban layout and various forms of violent incidents, urging scholars and practitioners to delve deeper into the spatial logic of urban warfare for a better holistic understanding of urban security.

As it stands, a substantial amount of academic literature has been reviewed. Nevertheless, specific notable gaps in the literature are further emphasised. The literature studies the Mumbai and Paris attacks from various perspectives, such as social network analysis (Azad and Gupta, 2011) and the psychology of terrorism (Borum, 2004). Further investigations are needed, specifically focusing on the spatial aspects of these attacks. Analysing spatial organisation, violence patterns, and the relationship between physical factors in urban environments during the attacks must be involved. The literature lacks a comparative analysis of urban warfare incidents in more than one city on the grounds of linking the city's spatial layout with target reachability. Therefore, this thesis chooses two cases with similar temporal yet contrasting spatial characteristics: Mumbai and Paris. Analysing the similarities and differences in the spatial dynamics, tactics, and impacts of these attacks would improve the perception of how urban environments shape malicious activities.

The specificities of how buildings in urban planning impact urban warfare are underexplored. A substantial body of scholarly work has investigated visibility in urban environments, analysing factors such as the scope of vision from different vantage points and its quantitative aspects (Bada and Farhi, 2009; Vaughan and Sailer, 2017). These studies have systematically examined visibility within diverse urban settings. However, it is noteworthy that the exploration of visibility concerning terrorism in urban areas remains a significant gap in the existing literature. Determining what part of the urban realm is visible can be paramount in understanding high-speed attacks (as the perpetrators used vehicles during the assaults), as it

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[5] Islamic-State-in-Iraq-and-the-Levant

may profoundly influence their decision-making process regarding their chosen targets. Hegazi et al. (2022) discuss the vulnerability assessment of heritage buildings, emphasising space syntax analysis. Additional research is required to examine the spatial dimensions of vulnerability, such as the visibility of affected areas. Consequently, the existing literature is used to study visibility in an urban context powered by terrorism.

Multiple studies have offered insights into urban warfare but lack a framework that integrates spatial and psychological dimensions. Hillier and Hanson (1984) analyse the social logic of space, while Hillier (2016) questions the cities' purpose and spatial form. There is a gap in synthesising ideas into a framework to guide investigations in urban warfare. Urban form's impact on war needs further exploration. Studies by Glaeser and Shapiro (2002) and Zhukov (2012) analyse the effects of terrorism and the diffusion of insurgent violence in urban areas. A comprehensive analysis is needed to understand how urban forms influence urban warfare. Addressing literature gaps contributes to understanding the role of urban environments in urban warfare and, with further research, can provide insights for planning, policy development, and conflict resolution strategies. Future research should fill gaps by conducting empirical investigations integrating spatial analysis and urban planning approaches to realise the dynamics of urban warfare in cities such as Mumbai and Paris.

3. Case Studies

3.1 Paris and the 2015 attacks

Figure 3 – An illustrated collage of Paris
Source - Adapted from Midjourney by the author

Figure 4 – Urbanisation of Paris
Source – Portella (2017)

Paris is known for its compact and dense urban layout, characterised by narrow streets, historic architecture, and well-defined neighbourhoods, as illustrated in figures 3 & 4 above. The city is renowned for its iconic landmarks and cultural heritage buildings that act as prominent tourist attractions. With a total population of 2.1 million (Insee, 2023), it forms the capital city of France and is located in the north-central part of the country *(Fig. 5)*. Lying on the Seine River, which flows through the city, it divides itself into the Right Bank (Rive Droite) and the Left Bank (Rive Gauche) *(Fig. 6)*. Since the 1980s, France has been an open ground for terrorism.[6] Scholars have noted that "throughout the 1980s and much of the 1990s, France was considered a haven for international terrorists" (Shapiro and Suzan, p. 68).

[6] This is still the popular image of French policy toward terrorism. According to a recent statement by Robert McFarlane, a National Security Advisor in the Reagan administration, 'with respect to terrorism, the French have been willing to wink at terrorists coming through and even finding safe haven in France as long as they didn't kill anybody in France'. Hannity & Colmes Show, Fox Network, September 17, 2002, Transcript # 091701cb.253

Paris was shaken on 13 November 2015 by a series of terrorist attacks organised by the Islamic State (IS)[7] militant group, leaving 130 people dead and 350 injured.[8] The targeted locations in Paris include the Bataclan Concert Hall, Stade de France stadium and five other locations, tabulated in Table 1 in the following Datasets chapter. These attacks were, as ISIS claimed, "a response to France's campaign against its fighters and insults against Islam's prophet," which occurred earlier in the same year (Muro, 2015, p. 1).

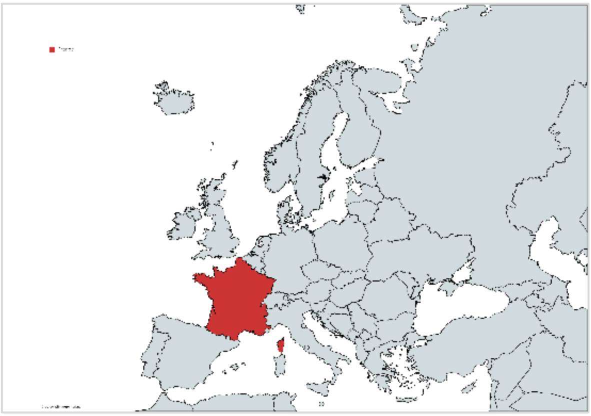

Figure 5 – Map depicting France in the European subcontinent
Source - Generated by the author using https://www.mapchart.net/

Figure 6 - Map of Paris, marked with the appx. area of study
Source – Generated by the author using https://snazzymaps.com/

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[7] *Supra* note 5, at 9.
[8] Paris attacks: What happened on the night

3.2 Mumbai and the 2008 attacks

Figure 7- An illustrated collage of Mumbai
Source – Adapted from Midjourney by the author

Figure 8 - Urbanisation of Mumbai
Source – Mumbai (2018)

Mumbai is a densely populated and sprawling metropolis with a vast urban landscape *(Figs. 7 & 8)*. It is the capital city of Maharashtra in India *(Fig. 9)*. Located on the western coast, with several waterfront areas, and a natural harbour *(Fig. 10)* it has a population of about 21 million (Macrotrends, 2023). With a mix of high-rise buildings, slums, residential areas and iconic landmarks, "Mumbai is India's commercial and entertainment centre" (Rabasa et al., 2009, p. 11). On 26 November 2008, The Lashkar-e-Taiba[9] group infiltrated the city via its waterways, instigating a series of attacks throughout the city. The city's geography played a role in the attackers' choice of targets, including the targeting of the Taj Mahal Palace Hotel, which overlooks the Arabian Sea (Rabasa, Blackwill and Chalk, 2009). This pivotal juncture in Mumbai's history marked the gravest incident, resulting in the loss of 174 lives and the injuring of nearly 300 individuals throughout the harrowing four-day onslaught orchestrated by the perpetrators.[10]

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[9] *Supra* note 4, at 8.
[10] https://edition.cnn.com/2013/09/18/world/asia/mumbai-terror-attacks/index.html

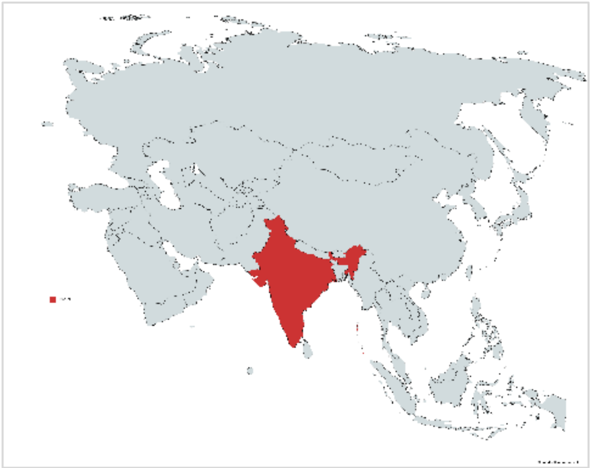


Figure 9- Map depicting India in the Asian subcontinent
Source - Generated by the author using https://www.mapchart.net/

Figure 10 - Map of Mumbai, marked with the appx. area of study
Source – Generated by the author using https://snazzymaps.com/

3.3 Why compare Mumbai and Paris

The attacks of 9/11 in New York are a prime event in the history of terrorism, with which many acts of war are compared (Glaeser and Shapiro, 2002; Frank, 2011). Comparative studies seek to distil lessons from subsequent instances of urban warfare and enrich the understanding of the relationship between spatial structures and the dynamics of warfare activities. Authors such as Savitch (2005), Gaffikin & Morrissey (2011) and Rifai & Emekci (2022) have been comparing cities with other cities. Robinson (2016) echoes a parallel perspective that underscores the imperative of adopting a broader, global framework when delving into urban studies. She advocates for an innovative reconfiguration of comparative methodologies and introduces a novel typology of strategies to navigate urban comparative research.

Adopting this method of comparison broadens the scope of urban research and opens up a vast source of potential knowledge with worldwide relevance. This theory resonates with the ethos of Space Syntax theory, where the configuration of urban spaces and their intricate interplay with sociocultural dynamics informs a holistic understanding of the urban fabric. Thus, within the context of this research, the exploration is extended beyond Paris to encompass Mumbai in later stages. This comparison aims to follow the studies detailed above.

4. DATASETS

4.1 Data from the Global Terrorism Database and Kaggle

The Global Terrorism Database (GTD) is a reputable and all-encompassing repository providing intricate insights into global terrorist occurrences.[11] This resource is meticulously developed by the National Consortium for the Study of Terrorism and Responses to Terrorism (START), a distinguished research hub at the University of Maryland in the United States (LaFree and Dugan, 2007). From 1970 onwards, the database has been a document of terrorism-related information, rendering it an epitome of comprehensiveness and reliability. The GTD encapsulates diverse terrorist incidents, including bombings, targeted assassinations, armed assaults, hostage scenarios, and many other acts of violence perpetrated by international and domestic terrorist factions all over the World. For this particular thesis, the exact coordinates of the attack points, both for Paris and Mumbai, were extracted using GTD. The coordinates are stipulated in Tables 1 & 2.

An additional resource used to verify and confirm the datasets obtained from GTD is Kaggle.[12] Kaggle serves as an online ecosystem and platform repository for diverse datasets, competitive endeavours, and projects within data science. It traces back to 2010, culminating in its acquisition by Google in 2017. Kaggle fosters a collaborative milieu that facilitates engagement for data scientists, researchers, and enthusiasts alike. Within this interactive sphere, individuals can readily access and engage with an expansive array of datasets, exchange code and insights, and actively participate in competitions centred around machine learning. The spatial coordinates acquired through the Global Terrorism Database (GTD) are cross-referenced with Kaggle's resources, and a measure is undertaken to enhance the precision and certainty of the attack coordinates. This verification process aligns with the principles of space syntax, which emphasise the meticulous analysis and validation of spatial data.

[11] *Supra* note 1, at 2.
[12] https://www.kaggle.com/datasets

Table 1
The coordinates of the attacks in serial order Paris, 2015, obtained via GTD.

id	Name	Latitude	Longitude
1	Stade de France - 1st attack	1136014.7	618704.84
2	Stade de France - 2nd attack	1135885.3	619004.1
3	Fast Food Outlet	1135745.7	619010.4
4	Le Carillon Bar	1130171.3	619440.73
5	Le Petit Cambodge	1130180.8	619460.11
6	Rue De la Fountaine	1129816.4	619633.61
7	Bataclan Concert Hall	1129227.7	619686.62
8	La Belle Equipe bar	1128204.3	620484.82
9	Le Comptoir Voltaire	1127816.9	621282.9

Table 2
The coordinates of the attacks in serial order Mumbai, 2008, obtained via GTD.

id	Name	Latitude	Longitude
1	Chhatrapati Shivaji Terminus Railway Station	18.941551	72.835703
2	Cama Hospital	18.942054	72.832265
3	Leopold café and bar	18.923427	72.831089
4	Colaba Police Station	18.922176	72.830977
5	Taj Mahal Hotel	18.921607	72.833276
6	The Oberoi-Trident hotel	18.926883	72.820304
7	Nariman House	18.916568	72.827568

Images for attack points in Paris and Mumbai are shown in Figures 11 and 13 respectively.

4.2 Data extracted from other sources

In this section, all information gathered from various sources (explained below) is compiled in tables and maps. This data is crucial for this thesis, as it forms the foundation of the research.

4.2.1 For Paris

Eleven perpetrators were responsible for the Paris 2015 attacks.[13] They formed three groups who drove around the city in stolen black cars and attacked multiple locations with AK-47s.[14] Following these events, eyewitness testimonies (Ray, 2022) were recorded, with the Netflix documentary series "13 November: Attacks on Paris" (2018) offering an additional source of insight. Drawing from these resources, the routes undertaken by the three groups on the night of the massacre are reconstructed by the author of this paper in Figure 12. The vehicles were found abandoned after a police chase, which left nine perpetrators dead, and two were arrested. Later, the police released house locations where the perpetrators resided before the attack. The sequence of the attacks is documented in Table 3 below.

Table 3

The Sequence of Attacks in Paris 2015, colour-coded according to team formation.

WHEN	WHERE	HOW	WHO	TYPE
21:20	One Entrance of Stade de France	Suicide Bomber	Bilal Hadfi	Planned
21:30	Another Entrance of Stade de France	Suicide Bomber	Ahmad- Al-Mohammed	Planned
21:53	Fast food outlet near the stadium	Suicide Bomber	M Al Mahmod	Planned
21:25	Le Carillon Bar	Gun Fires	Salah Abdeslam	Planned
21:25	Le Petit Cambodge Restaurant	Gun Fires	Mohammed Abrini	Not planned
21:32	Rue de la Fontaine au Roi	Gun Fires	Chakib Akrouh	Not planned
21:36	La Belle Equipe bar	Gun Fires	Abdelhamid Abaaoud	Not planned
21:40	Le Comptoir Voltaire Restaurant	Suicide Bomber	Brahim Abdeslam	Planned
21:40-00:20	Bataclan Concert Hall	Gun Fires	Omar Ismail Mostefai Samy Animour Foued Mohamed-Aggad	Planned

[13] *Supra* note 8, at 12.

[14] 'Operator's Manual for AK-47 Assault Rifles'. Department of the Army, produced by 203d military intelligence battalion.

a) Stade de France Stadium
Source - abc news

b) Le Petit Cambodge Restaurant
Source - mirror.co.uk

c) Bataclan Concert Hall
Source - reuters.com

d) Le Carillon Bar
Source - gettyimages

e) Le Comptoir Voltaire Restaurant
Source - latribune

f) La Belle Equipe bar
Source - wsj.com

Figure 11 –Buildings attacked in Paris in 2015
Source – Author of this paper

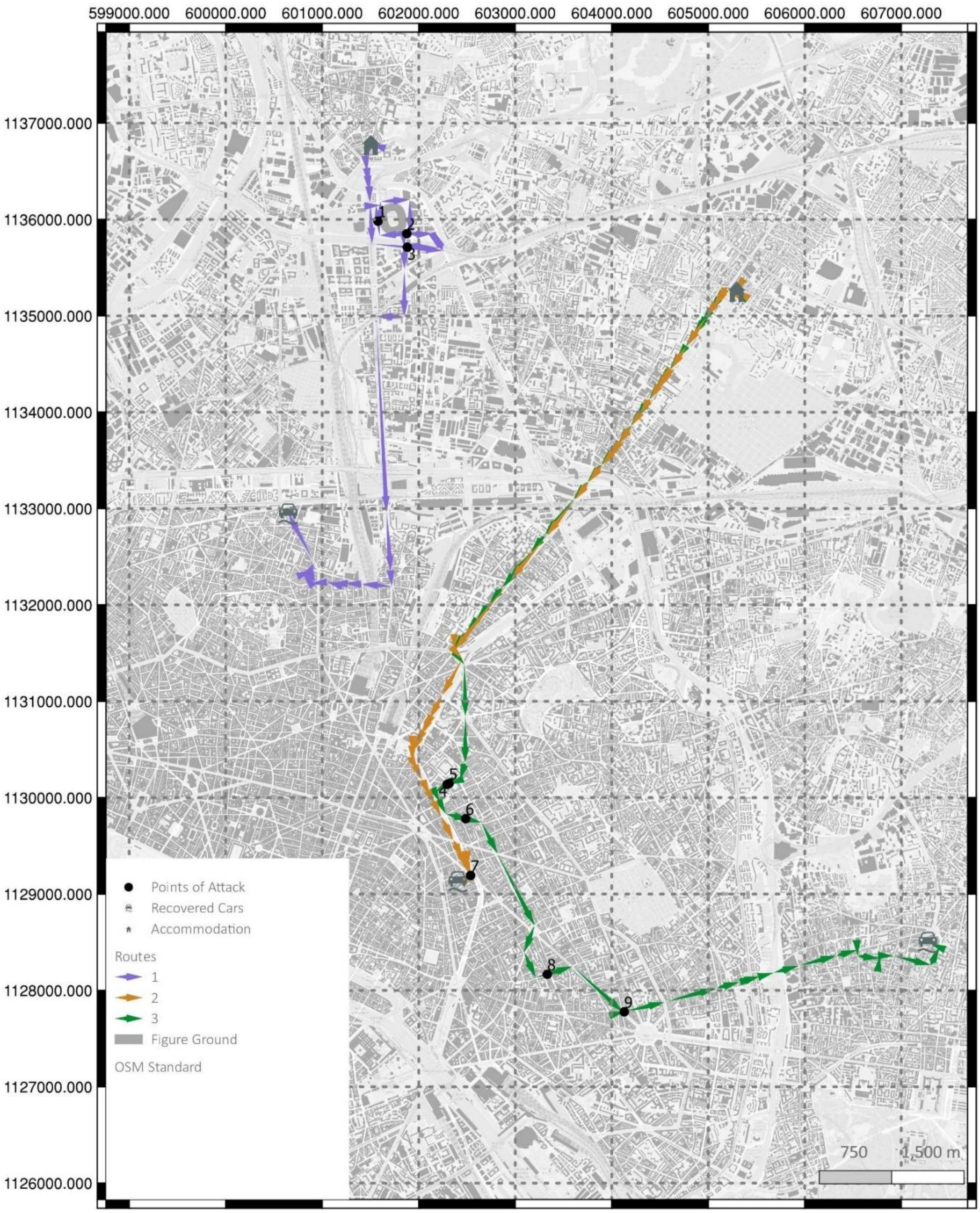


Figure 12 – Routes 1, 2 & 3 constructed on the map of Paris, showing the commencement (accommodation), mid-way journey (attacks) and conclusion (cars found) and overall coordinates
Source – Author of this paper

4.2.2 For Mumbai

The Mumbai attackers came by sea, sailing from Karachi on a Pakistani cargo vessel (Rabasa, Blackwill and Chalk, 2009). Ten perpetrators landed on two different points on the city's southern coast. A document published by the Federation of American Scientists titled 'Mumbai Terrorist Attacks (November 26-29, 2008)' [15] reported that the attackers further divided themselves into five teams of two each. They meticulously targeted iconic landmarks such as the Taj Mahal Palace Hotel, the Oberoi Trident Hotel, and the Chhatrapati Shivaji Terminus railway station,[16] marked in Figure 14. The previously mentioned report, and Rabasa, Blackwill & Chalks' paper published in 2009, mentions cars being stolen by the perpetrators to commute from one insurgency point to the other. However, unlike Paris, no records or traces can list which routes were taken for the attacks. The chronology of the attacks, with their respective perpetrators, is documented in Table 4.

Table 4
The Sequence of Attacks in Mumbai 2008, colour-coded according to team formation.

WHEN	WHERE	HOW	WHO (Perpetrators)	TYPE
21:20	CST Railway Station	Kalashnikov rifles and lobbed grenades	Mohammed Ajmal Amir Kasab and Ismail Khan	Planned
21:40	Cama Hospital	Firing	Mohammed Ajmal Amir Kasab and Ismail Khan	Not planned
21:40	Leopold café and bar	AK-47 Assault Rifles, Grenade	Abdul Rehman Bada and Abu Umar	Planned
21:41	Colaba Police Station	AK-47 Assault Rifles, Grenade	Abdul Rehman Bada and Abu Umar	Planned
21:38	Taj Mahal Hotel	Gun Fires	Abdul Rehman Bada and Abu Umar	Planned
21:43	Taj Mahal Hotel	Gun Fires and grenades	Shoaib and Javed	Planned
22:00	The Oberoi-Trident hotel	Gun Fires	Abdul Rehman Chotta and Fahadullah	Planned
22:25	Nariman House	Gun Fires	Babar Imran and Nazir	Planned

[15] https://irp.fas.org/eprint/mumbai.pdf
[16] *Supra* note 3, at 8.

a) Chhatrapati Shivaji Terminus
Source - Guardian.com

b) Nariman House
Source - The Indian Express

c) Colaba Police Station
Source -[Hindustan Times]

d) Leopold Café and Bar
Source - [Flickr]

e) Cama Hospital
Source - [Mumbai Mirror]

f) Taj Mahal Hotel
Source -[The Telegraph]

g) The Oberoi Trident Hotel
Source -[Rediff.com]

Figure 13 –Buildings attacked during 26/11 in Mumbai
Source – Author of this paper

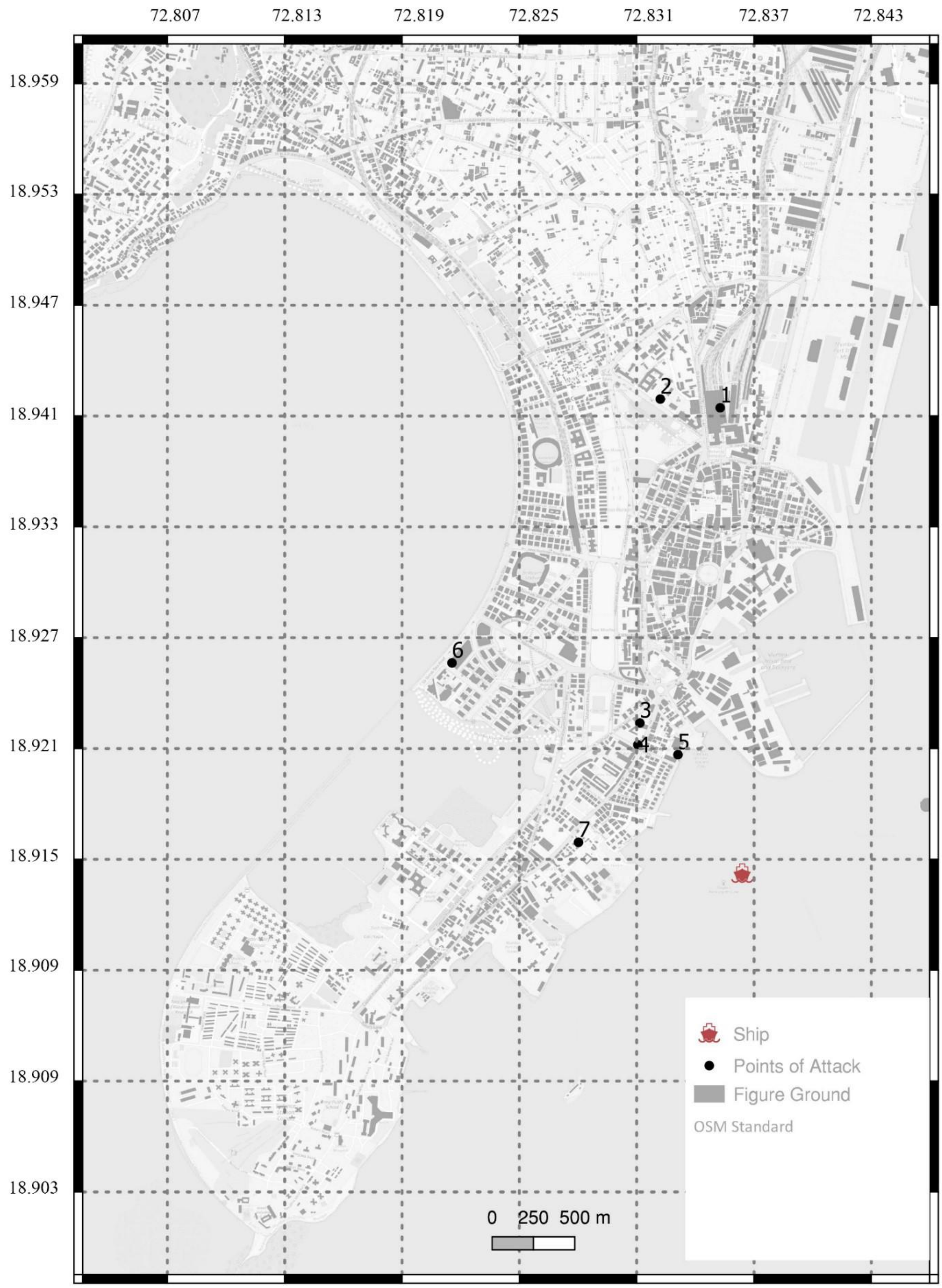


Figure 14 - Map of Mumbai, showing the position of attacks and overall coordinates
Sources – Author of this paper

5. METHODOLOGY

Space syntax is a science-based approach to studying the relationship between spatial organisation and social, economic, and environmental factors in buildings and urban areas. It was developed in the 1970s by Bill Hillier, Julienne Hanson, and colleagues at the Bartlett in University College London. It uses quantitative analysis and geospatial computer technology to study spatial configurations at all scales. This paper uses the concepts provided by space syntax as it has been widely applied to explore the relations between spatial organisations within the built environment (Rokem, Weiss and Miodownik, 2018; Hegazi *et al.*, 2022; Lee, Ostwald and Zhou, 2023). It examines the city layout with respect to well-connected streets and how they affect the navigation of the perpetrators in the case of Paris and Mumbai.

The initial phase of the methodology involves the comprehensive collection of spatial data consisting of the street network. An axial map, a widely used line-based representation of the urban system used in the space syntax community (Hillier and Hanson, 1984), is drafted for Paris and Mumbai by the author, using Open Street Maps[17] as the base. These maps are a conclusion of straight lines that connect two or more spaces without passing through any other space. Furthermore, the axial maps are converted to segment maps, simplifying the complex spatial information (Turner, 2007). Doing so helps break down the long, intricate connections (achieved by an axial map) into individual street segments, providing an enhanced representation of how people navigate a city.

Furthermore, the maps used in this analysis are not drafted for the whole cities but only for a defined area around the insurgency points (the points of attack), which form the study area, to a total radius of 9 kilometres in both cases. The reliability of network analysis is improved by

[17] https://www.openstreetmap.org/
OSM relies on crowdsourced data, which can vary in accuracy and completeness. Contributors may have different levels of expertise and may not always provide up-to-date information. Iinaccuracies and outdated information may be present. Nonetheless, efforts to enhance the accuracy of the maps, particularly within the designated study area have been made.

creating a street network model larger than the study area. An extended model, or the buffer area, is constructed beyond the boundaries of the study area.

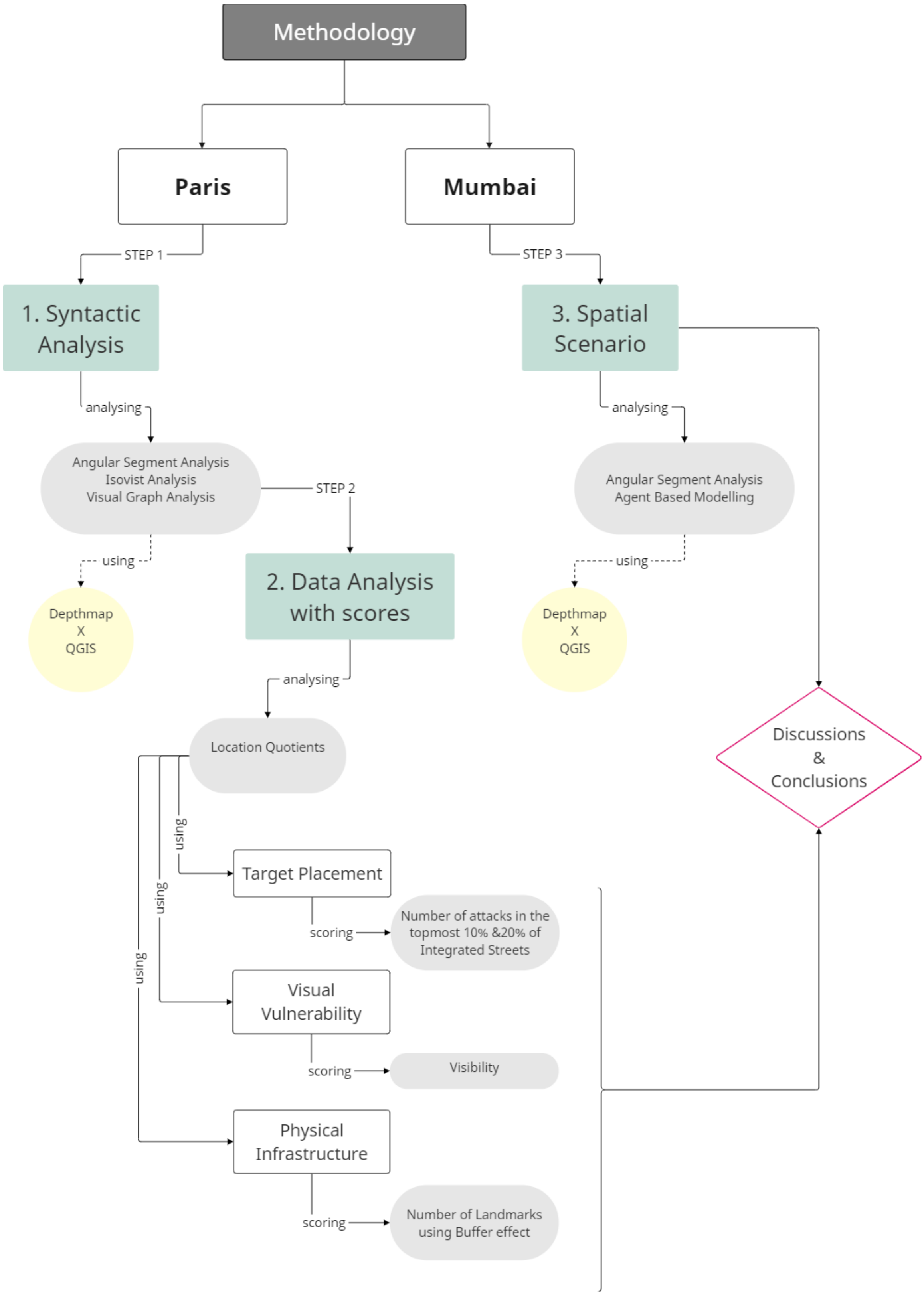


Figure 15 – Flow chart of the Methodology followed in this paper
Sources – Author of this paper

The entire model is then analysed, although only the results within the smaller study area in the centre are reported (Gil, 2017; Lee, Ostwald and Zhou, 2023). Adopting this approach reduces the impact of edge effects, which can distort the results of network centrality analysis. An overview of the methodology followed in this research paper is explained using a diagram in Figure 15. This thesis uses three distinct methods to address the research question mentioned in Chapter 1 and test the hypothesis. The outlines of the methods are laid below.

5.1 Syntactic Analysis for Paris

In this method, space syntax techniques such as axial line analysis (ALA), angular segment analysis (ASA), isovist analysis (ISA) and visual graph analysis (VGA) are used to study syntactic parameters like integration (to-movement), connectivity and visibility for the study area of Paris. This paper combines ASA and ISA/VGA techniques, as discussed by Desyllas and Duxbury (2001), to comprehensively explore aspects related to wayfinding and visual accessibility. Integration is the fundamental value for this paper, as research done by Lee, Ostwald and Zhou (2023) suggests they are closely related to human behaviour or movement patterns in the built environment.

To delve deeper into the subject, grasping the precise terminology often discussed in the Space Syntax discourse is imperative. Hillier and Hanson explain the concept of integration in their seminal work "The Social Logic of Space," published in 1984, as the level of direct access and visibility between spaces. Choice, however, relates to the number of possible paths and routes between spaces, influencing movement options in a spatial configuration, and connectivity involves the degree of spatial linkage and accessibility within a layout.

The initial step in the methodology involves the creation of an axial map via AutoCAD software, which is subsequently transformed into a segment model using DepthmapX software (Turner, 2004). Converting an axial map to a segment map is crucial due to the complexity of the axial representation. The analysis extends to segment maps encompassing varying radii, ranging from 800 meters to a comprehensive global radius (Gil, 2017; Hillier, 2019).

Geographic Information System (GIS) software, specifically QGIS, is used to enhance the comprehension and visualisation of these findings. QGIS aids in the spatial analysis and visualisation of geospatial data, enabling a comprehensive presentation of the outcomes. After thoroughly examining the maps and gathering all the vital information, the focus shifts to mapping all the terrorism sites (using latitude and longitude values) on the map. Furthermore, the routes taken by the perpetrators are determined (using eyewitness reports discussed in Chapter 3) and mapped in QGIS.[18]

As defined by Bill Hillier in Space Syntax terms, an isovist is a visible space from a particular vantage point within a given environment (Benedikt, 1979; Turner and Penn, 1996). In this study, the utilisation of ISA or Isovist Analysis takes on dual dimensions: point-based, where it focuses on individual vantage points, and path-based, wherein the emphasis is on trajectory-related analysis. A point-based Isovist approach was employed to accurately depict the building's positioning within the street concerning the point of attack. This step involved the creation of Isovists from the building's facade directed towards the road, facilitating the calculation of the area of the Isovist and, notably, its most extensive line of sight (Bada and Farhi, 2009; Vaughan and Sailer, 2017). The latter is used to determine the building's visibility from the approach taken by the perpetrators. Furthermore, path-based Isovists and Visual Graph Analysis (VGA), as studied by Bada and Farhi (2009), proved valuable in assessing the overall visibility encompassing the three distinct routes in this paper.

5.2 Evaluation with Scores for Paris

The syntactic data is analysed via the 'Risk Layers' concept, a term borrowed from Lum and Kennedy (2012). Risk values computed from these layers can be used along with actual terrorism incidents to calculate Location Quotients (LQs). LQs are mapped to identify the areas with the highest likelihood of attacks (Lum and Kennedy, 2012) to assess relative risk. Each layer is assigned a value; hence, locations with the highest and lowest quotients are noted (Li

[18] EPSG 27571 for Paris and 4326 (OTF) for Mumbai are used. EPSG stands for European Petroleum Survey Group and is an organization that maintains a geodetic parameter database with standard codes, the EPSG codes, for coordinate systems, datums, spheroids, units and such alike.

et al., 2021). Previous studies have used this method to explore the urban environment from the perspective of terrorism, incorporating a comprehensive analysis (Glaeser and Shapiro, 2002; Savitch, 2005; O'Loughlin *et al.*, 2010; Hegazi *et al.*, 2022). This present study encompasses an evaluation of the following layers:

5.2.1 Target placement

How integrated or segregated are the selected targets in the urban fabric?

The location of attacks is marked on the map to analyse their placement. This step involves tallying the number of attacks that occurred within the upper 10% and 20% integrated streets. Through this method, it can be determined what percentage of attacks occurred in the most integrated streets of Paris' urban layout. This methodology builds on prior research that distinguishes between collective and individual terrorism occurrences (Rokem, Weiss and Miodownik, 2018) tested in Jerusalem.

5.2.2 Visual vulnerability

What is the visibility integration of the selected targets from the street segment through which it is approached?

Each point of attack has a specific visual integration value (established through VGA) and an observable visible length from the street through which they were approached (determined through ISA) by the perpetrators. This approach determines a visibility score for each targeted point, listing the target that offered the maximum and minimum visible surface with respect to the route of attack.

5.2.3 Physical infrastructure

Where are the historical landmarks present around the selected targets?

In the aftermath of the 9/11 incident, where historic landmarks became targets, a trend has emerged, highlighting the vulnerability of landmark buildings as potential epicentres of terrorist activities (Frank, 2011; Pullan and Baillie, 2013). Consequently, this study determines whether there is an evident trend in the placement of attack points, considering proximity to landmark buildings.

5.3 Determining Spatial Scenarios of Mumbai, using Paris

The analysis of Paris is followed by that of Mumbai to build on the refined comprehensive database available for the former. Given the absence of a designated route, the perpetrators took in the case of Mumbai, agent-based simulation (ABS) is used to examine the syntactic attributes of integration and visibility along the most likely route taken. Supplementary Space Syntax techniques, including axial line analysis (ALA) and visibility graph analysis (VGA), are employed to uncover the city's prevailing generic patterns and spatial attributes.

6. LIMITATIONS

- The study aims to determine urban terrorism and its broader patterns, focusing on a general understanding rather than precise predictions. Choosing not to make specific predictions might make it harder for the study to provide practical advice or strategies for urban security planning. By avoiding forecasts, the study might miss the chance to find detailed links between building features, city layouts, and terrorism.
- There is a significant discrepancy with the travel route data in Paris. It was collected from eyewitness reports and additional data, which might be inaccurate and potentially have mistakes. Additionally, the maps for both cities were drawn by hand, which could introduce inaccuracies.
- Another notable limitation of this study is the exclusion of data related to the Stade de France Stadium, where attacks 1 and 2 occurred. Due to the stadium's distinct spatial characteristics and enclosed nature, it was omitted from the urban analysis, which may impact the comprehensiveness of the findings.
- The heights of the buildings are not taken into account when constructing Isovists for the visibility analysis. The analysis focuses solely on the two-dimensional plane, i.e., it does not consider the vertical dimension of the urban environment. This limitation should be acknowledged when interpreting the results, as it may affect the accuracy of the visibility analysis.
- Lastly, due to the secretive and clandestine nature of terrorist activities, the overall information about terrorist incidents, perpetrators, or their motivations might be inaccurate.

7. RESULTS

In the scope of this thesis, the primary objective is assessing the vulnerability of points attacked in Paris through the application of diverse criteria outlined in the Methodology section. This endeavour aims to determine the distinctive spatial attributes of the city and delve into the rationale behind the chosen routes of the perpetrators. Further, this inquiry delves into their perception of the urban environment and how the city and, specifically, how each targeted building or street projected itself to the perpetrators.

7.1 Analysing the route selection

The Angular Segment Analysis model is drawn and analysed within the designated study area of Paris. This model is implemented across a range of scales (in this case, Radii), spanning from a local extent with a radius of 400 meters to a global scope defined by the radius 'n'. Given that the mode of travel involved automobiles, encompassing greater distances (global) compared to pedestrian mobility (local), the radius selection naturally inclined towards higher values, starting potentially from 2000 meters and extending upward.

Considering the maximum distance of 9 kilometres between the farthest attack points in Paris, a buffer zone spanning 9 kilometres around each attack location is adapted to facilitate a viable study framework. This buffering process eventually forms an ovoid or elliptical shape (Fig. 16), resulting in a maximum 9000-meter radius for large-scale analysis. A parallel radius is adopted for Mumbai, maintaining uniformity in the study methodologies for both cities.

Upon analysing integration values across various radiuses in QGIS, it is observed that the network of radius 6000 meters has an average integration value of 1.20. This average lies between the values obtained for Radius 2000 (local) and Radius N (global), which were 1.13 and 1.23, respectively *(see Appendix 1).* These integration values are obtained through analysed maps via QGIS *(figures 17 & 19)*, and the values are extracted as Excel files. Therefore, in the case of Paris, this observation validates the comprehensive representation of the urban network at a radius of 6000 meters or 6 kilometres throughout the paper *(Fig. 18)*.

Figure 16- NAIN_RN_Paris_Whole Map
Source – Author of this paper

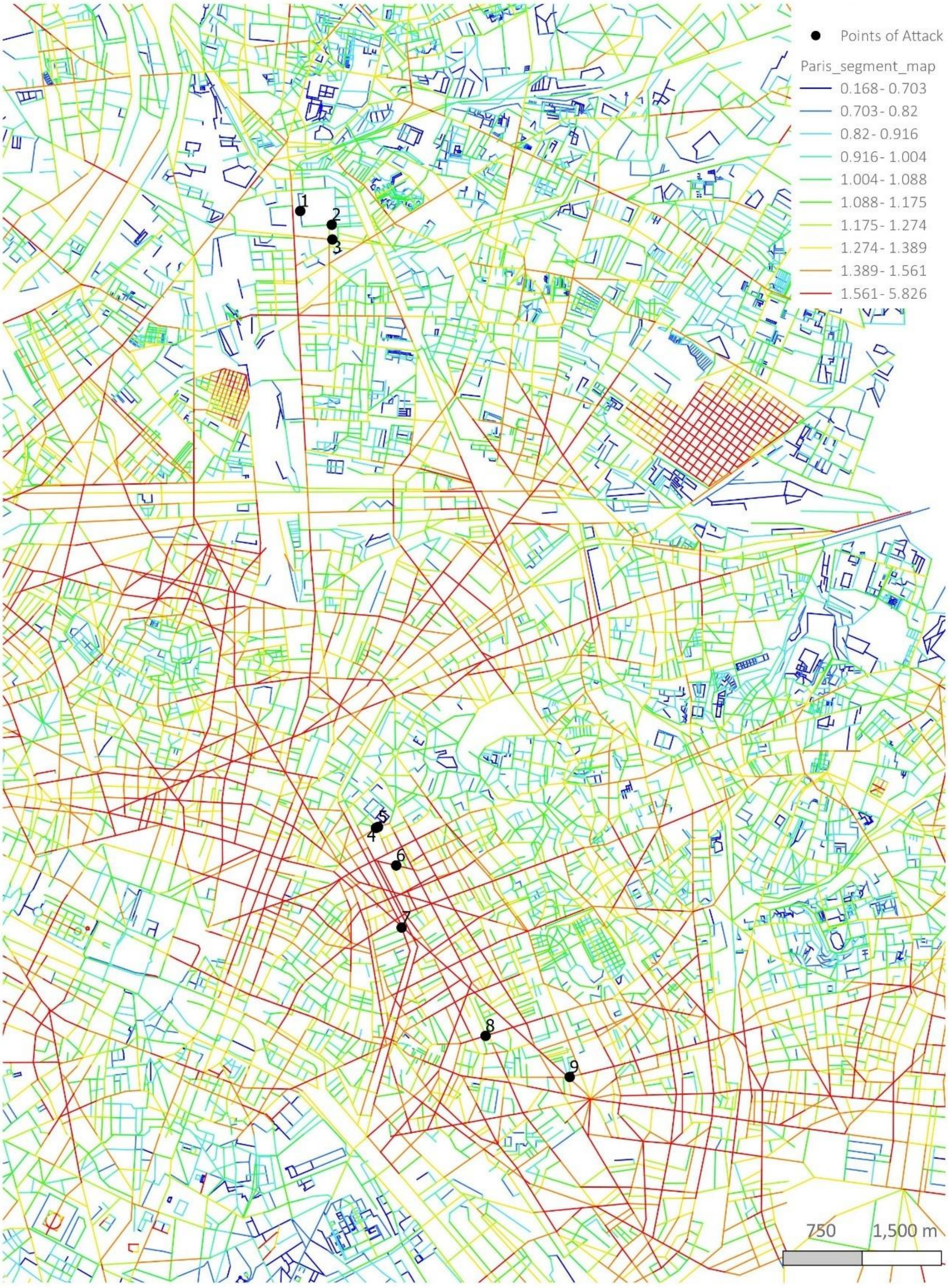


Figure 17- NAIN_R2000_Paris
Source – Author of this paper

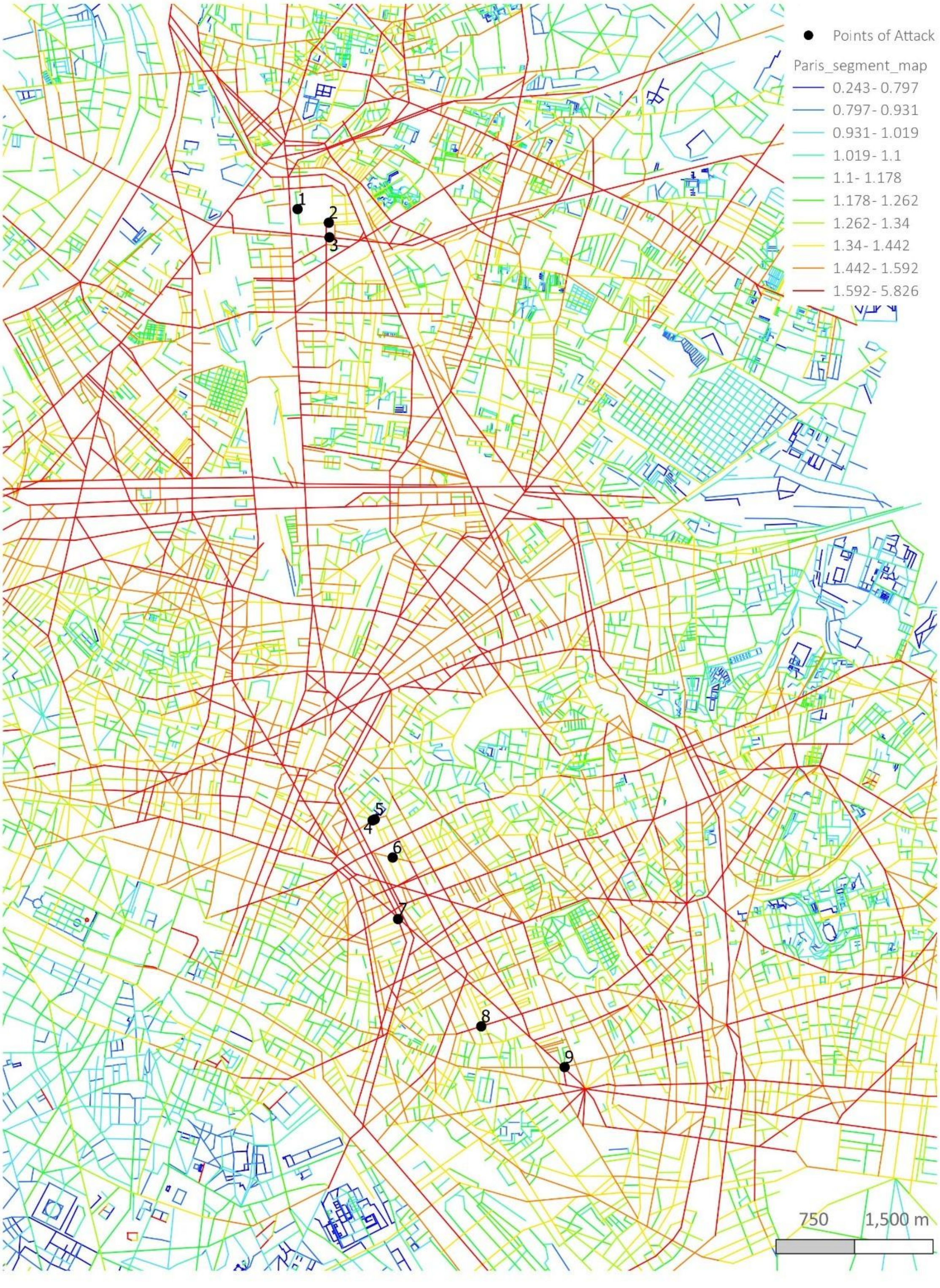


Figure 18- NAIN_R6000_Paris
Source – Author of this paper

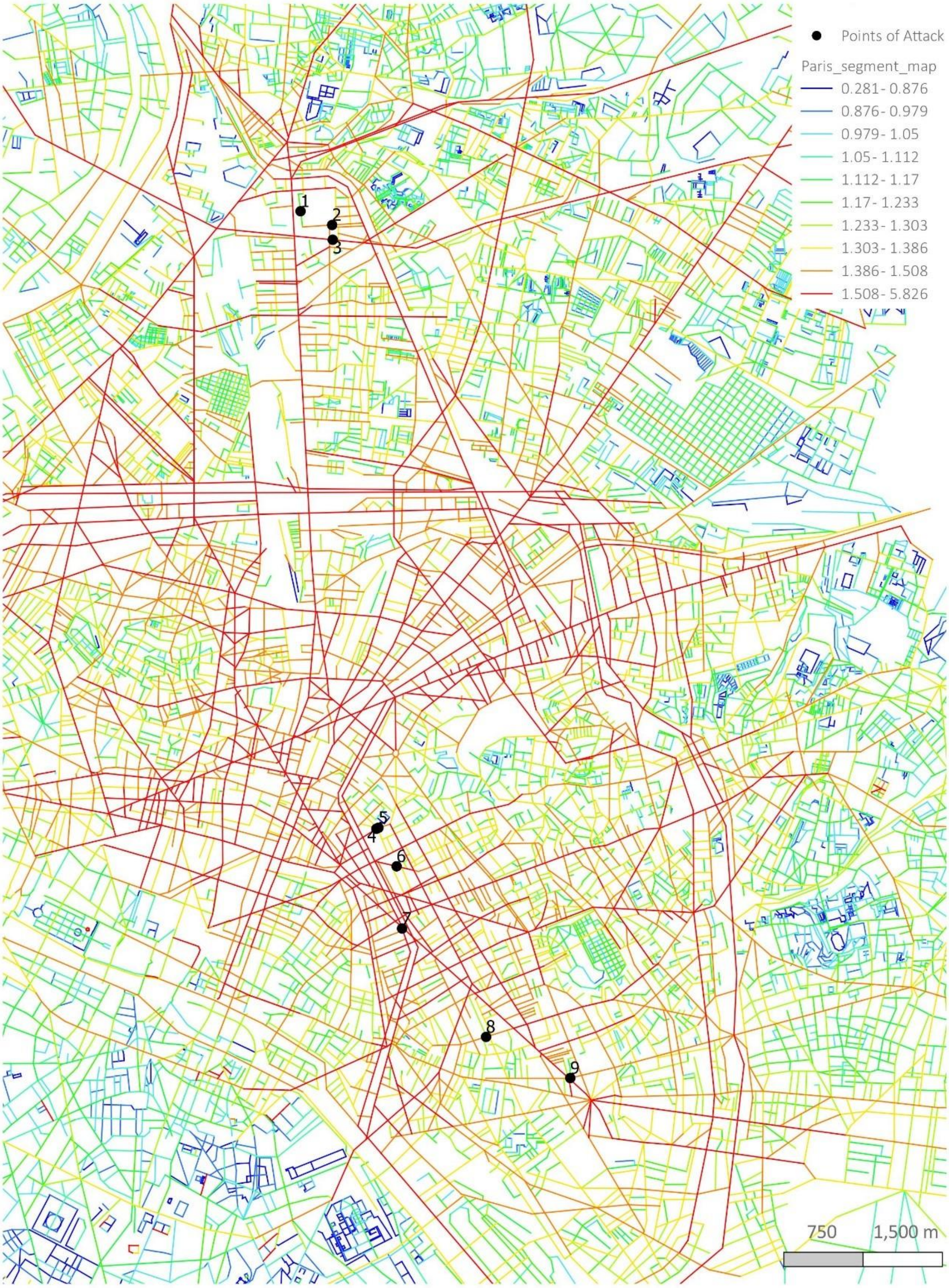


Figure 19- NAIN_RN_Paris
Source – Author of this paper

Following the analysis of the whole study area, this section focuses on the integration value of routes taken by the perpetrators within the entire model. The line segments travelled during the incidents for each route are selected *(Fig. 20)*, and an average value of integration, number of segments and segment lengths are noted. Each segment is a section of streets or pathways within an urban area, and segment length is its respective measurement.

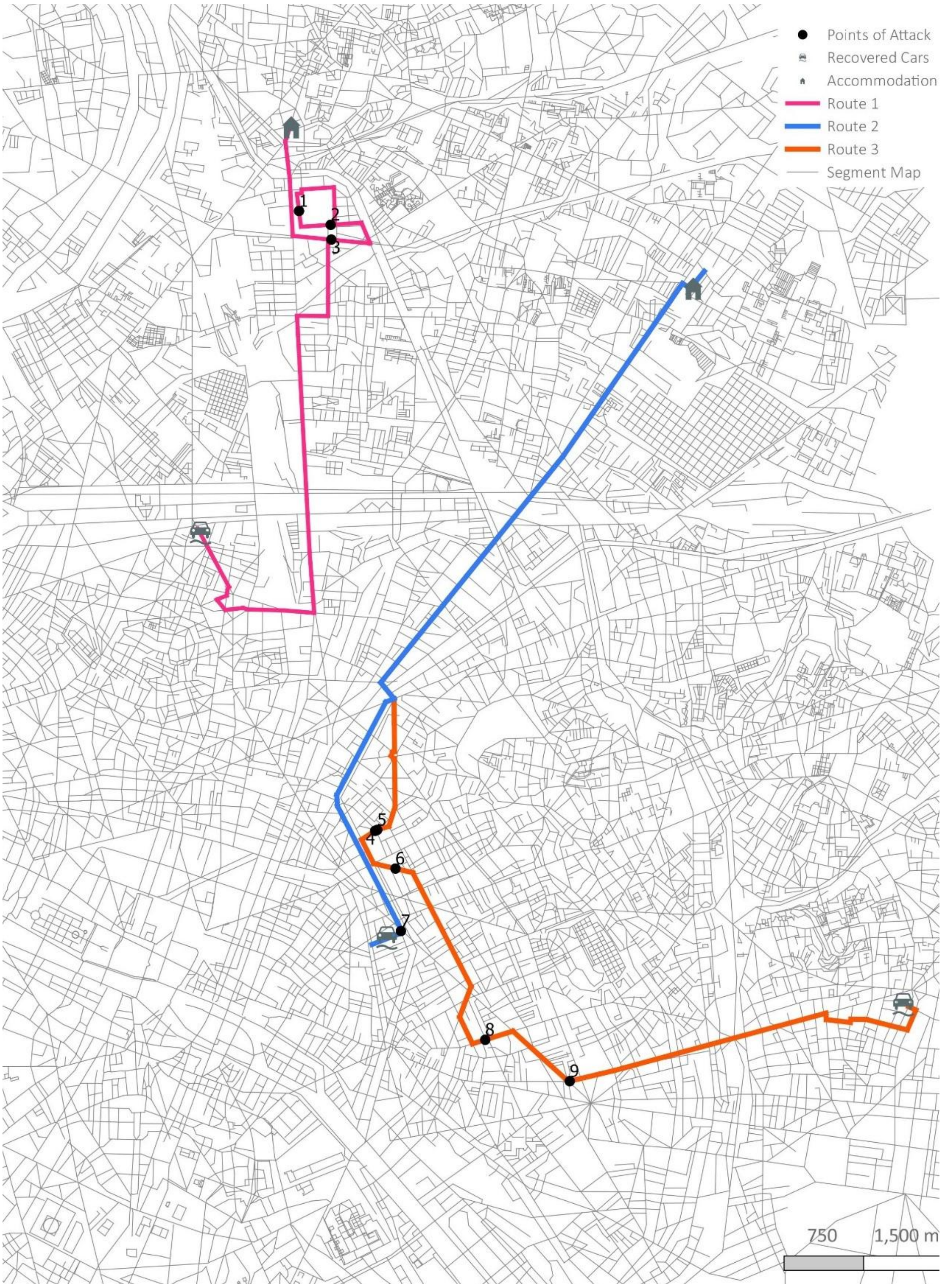


Figure 20 – The routes taken superimposed on the segment map of Paris
Source – Author of this paper

Route 1 exhibited an average value of 1.77 with respect to the whole study area, Route 2 also maintained an average value of 1.77, while Route 3 demonstrated a slightly lower average value of 1.66 *(see appendix 2.1, 2.2 & 2.3 for all the routes).* These values are presented in Table 5 for reference.

Table 5 – Statistical data on all 3 Routes

Route	Number of Segments	Average Integration Value	Segment Length
1	31334	1.77	8336.84
2	27836	1.77	8112.28
3	42056	1.66	13855.38

7.2 Unfolding Target Vulnerability (Risk Layers)

Subsequently, following the spatial enquiry involving the routes, this section focuses on the attributes of the location of the individual points of attack or targets, which forms Risk Layer 1. Table 6 below demonstrates how the targets throughout Paris are spread out within the top 10% and top 20% of the highest integrated streets at radius 6000, predicting city-scale movement. Among the occurrences of attack, four of nine attacks occurred within the uppermost 10% integrated streets, while three were within the top 20%. In contrast, two cases transpired within the street segments in the bottom range of integration at this scale, namely the Stade de France Stadium entrances. The map with the integration of streets is represented in Figure 21 below.

Table 6 – Targets lying in the top 20% of Integrated Streets in Paris

id	Name	Latitude	Longitude	Top 10% integrated Streets	Top 20% integrated Streets
1	Stade de France - 1st	1136014.727	618704.8421	/	/
2	Stade de France - 2nd	1135885.342	619004.1022	/	/
3	Fast Food Outlet	1135745.682	619010.3979	yes	/
4	Le Carillon Bar	1130171.341	619440.7344	/	yes
5	Le Petit Cambodge	1130180.769	619460.1087	/	yes
6	Rue De la Fountaine	1129816.404	619633.6124	/	yes
7	Bataclan Concert Hall	1129227.688	619686.6237	yes	/
8	La Belle Equipe bar	1128204.263	620484.8167	yes	/
9	Le Comptoir Voltaire	1127816.947	621282.9005	yes	/

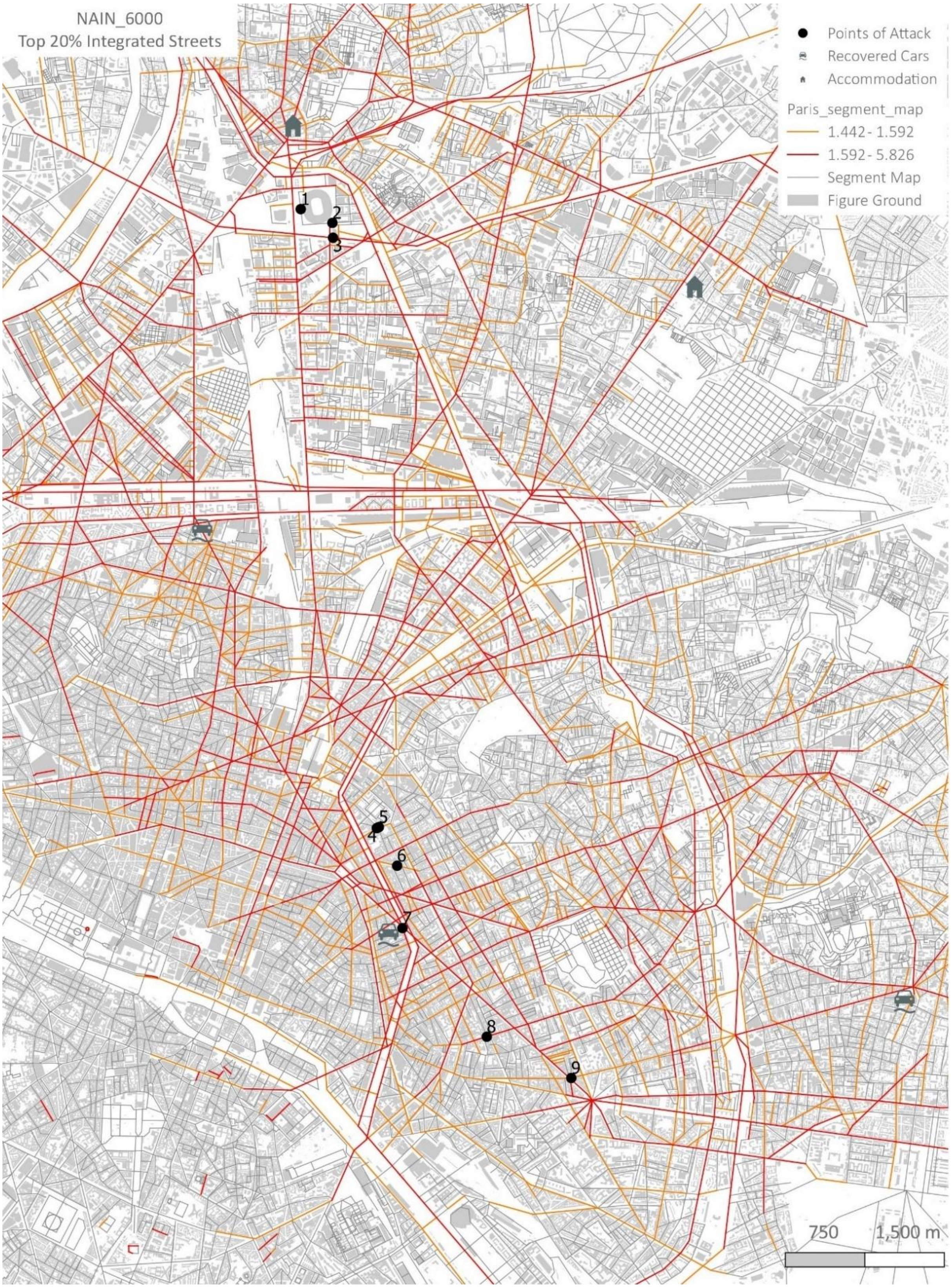


Figure 21 – NAIN_R6000_ParisMap_Top 20% Integrated Streets (See Fig.18 for reference)
Source – Author of this paper

Continuing from the spatial distribution of the targets, this section focuses on assessing the visual integration of the same, forming Risk Layer 2. The analysis is conducted through the utilisation of Path Isovists along the three routes the perpetrators took. As discussed in the Case Study chapter, they travelled via vehicles at a steady speed; hence, the maps below *(Figs. 22, 23 & 24)* show the extent of visibility at an angle of 120 degrees (considering the view from the windshield of a car) along each route during the perpetrators' vehicular movements. It is essential to mention that the buildings' height is not considered when creating isovists. This method focuses solely on the two-dimensional layout of the area. This approach enables an overview of the visual connections and interactions along the chosen paths towards the attacked buildings and streets as the attackers navigated through the urban environment in their respective vehicles.

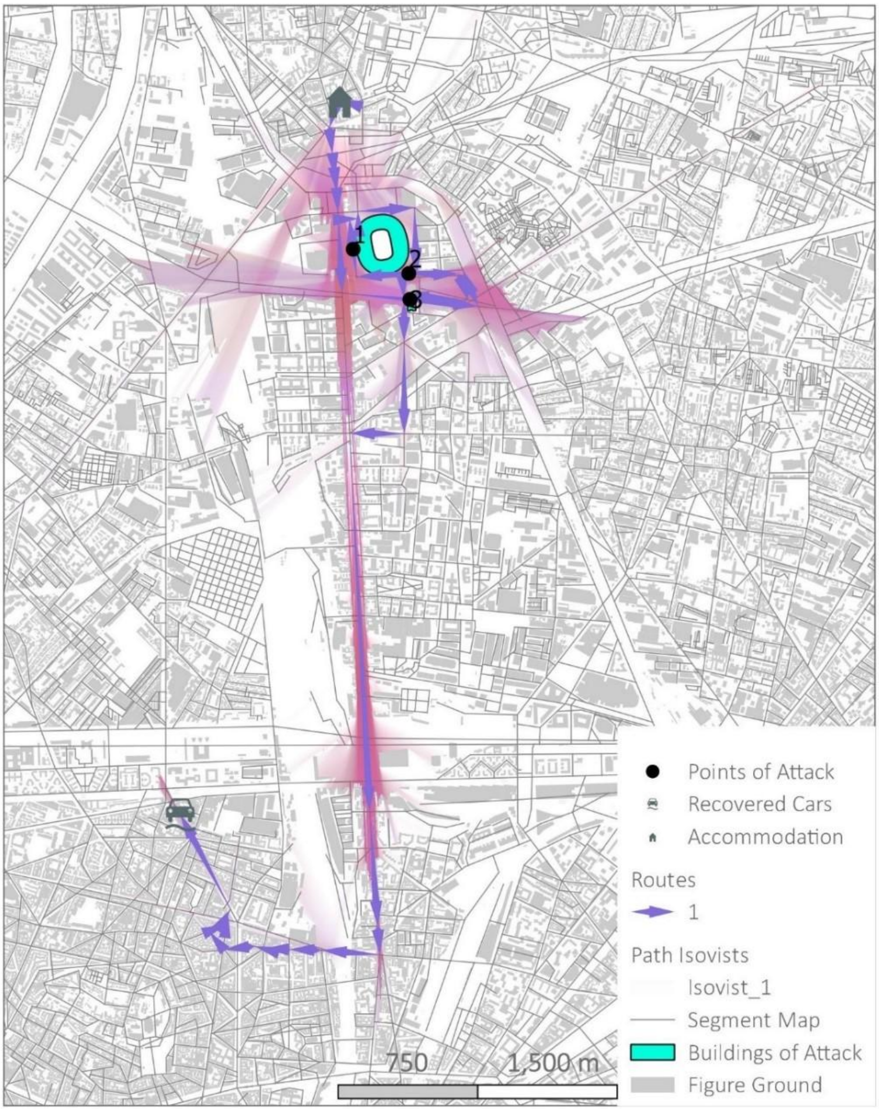


Figure 22 – Extent of visibility for Route 1
Source – Author of this paper

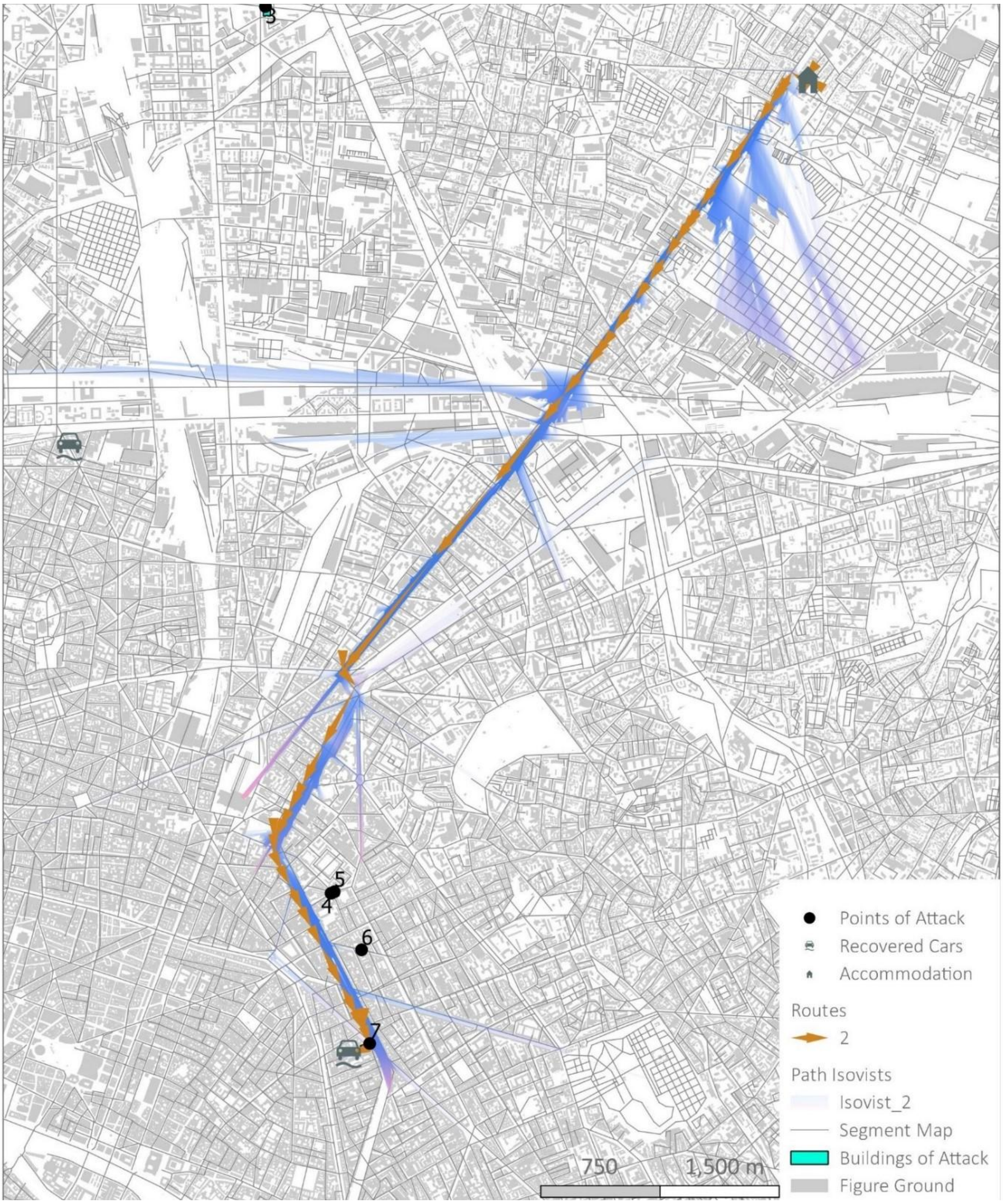


Figure 23 – Extent of visibility for Route 2
Source – Author of this paper

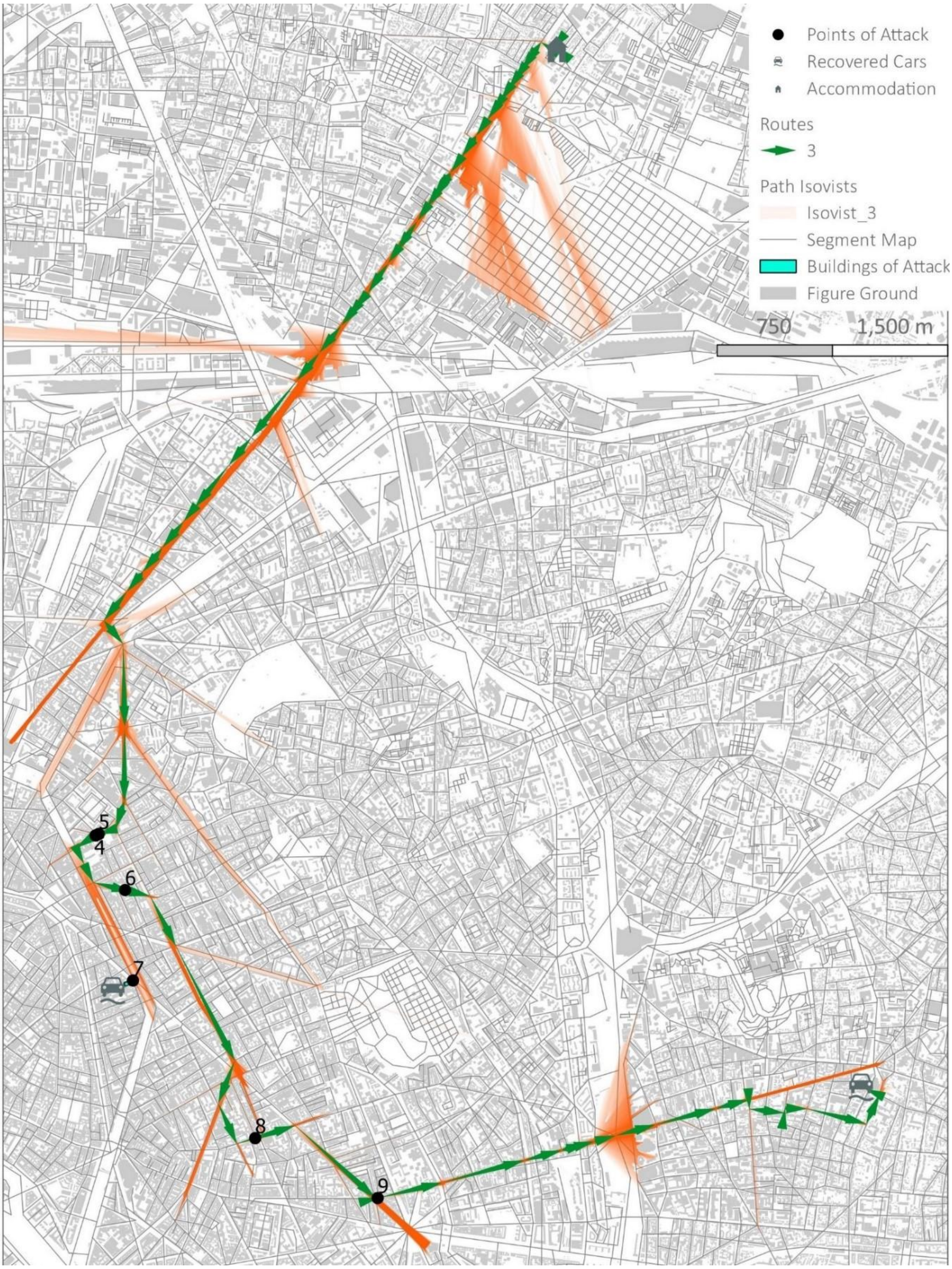


Figure 24 – Extent of visibility for Route 3
Source – Author of this paper

Incorporating quantitative metrics into the visibility analysis, point isovists are constructed from the vantage points, i.e., the attack locations, towards the streets used for the approach. This method involves drawing a line starting from the edge of the targeted building (that is visible first) and extending towards the street through which the building was approached. The outcome is a point isovist, through which the visual distance in meters at which the targeted points or structures become perceptible is noted. Notably, this approach, like path isovists, considers only the two-dimensional layout of the urban environment and does not factor in the height of the buildings.

The isovist distance is determined using two distinct methods. First, it is measured from the point where there is a change in the angle of view, typically when transitioning from one street to the street containing the building (referred to as Type A). Alternatively, the maximum visible distance is recorded when approaching a building via a straight street without any changes in angle (referred to as Type B). These two methods are visually explained in Figure 25. These methods also aided in defining the radius around the building. In the case of Type A, the radius extended to the last street change leading to the street with the building. For Type B, the radius was determined by the length of the straight street leading to the attacked building.

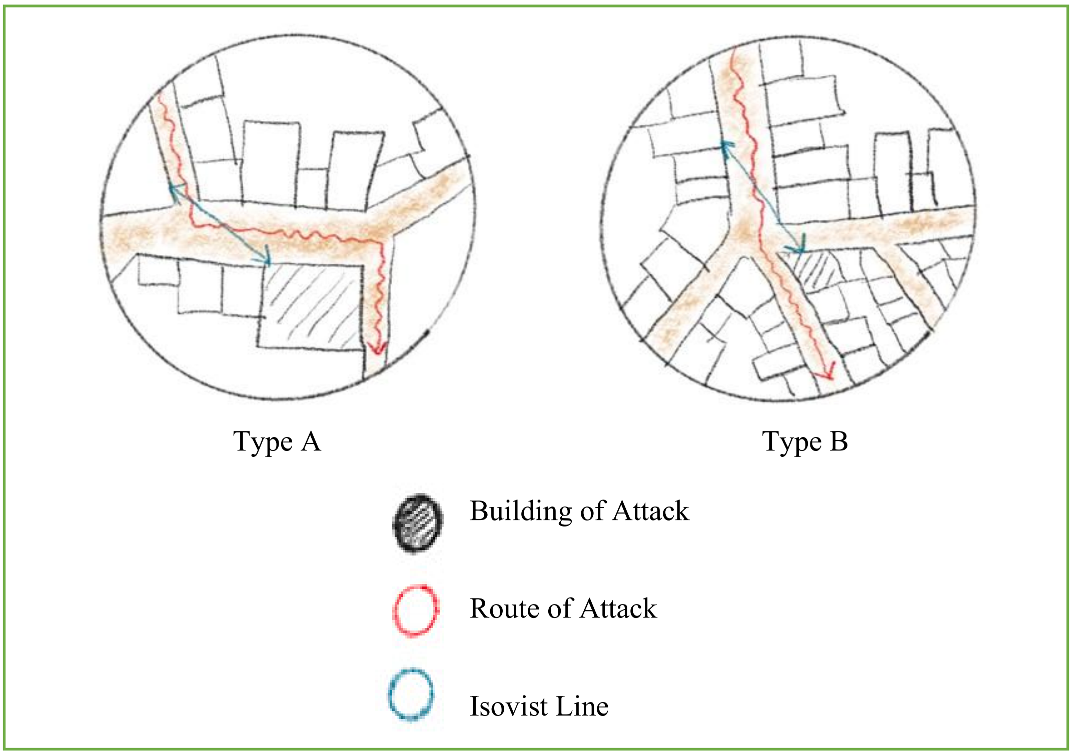


Figure 25 – Hand drawn sketches to explain the methods determining the selection criteria of the line of Isovist
Source – Author of this paper

The isovist length is decided under the Type A criteria for the fast food outlet, Le Carillon Bar, Le Petit Cambodge, Rue De la Fountaine, and La Belle Equipe bar. In contrast, Type B is assigned to The Bataclan Concert Hall and Le Comptoir Voltaire. Through this method, the study quantifies visibility and improves the assessment of visual integration by identifying the exact distances at which the attacked points and buildings became visible. The diagrammatic representation for the point isovists and lengths are presented in Figure 27. This analysis indicates that points farther from the routes taken by the perpetrators are more susceptible to attack because they remain visible for longer durations, making them more noticeable targets. This heightened vulnerability can be linked to how the urban layout is structured. Table 7 suggests that Rue de la Fountaine exhibits the highest visibility from the longest distance. In contrast, the Fast-Food Outlet has the least length within all the attacked locations.

In essence, isovist length focuses on the extent of visibility from a single point. At the same time, visual integration evaluates how well-connected and visible a point is within the larger spatial context. Both concepts are essential in understanding spatial relationships and human movement within urban environments. Hence, Visual Integration (HH), described in the following section, determines how the attack locations are visibly integrated within the street network.

Using the same radius employed for isovist length analysis, visual graphs are generated for each location through Depthmap software *(Fig. 27)*, resulting in quantifiable visual integration values. To conduct the visual integration analysis, the streets are divided into cells. Specifically, attention is given to the grid cells directly adjacent to the attacked building's edge, and their values are documented as shown in Figure 26. The selection average value signifies the level of visual integration for that particular building edge within the more extensive street network. A higher value indicates an increased susceptibility to being observed and potentially targeted during an attack. The Fast-Food Outlet has the highest HH, while Le Carillon Bar has the lowest values, as represented in Table 7.

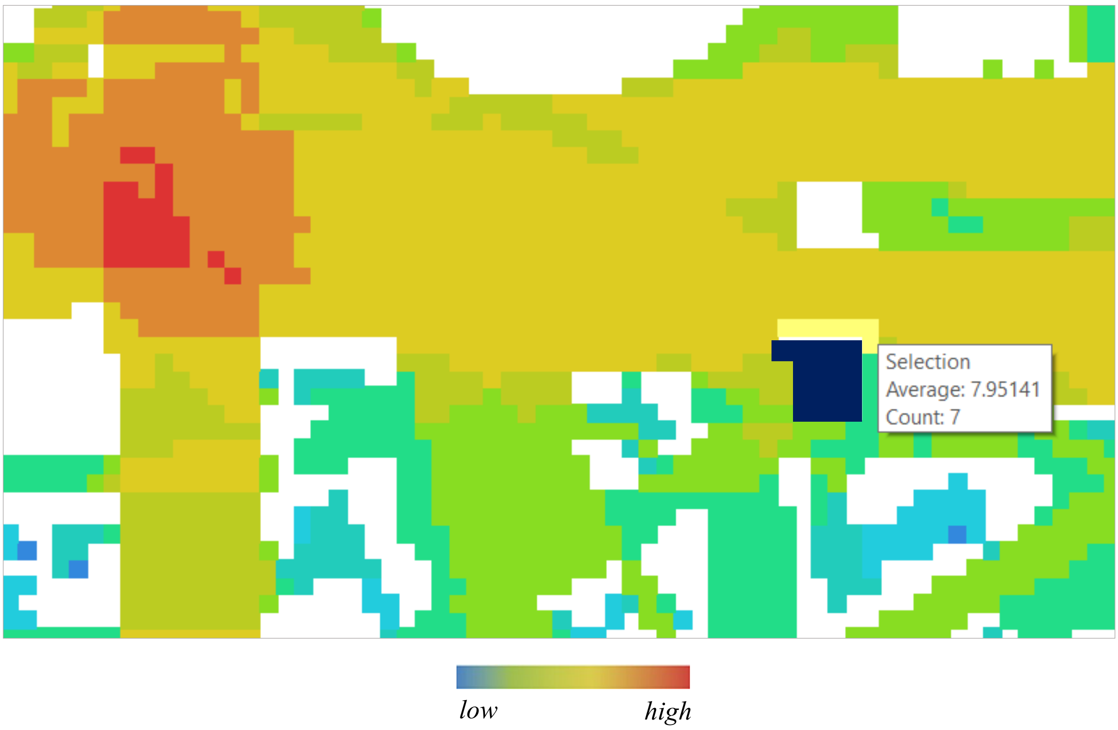
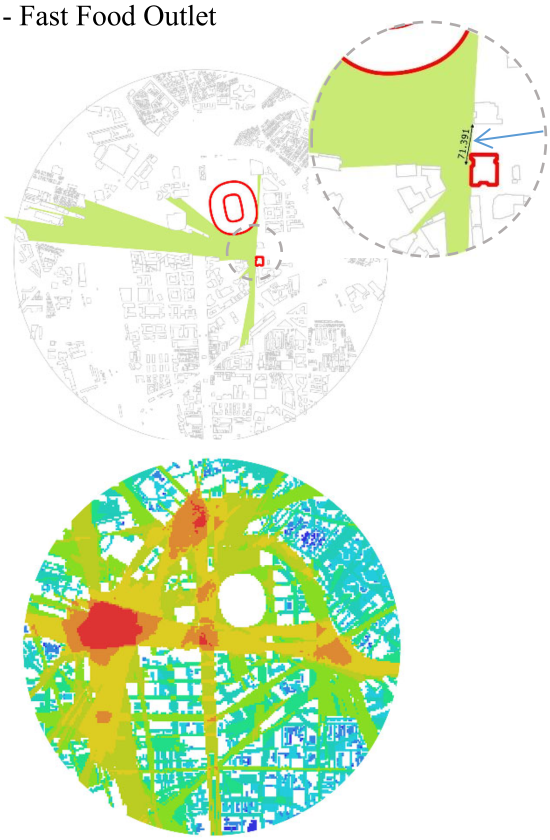
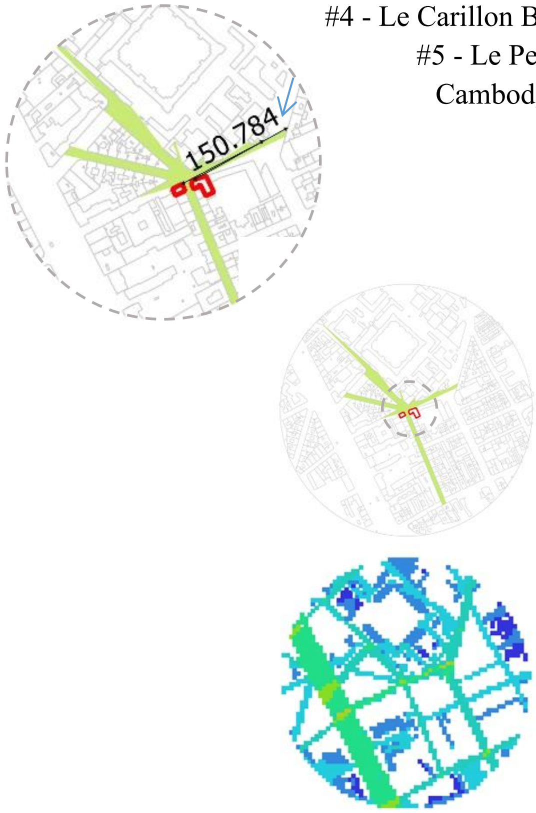


Figure 26 – Blow up of an area, showing the selected grid cells corresponding to the attacked building
Source – Author of this paper

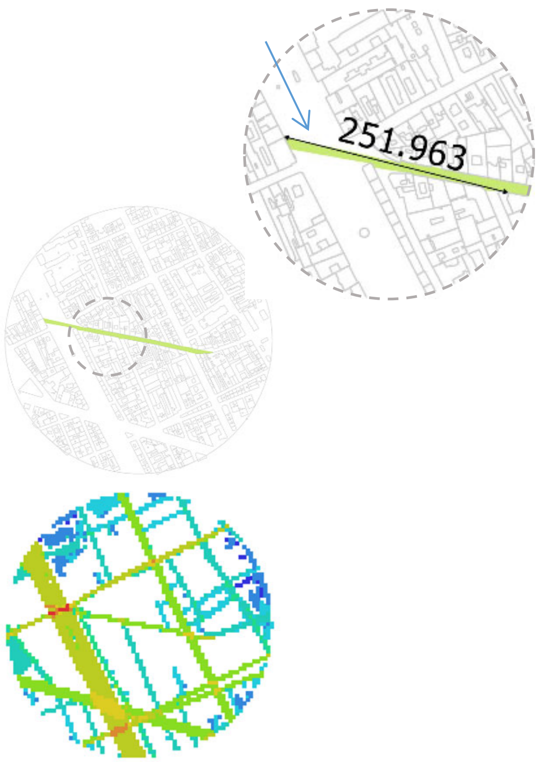
#3- Fast Food Outlet



#4 - Le Carillon Bar
#5 - Le Petit Cambodge



#6 - Rue De la Fountaine



#7 - Bataclan Concert Hall

Figure 27 – Point isovists, Isovist Length and VGA (Visual Graph Analysis) of the points of attack
Source – Author of this paper

Table 7 quantifies the data of isovist length and the visual integration for each point of attack. However, it is essential to note the study's exclusion of the data for the Stade de France Stadium, involving attacks 1 and 2. These attacks occurred within the confines of the stadium, and the stadium's spatial characteristics differ significantly from the urban environment examined in this research. Given the boundary wall surrounding the stadium and its unique nature, it was deemed inappropriate to include it in the urban analysis conducted in this study.

Table 7 – Length of Isovist of each attack point, along with its Visual Integration within the street network
Source – Author of this paper

id	Name	Visible Length of Isovist	Visual Integration (HH)
1	Stade de France - 1st	0	0
2	Stade de France - 2nd	0	0
3	Fast Food Outlet	71.391	7.95
4	Le Carillon Bar	150.784	4.1
5	Le Petit Cambodge	130.498	4.2
6	Rue De la Fountaine	251.963	4.95
7	Bataclan Concert Hall	164.705	5.135
8	La Belle Equipe bar	130.953	4.07
9	Le Comptoir Voltaire	101.603	4.78

Following further in the line of investigation, the number of landmark structures positioned within a radius from 1 km to 1.5 km of each point of attack forms Risk Layer 3. These radii are selected based on the nearest existing landmark to the point of attack, 0.75 km. Hence, a buffer of up to 1.5 km is chosen to make the study flexible. This analytical step aims to discern whether the selection of targets is intentionally influenced by their proximity to landmarks that attract higher human footfall, potentially amplifying the impact of the casualties. The choice of landmarks is based on an official list provided by the Parisian government. These chosen landmarks are plotted onto the map, and as previously mentioned, specific radii are constructed around each attack point, as illustrated in Figure 28.

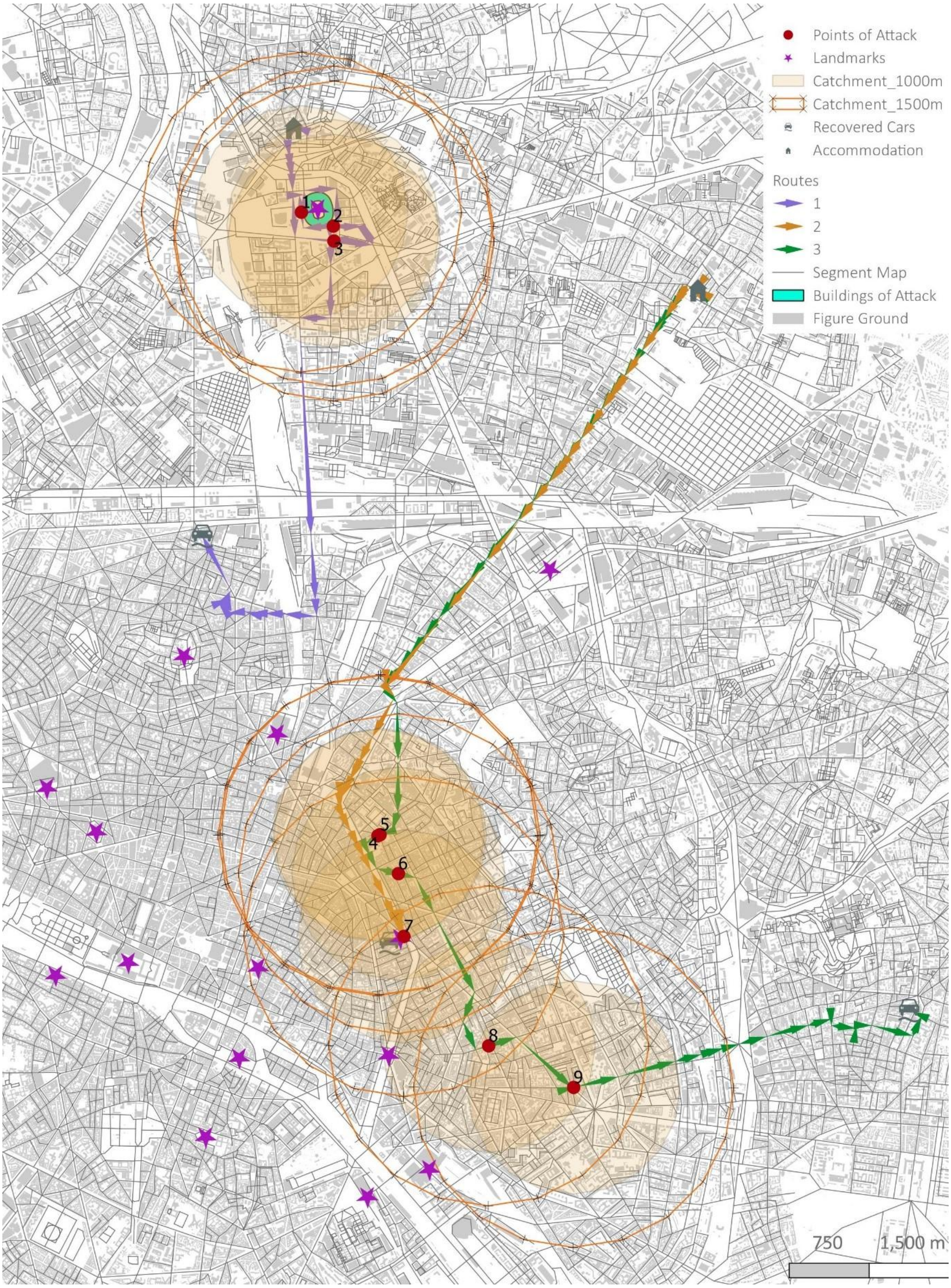


Figure 28 – Radius of 1 and 1.5 km around Point of Attacks in Paris, containing Landmarks
Source – Author of this paper

Table 8 summarises the number of landmarks. This systematic analysis sheds light on the interplay between attack locations and their proximity to significant historical landmarks, providing a nuanced understanding of potential targeting strategies.

Table 8 – Number of Landmarks within the specified radius of each attack point
Source – Author of this paper

id	Name	Landmarks within 1 km	Landmarks within 1.5 km
1	Stade de France - 1st	1	0
2	Stade de France - 2nd	1	0
3	Fast Food Outlet	1	0
4	Le Carillon Bar	1	1
5	Le Petit Cambodge	1	1
6	Rue De la Fountaine	1	0
8	Le Comptoir Voltaire	1	2
9	Bataclan Concert Hall	1	2
7	La Belle Equipe bar	0	0

7.3 Data analysis (Location Quotient)

After quantifying all the risk layers, including street network placement, visibility access, and proximity to landmarks, the location quotient for each attack point is computed. This section entails assigning scores to each attack point based on these risk layers to determine the varying levels of vulnerability among the attacks. This analysis aims to gain insights into the urban layout and addresses the initial spatial inquiry posed at the outset of this thesis.

A Score Indicator is developed for the three Risk Layers. Based on Li et al.'s (2021) quantitative analysis of the Global Terrorism database, the ten-factor method is applied. The highest level of vulnerability, representing the most severe event, is assigned 10 points, while the lowest level receives 1 point. The indicator scores are presented in Table 9. In summary, this comprehensive analysis offers valuable insights into urban spatial vulnerability concerning terrorism.

Table 9 – Indicator Score Details
Source – Author of this paper

Factor	Index	Situation	Score
Placement in the Street Network	Situated in the top 10% of the Integrated streets		10
	Situated in the top 20% of the Integrated streets		05
Visibility access	Visible Length of Isovist	70.0 – 110.9	02
		111.0 – 150.9	04
		151.0 – 190.9	06
		191.0 – 230.9	08
		231.0 – 270.9	10
	Visual Integration (HH)	4.0 – 4.8	02
		4.9 – 5.6	04
		5.7 – 6.4	06
		6.5 – 7.2	08
		7.3 – 8.0	10
Proximity to Landmarks	Landmarks within 1 km		10
	Landmarks within 1.5 km		05

The Indicator Score table is used to assign scores to each attack point. In Table 10, the values of each Risk Layer are presented, accompanied by the corresponding scores. Notably, The Bataclan Concert Hall achieved the highest score of 40, while The Stade de France Stadium attained the lowest score of 10. However, it is essential to acknowledge the limitations of the stadium mentioned earlier in this paper, which may have influenced its low score. Therefore, the lowest score is disregarded. Consequently, Le Comptoir Voltaire is identified as the attack point with the lowest score in this research, scoring 14. In summary, this scoring process provides a comprehensive evaluation of the vulnerability of each attack point within the urban layout.

Table 10 – Location Quotient for Paris
Source – Author of this paper

Name	Top 10% integrated Streets	Top 20% integrated Streets	Isovist Length	(HH)	Landmarks within 1 km	Landmarks within 1.5 km	Score
Stade de France - 1st	/	/	0	0	1 *(10)*	0	10
Stade de France - 2nd	/	/	0	0	1 *(10)*	0	10
Fast Food Outlet	Yes *(10)*	/	71.391 *(02)*	7.95 *(10)*	1 *(10)*	0	32
Le Carillon Bar	/	Yes *(05)*	130.498 *(04)*	4.1 *(02)*	1 *(10)*	1 *(05)*	26
Le Petit Cambodge	/	Yes *(05)*	150.784 *(04)*	4.2 *(02)*	1 *(10)*	1 *(05)*	26
Rue De la Fontaine	/	Yes *(05)*	251.963 *(10)*	4.95 *(04)*	1 *(10)*	0	29
Bataclan Concert Hall	Yes *(10)*	/	164.705 *(06)*	5.135 *(04)*	1 *(10)*	2 *(05 x 2)*	40
La Belle Equipe bar	Yes *(10)*	/	130.953 *(04)*	4.07 *(02)*	1 *(10)*	2 *(05 x 2)*	36
Le Comptoir Voltaire	Yes *(10)*	/	101.603 *(02)*	4.78 *(02)*	0	0	14

7.4 Determining Spatial Scenarios for Mumbai

Following the spatial analysis of Paris, this section delves into the examination of Mumbai, a city surrounded by water, and the infamous 26/11 attacks that unfolded within it. Given the absence of detailed route information that the perpetrators took, the aim of studying Mumbai is to assess if the learning from Paris is similar to Mumbai's analysis. Figure 29 represents the buffer map of Mumbai at a radius N, constructed for this study, however, to keep the studies similar, a similar radius of 6000 meters of the study area *(Fig. 30)* is chosen for Mumbai.

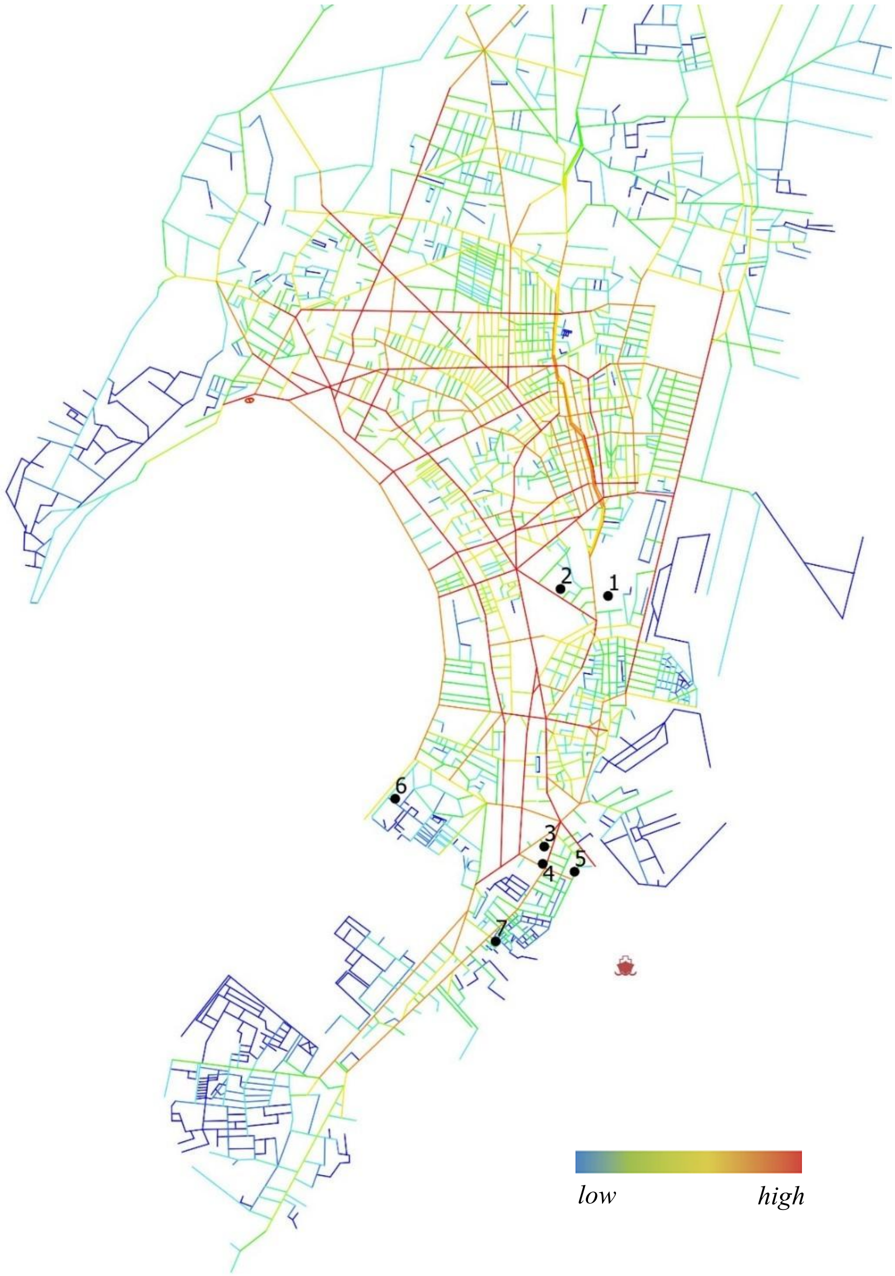


Figure 29- NAIN_RN_Mumbai
Source – Author of this paper

Similar to Paris, the topmost 10-20% integrated streets are highlighted, to determine the number of attacks that occurred within them. Four out of seven attacks, namely, The Chhatrapati Shivaji Terminus Railway Station, Cama Hospital, Colaba Police Station and the Taj Mahal Hotel occurred within the highest integrated streets in the urban fabric of Mumbai, represented in Figure 31. Refer to Table 11 for the names of attacks with their corresponding numbers.

Figure 30- NAIN_R6000_Mumbai
Source – Author of this paper

Figure 31 – NAIN_R6000_Mumbai_Top 20% Integrated Streets (See Fig. 30 for reference)
Source – Author of this paper

Since detailed route information is unavailable for Mumbai, two alternative analyses are employed. First, a Visual Graph analysis (Figure 32) is conducted to visualize the city's spatial layout. Mumbai's unique waterfront geography results in limited visual integration along the city's edges. This is represented in the visual graph by a central red area surrounded by a blue periphery, following space syntax conventions.

Second, an Agent-Based analysis (Figure 33) is carried out using the Southern Coast as the entry point for agents, simulating the possible routes the attackers might have taken based on visual integration criteria. The agents are configured to die after they cross a maximum of 1000 grid cells. The analysis reveals that the agents' movements align with all the attack points, except for attack point number 6, which remains inaccessible to the agents. The details are provided in Table 11.

Table 11 – Spatial Characteristics of Mumbai attack points
Source – Author of this paper

id	Name	Top 10-20% integrated Streets	Accessible through Agent Trails
1	Chhatrapati Shivaji Terminus Railway Station	Yes	Yes
2	Cama Hospital	Yes	Yes
3	Leopold café and bar	/	Yes
4	Colaba Police Station	Yes	Yes
5	Taj Mahal Hotel	Yes	Yes
6	The Oberoi-Trident hotel	/	Yes
7	Nariman House	/	Yes

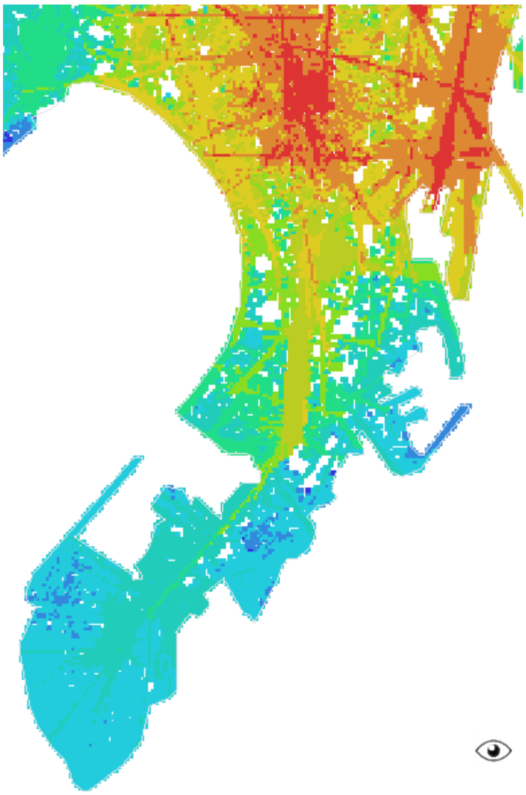


Figure 32 – Visual Graph Analysis of the Study Area of Mumbai
Source – Author of this paper

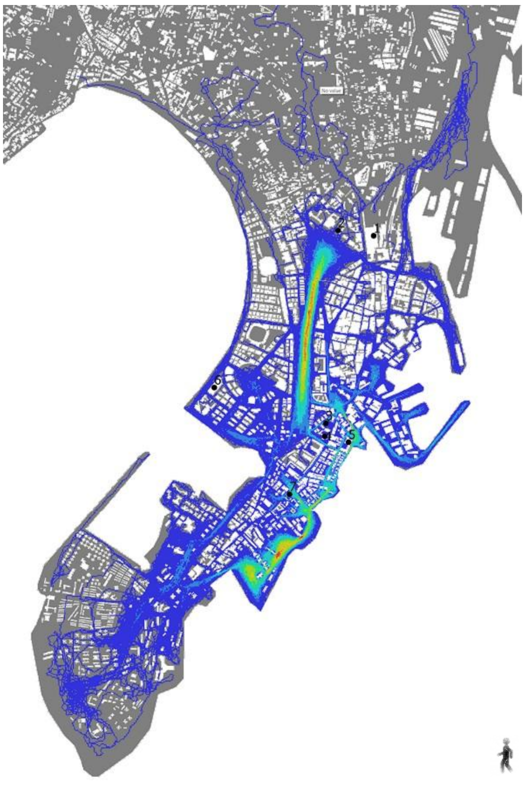


Figure 33 – Agent Based Analysis of the Study Area of Mumbai
Source – Author of this paper

A spatial correspondence emerges between agent flow and the urban street integration. In the magnified view (Fig. 34), the agent origin points are marked, demonstrating their dispersion across the urban fabric of Mumbai. The prevalence of red indicates heightened agent attraction, while extensive blue regions signify limited agent access. Grey areas represent locations the agents did not reach. This integration pattern aligns with agent movement, highlighting the significance of spatial configuration in guiding agent trajectories.

Figure 34 – Blowup of the Study Area of Mumbai showing the origin points of the agents, to compare Agent Trails and Network Integration
Source – Author of this paper

8. DISCUSSIONS AND CONCLUSIONS

From its initiation, this thesis has delved into an intricate analysis of two distinct yet interconnected urban settings, Paris and Mumbai. Within the confines of these cities, it sought to unravel the spatial attributes influencing patterns of attacks in contested environments. Bill Hillier's Space Syntax framework emerged as an indispensable tool in this exploration, helping to uncover the underlying spatial logic that shapes urban security dynamics.

The analysis of route selection in Paris conducted through an Angular Segment Analysis model with varying radii reveals that a 6000-meter radius effectively represents the urban network's cohesion, balancing local and global integration values. Comparing these values, it can be concluded that Route 3 has the lowest value of 1.66, making it the least integrated among the three routes. However, Routes 1 and 2 share the same value of 1.77, signifying equal integration in the space syntax analysis. Notably, all three routes surpass the study area's average integration value, which stands at 1.20 at a radius of 6000 m. This highlights the interpretation that the routes were positioned within the more integrated part of Paris' urban layout. This observation underscores the significant role played by the city's spatial configuration in influencing the selection of well-connected routes, thus enhancing the comprehension of the impact of the urban fabric on such incidents.

Further, in this multifaceted analysis, three distinct risk layers deepened the understanding of the vulnerability and targeting strategies of the attack points in Paris. Risk Layer 1, which focuses on the spatial distribution of attack points, evidently suggests that the majority of the attacks are concentrated within the top 10% and 20% of the highest-integrated streets. This concentration within well-connected urban spaces suggests a strategic choice by perpetrators to target areas with higher accessibility, either voluntarily or involuntarily.

Subsequently, Risk Layer 2 focuses on the local and global visibility of the attack points. Rue De La Fountaine stands out for its highest isovist length and high visual integration value, highlighting its strong integration into the urban fabric. Le Carillon Bar, Le Petit Cambodge, La Belle Equipe Bar, and Le Comptoir Voltaire exhibited notable isovist lengths, indicating visibility within the local surroundings, but their comparatively lower visual integration values suggest suboptimal connectivity in the global urban context. Finally, Bataclan Concert Hall demonstrates both extensive visibilities, as indicated by a significant isovist length and strong connectivity, with a higher Visual Integration value, portraying its prominent role in the urban layout, locally or globally. This analysis underscores the varying spatial characteristics of these locations, emphasising their differing levels of local and global visibility and visual integration, respectively, within the urban environment.

While prior studies have indeed delved into spatial inquiries related to terrorism in urban environments as discussed in the Literature review, many of these have primarily focused on aspects such as street layouts and similar elements. Notably, there is a scarcity of previous research that examines the visibility within contested cities, particularly in relation to target points. Therefore, this study stands as an effort in this regard, aiming to pave the way for further exploration and deeper insights into this critical aspect of urban security dynamics.

Risk Layer 3, which delves into the proximity of attack points to landmarks within a broader 1.5-kilometre radius, aims to shed light on whether attackers select targets in close proximity to prominent landmarks that attract substantial human foot traffic. This analysis indeed reveals intriguing correlations; for instance, the presence of Le Comptoir Voltaire and Bataclan Concert Hall near multiple landmarks hints at a potential targeting strategy. However, it's important to acknowledge a limitation in this approach. Proximity to landmarks may not always be indicative of a significant scenario, as not every landmark necessarily attracts a large number of tourists or visitors. Nonetheless, it remains a valuable avenue of study, as it could potentially provide insights into the decision-making processes of attackers in certain situations.

By employing a well-structured scoring methodology that encompasses spatial integration, visibility analysis, and landmark proximity, this study unveils attack patterns within the urban fabric of Paris. The synthesis of the three analysed Risk Layers highlights Bataclan Concert Hall as the most vulnerable among all attack points. Interestingly, although Rue de La Fountaine boasts the longest isovist length, it does not claim the highest overall score. This is because it does not reside within the highest-integrated streets of the network, emphasising the significance of comprehensive spatial integration in assessing vulnerability. Likewise, the fast-food outlet, situated in front of the Stade de France Stadium, possesses the highest global visual value. However, because of its limited local visibility, it does not secure a high position in the scoring chart. This emphasises the importance of both global and local visibility when evaluating the overall vulnerability of a location within an urban network.

Highly integrated streets mostly appeared as the preferred target locations, as per this thesis. However, Le Comptoir Voltaire, which lies within the topmost integrated streets, did not score highly in the ranking table. This can be attributed to its lack of proximity to any significant landmarks, emphasising that landmark proximity also plays a crucial role in determining vulnerability in an urban layout.

Transitioning to the analysis of the Mumbai attacks, the absence of detailed route information led to a focus on spatial integration, in line with Space Syntax principles. This approach aligned with Paris's findings, as four out of seven attacks occurred within Mumbai's highest integrated streets. Visual Graph and Agent-Based Analyses demonstrated the critical role of spatial attributes, particularly visual integration, in guiding agent movement and potentially influencing attack patterns.

In conclusion, this thesis underscores the pivotal role of spatial attributes in shaping the dynamics of attacks in contested cities. Whether through the lens of urban configuration in Paris or spatial integration in Mumbai, the Space Syntax framework has illuminated the interplay between integration, visibility, and landmark proximity in such events. Ultimately, this study advances the knowledge of urban dynamics and emphasises the significance of Space Syntax principles in analysing urban configurations.

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*Appendix 1 – Table showing the average values of integration at radius 2000, 6000 and N for Paris. **

Depthmap_R	Angular_Co	Axial_Line	Segment_Le	Connectivi	NAIN_R2000	NAIN_R6000	NAIN_RN
45130	0.97744924	24983	220.7901	2	1.0950664	0.61671674	0.8094129
45131	1.0160456	24984	254.85663	2	0.91401249	0.67340165	0.84820521
45132	1.1519985	24985	268.14325	2	1.0752438	0.73266357	0.89682144
45133	1.9988317	24986	80.201729	3	0.9238236	0.81420523	0.94758105
45134	1.1685169	24986	193.1568	3	1.0933688	0.82105577	0.95937747
45135	1.0081716	24987	266.58148	2	0.99286002	0.89966184	1.0105389
45136	6	24988	293.41486	6	1.0537437	0.91367322	1.0239514
45137	6.9749494	24989	35.977848	8	1.4349327	1.420864	1.3425096
45138	5.0250502	24989	0.002134491	6	1.3105557	1.4038048	1.3352551
45139	5.0250502	24990	0.002134491	5	1.3105557	1.4038048	1.3352551
45140	1.34E-08	24990	1.1071477	2	1.3056439	1.4046487	1.3352551
45141	9.8814878	24991	31.808315	10	1.4058582	1.2597731	1.2504678
45142	1.062696	24992	59.359154	3	1.0885276	1.1598749	1.2024753
45143	3.2279015	24992	111.13171	4	1.0646659	1.1961293	1.2020129
45144	0.52955568	24993	116.27729	2	1.1389871	1.2217907	1.2372867
45145	2.9774706	24994	124.81607	4	1.2495128	1.2782303	1.2815622
45146	1.2614875	24994	17.098352	3	1.2261097	1.2772052	1.2815217
45147	4	24995	161.39595	4	1.0390202	1.1755226	1.2521374
45148	4	24996	105.20153	4	1.1019213	1.2234036	1.2666677
45149	0.57374483	24997	72.216522	1	0.97576421	1.0922613	1.1605177
45150	2.5737448	24998	33.122513	3	1.1938995	1.2077323	1.2600819
45151	4	24999	125.39121	4	1.1845375	1.2068464	1.2532433
45152	2	25000	144.39375	2	0.99758023	1.0581052	1.1740921
45153	0.21741746	25002	66.866066	1	0.96687341	1.1950477	1.2374997
45154	2.2174175	25003	15.003599	4	1.0526928	1.2438325	1.2777808
45155	4	25003	55.218159	5	1.0598847	1.2591572	1.2779691
45156	1.0148787	25004	37.072369	1	0.6221233	1.0622729	1.0582515
45157	4	25005	217.36621	5	1.2578764	1.5977415	1.5102799
45158	4	25005	147.9753	5	1.2932187	1.6268426	1.5105872
45159	1.9923635	25006	48.728436	3	0.86540049	1.1308808	1.1162759
45160	1.3679543	25006	53.985626	3	0.86101335	1.1252766	1.1162761
45161	0.79708815	25007	16.748495	2	0.89047021	1.1550416	1.1395614
45162	2.3981507	25008	64.112442	3	0.98898309	1.2357647	1.2043276
				3.687000421	1.13	1.20	1.23

**This table has values from 1 – 45162. The table has been cut short only for representation purposes.*

*Appendix 2.1 – Table showing the average values of integration for route 1 travelled in Paris. **

Depthmap_R	Angular_Co	Axial_Line	Connectivi	NAIN_R6000
3616	4	2329	6	2.0250411
3617	4	2329	6	2.0238729
3618	4	2329	6	2.0021975
3858	5.5851569	2378	7	1.7492487
4558	2.9717765	2517	4	1.6108379
4559	2.6681185	2517	5	1.6187148
4560	3.3318813	2517	5	1.607192
4562	3.4063962	2517	5	1.6194309
4563	3.4225748	2517	5	1.6178825
4564	2.5774252	2517	5	1.6087782
4565	4	2517	6	1.6065586
4584	2.0135734	2520	4	1.6917402
4585	1.3521433	2520	4	1.6860194
4586	3.4231873	2520	5	1.6989992
4587	4	2520	6	1.7195187
4588	4	2520	6	1.7219293
7768	3	3632	4	1.4968688
7778	2.4862039	3634	4	1.6542728
7779	3.4600744	3635	4	1.3906404
7780	2.0087872	3635	4	1.3895758
7781	2.0284564	3635	4	1.386418
7782	2.9676285	3635	4	1.3787233
7783	1.9382384	3636	3	1.3823954
7785	4	3636	5	1.3610317
7795	2.0111978	3640	2	1.1543295
7796	2.0478854	3641	2	1.2332629
31012	1.1263239	18460	3	1.7292563
31013	3.0153801	18460	5	1.721287
31142	4	18487	6	1.5380467
31143	2.243634	18487	4	1.5545956
31144	2.2855685	18488	4	1.4828831
31145	4.2689776	18489	6	1.4397687
31146	2.904016	18489	5	1.4289291
31264	2.2796347	18519	3	1.626236
31281	2.6731076	18520	5	1.663535
31282	2.2796347	18520	4	1.6645329
31331	3.198637	18543	4	1.3367511
31333	4	18545	5	1.4395766
31334	3.9999998	18545	6	1.3951901
	2.874258499	403577	4.7	1.77

**This table has values from 1 – 31334. The table has been cut short only for representation purposes.*

*Appendix 2.2 – Table showing the average values of integration for route 2 travelled in Paris. **

Depthmap_R	Angular_Co	Axial_Line	Connectivi	NAIN_R6000
11146	3.1418753	5377	5	1.8229847
11147	1.5098195	5377	4	1.8175957
11148	2.7819328	5377	5	1.8028605
11149	4.5663724	5377	6	1.8425374
11150	4	5377	6	1.7692891
11151	3.0925794	5377	5	1.7510612
11152	1.9333066	5377	4	1.773098
11153	1.9381179	5377	4	1.7761935
11154	2.055053	5377	4	1.7916934
11155	1.0273806	5377	3	1.8071026
22289	4	12736	5	1.2207923
22294	4	12739	5	1.4042501
31652	1.3823746	18683	3	1.7594401
31653	1.9385908	18683	4	1.7600958
31654	1.9998093	18683	4	1.7592477
31655	1.9993412	18683	4	1.763216
31656	3.0215526	18683	5	1.7618513
31657	2.9796276	18683	5	1.7508385
31658	1.9345918	18683	4	1.739876
31659	3.0857806	18683	5	1.7373421
31660	3.9999998	18683	5	1.7248183
31661	1.624718	18684	3	1.7612425
31662	1.9502764	18684	4	1.7470865
31664	1.6142751	18685	3	1.7588507
31665	2.6560647	18685	5	1.8080928
31666	3.6921444	18685	5	1.8132504
31667	1.794574	18685	5	1.8159312
31668	4.5132818	18685	6	1.8009262
31669	3.9999998	18685	6	1.8158197
31670	4	18685	6	1.8169526
31671	4	18685	6	1.8310593
31672	4	18685	6	1.7440791
31673	3.0515451	18685	5	1.7539033
31674	2.9484549	18685	5	1.7516001
31675	2.0846891	18685	4	1.7442405
31676	2.0846891	18686	4	1.7672503
31677	2.9825211	18686	5	1.6770498
35439	2	20055	2	1.2725611
37836	4	21435	4	1.3893956
	256.4858778	869188	5	1.77

**This table has values from 1 – 37836. The table has been cut short only for representation purposes.*

*Appendix 2.3 – Table showing the average values of integration for route 3 travelled in Paris. **

Depthmap_R	Angular_Co	Axial_Line	Connectivi	NAIN_R6000
32094	2.0229466	18756	4	1.6221112
32095	1.8613745	18756	4	1.6232458
32096	2.1453516	18756	4	1.6199297
32097	1.8621366	18756	4	1.6205245
32098	3.0632949	18756	5	1.6186018
33104	4	19071	6	1.5941386
33105	4	19071	6	1.6049463
33106	4	19071	6	1.6268405
33107	4	19071	6	1.699711
33108	2.8802485	19071	5	1.6940609
33109	2.1379113	19071	4	1.6956687
33110	2.9818401	19071	5	1.6903193
33111	4	19071	6	1.6847767
33112	3.0571864	19071	5	1.6763045
33113	1.972821	19071	4	1.685253
33114	2.9699929	19071	5	1.6838673
33115	2.9301486	19071	5	1.6901262
33116	2.8129916	19071	5	1.6849086
33211	2.5497174	19104	4	1.5801015
33212	2.0338049	19104	4	1.5802118
33213	2.0127969	19104	4	1.5834672
33214	2.8767614	19104	4	1.5759052
33215	2.5269191	19104	5	1.5693469
33299	3.0437696	19139	5	1.5476034
33300	2.9562306	19139	5	1.5443156
33737	5.9171739	19317	7	1.5136434
33738	3.7612815	19318	6	1.4717064
33739	1.3417735	19319	3	1.3049117
40664	2.8851576	22816	4	1.4527998
40990	2.0016661	22933	3	1.1911601
40992	4	22934	5	1.1930743
41080	1.8880401	22981	4	1.3519211
41093	4	22989	5	1.2473724
41095	2.148803	22990	4	1.2718132
41096	4	22990	6	1.2749083
41097	4	22990	6	1.289431
41098	4	22990	5	1.2646643
41244	0.98396087	23034	3	1.4003153
42056	4	23484	5	1.3096615
	450.831326	1961183	4.7	1.66

**This table has values from 1 – 42056. The table has been cut short only for representation purpose.*