443

Spatial Segregation and Insecurity in Mexico City

Santo Domingo and its western border with *Ciudad Universitaria*

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ABSTRACT

Over the last decades, Mexico City has become a hazardous metropolis in which the sense of insecurity increases every day (Davis, 2008). In 2010 the crime rate was 44,055 reported incidents per 100,000 habitants, while in 2018, 69,716 cases were reported per 100,000 habitants in the Mexican capital (INEGI, 2019). Thus, this paper looks to understand the relationship between space and street related crimes under the scope of spatial analysis and physical characteristics of the city network.

By executing a comparative study between space syntax integration and choice analyses, the “movement economies” and “natural movement” theories (Hillier, 1996), retail and crime data, this research looks to find out what are the spatial features most commonly followed by criminal behaviour. Specifically contrasting pedestrian robbery and assault – two of the most reported street-related crimes in Mexico City (ADIP, 2018).

Even though the perception of insecurity in large empty spaces in Mexico City remains, the findings of this study suggest that these kinds of places are not as hazardous as expected concerning the most common street crimes towards pedestrians. The shorter segments of the study area mean more commercial activity, more permeability, and therefore more crime. This project encourages the understanding of our streets from the insecurity perspective. It provides insight for developing urban strategies and drives public policy planning towards a safer city for pedestrians. This study assists to identify certain space-related characteristics that could be modified or considered when looking to improve security within the public realm.

KEYWORDS

Spatial configuration, criminal behaviour, robbery, urban border, residential area.

1 INTRODUCTION

1.1 Mexico City and the urban frontier

Mexico City is now considered one of the largest cities in the world with over 20 million inhabitants (World Population Review, 2020). Because of its large expansion, nowadays different city spaces have become vulnerable and face different isolation problems. On the one hand, fences and barriers are being built to make the city a "safer" place. On the other, poor policy planning and informal urbanization have created spatial urban frontiers (borders) at all scales within the city. In this research, an urban frontier is defined as a spatial phenomenon created in places where there is either very low or non-existed spatial permeability. It is the scenario where tangible strong edges arise, preventing people to move freely through public space. Jane Jacobs explains that the "root trouble" surrounding urban frontiers or borders "is that they are apt to form dead ends for most users of city streets. They represent, for most people, most of the time, barriers" (Jacobs, 1961, p. 259). As one of the most populated metropolises in the world, Mexico City frequently has to deal with this issue.

In Jan Gehl's words, an edge (border) "is where city meets building" (Gehl, 2010, p. 75). A "soft edge" is the one that has openings, is visually permeable, and offers the pedestrian an excuse to stay around a bit longer, such as commercial corridors holding different retail and catering activities. In contrast, the "hard edge" is the space that is completely closed to people passing by, like long walls or highways in the middle of the city; there is none or partial visual and spatial permeability, and it generates little pedestrian movement (Gehl, 2010). For a long time now, the Mexican capital has become a dangerous city in which the insecurity perception increases every day (Davis, 2008). According to the Digital Agency of Public Innovation of 2018 (ADIP by its Spanish acronym), in the last years, one of the most reported crimes was pedestrian robbery. Assault – although not one of the most reported crimes – was also considered for this investigation because its numbers are significant, and it is a very common street-related crime in Mexico City (fig. 1a).

Therefore, this research is focused on studying the street criminal patterns in *Santo Domingo* in Mexico City, emphasising an important urban frontier phenomenon: the railway line and railway station *Metro CU* between the residential area of *Pedregal de Santo Domingo* and the National Autonomous University of Mexico – also known as UNAM or *Ciudad Universitaria* (fig. 1b). It was looked if there was a relationship between the spatial configuration and the criminal activities developed in the area. If so, what kind of relation holds the spatial configuration to specific street crimes?

Figure 1: Leading crimes and their rates over three years (2017, 2018, 2019). The data refers only to the crimes reported in the political demarcation of Mexico City, excluding its metropolitan area **(a)**. Source: https://datos.cdmx.gob.mx/. Study area demarcation **(b)**. Source: author.

1.2 Case study

The central campus of the National University opened its doors in the spring of 1954 (Noelle, 2004). The neighbourhood of *Santo Domingo* started to develop in 1971 due to the largest urban invasion ever seen in Latin America, in which more than 100,000 people arrived (Poniatowska, 2000). *Pedregal de Santo Domingo* started as an informal urban settlement with no facilities and housing made of any material its inhabitants had on hand (fig. 2a). Gradually, with great determination and hard work, the informal settlement built its identity and became a regular working-class neighbourhood (fig. 2c). When in 1977 the second section of the National University campus started to operate (UNAM, 2016) a new entrance was built to the east. This access provided a direct connection to *Santo Domingo* and nowadays is used for hundreds to enter the campus from both the rail station and *Santo Domingo*. Aware or not, when the rail tracks and the station were built in 1983, they created an urban frontier phenomenon between *Santo Domingo* and *Ciudad Universitaria* (fig. 2b).

The southwestern section of *Santo Domingo* is confined by a storage area and *La Cantera* – a former basalt mine, an ecological reserve, and football training fields since 1996 (Executive Secretary of the REPSA, 2008). Thus, the southwestern boundary of *Santo Domingo* is isolated from the global street network. "Borders can thus tend to form vacuums of use adjoining them" (Jacobs, 1961, p. 259). A vacuum of use is the area adjacent to a border that is poorly used or not used at all due to its spatial segregation and therefore lack of human flow (Jacobs, 1961). Because of these characteristics, its history, and its fame of criminal activity, *Pedregal de Santo Domingo* is nowadays unpleasantly perceived by outsiders.

Following the research objectives, the leading research questions were:

> What is the relation between the spatial configuration and criminal activities in *Santo Domingo*, its urban frontier, and its surrounding area?
>
> To what extent is this relationship shaped by the barrier effect of major infrastructure on the west?

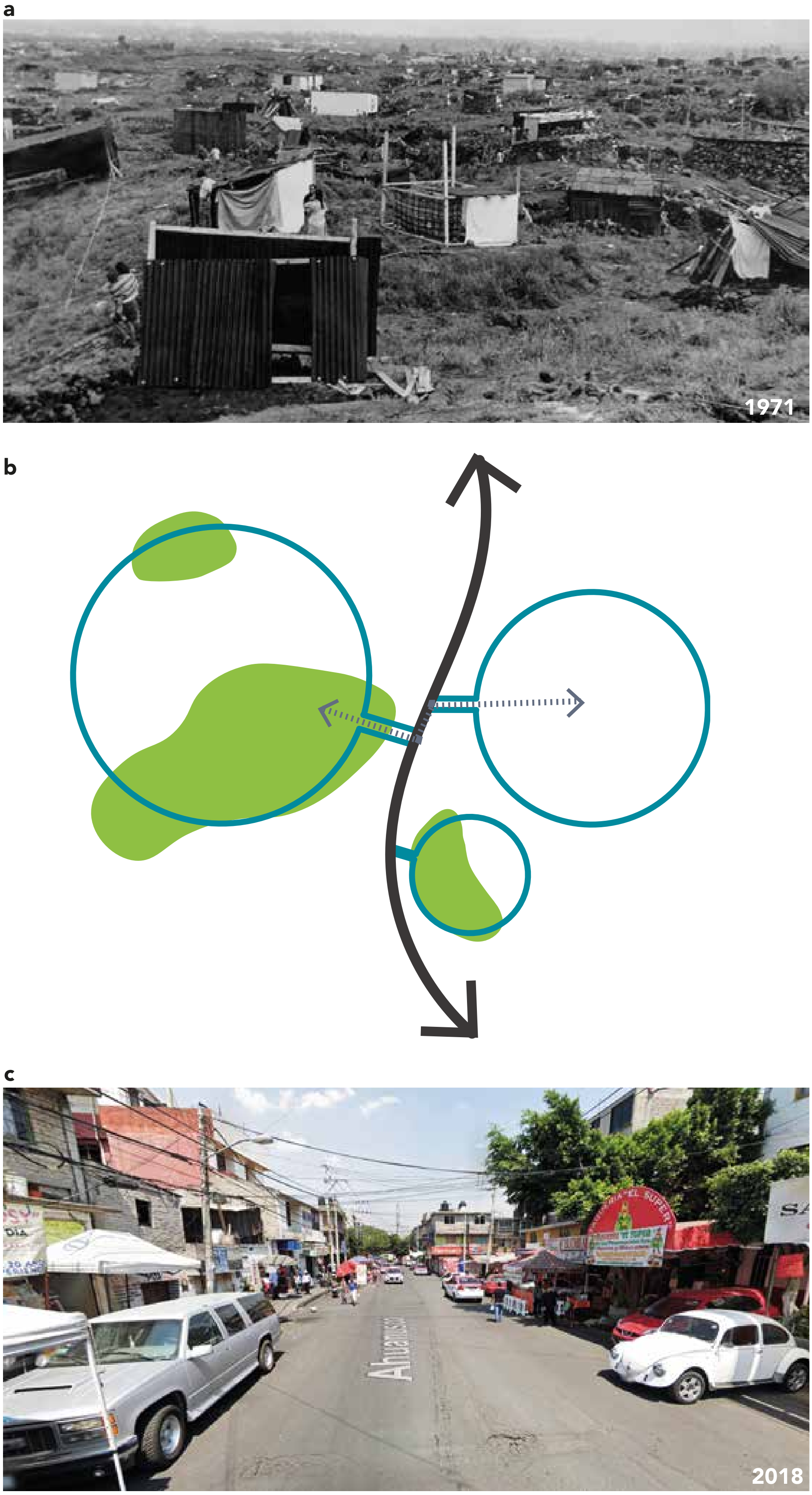

Figure 2: *Santo Domingo* at the beginning of the invasion **(a),** graphic representation of *Santo Domingo's* urban frontier phenomenon **(b)**, *Santo Domingo* as it looks in recent years **(c)**. Source: Federal Administration of Security, National General Archive (a); author (b); Google Maps, 2020 (c).

2 LITERATURE REVIEW

Since the second half of the 20th century, studying crime patterns and the relation and influence they have with the man-built environment, have created different theories and approaches on how the city should be shaped to achieve less insecure streets. Throughout the years, different spatial and behavioural features such as "natural surveillance" (Jane Jacobs, 1961) and "privatising areas" (Oscar Newman, 1972) have been researched. In recent years, proposals developed by the New Urbanism movement (Al Zelinka and Dean Brennan, 2001) and through Space Syntax theory (Bill Hillier and Ozlem Sahbaz, 2012), have explored the initial suggestions of Jacobs and Newman in European and North American cities and explain to what extent they could or could not prevent criminal activity. Furthermore, they detailed social and spatial characteristics that might help to foster crime in the cities of the 21st century.

2.1 Natural surveillance and the course of border vacuums

Jacobs primary states that city inhabitants are the main actor that contributes to the security levels of an urban area "a well-used city street is apt to be a safe street. A deserted city street is apt to be unsafe" (Jacobs, 1961, p. 34). Furthermore, due to the "simplification of use" or "monofunctional areas", and physical barriers, the immediate areas next to urban frontiers would have a few scattered people and will form "vacuums of use", meaning that the natural surveillance cannot be achieved (Jacobs, 1961). Places with these characteristics are socially and spatially isolated and therefore lead to a sense of insecurity (Jacobs, 1961). To achieve public safety, Jacobs insists on reaching a balance between locals and strangers in the streets through three main qualities. Firstly, public space and private space should be properly differentiated from each other. Secondly, streets must always be monitored by both residents and strangers, buildings should encourage usage towards the street instead of closing themselves to it. Finally, continuous pedestrian activity is required to keep an eye on the streets and to increase the number of people that look from inside a building to the streets (Jacobs, 1961).

The area where the rail station is situated between *Santo Domingo* and *Ciudad Universitaria* indeed has an important local and foreign pedestrian flow. Additionally, it has a significant supply of local street food venues and commercial activities. Nevertheless, it shapes an urban frontier for walkers. The sense of insecurity and the actual crime rate in *Santo Domingo* make it relevant to study. In peak hours, hundreds of people from the eastern residential area arrive at the station to take the train to the northern part of the city, – between 90,000 and 250,000 people use the station every day (Camacho, 2014) – whereas hundreds of students and workers descend from the train to enter the university. At the same time, a fair number of both students and workers walk through a narrow street in *Santo Domingo* to the train station only to cross through it towards the university.

2.2 Crime patterns in street networks

More recent studies developed by Bill Hillier and Ozlem Sahbaz, regarding crime incidence in the street network, illustrate the different factors – and the relation they hold to each other – that might foster a certain type of criminal activity in specific locations. The authors suggest that factors such as "space structure, movement, densities and land use mixes" (Hillier & Sahbaz, 2005, p. 457) are interrelated with street crimes. Since robbers tend to target mostly "a moving, or temporarily static, person", Hillier & Sahbaz propose two primary risk factors for pedestrians. First, how long people remain on a determinate street: time risk. The longer one spends on a segment, there are better chances to become a target. It is assumed that, on average, a person will remain longer on a segment due to its length. Second, how many people are walking at the same time on that street; the more people on the street, the less likely it is to be the target: people risk (Hillier & Sahbaz, 2005). They point out that streets that possess mixed land use with a fair number of residents are relatively safe. Besides, following Jane Jacobs' principles, they suggest that dwellings should face each other to provide "natural surveillance" to make the streets safer. In addition, they describe that a permeable street network is a safe street network. However, permeability should be carefully designed, not too high, not too low (Hillier & Sahbaz, 2008).

When contrasting the spatial properties of the street network through space syntax analyses to robbery, housing density, and land use mix, they found that a greater frequency of criminal activity was developed on globally strong integrated segments. Furthermore, those segments showed weak integration at a local scale and did not belong to the high street (Hillier & Sahbaz, 2012). They also proved "that higher residential populations linked to spaces – that is, to street segments – are pervasively associated with lower rates of both residential burglary and street robbery. There is safety in numbers" (Hillier & Sahbaz, 2012, p. 135). Within the public space, these numbers follow the principles of natural movement. It has been demonstrated that the city's network configuration influence movement patterns (Hillier, 2007). "Through its configuration, the street network creates a basic pattern of movement flows, and these flows then shape land use choices, according to the need for different land uses to be close to or remote from movement" (Hillier & Sahbaz, 2012, p. 120). Then, retail, and commercial activity are usually found on highly integrated street segments – whether local, global, or both. However, it is considered that it is more likely to encounter local commercial activity, higher pedestrian density, and retail in locally integrated areas rather than those which are globally integrated. Following pedestrian's movement patterns, Hillier & Sahbaz state that "selecting moving people randomly as victims will also lead to higher numbers of victims on more populated segments" (Hillier & Sahbaz, 2012, p. 128).

2.3 The impact of environmental design and community dynamics in criminal activities

Taylor & Gottfredson (1986) suggest some elementary features that offenders take into consideration when they are about to commit a crime: permeability, ease of internal circulation, land use, and pedestrian insularity. They imply that if the permeability is too high robbers have more access and escape routes and if it is too low a few or no people would walk in the area. The ease of internal circulation means that a two-way street is supposed to be spatially better for offenders rather than a one-way street and cul-de-sacs because they will have more options to escape even if they are detected. In terms of land use, if within the neighbourhood and its surrounding area different commercial activities are developed, these should function as attractors and increase pedestrian mobility making the streets more secure. This statement is consistent with Hillier's concepts of movement economies and natural movement. These ideas state that the spatial configuration of the place will effortlessly attract people towards certain locations, the continuous people's flow will increase the retail land use, and this last, in turn, will draw more people to the area and so on (Hillier, 1996) (Hillier, 2007). However, if in the surrounding area of the neighbourhood the land use is strictly residential or "worst", if it is of industrial nature such as railroads – this being the case in *Santo Domingo* – then the disruption of the pedestrian flow might increase the patterns of insecurity. Finally, the "degree of pedestrian insularity" suggests that if the pedestrian flow is low and local, the offender has more chances to be noticed as an outsider. In contrast, if the area is wide and full of activity it is more likely that several potential offenders choose that location to commit a crime (Taylor & Gottfredson, 1986).

Although the relation between space and crime has been examined through the last decades, most of the studies are focused on European and North American cities – within the USA. Urban space vulnerability is not a new subject for Mexican cities. However, when researching for previous investigations specifically about spatial vulnerability and street crime statistics in Mexico none involved the use of spatial analysis as the leading tool. Therefore, this research is relevant and hopefully will trigger a discussion about approaching safety on the streets from a different perspective. Especially in problematic and extensive urban areas such as Mexico City.

3 DATASETS AND METHODS

This chapter describes the process of data compilation, spatial analysis, and methods used to map and understand the spatial behaviour of robbery and assault in *Santo Domingo*, Mexico City. Space syntax network analysis (Hillier & Hanson, 1984) was the main spatial analysis method, in addition to QGIS analysis and plotting tools.

3.1 Data collection

The crime data set was obtained from the Digital Agency of Public Innovation, Data Portal of Mexico City. It specifies the exact location where the incident took place and considers all reported crimes from 2017, 2018, and 2019 (ADIP, 2018). The street network model, population density, and commercial activity data were found at the National Institute of Statistics and Geography (INEGI, 2019). The land use data was taken from both the Secretariat of Housing and Urban Development and the Digital Agency of Public Innovation, Data Portal of Mexico City (SEDUVI, 2020) (ADIP, 2018). All data sets were cleaned and processed through Excel and QGIS software before performing the analyses.

3.2 Model considerations and analysis methods

The spatial analysis measured the potential movement patterns for both pedestrians and vehicles against the criminal and commercial activity, to unveil the relationship between *Santo Domingo's* spatial configuration, robbery, and assault. Additionally, google street view was used to observe the current socio-spatial characteristics of the area and compare them to the spatial analysis to reinforce the findings of this research (Google Earth, 2020) (Google Maps, 2020).

The street network spatial analysis was run at different scales in QGIS using the space syntax toolkit to determine the level of integration– "the measure of distance from any space of origin to all others in a system" (Hillier & Hanson, 1984, p. 108), and choice, which contemplates how likely is that people or vehicles select a street segment within the city network to pass through it (Hillier, et al., 1987). The model comprehends a radius of approximately 7.5km to minimise the edge effect – the term used when the model has artificial boundaries and these might influence the outcome of the network analysis (Gil, 2017). Integration and choice analyses were run for radius 400, 800, 1200, 2000, 3000 and 5000 to compare amongst them and identify how *Santo Domingo* spatially behaves at different scales. This comparison supported the findings regarding the relationship shaped between spatial configuration and street-related crimes.

Afterwards, the crime and commercial activity data were joined to each segment of the street network model – which already hold the integration and choice values – to look for a relation between them and its distribution according to the segment length. Only pedestrian robbery and assault were analysed in this study due to their relation to public space. Furthermore, the spatial analysis was contrasted to the segments with the aggregated value of the criminal and commercial activity to develop the statistical analysis.

3.3 Statistical analysis

Once the model was fully calibrated with all the data in it, a series of correlation and statistical studies were performed. These aimed to evidence-based prove the relationship between crime patterns and space within *Santo Domingo* and its surroundings. Moreover, the statistical analysis was employed to recognise the spatial characteristics that are more likely to specifically foster robbery and assault within the study area. SPSS software was used to perform the statistical correlations and develop graphics. Excel was also used to produce graphics, and tables.

3.4 Limitations

The population data extracted from the National Institute of Statistics and Geography corresponds to the 2010 population census. The crime data comprehends only the cases reported to the General Attorney of Justice of Mexico City (PGJ by its Spanish acronym) for three years and not the actual number of crimes.

4 RESULTS

4.1 Land use and population

The neighbourhood of *Santo Domingo* is densely constructed. Its land use is almost entirely residential with commercial activity on the ground floor. It has some services – mainly schools – and almost no open public spaces, whether green areas, parks, or plazas. In contrast, the university campus offers wide green and leisure spaces. *Santo Domingo* is also densely populated. According to the literature review, its high dwelling and residents' density – the data contemplates only the borough where *Santo Domingo* is located and not the entire Mexico City – are characteristics that should encourage a secure neighbourhood. However, the crime reports tell a different story (fig. 3).

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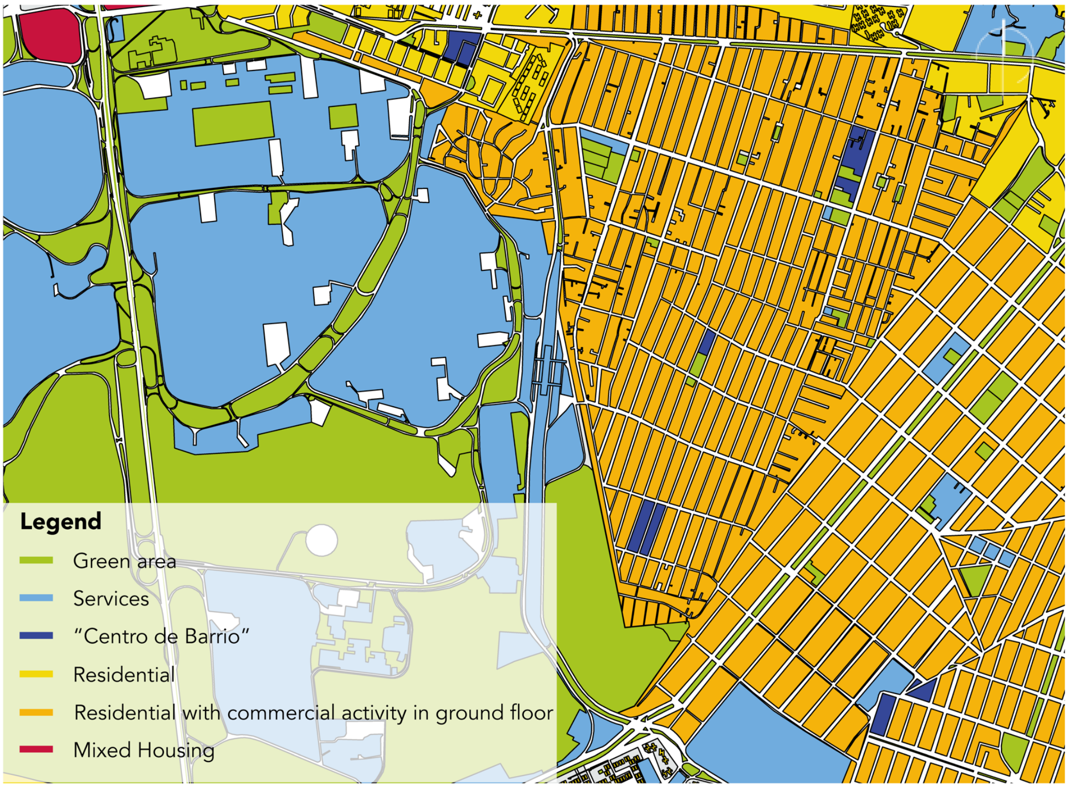

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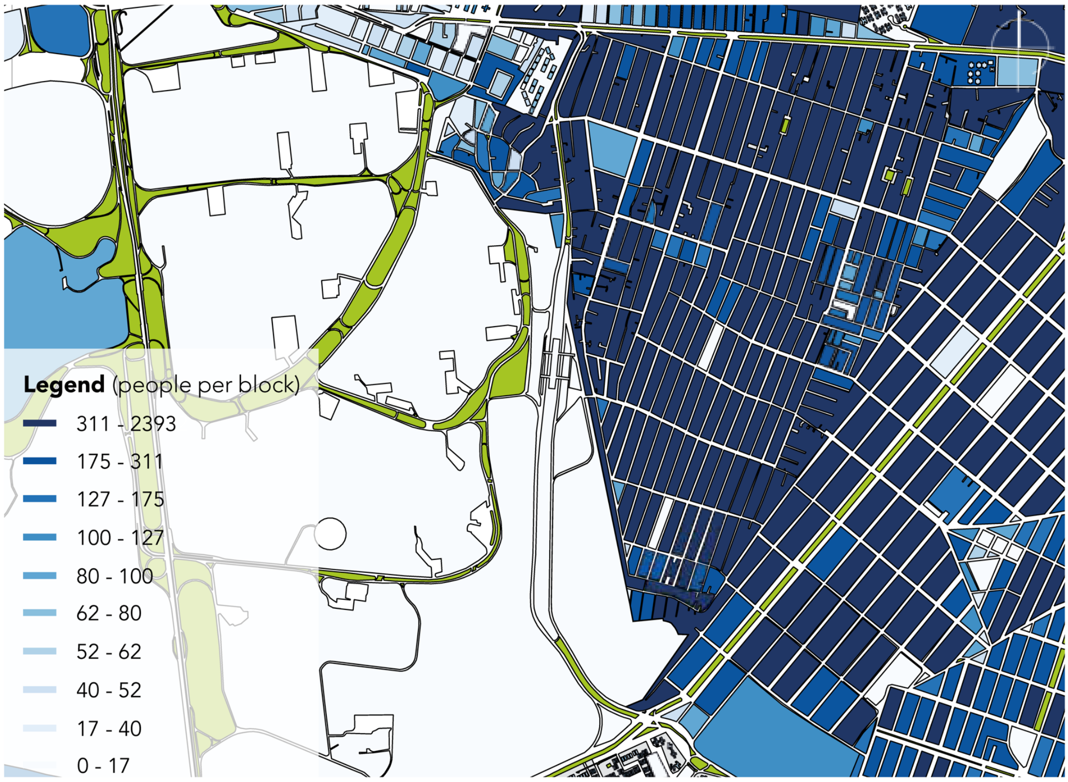


Figure 3: Land use map **(a)**, population density map **(b)**. Source: author.

4.2 Spatial analysis

Figure 4: Street id. Source: author

Table 1: Different features and average integration values for various scales of the streets highlighted in figure 4. Avenue *Delfín Madrigal* (the urban frontier) is considered as three different streets due to its contrasting spatial characteristics. Source: author

Street (ID)	Orientation	Street length (m)	Segment number	Average segment length	NAIN 400	NAIN 800	NAIN 1200	NAIN 2000	NAIN 3000	NAIN 5000
Delfín Madrigal 1	N-S	850.46	13	65.42	1.396892308	1.226536154	1.193615385	1.226692308	1.089963077	1.013145385
Delfín Madrigal 2	N-S	2059.28	7	294.182857	1.132358571	1.149674286	1.039122857	0.971451429	1.042078571	1.01695
Delfín Madrigal 3	N-S	1906.99	5	381.398	1.093474	1.062142	0.99549	1.075446	1.134412	1.055688
Jumil	N-S	1773.53	9	197.058889	1.390325556	1.428488889	1.49224	1.519881111	1.296415556	1.089114444
Ahuanusco	W-E	843.43	19	44.3910526	1.799934211	1.733378947	1.642648947	1.423303158	1.217950526	0.95389

Table 2: Different features and average choice values for various scales of the streets highlighted in figure 4. Avenue *Delfín Madrigal* (the urban frontier) is considered as three different streets due to its contrasting spatial characteristics. Source: author

Street (ID)	Orientation	Street length (m)	Segment number	Average segment length	NACH 400	NACH 800	NACH 1200	NACH 2000	NACH 3000	NACH 5000
Delfín Madrigal 1	N-S	850.46	13	65.42	1.256097692	1.286935385	1.287352308	1.273563077	1.240306923	1.221220769
Delfín Madrigal 2	N-S	2059.28	7	294.182857	0.417202857	0.650784286	0.85732	0.973001429	1.108185714	1.199022857
Delfín Madrigal 3	N-S	1906.99	5	381.398	0.211542	0.558818	0.784656	1.01531	1.098572	1.14328
Jumil	N-S	1773.53	9	197.058889	0.757185556	1.015154444	1.108773333	1.17638	1.138622222	1.094121111
Ahuanusco	W-E	843.43	19	44.3910526	1.273099474	1.278471053	1.289010526	1.286457368	1.232755789	1.116120526

At different local radii, the street network of *Santo Domingo* is more integrated and accessible in the streets that are west-east orientated – with a shorter average segment length – than the streets that run north-south – with a considerably longer average segment length (fig. 4) (tables 1 & 2). For example, the average NAINr 400 of the west-east street *Ahuanusco* – showed in pink in figure 4 – is 1.799934211, while the same measure for the north-south street *Jumil* – showed in blue in figure 4 – is 1.390325556. However, the difference in the value of integration between both streets becomes shorter as the radii increases. At NAINr 1200 the west-east street has 1.642648947 and the north-south street 1.49224, and for NAINr 5000 the first has a 0.95389 integration value while the last has 1.089114444 (table 1). The segments concerning the urban frontier also change their behaviour according to their length in three different areas. The shorter segments of the urban frontier *Delfín Madrigal* – showed in three shades of yellow in figure 4 – are more integrated than its longer segments at a local level. The values become more homogeneous as the radii of analysis increase (table 1). Spatially, this indicates that *Delfín Madrigal*'s less integrated streets – corresponding to the longest segment average – are potentially less used by pedestrians who live in the surroundings.

The west-east street *Ahuanusco* has pretty even choice values at a local scale. However, it becomes weaker at NACHr 5000 with a value of 1.116120526. Compared to *Ahuanusco's* NACHr 400 value of 1.273099474, the north-south street *Jumil* has a considerably lower average choice value: 0.757185556. Meaning that in average the examined west-east street has many more possibilities to be chosen by people, therefore by offenders too to transit over the analysed north-south street (Taylor & Gottfredson, 1986). In this sample, the street running north to south (*Jumil),* has average choice values consistently lower than the street running west to east (*Ahuanusco)*. The urban frontier's (*Delfín Madrigal's)* northern segments – with shorter average segment length – stay quite homogenous in choice at all radii of analysis (table 2). However, when *Delfín Madrigal* changes its permeability and becomes a hard edge, the segments that form part of it show poor choice at a local (pedestrian) scale. The second section of the road identified as the urban frontier or border (*Delfín Madrigal* 2 in figure 4), has a NACHr 400 of 0.417202857, the third section (*Delfín Madrigal* 3 in figure 4) a NACHr 400 of 0.211542, which is a great contrast with the first section's (*Delfín Madrigal* 1 in figure 4) NACHr 400 of 1.256097692. Then, it will be more likely to find people moving within a 400 radius in *Delfín Madrigal's* first range than in *Delfín Madrigal*'*s* second range, and more people might rather choose to walk on *Delfín Madrigal* 2 than on *Delfín Madrigal* 3. On a global (vehicular) scale, the first section of the urban frontier slightly decreases its value, while the second and the third sections considerably increase theirs. In fact, the segments associated to *Delfín Madrigal* 2 and 3 have their highest choice value at radius 5000, meaning that they have been designed for vehicles, not for people.

4.3 Criminal and commercial activity

The distribution of pedestrian robbery is linearly concentrated (fig. 5.1). Hillier & Sahbaz suggest considering the robbery clusters as “hot lines rather than hot spots” (Hillier & Sahbaz, 2005, p. 458) due to their arrangement within the street network. Although, there are hot spots around the rail station. The hot spots and clusters of “hot lines” are considered when three or more crimes are found close to each other within a radius of up to 100 meters. The linear distribution of robbery is highly attracted towards the west-east orientated streets rather than to the north-south ones. 55.6% of the crimes are distributed along the west-east streets, not a striking number though. However, the linear spatial distribution in meters occupied by the segments in west-east streets is only 26.62% within *Santo Domingo*; then 55.6% of robbery is committed in 26.62% of the streets (fig. 5.2). Along the urban frontier, 69.7% of the crime is accumulated just about the railway station, 24.24% is found in the northern and more permeable segments of *Delfín Madrigal* (the border) and with only a 6.06% rate, there is almost no crime to the south (fig. 5.2).

Assault has a similar spatial distribution to robbery. In this case, 49.10% of the events took place on the west-east streets in *Santo Domingo*. Thus, almost half of the assaults were distributed in only 26.62% of *Santo Domingo’s* grid. The urban frontier shows similar patterns too, 87.5% of the assaults were located around the train station (*Metro CU)*, only 12.5% in the northern section of the avenue, and no cases were reported where *Delfín Madrigal* becomes an impenetrable border (fig. 5.3).

When overlapping and adding assault to robbery, most of the “hot lines” remain the same. 53.66% of crime took place in the west-east orientated streets, meaning that a bit more than half of the most frequent street crimes, occurs only within 26.62% of *Santo Domingo’s* streets. On the urban frontier, the railway station attracts almost three-quarters of street crime, while the northern permeable segments have an incidence of 22.97% and both southern paths only have a 5.41% rate (fig. 5.1 & 5.4).

The incidence of commercial activity in general displays a resemblance with the crime distribution. The shorter segments are clustered with retail, while the longest segments have the commercial activity more spread (fig. 7.2).

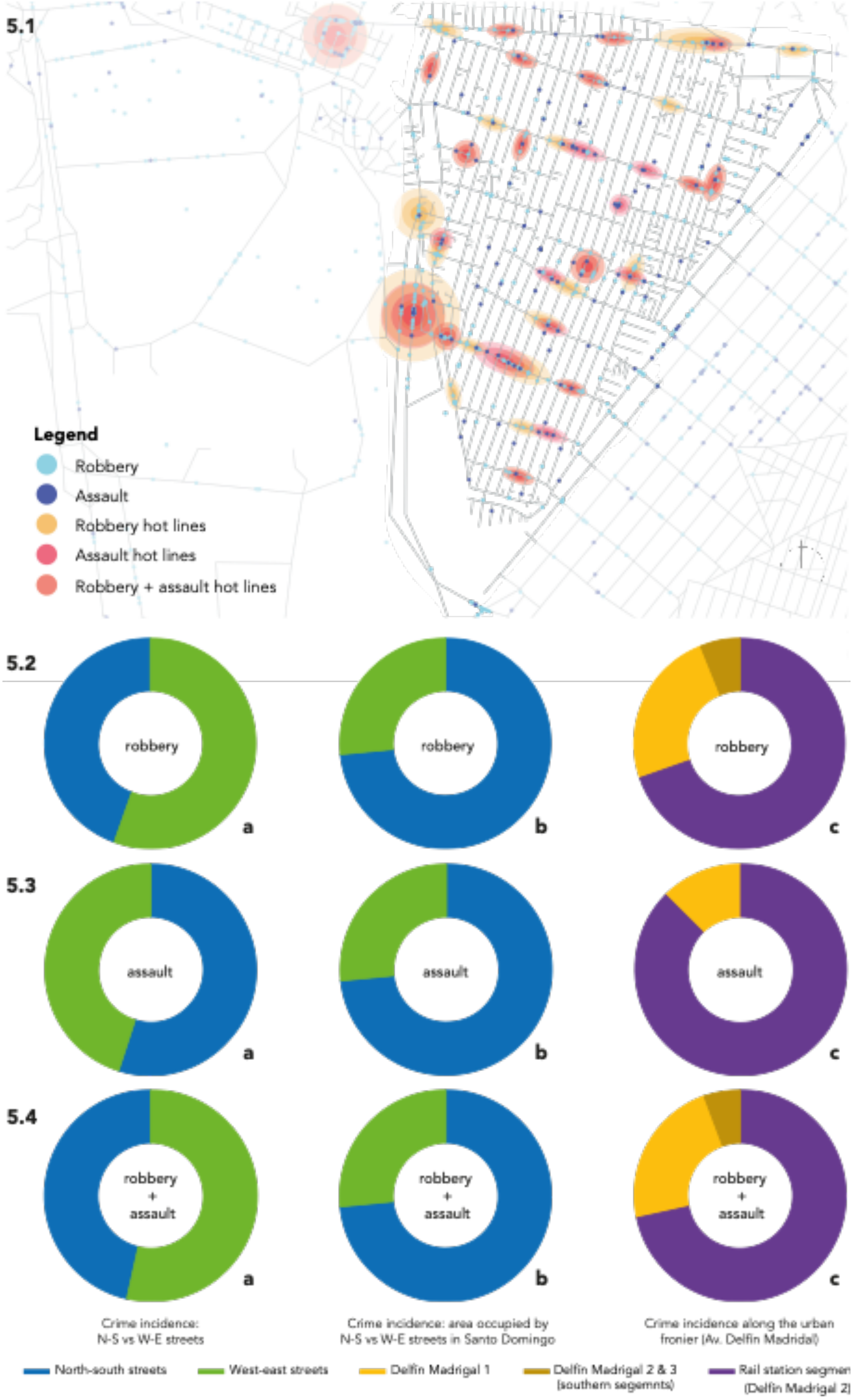


Figure 5: **5.1**, Robbery and assault, emphasising the hot spots and "hot lines". **5.2** Robbery: N-S vs W-E streets (a); robbery: area occupied by N-S vs W-E streets (b); robbery along the urban frontier (c). **5.3** Assault: N-S vs W-E streets (a); assault: area occupied by N-S vs W-E streets (b); assault along the urban frontier (c). **5.4** Street crime: N-S vs W-E streets (a); street crime: area occupied by N-S vs W-E streets (b); street crime along the urban frontier (c). Source: author

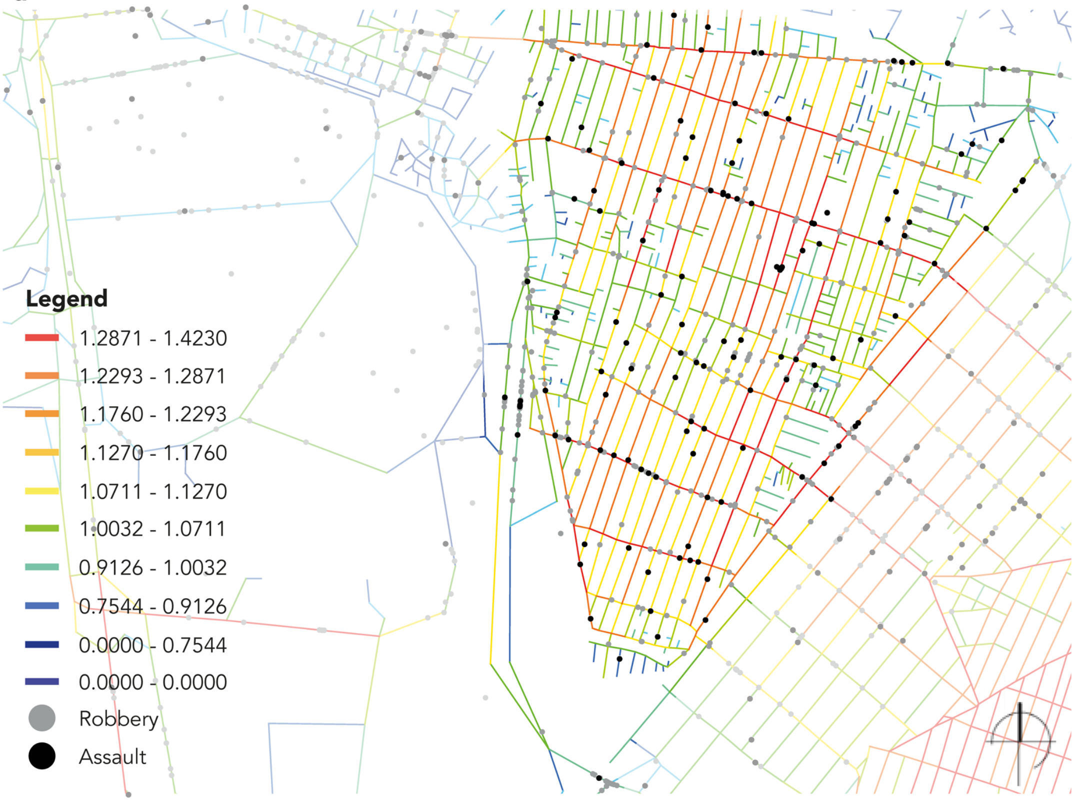
4.4 Spatial analysis, crime distribution and commercial activity

Many times, the segments that have high integration values at both local and global scales represent centralities (Hillier & Sahbaz, 2005). In those locations, the land use and the grid structure should be different from the rest of the neighbourhood (Hillier, 1999). Nevertheless, *Santo Domingo* is characterized by being a homogeneous residential area with commercial activity on the ground floor (fig. 3a & 7.2). According to Hillier & Sahbaz, Taylor & Gottfredson and Jacobs, if streets have a mixed land used that includes residential and commercial activities, the urban grid would have a continuous flow of locals and strangers, therefore, those spaces should be safer than the ones that are entirely residential or entirely commercial, those which are "monofunctional". However, although the area has a balance between residential and commercial activity, it could be stated that most of *Santo Domingo* is currently working as a monofunctional space given that "a single group of people, a single occupation, a single social group or age group has been more or less isolated from the other groups in society" (Gehl, 2011, p. 102). In this case, the social group inhabiting *Santo Domingo* and the land use are making it more or less homogeneous.

Both criminal and commercial "hot lines" are usually found in the streets' segments that are better connected – a better connection involves a fair number of segments (4-6) directly linked to another segment – and have higher local integration and choice values. This last statement is further developed in the upcoming section *Street average patterns* on page 21. "Since the linear pattern of robbery more or less follows the pattern of local spatial integration, and spatial integration is known to approximate movement patterns, it would seem likely that what we are seeing is that there is more robbery where are more people" (Hillier & Sahbaz, 2005, p. 458) (fig. 6a). In this case, regardless of the land use and the grid structure – since it is homogeneous. Furthermore, these streets tend to be west-east orientated – composed of shorter segments – rather than north-south orientated – composed of longer segments. In contrast, throughout the urban frontier, the segments which correspond to the railway station have a great crime incidence, although they are not the best-connected nor integrated or accessible ones (fig. 6). The station itself is an attractor to criminal activity due to the huge exchange of people. The number of strangers walking in and out of it increases the possibilities of the offender to blend even if spatially is not the best location to attack (Taylor & Gottfredson, 1986). The informal commercial activity developed around the station could also be a factor that helps to increase the criminal rates because it creates labyrinthine paths around the station. This is not clear when running the spatial analysis, but it is when looking at pictures of the site (fig. 7.1). The northern segments of *Delfín Madrigal* behave similarly to the internal grid of *Santo Domingo*. However, the less integrated street segments south of the rail station do not have significant criminal behaviour.

Furthermore, commercial activity presents itself more frequently in the segments that are locally accessible and integrated – the same behaviour as crime. Besides, both commerce and crime seem to ignore the southern segments of Av. *Delfín Madrigal* which shapes the urban frontier (fig. 7.2). The .497** Pearson correlation between the two variables shows broadly that indeed the places in which there is commerce there is also criminal activity (fig. 6 & 7) (table 3).

a



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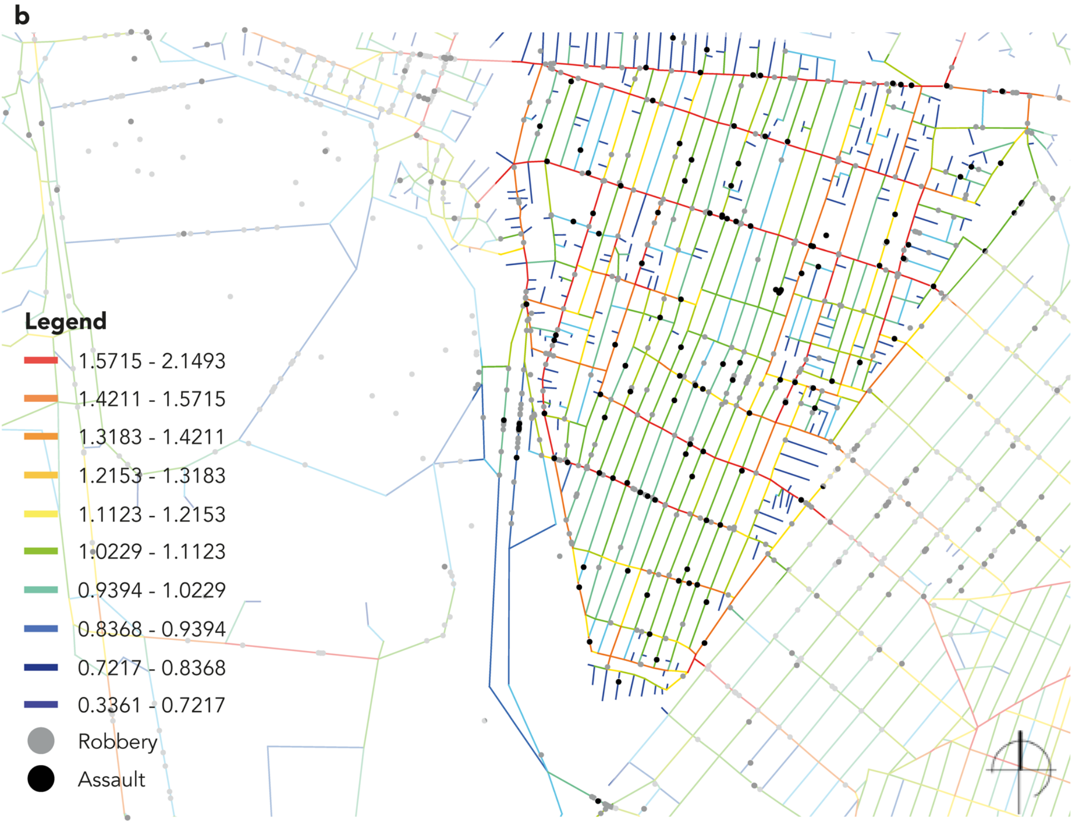


Figure 6: Criminal activity on NAINr 1200. Criminal "hot lines" distribution along the best-integrated streets segments **(a)**. Criminal activity on NACHr 1200. Criminal "hot lines" distribution along the streets' segments with higher choice value **(b)**. Source: author

7.1

7.2

Figure 7: **7.1** Pedestrian activity surrounding the rail station. Photos a & b: author, 2014. Photo c: Google Maps, 2018. **7.2** Criminal and commercial overlapped “hot lines” along the streets’ segments. Source: author

Table 3: Correlation between crime and commerce count per segment. Source: author

Correlation		
		Commerce Count
Crime Count	Pearson Correlation	,497**
	Sig. (2-tailed)	0.000
	N	3112

**. Correlation is significant at the 0.01 level (2-tailed).

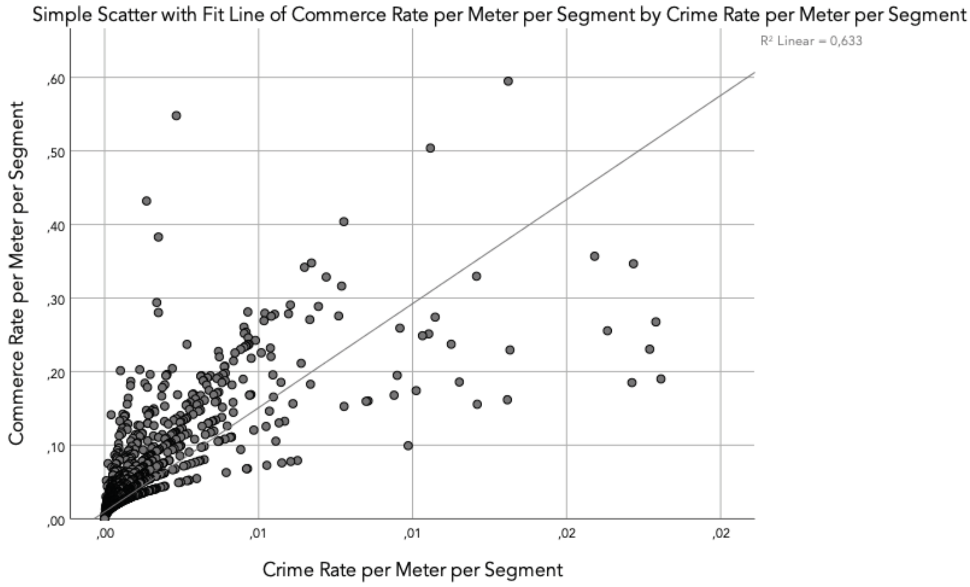
4.5 Crime rate

So far it has been suggested the relationship hold between crime, commerce, and the spatial configuration of the residential neighbourhood of *Santo Domingo* and the implications of Av. *Delfín Madrigal* acting as an urban frontier to its western edge. However, a more detailed analysis was needed to better understand these associations. To fulfil this, a rate of crimes per segment was achieved by dividing the count of crimes per segment between the length of each segment. Since it is not the same to have 5 crimes in a segment of 50 meters as having 5 crimes in a segment of 250 meters. The darker the segment, the more criminal activity per every linear meter (fig. 8a). The same exercise was made for commercial activity (fig. 8b).

The previously mentioned west-east street *Ahuanusco* stands out along with the immediate area surrounding the railway station in both maps. Furthermore, the urban frontier is very lightly coloured meaning that there are indeed very few activities of any kind. Concerning the vacuums of use shaped close to the urban frontiers, Jacobs explains that many times they might only be lonely and dull spaces that lack social activity, that “there is nothing dramatic in any way about a border vacuum” (Jacobs, 1961, p. 261). The correlation between crime and commercial index rate per meter per segment is .773**. Indeed, where there is commerce there is robbery and assault (fig. 8) (table 4).

Figure 8: Criminal rate per meter per segment where *Ahuanusco* Street and the segment where the railway station is located stand out **(a)**. Commercial rate per meter per segment where *Ahuanusco* Street and the segment where the railway station is located stand out along with most of the west-east oriented streets in contrast to those orientated north-south **(b)**. Source: author.

Table 4: Scatter plot between crime and commerce rate per meter per segment. Correlation between crime and commerce rate per meter per segment. Source: author.



Correlation		
		Crime rate per meter per segment
Commerce rate per meter per segment	Pearson Correlation	,773**
	Sig. (2-tailed)	0.000
	N	3112
**. Correlation is significant at the 0.01 level (2-tailed).		

4.6 Street average patterns

Figure 8 emphasise the difference between the west-east streets and the north-south streets. To study the contrasting features of each street, a sample of these has been highlighted for this section. The west-east streets are coloured in shades of green – *Ahuanusco* remains in pink – and the north-south streets are emphasised in blue hues – the urban frontier *Delfin Madrigal* remains in yellow – (fig. 9) so the next graphs can be better understood.

The average value of different local radii of spatial analysis of each street was calculated to test whether the streets with higher permeability (shorter segments lengths) are the streets that are showing a higher level of choice and integration and if the same streets have higher crime and commercial rates (tables 5 & 6).

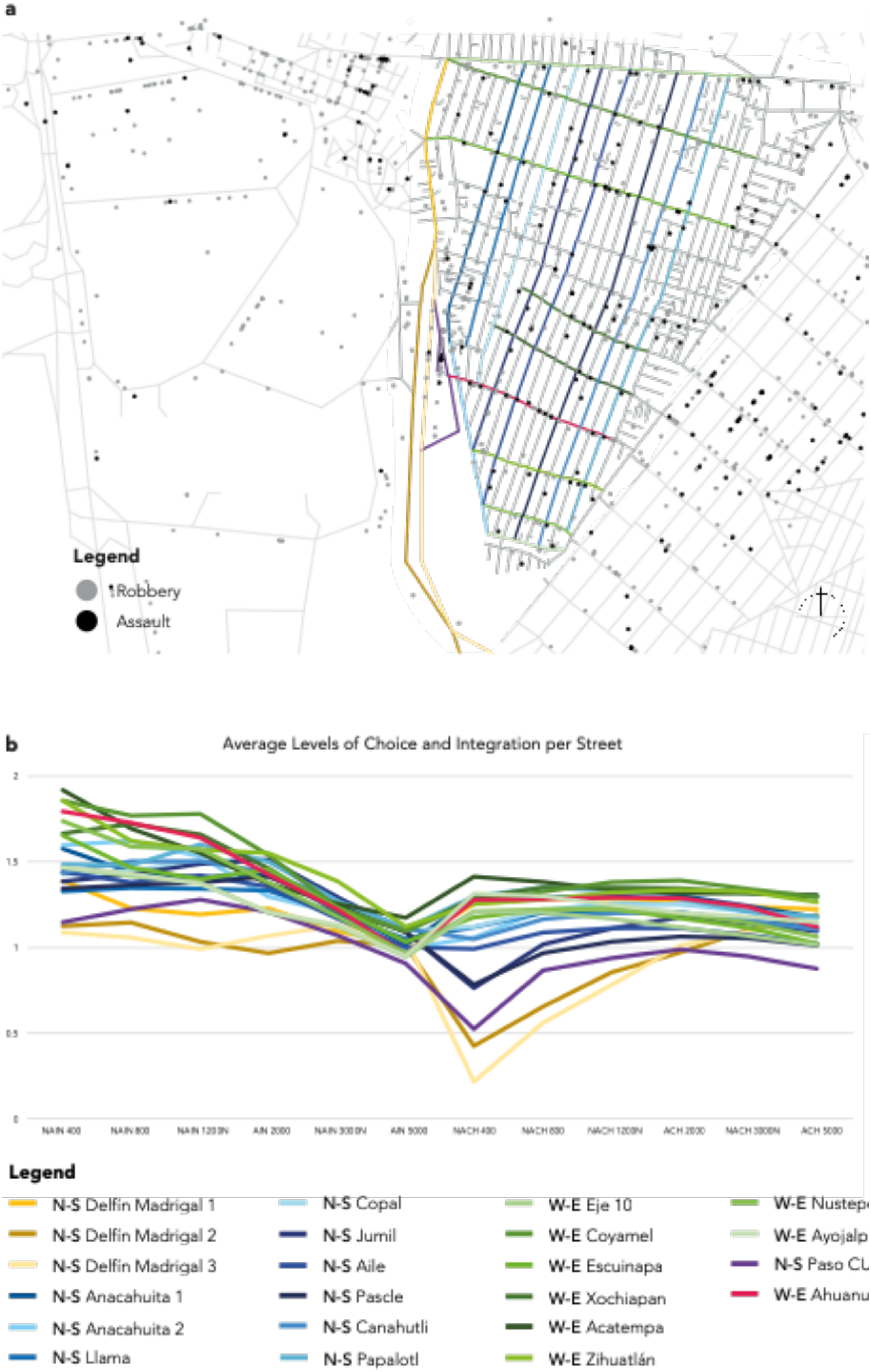


Figure 9: Street id **(a)**. Average integration and choice values of some streets **(b)**. The urban frontier *Delfín Madrigal* is divided into three parts due to its different spatial characteristics. West-east oriented streets are shown in green, those orientated north-south in blue. Source: author

Tables 5 & 6, Different NAIN radii analysis compared to some streets' features in the urban frontier and *Santo Domingo* **(a)**. Different NACH radii analysis compared to some streets features in the urban frontier and *Santo Domingo* **(b)**. Source: author

Street (ID)	Orientation	Street length (m)	Segment number	Average segment length	Commerce count	Crime count	Commerce rate per meter per segment	Crime rate per meter per segment	NAIN 400 (average)	NAIN 800 (average)	NAIN 1200 (average)	NAIN 2000 (average)	NAIN 3000 (average)	NAIN 5000 (average)
Delfín Madrigal 1	N-S	850.46	13	65.42	96	9	0.112880088	0.010582508	1.396892308	1.226536154	1.193615385	1.226692308	1.089963077	1.013145385
Delfín Madrigal 2	N-S	2059.28	7	294.182857	84	11	0.040790956	0.005341673	1.132358571	1.149674286	1.039122857	0.971451429	1.042078571	1.01695
Delfín Madrigal 3	N-S	1906.99	5	381.398	106	54	0.055584979	0.028316876	1.093474	1.062142	0.99549	1.075446	1.134412	1.055688
Paso CU	N-S	796.51	5	159.302	74	7	0.092905299	0.008788339	1.148192	1.22916	1.284018	1.2142	1.0752	0.90626
Anacahuita 1	N-S	1283.51	23	55.8047826	208	31	0.162055613	0.024152519	1.58148	1.443593913	1.408426957	1.438771304	1.206093478	1.01153087
Anacahuita 2	N-S	852.27	8	106.53375	34	20	0.039893461	0.023466742	1.60456375	1.62766375	1.53442125	1.29568375	1.19919	0.9836175
Llama	N-S	1293.7	15	86.2466667	33	2	0.025508232	0.001545953	1.331236	1.352628	1.350460667	1.337751333	1.199415333	1.040012667
Copal	N-S	1458.66	14	104.19	54	11	0.037020279	0.007541168	1.431917143	1.453775714	1.515073571	1.514108571	1.292718571	1.089475714
Jumil	N-S	1773.53	9	197.058889	36	16	0.020298501	0.009021556	1.390325556	1.428488889	1.49224	1.519881111	1.296415556	1.089114444
Aile	N-S	2014.24	13	154.941538	63	13	0.031277306	0.006454047	1.447756154	1.383327692	1.42542	1.359336154	1.168561538	0.995854615
Pascle	N-S	2174.94	11	197.721818	50	14	0.02298914	0.006436959	1.346666364	1.370870909	1.38309	1.418748182	1.246802727	1.088006364
Canahutli	N-S	2170.27	19	114.224737	64	11	0.029489418	0.005068494	1.443790526	1.508778947	1.509577895	1.439285789	1.267665263	1.10599
Papalotl	N-S	2128.18	22	96.7354545	228	24	0.107133795	0.011277242	1.48583	1.4825	1.60778	1.50529	1.26908	1.104857727
Eje 10	W-E	1358.2	35	38.8057143	209	29	0.153880135	0.021351789	1.924808571	1.694320571	1.548372286	1.368169714	1.249543429	1.164344
Coyamel	W-E	1620.73	31	52.2816129	104	20	0.064168615	0.012340118	1.671199355	1.725614839	1.6646	1.462354516	1.209737419	1.087133548
Escuinapa	W-E	1564.79	31	50.4770968	281	43	0.179576812	0.027479726	1.864107419	1.771791613	1.782892903	1.541952581	1.228261613	1.087924839
Xochiapan	W-E	633.09	12	52.7575	66	9	0.10425058	0.014215988	1.661639167	1.4664325	1.398735	1.458581667	1.229970833	1.028699167
Acatempa	W-E	686.04	13	52.7723077	58	15	0.084543175	0.021864614	1.863720769	1.623853077	1.568870769	1.549114615	1.383760769	1.113554615
Ahuanusco	W-E	843.43	19	44.3910526	175	52	0.207486098	0.061653012	1.799934211	1.733378947	1.642648947	1.423303158	1.217950526	0.95389
Zihuatlán	W-E	605.26	12	50.4383333	92	7	0.152000793	0.011565278	1.743265	1.591331667	1.5762625	1.3805225	1.174356667	0.9574175
Nustepec	W-E	422.62	10	42.262	33	7	0.078084331	0.016563343	1.470948	1.419399	1.383426	1.2015	1.120874	0.938377
Ayojalpa	W-E	352.65	10	35.265	7	2	0.019849709	0.005671346	1.470948	1.436047	1.375786	1.205374	1.131655	0.943407

a

Street (ID)	Orientation	Street length (m)	Segment number	Average segment length	Commerce count	Crime count	Commerce rate per meter per segment	Crime rate per meter per segment	NAIN 400 (average)	NAIN 800 (average)	NAIN 1200 (average)	NAIN 2000 (average)	NAIN 3000 (average)	NAIN 5000 (average)
Delfín Madrigal 1	N-S	850.46	13	65.42	96	9	0.112880088	0.010582508	1.256097692	1.286935385	1.287352308	1.273563077	1.240306923	1.221220769
Delfín Madrigal 2	N-S	2059.28	7	294.182857	84	11	0.040790956	0.005341673	0.417202857	0.650784286	0.85732	0.973001429	1.108185714	1.199022857
Delfín Madrigal 3	N-S	1906.99	5	381.398	106	54	0.055584979	0.028316876	0.211542	0.558818	0.784656	1.01531	1.098572	1.14328
Paso CU	N-S	796.51	5	159.302	74	7	0.092905299	0.008788339	0.516172	0.86678	0.93941	0.99094	0.946016	0.874168
Anacahuita 1	N-S	1283.51	23	55.8047826	208	31	0.162055613	0.024152519	1.282786957	1.289061304	1.293565652	1.299002609	1.238738696	1.16927087
Anacahuita 2	N-S	852.27	8	106.53375	34	20	0.039893461	0.023466742	1.050375	1.21517875	1.253825	1.25005	1.2067775	1.12278625
Llama	N-S	1293.7	15	86.2466667	33	2	0.025508232	0.001545953	1.114846667	1.201132	1.213726667	1.203313333	1.157066667	1.106906
Copal	N-S	1458.66	14	104.19	54	11	0.037020279	0.007541168	1.114719286	1.213016429	1.234692857	1.255817143	1.211312857	1.165757143
Jumil	N-S	1773.53	9	197.058889	36	16	0.020298501	0.009021556	0.757185556	1.015154444	1.108773333	1.17638	1.138622222	1.094121111
Aile	N-S	2014.24	13	154.941538	63	13	0.031277306	0.006454047	0.987228462	1.084270769	1.111176154	1.108849231	1.068141538	1.013794615
Pascle	N-S	2174.94	11	197.721818	50	14	0.02298914	0.006436959	0.775406364	0.9663	1.031875455	1.062994545	1.052621818	1.00856
Canahutli	N-S	2170.27	19	114.224737	64	11	0.029489418	0.005068494	1.039935263	1.163503684	1.197226316	1.200602105	1.152135789	1.097412632
Papalotl	N-S	2128.18	22	96.7354545	228	24	0.107133795	0.011277242	1.2972	1.34918	1.33089	1.28215	1.204319091	1.177136364
Eje 10	W-E	1358.2	35	38.8057143	209	29	0.153880135	0.021351789	1.409383714	1.378458857	1.331162	1.310535714	1.312946	1.301295143
Coyamel	W-E	1620.73	31	52.2816129	104	20	0.064168615	0.012340118	1.285074839	1.345565484	1.346409032	1.344195484	1.316610645	1.289871613
Escuinapa	W-E	1564.79	31	50.4770968	281	43	0.179576812	0.027479726	1.263900323	1.323548387	1.380915806	1.390594839	1.335158387	1.288507419
Xochiapan	W-E	633.09	12	52.7575	66	9	0.10425058	0.014215988	1.172805833	1.218639167	1.221594167	1.168533333	1.1081275	1.016644167
Acatempa	W-E	686.04	13	52.7723077	58	15	0.084543175	0.021864614	1.248742308	1.277177692	1.316884615	1.330797692	1.323893077	1.260251538
Ahuanusco	W-E	843.43	19	44.3910526	175	52	0.207486098	0.061653012	1.273099474	1.278471053	1.289010526	1.286457368	1.232755789	1.116120526
Zihuatlán	W-E	605.26	12	50.4383333	92	7	0.152000793	0.011565278	1.207015833	1.218021667	1.219056667	1.191766667	1.142028333	1.056155833
Nustepec	W-E	422.62	10	42.262	33	7	0.078084331	0.016563343	1.209531	1.200754	1.168028	1.116891	1.062306	1.008618
Ayojalpa	W-E	352.65	10	35.265	7	2	0.019849709	0.005671346	1.319164	1.299529	1.250496	1.201415	1.175522	1.146194

b

The graph in figure 9b shows the average integration and choice values of the street sample in the study area. These values are condensed in tables 5 & 6. From the numbers on the tables and the graph, it is possible to become aware that streets with larger average segment lengths (shown in blue in figure 9 and tables 5 & 6) have lower levels of choice and integration in contrast to those streets with shorter average segment length (showed in green in figure 9 and tables 5 & 6).

The urban frontier behaves in different ways according to its segment lengths. The northern section (*Delfín Madrigal 1*) is more permeable and has more commercial activity. The third section *(Delfín madrigal 3)* has the lowest choice and integration values in most of the analysis radii. However, one of its segments is exactly where the access to the rail station is located, making it one of the most vulnerable ones (represented in purple in figure 9 and tables 5 & 6). For this research that segment is an exception to the pattern followed by the rest of the area, it is one of the longest with the lowest average choice and integration values, and low commercial incidence. Nevertheless, it proved to be the second street with more criminal activity. The west-east street *Ahuanusco* (pink) is one of the streets with higher levels of choice and integration and it is also the street that has the higher rates of both crime and commerce (fig. 9 & 10).

Furthermore, figure 10 graphically synthesises the average segment length, and the criminal and commercial rates of the street sample portrayed in figure 9a. It visually reinforces how west-east streets have a higher criminal and commercial rate and consist of shorter segments over the north-south streets. Besides, *Ahuanusco's* criminal and commercial rate contrast with its short average segment length.

Santo Domingo is an active residential and commercial neighbourhood where insecurity perception and actual crime rates are a continuous concern for its inhabitants, whether local or just passing by. This study emphasises the correlation between the criminal and commercial rate since the area has an extensive commercial activity very likely indeed led by its spatial configuration. Besides, the popular perception of fear in segregated isolated spaces is questioned given that the results showed that the studied hard edge has a controversial outcome regarding its spatial relation to crime and the spatial configuration of *Santo Domingo's* neighbourhood. In the future, a deeper statistical analysis of the relation between spatial properties, criminal and commercial rate and other variables could be conducted to lead the findings in this research towards specific policies to improve security in this city sector.

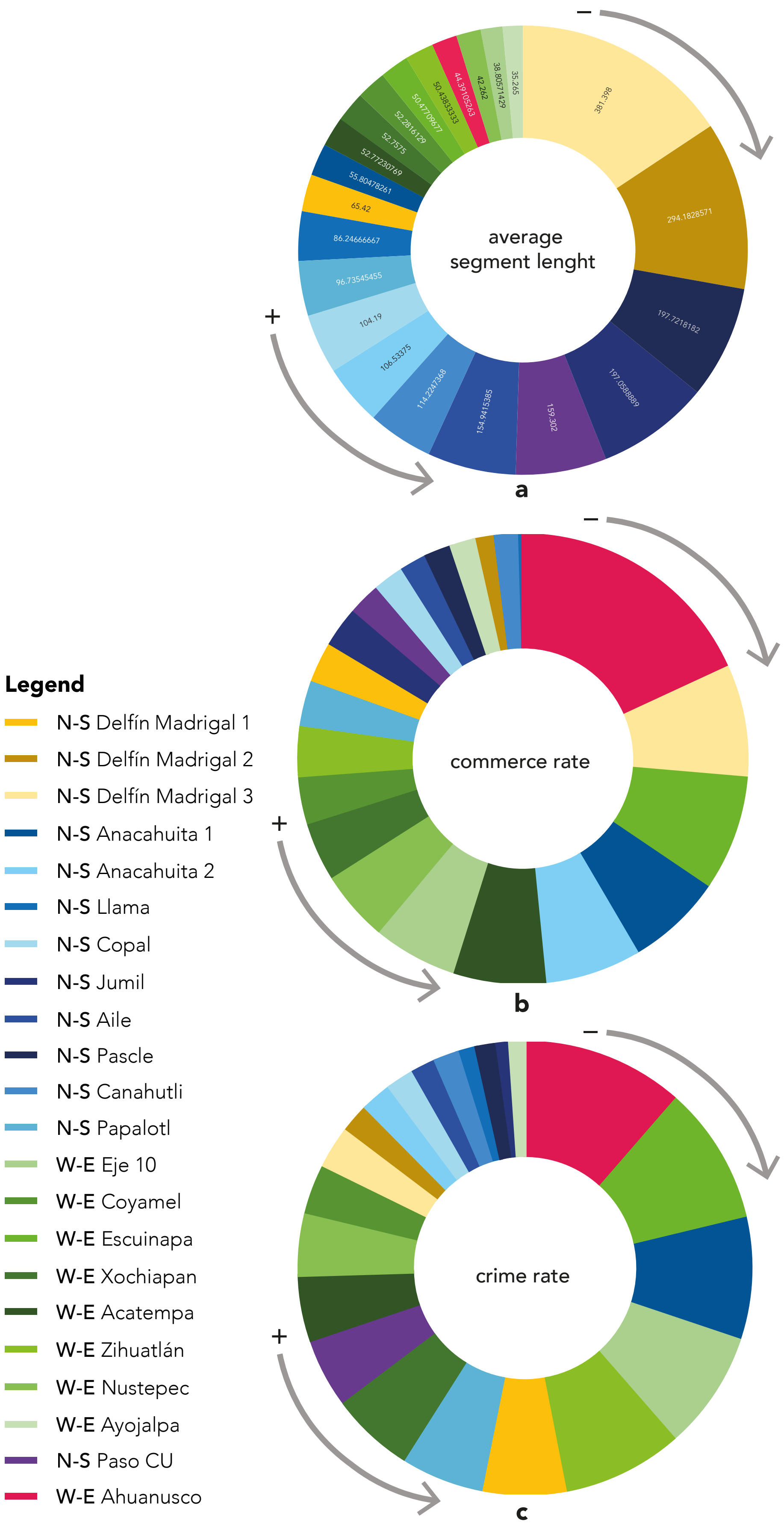


Figure 10: Segment length **(a)**, commerce rate by meter by segment **(b)**, and crime rate by meter by segment **(c)**. Source: author

5 CONCLUSIONS

Santo Domingo's spatial configuration shows that it does not have significant spatial segregation. The urban frontier located on its western border certainly contributes to its spatial connections to the city street network, however, it does not seem to impact as much *Santo Domingo's* accessibility patterns. Oddly, seems to be the other way around. Because the southwest edge of *Santo* Domingo is not connected to the urban frontier, the urban frontier is spatially segregated. The segregated hard edges of the urban frontier do not foster any kind of activity, not commercial, pedestrian, or criminal. Be that as it may, as part of the poorly locally integrated segments along the barrier, the rail station indeed fosters criminal activity due to the high quantity of people using it. The rail station is an inconsistency; as part of the urban frontier has the lowest choice and integration values, it strongly divides the university campus and the residential area. Nevertheless, one of its segment lines has one of the highest values for crime per meter per segment and it is also the mean through which people can cross *Delfin Madrigal*. In Jane Jacobs words "a railroad station interacts with its surroundings differently from a railroad track" (Jacobs, 1961, p. 264). To fully understand the criminal behaviour around the railway station, a purely pedestrian model should be run since some minor pedestrian paths do not appear in the model used for this research.

When it comes to *Pedregal de Santo Domingo* the shorter segments – mostly west-east orientated – mean more commercial activity, more permeability, and therefore more crime. Crime street patterns – robbery and assault – follow the principles of movement economies and natural movement. Although the area is homogeneous in terms of land use and all the streets have diverse commercial activities, the segments and streets that are locally highly integrated are the streets that have more commercial venues. Through the principle of movement economies, spatial configuration at the beginning attracts pedestrian movement, which subsequently fosters commercial land use, and this will draw more people in a "multiplier effect" (Hillier, 1996) (Hillier, 1999). This reflects a higher accumulation of people and "natural surveillance" (Jacobs, 1961). Besides, the natural movement phenomenon pulls more crime towards the area since it is easier for the offenders to blend within the crowd (Taylor & Gottfredson, 1986). Hillier & Sahbaz proved that "high rates of robbery are associated with poorly connected segments in integrated locations – close to the high street, we might say, but not on it." (Hillier & Sahbaz, 2012, p. 131). Still, in the analysed neighbourhood, the segments with high crime rates do belong to one of the local high streets (west-east orientated *Ahuanusco* street), which is also not poorly connected. Moreover, Hillier & Sahbaz imply "that incidence rises with increasing length of segment, as expected from the primary risk concept". (Hillier & Sahbaz, 2012, p. 131). In *Santo Domingo,* the "time risk" definitely does not follow the segments' length; the streets with more criminal activity have shorter segments than those with less crime reports. The "time risk" might however develop due to the high commercial activity – including a significant amount of street vending –, which may cause people to temporarily stop walking along the streets. These arguments prove that street criminal patterns and their spatial features indeed change according to the city and the society analysed, which makes the subject interesting and relevant to keep studying.

Even though there is a constant public perception of insecurity in large empty spaces in Mexico City, the findings in this research suggest that these kinds of places are not as dangerous as expected concerning the most common street crimes towards pedestrians – at least when talking about *Santo Domingo*. This does not mean that the segregated areas are crime-free, but their incidence is lower than in crowded and well-connected streets. Street crime patterns in *Santo Domingo* proved that even though "security is in numbers" (Hillier & Sahbaz, 2012), it is to some extent likely to become a target to robbers and assaulters if the area is too crowded.

Limitations

This research was done on a remote basis when the coronavirus pandemic started to peak all over the world. Some other studies such as conducting interviews for both residents and non-residents of *Santo Domingo* about fear perception, gate counts, and movement tracing could help strengthen the results demonstrated in the present paper. Nevertheless, the outcome is significant and encourages further research and analysis on the subject.

Further research and analysis

For more detailed outcomes the period when the offence took place could be considered. This might be done by dividing the hours of the day into morning, afternoon, night, and peak hours – when the rail station is more active due to people exchange. Furthermore, a social study on *Santo Domingo's* virtual community – "meaning the simple fact of regular co-presence resulting from spatial design" (Hillier & Sahbaz, 2012, p. 136) – and how community sense is perceived in the area, could significantly add to the present outcomes. The social and community studies should also consider the proximity *Santo Domingo* has to the university campus since now a day it accommodates a strong number of students and university workers. This group of people daily dynamics differ from the patterns people who have no relation to the campus has. Besides, within the residential area and inside the university there is a drug deal presence (ADIP, 2018). Therefore, robbery and assault might be somehow related to other crimes such as minor drug deals.

The insights found could help to investigate other areas of Mexico City under the same scope and compare how different zones in the same city spatially behave and relate to specific street related crimes. This would be to fulfil a major impact on public policy planning, design, and social programs towards a safer city focused on people and the public sphere we all share every day. This research could also serve as a foundation for other criminal street behaviour studies in Mexican and Latin American cities, which sometimes face similar urban vulnerabilities. Given the specific results considering the study area, three questions are raised for further research. How would the criminal patterns and the urban frontier phenomenon evolve if the station was relocated? Which would be the new social patterns if *Delfín Madrigal* made its walls more permeable? Which social characteristics are related to street-criminal patterns in *Santo Domingo*?

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