

ACCESS TO SECURITY SERVICES AND CRIME PATTERNS. CASE STUDY: MANIZALES, COLOMBIA

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Abstract

Accessibility planning allows a better understanding of the operational characteristics of transport networks in relation to economic, socio-demographic, and land-use variables. It has, however, experienced a much slower adoption in the Global South as opposed to industrialized societies, focusing mostly on work opportunities and other basic services. The city of Manizales in Colombia is considering incorporating accessibility models as part of policy design and decision-making processes for the implementation of new services. In this regard, we set out to assess the relationship between locations of police stations, operational characteristics of the transport network, and criminal offences by using territorial accessibility measures. Our research seeks to contribute to the debates on the applicability and usefulness of accessibility measure when applied to specific services in a developing context. The research builds on primary data obtained in a period of over a year with the aid of GPS equipment. These data are contrasted with information on criminal offences attended by local authorities. Our analyses confront accessibility levels on the road network and spatial coverage of police stations with density of reported criminal offences. These analyses suggest correlations between areas of the city with higher density of criminal offences and constraints of local capacity and accessibility of police facilities. We provide evidence of the role of accessibility in seamlessly unrelated services and produce new information that can strengthen criteria for land management and locations of urban facilities in mid-sized cities.

Keywords: accessibility; criminal offences; police stations; coverage.

1. INTRODUCTION

Modern international literature centres accessibility in urban transport research and it is becoming a constant reference in policy and practice in different contexts, particularly in relation to the social, economic, and spatial considerations and implications of transport development (Jones and Lucas, 2012). Despite advances in the use of accessibility metrics in transport research and recent examples of

their use from different perspectives, applications of the concept in Colombia, and generally in Latin America, are still limited in both number and scope (Escobar et al, 2013). This research seeks to contribute to current knowledge concerned with urban accessibility from the perspective of crime and security. Using the case of Manizales, the capital of the province of Caldas in Colombia (see Figure 1). We use spatial analysis and geographical accessibility estimations to explore the interactions between locations of police stations, crime occurrences, and transport infrastructure in areas with different socio-demographic characteristics. The research seeks to produce evidence regarding: 1) the applicability of accessibility analysis beyond traditional analysis of work opportunities and services, and 2) the relevance of integrated transport-security planning in cities with relevant concentrations of crime and rapidly changing urban structures.

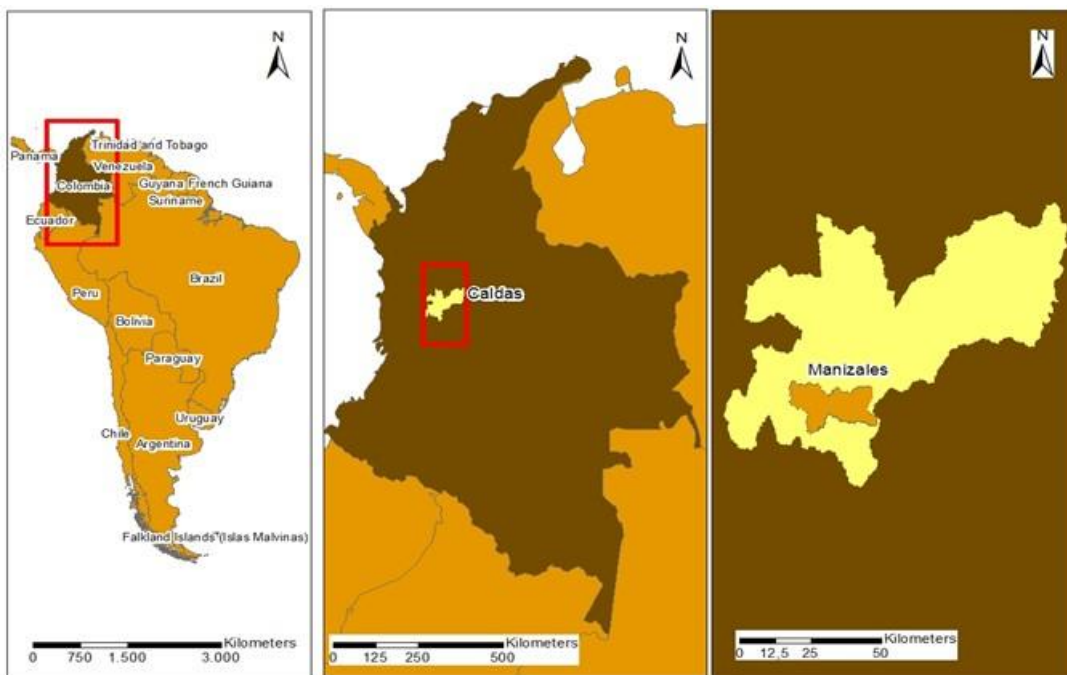


FIGURE. 1 - GEOGRAPHICAL LOCATION OF MANIZALES
Source: Authors.

Manizales is a mid-sized city in the west-central region of Colombia (2,150 m.a.s.l., 404,000 inhabitants), it is characterized by steep topography that has governed urban development patterns, leading to scattered concentration of the population and a discontinuous network of urban infrastructure for connectivity, public spaces, and other urban amenities and services. These conditions produce a visible socio-spatial, and sometimes physical, segregation of specific social groups, which we hypothesize to be strongly related to the availability of urban infrastructure (or lack thereof), including police stations and other related facilities.

The research is informed by data produced for the "Master Mobility Plan", where urban planning models were applied to supply infrastructure networks according to the different nodes of activity and modes of

transport available (Alcaldía de Manizales, 2011). The analysis of activity-location is a field of research that has been directly related to territorial planning, logistics, and mobility, among others, being essential to allow such studies to accurately represent available spatial information (Todes, 2012). Despite efforts to achieve a sustainable and equitable land-use and transport system, evidence from cities in the Global South reflects not only tendencies toward the concentration of activities and urban primacy but also an unequal distribution of quality of transport infrastructure, high levels of pollution, and low levels of wellbeing depending on the spatial distribution of wealth and security in the space (Oviedo and Davila, 2016). This research quantifies and analyses information on crimes listed and responded to by local police between 2011 and 2014 within three categories: life threatening, robbery & assault, and minor events. The analysis seeks to contribute to what some authors (Ekblom, 1988; Borne and Wernicke, 2003; Chainey and Ratcliffe, 2005) have identified as essential information requirements for the study of criminal occurrences. Such requirements range from the production of clear and concise data on crime issues at the neighbourhood, local, and larger scales to the generation of data on crime hotspots for effective allocation of police forces and optimization of resources for security and policing agencies. Analyses performed in search for data that can contribute to the prevention and reduction of crime are particularly relevant in the context of Colombia (Ruiz, 2012), where security challenges will in the near future become more complex in the face of a potential resolution of the longstanding internal conflict with guerrillas and paramilitary groups (Barco and Arana, 2014). Insights from the research aim to not only inform local policing agencies in Manizales and other urban areas of Colombia and cities in the Global South but also contribute to existing debates and approaches to the use of accessibility in the analysis of different (non-transport) sectors of urban policy. In a recent research, Soifer (2012) suggested safety from crime as a key factor in assessing the effectiveness of government. This, however, is often a difficult variable to quantify, with most approaches overlooking the spatial dimension of crime (Faria et al., 2013), spatial impact of organised crime (De Leo, 2017), spatial patterns of crime (Ceccato and Oberwittler, 2008), requiring additional evidence on potential correlations between transport infrastructure and socio-spatial crime patterns. Closer examination of the geographies of accessibility and distribution of security and police facilities may contribute to a better understanding of the dynamics of crime in cities with different territorial characteristics. On the other hand, accessibility is a measure of the interaction between a set of activities using one or more transport modes (Morris et al., 1979). The classic definition of this term is expressed by Hansen (1959) as “[...] the potential of opportunities for interaction”. The concept of accessibility can be traced back to the 1920s, with early applications in location theory and regional economic planning (Batty, 2009). Accessibility measures have thus informed research on various topics including economic development (MacKinnon et al., 2008), characteristics of transport infrastructure and mobility (Escobar and García, 2012), coverage of transport services (Straatemeier, 2008), demographic and urban growth (Kotavaara et al., 2011),

provision and service location (Higgs et al, 2013; Park, 2012), urban planning (Lotfi and Manoucheri, 2015; Weismayer et al, 2017), access to public parks (Wang et al, 2013), social cohesion (López et al, 2008), sustainability (Cheng et al, 2007; Vega, 2011), agriculture and natural resources, among other fields. In Colombia, research on accessibility is limited, partly because of technology gaps and technical capacity issues. However, models of territorial accessibility and spatial diagnostics of potential and measured mobility have been progressively integrated as part of planning policies in cities like Manizales. Two examples of the use of spatial analysis in criminal studies are also identified in the country, supporting the need for further research integrating the two disciplines (Munar, 2014). The use of GIS visualization capabilities and production of geo-statistics that explain the road network in conjunction with data on the location of police stations and crime hotspots are expected to provide a detailed picture of the problem of accessibility to security in the municipality (Bello, 2012).

2. METHODOLOGY

In general way, the methodology have five stages and is described as follows.

2.1. Review and updating of the road network and georeferencing police stations

The road network is a digital node-and-link database representing (track segments) located geospatially. In this case, the graph is composed of 12,626 links and 8,837 nodes. The latest available information for the city (2011) and data collected by GPS equipment installed in different motor vehicles were overlapped in order to validate the road network. This procedure makes it possible to identify new transport infrastructure and to carry out a detailed improvement of the real condition of the road network. The georeferencing of police stations (30) as points on the model was carried out through direct observation and the information provided by the Central Police Command.

2.2. Analysis of database of crimes

From secondary data sources, we generated a database of crimes recorded in the city of Manizales between January 2011 and December 2014. Each record in the database has the following information: date, geographic location, type of offence, and numbers of injuries and deaths. The crimes were georeferenced in order to link the database generated with the spatial location of each event. Georeferencing of local crime occurrences evidenced their evolution throughout the city. In total, 4,956 crimes are registered in the database for the four-year period described.

2.3. Calculation of operative characteristics of the available road network

This calculation is based mainly on the analysis of operational speed observed on each link as part of the network, since this variable determines the overall performance of the network and becomes a key element in the calculations of accessibility (Geurs and Ritsema Van Eck, 2001). GPS equipment installed in different types of vehicles (car, motorcycle, truck, taxi) was used to validate the data collected. The network was loaded with daily average speeds per mode in each link.

2.4. Calculation of average mean accessibility

Contour measures (Geurs and Van Wee, 2004) were estimated for each police station in the database related to each node in the network based on impedance estimations that build on the operating speed parameters described above. This is calculated from the vector of average travel time (T_{vi}) (see Eq.(1)) from the set of nodes of police stations to other nodes in the network of study, based on the least impedance obtained given the operating speed of each link a . Subsequently, the vector calculating average travel time is related to the geographic coordinates (longitude, latitude) of each node in order to generate a matrix ($n \times 3$).

$$\overline{T_{vi}} = \sum_{j=1}^n t_{vi} / (n - 1) \quad i=1,2,3,\dots,n; \quad j=1,2,3,\dots,n \quad (1)$$

Nevertheless, although all nodes in the graph have defined coordinates and the numerical value of average travel time, not all points of space are sampled. This required us to predict the average travel time between some missing coordinates in order to build the isochronous curves. With this aim, the kriging method (Phatarapon et al., 2015), which is based on regression methods and theories of probability, weights (λ) the sampled points, multiplying them by the value of the variable of interest. In this case this variable is the average travel time (T_{vi}) for each observed point at a position X_i . The predicted value of the average travel time is given by $T^*_{vi}(X_0)$ (see Eqs. (2) and (3)).

$$T^*_{vi}(X_0) = \lambda_1 T_{vi}(X_1) + \lambda_2 T_{vi}(X_2) + \lambda_3 T_{vi}(X_3) + \lambda_4 T_{vi}(X_4) + \dots + \lambda_n T_{vi}(X_n) \quad (2)$$

$$T^*_{vi}(X_0) = \sum_{i=0}^n \lambda_i T_{vi}(X_i) \quad (3)$$

Weighting is based on the distance between sample points and the point for which the travel time is predicted (in minutes), and the sum of these weights must equal one (1.0) so that the expected value of the prediction is equal to the expected value of the variable, provided that the requirement of unbiasedness is met (see Eq. (4)). To validate the predictions made by the cross-validation method containing the assessment of each sample point with the same prediction, a procedure that minimizes the sum of errors of all points used is sought.

$$E(T^*_{vi}(X_0)) = E(T_{vi}(X_0)) \quad (4)$$

2.5. Analysis of coverage of isochrones curves

This stage of the research describes the connection between the socio-demographic characteristics of the zones and the response time of police officers from a given police station attending an emergency. Using GIS, it was possible to define the isochronous curves obtained by applying the Kriging model using socio-demographic information on the study area: 404,805 inhabitants living in 95,361 households in an area of about 39.3 Km², according to socioeconomic stratum, where stratum 1 is households with low economic capacity and stratum 6 are households with high economic capacity (See Figure 2).

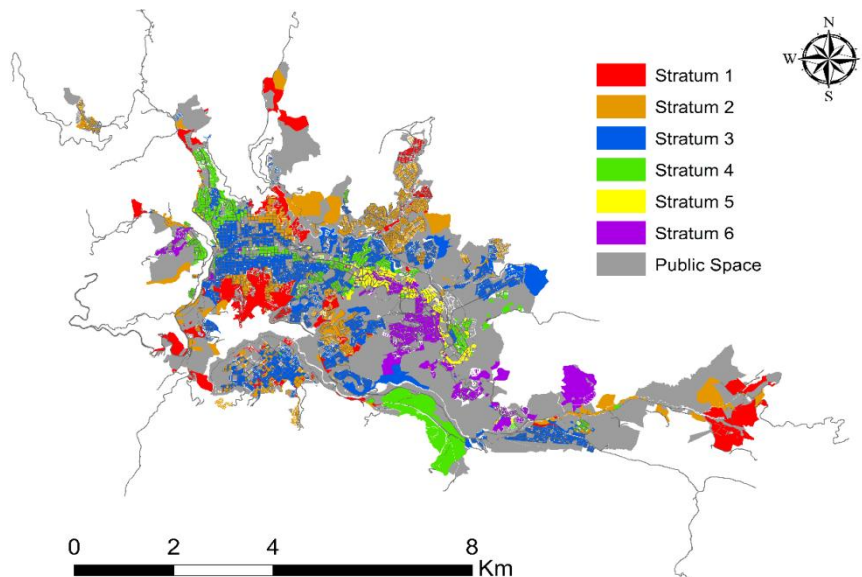


FIGURE. 2 - INCOME LEVELS (STRATA) OF THE CITY OF MANIZALES. SOURCE: MUNICIPAL DEPARTMENT OF PLANNING
Source: Authors.

This made it possible to calculate the percentages of the population, number of households, and area that are covered by the different isochrones curves. Some authors (Luna and Soifer, 2015) have stated that the service time of response by the police in Colombia is around 27 minutes. This is higher than average compared to other countries in the region such as Uruguay (22 minutes) and lower than in other countries such as Venezuela (38 minutes). However, according to a report submitted by Bogotá's Secretary Government (El Tiempo, 2008), the local police attend an emergency call in five minutes and 13 seconds, while the international standard for this type of operation is about 8 minutes. Given the very wide difference between data obtained from an opinion survey and the data presented by a state entity, in this research we assume that five minutes is the immediate response time for any emergency. However, this time has been increasing in recent years in the Latin America context (Zechmeister et al, 2017).

3. RESULTS AND DISCUSSIONS

3.1. An overview of crime in Manizales

Total crimes per year for our timeframe by type of incidents are shown in Table 1; 64% of them are related to robbery and assault, 27% to minor events and 9% to Life threatening. As shown in Table 1, the number of life-threatening events in the city decreased at an annual rate of 7.1% between 2011 and 2014; in spite of the fact that Manizales registers an 8% decrease in the number of life-threatening events (downward trend during the last 15 years) between 2016 and 2017 (MCV, 2017), it registers an index of the number of life-threatening per 100 thousand inhabitants (21) more than twice the value minimum recommended internationally (10). This is a relevant finding from the survey as it suggests a significant reduction in this type of crime in the period of analysis, which we hypothesize to be related to adequate coverage and higher efficiency of police response. This information will be analysed in more detail in the accessibility assessment.

TABLE 1 - TOTAL CRIMES PER YEAR.

Type of criminal event	2011		2012		2013		2014		Total events
	N° of events	% of total	N° of events	% of total	N° of events	% of total	N° of events	% of total	
Life threatening	127	13%	117	8%	116	9%	102	8%	462
Robbery and assault	615	61%	878	63%	869	65%	806	66%	3,168
Minor events	267	26%	398	29%	347	26%	314	26%	1,326
Total	1,009	100%	1,393	100%	1,332	100%	1,222	100%	4,956

Source: Authors' calculations.

Robbery and assault showed positive tendencies between 2012 and 2014 with a significant decrease between 2011 and 2012. These changes can be attributed to a number of factors beyond the scope of this research. However, the spatial distribution of these events and their relationship with socio-demographic figures in different areas of the city are analysed in the following sections, allowing insights on observable relationships between coverage and crime incidence to be drawn. The historical evolution of minor events in the period of analysis shows a similar tendency to robbery and assault. A reduction of 11.2% per year occurred between 2012 and 2014 even though there was increase of nearly 49% between 2011 and 2012. These data set a relevant baseline for our accessibility analysis.

Other relevant variables for analysis are crime reporting and perceptions of security. Coverage of police stations can be potentially related to frequency of crime reporting, at least at aggregate levels. These data help depict general perceptions of trust in police forces and neighbourhood security. According to data from DANE (2016), 27.9% of crimes in Manizales are reported by victims, which is lower than the

national average for the 28 major urban areas (29%) in Colombia. This suggests limited confidence in local authorities and security agencies, although it may also be related with issues of accessibility of police facilities. In industrialized countries, rates of reporting can range from 39% to 67% according to Van Kesteren et al. (2000). Perception of security or insecurity is a relevant factor in relation to the efficiency of security forces. In general, the urban population in Colombia tends to have a high perception of insecurity, which can be influenced by perceived coverage of police services, crime frequency, and physical and socioeconomic factors such as the quality of the built environment, social life, community cohesion, and poverty (Van der Berg et al., 2011). In Manizales, 13.2% of people over 15 years of age perceive their city as unsafe. Although this figure is high, it is considerably lower than the average for the 28 major urban areas in the country (62.7%) (DANE, 2016).

3.2. Accessibility analysis

The accessibility analysis in this study is addressed from three complementary perspectives: i) percentage coverage of population variables by stratum according to the mean travel time from all police stations; ii) number and percentage of criminal events by crime category for each of the isochronous curves; and iii) spatial variation of the number of events per crime type for each of the years of analysis. The three types of analyses allow comparisons and drawing of connections in order to support the conclusions and future research lines that are presented below. The percentage of the population covered by the strata with the respective isochronous curves in Figure 3a shows that given the spatial position of the police stations and the operating characteristics of the transport infrastructure network. In Strata 3 and 6, the majority of the population are covered by lower average travel times than the population in strata 4 and 1. Furthermore, when analysing the cumulative percentage of population by stratum (see Figure 3b) for an average travel time of 5 minutes from police stations (hypothetical assumed immediate reaction time), the layers of Strata 3 and 6 have population coverages of 48 and 47% respectively, followed by Stratum 2 (36%), Stratum 1 (29%), Stratum 4 (26%), and Stratum 5 (20%). Table 2 shows an analysis of the number of police stations available per stratum as well as the calculation of the number of available agents per thousand inhabitants, considering that each police station has a total of four officers available at any one time (data obtained from primary observations) who can support any emergency or situation. It was found that Stratum 4 had a higher rate of available agents per 1,000 inhabitants (0.55), followed by Stratum 1 (0.53), Stratum 6 (0.48), Stratum 2 (0.23), Stratum 3 (0.22), and Stratum 5 (0.00).

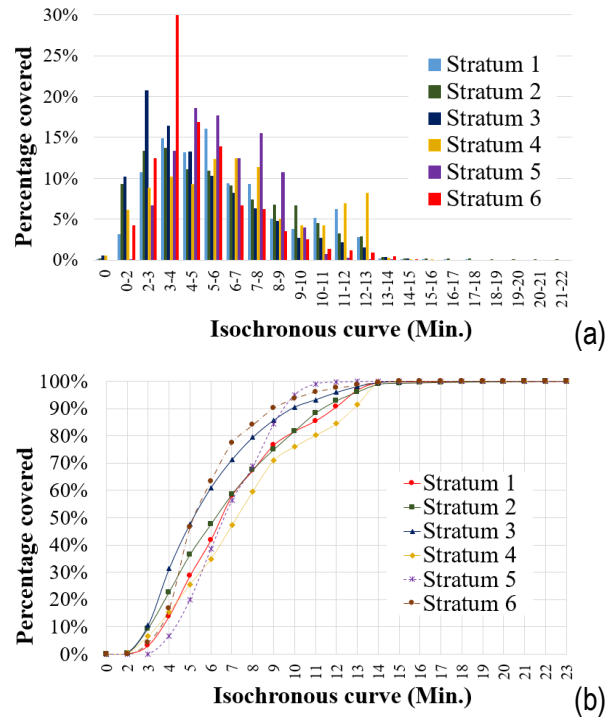


FIGURE 3. (A) POPULATION COVERAGE BY STRATUM AND ISOCHRONOUS CURVE; (B) CUMULATIVE POPULATION COVERAGE BY STRATUM AND ISOCHRONOUS CURVE
Source: Authors' calculations.

TABLE 2 - INDEX OF AVAILABLE POLICE OFFICERS AND STRATA.

Strata	Number of station police officers	Police officers available in an emergency	Inhabitants (× 100k)	Police officers available / 100k inhabitants.
1	4	16	30.1	0.53
2	6	24	103.2	0.23
3	11	44	200.1	0.22
4	7	28	51.1	0.55
5	0	0	14.1	0.00
6	2	8	16.6	0.48
Total	30	120	415.1	0.29

Source: Authors' calculations.

Although Stratum 4 has one of the lowest population coverage within the immediate reaction time, it also has the highest number of agents available per 1,000 inhabitants. Stratum 5, in both cases, has the lowest population coverage within the immediate reaction time, with a null index of available officers per 1,000 inhabitants given the absence of police stations in the surroundings. Stratum 3 has the highest population coverage with regard to immediate reaction time despite a very low rate of availability of officers per 1,000 inhabitants. In general, analysing data of the city, only 42% of the population can be reached within an average reaction time of five minutes, with an availability of 0.29 police officers per 1,000 inhabitants. Regarding coverage within the immediate reaction time, Strata 1, 2, 4, and 5 are below the city's average, while Strata 2, 3, and 5 are below the city average for number of available agents per 1,000 inhabitants.

Related with life-threatening events, the distribution of coverage by year seems to suggest that crimes occur closer proximity to police stations (See Figure 4a and 4b). However, due to lack of evidence it is not possible to infer that the location of stations has an impact on the occurrence of homicides and other crimes against life. Instead, it can be concluded that although the conditions of accessibility to police stations (i.e. location and conditions of the road network) have no observable impact on the occurrence of this type of crime, better coverage and accessibility may lead to a better response by security forces once the event has taken place. In short, better accessibility and coverage of police stations may influence the outcome of the investigations and procedures that follow the crime, which may have meaningful implications in relation to the delivery of justice. Analysing the percentage coverage of the total accumulated registered events of this kind reveals that within the immediate reaction time (5 minutes) it was 35% in 2011, 47% in 2012, 55% in 2013, and 42% in 2014. This means that, for example, in 2013 and 2012 almost 50% of murder cases occurred in places located within a maximum of 5 minutes' average travel time from police stations, and this percentage fell from 2011 to 2014.

Related with Robbery and assault events, it is observed that the distribution of the number of thefts and assaults compared with the average travel time offered by the infrastructure network has a reduced concentration for low average response times (See Figure 4c and 4d). Comparing both crimes described, the two curves show asymmetry, and the curve for robbery and assault has less kurtosis. Considering the cumulative percentage of events of this kind according to the immediate reaction time (5 min.), 37% were covered in 2011, 33% in 2012, 25% in 2013, and 38% in 2014. This means that compared to the events classified as life-threatening, robbery & assault events are registered in places that police officers must spend a greater average travel time to reach.

Related with Minor events, similar distributions are observed for 2011 and 2012 with time curves that are reduced for the years 2013 and 2014. This indicates that the minor events in that years were increasingly focused in areas near to police stations. For the immediate reaction time (5 min.) coverage was 27% in 2011, 13% in 2012, 53% in 2013, and 50% in 2014. Comparing the cumulative percentages of events in relation to the immediate reaction time for each type of event, in 2011 a greater proportion of robbery and assault events occurred. Murders comprised the highest share of events in 2012 as well as in 2013. Finally, in 2014, minor events – fights – comprised the highest share of reported events.

Figure 5 shows Manizales neighbourhoods according to the life-threatening rate for each year of study. Neighbourhoods in shades of green have homicide rates lower than the national value for that year, while neighbourhoods from yellow to red have higher rates than the national average. Likewise, the areas enclosed by a red line in Figure 10b are those that show values higher than the current national average in the four years of study. This index according to the stratum, has a negative trend, showing

that the value for 2014 is just over 24 homicides per 100,000 inhabitants, lower than in the previous year in Colombia (31 homicides per 100,000 inhabitants in 2013). The change in the index by stratum showed that the annual trend of all strata is to decrease, except for Stratum 2 that has the highest life-threatening rate, even above the national average. Moreover, comparing Stratum 1 with Stratum 6, the lower income segment has a murder rate up to four times higher than the higher income segment.

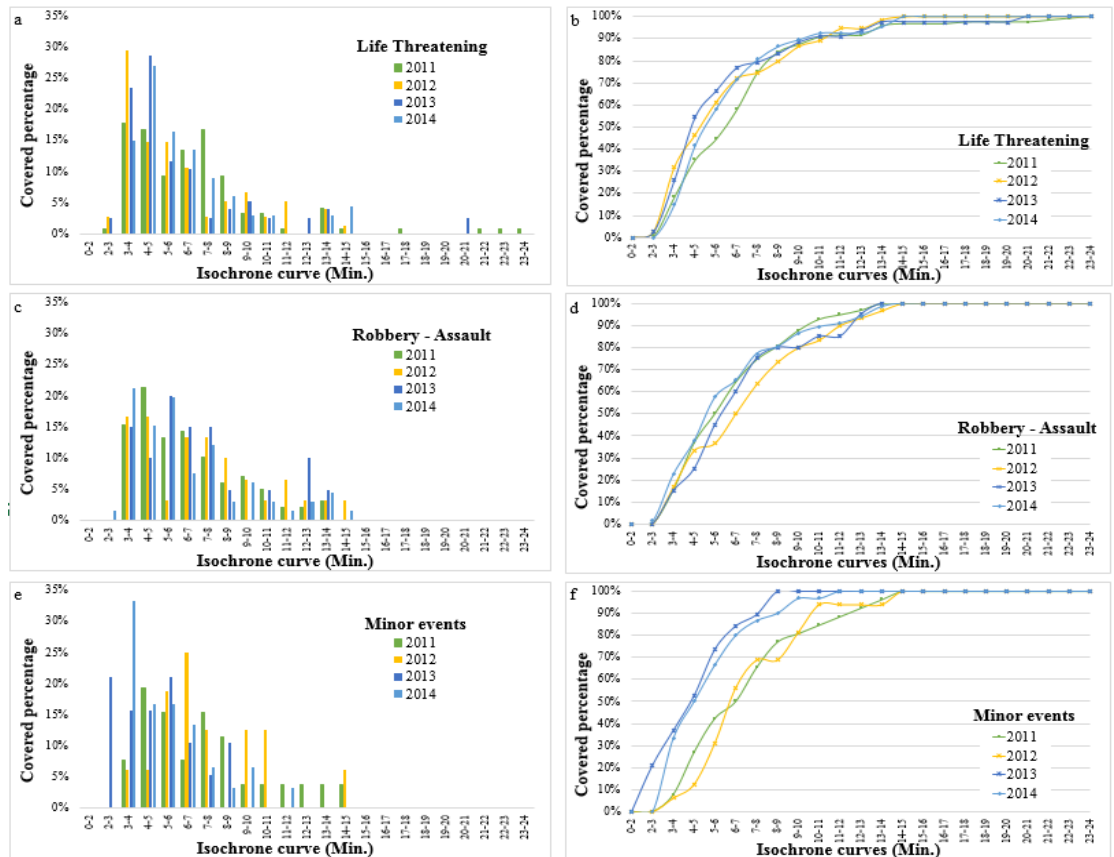


FIGURE. 4 - PERCENTAGE COVERAGE PER TYPE OF CRIME IN 2011–2014. VARIATION IN: A, B) LIFE-THREATENING EVENTS, C, D) ROBBERY AND ASSAULT EVENTS, AND E, F) MINOR EVENTS
Source: Authors' calculations.

The old city downtown, the market, and two suburban areas – one in the south and one in the north – registered higher rates than the national average. In the four years of study, the highest registered value was reported in one of neighbourhoods of Stratum 6 for the year 2012, with 671 murders per 100,000 inhabitants. Meanwhile, the highest registered rate of murders for a neighbourhood in Stratum 1 was 226 per 100,000 inhabitants and was registered in 2012.

The variation of robberies and assaults index observed between 2011 and 2014 also shows that in Strata 5 and 6, the index had fallen by 2014 compared with 2013. Nevertheless, the general trend after four years is increasingly clear, revealing, for example, that the value of the index in Stratum 6 was almost nine times higher compared to Stratum 1 (years 2012 and 2013). The highest value registered is observed in Stratum 6, located in a residential and commercial sector (see Figure 6c, highlighted in red

colour), with 8,986 thefts per 100,000 inhabitants registered in 2013; this contrasts with the higher value obtained in neighbourhoods of Stratum 1 for the same year: about 1,612 per 100,000 inhabitants.

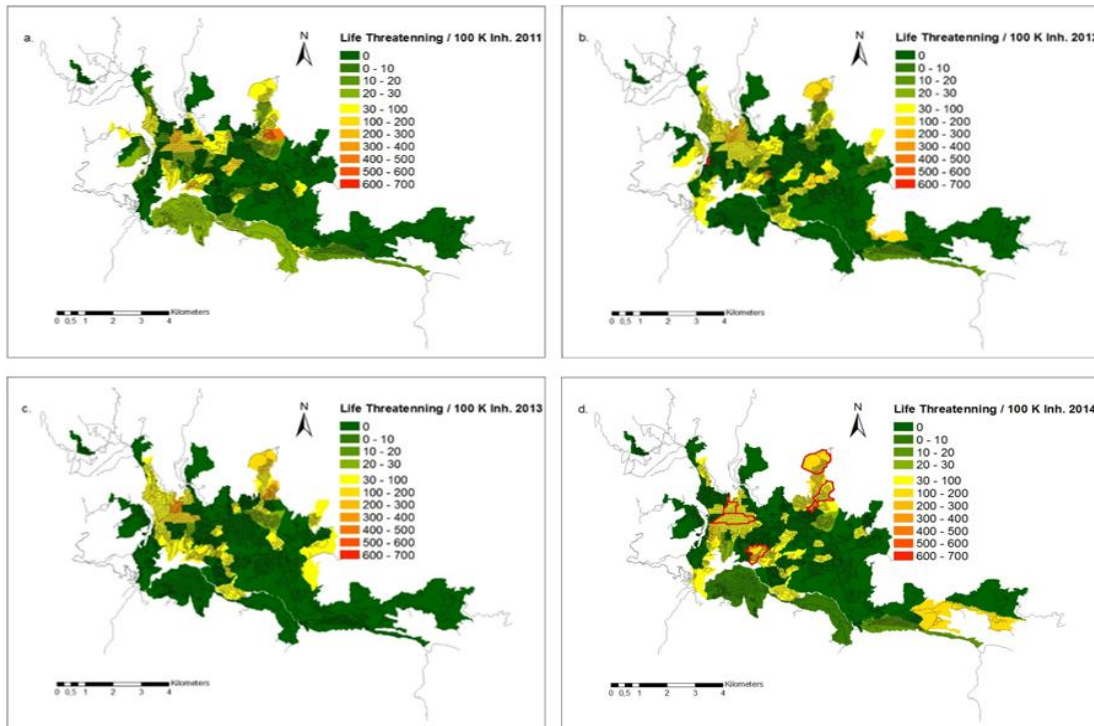


FIGURE 5 - INDEX OF LIFE-THREATENING EVENTS BY NEIGHBOURHOOD PER 1000 INHABITANTS. A) 2011, B) 2014
Source: Authors' calculations

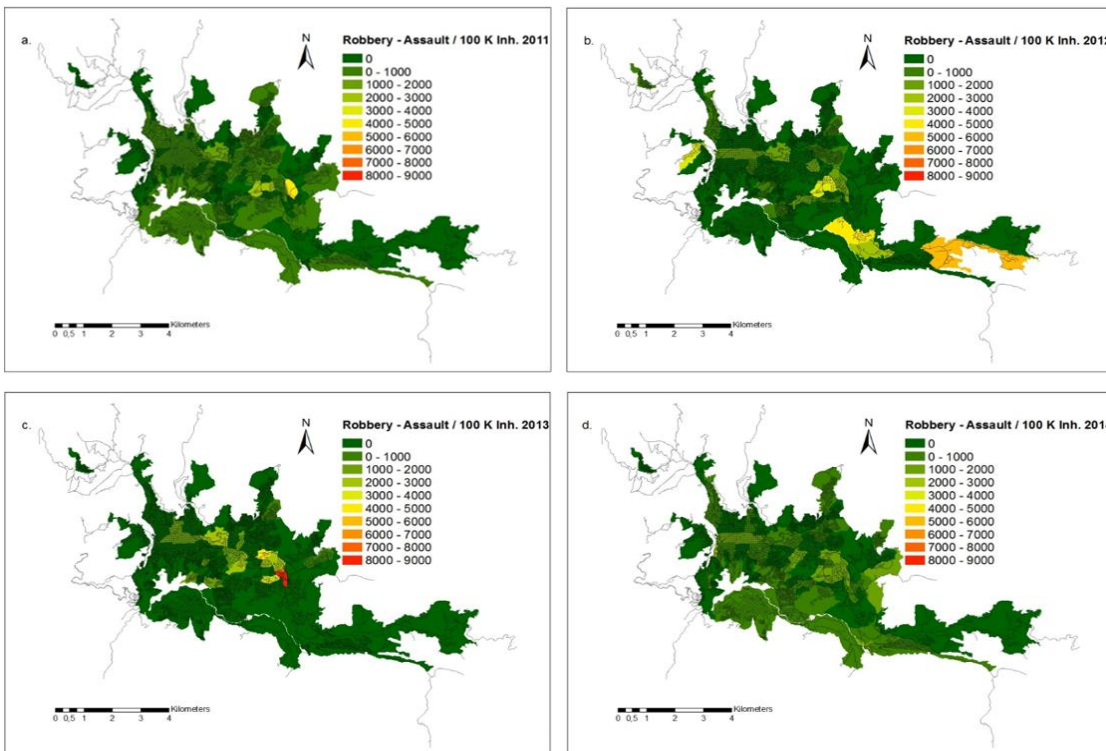


FIGURE 6 - ROBBERY AND ASSAULT INDEX PER 1000 INHABITANTS BY NEIGHBOURHOOD. A) 2011, B) 2012, C) 2013, D) 2014

Source: Authors' calculations.

On the other hand, the variation of minor events (fights) observed between 2011 and 2014 shows that Strata 5 and 3 have fairly stable homogeneous trend, and it is remarkable that not even a fight was registered during the four years in Stratum 5. Strata 1 and 4 show a downward trend of the index value; Strata 2 and 6 show an upward trend, which is stronger in Stratum 2, and it is precisely these two strata that showed the highest values of the index for 2014. In Figure 7, neighbourhoods are ranked by the index of minor events, with the highest registered value of this index (5,169 minor events per 100,000 inhabitants registered in 2012) in the neighbourhood of Palogrande (Stratum 6, Figure 7b, shaded in red). The football stadium, where fights between football fans are unfortunately quite common, is located in this neighbourhood. Likewise, the football stadium zone is highlighted in the same neighbourhood as the sector of university dormitories, which have a high student population and consequently disturbances of the peace are reported more often.

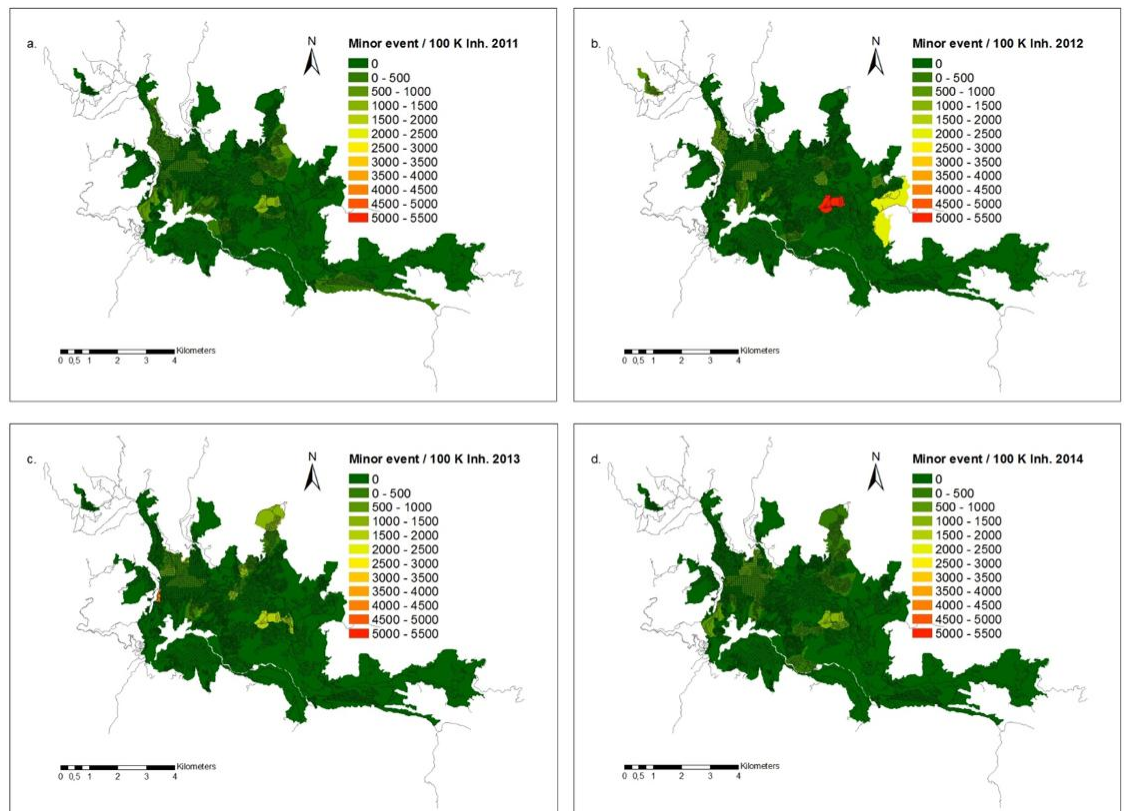


FIGURE. 7 - INDEX OF MINOR EVENTS PER 1000 INHABITANTS BY NEIGHBOURHOOD. A) 2011, B) 2012, C) 2013, D) 2014
Source: Authors' calculations.

4. CONCLUSIONS

It is noteworthy that for the three indices studied, the highest values of coverage and access are found in neighbourhoods of Stratum 6. Stratum 1 has a higher participation in the life-threatening rate. However, the identified neighbourhoods with life-threatening indices above the national average during

the four years mostly belong to Strata 2, 3 and 4, and only one belongs to Stratum 1. It was observed that under current operating conditions of the road infrastructure, only 42% of the population are able to receive police attention within the immediate time period (a maximum of 5 min.). Poorer coverage conditions are observed in Stratum 5, particularly considering that it is the only stratum without a permanent police station. Among others, Stratum 5 registered an increase in the rate of robbery and assault events, although a zero rate of minor events was registered during these four years.

Minor crime events seem to be a recurrent issue in Manizales and tend to be located in proximity to leisure areas and night-activity sectors. Results from the analysis reveal that although there is a degree of socio-spatial segregation in the city and spatial disparities in relation to access to police services, these may be more closely related to geographical and physical constraints than to socio-demographic differences. In this regard, public policies for security and crime reduction seek to respond to crime hotspots by providing police facilities in close proximity. However, insufficient consideration of the infrastructure that allows access from police facilities to the areas of concentration of crime means that despite the geographical proximity between police stations and some neighbourhoods, response times are very long in comparison with areas with better infrastructure coverage.

The link between socio-demographic stratification, crime, and access to security services can be explained partly by patterns of infrastructure investment and the criteria governing the distribution of police services. On the one hand, infrastructure tends to be concentrated in areas of higher attractiveness and activity, and as land in such areas tends to have higher value, medium-high and higher income groups are concentrated in these areas. This leads to the better accessibility observed in Strata 4 and 6. On the other hand, there seems to be a correlation between poverty and need for security, at least with regard to the distribution of police services. Stratum 1 has the highest availability of police officers per inhabitant, whereas in Stratum 5 there is almost no police presence.

The results suggest that the distribution of access to police services is governed by the combination of attractiveness (i.e. higher police presence in the city centre, areas of high day and night activity) and perceived potential for the occurrence of crime in relation to socioeconomic conditions (i.e. poor neighbourhoods may be more prone to concentration of crime, particularly in relation to robbery). In addition, higher income neighbourhoods tend to have a higher presence of private security, which can often deal with minor events and other crime occurrences. However, lack of a better distribution of police facilities leads to spatial and social inequalities in access to emergency police services that leaves both low-income and high-income groups with deficits of accessibility to security services. However, crime in Manizales is decreasing in aggregated terms but its spatial distribution may change over time, which requires an adequate distribution of police facilities. Positive evolution, a reduction in crime, may be related to police presence and efficiency as well as social and economic dynamics.

Maritz and Marshiri (2000) conclude that accessibility analysis may inform security policy in developing contexts, which supports the relevance of the connections sought by this research.

The methodology used in this research shows the relevance of linking the provision of security services with the operational characteristics of the transport network and it may better inform planning and logistic decision-making by police authorities. In this regard it is possible to replicate the method presented in this paper in other urban contexts in both Latin America and other regions of the Global South, and as a minimum, provides guidelines on the production of new information for future urban planning purposes.

FUTURE RESEARCH

The current methodology overlooks the time dimension of crime occurrences, which can help tailor the design of police services better, and more detailed information on the characteristics of the network and traffic volumes at different times of the day would also be beneficial for improving accessibility estimates. In addition, future research could include GPS data of actual police vehicles, reflecting the effects of priority circulation and driving patterns of police officers.

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REFERENCES

- Alcaldía de Manizales. (2011). *Plan de Movilidad de la ciudad de Manizales 2010–2040*. Manizales: Secretaría de Tránsito y Transporte - Universidad Nacional de Colombia.
- Barco, J.N., & Arana, J.E. (2014). Criminality behavior in Colombia, 2013. *Revista Criminalidad*, 56(2), 11–33.
- Batty, M. (2009). Accessibility: in search of a unified theory. *Environment and Planning B: Planning and Design*, 36, 191–194.
- Bello, C. (2012). New challenges for police corps in a globalized world. *Revista Criminalidad*, 54(2), 133–147.
- Ceccato, V., & Oberwittler, D. (2008). Comparing spatial patterns of robbery: Evidence from a Western and an Eastern European city. *Cities*, 25, 185–196.
- Chainey, S., & Ratcliffe, J. (2005). *GIS and Crime Mapping*. Chichester: John Wiley & Sons.
- Cheng, J., Bertolini, L., & Clercq, F. (2007). Measuring Sustainable Accessibility. *Transportation Research Board: Journal of the Transportation Research Board*, 2017, 16–25.
- DANE (2016). *Encuesta de convivencia y seguridad ciudadana*. Bogotá: Departamento Administrativo Nacional de Estadística.

- De Leo, D. (2017). Urban planning and criminal powers: Theoretical and practical implications. *Cities*, 60, 216-220.
- Eklblom, P. (1988). *Getting the Best Out of Crime Analysis*. London: Home Office Crime Prevention Unit.
- El Tiempo. (2008). *Ambulancias tardan en promedio 35 minutos y 12 segundos en atender emergencias en Bogotá*. Retrieved June 15, 2017, from <http://www.eltiempo.com/archivo/documento/CMS-4687511>.
- Escobar, D.A., & García, F.J. (2012). Territorial accessibility analysis as a key variable for diagnosis of urban mobility: a case study Manizales (Colombia). *Procedia – Social and Behavioral Sciences* 48(0), 1385–1394.
- Escobar, D.A., García, F.J., & Cadena, C.M. (2013). Political determinants and impact analysis of using a cable system as a complement to an urban transport system. *Proceedings of 1st International Conference on Innovation and Sustainability - ICOIS2013. Redesigning Relationships for Government, Business and Community*. Kuala Lumpur (Malaysia). Retrieved September 21, 2017, from <http://opac.pnm.gov.my/lib/item?id=chamo:788709&fromLocationLink=false&theme=PNM2>
- Faria, J.R., Ogura, L.M., & Sachsida, A. (2013). Crime in a planned city: The case of Brasília. *Cities*, 32, 80-87.
- Geurs, K.T., & Ritsema Van Eck, J.R. (2001). *Accessibility Measures: Review and Applications. Evaluation of Accessibility Impacts of Land-use Transport Scenarios, and Related Social and Economic Impacts* (RIVM Report 408505006). Utrecht: National Institute of Public Health and the Environment. Retrieved July 6, 2017, from <http://www.rivm.nl/dsresource?objectid=171931c0-1023-4d50-8a3e-99f8ea126b74&type=org&disposition=inline>
- Geurs, K.T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: review and research directions. *Journal of Transport Geography*, 12, 127–140.
- Hansen, W.G. (1959). How accessibility shapes land use. *Journal of the American Institute of Planners*, 25(2), 73–76.
- Jones, P., & Lucas, K. (2012). The social consequences of transport decision-making: clarifying concepts, synthesising knowledge and assessing implications. *Journal of Transport Geography*, 21, 1–3.
- Kotavaara, O., Antikainen, H., & Rusanen, J. (2011). Population change and accessibility by road and rail networks: GIS and statistical approach to Finland 1970–(2007). *Journal of Transport Geography*, 19(4), 926–935.
- Langford, M., Higgs, G., & Fry, R. (2013). Investigating variations in the provision of digital services in public libraries using network-based GIS models. *Library & Information Science Research*, 35(1), 24–32.
- Lotfi S., & Manoucheri Miandoab, A. (2015). Evaluating urban service accessibility in the medium sized cities of Iran. *Theoretical and Empirical Researches in Urban Management*, 10(4), 77-95.
- López, E., Gutierrez, J., & Gómez, G. (2008). Measuring regional cohesion effects of large-scale transport infrastructure investment: an accessibility approach. *European Planning Studies*, 16(2), 277–301.
- Luna, J.P., & Soifer, H.D., (2015). *Surveying state capacity*. Americas Barometer Insights 119. Retrieved July 6, 2017, from <https://www.vanderbilt.edu/lapop/insights/IO919en.pdf>
- Mackinnon, D., Pirie, G. and Gather, M. (2008). Transport and economic development. In: Knowles, R., Shaw, J., Docherty, I. (Eds.), *Transport Geographies: Mobilities, Flows and Spaces*, 10–28. Oxford: Blackwell.

- Manizales Como Vamos(2017). Informe de calidad de Vida Manizales. Available at: [http://manizalescomovamos.org/wp-content/uploads/\(2017\)/09/IMCV\(2017\)_completo-rr-1.pdf](http://manizalescomovamos.org/wp-content/uploads/(2017)/09/IMCV(2017)_completo-rr-1.pdf). (In Spanish)
- Maritz, J. and Mashiri, M. (2000). Application of the Accessmap/Flowmap model in the location of police stations in displaced rural areas. URISA.
- Morris, J., Dumble, P. and Wigan, M. (1979). Accessibility indicators in transport planning. *Transportation Research*13, 91–109.
- Munar, E., (2014). Analizando y modelando la violencia interpersonal en la ciudad de Bogotá durante el año (2011), con apoyo en información geográfica. *RevistaCriminalidad*56(3), 103–117. (In Spanish)
- Osborne, D.A., & Wernicke, S.C. (2003). *Introduction to Crime Analysis. Basic Resources for Criminal Justice Practice*. Binghamton: Haworth Press.
- Oviedo, D. and Dávila, J. (2016). Transport, urban development and the peripheral poor in Colombia— Placing splintering urbanism in the context of transport networks. *Journal of Transport Geography*51, 180–192.
- Phatarapon, V., Pongtep, P., Suparda, K. andNuchananporn, P. (2015).A comparison of spatial interpolation methods for predicting concentrations of particle pollution (PM10). *International Journal of Chemical, Environmental & Biological Sciences (IJCEBS)* 3(4).
- Park, S. (2012). Measuring public library accessibility: a case study using GIS. *Library & Information Science Research*34(1), 13–21.
- Ruiz, A. (2012). SIG, Crimen y Seguridad. Análisis, Predicción y Prevención del fenómeno criminal. Master's thesis. Máster en Tecnologías de la Información Geográfica. Madrid: Universidad Complutense de Madrid. (In Spanish)
- Soifer, H. (2012). Measuring state capacity in contemporary Latin America. *Revista de Ciencia Política*, 32(3), 585–598. [http://dx.doi.org/10.4067/S0718-090X\(2012\)000300004](http://dx.doi.org/10.4067/S0718-090X(2012)000300004).
- Straatemeier, T. (2008). How to plan for regional accessibility? *Transport Policy*1, 127–137.
- Todes, A. (2012). Urban growth and strategic spatial planning in Johannesburg, South Africa. *Cities*, 29(3), 158-165. [http://dx.doi.org/10.1016/j.cities. \(2011\).08.004](http://dx.doi.org/10.1016/j.cities. (2011).08.004)
- Van den Berg, P., Arentze, T. and Timmermans, H. ((2011)). Estimating social travel demand of senior citizens in the Netherlands. *Journal of Transport Geography*19(2), 323–331.
- Van Kesteren, J. V., Mayhew, P. and Nieuwbeerta, P. (2000). Criminal victimization in seventeen industrialized countries. WODC.
- Vega, A. (2011). A multi-modal approach to sustainable accessibility in Galway. *Regional Insights*2(2), 15–17.
- Wang, D., Brown, G. and Mateo-Babiano, I., (2013). Beyond proximity: an integrated model of accessibility for public parks. *Asian Journal of Social Sciences & Humanities*2(3), 486–498.
- Weismayer, C., Ponocny, I., Sedlacek, S., Stross, B. and Dressler, S. (2017). The relationship between natural urban surroundings and residents' Well-Being. *Theoretical and Empirical Researches in Urban Management* 12(1), 21-37.
- Zechmeister, E., Lupu, N. and Cohen, M. (2017). Democracy and Governance in the Americas: Key Findings from LAPOP's AmericasBarometer. *Americas Barometer Tropical Brief #30*.