ACTA UNIVERSITATIS LODZIENSIS
FOLIA IURIDICA 94, 2021

https://doi.org/10.18778/0208-6069.94.05

Member since 2018
JM13714

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LAND USE AND FACILITIES AND THE SPATIAL DISTRIBUTION OF URBAN PROPERTY CRIME

Abstract. The main research problem of this article is to check whether and how selected land use and facilities influence the spatial distribution of different kinds of urban thefts (and burglary) in Krakow. The analysis uses data on all crimes committed in Krakow in the years 2016–2018. Its results are generally consistent with the results of other similar studies in so far as they indicate a relationship between the increased criminal activity of perpetrators and the availability of potential victims or objects of attack. Both the higher density of crimes in general and theft in general occurred above all in facilities or in the immediate vicinity of facilities which accumulate large communities for various purposes (activity nodes) or in places which produce the high intensity of people flows (communication nodes). One land use and facilities coexist with an increased density of all types of thefts, while others coexist only with some of them. The results, however, seem inconsistent with the rational choice theory assumptions as high crime density rates were observed in the immediate vicinity of public and private monitoring cameras, as well as within 50 meters of police stations.

Keywords: crime mapping, spatial analysis of crime, spatial statistics, geographic information systems (GIS), property crime.

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FORMY I FUNKCJE ZAGOSPODAROWANIA PRZESTRZENI MIEJSKIEJ A PRZESTRZENNY ROZKŁAD PRZESTĘPSTW PRZECIWKO MIENIU

Streszczenie. Głównym problemem badawczym niniejszego artykułu jest sprawdzenie, czy i w jaki sposób wybrane formy i funkcje zagospodarowania przestrzeni miejskiej wpływają na rozmieszczenie kradzieży oraz kradzieży z włamaniem. W analizie wykorzystano dane dotyczące przestępstw zarejestrowanych w latach 2016–2018 w obrębie administracyjnych granic miasta Krakowa. Rezultaty przeprowadzonych badań są zasadniczo zgodne z wynikami podobnych analiz w zakresie, w jakim wskazują one na związek pomiędzy wzmożoną aktywnością przestępczą sprawców a dostępnością potencjalnych ofiar lub obiektów ataku. Większe zagęszczenie zarówno przestępstw ogółem, jak i kradzieży ogółem występowało przede wszystkim w tych obiektach lub bezpośredniej bliskości obiektów, które w różnych celach gromadzą duże zbiorowości (węzły aktywności) lub są miejscem licznych przepływów ludzkich (węzły komunikacji). Co jednak istotne, jedne tego typu funkcje zagospodarowania współwystępują ze zwiększonym zagęszczeniem wszystkich typów kradzieży, inne zaś jedynie niektórych z nich. Wyniki niniejszych badań nie pozostają natomiast w zgodzie z podstawowym założeniem teorii racjonalnego wyboru, wskazując na wysokie zagęszczenie przestępstw w bezpośrednim sąsiedztwie kamer monitoringu publicznego i prywatnego, jak również w odległości do 50 metrów od komisariatów policji.

Słowa kluczowe: mapy przestępczości, analiza przestrzenna przestępczości, statystyka przestrzenna, system informacji geograficznej (GIS), przestępczość przeciwko mieniu.

The influence of spatial factors on crime distribution has been explored for over two centuries.[1] Nonetheless, contemporary advanced crime mapping tools enable more complex and in-depth analyses than were available to the researchers of the cartographic school and the Chicago school of criminology. The GIS-based software not only allows to identify crime patterns and clusters, but also to understand the relationships between crime and the socio-demographic, architectural, urban, and functional characteristics of its location. Regrettably, utilization of these tools is still rather uncommon among Polish researchers and, in particular, our criminologists.[2] This primarily results from the virtual lack of cooperation of the police and other public security institutions with academia. In consequence, even the few organizations that have proper access to the crime mapping software are unable to fully utilize its potential, and their personnel lack qualifications to make use of the collected data. On the other hand, the researchers who possess the required knowledge and competence are usually denied access

[1] Andre-Michel Guerry and Adriano Balbi compiled the *Moral Statistics of France*, presenting the spatial distribution of crime and other anti-social behaviours (Friendly 2007).

[2] In Poland, they have been utilized mostly by social geographers, but relevant empirical studies are scarce (for the most current review of Polish empirical research on crime mapping see Mordwa 2016 and Lisowska-Kierepka 2019).

to databases.[3] This present study is thus one of a few Polish attempts to utilize the crime mapping tools in crime spatial analysis.

Crime mapping analyses assume that each location constitutes a different microenvironment characterised by the socio-economic status of its inhabitants and users, the efficiency of formal and informal social control, the level of social cohesion, the frequency of incivilities, the architectural and urban design, and spatial development. All these factors can influence the given location's vulnerability to crime and public order disturbance. The most influential theories of criminal aetiology, which consider spatial factors, fall into two groups. First are the creators and followers of the Chicago school focus upon the characteristics of a community that inhabits or permanently uses a given area (its socio-economic status, racial, ethnic and cultural heterogeneity, rental instability, geographic mobility, etc.). The so-called social ecologists explored the environment's influence on the integration of individuals with the (local) community, and thus on the distribution of anti-social behaviours. Some of the best-known theories of this kind include the social capital theory (Rosenfeld et al. 2001), the social cohesion theory (Hirschfield and Bowers 1997), and the collective efficacy theory (Morenoff et al. 2001). Conversely, the research presented in this paper is much closer to the views of the second group, so-called environmental criminologists, who traced the varied spatial distribution of crime to the environment's physical, architectural, urban, and functional features, as well as to its usage patterns.[4] Some of the most influential theories of this kind include the routine activities theory, the rational choice theory, and the crime pattern theory.

The routine activities theory assumes that crime is more likely to occur when three elements converge in space and time: a suitable target, a motivated offender, and a lack of a capable guardian (Cohen and Felson 1979). However, at the same time, this theory presents the relationship between crime distribution and the activities of space administrators (landlords, tenants, managers). The number of crime opportunities also stems from attention to the quality of formal and informal

[3] According to Feng et al. (2006), it is noteworthy that research into urban crime space in Western literature mainly focuses on developed countries, and many theoretical prototypes are also associated with developed countries. This applies in particular to Anglo-Saxon countries, where the flourishing of crime mapping is largely the result of close and long-standing cooperation between the police or other public security institutions and the academia (naturally, economic factors are also relevant). In recent years, more works from other parts of the world have been published (Sarangi and Youngs 2006) and China (Liu 2005), but still not many of them authored in developing countries of Central-Eastern Europe.

[4] While there is a tendency within the literature to consider environmental criminology and social ecology as competing conceptual frameworks (Braga and Clarke 2014), the perspectives can have joint utility for crime analysis. In particular, observations from crime-and-place research suggest that understanding community-level context may help explain some of the more nuanced research findings (Piza et al. 2017).

social control and adequate security, e.g. intercoms, surveillance cameras, lighting, the work of porters or security companies; and CPTED solutions.

The rational choice theory assumes that an individual offender, who decides to commit a crime in a specified place and time, intends to maximize the potential value to be gained by committing the act and to minimize their effort and the chances of getting caught (Cornish and Clarke 1986). The offender's decision is a result of informed consideration and weighing the costs, benefits, and risks of committing a particular crime, and thus the characteristics and purpose of the place of offence are very important for his or her decision (Hayward 2007). The rational choice theory – just as environmental criminology in general – is heavily oriented towards the situational aspects of crime. Its practical implications are situational crime prevention strategies. These include any activity of guardians, which increases the effort put into the crime by the perpetrator in order to achieve the assumed goal by: (a) increasing perceived risks, (b) reducing anticipated rewards, (c) removing excuses, and (d) increasing perceived effort (Clarke 1997).

Crime pattern theory can be considered a development of the above two theories: urban space planning sets patterns of everyday behaviour of individuals functioning in that space, and shapes the circumstances of their interactions, thus contributing to the supply of crime opportunities. The rational perpetrator selects the target of attack within the so-called action space, the boundaries of which are essentially determined by the daily routine of the perpetrator himself, as well as the potential victims of the crime (Brantingham and Brantingham 1981). In this space, three key types of areas carrying an increased risk of victimization have been identified: nodes, where many people gather simultaneously for a specific purpose, e.g. learning, work, leisure, entertainment (e.g. home, work, school, shopping centres, communication nodes); paths connecting individual nodes (e.g. to/from school, work, shopping, recreational activities, etc.) and edges – real or imagined boundaries separating spaces significantly differing in terms of their development or functions. It has been empirically confirmed that crime – in particular against property – is often concentrated along well-travelled routes (e.g. main streets, but also near public transport stops), in nodal places where large numbers of people gather for various purposes and in zones located near the edges, where crime opportunities occur more often (e.g. due to the fact that the presence of strangers, including potential offenders, in the "border area" between two different areas may easily go unnoticed) (Higgins and Swartz 2018).

Also, bearing in mind the appeal of a given area as a space for a potential criminal attack, the following were distinguished: crime generators – places that favour crime through the attraction of large numbers of people (e.g. stations, tourist attractions, boardwalks, and business/shopping streets, facilities and areas dedicated to the organization of mass events, popular recreational areas); crime attractors – places where criminal opportunities are well known to offenders (e.g. bars and nightclubs, large-scale shopping facilities, unguarded car parks); in particular, they attract multiple perpetrators (repeat offenders); crime detractors – areas which, for various reasons, discourage the perpetrator from committing prohibited acts, e.g. due to the high quality or number of safeguards or the lack of potential subjects or objects of crime (e.g. monitored areas, fenced estates or areas constantly patrolled by the police) (Sypion-Dutkowska 2014; Higgins and Swartz 2018).

The results of research to date suggest that the factors which increase the amount of property crime, are above all:

– public transportation nodes, e.g. public communication stops, metro stations, bus or train stations (Feng, Dong and Song 2016; Kennedy and Caplan 2012; Loukaitou-Sideris, Liggett and Iseki 2002; McCord and Ratcliffe 2009; Poister 1996);

– commercial centres, e.g. supermarkets, shopping centres, shopping streets, markets (Brantingham and Brantingham 1995; Brantingham and Brantingham 1981, Kinney et al. 2008, LaGrange 1999; Lu 2006; Skubak Tillyer and Walter 2019);

– residential parcels (Kennedy and Caplan 2012; Lu 2006; Roncek, Bell and Francik 1981);

– unguarded car parks (Lu 2006);

– eating establishments, e.g. restaurants, fast food bars (Brantingham and Brantingham 1995; Brantingham and Brantingham 1981);

– places of alcohol distribution, e.g. pubs, bars, and liquor stores (Toomey et al. 2012; Wechsler et al. 2002);

– drug dealing locations (Ratcliffe and Taniguchi 2008; Kennedy and Caplan 2012);

– buildings and locations used as sport facilities, e.g. sport clubs, stadiums (Brantingham and Brantingham 1995; Kurland et al. 2014; Ristea et al. 2018);

– youth hangouts/youth clubs (Brantingham and Brantingham 1995);

– education institutions e.g. schools, universities (Kinney et al. 2008; LaGrange 1999);

– pawnshops (Kennedy and Caplan 2012).

Sypion-Dutkowska and Leitner (2017) have recently carried out a thorough review of previous most important research on the influence of numerous, different land use types on crime distribution. It led them to the conclusion that the results of previous studies are ambiguous and provide only fragmentary knowledge, and that further research in this field is needed. In addition, the authors themselves conducted one of the few surveys in Poland, taking into account the numerous land use and facilities in relation to numerous categories of crime. Referring to the assumptions of crime pattern theory, they pointed out the main crime attractors (alcohol outlets, clubs and discos, cultural facilities, municipal housing, and commercial buildings) and detractors (grandstands, cemeteries, green areas, allotment gardens, and depots and transport base). The also noted that the influence of land use types analyzed is usually limited to their immediate surroundings (i.e. within a distance of 50 m) especially when it comes to commercial crimes and theft of property.

1. METHODOLOGY

The main research problem of this article is to check whether and how selected land use and facilities influence the spatial distribution of different kinds of urban thefts (and burglary) in Kraków. The analysis uses data on crimes committed in Kraków gathered by the Municipal Police Headquarters in Kraków. The data comes from the Electronic duty logbook kept by police, which contains information about all types of crimes.

Data

According to the data gathered by Municipal Police Headquarters in Kraków, in the years 2016–2018 49,198 crimes were registered, including 47,769 crimes that were committed in that period.[5] In this paper, an analysis of the latter, namely crimes that were committed from 2016 to 2018, is presented. Because the main purpose of the analysis was to determine the relationship between different types of urban space development and property crimes, certain types of property crimes were distinguished. Namely, all types of thefts and burglaries were subjected to analysis. Theft was defined as larceny – a crime involving the unlawful taking of the personal property[6] – and burglary was identified as an unlawful entry into a building or other location for the purposes of committing theft.[7] Additionally, separate analyses of pickpocketing, bicycle thefts, vehicle thefts, vehicle burglaries, home or apartment burglaries and commercial building burglaries were carried out.

Pickpocketing is distinguished based on *modus operandi* – thefts of pickpocketing are thefts that involve pulling something out of a pocket, backpack or purse. Bicycle thefts are defined simply as the unlawful taking of other people's bicycles. Vehicle thefts are thefts that involve the unlawful taking of someone else's vehicle (mainly car) or property from that vehicle; and vehicle burglaries are car thefts that involve breaking in. Finally, home or apartment burglaries and commercial building burglaries are examples of burglaries committed in particular locations – respectively in residential and commercial buildings.

[5] The difference between the number of registered crimes and the number of committed crimes is due to the fact that some crimes are reported or discovered (and thus registered) with a delay.

[6] Art. 278 of the Polish Criminal Code.

[7] Art. 279 of the Polish Criminal Code.

Crime data took the form of geographical coordinates and addresses describing specific points on the map. The table below contains information about the number of all property crimes included in the analysis.

Table 1. Number of incidents registered in 2016–2018[8]

Type of property crime	Number
Theft (all types)	14,423
Pickpocketing	4,282
Bicycle theft	1,333
Vehicle theft	1,091
Burglary (all types)	3,889
Vehicle burglary	1,167
Home or apartment burglary	813
Commercial building burglary	319
All crimes	47,769

Furthermore, in the course of the analysis, spatial data on selected elements of urban space were used. To be more precise, information about various building development functions was listed, as well as data on the following points in space: police stations, public CCTV cameras, private CCTV cameras, ATMs, public transport line routes, green areas, cemeteries, gas stations, churches and chapels. Except for the data on the location of churches and chapels – which were obtained through OpenStreetMap[9] – all spatial data on elements of urban space, including data on building development, were obtained from the Department of Security and Crisis Management in Kraków.

Data regarding police stations, public CCTV cameras, private CCTV cameras, ATMs and petrol stations were listed in the form of geographical coordinates and addresses describing specific points on the map. Data on development functions of buildings, green areas, cemeteries, churches and chapels were presented in the form of polygons representing particular locations on the map. And data regarding routes of public transport lines were presented in the form of polylines (polygonal chain), i.e. connected series of line segments.

Basic information for all urban space elements included in the analysis are summarised in Table 2. Data regarding the building development function are presented in a separate table (see Table 3).

[8] All tables and figures are the authors' own elaboration.

[9] Page source: https://overpass-turbo.eu/

Table 2. Elements of urban space taken into account in analysis

Element of urban space	Type of vector data	Number
Police stations	points	9
Public CCTV cameras[10]	points	184
Private CCTV cameras	points	2,384
Green areas	polygons	1,292
Cemeteries	polygons	16
ATMs	points	454
Public transport line routes	polylines	148
Gas stations	points	107
Churches and chapels	polygons	198

There are nine building development functions[11] included in the analysis: residential buildings; production, service and utility buildings; commercial buildings; transport and communications buildings; industrial buildings; buildings used as education, science, culture and sport facilities; offices; tanks, silos and warehouses; hospitals, medical care facilities. "Residential buildings" constitute the most numerous category (40% of all buildings), containing buildings where at least half of the floor space is used for residential purposes. The second most numerous category of building development function contains "production, service and utility buildings," which in Kraków primarily includes allotment gardens and utility buildings such as storage houses e.g. garages or sheds, located in residential areas.

A similar number of buildings was classified as either "commercial" or "transport and communications buildings." The first group of buildings comprises markets, flea markets, shopping centre, and independent stores and boutiques. While the category of "transport and communications buildings" consists of e.g. public transport stations (railway stations, bus stations), tram and bus depots, garage buildings and parking buildings, "industrial buildings" are mostly factories, production facilities and workshops. The category of "buildings used as education, science, culture and sport facilities" is very broad and contains facilities such as universities, schools, kindergartens, museums, and cinemas, theatres, botanic gardens, stadiums and sports halls. The "office" label is reserved for banks, post offices, courts, city offices, public administration buildings and private company offices. "Tanks, silos and warehouses" are simply tanks, silos, warehouse buildings and other storage spaces. Last but not least, "hospitals, medical care facilities" are

[10] Data for the end of 2018.

[11] All of the above functions are described in detail in the Classification of Fixed Assets established by the Regulation of the Council of Ministers in 2016. http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20160001864/O/D20161864.pdf

buildings of hospitals and medical care facilities in which medical and nursing services are provided.

Table 3. Building development functions taken into account in analysis

Building development function	Number of polygons	Area (m^2)
Residential buildings	51,865	23,718,335.774
Production, service and utility buildings	22,318	12,648,356.658
Commercial buildings	2,822	2,187,422.706
Transport and communications buildings	2,739	2,997,290.923
Industrial buildings	1,440	401,129.400
Buildings used as education, science, culture and sport facilities	978	3,842,020.902
Offices	902	2,060,319.462
Tanks, silos and warehouses	775	1,202,655.553
Hospitals, medical care facilities	247	1,201,219.875
Other non-residential buildings	39,186	524,377.012
Total	**123,272**	

Analysis

In order to find the causes for differences in the spatial distribution of particular property crimes, two types of analyses were conducted. The first one consisted of density calculation of the particular types of property crimes within seven areas of the potential impact of all included factors. These areas were determined by creating, for each element (point, polyline or polygon), seven buffers at the following distances: 0–20 m, 20–50 m, 50–100 m, 100–200 m, 200–300 m, 300–400 m and 400–500 m.[12] After that, the spatial combination[13] of data on property crimes and data on buffers for all factors was made. As a result, information about the number of the particular types of crimes that were committed during the examined period within the buffers was obtained. These numbers were divided by buffers areas and multiplied by 1,000. The density coefficients calculated in this way were presented in the form of graphs (see Fig. 1–9).

The second type of analysis was an analysis of density of particular property crimes in different types of buildings. For the purposes of such analysis, spatial data on building development functions were used. Similarly to the first analysis, a spatial combination of data on selected types of crime and data on buildings

[12] Calculations were performed with the ArcGIS Pro software (the *Multiple Ring Buffer* tool).

[13] The *Spatial Join* tool was used – a GIS operation that affixes data from one feature layer's attribute table to another from a spatial perspective.

was made, but this time the areas of potential impact (in the form of buffers) were not taken into account. This operation resulted in obtaining information about the number of thefts, burglaries and all crimes committed in particular types of buildings (see Table 1). In order to get the coefficient in the form of the number of crimes per 1 ha, obtained numbers were divided by the area of the particular types of buildings (see Table 3) and multiplied by 1,000. Moreover, to enable comparison, coefficients for different types of crimes have been standardized and the results of this standardization were presented in the form of a graph (see Fig. 10–18).

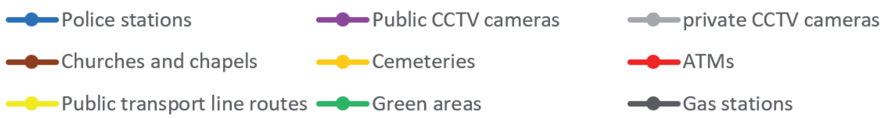
It is important to notice that two parts of the analysis described below use two different types of data: (1) points (cameras, police stations, gas stations, ATMs), lines (transport routes) and polygons (cemeteries, green areas, churches and chapels), in the case of selected, characteristic points in space, and (2) polygons, in the case of building development functions. The distance referred to in the analyses is the distance from a certain point or from borders of the polygon, which significantly affects the nature of the first of the value range taken into account in the study. At a distance of 20 m from a point that represents a large-area building, events in this buffer area can be either inside this object or in its immediate vicinity. A distance of 20 m from the polygon's borders means that these events take place beyond it. Therefore, in the text, we use expressions referring to the relationship of proximity, and not to „being contained within."

2. RESULTS

The analyses carried out allow for an interesting insight into the relationship between different types of property crimes and various functions of property development, as well as points in space such as police stations, public CCTV, private CCTV, ATMs, public transport line routes, green areas, cemeteries, gas stations and churches/chapels (hereinafter referred to as "factors"). The results of the analyses will be presented in this subsection as follows: first, the identified relationship between property crimes and the above-mentioned characteristic points in space will be discussed, initially as a whole, and then broken down into individual types of crime. Then, a similar formula will present the relation of property crimes with building development functions. The description of the results will be accompanied by their graphical representation.

Theft Density within the Areas of Influence of Selected Factors

The following charts graphically present the results of the analyses carried out. They should be interpreted with the following key:



A more detailed description of the results is provided further in this section.

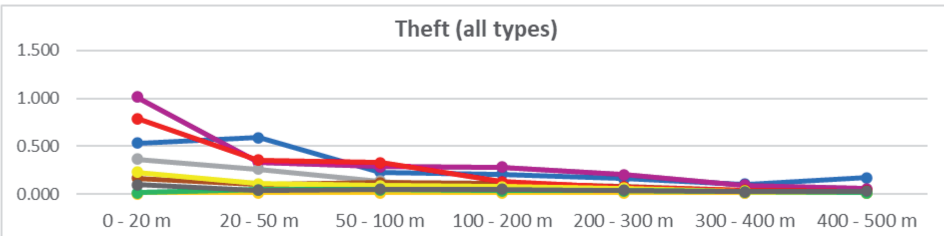


Figure 1. Theft density within the areas of influence of selected factors

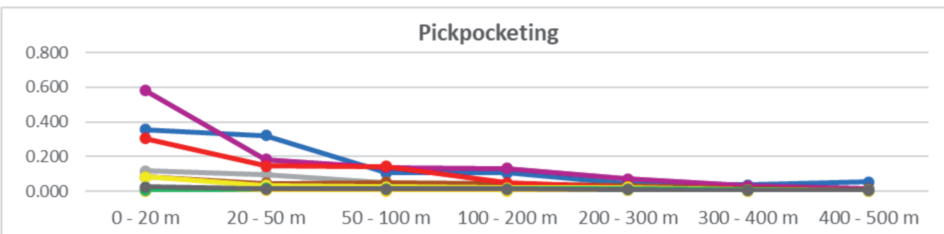


Figure 2. Pickpocketing density within the areas of influence of selected factors

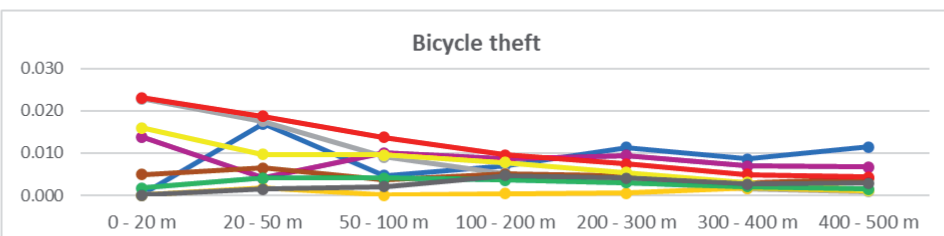


Figure 3. Bicycle theft density within the areas of influence of selected factors

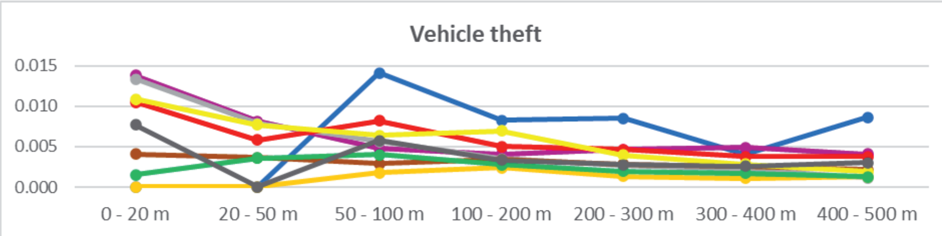


Figure 4. Vehicle theft density within the areas of influence of selected factors

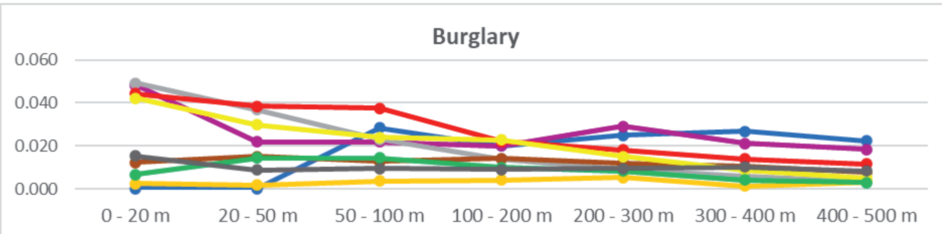


Figure 5. Burglary density within the areas of influence of selected factors

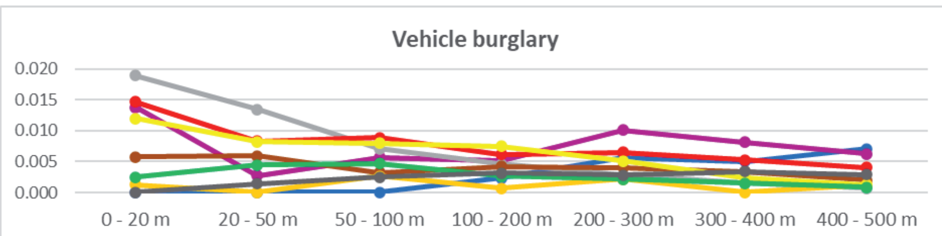


Figure 6. Vehicle burglary density within the areas of influence of selected factors.

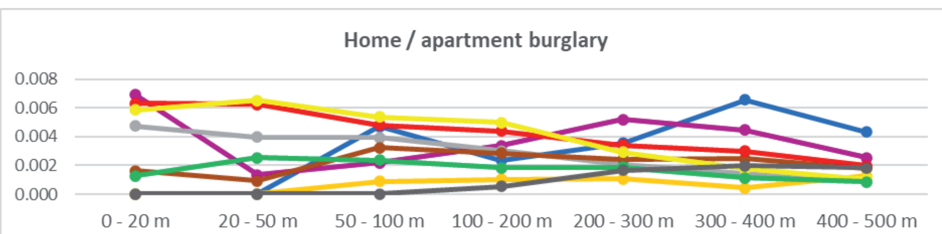


Figure 7. Home/apartment burglary density within the areas of influence of selected factors

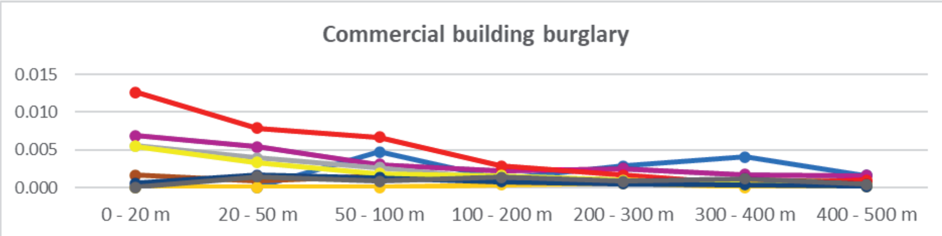


Figure 8. Commercial building burglary density within the areas of influence of selected factors

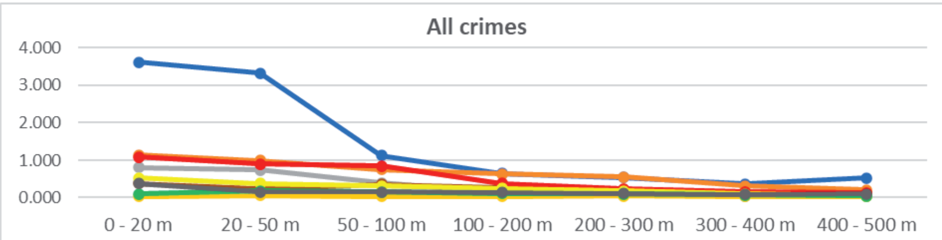


Figure 9. Crime density within the areas of influence of selected factors

An analysis of the density of theft (all types combined) in relation to their distance from selected, characteristic points in space shows that a greater density of these types of incidents in Kraków can be observed primarily within 20 m from public CCTV cameras and ATMs, and 50 m from police stations. Other factors whose proximity coexists with greater density of thefts, are the locations of private CCTV cameras and, to a lesser extent, the direct proximity of public transport line routes.

In the case of pickpocketing, the highest density of these types of events is related to the direct proximity of city monitoring cameras. The proximity of ATMs, police stations and public transport line routes is associated with pickpocketing to a smaller, but still significant extent.

Bicycle theft is a very specific type of theft, which is more difficult to analyze due to its relatively small number. The results, in this case, are ambiguous. The highest density of these types of incidents occurred in Kraków in the area up to 50 m from the nearest ATM and a private CCTV camera, in direct proximity (up to 20 m) of public transport line routes and public CCTV cameras, and 20–50 m from the police stations. A very small reverse relation may be observed with bicycle theft and distance from gas stations – there are slightly more thefts of this kind further from those facilities than in their direct proximity.

The density of vehicle theft in Kraków is the greatest in the direct proximity of private and public CCTV cameras, public transport line routes, ATMs and gas stations. Especially noteworthy is the very low density of these types of incidents at a distance of up to 50 m from the police station and relatively large at greater distances from these facilities.

Burglary, just like vehicle theft, is characterized by a very low density of incidents within 50 m of the nearest police station. Factors, which co-occur with increased burglary density, are the proximity of private and public CCTV cameras at a distance of 50 m, ATMs (up to 100 meters distance) and communication line routes (mostly up to 50 m, but also – to a lesser extent – up to 200 m).

The density of vehicle burglary is the greatest within 50 m from private CCTV cameras and within proximity (up to 20 m) of public CCTV cameras, ATMs and communication line routes (to a lesser extent also within 20–200 m from these routes). The inverse relations between the density of these types of incidents and the distance from not only police stations, but also gas stations is noteworthy and distinguishes this type of theft from vehicle theft analysed earlier.

There is a positive relation between the density of burglary of an apartment or a house and the distance from public transport line routes. The direct proximity of public CCTV cameras also coincides with such incidents. As in the case with vehicle theft and burglary, the low density of these types of events should be noted at a distance of up to 50 m from police stations – and, in case of this type of theft, also gas stations and cemeteries – and relatively high at greater distances from these facilities (the highest at a distance of 300–400 m).

While analysing data on burglary into commercial facilities, it can be observed that by far the highest density of these types of incidents is associated with the proximity of ATMs, and, to a lesser extent, also public and private CCTV cameras and public transport line routes. A very low density of those incidents takes place in the immediate proximity of police stations.

In the case of analysis performed for all crimes committed in Kraków in 2018, the only clear relationship is the much higher density of these incidents within proximity (up to 50 m) to police stations. It is worth noting that, previously, a reverse relation with a direct proximity of a police station was often mentioned. Therefore, it differs significantly from most types of theft and burglary.

To sum up, due to the analysis of the density of different types of theft in relation to their distance from selected characteristic points in space, some regularities can be observed. The facilities which coexist with a greater density of theft of a particular type, are presented in the below table. In general, two types of both positive and reverse relations can be observed. Firstly, there exists a relation similar to linear function or exponential function, without any major derogation. This relation is marked in the table as (A). Secondly, there is a relation that differs from those marked as (A) at one or two points. This relation is marked in a table as (B). A category that is inconsistent with its generally linear or exponential character is listed in a bracket with annotation showing the direction of this derogation. For example, the “0–20L” the annotation signifies that this relation differs from linear or exponential relation in category 0–20 m, in which the density of incidents is lower than it would be in an ideal linear or exponential relation. Similarly, the “20–50H” annotation signifies that this relation differs from linear or exponential relation in category 20–50 m, in which the density of incidents is actually higher than it would be in an ideal linear or exponential relation.

Table 4. Facilities which coexist with a greater density of incidents of a particular type

Incidents	Positive relation	Reverse relation
Theft	public CCTV cameras (A) ATMs (A) police stations (B: 0–20L) private CCTV cameras (A) public transport line routes (A)	
Pickpocketing	public CCTV cameras (A) ATMs (A) police stations (A) public transport line routes (A)	
Bicycle theft	ATMs (A) private CCTV cameras (A) public transport line routes (A) public CCTV cameras (B: 20–50L) police stations (B: 0–20L, 20–50H)	gas stations (B: 300–400L, 400–500L)
Vehicle theft	private CCTV cameras (A) public CCTV cameras (A) public transport line routes (A) ATMs (B: 50–100H) gas stations (B: 20–50L)	
Burglary	public CCTV cameras (B: 200–300H) private CCTV cameras (A) public transport line routes (A) ATMs (A)	police stations (reverse relation with a direct proximity)
Vehicle burglary	private CCTV cameras (A) public CCTV cameras (0–20 high density, 20–300 reverse relation, 300–500 linear relation) ATMs (A) public transport line routes (A)	police stations (A) gas stations (A)
Home/ apartment burglary	public CCTV cameras (0–20 high density, 20–300 reverse relation, 300–500 linear relation) private CCTV cameras (A) public transport line routes (A)	police stations (B: 50–100H, 400–500L) gas stations (A) cemeteries (B: 300–400L)

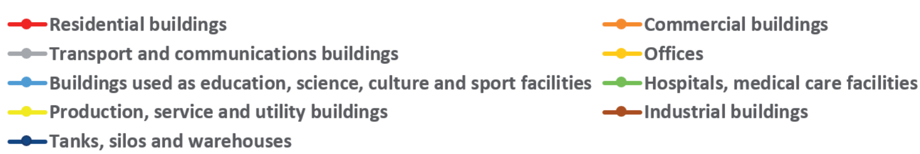
Table 4. (continued)

Incidents	Positive relation	Reverse relation
Commercial building burglary	ATMs (A) with a direct public CCTV cameras (A) private CCTV cameras (A) public transport line routes (A)	police stations (reverse relation proximity)
All crimes	police stations (A)	

After presenting the factors in the above table, it becomes clear that most of them coexist with an increased density of almost every type of theft – however, the degree of this relationship varies. CCTV cameras are an example of a point in space around which there is a greater density of theft. However, there are types of theft that are registered mainly around public CCTV cameras – like pickpocketing or burglary of an apartment or a house, as well as types recorded more often around private CCTV cameras – like bicycle thefts or vehicle thefts. Similarly, the importance of the proximity of an ATM, another characteristic point, co-occurs with a greater density of almost every type of theft, except for burglary of an apartment or a house – especially theft within a commercial object, bicycle theft and pickpocketing.

Theft Density within the Areas of Various Functions of Property Development

The following charts graphically present the results of the analyses carried out. They should be interpreted with the following key:



A more detailed description of the results is provided further in this section.

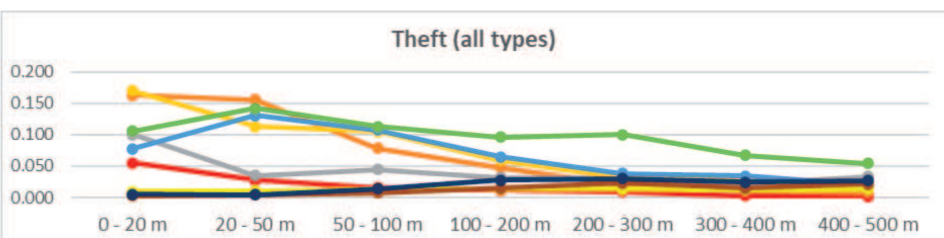


Figure 10. Theft density within the areas of various functions of property development

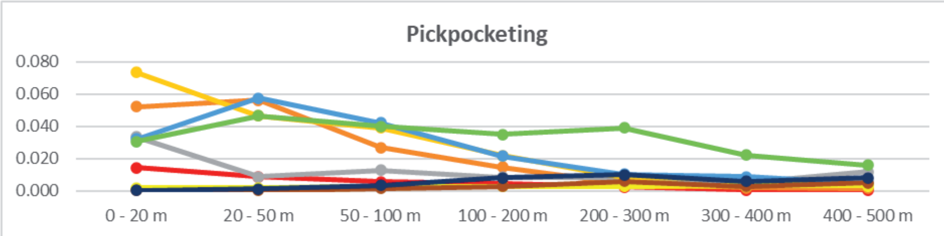


Figure 11. Pickpocketing density within the areas of various functions of property development

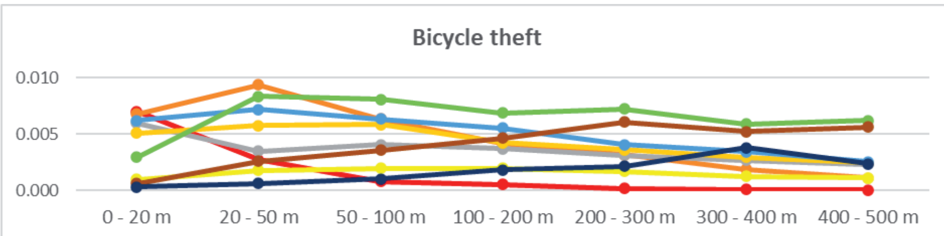


Figure 12. Bicycle theft density within the areas of various functions of property development

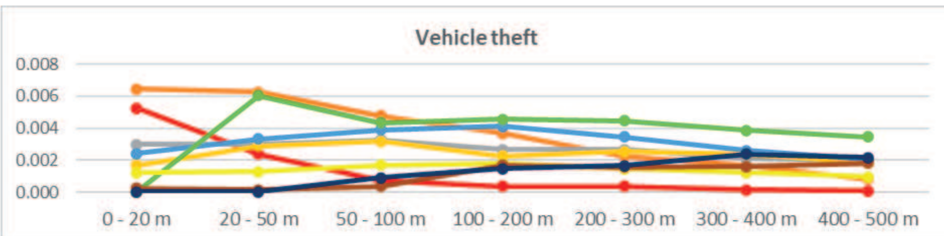


Figure 13. Vehicle theft density within the areas of various functions of property development

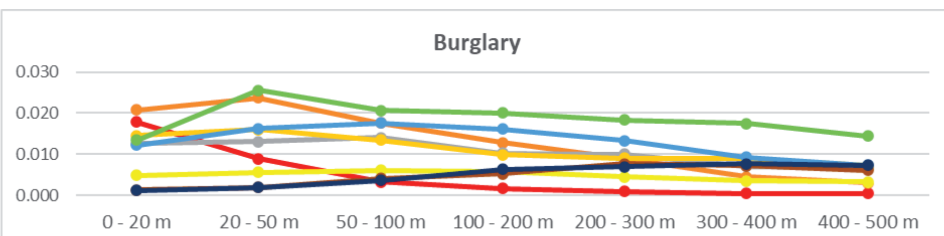


Figure 14. Burglary density within the areas of various functions of property development

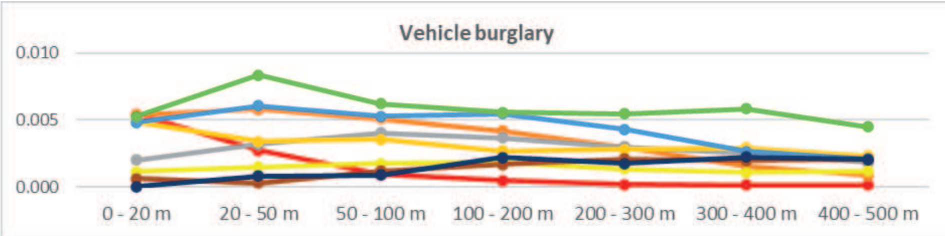


Figure 15. Vehicle burglary density within the areas of various functions of property development

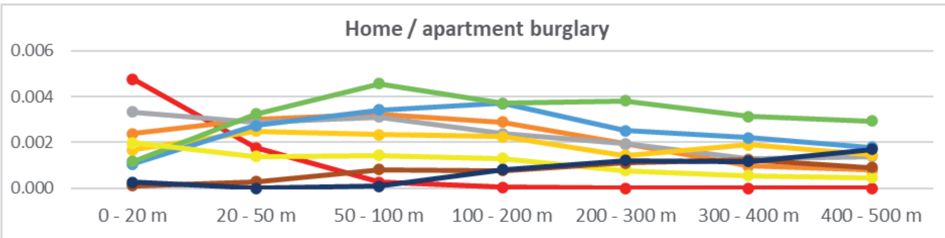


Figure 16. Home/apartment burglary density within the areas of various functions of property development

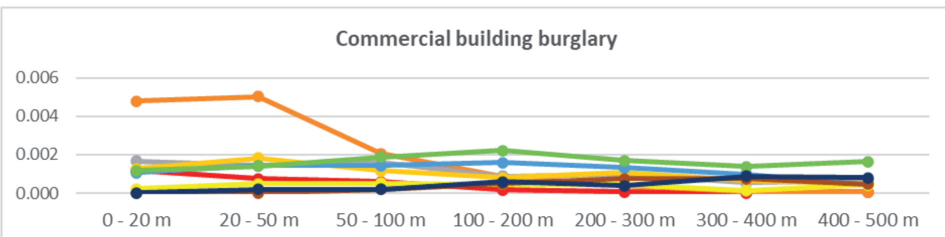


Figure 17. Commercial building burglary density within the areas of various functions of property development

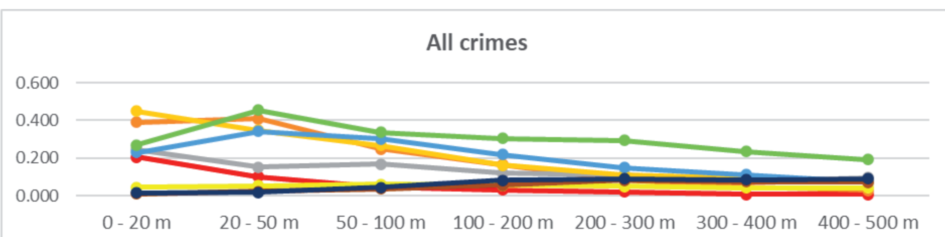


Figure 18. Crime density within the areas of various functions of property development

Analysing total theft density, without dividing it into various types (later referred as overall theft analysis), one can primarily notice a linear relationship between the number of these incidents and the distance from commercial buildings and offices, as well as a close to linear relationship between the number of these incidents and the distance from hospitals, medical care facilities and buildings used as education, science, culture and sport facilities (where the main difference is that the density in the immediate proximity, up to 20 m, is less than at a distance of 20–50 m). Theft density is also greater within proximity to transport and communications buildings. It is also noteworthy that the density of thefts is only slightly higher in the immediate proximity of residential buildings than in a further distance from them. There is a very small reverse relation with the proximity to industrial buildings, tanks, silos and warehouses – there are slightly more thefts of this kind further from those facilities than in their direct proximity.

Pickpocketing is concentrated within proximity to offices. A close linear relationship can also be observed between the number of pickpocketing and the distance from shopping facilities and education, science, culture and sports buildings – as was the case for the overall theft analysis (without breaking down into sub-types). The analysis reveals that, as was the case with overall theft analysis, the density of pickpocketing is also higher in the immediate proximity of transport and communications buildings and its density is only slightly affected by the proximity of residential buildings. Again, as in the case with overall theft density, a very small reverse relation with the proximity to industrial buildings, tanks, silos and warehouses can be observed.

A greater density of bicycle theft can be observed in the immediate proximity not only of commercial buildings, but also residential buildings. Also, a lesser (although still observable) relationship of this density with a distance from offices can be observed, distinguishing it from other types of theft. It is also worth noting the inverse relation between the density of bicycle thefts and the distance from industrial buildings, as well as tanks, silos and warehouses – the further from those facilities, the higher the density of these incidents.

Vehicle theft, similarly to bicycle theft, can be characterized by greater density in the immediate proximity of residential buildings, as well as commercial buildings. A high density of these types of incidents can be observed within 20–50 m distance from hospitals and medical care facilities. It is also noteworthy that their relation to the distance from offices came out to be irrelevant. Moreover, the inverse relation between the density of vehicle and vehicle theft and the distance from industrial buildings, tanks, silos and warehouses can be observed, as is the case with bicycle theft.

Analyzing the density of burglary we can observe similar relationships as observed with bicycle theft or vehicle theft. We may talk about its greater density in the immediate vicinity of residential buildings and commercial buildings (although in the case of the latter, burglary occurs even more often within 20–50 m distance than at up to 20 m from them), as well as high density of such incidents at a distance of 20–50 m from hospitals and health care facilities. There exists a small, but visible relation with distance from offices, as well as an inverse relation between burglary density and distance from industrial buildings, as well as tanks, silos and warehouses.

Vehicle burglary density also shares similar characteristics. It is higher in the immediate proximity of residential buildings and commercial buildings (with a similar restriction as in the case of burglary) and high near hospitals and medical care facilities, especially at a distance of 20–50 m from them. It remains high at a distance of up to 200 m from buildings used as education, science, culture and sport facilities, to fall significantly further away from them. There is, same as with previous types of theft and burglary, small inversed relation with distance from industrial buildings as well as tanks, silos and warehouses.

In the case of burglary into an apartment or house, a definitely greater density of these types of incidents occurs, of course, in the immediate proximity of residential buildings. The relatively high density of such burglaries near hospitals and medical care facilities is also worth noting, especially at a distance of 50–100 m from these facilities. The same observation applies to the buildings used as education, science, culture and sport facilities, especially distance of 50–200 m from them. Small inversed relation with distance from industrial buildings as well as tanks, silos and warehouses can be observed as well.

The density of burglary into commercial facilities is, naturally, the largest in the immediate proximity of commercial buildings, within 50 m of them. Similarly to other types of theft and burglary, small inverse relation with distance from industrial buildings, tanks, silos and warehouses may be noted.

While analysing the density of crime, without dividing it into particular types, several regularities can be observed. First of all, it is the largest in the immediate proximity of commercial buildings, within 0–50 m from them, as well as from offices. It worth to note a higher density of crime within 50–100 m distance from hospitals and medical care facilities, as well as buildings used as education, science, culture and sport facilities. Also, the proximity of residential buildings, as well as transport and communication buildings coexists with a higher density of crime in Kraków. Finally, as with thefts and burglaries, there is a small inverse relation with distance from industrial buildings, tanks, silos and warehouses.

In conclusion, due to the analysis of the density differences of different types of thefts and burglaries within the areas of impact of selected development functions, some regularities can be observed. Particular development functions that co-occur with a higher density of theft or burglary of a particular type are presented in this table. Again, in general, two types of both positive and reverse relations can be observed. Firstly, there is a relation similar to linear function or exponential function, without any major derogation. This relation is marked in the table as (A). Secondly, there is a relation that differs from those marked as

(A) at one or two points. This relation is marked in the table as (B). A category that is inconsistent with its generally linear or exponential character is listed in a bracket with annotation showing the direction of this derogation. For example, the “0–20L” annotation means that this relation differs from linear or exponential in category 0–20 m, in which the density of incidents is lower than it would be in case of an ideal linear or exponential relation. Similarly, “20–50H” annotation means that this relation differs from linear or exponential relation in category 20–50 m, in which the density of incidents is actually higher than it would be in an ideal linear or exponential relation.

Table 5. Selected development functions which coexist with a greater density of incidents of a particular type

Incidents	Positive relation	Reverse relation
Theft	commercial buildings (A) offices (A) hospitals and medical care facilities (B: 0–20L) buildings used as education, science, culture and sport facilities (B: 0–20L) transport and communications buildings (just direct proximity)	industrial buildings (A) tanks, silos and warehouses (A)
Pickpocketing	offices (A) commercial buildings (A) buildings used as education, science, culture and sport facilities (B: 0–20L) transport and communications buildings (B: 0–20L, 200–300H)	industrial buildings (B: 300–400H) tanks, silos and warehouses (B: 300–400H)
Bicycle theft	commercial buildings (B: 0–20L) residential buildings (A) offices (B: 20–50H, 50–100H)	industrial buildings (B: up to 200 m, from 200 m positive relation) tanks, silos and warehouses (B: 400–500H)
Vehicle theft	commercial buildings (A) residential buildings (A) hospitals and medical care facilities (B: 0–20L)	industrial buildings (A) tanks, silos and warehouses (A)
Burglary	commercial buildings (B: 0–20L) residential buildings (A) hospitals and medical care facilities (B: 0–20L)	industrial buildings (A) tanks, silos and warehouses (A)
Vehicle burglary	commercial buildings (A) residential buildings (A) hospitals and medical care facilities (just 20–50 m) buildings used as education, science, culture and sport facilities (B: 0–20L)	industrial buildings (A) tanks, silos and warehouses (A)

Table 5. (continued)

Incidents	Positive relation	Reverse relation
Home/ apartment burglary	residential buildings (A) transport and communications buildings (A)	industrial buildings tanks, silos and warehouses
Commercial building burglary	commercial buildings (A)	industrial buildings (A) tanks, silos and warehouses (A)
All crimes	commercial buildings (A) offices (A) hospitals and medical care facilities (B: 0–20L) buildings used as education, science, culture and sport facilities (B: 0–20L) transport and communications buildings (A)	industrial buildings (A) tanks, silos and warehouses (A)

In this table many development functions have been placed in relation to almost every analysed type of theft, as with the analysis conducted with relation to distance from selected characteristic points in space. They differ in the degree of observable relation as well. Commercial buildings, around which we can observe the highest density of theft in general and some of the particular types of property crimes – pickpocketing, bicycle theft, vehicle theft, burglary, vehicle burglary and burglary into commercial facilities – are not associated with greater density of burglary into an apartment or house. The proximity of residential buildings, on the other hand, which is in direct relation to the density of this type of theft, does not turn out to be as important in the case of pickpocketing and burglary into commercial facilities. Some development functions appear only for certain types of thefts. It is worth to notice the relation between hospitals and health care facilities with such types of theft as vehicle theft, burglary, vehicle burglary, as well as burglary into apartments or houses (although most often they occur not in the immediate proximity of these facilities, but a bit further). The proximity of transport and communication buildings coincides with pickpocketing. There is an inverse relation between all types of theft and burglary density and distance from industrial buildings, as well as tanks, silos and warehouses – in most cases the relation is small, but visible. In rare cases, such as bicycle theft and vehicle burglary, this relation seems stronger.

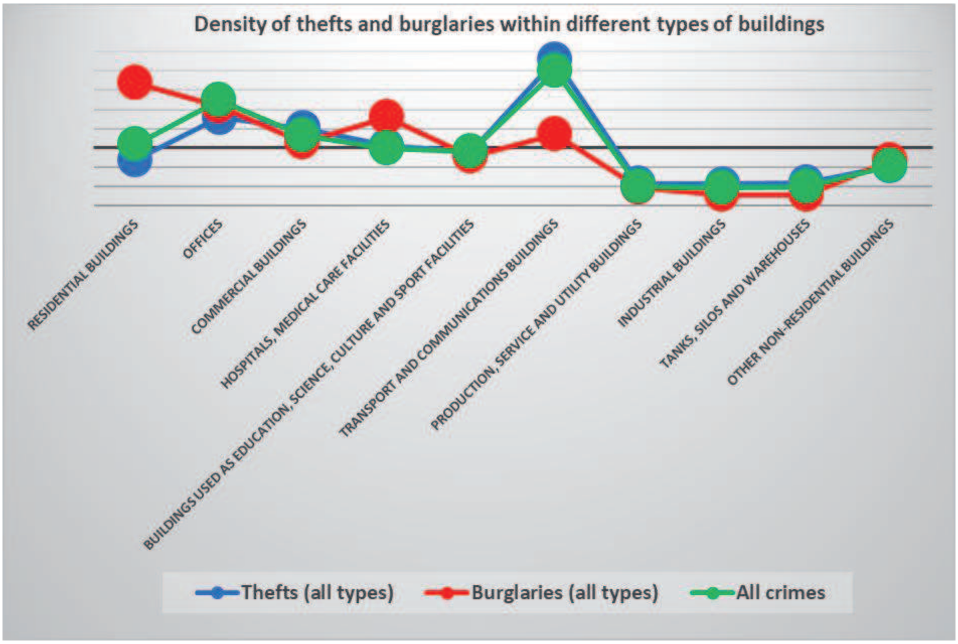


Figure 19. Density of thefts and burglaries within different types of buildings

The analysis of incidents that occurred within different types of buildings is presented in the chart above, simplified to three categories of incidents for better readability. Several characteristic patterns can be observed here. Residential buildings coexist significantly with a higher density of burglary than other crimes and thefts, and transport and communications buildings exactly the opposite – with a lower density of burglary. A lower density of crime, theft and burglary in the proximity of production and industrial buildings, tanks, silos and warehouses is also noteworthy. This particular analysis, as it was described in a methodology section, was conducted without the use of multiple buffer methods. Therefore it takes into account only incidents that were located within the range of polygons assigned to one of those development functions and excludes incidents that happened in their proximity. Raw data used for that analysis is presented in a table below.

Table 6. Density of thefts and burglaries within different types of buildings

Building development function	Theft		Burglary		Crime	
	N	Density (N/ha)	N	Density (N/ha)	N	Density (N/ha)
Residential buildings	2,654	1.119	971	0.409	10,351	4.3641
Production, service and utility buildings	1,074	0.849	165	0.130	2,852	2.2548
Commercial buildings	12	0.055	8	0.037	52	0.2377
Transport and communications buildings	764	2.549	59	0.197	1,594	5.3181
Industrial buildings	226	5.634	9	0.224	469	11.6920
Buildings used as education, science, culture and sport facilities	10	0.026	4	0.010	24	0.0625
Offices	303	1.471	30	0.146	764	3.7082
Tanks, silos and warehouses	363	3.018	39	0.324	1,051	8.7390
Hospitals, medical care facilities	10	0.083	1	0.008	23	0.1915
Other non-residential buildings	92	1.754	15	0.286	210	4.0048
Total	**5,508**		**1,301**		**17,390**	

3. DISCUSSION

The results of the conducted analyses are undoubtedly in line with the assumptions of the theories of environmental criminology referred to above, in so far as they indicate a relationship between the increased criminal activity of perpetrators and the availability of potential victims or objects of attack. Both the higher density of crimes in general and theft in general occurred above all in facilities or in the immediate vicinity of facilities which accumulate large communities for various purposes (activity nodes: commercial buildings, offices, residential buildings, buildings of education, science, culture and sport, ATM's, gas stations) or in places which produce a flow of people (communication nodes: transport and communications buildings over public transport line routes). The reverse relationship can be observed in relation to categories of land use and facilities, which relate to places that (usually) do not generate large clusters of people (i.e. industrial buildings, tanks, silos and warehouses, production, service and utility buildings). Bearing in mind the assumptions of the theory of rational choice, it is worth noting that committing theft in this type of objects may be associated with greater effort on the part of the perpetrator (often accessing more peripherally located objects, less efficient escape routes, potential problems with loot disposal etc.).

Land use categories in the vicinity of which no increase in the density of criminal events was recorded were green areas and churches and chapels. The first category is internally very diverse: some of them are areas regularly or recurrently gathering larger human communities (parks, squares, green areas), often adjacent to residential or commercial areas. Some are peripherally located and rarely frequented areas, which do not provide many criminal opportunities. It cannot be excluded that some of these areas have the property of „attracting" perpetrators, but this would require further, more in-depth analyses. The results of previous research on places of similar nature are quite ambiguous.[14] Churches, chapels and cemeteries are categories that raise most doubts in interpretation. These are facilities that can potentially provide criminal opportunities because they regularly or recurrently gather large clusters of people (especially facilities visited for tourist purposes, which are common in Kraków). Some of them are a particularly attractive object of attack (elderly people, tourists), and goods gathered in religious buildings can also motivate criminals. However, the analysis did not show that the crime density ratio (including theft) increased nearby. Perhaps their special nature stops some of the more „spiritual" perpetrators from criminal activity in this area.

As Cohen and Felson (1979) emphasized, an opportunity is crime specific, and therefore, when analysing the situational conditions conducive to committing crimes, their diversity should be taken into account. The results of the conducted analyses indicate that one land use and facilities coexist with an increased density of all types of thefts, while others coexist only with some of them. For example, a greater density of vehicle theft was observed primarily in the immediate vicinity of residential buildings, commercial and service buildings, and around gas stations. All these locations can be confirmed with the results of other research to date on this type of crime. Lu (2006) found that auto theft locations in Buffalo were associated with commercial locations with parking lots and residential areas. Potchak et al. (2002) investigated auto theft in the theoretical context of routine activities theory and found that car theft is more likely on major and frequently

[14] Some studies show that green urban spaces serve as a deterrent to crime, in general, or some type of crime (Kuo and Sullivan 2001; Sypion-Dutkowska and Leitner 2017; Shepley et al. 2019) and others that in some circumstances they can attract certain anti-social behaviors. For instance, DeMotto and Davies (2006) proved that in areas with high levels of resource deprivation and physical disorder parks may function as criminal marketplaces. Another study finds that although parks, in general, are associated with increased levels of crime in the surrounding area, specific park characteristics are related to higher crime levels (Groff and McCord 2012). Moreover, it has been shown that observation of crime in parks should take into account temporal variables: spatial-temporal analysis of property crime is more positively associated with crime but only during spring and summer seasons (Quick and Law 2019).

travelled roads, and gas stations are usually located along such roads.[15] The higher density of vehicle thefts within 20–50 m from hospitals and medical care facilities, as well as lower around offices, which has been observed in this study, is also noteworthy. It may be associated with the fact that office buildings are more often equipped with parking lots (sometimes guarded or equipped with various types of anti-theft devices). In the case of hospitals and medical facilities, drivers are often forced to use temporary parking areas in public spaces, which significantly increase the likelihood of theft (cf. Clarke and Mayhew 1994). Meanwhile, near the offices, a relatively high rate of bicycle theft was observed – an increasingly popular commuter vehicle for Poles – as well as pickpocketing. The latter showed an increased level of density also near other crime generators, such as transport and communications buildings, as well as buildings used as education, science, culture and sport facilities.

The results obtained in these studies, however, raise some significant interpretation doubts as to one of the fundamental assumptions of all key theories of environmental criminology. The rational choice of criminal opportunities should essentially mean avoiding places that increase the chance of foiling the commission of a crime or apprehending the perpetrator. The presence of a capable guardian should act as a deterrent to the perpetrator, but it may manifest with the activity of people (police patrol, security guards' or place managers' surveillance, informal social control exercised by residents, etc.[16]) or devices (CCTV cameras, street lighting, etc.). The findings of a systematic meta-analysis of the high-quality research on the effectiveness of CCTV on crime in public space showed that CCTV can have a significant effect on crime reduction, especially in car parks and is most effective when it is combined with street lighting improvement (Welsh and Farrington 2009[17]). This effect is often observed in relation to crimes

[15] Levy and Tartaro (2010) in their research on repeat auto theft victimization in Atlantic City treated gas stations as one of the activity nodes.

[16] Cornish and Clarke (2003) in their classification of situational crime prevention differentiate three types of surveillance that can be used for crime prevention: formal surveillance, natural surveillance, and surveillance by employees/place managers.

[17] It should be emphasized that the results of research on the effectiveness of monitoring are highly ambiguous. So far only a few review papers fairly summarizing the findings have been published. The meta-analysis of Welsh and Farrington (2009) including 44 experimental studies indicates a 16% decrease in crime. A closer look at the results, however, leads to the conclusion that this fact is primarily due to a significant decrease in crime in closed parking lots (51%). Meanwhile, the recorded decline in crime in public space was relatively small (7%) and statistically insignificant. Undoubtedly, the methodological quality of research conducted in the area of evaluation of activities in the field of preventing and combating crime significantly differentiates the results obtained. It is clear from the meta-analysis by Weisburd, Lum and Petrosino (2001) that the less internally accurate the methodology of the study, the more likely it is to show a positive or expected relationship between the analysed variables. Similar conclusions were reached by the authors of a meta-analysis of 136 studies on preventive measures focused on monitoring public space (primarily CCTV and CPTED activities, e.g. street lighting) and their impact on crime (Welsh et al. 2011).

against property, including primarily car theft, pickpocketing, shoplifting, burglary, property damage (Alexandrie 2017). There is also scientific evidence showing that a highly visible presence of police or other local guardians (Welsh, Farrington and O'Dell 2010) has a deterrent effect on perpetrators (Sherman and Eck 2002; Weisburd and Eck 2004; Bowers et al. 2011)[18]. Meanwhile, in the studies presented here, high crime density rates were observed in the immediate vicinity of public and private monitoring cameras, as well as within 50 meters of police stations. Although at first glance this may call into question the rationality of the perpetrators of crimes against property in Krakow, making a thorough assessment of the results obtained, one cannot forget about three important issues.

First, observations made in the studies do not necessarily exclude the assumption of an informed and competent risk calculation by perpetrators. Rational offenders may just consider the potential benefit from a crime committed in the area of intensive surveillance as greater than the risk. In Poland, where anecdotal stories about the poor quality of recordings from CCTV cameras are well known, this kind of reasoning would not be surprising. Secondly, the issue of correctness of geocoded data may also be relevant. It is based on police reports providing addresses of crime locations. Although we strive for the greatest accuracy in this regard, there are times when a certain event is assigned to an incorrect address; to the nearest address that does not coincide with the actual place of committing the act; or to any address where the address of committing the act is impossible for the Police to determine. It was not a very good practice, used in similar situations, to identify the locations of police stations. Although police officers are more and more aware of the impact of this type of data inaccuracy on the results of spatial analysis, it cannot be ruled out that this habit has still not been fully eradicated. Moreover, some crimes whose density was taken into account in the research may be committed in such a way and in such circumstances that the presence of a camera monitoring the (semi) public space may not be relevant to detecting the perpetrator. A perpetrator of car theft or theft with burglary will not be indifferent to his image being recorded by a CCTV camera outside the building. On the other hand, a perpetrator of pickpocketing committed inside a building in a crowded club on a busy street can be completely indifferent to that fact. Unfortunately, the data we had at our disposal did not allow us to take these circumstances into account. Thefts – regardless of whether they were committed indoors or outdoors – are attributed to the nearest address. Therefore, it is impossible to state, in specific circumstances of the perpetrator's spatial activity, if the presence of a camera monitoring public space should be part of the perpetrator's rational calculation or not. Finally, it is also possible that

[18] For the sake of further considerations it is important to notice that the crime reducing effect was observable only for directed police patrols targeted to crime hotspots and not just for a random presence of police (Sherman and Eck 2002; Weisburd and Eck 2004).

the higher density of events recorded in the vicinity of cameras or in the vicinity of police stations is not due to the above-average activity of perpetrators in these areas, but to a higher detection rate. Therefore, such factors cannot be treated as generating greater density of thefts around them, but as increasing their detection and likelihood of the successful apprehension and conviction of the perpetrator.

Taking into consideration most influential theories of criminal aetiology, this research – both its results and limitations – as well as other crime mapping studies, we highly recommend further studies on the subject of spatial distribution of urban (property) crime. To ensure high validity of studies we argue for more extensive use of methods allowing to control for most important variables other than those related to urban space, i.e. socio-economical ones. We are aware that in Polish context getting to certain types of more advanced data might be difficult in a particular institutional and organizational setup that researchers and city authorities are involved in. Nonetheless we recommend including in further studies such information as real population density (day/night) and socio-economic structure of local communities. This way the sole effect of spatial factors may be determined while maintaining control over other significant variables. Such data may be obtained e.g. from cooperation with big data management companies, that analyse information coming from mobile phones (see i.a. Pędziwiatr, Stonawski and Brzozowski 2019).

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