International Journal of Geo-Information

MDPI

Editorial

Urban Crime Mapping and Analysis Using GIS

Alina Ristea [1] and Michael Leitner [2,*]

[1] Boston Area Research Initiative, School of Public Policy and Urban Affairs, Northeastern University, Boston, MA 02115, USA; a.ristea@northeastern.edu

[2] Department of Geography and Anthropology, Louisiana State University, E-104 Howe Russell Geoscience Complex, Baton Rouge, LA 70803, USA

* Correspondence: mleitne@lsu.edu; Tel.: +1-225-578-2963

Received: 18 August 2020; Accepted: 20 August 2020; Published: 25 August 2020

On 22 April 2018, the authors were invited by the Editor-in-Chief, Prof. Wolfgang Kainz, to establish a Special Issue in the *ISPRS International Journal of Geo-Information* on "Urban Crime Mapping and Analysis Using GIS". On 10 June 2020, more than two years after this initial invitation, the final of a total of 17 articles was published, bringing this Special Issue to a very successful conclusion. This Special Issue is a follow-up publication of an edited book [1] and two previously published Special Issues [2,3] on crime analysis, modeling, and mapping.

In our first call for papers, sent out on 4 December 2018, we believed that this new collection of papers would contribute to the contemporary research agenda on spatial and temporal crime-related issues. We encouraged submissions of both theoretical as well as application-oriented papers dealing with these emerging issues. Specifically, our interest was in papers that covered a wide spectrum of methodological and domain-specific topics, highlighting both the breadth and the depth of current research and application in the geography of crime. The suggested topics included a list of almost 30 themes, ranging from big data, crime forecasting, and risk terrain modeling to social media, university campus crime, and 3-D crime modeling.

The 17 articles included in this Special Issue are published by a total of 59 authors, for an average of 3.5 authors per paper. One article is single-authored, six are co-authored by two researchers, two are authored by three researchers, four by four researchers, two by five authors, and two by seven researchers, respectively. The highest number of contributors (24) are from the USA, followed by China (16), with others coming from Belgium and Serbia (four each); Austria, Ecuador, and Iran (three each); and Hungary (two). The vast majority of authors (49 out of 59) come from academia, with a diverse and long list of scientific departments, ranging from geography/geographic information science (22 out of 49) to engineering (8 out of 49), environment (7 out of 49), and criminology/criminal justice (5 out of 49), just to mention the most commonly cited affiliations. The remaining authors have a governmental (eight) or private sector affiliation (one). Surprisingly, only one [4] of the 17 articles has a police officer listed as collaborator and co-author. To summarize, "Urban Crime Mapping and Analysis Using GIS" is a topic of much interest mostly to academia, but also to the government. Research in this area is foremost carried out by geographers/geographic information scientists, but also by engineers, environmentalists, criminologists, and criminal justice experts. While research is carried out in different regions world-wide, the focus of study areas seems to be urban areas in the USA.

The 17 articles included in this Special Issue are classified into the following eight main themes:

- Theory testing (one article);
- Crime perception (three articles);
- Crime risk (two articles);
- Diffusion, spillover, and displacement (three articles);
- Space and time (three articles);
- International regional Studies (three articles);

- Crime-related (one article);
- Review article (one article).

The following discussion briefly summarizes the core message of each of the 17 articles organized by research topic, reflecting the depth and the breadth of urban crime mapping and analysis using GIS.

Theory Testing

The first in the series of 17 articles relates to theory testing, specifically the process of deciding whether the empirical evidence in a sample of cases supports or does not support a defined theory. The authors, [4], put forward detailed arguments examining the broken windows theory at the neighborhood (i.e., block group) level in the city of Milwaukee, WI (US). It is argued that further examination of this theory is needed for several reasons that include (1) aggressive broken window policing targeting minority populations; (2) differences in crime severity (Part I vs. Part II crimes); (3) disorder types and their influence in crime (physical vs social); and (4) the racial stratification of neighborhoods. As discussed in other recent literature, the findings in this research show that the general idea of disorder being associated with crime rates is only partially true. The effect is limited to public space disorder, with a stronger impact of Part II offenses, indicating that neighborhood decline is more related to less serious crime types. Consequently, community-law partnerships are suggested to better address neighborhood incivilities.

Crime Perception

The main research focus of the next three articles in this Special Issue is safety perception. In the first study by [5], digital sketch maps (designed in the form of a web application) are used to collect residents' local sense of safety for nine large, medium, and small-sized Hungarian cities. The main goal of this research is to determine explanatory motives for the safety perception of study participants. Overall outcomes are somewhat mixed and reflect similarities and differences between observed urban areas. The residents' judgement whether a place feels safe or not seems to be largely dependent on how often a place is attributed as being safe and the frequency of officially reported crime events. In contrast, the size of the city as well as the gender of respondents do not seem to significantly influence the overall judgement of places. Finally, the results highlight the importance of locality in the perception of safety research.

The research presented in the second article by [6] falls into a similar vein. It also applies sketch maps collected through household surveys to understand residents' perception of safety in a specific neighborhood in Worcester, MA, where a community-based crime reduction project, funded by the U.S. Department of Justice, has been implemented. The collected perception of safety information is analyzed for differences by gender and the length of residency in the neighborhood, as well as for its relationship to officially reported crime data. The interpretation of results in the form of bivariate maps shows a varied strength in the relationship between perceived safety and reported crime. In addition, the gender and length of residency are significant factors shaping the perception of safety. Based on the outcomes of this research, the authors identified two related implications that should be of interest to community development practitioners. First, recorded crime as measured by police data is an imperfect proxy for neighborhood safety; second, comprehensive community-based development initiatives should be prepared to develop differentiated strategies that address a broad range of safety perceptions and crime experiences among a diverse group of residents.

While the previous two articles explored the safety perception of urban residents, the next article by [7] assesses police officers' perception of places prone to crime in their patrol area in order to effectively perform their police duties. The study area is the municipality of Novi Beograd, one of the 17 municipalities of the city of Belgrade, the capital of the Republic of Serbia. A sample of 54 police officers from this municipality's police station are selected to be included in this study. They are asked to mark on an A3 format color orthophoto map of Novi Beograd all locations where, according to their knowledge, residential burglary crimes are concentrated (hotspots). These perceived hotspots are

then compared to officially reported crime locations for an accuracy assessment. The results of this study show that the situational awareness of police officers is not at a desired level, with the ineffective dissemination of relevant data and information as one of the possible reasons.

Crime Risk

The first of two articles devoted to crime risk research is published by [8], and it examines the spatiotemporal pattern and interaction effects of pick-pocketing and motor vehicle theft, using the reported crime data collected by the police department of a large Chinese city. As expected, both crime types are spatially clustered in different hotspot areas, however a small number of hotspots from each of the two crime types spatially overlap, pointing to some degree of spatial interaction. In addition, the results from repeat and near repeat analysis indicate that both crimes are also spatiotemporally clustered and that they show space–time interaction for each individual crime and between both crime types (cross-crime type interaction). For example, after an initial motor vehicle theft, the risk of another motor vehicle theft to occur at the same or nearby locations is statistically significantly higher than if no motor vehicle theft had happened originally. This significantly higher risk is found to continue for 49 days and within 100 m of the initial crime. However, repeat and near repeat analysis shows that the risk of another motor vehicle theft to occur is actually slightly higher if the initial crime constitutes a pick-pocketing event instead of another motor vehicle theft (cross-crime type interaction). Albeit, this result is only found for motor vehicle thefts committed at the same location and within six weeks (42 days) of the original pick-pocketing crime. This means that pick-pocketing victimization may have a better ability to predict motor vehicle theft victimization, but only for a repeat event and for up to six weeks following the initial pick-pocketing crime.

The second article devoted to crime risk research published by [9] proposes a contextual effects model based on the Bayesian spatial modeling strategy to investigate contextual effects on neighborhood burglary risks. The study area is the Jianghan District, one of the most prosperous urban districts in the city of Wuhan in China, consisting of 13 sub-districts and 116 neighborhoods. In general, contextual effects denote the impact that higher-level units (in this case, the 13 sub-districts) have on lower-level units of analysis (in this case, the 116 individual neighborhoods making up the 13 sub-districts). Such effects are often neglected in Bayesian spatial crime analysis. The proposed contextual effects model accounts for the effects of independent variables, overdispersion, spatial autocorrelation, and contextual effects, and is compared to a conventional Bayesian spatial model. Both models are fit to residential and commercial burglaries provided by the city's police department from 2012 to 2015. Crimes are aggregated at the neighborhood level and serve as the dependent variable. Seven independent variables, including demographic, socioeconomic, land use, and density of police stations, are used as potential risk factors.

The results of this study suggest that both the conventional and the contextual effects models identified densities of population (demographic variable), bars, and department stores (land use variables) to exhibit a strong association with burglary risks. The remaining independent variables turn out to be not statistically significant. While both models show very similar outcomes, the contextual effects model is preferred, since it provides insights into contextual effects on crime risks.

Crime Risk Diffusion, Spillover, and Displacement

A topic identified in the Special Issue includes studies on displacement and diffusion of crime. Crime displacement is the relocation of crime generally occurring due to police efforts on stopping crime. Crime diffusion results in the reduction in crime in areas related to crime prevention interventions and an increase in crime in mostly adjacent areas that are not directly targeted by the same interventions.

The research by [10] deals with two difficult challenges occurring in the developing world—namely, the data availability (or lack thereof) and the questionable crime concentration in urban settings. The authors investigate the spatial crime distribution in Guyana, South America, through information from archival newspapers. As a first result, crime in Guyana is considered a coastal feature, clustered

around Georgetown and its environs, with significant hotspots along the coast. However, the 20-year long temporal analysis of violent crime suggests that crime hotspots have changed throughout the years. More specifically, violent crime has moved away from the coast, spilling over into indigenous peoples' landscapes (there are nine Amerindian nations in Guyana), being connected with the movement of weapons away from the coast. Therefore, the authors recommend the extension of policing measures towards the Amerindian landscapes, not only for Guyana, but also for other Latin American states with demographics like Guyana's.

In the second article included under this research topic, [11] analyze the existence, distribution, and predictive ability of crime displacement in large cities in China, focusing on burglaries. The authors show that, similar to Western cities, the crime displacement phenomenon occurs in response to crime interventions, by using the repeat and near-repeat (RNR) calculator. In addition, the authors develop a new statistical method—the spatial-temporal crime displacement (STCD) detector—inspired by the Knox method, to identify pairs of displacement (change of activity nodes). Interestingly, the results show that the majority of activity nodes are only displaced by about five kilometers. To detect displacements, the study area is divided into 200 m $*$ 200 m units. The capture rate and the prediction accuracy index (PAI) are used to evaluate, if the information from the spatial displacement of crime contributes additional predictive power, for both the RNR and STCD methods. The results show that the STCD has a lower crime prediction ability than the RNR. However, among the successfully predicted burglaries, some burglaries were captured by only one method, while others were captured by both methods. Overall, multiple burglaries could only be predicted by the STCD rather than the RNR, showing the importance of this new displacement detector method.

In a similar manner, [12] study the enhancement of spatial accuracy for crime prediction, focusing on burglaries at the community level in the city of Wuhan. The authors propose the inclusion of environmental factors in the spatiotemporal crime prediction model through anisotropic diffusion (AnisDM), because traditional diffusion models do not consider additional factors of the geographical area. To determine the parameters in the model, a near-repeat analysis is first considered, and the resulting information is finally combined with the size of the grid and the time duration (e.g., 400 m and 28 days). The prediction accuracy index (PAI) is used to calculate the prediction effectiveness for the AnisDM, in comparison with two other models, namely Kernel Density Estimation (KDE) and the isotropic diffusion model (IsotDM). The theoretical basis of the AnisDM is consistent with that of the IsotDM, and both are based on the near-repeat theory. In this research, the study area is divided into different regions according to crime-risk values estimated by the algorithms (grid cells with 0.5%, 1%, 5%, and 10% of the crime risk ranking). The hit rate and the PAI of the AnisDM are greater than or equal to that of the IsotDM and the KDE, especially for very high and high risk rankings. However, as crime risk decreases, the prediction effect of the AnisDM gradually approaches that of the IsotDM.

Space and Time

The next three articles explore either exclusively the temporal component of crime [13], or both the spatial and temporal components of crime, concurrently [14,15]. The main research motivation in the article by [13] is associated with crime types, such as burglaries, that possess poor temporal information. The researcher's goal is to increase the temporal accuracy of such crime types applying eight different temporal approximation methods. Six of them are existing methods that include four naïve and two aoristic methods. The other two are novel temporal approximation methods that are based on the idea that temporal distributions of crimes stay more or less stable over time. This means that burglary crimes from a retrospective period possess a temporal distribution very similar to the distribution of observed burglary crimes in the current period. The first novel method, referred to as retrospective temporal approximation (RTA), directly applies this idea and uses solely historical burglary crimes with accurately known time stamps to "estimate" future burglary crimes. The second novel method enhances one of the two aoristic method results with probability values derived from historical crime data with accurately known time stamps. It is called extended retrospective temporal

approximation (RTA_{ext}). All eight temporal approximation methods are tested and evaluated on three different crime types, including apartment, car, and house burglaries from Vienna, the capital city of Austria. The results from the eight temporal approximation methods show that both novel RTA methods, especially the simple RTA, are at least equal or clearly superior to the other six existing temporal approximation methods. This means that accurately known time stamps from historical burglary data may be able to estimate future time stamps for burglary crimes, for which accurate temporal information is not available.

Of the two articles that consider both spatial and temporal components of crime, concurrently, the study by [14] applies graph theory to a burglary dataset from a large Chinese city, in order to explore elevated crime risk resulting from specific crime patterns represented by subgraphs. Crime patterns consist of three known basic patterns, including "repeat" (two crimes occur at the same place shortly after each other), "shift" (two crimes occur at different places shortly after each other), and "co-occurrence" (two crimes occur at different places simultaneously), and four combinations of the three basic patterns ("repeat and shift", repeat and co-occurrence", "shift and co-occurrence", and "co-occurrence, repeat, and shift"). For example, two different properties A and B being burglarized at the same day, and each of them being burglarized again shortly thereafter, would be identified as a "co-occurrence, repeat, and shift" pattern. The results show that combined patterns create much higher levels of risk compared to basic patterns, with "co-occurrence, repeat, and shift" generating the highest level of crime risk, while "repeat" generated much lower levels of crime risk. Consequently, distinct risk patterns suggest different levels of crime prevention measures and crime prediction methods.

The third and final article in this section by [15] examines the impact that "Strike Hard", an enhanced law-enforcement strategy in China, has on the repeat and near-repeat residential burglary patterns in the Chayong District in Beijing, China across three distinct periods (pre- "Strike Hard", "Strike Hard", and post- "Strike Hard"). The results suggest that the "Strike Hard" campaign helped reduce repeat burglary risk during the intervention, but increased repeat burglary risk after the cessation of the intervention. With respect to near repeats, the findings are very similar; however, the intervention produced a not statistically significant decrease. These results suggest that spatiotemporal displacement may have been an undesired by-product of "Strike Hard". This study from a non-Western setting provides further evidence of the generalizability of findings related to repeat and near repeat patterns of burglary. It further highlights the limited preventative effect that the "Strike Hard" enhanced law enforcement campaign had on burglary in the Chayong District of Beijing.

International Regional Studies

The topic of regional crime studies around the world, includes research from Quito (Ecuador), Belo Horizonte (Brazil), and Louisville (USA).

The first case study by [16] in Quito, Ecuador, identifies spatial patterns of seven different crime types (fraud, homicide, human trafficking, larceny, murder, rape, and robbery) and tests their associations with the index of Unsatisfied Basic Needs (UBN). This represents a multidimensional index of poverty widely used in Latin America that considers both Communitarian Policy Units (CPU) and population densities. The associations are tested through Spearman correlation and explained through Geographically Weighted Regression (GWR). Additionally, the spatial autocorrelation index, Getis-Ord Gi*, is calculated to identify the hotspots and coldspots of the different types of crime. The results show that hotspots of crime are mainly located in urban parishes, with a high concentration of night-time entertainment venues which can play the role of crime attractors and generators. On the other hand, rural parishes have a high level of poverty, but a low level of crime, partly due to the stronger social cohesion in these communities. However, the eastern rural parishes are influenced by crime that spill-overs from the adjacent urban parishes. Overall, this work shows that a more complex approach is important and needed to be executed by the Ecuadorean police, who, thus far, have only considered the identification of crime densities.

Similarly, the second case study by [17] proposes a quantitative model to determine whether income inequality (average household income and exposure to poverty) can explain the geography of residential burglary in Belo Horizonte, Brazil, while controlling for land-use type, density, and accessibility. The data used in this case study are from the 2010 Census at the level of census sectors as spatial units, real-estate registry, OpenStreetMap, and from the police. The GWRisk standardization method is employed to estimate rates of burglary per house and per apartment from total burglary counts. The study shows that although the average household income is positively related to house burglary risk, it is not statistically significant for apartment burglary risk. Interestingly, a higher exposure to poverty has no statistically significant effect on burglary risk for either houses or apartments. While acknowledging that crime-inequality relationships are controversial, the results of this research support other studies which argue that burglaries follow an opportunistic distribution rather than one based on the exposure to different economic groups.

Finally, a regional study by [18] for Louisville, KY (USA), investigates differences in space and time locations between gunshot detection technology (GDT) data and 911 calls for gun violence. The two datasets are depicted through methods, such as hot spot mapping, near repeat diagnosis, and (spatial) regression, including ordinary least squares (OLS) and spatial lag models based on neighborhood characteristics derived from theorical criminology. While recognizing that the count of 911 calls is about 50% of GDT entries, the results show that GDT-generated hot spots are more spatially extensive in a part of the study area which is well-known for high levels of segregation, poverty, and violent crime. A possible explanation includes the underreporting of gun violence using 911 calls from disadvantaged neighborhoods. The subsequently conducted near repeat analysis shows an increased risk of gun-related events at nearby locations (roughly two city blocks away), following an original gun-related event. Lastly, the (spatial) regression models for all GDT events suggest that the percentage of vacant housing and percentage blacks are both positively statistically significant. This result is discovered for unreported events—i.e., detected GDT events without a 911 call recorded in the following hour and within a one-kilometer radius.

Crime-Related

One crime-related topic tackled in this special issue includes the simulation of traffic accidents for a better geolocation of road emergency services (RESs). In this research, [19] test a multi-criterion (fuzzy analytical hierarchy process—FAHP) approach in the Khuzestan Province, Iran. Experts' opinions are used in the fundamental step of determining the main factors for locating RESs, resulting in nine main criteria and 19 sub-criteria, including data on population, safety, natural factors, land use compatibility, road type, traffic level, and high crash zones. The results show that areas with a high density of fatal accidents have a lack of RESs. Additional results suggest that the FAHP methodology is not only suitable for determining best RESs locations, but is also transferable to alternative study areas. However, the weight of each criterion affects the calculation, and thus the correct weighting of factors highly influences the results. As a conclusion, RES stations are not appropriately distributed along major roads, and, through this analysis, decision-makers and authorities can approach a re-arrangement of stations for a faster response of emergency services, resulting in a lower number of accidents causing death.

Review Article

In the only review article of this Special Issue, [20] discuss solution methods that can be used to solve the so-called police patrol routing problem (PPRP), a complex problem that is currently underexposed in the academic literature. The PPRP is complex, since police must proactively patrol and prevent offenders from committing crimes but must also reactively respond to real-time incidents. Efficient patrol strategies are crucial in order to manage scarce police resources and minimize emergency response times. This review is based on 30 articles that focus on the dynamic vehicle routing problem (DVRP) with a link to police. The solution methods most convenient to address this PPRP identified by

the authors of this review could be (hybrid) genetic algorithms, routing policies, and local searches based on a network Voronoi diagram.

Acknowledgments: The editors express their gratefulness and gratitude to all the reviewers for their support and their critical and constructive comments for each manuscript. This has added significantly to the quality of the entire Special Issue. Finally, we thank the Special Issue Managing Editor, Valeria Sun, for editorial assistance throughout the preparation of this Special Issue and the Editor-in-Chief Wolfgang Kainz, for inviting us to establish this series of articles.

Conflicts of Interest: The authors declare no conflict of interest.

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