# JDiBrief - Analysis

## Street Networks and Risk:

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**PURPOSE**: Research shows that crime is more likely to occur at some places than others. One common aim of crime mapping is, therefore, to identify where 'hotspots' occur. This may be achieved by identifying which areas (*e.g.* police beats) have the highest crime, or by using Kernel Density Estimation (KDE). A problem with these approaches, however, is that they ignore one of the main factors that influences where many types of crime can occur: the street network. In doing so, they do not allow the analyst to see if particular features of the street network affect crime risk, or to deploy resources to the precise locations at greatest risk. This Brief discusses one reason why risk may vary between street segments, how such effects can be tested, and describes further analyses that may inform crime prevention and operational policing.

**THEORY**: The street network determines the routes that people can take between locations, and hence the places with which they will become aware. In the case of offenders, it also influences the opportunities for crime they are likely to encounter. Some routes (*e.g.* the shortest ones) will be more popular than others and hence are more likely to be familiar to people, including offenders. Theory suggests that more popular streets will thus experience more crime and existing research supports this. Segment characteristics hence appear to provide a useful indication of the potential for crime, and since neighbouring streets can be of significantly different character, patterns at this scale identified using traditional hotspot analysis approaches (*e.g.* KDE) may be misleading.

**METHOD**: In addition to crime data regarding crime locations, data are required that define the configuration of the street network (e.g. Ordnance Survey data) and, where the analyst is interested in crime risk, the number of targets on each street segment (e.g. households in the case of residential burglary). Having assembled the necessary data, it is necessary to code street segments according to their usage. A simple categorical coding scheme that may be used is road type (e.g. Major Road, Minor Road, Local Road, Cul-de-Sac, and so on). A more sophisticated approach, which provides more precise estimates of street segment usage, uses techniques from a branch of mathematics known as graph theory. Such analysis can be conducted using tools such as the Urban Network Analysis package for ArcGIS. After the street segments have been classified in this way, a Geographical Information System can be used to "join" the crime events to the street segments and analyses conducted to see if crime risk is associated with estimated street usage.

**APPLICATION**: Analyses conducted for Merseyside (UK) clearly indicated that roads that would be expected to be used the most (e.g. Major Roads) had higher rates of burglary than those expected to be used the least (e.g. residential roads). Burglary risk was particularly low for Cul-de-Sacs and Private roads. These patterns were most prominent during the daytime. Analyses conducted for the West Midlands, using techniques from graph theory, also showed that streets that are estimated to be used more frequently experience higher burglary risk, but that graph theory estimates are more precise than the street segment classification method based on road type.
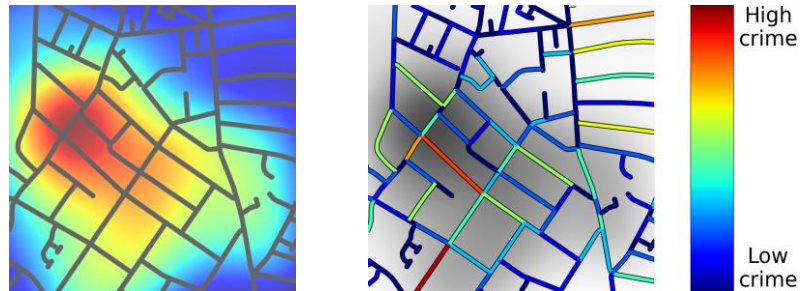
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## Street Networks and Risk: PURPOSE & THEORY (2 of 5)

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**Figure 1** Comparison of KDE and street segment analysis: risk varies considerably from street to street (right panel), but this is lost in a KDE 'heat map' (left panel).



The 'Hot Routes' JDiBrief describes how risky streets can be identified analytically. In this Brief, we discuss one reason why risk may vary between streets, and how such effects can be tested. We also describe further analyses that may inform crime prevention and operational policing.

**THEORY**: *Crime pattern theory* (CPT) is concerned with how people's routine activities (including those of offenders) influence crime risk. People develop routine activity spaces, and an awareness of them, as a result of travelling to and from the places they commonly frequent (*e.g.* home, work, and so on). For criminals, it is where their awareness spaces overlap with opportunities for crime that - according to the theory - they are most likely to offend. Consequently, in places where the awareness spaces of many offenders intersect with crime opportunities, crime hotspots will form.

The street network determines the routes that people can take between locations, and hence the places of which they become aware. Some routes (*e.g.* the shortest ones) will be more popular than others. Similarly, some street segments (sections of road between junctions) feature in routes more often than others: cul-de-sacs, for instance, are unlikely to feature in many. Since the level of use of a street reflects how often it features in offender awareness spaces, CPT suggests that more popular streets will experience more crime. Existing research supports this: the risk of burglary is highest on those streets most likely to feature in travel routes, and lowest on cul-de-sacs or private roads. Segment characteristics thus appear to provide a useful indication of the potential for crime.

Since neighbouring streets can be of significantly different character, patterns at this scale cannot be identified using traditional hotspot analysis approaches (*e.g.* KDE). Because of this, attempts at explanation and intervention may fail when these methods are used, and it is therefore necessary to consider approaches which account for street network effects. Put simply: since many crimes occur on the street, why shouldn't crime analysis focus on streets?

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## Street Networks and Risk: METHOD (3 of 5)

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**METHOD**: The first step in street segment analysis is to assemble street network data. In the UK, this may be obtained from the Ordnance Survey (OS), via the MasterMap product. OS also provides free Meridian data (see Figure 2), which, while not as detailed as MasterMap, may be sufficient in many cases. An alternative open data set is OpenStreetMap (OSM).

**Figure 2** Street network data for an example area obtained from: a) OS MasterMap (left panel); and b) OpenStreetMap (right panel).



If the analysis is concerned with the *risk* of crime, rather than its *count*, it is also necessary to estimate the number of potential targets on each street segment. In general, this is difficult, but appropriate choices exist for some cases: for crimes against households (*e.g.* burglary), for example, OS address point data can be used. OSM data may also be used, but it is important to note that, since it is generated by the public, it may be less detailed or complete than OS data.

Having assembled data, it is necessary to code the street segments using a Geographical Information System (GIS) to indicate their usage. This can be done in a number of ways, depending upon the aim of the analysis. One approach is to classify street segments in terms of whether they are part of a cul-de-sac or a through road. This is not usually indicated in street network datasets, so it may be necessary to classify segments manually, which can be time-consuming.

Street segments can also be classified in more detail. For instance, the OS differentiate between Motorways, A, B, Minor, Local and Private roads. A, B and Minor roads are those that people typically use to travel between neighbourhoods/towns, and that many people will regularly use. In contrast, Local and Private roads are typically used only to reach a particular residence, and are most likely to feature at the start/end of a journey. They are most likely to be known by residents.

A more sophisticated approach uses a branch of mathematics known as graph theory. In one such method, a calculation is performed to estimate how frequently each street segment is likely to be used by people travelling through the network. This is done by identifying the shortest paths between each pair of junctions. Street segments that feature in the largest (smallest) number of shortest paths are identified as those most (least) likely to be used and therefore known. This type of analysis can be conducted using, for example, the Urban Network Analysis package for ArcGIS.

Once the street segments have been classified, a GIS must be used to link the crime data to the street network data (see the 'Hot Routes' JDiBrief). The data can then be analysed to see if there is a relationship between crime and features of the network (*e.g.* segment classification), or to produce maps that show where research suggests the risk of crime might be highest.

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## Street Networks and Risk: CASE STUDY (4 of 5)

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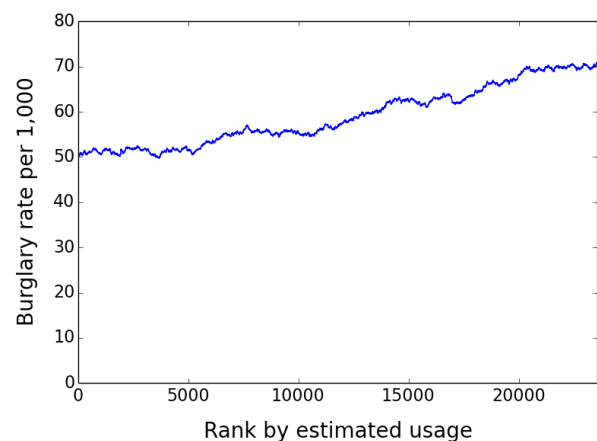UCL Department of Security and Crime Science

**APPLICATION**: Analyses for one policing area on Merseyside (UK) examined how the risk of residential burglary varied for cul-de-sacs and other types of road. Very clear findings emerged (see Table 1). More detailed analyses conducted using a sophisticated type of statistical model confirmed that these results could not be explained by other factors (*e.g.* levels of deprivation). It was also apparent that risk was higher on street segments that were more connected to others, and therefore potentially more likely to be used on journeys. Finally, additional analyses suggested that the differences in risk were more apparent during the day than at night.

| Burglary rate | A&B Roads | Minor Roads | Local Roads | Cul-de-sacs | Private Roads |
|---|---|---|---|---|---|
| **Overall** | **46.3** | **36.9** | **29.2** | **19.9** | **15.4** |
| *Day* | 63.9 | 49.4 | 32.5 | 24.7 | 23.4 |
| *Night* | 43.8 | 41.9 | 38.4 | 23.4 | 17.9 |

**Table 1** Rate of residential burglary by type of street segment (Johnson & Bowers, 2010, 2013)

In a second example, an analysis of residential burglary in the West Midlands used the graph theory approach discussed in the Method brief (as well as the Ordnance Survey (OS) road classification system) and found a clear association between crime risk and estimates of how regularly street segments were expected to be used by people.

**Figure 3** The relationship between estimated usage and crime risk: a) street network with segments coloured according to their estimated use; and b) (smoothed) average crime rate when segments are ordered according to this estimated use.



Interestingly, the research presented in the second example suggested that while the OS street classification used above (*e.g.* A Roads and Local Roads) was useful in the analysis performed, it is not always reliable. That is, in some cases roads that would be expected to be used more than others based on their description (*e.g.* an A Road) were actually estimated to be used less frequently using the graph theory approach, suggesting that the latter approach may be more reliable and offer further insight than the OS classification system. This may be particularly helpful in identifying and differentiating between those streets that have the highest *potential* for crime.

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**GENERAL RESOURCES**

- SANET: http://sanet.csis.u-tokyo.ac.jp

- GeoDaNet: https://geodacenter.asu.edu/software

- ArcGIS network analyst

- Urban Network Analysis: http://cityform.mit.edu/projects/urban-network-analysis.html

- NetworkX package for Python: http://networkx.github.io/

**DATA SOURCES**

- Ordnance Survey: http://www.ordnancesurvey.co.uk

- OpenStreetMap: http://www.openstreetmap.org

**A SELECTION OF ACADEMIC PAPERS AND BOOK CHAPTERS**

- Andresen, M. A., & Malleson, N. (2011). Testing the stability of crime patterns: Implications for theory and policy. *Journal of Research in Crime and Delinquency*, 48(1), 58-82.

- Davies, T, & Johnson, S.D. (2014). Examining the Relationship Between Road Structure and Burglary Risk Via Quantitative Network Analysis. *Journal of Quantitative Criminology*, Advance online access.

- Johnson, S. D., & Bowers, K. J. (2010). Permeability and burglary risk: are cul-de-sacs safer?. *Journal of Quantitative Criminology*, 26(1), 89-111.

- Johnson, S.D., and Bowers, K.J. (2013). How guardianship dynamics may vary across the street network: A case study of Residential Burglary.  In S. Ruiter, W. Bernasco, W Huisman and G. Bruinsma (Eds.) *Eenvoud & Verscheidenheid: Liber amicorumvoor Henk Elffers*. Amsterdam: Wrije Universiteit Amsterdam.

- Partridge, H. (2013). Hot Routes. JDiBrief Series. London: UCL Jill Dando Institute of Security and Crime Science. ISSN: 2050-4853. Available from www.jdibrief.com