

Exploratory spatiotemporal data analysis and modelling of public confidence in the police in central London

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Summary

Improving public confidence in the police is one of the most important issues for the London Metropolitan Police Service (Met). Public confidence varies over geographic space and changes over time. Spatiotemporal analysis and modelling becomes more manageable with a thorough understanding of the underlying spatiotemporal autocorrelation structure of the phenomena under scrutiny. In this study, exploratory spatiotemporal analysis is conducted on repeated cross-sectional survey data from the Metropolitan Police Public Attitude Survey. This confirmed the presence of second order nonstationarity in public perceptions of the Met police.

KEYWORDS: spatiotemporal autocorrelation, public confidence, police, kriging

1. Public Confidence and the Metropolitan Police

Improving public confidence in the police is one of the most important issues for the Metropolitan Police Service (MPS/Met). In fact, the Mayor's Office for Policing and Crime (MOPAC) and the Met have agreed to the goal of improving public confidence in the Met by 20% up to 75% by 2016 (Mayor's Office for Policing and Crime, 2013). However, MOPAC/ the Met are not on track to achieving this target (Mayor's Office for Policing and Crime, 2014a). Figure 1 is a time series graph of the percentage of Public Attitude Survey (PAS) respondents rating the police as "good" or "excellent" for the period October 2006 to September 2013. Superimposed (in red) is the trend line of the percentages required to achieve a 20% confidence increase by 2016.

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Time series plot of confidence in the police in London

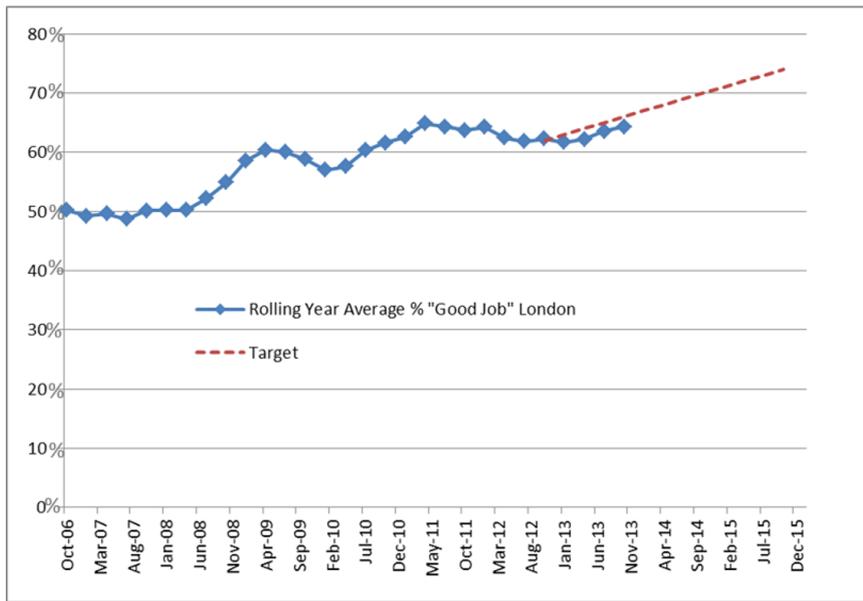


Figure 1 Trend line of confidence values per rolling quarter for London from October 2006 to September 2013 (blue) contrasted with the trend line required to meet the MOPAC target (red).

Current policy targets the improvement of public confidence at the aggregate level. However, to achieve this goal it is necessary to understand how confidence varies at the local level. Levels of confidence may vary throughout geographical space and change with time, and understanding these patterns is crucial to targeting improvement strategies. A local model based on the underlying spatiotemporal autocorrelation structure of public confidence may better model the heterogeneity in the phenomenon, and may also enable prediction of public confidence into the future. Examining the underlying spatiotemporal autocorrelation structure of public confidence is an important step toward this goal.

2. Spatiotemporal variability in public confidence

2.1. Description of the study area

London is the capital city of the United Kingdom. Located in the South-East region of England it consists of all the area within the M25 motorway over an area of approximately six hundred and seven (607) square miles. For administrative purposes London is divided into thirty-two boroughs. These boroughs are shown in Figure 2. Approximately 8.4 million people live in London.



Figure 2 Map of the thirty-two boroughs of London and the City of London.

2.2. Description of the dataset

The Metropolitan Police Public Attitudes Survey (PAS) has collected data on the experiences and perceptions of Londoners with respect to crime and anti-social behaviour since 1983 (Mayor’s Office for Policing and Crime, 2014b). The survey is conducted on a rolling basis whereby face-to-face interviews of approximately 100 persons per quarter are conducted.

At the borough neighbourhood level (two to three wards) confidence appears to be higher in West London, particularly South West London, although this trend becomes less apparent at lower levels of spatial aggregation. Figure 3 is a choropleth map of the percentage of Public Attitude survey (PAS) respondents rating the police as “good” or “excellent” for the period for the period April to June 2012. Darker color indicates greater confidence. This snapshot of confidence for the period April to June 2012 is an example of this tendency for more confidence in the west.

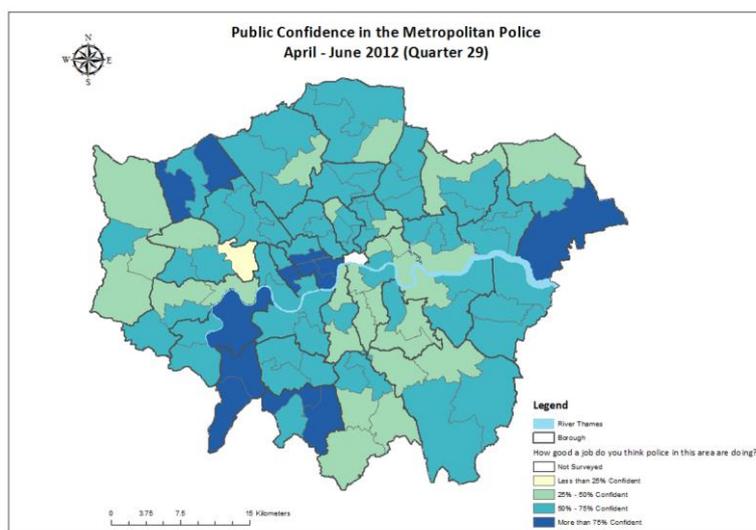


Figure 3 Choropleth map of confidence in the police April – June 2012.

2.3. Approach

Exploratory spatiotemporal analysis was conducted to understand the variations in confidence over the study period. The temporal, spatial and spatiotemporal autocorrelation structure of public confidence was examined using tools such as the autocorrelation functions (ACF), spatial, and spatiotemporal variograms. A progressive deepening approach was taken, such that the data was examined at different spatial and temporal resolutions. Table 1 provides some detail on the levels of aggregation used for each tool used.

Table 1 Spatial and temporal resolutions used for analysis

Tool	Temporal	Spatial
Time series	rolling quarter	London wide
ACF	rolling quarter	London wide
Choropleth Map	quarterly snapshots	Met borough neighbourhood
Variogram	quarterly snapshots	Met borough neighbourhood (centroids)
Spatiotemporal variogram	quarter	Met borough neighbourhood (centroids)

The temporal autocorrelation analysis was carried out using the ACF which measures the cross-correlation between observations of a series separated by temporal lags. The spatial autocorrelation analysis was measured using Local Moran's I and spatial variograms. The local Moran's I statistic is a local indicator of spatial association which allows significant clustering around individual locations to be discovered (Anselin, 1995). Variograms are powerful tools used to describe the autocorrelation structure of a dataset (Haining et al., 2010). Spatiotemporal autocorrelation analysis was conducted using the spatiotemporal variogram. This technique is less widely used and therefore warrants a more detailed explanation. The semivariance between all pairs of measurements is computed, the pairs grouped into bins according to the distance of separation and the average within each distance band is computed. For spatiotemporal variograms the semivariance is computed, as shown in Equation 1, for pairs of points at all spatiotemporal distances, where h is spatial lag, v is temporal lag, s is a point in space and t is point in time. As with the spatial variograms, these semivariances are grouped by spatiotemporal distance into bins and the average value per bin computed.

$$\gamma(h;v)=\frac{1}{2}E(Z(s,t)-Z(s+h,t+v))^2 \quad (1)$$

2.4. Findings

2.4.1. Temporal

Public confidence in the police exhibits weak temporal autocorrelation. The autocorrelation function plot below, figure 4, shows the amount of "relatedness" between confidence levels in London as a whole from 2006 to 2013. Figure 4 suggests that temporal autocorrelation exists for eight quarters with temporal autocorrelation strongest on the second lag with a value of +0.2.

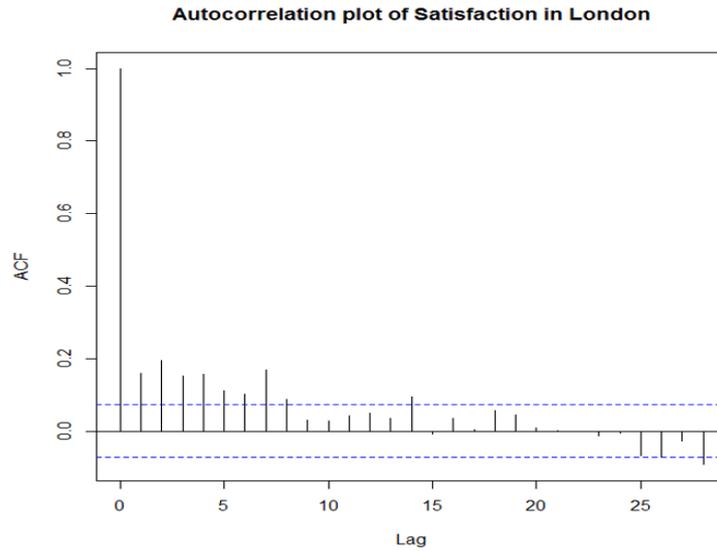


Figure 4 Temporal autocorrelation plot for London for the study period 2006 – 2013.

2.4.2. Spatial

Spatial autocorrelation levels varied considerably from quarter to quarter, with some quarters exhibiting no spatial autocorrelation at all. Figure 5, a variogram, describes the semivariance present for the period April to June 2012. The variogram is well structured with a clear nugget, sill and range. As expected, the variance between values increases as the distance of separation increases. Figure 5, suggests that the spatial autocorrelation tails off after approximately 7km.

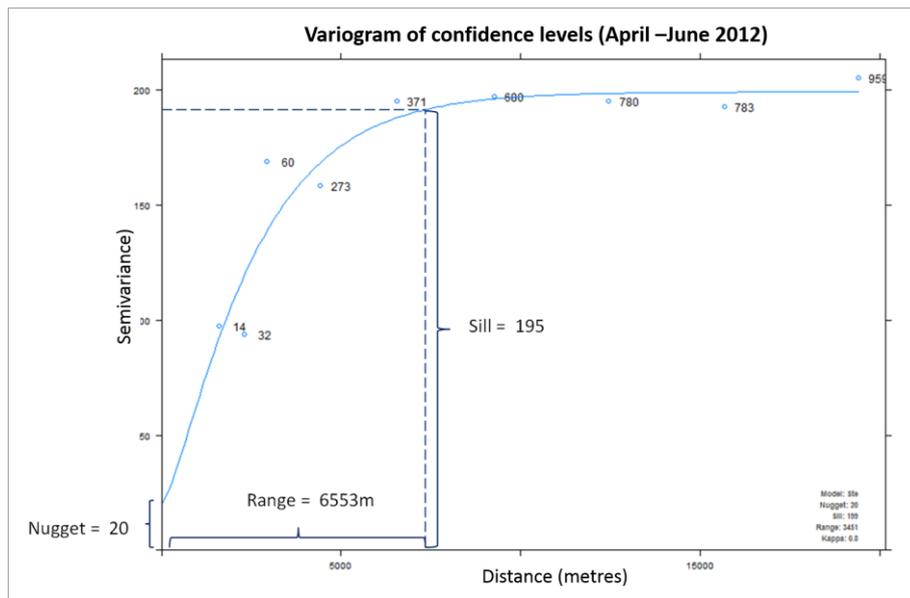


Figure 5 Variogram of confidence in the police April – June 2012

A local Moran's I test, Figure 6, confirmed the present of high-high clustering to the south-west in parts of Kingston, Merton and Sutton, as well as in some parts of west central London.

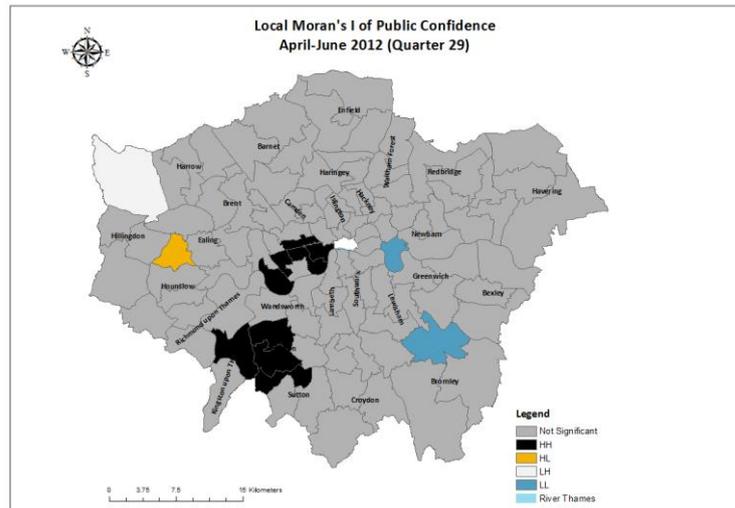


Figure 6 Local Moran's I map of confidence in the police April – June 2012

2.4.3. Spatiotemporal

As expected, spatiotemporal semivariance is smallest at lag zero and with variation increasing as the number of spatiotemporal lags increase. The strongest spatiotemporal autocorrelation occurs with the first and second spatiotemporal lags. In Figure 7, a 2.5 D representation of the spatiotemporal variogram, there is a clearer decomposition of autocorrelation in time (along the y axis) as opposed to space (along the x axis), especially apart from lag zero. This reflects the earlier finding of very weak temporal autocorrelation at the London-wide level.

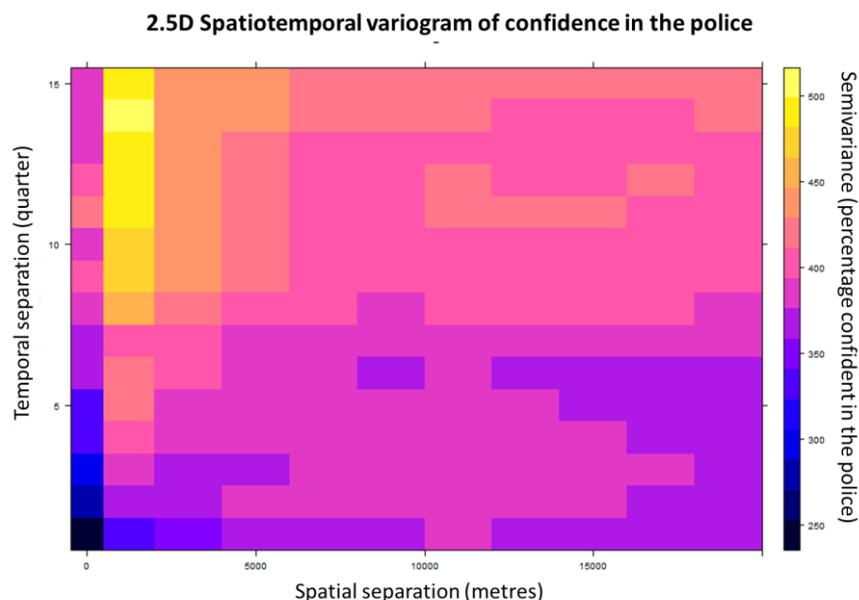


Figure 7 2.5D representations of a spatiotemporal variogram of confidence in the police

Spatiotemporal variability in the autocorrelation structure is visible in the 3D representation, Figure 8. The clear structure suggests that spatiotemporal autocorrelation is present. Particularly low semivariations can be seen at zero metres. This suggests that confidence of a borough neighbourhood can be confidently predicted for the next quarter, up to four quarters into the future. The presence of fairly low semivariance values up to 10,000 metres suggests that confidence values taken in one

borough neighbourhood can be used to improve predictions of confidence levels in areas up to 10,000 kilometres away.

3D Spatiotemporal variogram of confidence in the police

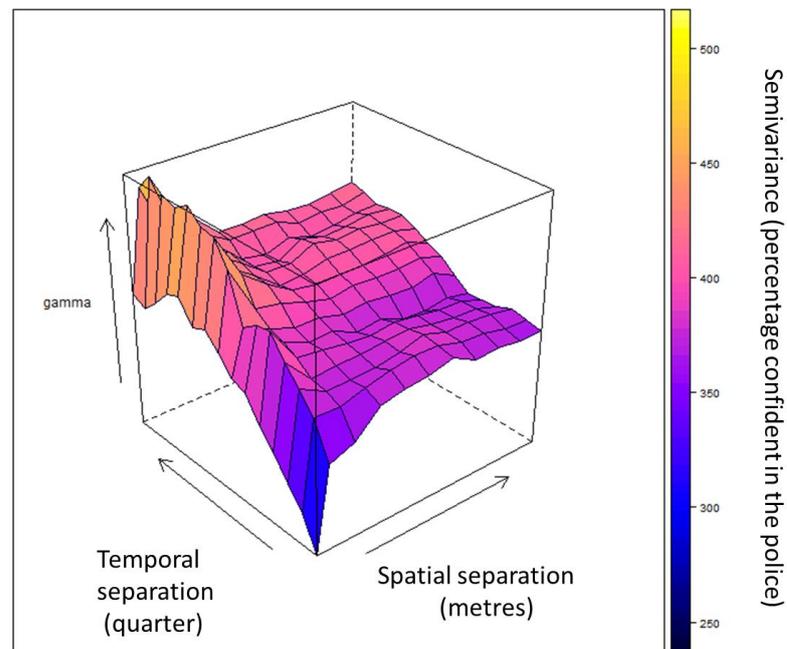


Figure 8 3D representations of a spatiotemporal variograms of confidence in the police

However, it should be noted that the sparsity of the survey data collected requires caution in interpreting these trends.

3. Conclusions

Exploratory spatiotemporal data analysis confirmed that public confidence in the police exhibits spatiotemporal heterogeneity and nonstationarity. Local models are preferable to global models particularly when modelling phenomena which are not stationary. The presence of spatiotemporal autocorrelation suggests that prediction of public confidence may be achieved. A model such as a local, dynamic spatiotemporal indicator kriging model may be able to achieve this. This model must be adapted to overcome the challenge of data sparsity. Various tools were used to examine the spatiotemporal autocorrelation structure of public confidence. Of the tools used the spatiotemporal variogram provided the most succinct picture of the autocorrelation structure and would be useful for parameterizing the model chosen.

4. Acknowledgements

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5. Biography

Dawn Williams is a member of the SpaceTimeLab for Big Data Analytics

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6. References

- Anselin, L., 1995. Local Indicators of Spatial Association—LISA. *Geogr. Anal.* 27, 93–115. doi:10.1111/j.1538-4632.1995.tb00338.x
- Fotheringham, A.S., 2009. “The Problem of Spatial Autocorrelation” and Local Spatial Statistics. *Geogr. Anal.* 41, 398–403. doi:10.1111/j.1538-4632.2009.00767.x
- Haining, R.P., Kerry, R., Oliver, M.A., 2010. *Geography, Spatial Data Analysis, and Geostatistics: An Overview*. 地理学、空间数据分析及地统计学：综述. *Geogr. Anal.* 42, 7–31. doi:10.1111/j.1538-4632.2009.00780.x
- Mayor’s Office for Policing and Crime, 2013. MOPAC Challenge Quarterly Performance Paper. Mayor’s Office for Policing and Crime.
- Mayor’s Office for Policing and Crime, 2014a. MOPAC Challenge Board: Confidence Transcript (Transcript).
- Mayor’s Office for Policing and Crime, 2014b. Public Confidence in Policing London: Public Attitude Survey (PAS) Frequently asked questions.
- Myhill, A., Bradford, B., 2012. Can Police Enhance Public Confidence by Improving Quality of Service? Results from Two Surveys in England and Wales. *Polic. Soc.* 22, 397–425. doi:10.1080/10439463.2011.641551