Violent Crime Hotspot Policing RCT

Data Analytics Lab

September 2023

This report provides a description of the design of a randomised control trial looking at the effect of additional patrols on violent crimes (with injury) in hotspots of those crimes and the results from an analysis of the resulting data.

1 Contents

2 Introduction

With increased pressure on public finances, it is imperative that police forces make the most of the resources they have available. This requires an understanding of the impact of policing activity, i.e. on levels of crime, so informed decisions can be made around the use of policing resources.

High visibility patrolling of crime hotspots is a common policing tactic, but the impact of these patrols is often unknown. To quantify the impact of these patrols on Violence with Injury (VWI) crimes, a Randomised Control Trial (RCT) was developed and deployed within the West Midlands. The project was funded by the Home Office via Project Guardian (West Midlands Police (WMP) Serious Youth Violence (SYV) team).

The RCT follows recommendations within the "Getting GRIP on Serious Violence Hotspots. A Report for West Midlands Police" document produced by the Cambridge Centre for Evidence-Based Policing (Sherman, Vickery, Rose, & Harinam, 2022). This document will be referred to as the "Cambridge report" for the rest of this document. The report outlines a six "T's" approach:

- Targeting
- Testing
- Tracking
- Tasking
- Training
- Technology

As part of the Home Office funding, multiple police forces are currently undertaking hotspot policing RCT's to tackle violent crimes and understand the impact of patrols. The Home Office are then collating the individual police forces' data and analyses to undertake a meta-analysis. Due to this, the general approach of the WMP RCT has followed the Cambridge report as recommended by the Home Office.

3 Literature Review

The College of Policing completed a review of previous hotspot policing research to create a hotspot policing toolkit, with best practice recommendations. This was primarily based around a previous systematic review (Braga, Turchan, Papachristos, & Hureau, 2019). It was noted that the majority of previous research explored (51 of 73) were from the USA and only 2 from the UK. Due to the geographical and social differences between UK and USA cities, this may mean that similar approaches have different results in the UK. Conclusions drawn from the review include:

- Crime tends to be concentrated in small areas across a geography (hotspots).
- Hotspot Policing has previously shown statistically significant reductions in overall crime. These reductions were most prevalent in reducing drug, disorder, property and serious violence offences, but the effect varies drastically across the literature.
- Randomised studies showed a smaller effect than quasi-experimental designs, but these were still statistically significant, showing a positive crime reduction effect.
- Previous analysis utilised parallel track experimental designs with some recent ones using cross-over designs.
- There is little evidence of crime displacement.
- A small but statistically significant diffusion of benefits (patrolling also reducing crimes in areas close to hotspots) (Weisburd, et al., 2006).
- Minor/conflicting evidence of residual effects from patrols. Anything from hours to multiple days. Previous studies on police crackdowns (short period of intense policing) showed a residual effect that lasted longer than the length of the police crackdown (Sherman L. W., 1990).
- For high visibility patrolling, a patrol length of 10-16 minutes was recommended, after which returns diminish (small hotspot size of street segment, from the USA) (Koper, 1995).
- Minimal previous cost/benefit analysis, with only 1 study identifying 5.6-23 Euros saved for every 1 Euro spent on patrols.

It is noted that hotspot policing is effective due to the deterrence and crime opportunity theories. The deterrence theory states that crime can be prevented when an offender perceives that the cost of committing a crime outweighs the benefits (risk). Hence by having more visible police officers patrolling, offenders will feel that there is an increased chance of being caught, so they are less likely to commit the offence (Braga, 2016). Crime opportunity is similar. Offenders tend to target high reward with little effort and risk. This is shown as three sides of a triangle, which if any are removed crime will reduce. These include offender, victim and location. Police patrols remove the location element.

4 Methodology

4.1 Targeting

A targeted approach was used for choosing the areas for the RCT, by using violent crime with injury hotspots. A spatial analysis was undertaken to identify areas which have been consistent hotspots over a long-time frame.

4.1.1 Data

Historical violence with injury (VWI) crime data including locations was used but was filtered to remove:

- Domestic abuse
    - Primarily inside residential homes, high visibility patrols likely to have minimal effect so removed.
- Violence against emergency workers and care home staff
    - As violence against police officers can only occur where police officers have previously patrolled. These crimes were removed as we wanted to remove previous decision making on where to patrol in the analysis.
    - Violence against care workers removed as these would primarily occur inside care homes, which high visibility patrolling would have minimal effect upon.

Between 1st Jan 2019 and 30th Sept 2022 (45 months), in the WMP area, there have been an average of 62.9 violence with injury crimes a day, with an average harm of 46,444 (Cambridge Crime Harm Index, CCHI). The CCHI is based on the number of days of the starting point sentences for each crime type (Sherman, Neyroud, & Neyroud, 2016).

Assessing the breakdown of violence with injury type crimes in Figure 1, it can be seen that 'Assault with Injury - s.47 - Assault occasioning actual bodily harm' is the most common offence at over 57%. Due to this crime's low harm (183 per crime), when we look at the proportion by harm, we get a different primary offences of 'Assault with Injury - s.20 - Malicious wounding: wounding or inflicting grievous bodily harm' (44.7%) and 's.18 - Assault with Intent to cause Serious Harm - Wounding with intent to do grievous bodily harm' (31.1%). This is due to their much higher harm values of 1,825 and 1,460 each. A detailed breakdown is in Appendix A – Historical Violence with Injury Crimes.

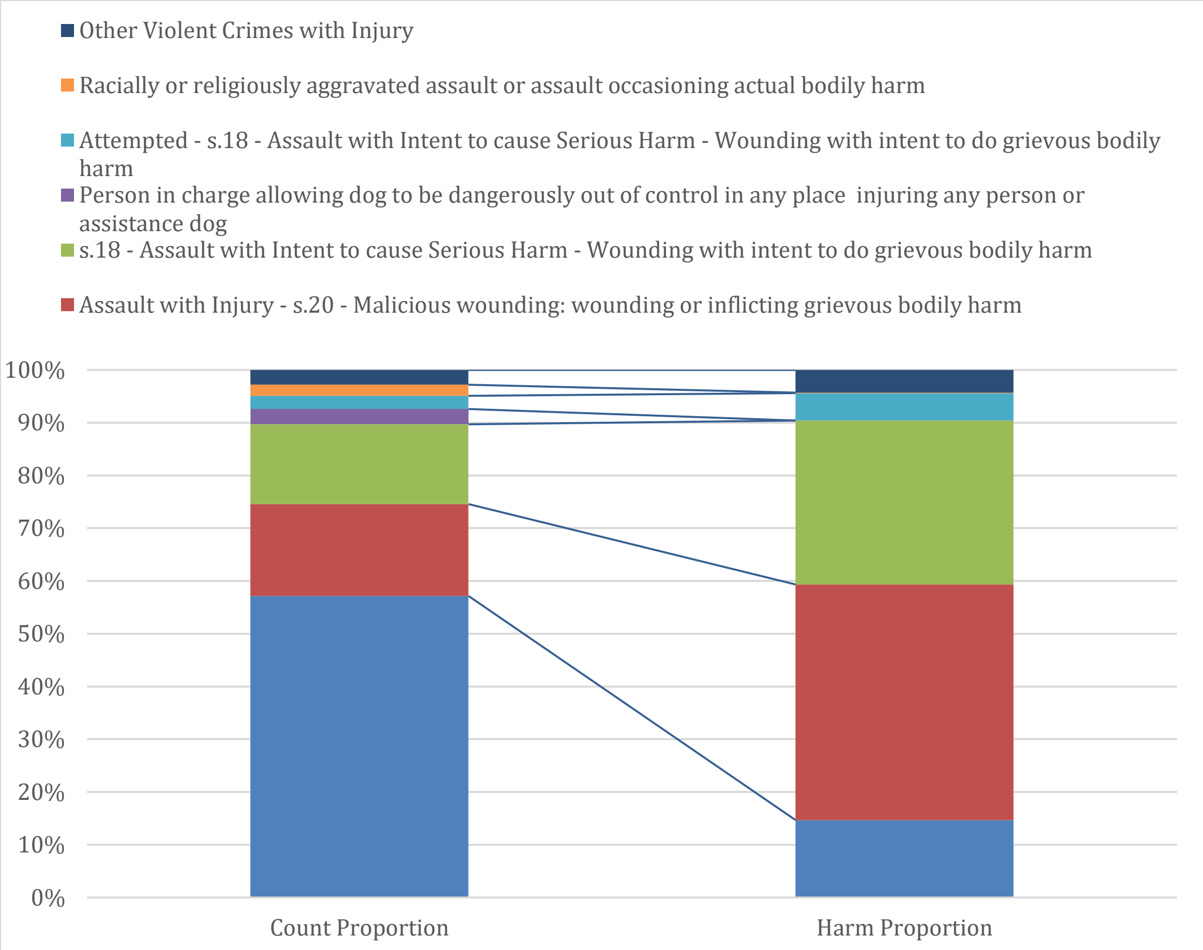


Figure 1: Historic Violent with Injury Crimes Proportions

4.1.2 Hotspot Identification

A point pattern-based approach was used. The reason for this is discussed in Appendix B – Hotspot Identification: Point Pattern vs Area Based. To highlight hotspots within the crime point pattern a quartic Kernel Density Estimation (KDE) was used. To ensure detailed hotspots a small grid of 10m x 10m squares was used. This resulted in 5318 x 3504 (9,019,018 squares) to cover the WMP area. A small sigma of 100m, as seen in Figure 4, was used to ensure small hotspots were identified. For city centres (very large hotspots), an even smaller sigma of 50m was used to delineate them into multiple smaller hotspots. Multiple maps were created to assess different aspects, including:

- Monthly maps, to assess if hotspots were consistent over longer time periods.
- Excluding night time crimes (8pm-5am). This was done as neighbourhood resource was going to be used, which tended not to work overnight. Hence it was desirable to remove hotspots that only existed at night.
- Serious Youth Violence (SYV) only (victim under 25). This project was funded as part of WMP Project Guardian, an initiative to reduce SYV. So, it was important to ensure that hotspots chosen also included SYV.

With hot areas (areas of high crime) identified, these then needed changing into patrol areas. This was done by manually assessing the hot areas and making decisions of the area's applicability to the project as well as possible boundary lines. These decisions were made with local officers to bring in local knowledge and expertise. Some hot areas were ignored due to aspects such as:

- Hotspots created by singular property i.e. pubs and clubs, hospitals, care homes and police stations
- Temporally inconsistent
- Night only
- Existing policing plans for the area existed

Boundary lines, such as in Figure 5, were drawn with the input of local officers. The boundaries were drawn to; maximise the amount of crime, minimize the size of the area but ensure it has a logical patrol route (i.e. minimise time of officers having to come back on themselves).

57 hotspots where taken forward into the RCT, with varying sizes (mean of 0.22km^2, 0.02-0.61km^2) and geographies (city centre/high street/residential/road and public transport links).

The final hotspots consist of only 1.4% of the WMP area but 16.9% of violent crimes with injury (April-21 to Sept-22) and 18.6% of the harm. For Serious Youth Violence specifically it is 17.2% and 18.7%, and blades causing injury it is 19.3% and 19.6%. Looking at crime intensity, measured as number/ harm of crimes per km^2, it can be seen that the hotspots are around 15x more intense than outside the hotspots. These hotspots and their locations across the west midlands can be seen in Appendix C – Map of Final Hotspots.

4.1.3 Hotspot Exploratory Data Analysis

As violence with injury crimes are not common, the central level of the number of crimes per day across the hotspots was only 0.13, as seen inTable 1. This also meant that there is an excess of zeroes in the count data, with 85.92% of hotspot days having no crime recorded. Also, multiple crimes on the same day in a hotspot was unlikely with only 0.91% of hotspot days having more than two crimes.

The counts of violent crimes per day per hotspot were shown to strongly follow a negative binomial distribution (Poisson not ideal due to data dispersion). This was the case for the hotspots individually, and all together. Zero inflated distributions were tested but did not improve results, see Table 2. The fitted negative binomial distributions mu values are equivalent to the mean number of crimes per day. The use of the negative binomial allows the distribution to fit the heavily right skewed data, as shown in Figure 2.

By converting all crimes to their harm, we obtain a semi-discrete dataset of 71 different values varying from 0 to 9,490. The harm dataset still has the same percentage of hotspot days with no crime recorded; in the resultant histogram shown in Figure 3, it can be seen that the semi-discrete dataset with an excess of zeroes is also multi-modal.

Table 1: Hotspot Crime Levels

	Crimes per Day across Hotspots		
Metric	Min	Median	Max
Number of Crimes	0.02	0.13	1.02
Harm of Crimes	12.44	101.84	916.63

Table 2: Hotspots daily crime count distribution fits

Distribution	AIC (mean)	Accuracy (Mean)
Poisson	535.50	93.49%
Negative Binomial	517.02	99.32%
Zero Inflated Poisson	519.51	99.03%
Zero Inflated Negative Binomial	517.02	99.32%
Note: Mean Fits across all 57 Hotspots		

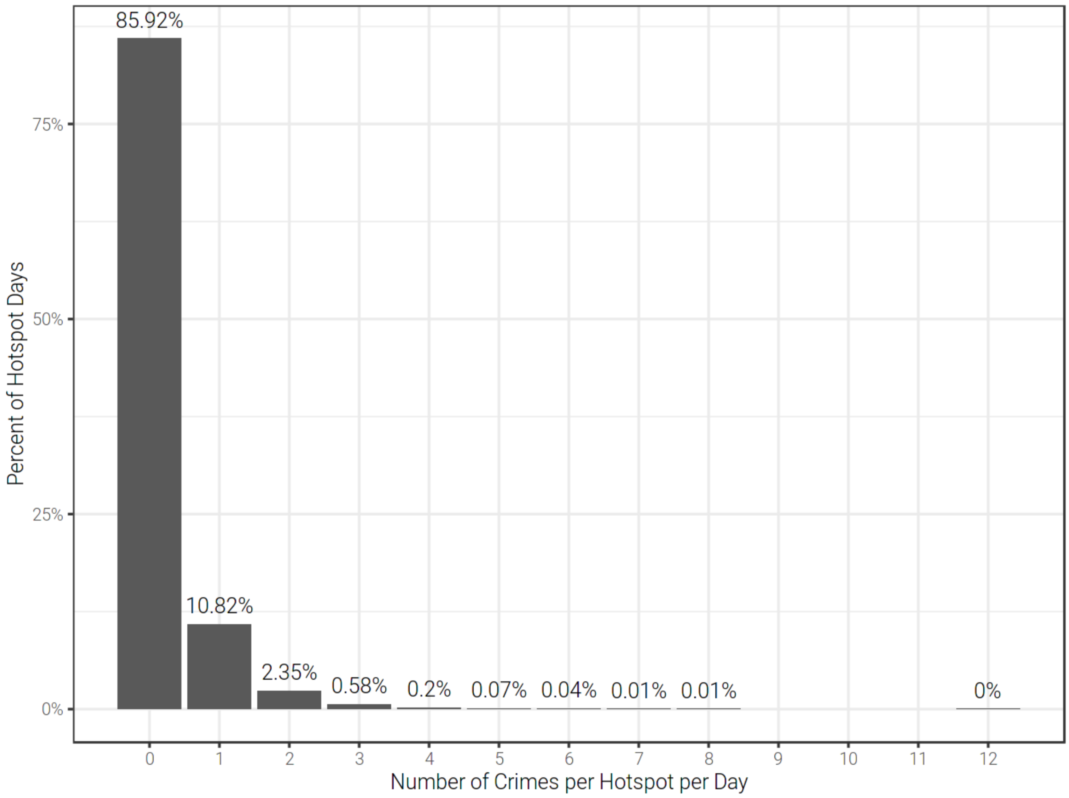


Figure 2: Histogram of historical counts of crime per day per hotspot

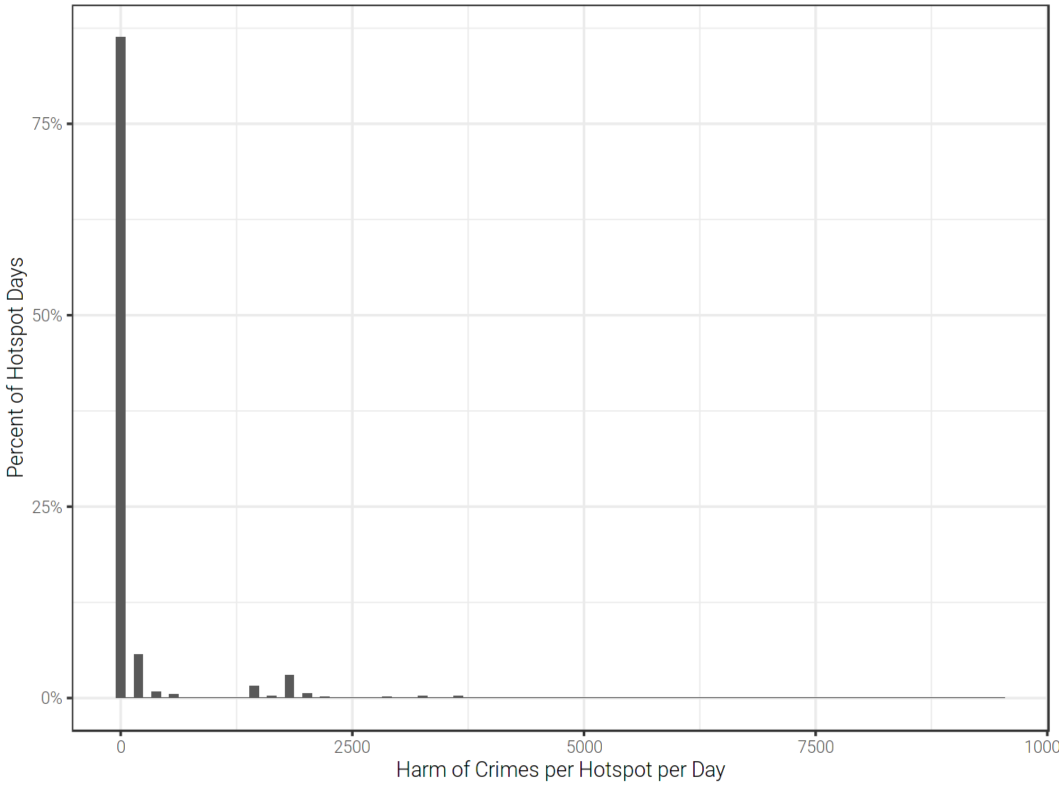


Figure 3: Histogram of historical harm of crime per day per hotspot

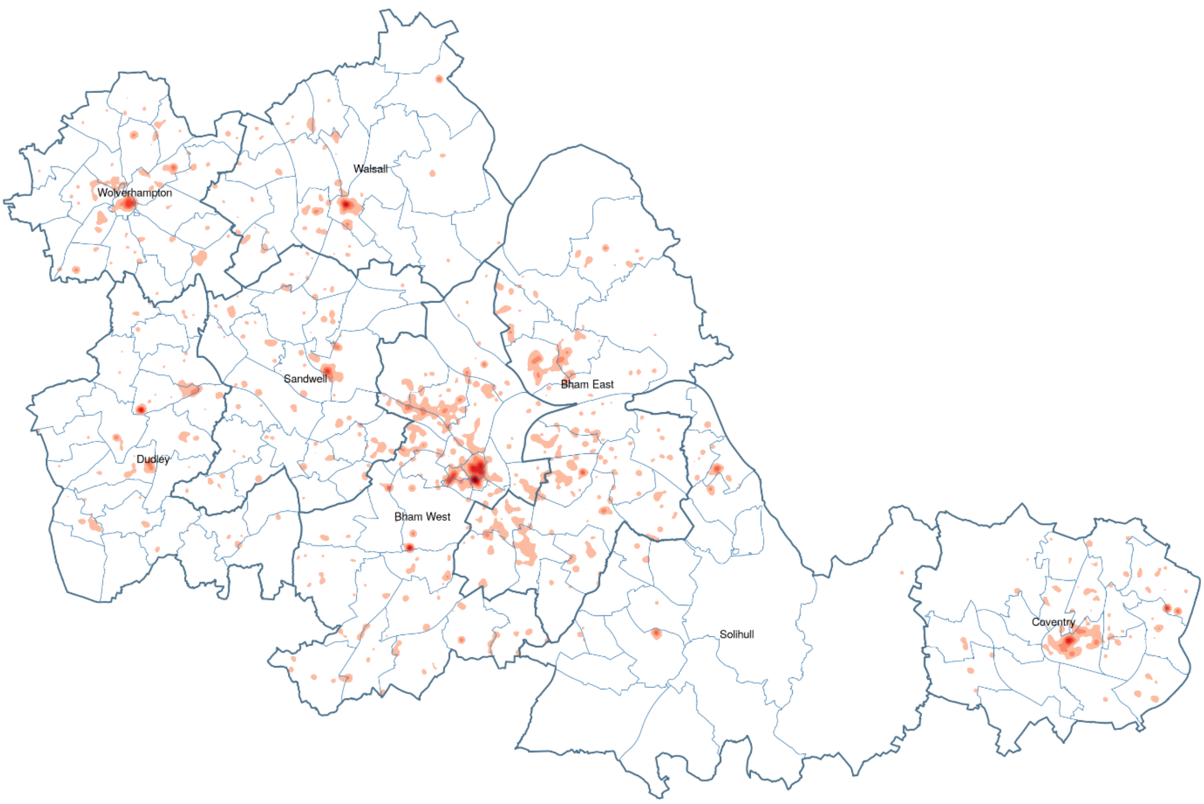


Figure 4: Quartic Kernel Density Estimation of Violent Crimes with Injury (Sigma; 100m)

Figure 5: Hotspots Identified using KDE -> Sensible boundary drawn

4.2 Tasking

The expectations of the patrols were set as:

- High visibility foot patrols (police uniform)
- Patrol whole hotspot (or as much as time allows)
- Undertake normal policing activity following existing laws and guidelines, i.e. stop and searches, collection of intelligence reports, community engagement.
- Patrols should be led by police officers (instead of PCSOs). This was due to the additional powers police officers have (i.e. stop and searches and arrests).

Due to resource limitations, it was not possible to have a dedicated hotspot policing resource, so the project relied on local policing overtime instead. This has led to some patrols being missed due to lack of resource availability.

To increase compliance of the RCT plan being followed, it was decided to share the entire patrol plan set out in this document with the local policing units well in advance of the RCT starting. This improved buy-in and allowed more time for planning shifts and overtime.

As the hotspots chosen were different sizes and different geographies (i.e. city centre or residential), they had differing lengths of time that they would take to patrol. Due to this the hotspots were split into two time groups; small and large, using a combination of hotspot size and estimated patrol times obtained from officers. The small group had patrol lengths of 20 mins and 35 mins, whereas the long group had 35 mins and 50 mins. With 35 mins crossing the groups. Based on the hotspot sizes and using information from the local policing leads, time groups were chosen for all the hotspots with a final split of; small, 22 hotspots (38.6%) and large, 35 hotspots (61.4%).

To test the impact of the time of day of the patrol, it was decided to have two groups; early and late. Time groups were used instead of exact times as this gave more control to local policing units. It was thought this would help enable higher compliance of the RCT plan being followed as it allowed local units to choose patrol times in-line with officer availability. As violent crime is uncommon in the morning it was decided to not start patrols until 11am. Due to using local policing units who work limited hours, it was not possible to do patrols in the middle of the night, so a finish time of 9pm was chosen. This gave two 5 hour groups of early (11am-4pm) or late (4pm-9pm).

4.3 Testing

To assess the impact of patrols, it was required to track violent crime occurrences within small geographical areas, in which the patrols would happen (the hotspot policing). Patrols that formed part of the RCT were in addition to the existing business as usual (BAU) policing activities in the hotspots.

4.3.1 RCT Experimental Design

A cross-over design was used, meaning that each area acted as its own control. This follows the recommendation within the "Cambridge Report" (Sherman, Vickery, Rose, & Harinam, 2022). Cross-over designs have many advantages to parallel track, especially in policing where parallel track would involve purposely not undertaking additional patrols in known crime hotspots. The control days had no additional patrols (BAU activity still happening) whereas the treatment days had one additional patrol, with varying times of day and time lengths of patrol. The cross-over design ensures geographical and social similarities within the comparable control and treatment datasets. The primary disadvantage of crossover is the impact of residual deterrence, where the impact of a patrol may last multiple days and hence be affecting the BAU days.

To maximize available data for the primary question of the impact of a patrol, the number of days in the RCT were split 50/50 into treatment days (additional patrol) and control days (BAU) for each hotspot. The split between early and late patrols was also made 50/50 for each hotspot. This gives 50% of days as BAU, 25% as an additional early patrol and 25% an additional late patrol. For the patrol lengths each group was split 50/50, so the small group of 15 mins and 35 mins is split 50/50, as is the large group of 35 mins and 50 mins.

The crossover design, as seen in Table 3, was randomised within the percentage splits.

Table 3: Crossover Design Patrol Plan Example

Hotspot Number	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day ...
1	No	No	No	Yes	No	Yes	No	...
2	Yes	Yes	No	Yes	Yes	No	Yes	...
3	Yes	Yes	No	No	No	Yes	Yes	...
...	...	...	...	...	...	...	...	...

With the experimental design chosen, it was required to understand the required length of the RCT to obtain enough data to analyse. There are many approaches to ascertaining experimental (sample) sizes based on expected effect sizes (in this case, the impact of patrolling). Due to the high skewness (not symmetrical), common statistical approaches based on standard deviations and/or normality are not applicable. This included effect size calculations of Cohens d, Hedges g and glass's delta and using z-test, t-tests and ANOVA for sample sizes and power. Many non-parametric variations for effect sizes were also not applicable, due to the use of the MAD statistic instead of standard deviation. As over 75% of the data are zeros, MAD is equal to zero. Also, rank based approaches such as Mann-Whitney and cliff's delta for the effect size had issues due to the ranks between datasets being equal for the first 85%+, due to all the zeros.

Due to issues with the more commonly found approaches, to understand the probabilities of obtaining notable results from the RCT a simulation approach was used instead. For different levels of crime reductions (as a percent), the control and treatment datasets have been sampled. The distribution of the control dataset, is presumed to be in line with the historical data (BAU) (mu = 0.164, size = 0.320). The negative binomial for the treatment datasets, had both parameters reduced by some reduction percentage (note, the decision to reduce the size parameter had no effect on the results, see Appendix D - Impact of Negative Binomial Size Parameter). 5,000 simulations were undertaken for each reduction percent tested, for each expected number of samples from the RCT. For treated vs control, in a 3 month RCT there would be 2622 samples (hotspot days) in each group (3 months = 92 days x 57 hotspots = 5244 x 50% = 2622). Early patrol compared to late patrol would have 1311 samples in each group (5244 x 50% x 50% = 1311). For each simulation a negative binomial GLM was fitted, with intercept and group, i.e. control vs treatment or early vs late, parameters. The group parameter was recorded from each simulation. See Figure 6 for a graphical representation of the process (for treated vs control, 2622 sample in 3 months). The power is defined as the probability that a true reduction of x would be seen within the sample size. Power is calculated as the percentage of negative group coefficients from the simulations within each reduction percentage. The full range of group coefficients for each reduction can be seen in Appendix E – Results of Experimental Design Simulations, where the percent of the group parameter distributions to the left of zero is the power. Graphing the power calculated against the reduction percentages, as seen in Figure 7, allows us to estimate the crime rate reduction required from the treatment to obtain noteworthy results from the 3 month trial.

For treatment vs control the impact of the extra patrol to reduce crime rates by at least 7.00% would have been required to have an 80% probability (power) that we will obtain a negative coefficient in a negative binomial GLM from our 2,622 samples per group. For late vs early (1,311 samples each), the difference in rates would have to be more than 9.79% (higher reduction required due to smaller datasets).

Taking into account the confidence intervals of the group coefficient from the fitted negative binomial, we obtain Figure 8. For each simulation, the fitted model group parameter's 90% confidence interval (CI) is recorded with the estimate. For example, the group parameter estimate could be -0.126, with a 90% CI of [-0.273, 0.019] in a simulation. This shows us that the group variable estimate is negative (extra patrol reduces crime rate), but the 95% confidence interval crosses zero, so we cannot say with 95% confidence that the extra patrol reduced crime. Assessing the reduction required for difference power levels, as expected, we see that the 95% confidence results require larger crime rate reductions compared to just using the estimate (50% confidence). So we can say that, to obtain 80% power, with 50% confidence we would need a crime rate reduction of 7.00%, whereas for 95% confidence we would need a true crime rate reduction of 19.96%.

These results gave a general idea of the possible results from the RCT and gave confidence that notable results should be obtainable from a 3 month trial, with 57 hotspots, with the plan outlined earlier in the document.

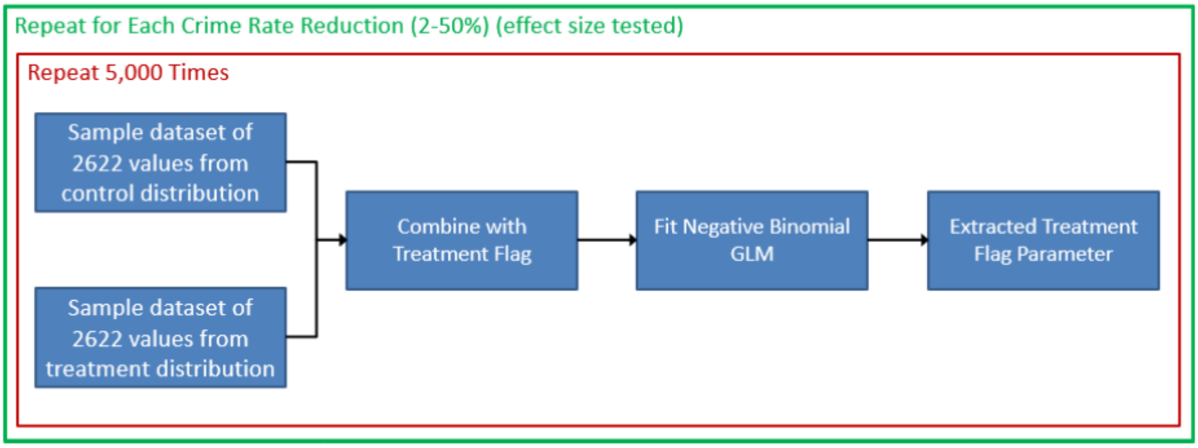


Figure 6: Process for estimating the required length of the RCT based on a range of possible crime reductions (effect sizes)

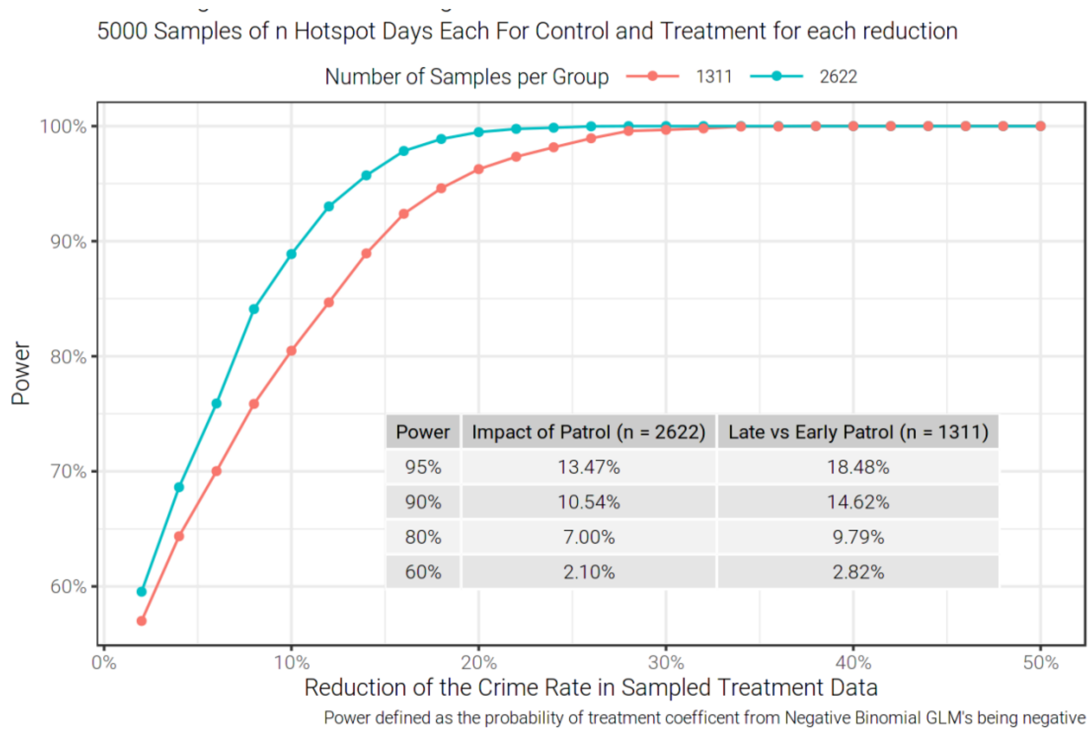


Figure 7: Summarised results from process for estimating the required length of the RCT based on a range of possible crime reductions (effect sizes)

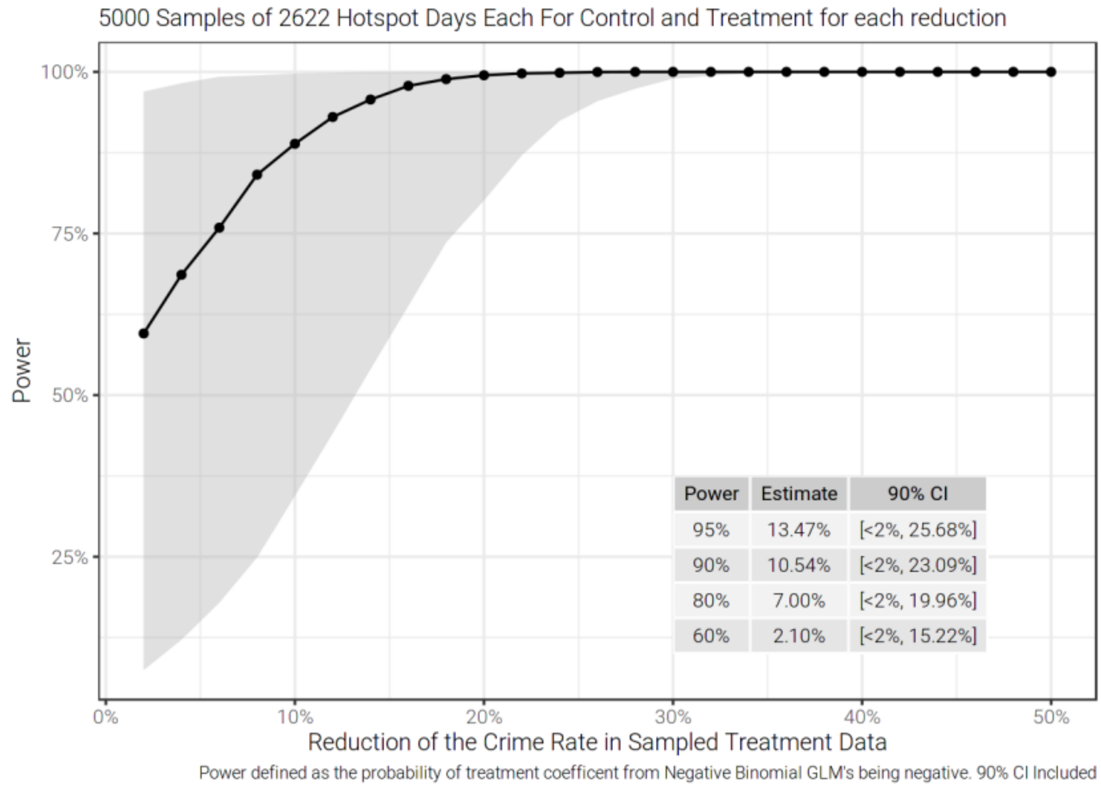


Figure 8: Summarised results with CI from process for estimating the required length of the RCT based on a range of possible crime reductions (effect sizes)

4.4 Training

As hotspot policing is not a new idea, many involved in policing were already aware of the approach. Local policing leads were involved in discussions all the way through the RCT design process. This ensured all involved understood the aims of this project, increasing buy-in. It is expected that this made the trial more successful (in terms of being able to gain compliance and so maximise information). Officers were briefed on the expectations of the patrols (high visibility foot patrols, which cover the whole hotspots), which is similar to their BAU patrols.

4.5 Tracking and Technology

There was a desire to have a mobile app available on police officer devices for the checking in/out of hotspot patrols (officer tracking), as well as recording activities like stop and searches undertaken. Due to IT limitations, it was not possible to produce this app in time for the start of RCT. Due to this, local policing leads recorded the patrols in an excel spreadsheet. This included; collar numbers (police officer ID's), hotspot and time arrived and left.

Later in the project the excel returns were replaced by a mobile app which geolocated the officer when the patrol started and ended and allowed capturing of information such as number of stop and searches undertaken. The other major advantage was automation. The app reduced the admin burden and allowed patrols that happened yesterday to be processed the next day and made available to everyone involved. No need to wait for submission and cleaning of excel files. This enabled local leads to better manage their officers.

Airwaves (officer GPS data), was used to confirm the patrols (i.e. that they were around the location of the hotspot at the times recorded). An example of this can be seen in Figure 9. Due to some gaps in airwaves data, if it was not available to confirm a patrol then the patrol was confirmed anyway, as there was no evidence to disprove the officer's patrol submissions. The tracking of the RCT compliance was available for all via a dashboard, and regularly checked by local leads to ensure high compliance. The compliance was reported internally as a KPI and discussed at all levels of the force.

Regular meetings were set up with local policing officers. In these meetings, the tracked compliance was reported and any issues discussed. This constant, open communication with the local policing leads, ensured any issues were dealt with quickly.

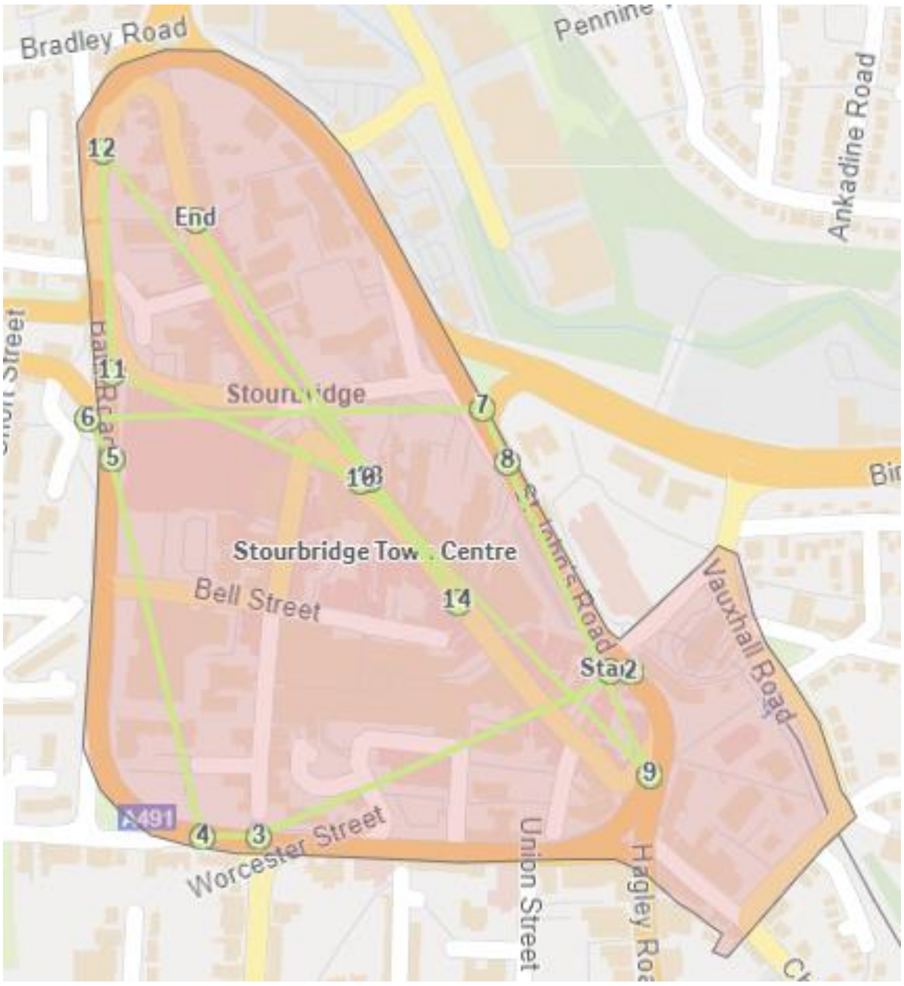


Figure 9: Example of Airwaves tracking of a patrol

4.6 RCT Compliance

Due to compliance not being 100%, the RCT was extended past the 3 months initially designed to obtain the required number of samples (a 2 month extension was required). There was an opportunity to further extend the RCT, which was taken, as it was thought the additional data would be worth it. The full RCT ran between 3rd Oct 22 and the 30th Apr 23 (210 days, 11,970 hotspot days). In total 4,425 patrols were completed, giving a final compliance of 74%. This meant that around 37% of the hotspot days had an additional patrol. This aligns with the Home Office recommendation of circa 1 in 3.

The primary reason reported for poor compliance was lack of resource availability. This was mainly due to major incidents, bank holidays and periods of low overtime pickup.

Utilising airwaves, it is also possible to show the increase in police presence on the additional patrol days. Using a simple metric of; number of airwaves pings (location points), in each hotspot, on each day from Neighbourhood resources (resources doing the patrols and BAU). This showed a 29% increase in Airwaves pings on additional patrol days compared to BAU days.

The patrol compliance was fed back to the Home Office as evidence of Guardian funding spend. Feedback from the Home Office has been very positive about how the RCT was designed and ran, as well as the quality of the returns.

The data for time length of a completed patrol has not been confirmed as the time gap between airwaves data was too large (pings were not made by the system frequently enough to sit within the targeted patrol time lengths). Also, the reported value was often very different from the patrol length in the plan. Due to this, it has been decided, despite it being included in the RCT experimental design, we do not have enough confidence in the data to draw meaningful conclusions as to the effect of patrol length of time.

4.7 Summary

57 Hotspots chosen for additional high visibility patrols. These consisted of 1.4% of the WMP area, but 16.9% of VWI crimes and 18.6% of their harm. Hotspots identified were small, with a mean area of 0.22km^2 (0.02-0.61km^2). Hotspot geographical properties varied but included; city centres, high streets and shopping centres, interchanges and residential.

A cross-over design was chosen with 50% of hotspot days having an additional patrol. Based on the expected level of crime reduction and the results from the simulations, it was decided that 3 months of patrols, would be enough data to perform the analysis.

Reported patrols were confirmed using Airwaves data. Due to compliance not being 100%, and the opportunity existing to obtain more data, the RCT was extended from 3 months to nearly 7 months. The final compliance was 74% (37% hotspot days had an additional patrol).

5 Results – Additional Patrol vs BAU Days

Data collected for each day for each hotspot was:

- Whether an additional patrol occurred
- The time the additional patrol occurred and for how long
- Information about officers involved in patrol
- Number of VWI crimes that occurred
- Total harm of the crimes

For the number of VWI crimes that occurred, the same filters (non-DA, etc.) were used as described earlier. Additionally, crimes reported by police were removed because if the patrol had not occurred the crime may not have been reported (the more police presence, the more reported crime).

The total number of completed patrols was 4,425, leaving 7,545 BAU hotspot days in the dataset. The number of days between additional patrol days had a median of 1.0 and a mean of 2.04

Assessing the averages between days with and without the additional patrols, seen in Table 4, we can see that:

- 6.98% reduction in the percentage of days with a crime
- 5.27% reduction in the number of crimes per HS day
- A larger reduction in the harm per HS day (17.34%)
- 12.74% reduction in the severity of crimes (harm per crime)

To further assess the results, bootstrapped means with 90% and 80% confidence intervals have been compared.

Based on experience and previous research, weekday and new years (eve and day) have been assessed. The results can be seen in Appendix F, where it can be seen that both weekday and new years have a large effect on the amount of crime.

Assessing the impact of the additional patrol flag in Appendix F, it can be seen that there is quite a lot of overlap between the means confidence intervals, showing that on average additional patrols have reduced crime within the sample, but possibly not the population.

Comparing averages could however be misleading as they do not take other factors into account (only assessing one aspect at a time), nor do the distribution of crimes / day (which are skewed) strictly speaking have a central tendency, hence modelling approaches have been utilised. Modelling also allows for control for the hotspots and is better suited for the distributions seen in the data.

Table 4: Comparing Additional Patrol Days to BAU

Hotspot Day Activity	Num	Num Crimes per HS Day	Pcnt HS Days with a Crime	Harm per HS Day	Harm per Crime
BAU	7545	0.151	11.93%	63.75	420.80
BAU + Additional Patrol	4425	0.145	11.10%	52.70	367.21
Change		-0.008	-0.83pp	-11.05	-53.59
Pcnt Change		-5.27%	-6.98%	-17.34%	-12.74%

5.1 Additional Patrol Flag Modelling

Due to the number of crimes per hotspot day following a negative binomial distribution, it was decided to use the negative binomial (log link) generalized linear model (GLM). Due to the design of the experiment, a mixed effects (hierarchical) model was used with hotspots as the random effect. Bayesian modelling has been utilised so credible intervals could be calculated (from the drawn posterior) to understand the possible range of answers. As the weekday and new years were shown to have a large effect on the response, it was decided to include these in the model. Also, due to compliance issues when running the RCT, different weekdays ended up with difference compliance levels. Including weekday allows the model to take this into account. Weakly informative priors were used. The final model used can be described as:

$$y = NB(\mu_i, \pi_i)$$

$$log(\mu_i) = a + \boldsymbol{x\beta}$$

$$\pi_i \sim exp(1)$$

$$a \sim N(0,2.5)$$

$$\beta \sim N(0,2.5)$$

Where:

$\boldsymbol{x}$ = Additional Patrol Flag + Weekday + New Years Flag + (1 | Hotspot)

Where weekday is modelled as a factor (one hot encoding) and new years and additional patrol flag were flag columns (0 or 1).

For shortness, with the log link of the negative binomial:

ln(crimes) = patrol + wday + ny + hs

crimes = exp(patrol + wday + ny + hs)

Hence, isolating the impact of the additional patrol flag

Patrol impact [%] = exp(patrol) - 1

The weakly informative priors were:

Intercept: Normal(0, 2.5)

Coefficients:

Additional Patrol Flag: Normal(0, 5.2), scaled from Normal(0, 2.5)

Weekday: Normal(0, 7.1), scaled from Normal(0, 2.5)

New Years Flag: Normal(0, 25.7), scaled from Normal(0, 2.5)

Reciprocal Dispersion: Exp(1)

Checking the model fit we get a root means square error (RMSE) of 0.4537 and mean absolute error (MAE) of 0.2431. The predicted model mean number of crimes per HS day was 0.146 which was very close to the actual. The model fit can be assessed using posterior predictive checks. These are graphically shown in Appendix F, where it can be seen that the predictions surround the actual mean.

The resultant posterior distribution for the additional patrol flag can be seen in Figure 10 and Table 5. From this it can be seen that there is an 86.6% probably that the additional patrols had a positive effect (in that they reduced crime). The mean of the coefficient was -0.0647, due to the model type this means that, exp(-0.0647)-1 = -6.265% reduction in the number of crimes per hotspot in a day if an additional patrol was undertaken.

As a percentage reduction is estimated, this means that the higher the crime in a hotspot, the larger the benefit is expected to be (number of crimes stopped). Due to this there will be a point where a hotspot is not hot enough (the crimes per day are too low) to warrant doing additional patrols.

The other parameters are seen in

Table 6, where it can be seen that Saturday and Sunday are higher than Friday (left out of model, so this forms the baseline). This is primarily due to Friday and Saturday nights crime often occurring early on Saturday and Sunday. New years is shown to cause a large increase (37.7%) over other days in the year.

Table 5: Patrol Flag Model Additional Patrol Flag Coefficient Result

Parameter	Mean	SD	Probability less than zero	Min	P25	Median	P75	Max
Additional Patrol Flag	-0.0647	0.0586	86.6%	-0.2908	-0.1039	-0.0650	-0.0260	0.1408

Table 6: Patrol Flag Model Other Parameters

Model Feature	Model Coefficient	Impact	Compared to
Monday	-0.2552	-22.5%	Friday
Tuesday	-0.2967	-25.7%	Friday
Wednesday	-0.2499	-22.1%	Friday
Thursday	-0.2870	-25.0%	Friday
Saturday	0.3555	42.7%	Friday
Sunday	0.1560	17.3%	Friday

New Years (Day and Eve)	0.3200	37.7%	Non New Year Dates

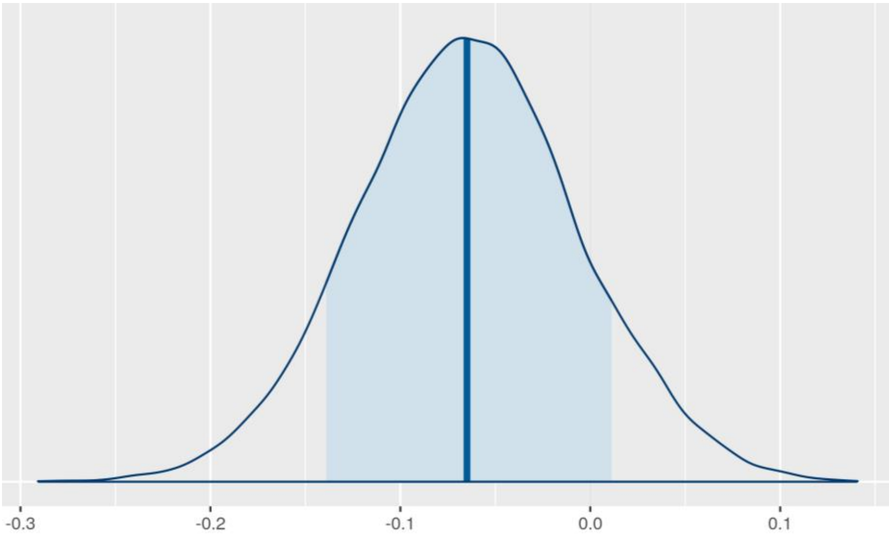


Figure 10: Patrol Flag Model Posterior Distribution, with 80% Credible Intervals

To assess at what level of crime the patrols are worthwhile undertaking, the government Cost of Crime analysis has been used (Home Office, 2018) with information about the average cost to undertake a patrol in an RCT. The cost of crime values were uprated to 23/24 prices using the latest HMT deflator (under the direction of Home Office). This gives a cost of violent crime of £16,900 (societal damage per VWI crime) and an average cost of a patrol of £124. This enables us to assess if the costs of the patrols are outweighed by the benefits to society. And most importantly, what level of crime needs to be seen in a hotspot before it is worthwhile undertaking hotspot policing.

Using the posterior distribution, it is possible to carry through the possible range of answers for the impact of a patrol on the day of patrol, to the rest of the analysis. As the impact is a percentage reduction, the impact was tested for a range of possible crime levels in a hotspot (0.05 VWI crimes a day up to 1). The results for this can be seen in Appendix F. From this we can assess the probability that the patrol is worthwhile, based on the different crime levels. This gives Figure 11, where we can see at a BAU crime level of 0.12 crimes per day in a hotspot has a 50% probability of a positive net impact. 60% requires a BAU of 0.15 crimes per day, 70% at 0.22 and 80% for 0.45. We can have more confidence of a positive net impact on hotspots with higher BAU levels of crime.

Assessing the net impact of an additional patrol at differing confidence we get Figure 12. This shows that, if we had a BAU number of crimes per day in a Hotspot of 0.25, we would expect a net benefit of an additional patrol on the day of the patrol of £134. Which, when compared to the cost of a patrol of £124, is good. This is at 50% confidence, so we can say with 50% confidence that the net benefit will be £134 or higher. We can also say with 20% confidence that the net benefit would be £331 or greater. At 70%, we have a net benefit of £20 or greater. At the 80% confidence, for a BAU of 0.25, we have a positive result (no benefit). These linear relationships are given as simple formulas below. Note the 124 is equal to the cost of a patrol.

Mean Net Impact of an additional Patrol [£] = 124 – 1032 * BAU Crime per Day in HS

P80 Net Impact of an additional Patrol [£] = 124 – 275 * BAU Crime per Day in HS

P70 Net Impact of an additional Patrol [£] = 124 – 577 * BAU Crime per Day in HS

P30 Net Impact of an additional Patrol [£] = 124 – 1535 * BAU Crime per Day in HS

P20 Net Impact of an additional Patrol [£] = 124 – 1821 * BAU Crime per Day in HS

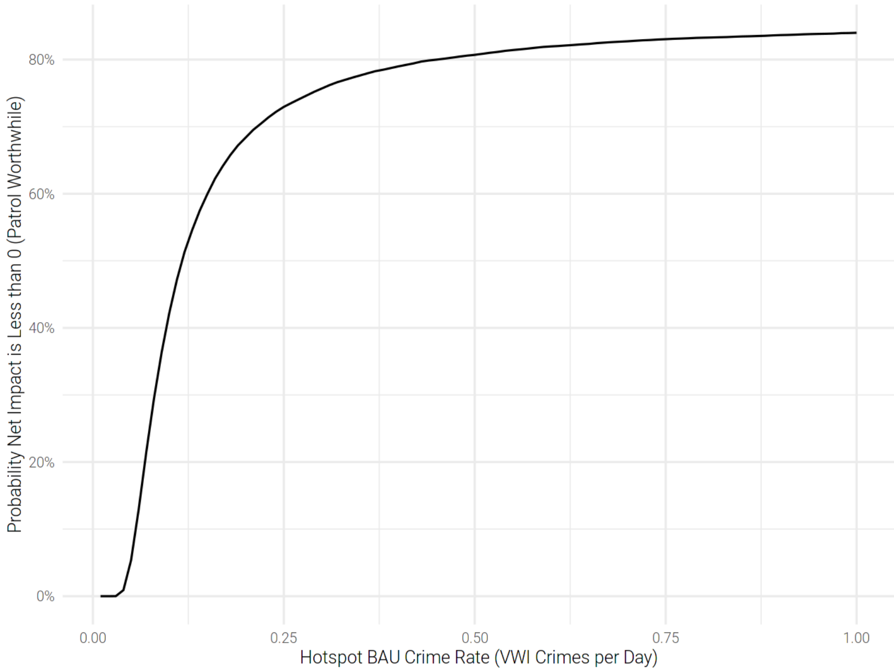


Figure 11: Probability that Patrol is Worthwhile Based on BAU Crime Level

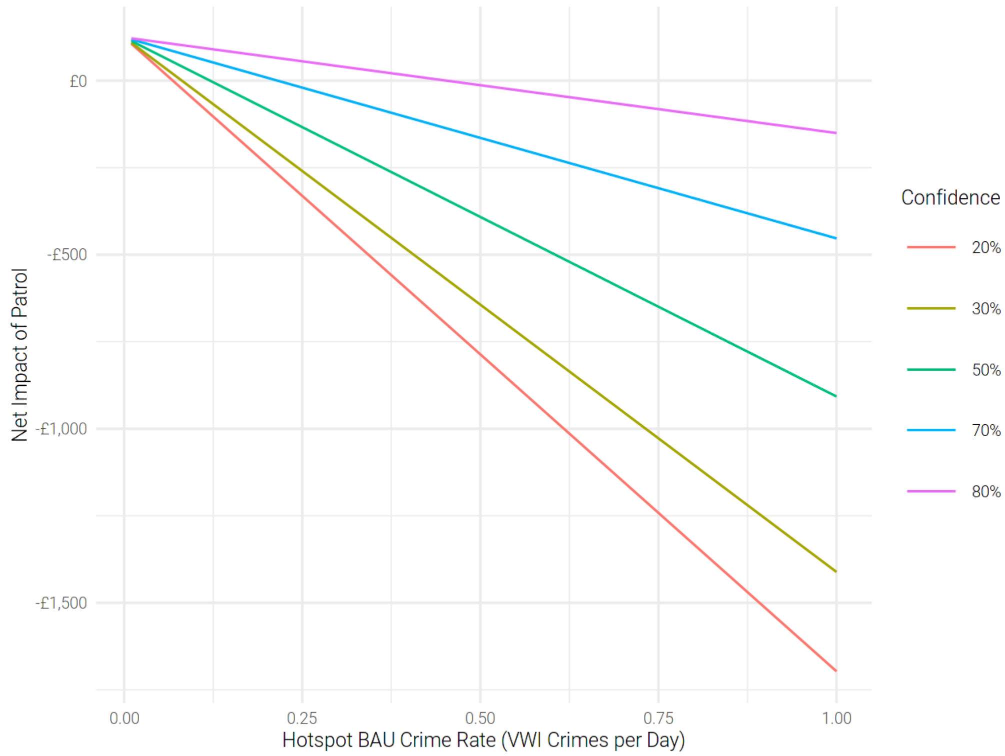


Figure 12: Net Impact of Additional Patrols by Hotspot BAU Crime

5.2 Overall Impact of RCT

Using the model, we can calculate the expected number of crimes if the additional patrols were not undertaken. The model results for the RCT data give an average number of crimes of 1776.45, with the additional flag feature set as zero for the whole RCT (no additional patrols undertaken) we would have expected 1817.92. So it is expected that the additional patrols across the RCT have saved (1817.92-1776.45) ≃ 42 VWI crimes. This can also be calculated with confidence due to the posterior distribution obtained from the model. The calculated distribution of the number of violent crimes stopped as part of the RCT can be seen in Figure 13. From this we can say that we are 70% confident that across the RCT VWI crimes were stopped. With 30% confidence we can say that at least 83 VWI crimes were stopped.

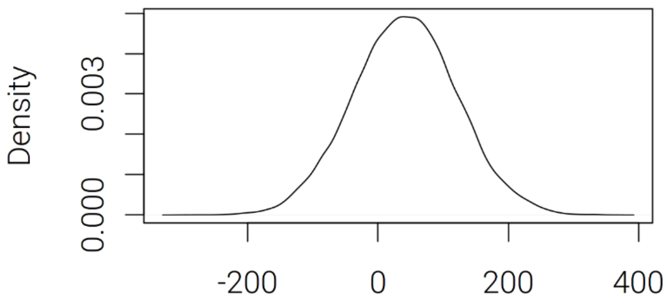


Figure 13: Distribution of the number of crimes stopped as part of the RCT

5.3 Summary

The results from the RCT show that an additional patrol is highly likely to reduce the levels of crime in a hotspot on the days of the patrol. The average crime reduction was 6.27%, and we can say with 50% confidence that hotspots above 0.12 crimes per day are worthwhile patrolling (0.22 at 70%). This is based on there being no multi day residual effect of the patrols. The model is told that the day after an additional patrol is BAU. This may not be the case so a model has been developed to take multi day residual effects into account.

6 Modelling Time of Day of the Patrol

Patrols were randomised 50/50 into early (11am-4pm) and late (4pm-9pm) in the patrol plan. To assess the impact of the time of day the same modelling approach has been utilised whereby there are two flags, one for when an early patrol occurred on a hotspot and one for late patrols.

Checking the model fit we get a RMSE of 0.4536 and MAE of 0.2431. Which is in-line with the previous model (no improvement from giving the model more information).

The results for Early and Late patrol flags can be seen in Figure 14 and Figure 15. From these we can see that the early patrols have a much larger impact (mean of -0.114 compared to -0.023). Early patrols also appear to be much more likely to have a positive impact (95% vs 62%). As VWI crime per hour tends to be higher in the late period, this was not the expected result. It is thought that for the late patrols, some of their benefit would actually be seen on the next day.

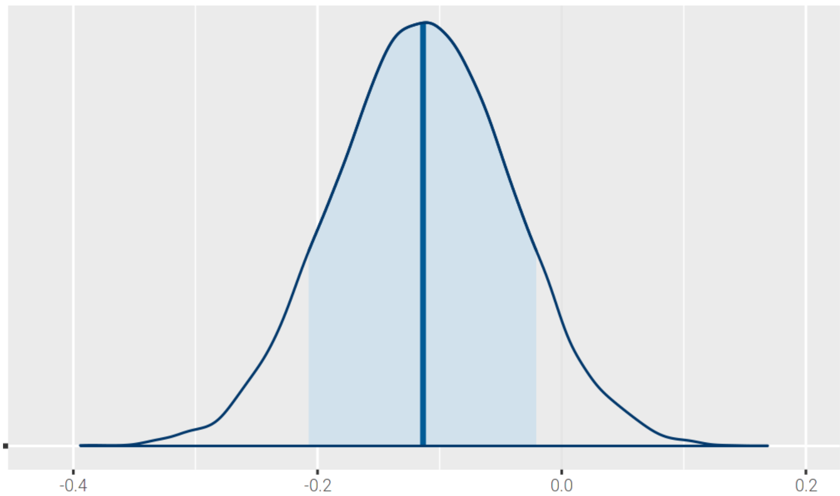


Figure 14: Additional Patrol Flag Early Posterior

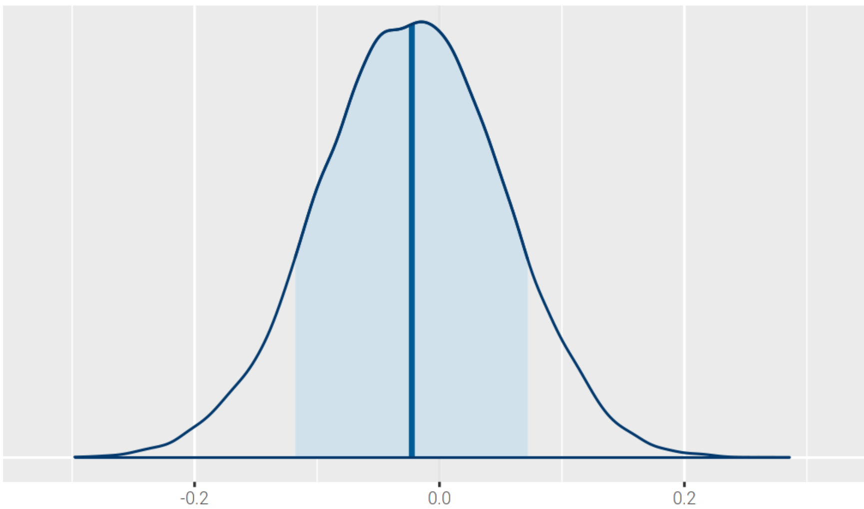


Figure 15: Additional Patrol Flag Late Posterior

7 Multi-Day Residual Effects of Patrols

To assess if patrols have a residual effect (any crime reduction effect lasts past the day of the patrol), a new feature is added which is equal to the number of days since an additional patrol was last undertaken in a hotspot (for the day of a patrol this number would be zero). It was decided to look up to one week after a patrol. Anything greater than 6 days from a patrol was grouped into “6 days”. The bootstrap mean results for the average crime per days for different number of days since a patrol can be seen in Table 7, and visualised in **Error! Reference source not found.**. This shows evidence of multiple days of impact. As the bootstrapped means confidence interval for “6 or More Days after Patrol” is entirely within the confidence interval for “5 Days after Patrol”, it was decided to combine these groups. This makes a new group “5 Days or More after Patrol”, which for the purpose of this analysis, is equal to BAU, the crime level without additional patrols. Looking at the means we can create

Table 8 by subtracting the BAU value. From this we can see a strong, if irregular, impact for the day and up to 3 days after a patrol. Based on this we can say that a patrol, plus its impact over the next 3 days, on average will reduce the number of crimes in that period by (a cumulative) 66.3% of the expected number of crimes per day in the hotspot. Again, analysing means, even with bootstrapping, can have shortcomings, so modelling has been utilised to take everything into account, including the shape of the data.

Table 7: Bootstrap Mean Results for Residual Effects

Days Since Patrol	Num HS Days	Mean (Bootstrap 5%)	Mean (Bootstrap 10%)	Mean	Mean (Bootstrap 90%)	Mean (Bootstrap 95%)
Day of Patrol	4425	0.132	0.134	0.144	0.153	0.156
Day after Patrol	2566	0.143	0.147	0.159	0.172	0.176
2 Days after Patrol	1576	0.122	0.126	0.140	0.155	0.159
3 Days after Patrol	981	0.111	0.115	0.131	0.148	0.153
4 Days after Patrol	642	0.143	0.148	0.173	0.198	0.206
5 Days after Patrol	419	0.117	0.122	0.150	0.179	0.189
6 or More Days after Patrol	1361	0.134	0.139	0.154	0.170	0.175
5 Days or More after Patrol (BAU)	1780	0.153	0.136	0.172	0.140	0.167

Table 8: Residual Effects Impact based on Means

Days Since Patrol	Mean	Difference from BAU	% Difference from BAU	Cumulative Difference from BAU	Cumulative % Difference from BAU
Day of Patrol	0.144	-0.028	-16.3%	-0.028	-16.3%
Day after Patrol	0.159	-0.013	-7.6%	-0.041	-23.8%
2 Days after Patrol	0.140	-0.032	-18.6%	-0.073	-42.4%
3 Days after Patrol	0.131	-0.041	-23.8%	-0.114	-66.3%
4 Days after Patrol	0.173	0.001	0.6%	-0.113	-65.7%
5 Days or More after Patrol (BAU)	0.172	0	0.0%	-0.113	-65.7%

7.1 Modelling Residual Effects

The same modelling approach has been taken, but replacing the additional patrol flag feature with the number of days since patrol, truncated with a max of 5. The days since patrol was one-hot encoded to obtain flag columns (0 or 1) for days 0 to 4. Day 5 (5 days or more after an additional patrol) was left out of the model as this is the BAU baseline.

This results in the model:

Num of Crimes in HS Day = Day0 + Day1 + Day2 + Day3 + Day4 + Weekday + New Years Flag + (1 | Hotspot)

Where weekday is modelled as a factor (one hot encoding) and new years and Day0 to Day4 as flag columns (0 or 1).

For shortness, with the log link of the negative binomial:

ln(crimes) = day0 + day1 + day2 + day3 + day4 + wday + ny + hs

crimes = exp(day0 + day1 + day2 + day3 + day4 + wday + ny + hs)

crimes = exp(day0) * exp(day1) * exp(day2) * exp(day3) * exp(day4) * exp(wday) + exp(ny) * exp(hs)

Weakly informative priors were used. Note the scale parameter has been adjusted by the model to ensure it is weakly informative covering the range of the data. These priors are recorded in Table 9.

Posterior predictive checks were used to ensure the model fit the data well, which was shown to be the case by the resultant graph in **Error! Reference source not found.**, which shows the predictions are close to and surround the mean.

Table 9: Residual Effects Model - Priors

	Intercept	day0	day1	day2	day3	day4	wday	new years	Aux
Location	0	0	0	0	0	0	0	0	exp(1)
Scale	2.5	2.50	2.50	2.50	2.50	2.50	2.50	2.50	
Adjusted	2.5	5.18	6.09	7.39	9.11	11.10	7.14	25.74	

7.1.1 Residual Flag Model Results

The coefficient results are in Table 10, and the drawn posteriors in **Error! Reference source not found.**. The results show that the day of patrol, 2 days after and 3 days after have probabilities of the coefficient being negative (reduction in crime) of over 90% (92%, 91% and 97%) (most of the posterior distribution is negative). One day after the patrol shows a mean effect of exp(-0.022)-1 = 2.17% reduction and a 59.5% probability that the level of crime is lower than BAU (5 days or more after a patrol). The result for four days after a patrol shows an increase in crime over BAU (73.4% probability). The mean of this is a exp(0.083)-1 = 8.67% increase.

The locations and spreads of the impact of a patrols on the different number of days since a patrol can be seen in Figure 16 and recorded in Table 11. From these it can be seen that a patrol appears to have the largest impact 3 days after the patrol occurred. Two days after and day of the patrol are similar and next most impactful, then the day after the patrol. Four days after a patrol has an opposite impact (crime tends to be higher than BAU), but also has the most uncertainty (spread of possibilities).

The shape that the model coefficients (after conversion to percentage changes) can be seen in Figure 17, which resembles the equivalent bootstrapped mean graph in **Error! Reference source not found.**. This was not the expected shape, with residual effects in other settings such as advertising campaigns, it would be expected that every day after an event the impact would be lower (i.e. exponential decay) up to a point before reaching a plateau. The shape shows the complex nature of the impact of patrols.

As the impact lasts multiple days (in order), the same results have been calculated but cumulatively. The cumulative impact can be seen in Figure 18 and Table 12. Note, the cumulative impact is still in relation to the BAU crime level for <u>one</u> day. For example, the mean impact is a 25.1% reduction for the day of the patrol and up to 2 days after. So, if a hotspot had a BAU average of one violent crime every 4 days, 0.25 a day, we would expect the patrol to reduce crime by 25.1%*0.25 = 0.063 VWI crimes. From these results and Figure 19, it can be seen that the maximum benefit from a patrol is realised when an additional patrol occurs and then it is just BAU for the next 3 days (40.4% reduction, 93.5% probability of a reduction).

Table 10: Residual Flag Model - Coefficient Result

Parameter	Mean	SD	Probability less than zero	Min	P25	Median	P75	Max
day0	-0.122	0.088	91.8%	-0.487	-0.182	-0.122	-0.062	0.232
day1	-0.022	0.095	59.5%	-0.417	-0.086	-0.022	0.042	0.396
day2	-0.145	0.107	91.3%	-0.594	-0.218	-0.145	-0.073	0.263
day3	-0.229	0.125	96.9%	-0.729	-0.312	-0.228	-0.144	0.259
day4	0.083	0.134	26.6%	-0.469	-0.007	0.084	0.174	0.649

Table 11: Residual Flag Model - Patrol Impact on VWI Crimes

Parameter	Mean	SD	Min	P25	Median	P75	Max
Day of Patrol	-11.51%	9.24%	-38.57%	-16.63%	-11.53%	-6.05%	26.05%
Day After Patrol	-2.17%	9.95%	-34.10%	-8.20%	-2.20%	4.29%	48.64%
2 Days After Patrol	-13.50%	11.28%	-44.78%	-19.55%	-13.50%	-7.07%	30.06%
3 Days After Patrol	-20.47%	13.31%	-51.78%	-26.82%	-20.36%	-13.45%	29.51%
4 Days After Patrol	8.67%	14.31%	-37.44%	-0.73%	8.80%	18.95%	91.32%

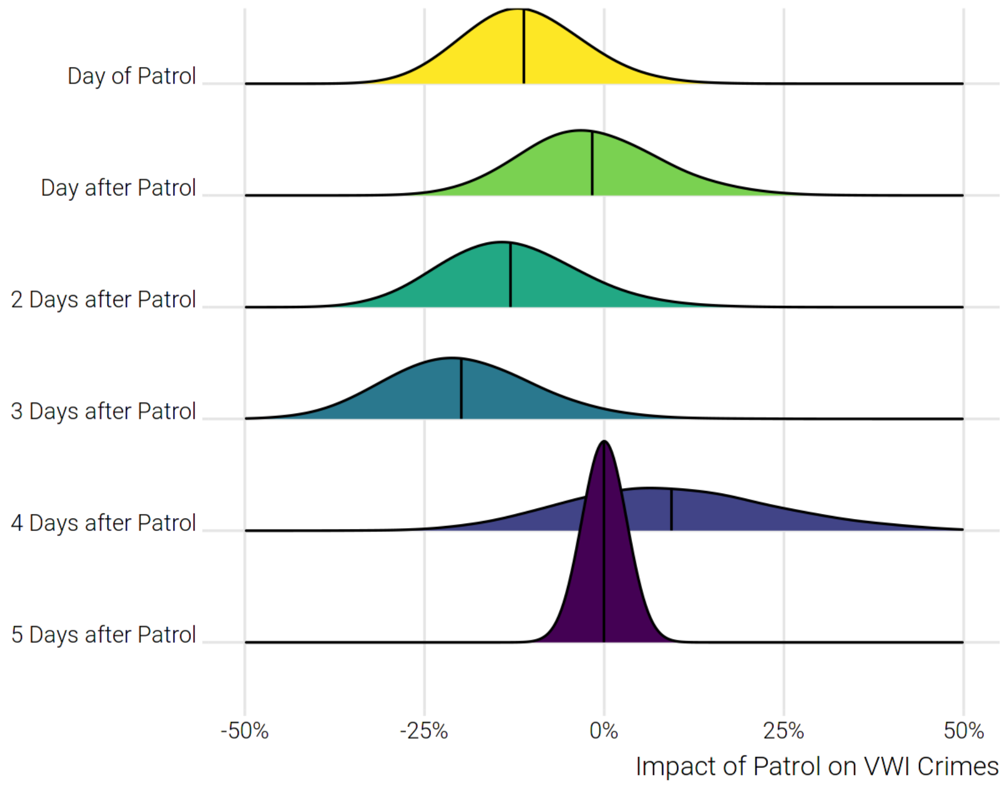


Figure 16: Residual Flag Model - Patrol Impact by Days After Patrol (Ridgeline)

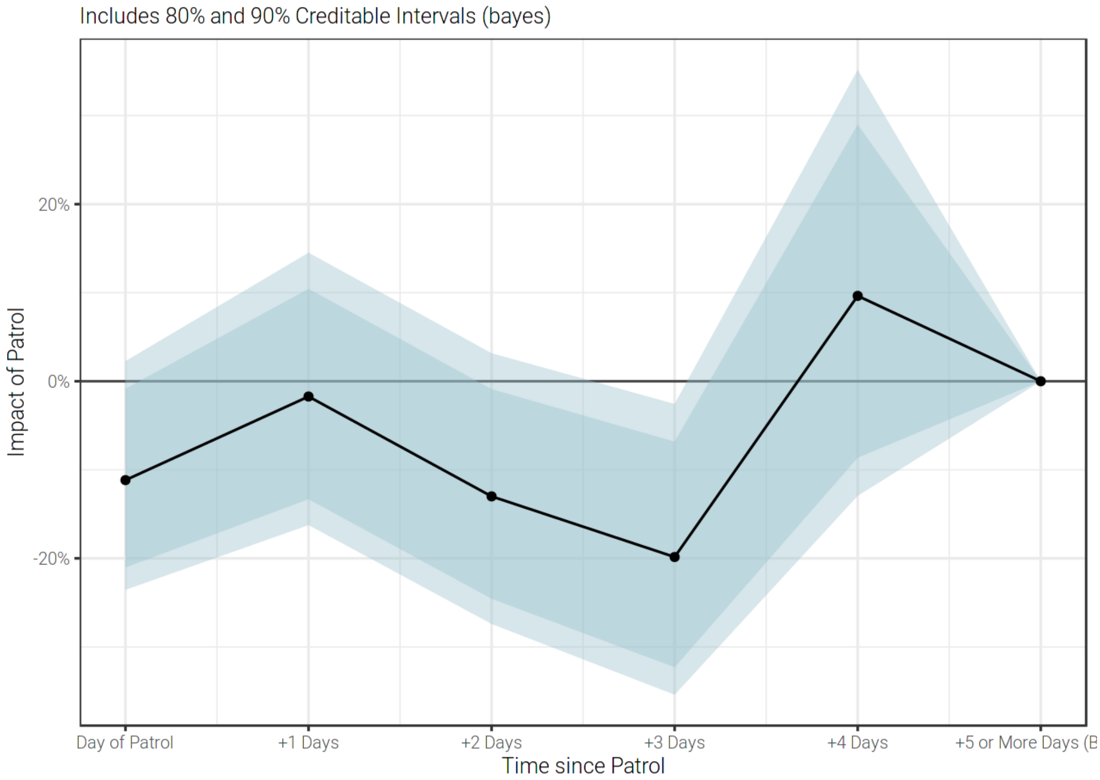


Figure 17: Residual Flag Model - Patrol Impact by Days Since Patrol (Ribbon)

Table 12: Residual Flag Model - Patrol Impact on VWI Crimes Cumulative

Parameter	Mean	SD	Probability less than zero	Min	P25	Median	P75	Max
Day of Patrol	-11.51%	9.24%	91.76%	-38.57%	-16.63%	-11.53%	-6.05%	26.05%
Day of and After	-13.43%	18.27%	79.63%	-56.16%	-22.70%	-13.43%	-3.00%	74.15%
Day of and 2 Days After	-25.11%	28.27%	87.11%	-72.53%	-36.56%	-25.08%	-11.48%	102.36%
Day of and 3 Days After	-40.44%	39.40%	93.51%	-84.41%	-52.33%	-40.37%	-25.77%	124.65%
Day of Patrol and 4 Days After	-35.28%	51.13%	82.90%	-88.50%	-50.83%	-35.23%	-14.53%	234.67%

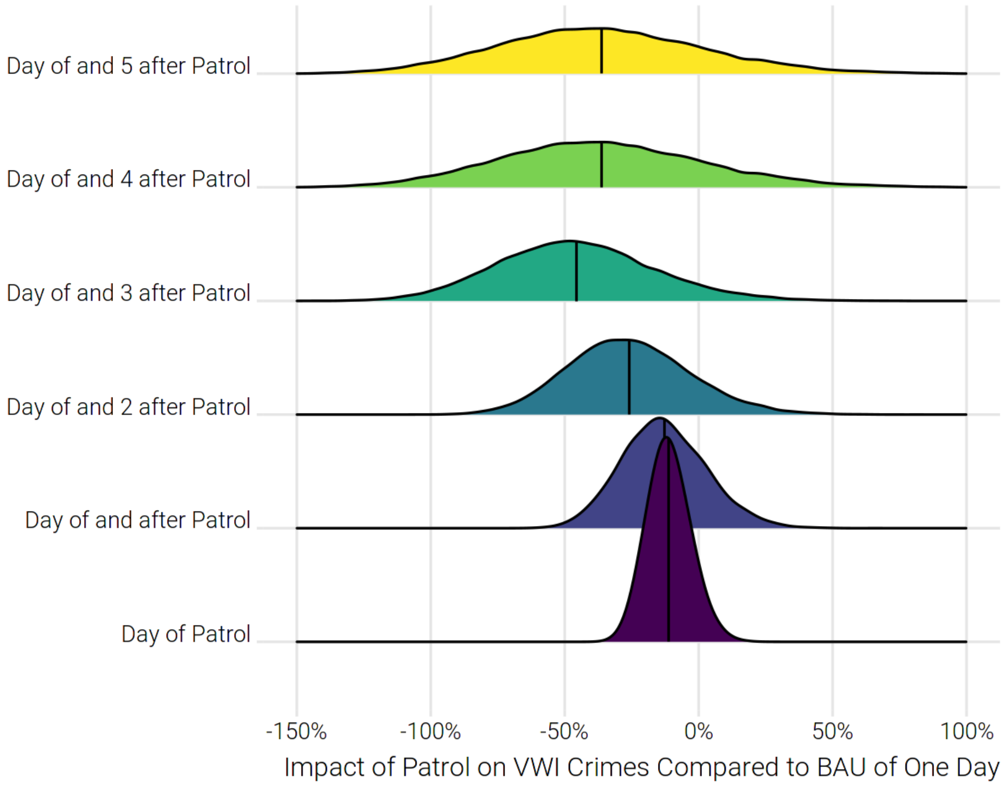


Figure 18: Residual Flag Model - Cumulative Patrol Impact by Days After Patrol (Ridgeline

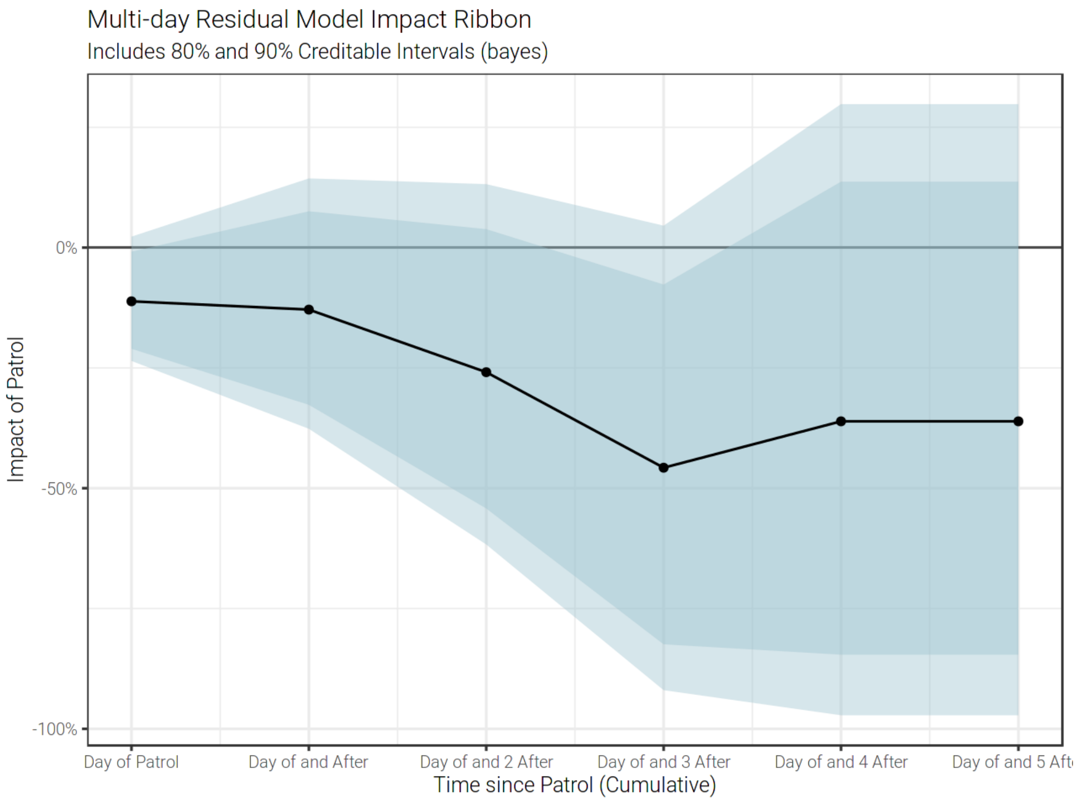


Figure 19: Residual Flag Model - Cumulative Patrol Impact by Days Since Patrol (Ribbon)

7.1.2 Residual Flag Model Net Impact of a Patrol

Similar to the basic model introduced in previous sections as a percentage reduction is shown, this section seeks to understand where and when the patrols have a positive outcome on balance. Again, using the Government Cost of Crime figures (given by the Home Office to use in this project) and the cost of a patrol, the net impacts of the patrols have been calculated. If the net impact is negative (greater reduction in crime than the cost of patrol), then the patrol is deemed as worthwhile undertaking. The probability of being worthwhile is related to the BAU level of crime and the number of days of residual effect allowed to occur (time between additional patrols). The results for this are shown in Figure 20 with the numbers of 50% confidence, 70%, 80% and 90% recorded in Table 13. These show that if it was desirable to be 80% confident in a net positive impact, and it was expected the leave 2 days between patrols, it would be worthwhile patrolling hotspots with BAU VWI crimes per day above 0.1.

By calculating the net impact of patrols, equations could be created linking the expected impact with the BAU crimes per day for a hotspot with different confidence levels. The equations are as follows:

Net Impact of an additional Patrol [£] = 124 – X * BAU Crime per Day in HS

Where the variables are chosen from:

Time to Next Patrol	20% Confidence	30% Confidence	50% Confidence	70% Confidence	80% Confidence
Day of Patrol	3019	2611	1949	1238	782
Up to 1 Day After	4433	3644	2296	872	36
Up to 2 Days After	7628	6486	4534	2492	1234
Up to 3 Days After	11937	10418	7904	5341	3717
Up to 4 Days After	11593	9635	6352	2920	733

Table 13: VWI Crime per Day Levels Required for Patrol to be Worthwhile

Time to Next Patrol	50% Confidence	70% Confidence	80% Confidence	90% Confidence
Day of Patrol	0.064	0.077	0.158	0.870
Up to 1 Day After	0.055	0.076	Inf	Inf
Up to 2 Days After	0.028	0.036	0.101	Inf
Up to 3 Days After	0.017	0.019	0.034	0.096
Up to 4 Days After	0.020	0.027	0.169	Inf

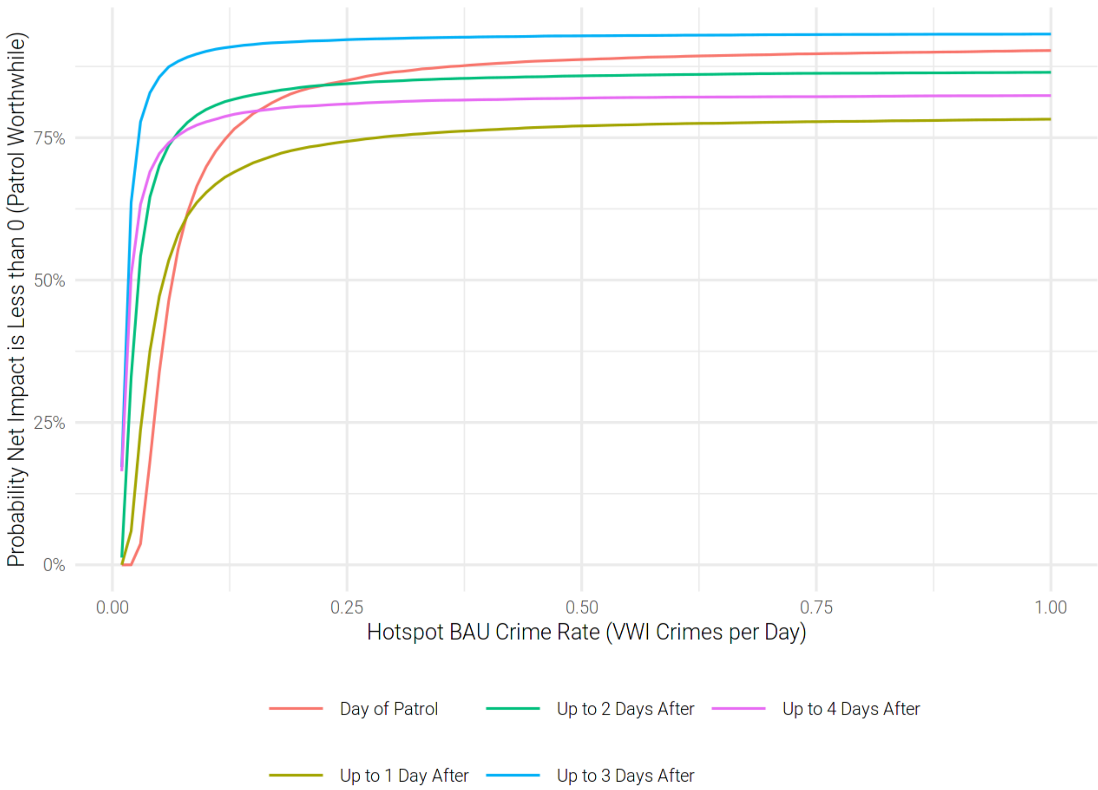


Figure 20: Residual Flag Model - Cumulative Probabilities of Patrol being Worthwhile

7.2 Overall Impact of RCT (With Residual Effects)

Using the model, it is possible to estimate the likely number of VWI crimes that did not occur due to the RCT patrols. This follows the same idea as in the section "**Error! Reference source not found.**". The model results for the RCT data give an average number of crimes of 1778.18, with the additional flag feature set as zero for the whole RCT (no additional patrols undertaken) we would have expected 1928.20. So, it is expected that the additional patrols across the RCT have saved (1928.20-1778.18) = 150.02 VWI crimes.

Using the model posterior distributions, Table 14 and Figure 21 were calculated. The probability that the number of crimes stopped is greater than zero was 84.3% (highly likely). Using the results, it can be said that with 75% confidence that the number of VWI crimes that did not occur due to the patrols was greater than 50; 50% confident that it was above 146 and 25% that it was above 249.

Table 14: Crimes Stopped Statistics (Residual Flag Model)

	Mean	SD	Min	Q1	Median	Q3	Max
With Patrols	1778	70	1514	1730	1777	1825	2149
Without Patrols	1928	70	1437	1822	1923	2027	2576
Crimes Stopped	150	149	-351	50	146	249	777

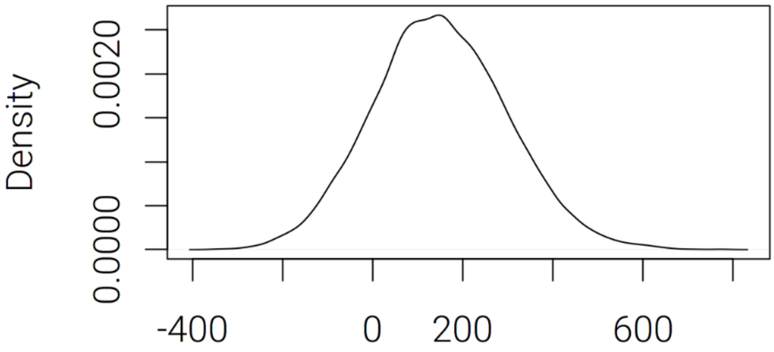


Figure 21: Distribution of the number of crimes stopped as part of the RCT (Residual Flag Model)

7.3 Summary

The results show strong evidence of a multi-day residual effect from the additional patrols undertaken in the RCT. This lasts up to 3 days after an additional patrol day.

Average crime reduction including up to 2 days was 25.1% and 40.4% when there is no additional patrol within 3 days. The model also showed how confident we can be in a positive effect (i.e. a crime reduction). With 2 and 3 days after a patrol cumulatively having probabilities of 87% and 94% that a crime reduction will be seen.

8 Checking Crime Spatial Displacement

There was a thought that the additional patrols in the hotspots, may not stop the crimes but moves them i.e. officers spotted on a high street so crime moves to side roads for example. This is known as crime spatial displacement. As noted in the literature review, previous research has not shown crime displacement but actually showed a diffusion of benefits, where crime was reduced near the hotspots by the patrols.

To check for spatial displacement, a 50m buffer zone was placed around the hotspots and the crime from this area recorded. Following the same analytical framework used earlier, but instead predicting the crime in the hotspot buffers. A negative binomial GLM was fitted with the additional patrol flag, weekday and new years (same as in Section Additional Patrol Flag Modelling).

The posterior distribution for the additional patrol flag distribution can be seen in Figure 22. In this we can see that the distribution straddles the zero (mean of 0.0076, 52.6% above zero, 47.4% below). This shows a neutral affect of the additional patrols in the 50m hotspot buffer areas. So, it appears that the additional patrols are not spatially displacing crime, but it also shows that the benefit from the patrols has not been seen outside the hotspots.

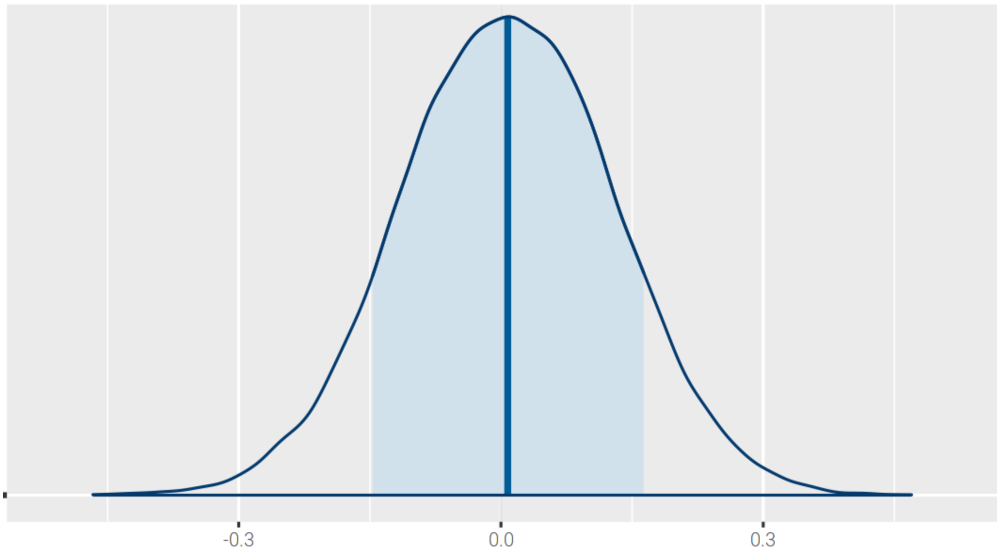


Figure 22: Additional Flag Coefficient Posterior (50m Buffer)

9 Project Summary and Recommendations

This project consisted of designing an RCT, running and collecting the required data and analysing to tease apart the impact of the explored intervention (additional high visibility patrols).

A VWI crime point pattern was used with a Kernel Density Estimation (KDE) to identify the hotspots. This allows for multiple maps to be produced with different bandwidths, helping identify hotspot edges especially in busy areas such as city centres. When assessing the hotspots, many aspects were taken into account to ensure the correct areas were picked. These included ensuring temporally consistent hotspots over a long time period, not driven by single location (e.g. a hospital) and not domestic abuse.

A crossover design was utilised. This ensured geographical consistencies in the data as well as ensure a decision was not made, where a crime hotspot was identified but purposely not given additional resource (so it could be used as a baseline, postcode lottery for our public). Due to the shape of the data (counts, an excess of zeros, high skewness), classical approaches of calculating required sample sizes were not applicable so a simulation approach was used.

It was found to be very important to utilise technology as part of tracking the compliance in an RCT. Despite lots of time spent on stakeholder engagement with those involved, patrols that did not occur were occasionally reported. The use of Airwaves (GPS) data and a mobile app (geolocated check-in and check-out) ensured confidence in the patrols happening. The mobile app also allowed for a dashboard to be updated daily with previous days' patrols, allowing police leads to understand their missed patrols and increase compliance in the future (which was seen by compliance improving month on month in the RCT).

Two models have been introduced, both Negative Binomial GLM's. This was chosen as the response variable followed a negative binomial and it allowed hotspots to be added as a mixed effect (desirable due to crossover design). The first model looked at the difference between the days with an additional patrol to those without (BAU) (modelled as a flag). The second model included multi-day residual effects (each day since patrol was its own flag feature). Both models show a percentage reduction from the patrols, so the higher the BAU crime level the greater the expected impact.

Comparing the result from the additional patrol flag model and the residual effects model for the day of patrol. The residual impacts model shows a larger impact from the patrols with a higher mean crime reduction (11.51% vs 6.26%) and probability of having a positive impact (91.76% vs 86.6%). Due to the residual impacts seen, it is thought that the full impact is hidden in the additional flag model due to the presumption that the day after a patrol is equivalent to BAU. In the model the BAU baseline (crimes per day) has been reduced by the residual effects, reducing the impact seen for the additional patrol flag coefficient.

The residual impact model showed that the residual effect of a patrol lasted circa 3 days, and with 80% confidence it can be seen to be worthwhile patrolling hotspots as quiet as 0.034 VWI crimes per day. As the number of days between patrols needs a randomised element (if patrol plan is very regular it may be learnt), it would not be recommended to have a patrol every 4 days, but vary the number of days between patrols between 1 and

4. Due to this a better recommendation may be to look at the impact after 2 days. This shows with 80% confidence that it is worthwhile patrolling hotspots above 0.1 VWI crimes per day. Overall, over the RCT period it is estimated that anywhere from 50 to 249 (Q1 to Q3) VWI crimes were stopped.

The analysis of the time of day of a patrol was inconclusive and impacted by the large residual effects seen.

Crime displacement was analysed using a 50m buffer zone around the hotspots which crime was also tracked in. This analysis shows no impact from the patrols in the buffer areas and therefore no evidence of a spatial displacement effect.

Appendix A – Historical Violence with Injury Crimes

Offence Title	Harm Each	Number	Proportion	Harm	Proportion
Assault with Injury - s.47 - Assault occasioning actual bodily harm	183	28,765	57.1%	5,249,612	14.7%
Assault with Injury - s.20 - Malicious wounding: wounding or inflicting grievous bodily harm	1,825	8,779	17.4%	16,021,675	44.7%
s.18 - Assault with Intent to cause Serious Harm - Wounding with intent to do grievous bodily harm	1,460	7,625	15.1%	11,132,500	31.1%
Owner or person in charge allowing dog to be dangerously out of control in any place in England or Wales (whether or not a public place) injuring any person or assistance dog	2	1,448	2.9%	2,869	0.0%
Attempted - s.18 - Assault with Intent to cause Serious Harm - Wounding with intent to do grievous bodily harm	1,460	1,273	2.5%	1,858,580	5.2%
Racially or religiously aggravated assault or assault occasioning actual bodily harm	19	1,031	2.1%	19,589	0.1%
Other Violent Crimes with Injury	996	1,428	2.8%	1,536,939	4.3%
Notes: Crime data from West Midlands from 01/01/2019 to 01/10/2022 (45 months), Harm from Cambridge Crime Harm Index					

Appendix B – Hotspot Identification: Point Pattern vs Area Based

A point pattern approach for identifying hotspots was used instead of choropleths based on predefined areas such as Output Areas or Wards. Most predefined area types tend to vary in size as they are based on number of households and may not make good areas for patrols (i.e. they could, for example, split a high street). Essentially, the modifiable areal unit problem comes into play. Also, hotspots can be lost at boundaries, as seen in Figure 23, where the obvious hotspot in the middle gets split up by the boundaries for areas A-D. This may lead to the hotspot not being identified or a less optimal one chosen. In Figure 23, the blue circle via point pattern contains 8 previous crimes (red dots). In the area-based approach we can see that area B has the most historical crimes at 4 crimes. Which is half the number in the blue circle, even though area B is larger than the blue circle.

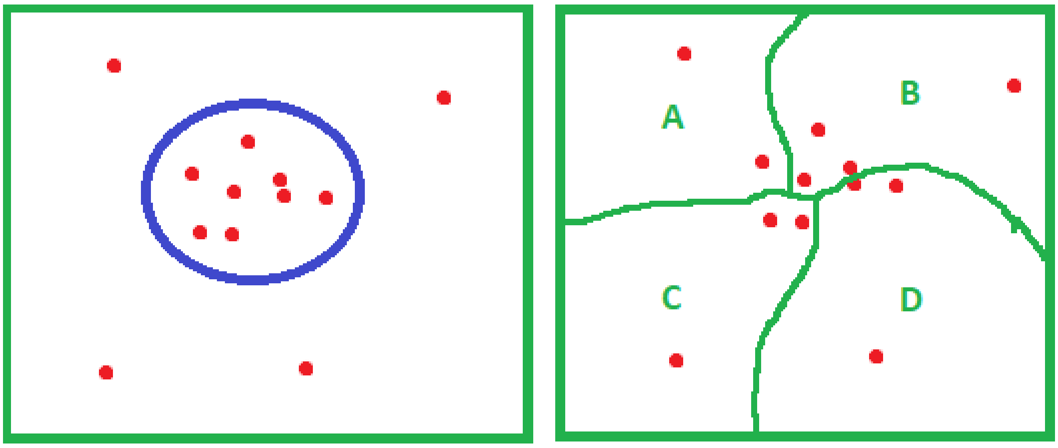
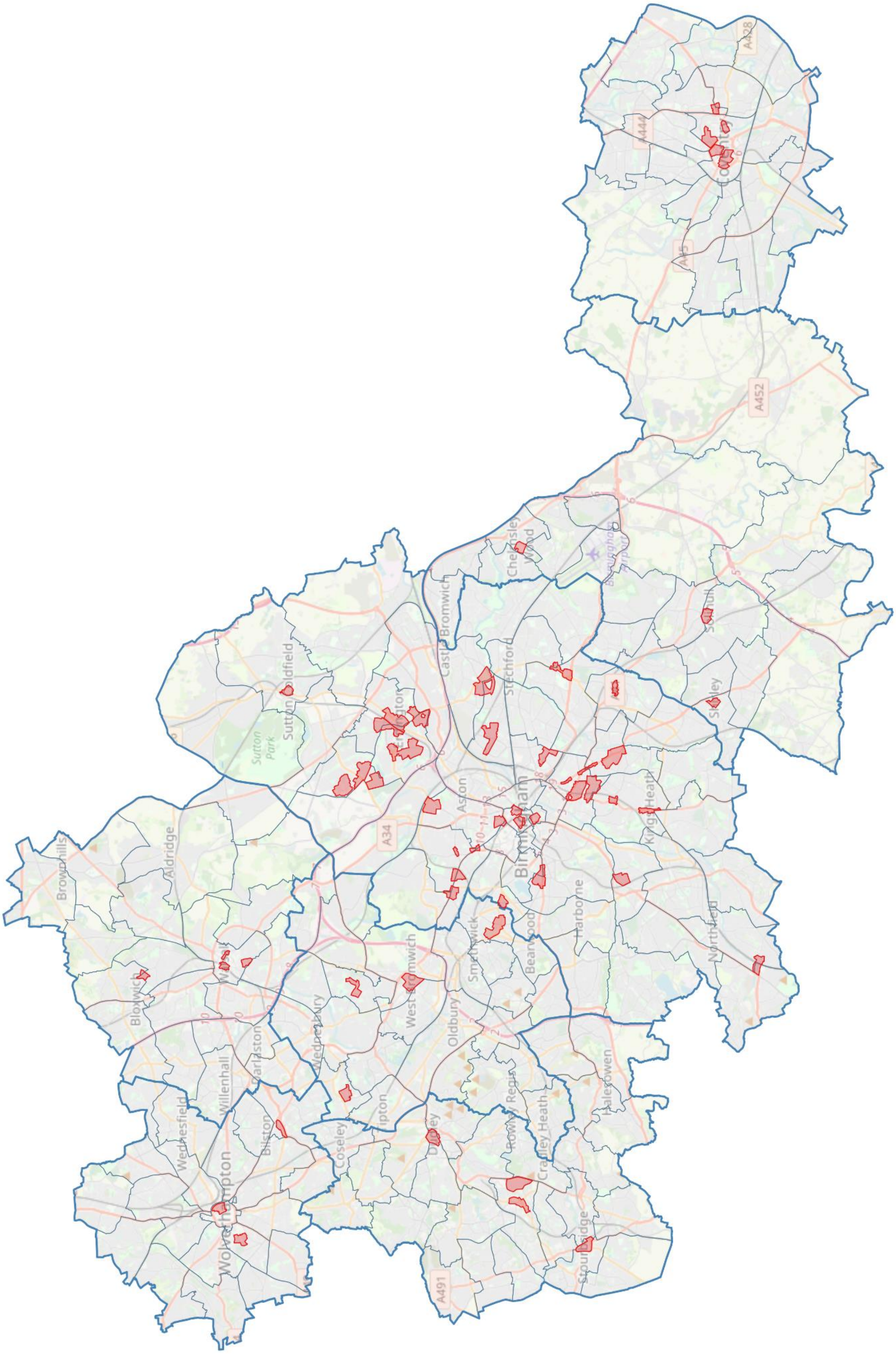


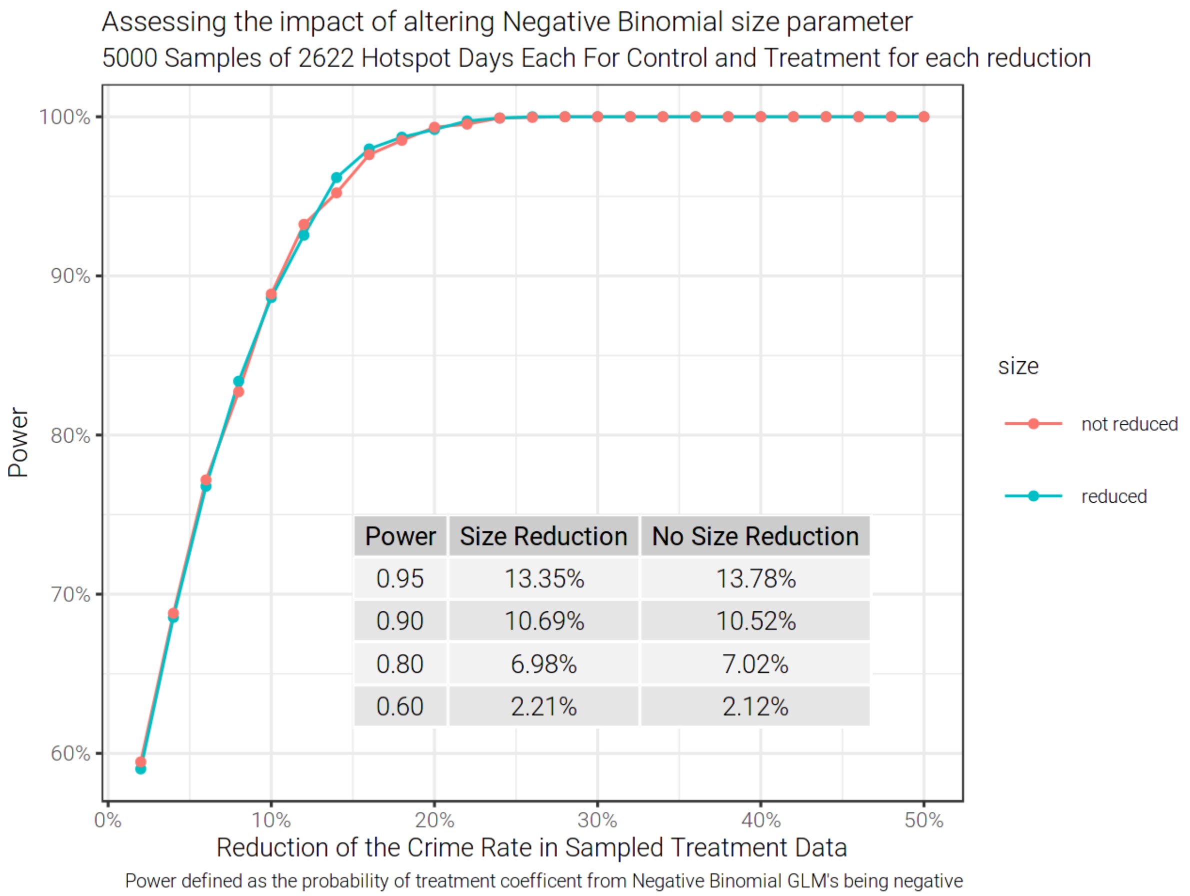
Figure 23: Left; Point Pattern Approach, Right; Area based approach

Appendix C – Map of Final Hotspots



Appendix D - Impact of Negative Binomial Size Parameter

Checking the impact of the assumption that the negative binomial size parameter would reduce with the mu parameter. The results show that when performing the sampling, decreasing the size parameter had minimal impact on the results.



Power	Size Reduction	No Size Reduction
0.95	13.35%	13.78%
0.90	10.69%	10.52%
0.80	6.98%	7.02%
0.60	2.21%	2.12%

Figure 24: Impact of Negative Binomial Size Parameter for Simulations

Appendix E – Results of Experimental Design Simulations

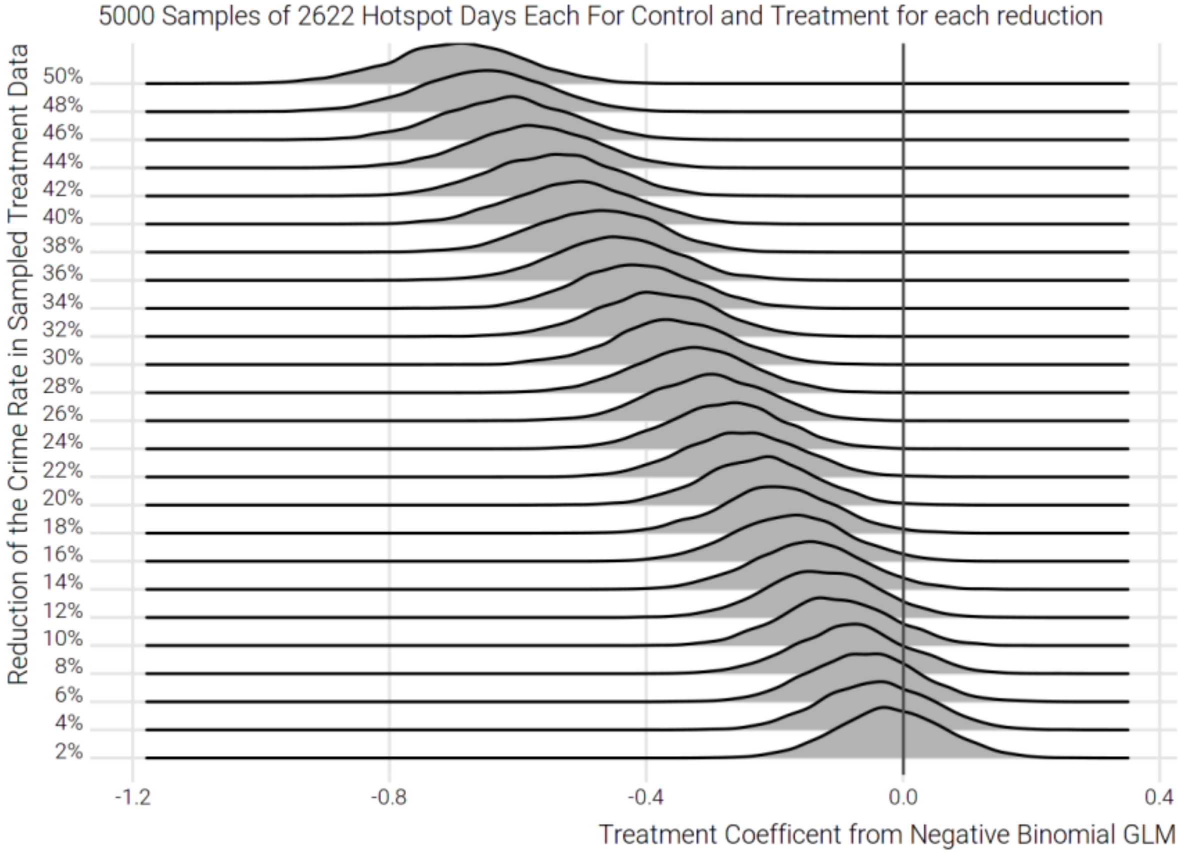
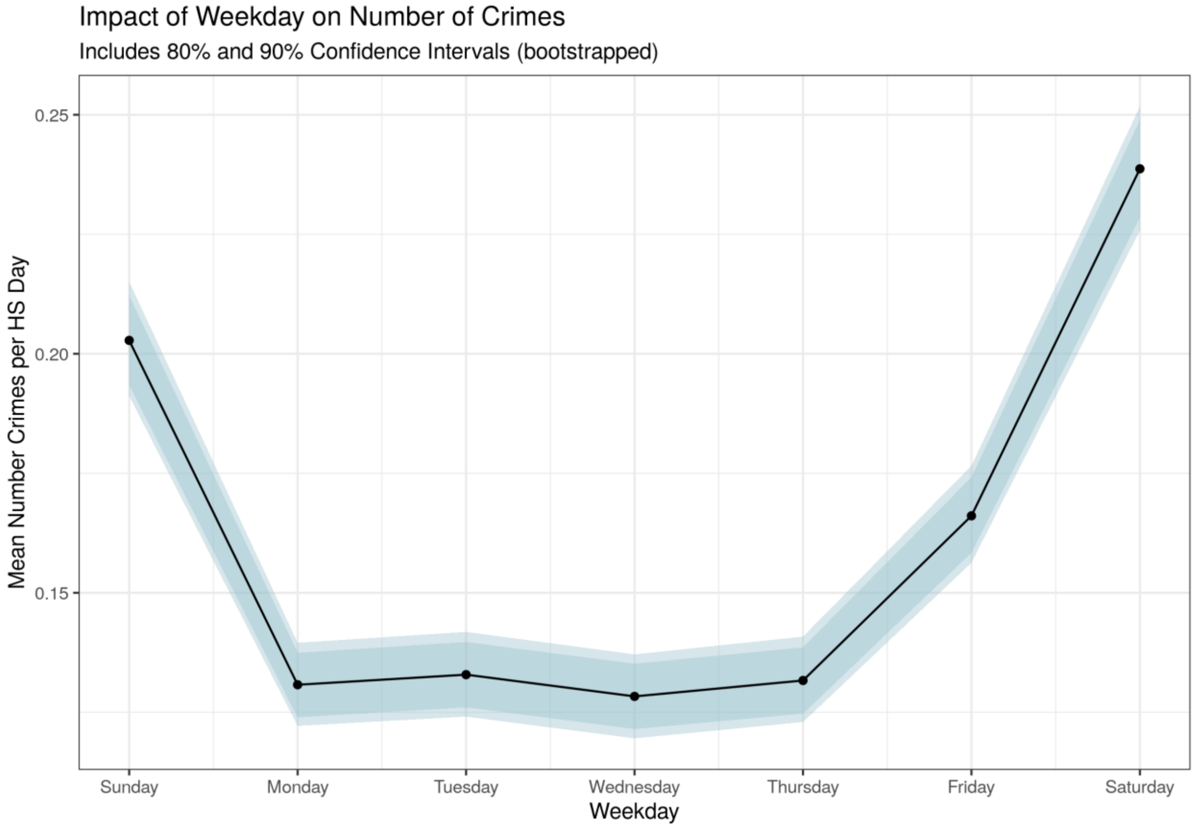
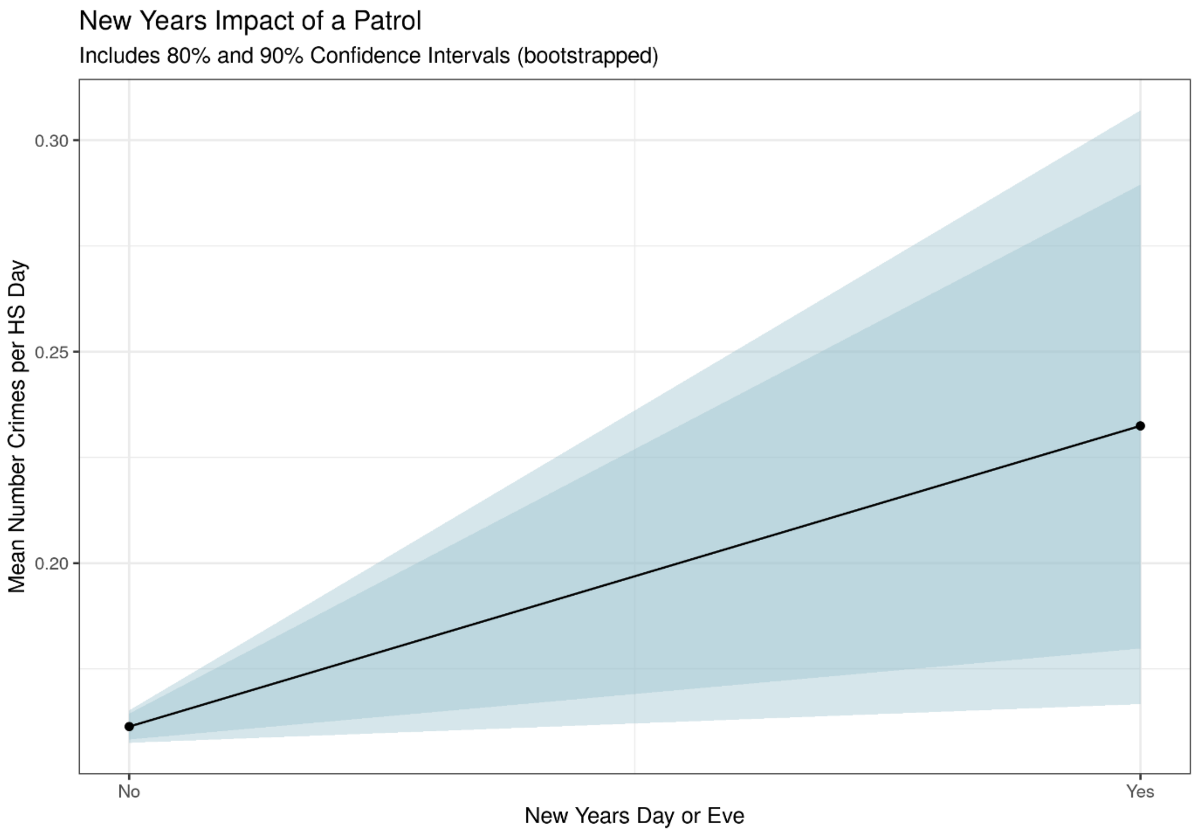
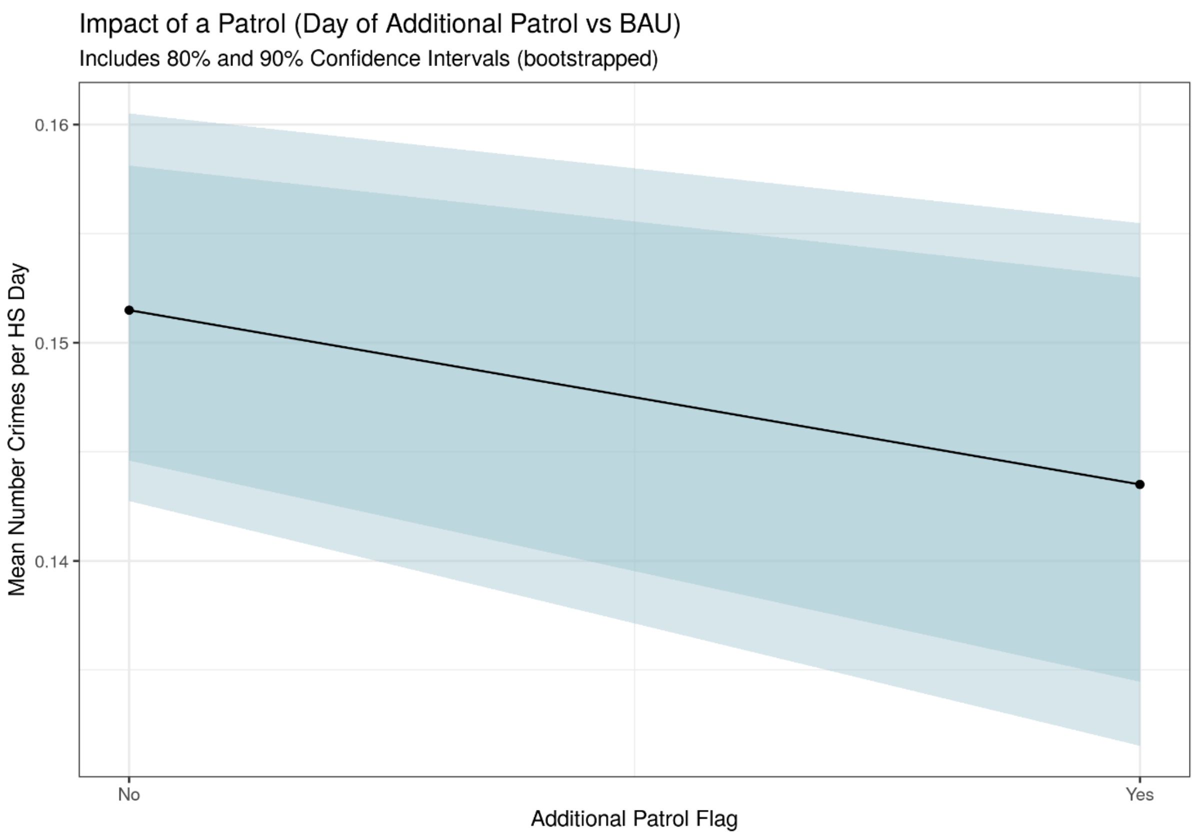


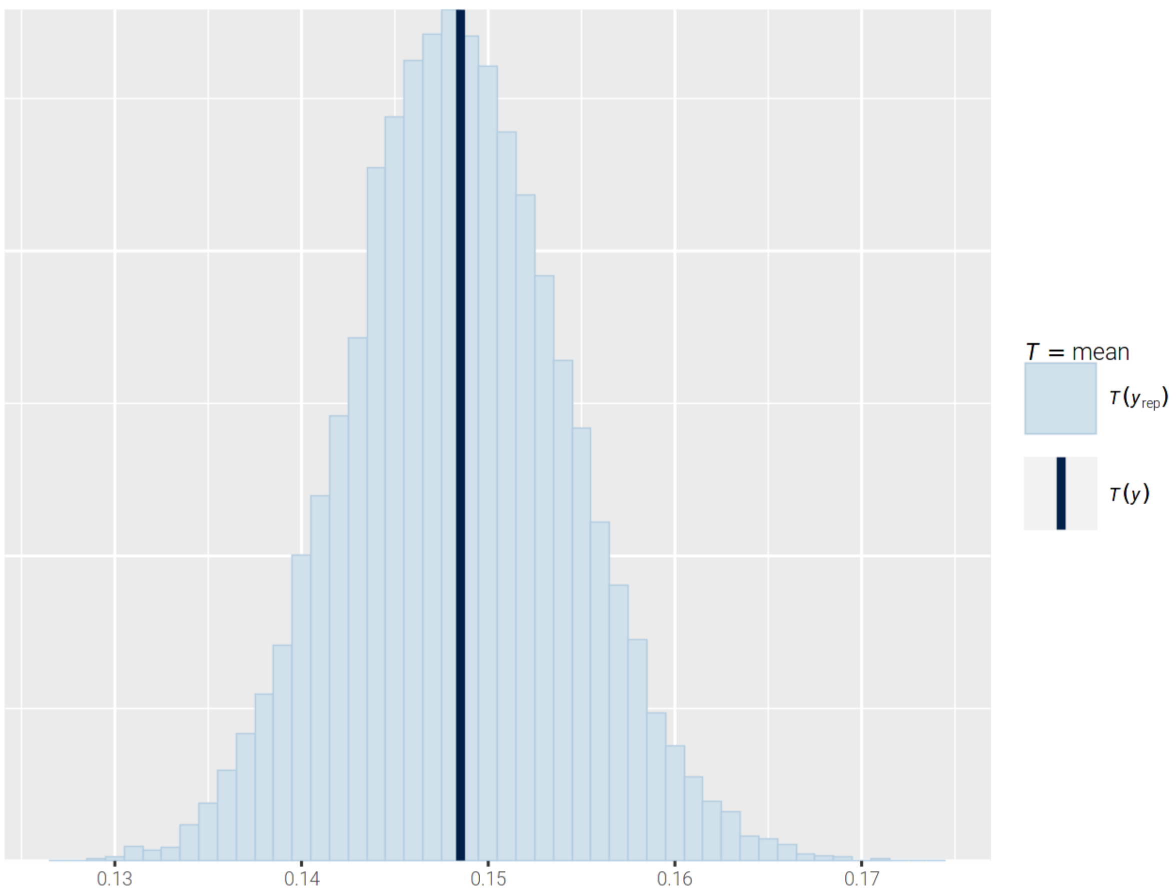
Figure 25: Full results from process for estimating the required length of the RCT based on a range of possible crime reductions (effect sizes)

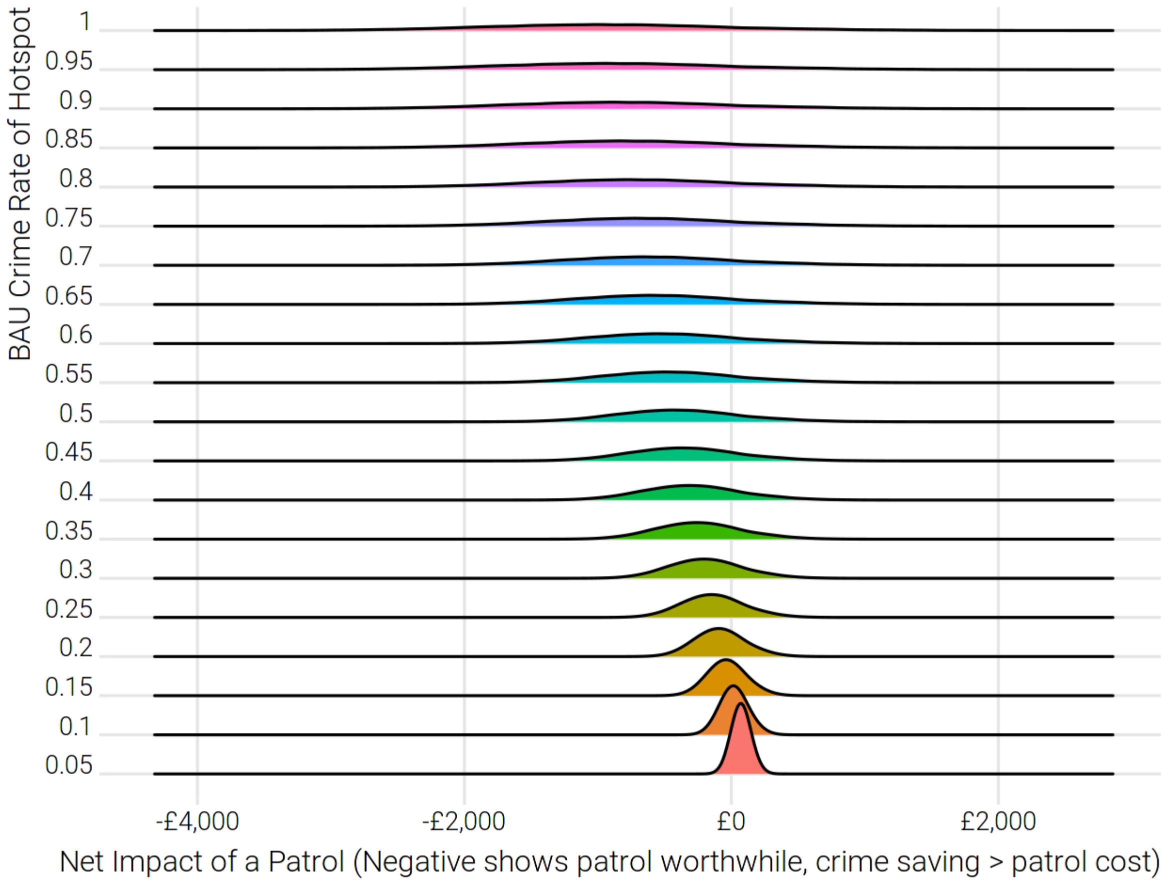
Appendix F – Additional Patrol Flag Results






Impact of a Patrol (Day of Additional Patrol vs BAU)
Includes 80% and 90% Confidence Intervals (bootstrapped)
0.16
0.15
0.14
Mean Number Crimes per HS Day
No
Yes
Additional Patrol Flag


0.13
0.14
0.15
0.16
0.17
T = mean
T(y_rep)
T(y)


BAU Crime Rate of Hotspot
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
-£4,000
-£2,000
£0
£2,000
Net Impact of a Patrol (Negative shows patrol worthwhile, crime saving > patrol cost)

Appendix G – Residual Impact Results

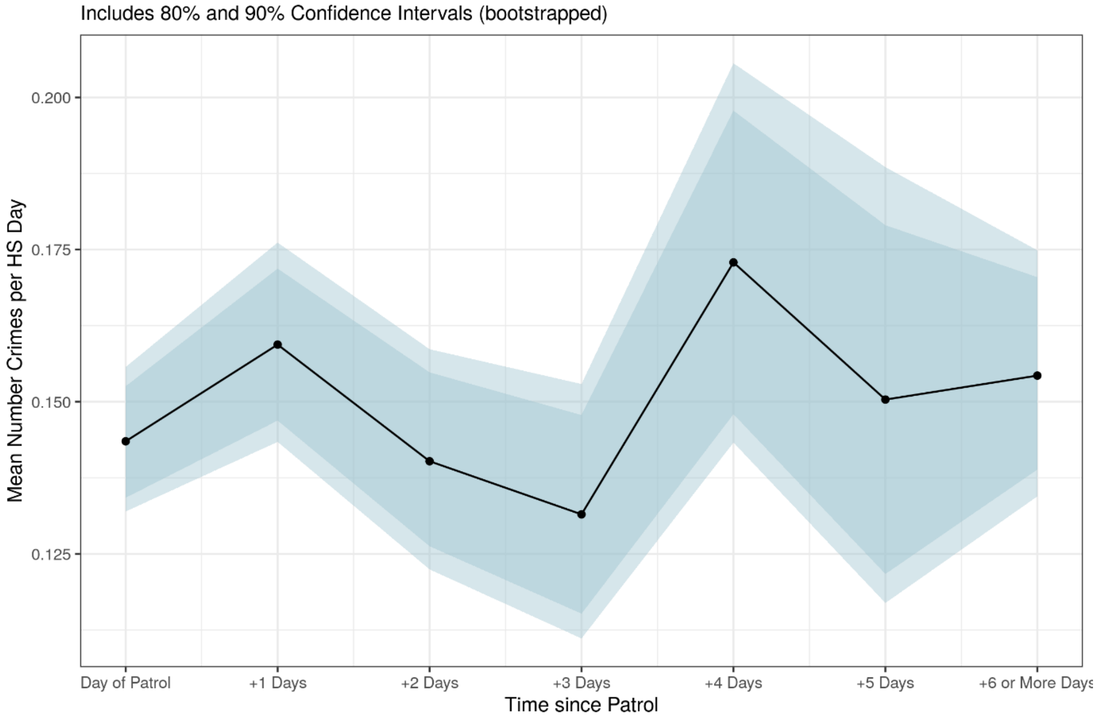


Figure 26: Multi-day Residual Impact (Up to 6 Days After) (Means Bootstrapped)

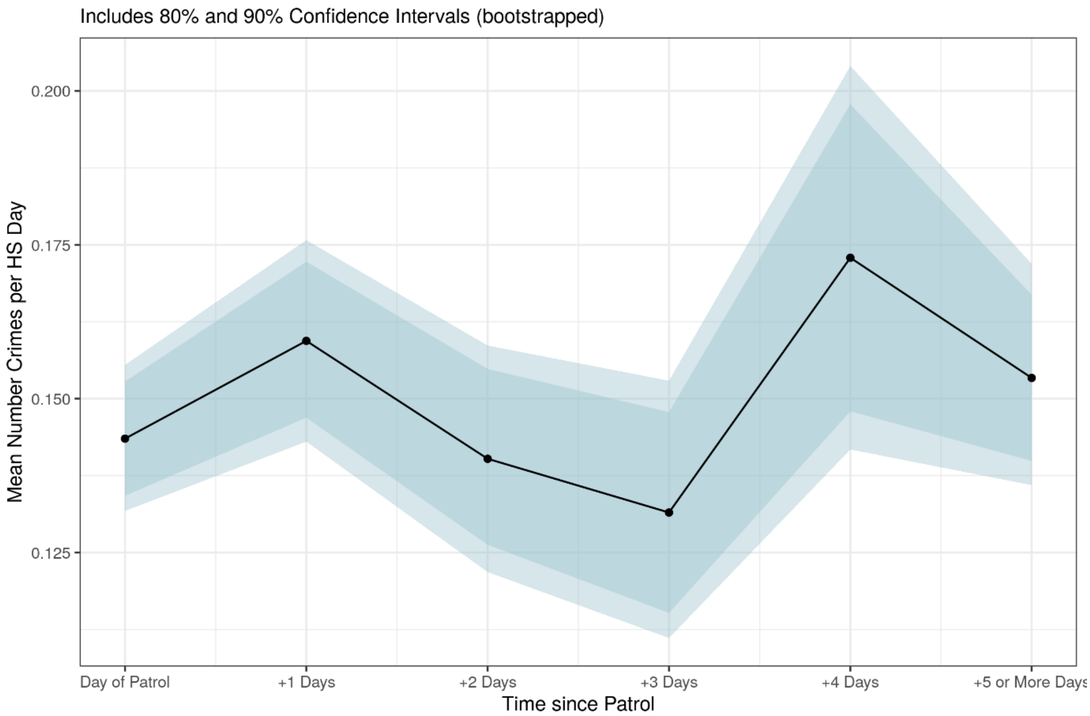


Figure 27: Multi-day Residual Impact (Up to 5 Days After) (Means Bootstrapped)

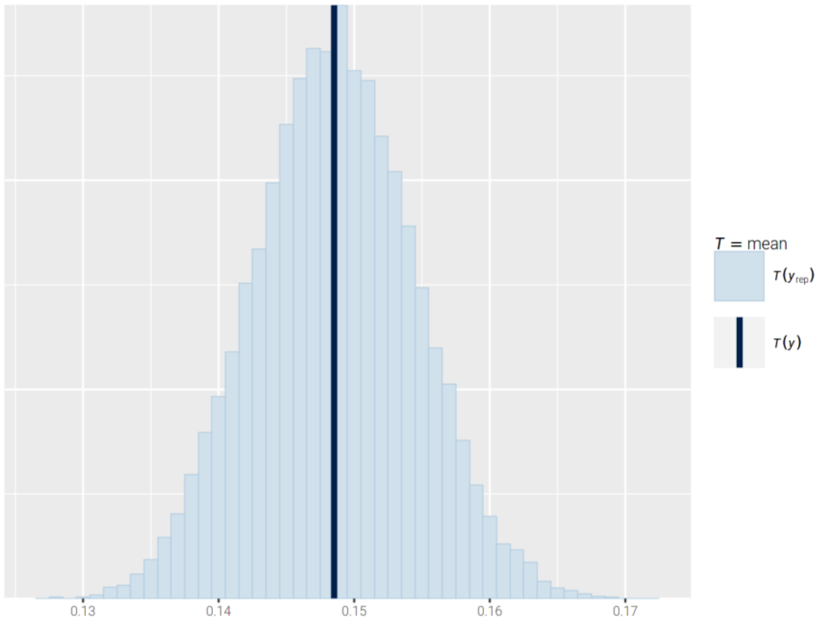


Figure 28: Residual Impact Model PP Check

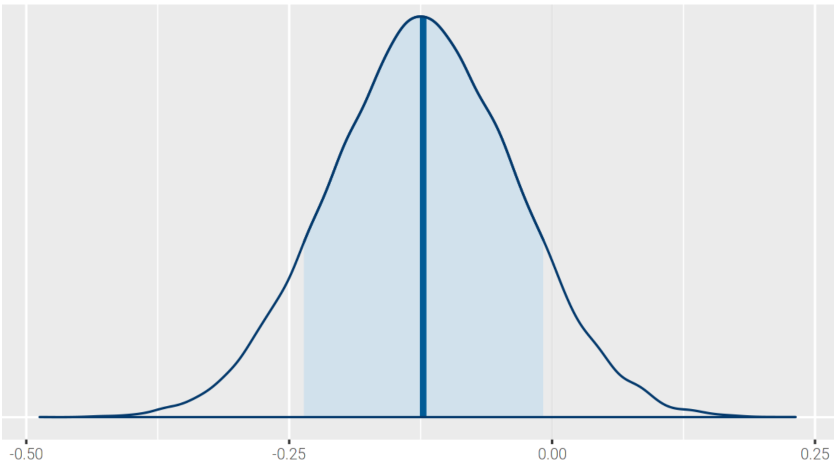


Figure 29: Day0

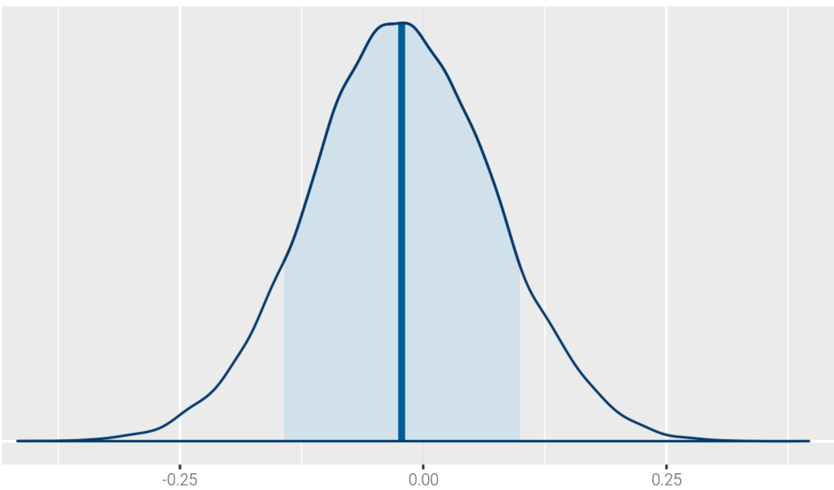


Figure 30: Day1

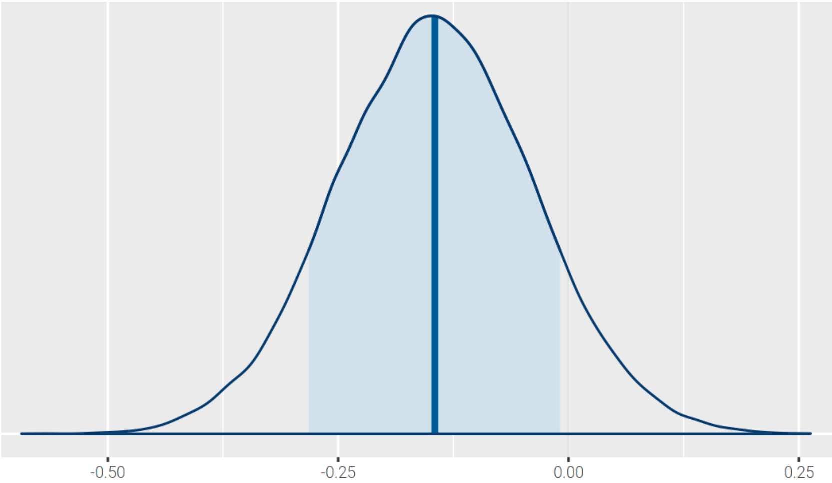


Figure 31: Day2

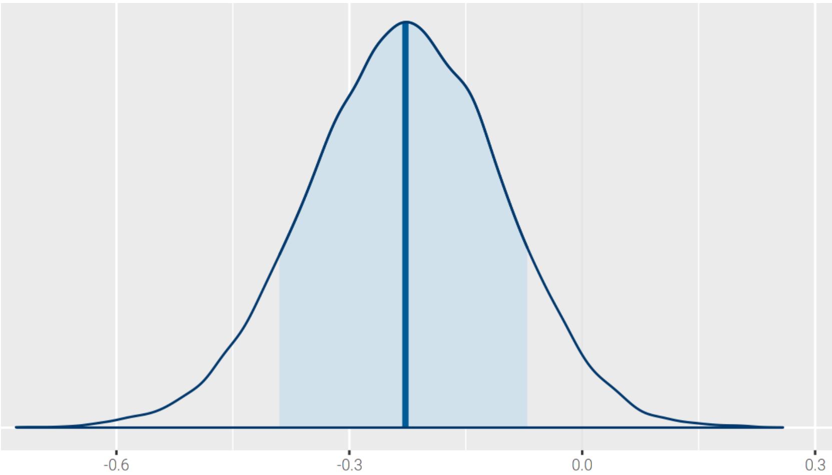


Figure 32: Day3

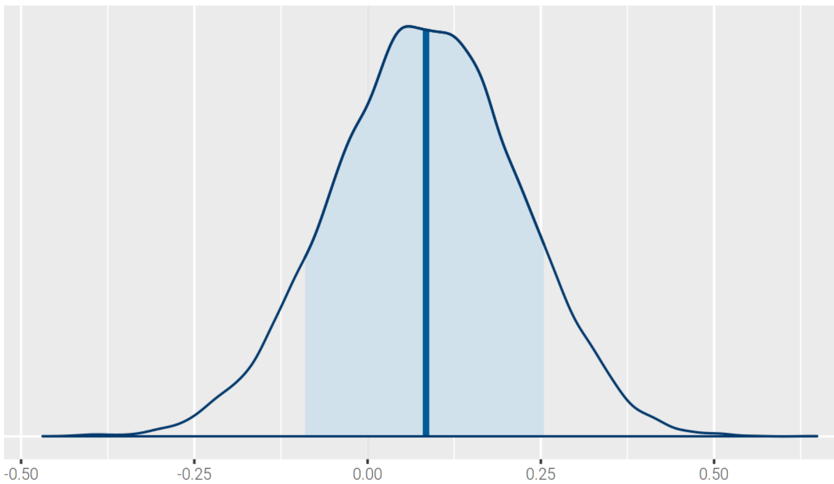


Figure 33: Day4

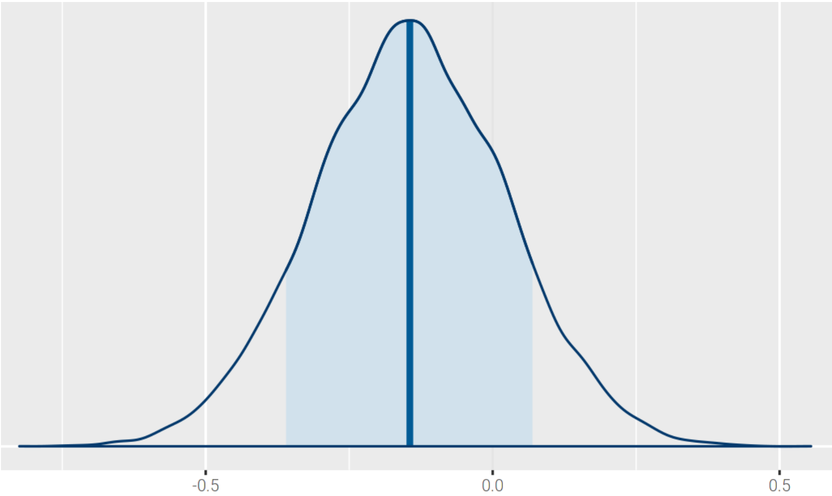


Figure 34: Day0 and 1

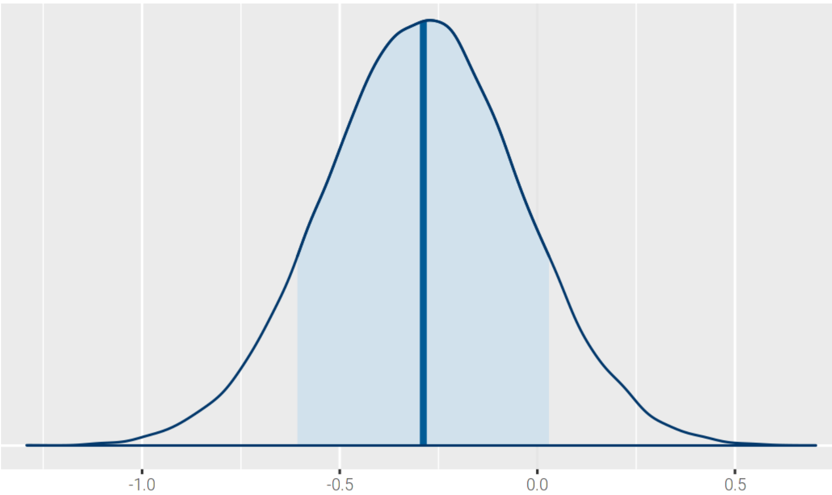


Figure 35: Day 0 to 2

Figure 36: Day0 to 3

Figure 37: Day0 to 4

References

Braga, A. A. (2016). Hot Spot Policing: Theoretical Perspectives, Scientific Evidence, and proper Implementation. *Preventing Crime and Violence*, 269–279.

Braga, A. A., Turchan, B., Papachristos, A. V., & Hureau, D. M. (2019). Hot spots policing of small geographic areas effects on crime. *Campbell Systematic Reviews*, 1-88. doi:https://doi.org/10.1002/cl2.1046

Home Office. (2018). *The Economic and Social Costs of Crime Second Edition.* UK Government.

Koper, C. S. (1995). Just enough police presence: Reducing crime and disorderly behavior by optimising patrol time in crime hot spots. *Justice Quarterly*, 649-672.

Sherman, L. W. (1990). Police Crackdowns: Initial and Residual Deterrence. *Crime and Justice, 12*, 1-48.

Sherman, L. W., Vickery, R., Rose, S., & Harinam, V. (2022). *Getting a GRIP on Serious Violence Hot Spots. A report for West Midlands Police.* Cambridge Centre for Evidence Based Policing.

Sherman, L., Neyroud, P. W., & Neyroud, E. (2016). The Cambridge Crime Harm Index: Measuring Total Harm from Crime Based on Sentencing Guidelines. *Policing: A Journal of Policy and Practice*, 171-183. doi:https://doi.org/10.1093/police/paw003

Weisburd, D., Wyckoff, L. A., Ready, J., Eck, J. E., Hinkle, J. C., & Gajewski, F. (2006). Does crime just move around the corner? A controlled study of spatial displacement and diffusion of crime control benefits. *Criminology*, 549-592.