PARTNER: A Geospatial Solution for Evidence-Based Police Patrolling

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Abstract

This study focused on providing geospatial evidence to develop a law enforcement patrol route. This process would allow supervisors and individual patrol officers to identify areas and subsequent patrol routes targeted to a specific crime within a predefined date range. This process would aid in efficiency, remove bias, and provide transparency in police tactics to the community. The tool PARTNER, Preliminary Analytic RouTing for Neighborhood Emergency Response, is a geospatial, geoprocessing solution for officers to create a route based on historic crime occurrences. This tool leverages hotspot analysis and Route Network analysis to determine the most efficient route for an officer to patrol the city, targeting the location where crimes have historically been higher than average as it relates to the rest of the city. This study created PARTNER to make this analysis reproducible and accessible by law enforcement to use in conjunction with intuition and personal analysis. PARTNER is designed for the new patrol officer unfamiliar with the patrolling area or to analyze alternatives for more seasoned officers who may desire a new perspective on crime within their corresponding jurisdiction. While the study is focused on the Fredericksburg Police Department in Virginia, the methodology applies to city, county, and state law enforcement with minor changes to the map setup regarding data conditioning.

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Background

Crime plays a vital role in the economic status of a city and is a defining characteristic of an area (Twinam, 2017). Developing a process to shift policing tactics from reactive to proactive would not only continue to modernize a police force but also create a community awareness of cause and effect within the police practices. Using evidence-driven procedures, a patrol officer can create a heightened sense of security within a community. Using historic crime patterns, an officer can fine-tune a repetitive presence in the community and the overall footprint of law enforcement for an area to facilitate this change within the community. This approach to policing does not entirely replace the "traditional" reactive or investigatory elements of policing but instead has the potential to provide a statistical and analytic methodology and reasoning for crime prediction (Meijer & Wessels, 2019).

With crime being an influential variable on the overall welfare of a community, it becomes imperative for the local police to be able to address and prevent crime within their jurisdiction. However, despite various methodologies of predicting possible crimes or conducting historical analysis of crime over periods, there is a margin of error and the probability variable that must be factored into police action to prevent crime. However, the solution remains the same: maintain a constant presence in the area. While the concept is simple, once things like staffing and budget constraints are considered, it is impossible to have an officer on every street corner and have enough reserve officers to respond to crimes being reported. Thus, patrolling the area is essential to maintain a police presence and have officers able to rapidly respond to a crime simultaneously.

The problem then shifts to developing a highly efficient and effective patrol method. There is no single patrol method or approach, as multiple variables dictate the best use of patrol methodologies. However, a patrol type can be tailored and adjusted based on the crime. Focusing on the crime only to direct a patrol negates most variables as it is only defined by the target crime(s). See Appendix 1 for formal patrol types that are used in standard police tactics.

Area of Study

Fredericksburg, Virginia, is 48 miles south of Washington, D.C., and 53 miles north of Richmond. Total area is approximately 10.5 square miles. As of the 2021 census, the population was 28,367. There are four zones that the police department uses as patrolling areas that nearly mirror the city wards. This area was selected as the study area due to the proximity of the analysis being conducted. While the study area is the primary focus for the tool developed, the methodology can be implemented in any city/town/jurisdiction of any size. The process remains consistent despite the physical location.

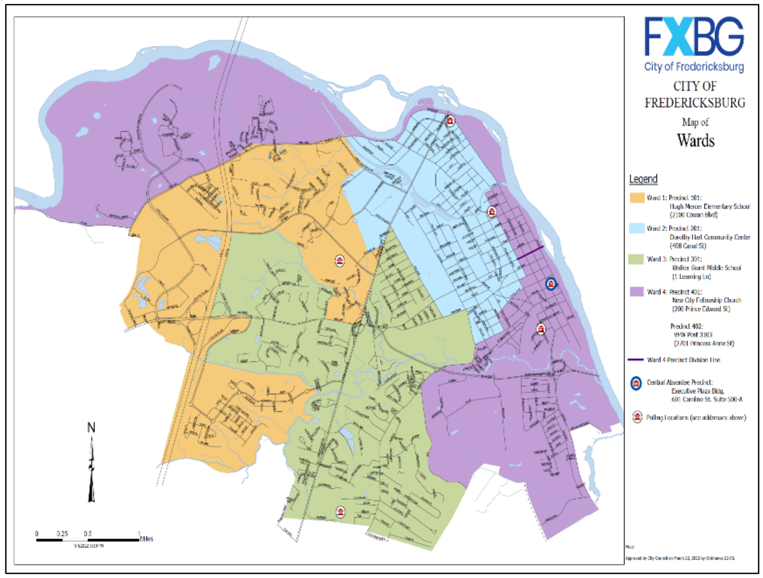

Figure 1: Map of Fredericksburg City and its Wards

Local Patrol Methodologies (Fredericksburg Police Department).

Upon a discussion with Officer Greg Baugher of the Patrol Division at Fredericksburg Police Department, insight was provided into how the patrol methodology is assigned and divided between officers and the city bounds. The city of Fredericksburg is divided into four patrolling zones, and each zone is allotted two officers per area. However, only one officer is assigned per zone; other officers support calls and emergency responses. This officer is the primary person responsible for the patrol efforts within the zone (MacCuish & Baugher, 2023).

Each zone patrol officer is also given a "Complaint Sheet" document. This document contains recent calls and complaints for the officers to be aware of and provides the locations (usually at the block level) to be present in to provide the community a high visibility patrol presence. This is similar to the data used for this study, as the communication logs for all activity involving the police department communication network were cataloged and conditioned.

Officer Baugher noted that the complaint sheets are "highly encouraged stops" to be incorporated into the daily patrol effort. He noted that how the officers decide to patrol is at their discretion, and there is little oversight of the supervisory staff in influencing where the officers need to be unless they happened to have missed a critical area that has been deemed as requiring an increased presence (MacCuish & Baugher, 2023).

Goals and Objectives

This project's first goal will be to provide transparency of the local police force and the activities within the community. While the individual officer will have the best intuition and understanding of an area of patrol responsibility, what they have learned and developed to expect from an area is not always well understood by the community they serve. Once incorporated with evidence-based decision-making, the bias and understanding of police activity can be validated by those now having deeper analytic insight into the individual officers' decision-making process.

The second main goal of this project is to further the hotspot analysis conducted for crime in an area. Crime mapping can include hotspots, zonal studies, crime profiles tied to geographic variables, and management of crime activities (Biswas, Das, & Das Chatterjee, 2021). Overall, hotspot analysis tends to be a focal point of many crime-based areal studies (Fitterer, Nelson, & Nathoo, 2015). One such study was done in Vancouver to assess crime areas to identify the areas where crimes occur so that police can be more responsive. Building from hotspot analysis as a form of Intelligence-led policing using the crime-based large dataset, analytic tools, and crime theory will likely generate unique ideas and solutions for preventing crime in an area. The prediction was that crime is likely to occur near an area where it has been occurring consistently enough to be statistically relevant. The desired approach to solving these revolving issues will identify hotspots and convert them into a route for patrol officers to incorporate into the regular patrols. This will not be a tool to create or predict areas that will likely have a crime, but rather aid in the police effort to reduce crime by being present in areas that are likely to have crime continually, based on the regular historical occurrence of similar crimes.

The tool developed was created in the study area and explicitly configured for the Fredericksburg Police Department. While this is a targeted study and use case, the model developed for the tool will be flexible enough to be used at any police department, agnostic of size, location, or jurisdiction. This would consist of importing patrol areas for the department, importing crime, applying a tessellation to account for equal area analysis, and adjusting the routing parameters. Developing the tool to have use beyond a single geographic location increases the overall applicability to city, county, and state-level law enforcement entities. This document provides a basic framework for the tool while serving as an analysis of the case study.

Methodology

Developing a methodology that allows for geospatial evidence to dictate the initial actions of a patrol officer will discourage the assumption that there is an underlying bias in the decision to be present in various areas within a jurisdiction. Development of this idea to provide transparency at the patrol level, an evidence-based approach will provide transparency and eliminate bias with geospatial enabling. The tool developed to create routes from crime occurrences is PARTNER: Preliminary Analytic RouTing for Neighborhood Emergency Response.

Data Acquisition

Data for this project required two primary layers to facilitate the development and analysis: the city road network, city/jurisdiction bounds, and the correlated crime data for the study location. Upon request, the Fredericksburg City GIS office provided shapefiles containing the city wards and the road network. This data was not exportable from the OpenData Initiative GIS portal hosting the city GIS data—called FredGIS—but was easily requested from the GIS office.

Crime data was procured from the local police department. For most crime datasets, there are multiple processes in which this data is retrieved based on various laws and policies. This information is hosted on the OpenData initiative GIS portal pages for some cities like Alexandria, Washington DC, and Richmond. However, in the case of Fredericksburg Crime Data, a formal Freedom of Information Act request was required. This was submitted by email to Lieutenant Ben Johnson of the Fredericksburg Police Department.

When acquiring the crime data through a FOIA request, the requestor and the FOIA officer must consider multiple elements. A review of federal and state laws on information sharing will dictate what elements and processes facilitate the mandatory release of information and what information may be associated with the release. The verbiage for the request to FPD was as follows:

> "I [Wesley MacCuish] am requesting the Date, Crime Category, and geographic location of police incidents, arrests, and/or responses allowed to be shared in accordance with Virigina Code 2.2-3706.1(C), (D), and (E) between the dates of January 1, 2022 through July 17, 2023. Please also remove or obfuscate any comprising elements in reference to the aforementioned state codes, 2.2-3706.1(H), and Public Law No. 114-185." - FOIA request, July 2023

Report #	Call Time	Nature	Location	Prime Unit	Disp.	Close Time
	03/09/2022 10:55	MENTAL HEALTH	1225 PARCELL ST		COM	03/09/2022 11:06:06
	03/09/2022 11:53	VEHICLE STOP	808 CAROLINE ST	320	VWR	03/09/2022 11:55:35
	03/09/2022 11:08	ASSIST	2200 COWAN BLVD	308	ASTD	03/09/2022 12:07:19
	03/09/2022 11:11	VEHICLE STOP	904 PRINCESS ANNE ST	313	SUM	03/09/2022 11:20:36
	03/09/2022 11:25	MENTAL HEALTH	600 JACKSON ST		BOL	03/09/2022 11:41:52
	03/09/2022 00:56	POLICE	1280 CENTRAL PARK	339	ASTD	03/09/2022 11:47:07
	03/09/2022 10:21	FRAUD	1001 CADMUS CT	328	NOA	03/09/2022 11:21:23
2022001146	03/09/2022 10:24	HIT RUN ACCIDENT	1201 GATEWAY BLVD	308	RPT	03/09/2022 11:53:40
	03/09/2022 11:41	BOLO	SPOTSY ECO LEFT 600			03/09/2022 11:42:33
	03/09/2022 11:03	FOLLOW UP	LPO - IRBY		LOG	03/09/2022 11:26:17
	03/09/2022 12:03	FRAUD			ITC	03/09/2022 12:04:30
	03/09/2022 12:18	911 HANGUP	1301-100 SAM PERRY		MISD	03/09/2022 12:20:36
	03/09/2022 12:19	MENTAL HEALTH	TOWNSEND,SHEILA		LOG	03/09/2022 12:20:23
	03/09/2022 11:56	MENTAL HEALTH	600 JACKSON ST	313	ADVS	03/09/2022 12:16:04
	03/09/2022 12:34	CHECK WELFARE	1704 LAFAYETTE BLVD		DUP	03/09/2022 12:40:08
	03/09/2022 12:40	LARCENY	447 EMANCIPATION HWY		LOG	03/09/2022 12:49:15
	03/09/2022 12:40	FOLLOW UP	LPO - GREEN		LOG	03/09/2022 13:03:47
	03/09/2022 12:42	FOLLOW UP	LPO - JACKSON		LOG	03/09/2022 13:02:05
	03/09/2022 14:16	FOUND PROPERTY	1300 AUGUSTINE AVE	307	ADVS	03/09/2022 14:44:25
	03/09/2022 13:26	MVA PROPERTY	990 BLUE GRAY PKWY		ITC	03/09/2022 13:27:30
2022001149	03/09/2022 12:36	DRINKING IN PUBLIC	110 GOODLOE DR	336	RPT	03/09/2022 14:20:57
2022001157	03/09/2022 17:18	ASSAULT	1001 SAM PERRY BLVD	341	RPT	03/09/2022 18:06:11
2022001150	03/09/2022 13:45	VANDALISM	1901-A HOWARD AVE	313	RPT	03/09/2022 14:51:40
	03/09/2022 13:25	VEHICLE STOP	512 LAFAYETTE BLVD	517	WWR	03/09/2022 13:35:00

Figure 2: Excerpt of data provided through FOIA from the Fredericksburg Police Department

Three essential elements are required for the crime data to have utility in this process: crime type/category, incident date, and geographic location. This would allow an analyst to ingest the data, classify the information based on types or parent/child relationships, and conduct a temporal analysis as required. The ideal delivery method would be as a table in an excel/.csv/.tsv format. The data in this format will be the easiest to ingest into a GIS. The data received was a 2000-page .pdf of police communication reports. Within the report, crimes were still annotated; however, additional items would need to be filtered out during the data conditioning portion.

Data Condition

City Data

Minimal data conditioning and manipulation were required for the City Ward and roads. The roads are a reference dataset for future processes, and the wards needed to have the overarching outline extracted. This process was done by tracing the outline as a new feature due to the small study area. However, if the study area is large, various geoprocessing tools can be conducted to combine wards/jurisdictions/other areal units into a single feature to define the study area.

Crime Data

Next, the crime data needed to be conditioned to a degree, allowing ingestion into the ArcGIS Pro environment. First, the .pdf needed to be converted into an Excel document to be used as a table. Data provided by FPD in a .pdf contained a section for street address, nature of communication, and a date time group. The conversion from .pdf to .csv was done through an Adobe capability online; however, this required the 2000-page document to be separated into 100-page documents. The final table product was 20 tables of crime data. See Appendix 2 for attempted alternatives to geocoding the data provided by FPD.

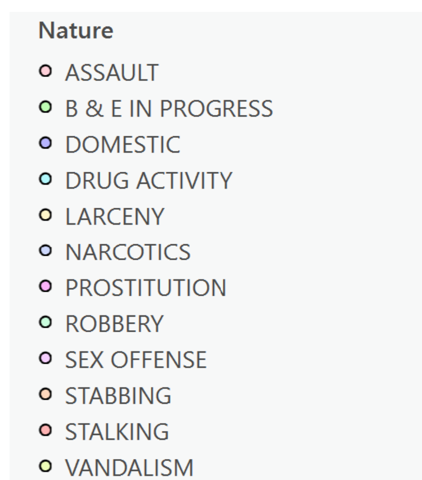

Figure 3: Crime Natures extracted from the Freedom of Information Act requested dataset

Various methods were used to prepare the tables for geocoding to find the most effective method that did not have enormous financial or time-consuming costs. While free, various geocoding services would only batch geocode 200-500 lines simultaneously (see appendix for attempted solutions disqualified from the study). The final process was adding a state and city field to the table, filtering the table only to include crime types shown in Figure 3. These crime types were selected based on a data review that led to an analytic decision based on frequency, prevalence, and severity. Once the data was filtered in Excel and the two location fields added, the only feasible solution was to use Esri Credits to geocode the tables in ArcGIS online.

Once the data was conditioned and ingested into ArcGIS Pro geocoding, the crime data should align within the study area. Of note, with the information provided through FOIA by the police station, some communication points were outside of the city boundaries. The points beyond the city boundary were discounted from the analysis in the project as they may be beyond the patrolling jurisdiction of the local police department.

Areal Unit Development

A review of the crime locations revealed multiple issues with the data regarding how the communication data was logged into the FPD database. Datapoints were written to addresses; however, it was assessed that the crimes likely were attributed to the nearest address rather than the exact coordinate, which may lead to false-positive locations within the dataset. The crime was attributed to an areal unit tessellation to mitigate this targeting location. The size of the tessellation was based on the visual correlation of crimes to the nearest roadway feature, with the final unit used as three-square acres as an inverted hexagon. While this could produce a study for the Modifiable Area Unit Problem (MAUP), as the scale of analysis can change various outcomes, this was not considered within the project's analytic decision-making (Nelson & Brewer, 2017).

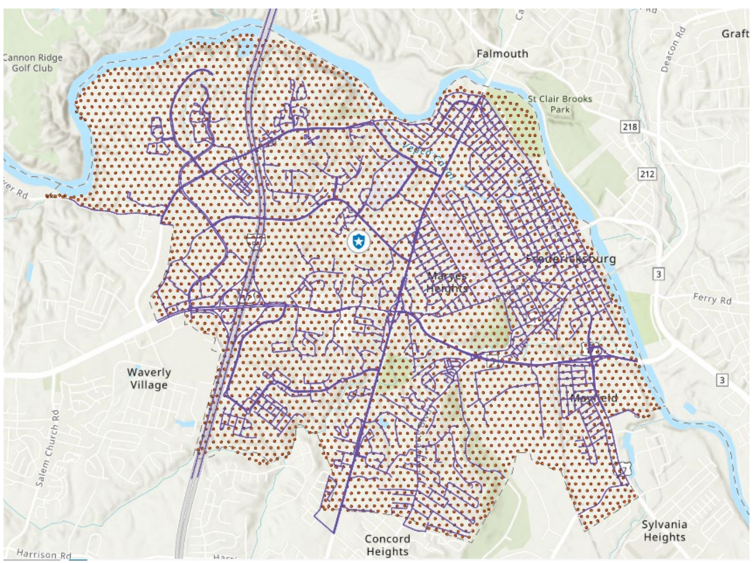

Figure 4: Visualization of Fredericksburg crimes as a tessellated points

Map Formatting for Geoprocessing

Once the areal units were defined, the tables were geocoded, and the subsequent process spatially joined the crime types to the areal units to preserve the unique crime counts. Using the *Summarize Incident Count* [1] from the Crime Analyst and Safety toolbox, each crime can be attributed as a field within the polygons and have the counts recorded within the record of spatially joined areal units. With this tool, the attributes within the tessellations are a unit identifier, and the crime counts per crime. The last step to condition the areal units with crime

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[1] Summarize Incident Count (Crime Analysis and Safety)—ArcGIS Pro | Documentation: Creates a feature class with coincident point counts. Coincident point counts for line and point features are determined by a specified maximum distance.

data was to convert the polygons to points using *Feature to Point*. This allows more road network availability for analysis when correlating incidents to an accessible location via roadway. This also mitigates opportunities for MAUP to become a factor of analysis as scalable polygons are removed from the analytic development of the data.

The map requires two more layers unique to the data in the workspace for the geoprocessing outputs to be replicable. To start, within a geodatabase, create a Feature Dataset and migrate the targeted road network into it. Next will be *Create Network Dataset*[2] and *Make Route Analysis Layer*[3] to condition the map by pointing analysis layers to the city infrastructure. These tools create an analysis zone within the map designed explicitly for route analysis. Within the route analysis layer, the following sublayers are established within the map: Stops, Routes, Point Barriers, Line Barriers, and Polygon Barriers. These layers are imperative to have within the map and the subsequent model as they are the foundation of the analysis being conducted with the geoprocessing tools. When the below model is implemented and run without the network and route analysis layers, multiple errors will be present, such as not having location data within the datasets or no applicable geometries existing when running the various tools.

Model Development

Once the map has been formatted and the data conditioned into an equilateral distribution of crime, the targeting of specific crimes for route development can be actioned. The first step was to identify a method of extracting high counts of a crime type within the dataset. The higher-than-average polygons were identified using a standard deviation-based symbology during the map formatting step. Using the below SQL process, this approach was used in a select-by attribute from the tessellated point layer to identify the crimes with a higher-than-average count. Once the features are selected, they are exported into the map as a standalone dataset, which can be used for the route analysis separate from the entire dataset.

```
PROSTITUTION_CNT > (SELECT AVG(PROSTITUTION_CNT) FROM TessPoints)
```

Once the standalone data is identified and segregated, that layer can be used in the *Add Locations*[4] to populate the route analysis layer. This step calculates the crime points within a 500-meter distance from the road network. The option to buffer the roads allowed for possible

[2] Create Network Dataset (Network Analyst)—ArcGIS Pro | Documentation: Creates a network dataset in an existing feature dataset. The network dataset can be used to perform network analysis on the data in the feature dataset.

[3] Make Route Analysis Layer (Network Analyst)—ArcGIS Pro | Documentation: A route network analysis layer is useful for determining the best route between a set of network locations based on a specified network cost.

[4] Add Locations (Network Analyst)—ArcGIS Pro | Documentation: Adds input features or records to a network analysis layer. The inputs are added to specific sublayers such as stops and barriers. When the network analysis layer references a network dataset as its network data source, the tool calculates the network locations of the inputs, unless precalculated network location fields are mapped from the inputs.

tessellation center points to be included in the dataset and subsequent geoprocessing output(s). The output is an updated network analysis layer where the crime-based selection has been included in the network analysis layer.

The final analytic geoprocessing component uses the updated network analysis layer and the *Solve*[5] tool to identify a route with the selected areas added to the updated route analysis layer. Two potential approaches were considered for the route development: a singular start point agnostic of the crime selection or a circular route where the start/end point is less critical. While starting at the police station near the city center may be advantageous in some cases, the FPD created four quadrants for officers to patrol. Having a location-agnostic start point allows officers to identify what part of the route is closest to them at any given point in the day, follow the route, and return to the starting point rather than the police station. Routes observed tend to have a segment within a quarter mile of the police station; thus, an officer may start a patrol from the police station using the route developed from crime instances and follow the suggested route to their assigned area. A non-circular approach gives more decision-making at the start/stop point than having every route begin and conclude at the police station.

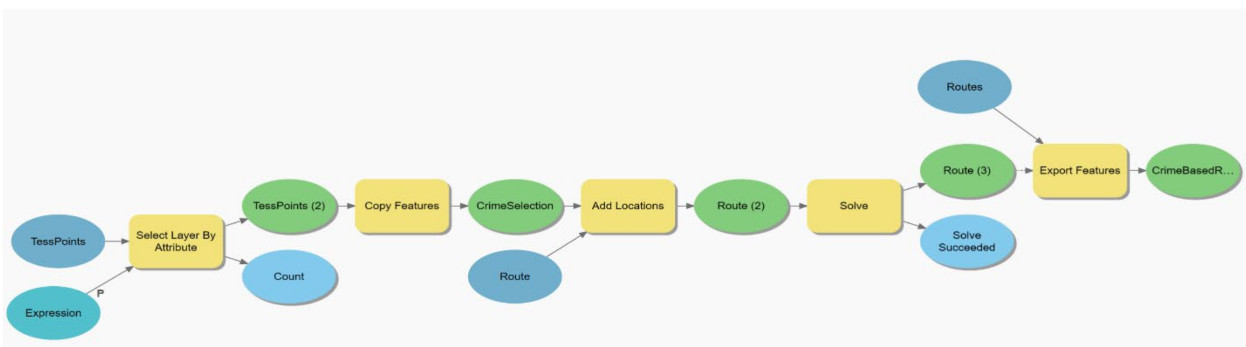

Figure 5: PARTNER tool represented in Esri's ModelBuilder

Sharing Route Data

The last step, though not necessary, is *Export Feature*. This tool takes the route created by the *Solve* geoprocessing and makes a standalone copy that can be displayed on the map separate from the network analysis layer. Another step that can be implemented is sharing the route to an ArcGIS Online portal. To do this step, within the *Solve* step, the option for including directions into the layer must be selected. A parameter can be implemented into the model that will allow the annotation of which officer is to be assigned the route through a naming convention prefix. Once the route is shared to an online environment, the individual officer can use web maps, web apps, and ArcGIS Navigator who may be allowed to access the route on either a Government Furnished Computer or a mobile device. This would allow the officer to access the pre-made routes on either device format to be implemented with daily duties.

[5] Solve (Network Analyst)—ArcGIS Pro | Documentation: Solves the network analysis layer problem based on its network locations and properties.

Alternatively, with special permissions, PARTNER can be shared as a single tool onto an ArcGIS Rest service as a geoprocessing service. The geoprocessing service is then converted into a widget in a web application that can be accessed by either a Government Furnished Computer or mobile device. With this option for route dissemination, the officer can generate their own route rather than rely on an analyst or headquarters element to produce and assign the route.

Results

The anticipated and achieved result of the project is using a model to generate a route based on designated crime hotspots from a historical perspective. This result, which was achieved, can allow for a dispatching/headquarters position to take the tasking of route development and share with the individual officers via email delivery of a shapefile or KML. For the FPD, the Government Furnished Computers operate on Computer-Aided Design software but may be able to ingest KML or .shp files. It is unknown how sharing a route layer would display or if the navigation-enabled content would prompt an officer with directions. However, it would likely display as the officer navigates the city. Operationally, this result will provide routes to the officer, but the patrol force cannot generate these routes independently and will need to request the creation and dissemination.

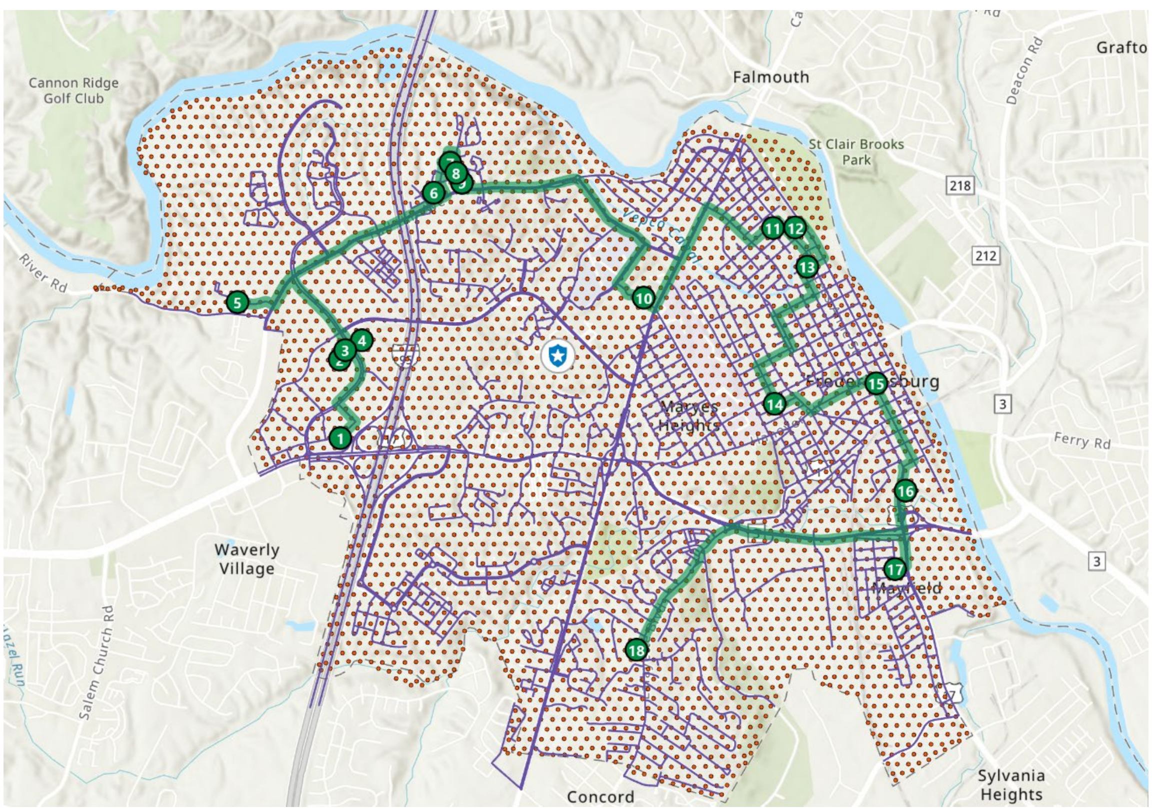

Figure 6: PARTNER generated route for prostitution hotspots in Fredericksburg annotating the route and stops

Future Works/Direction

The preferred end goal would be an application hosted publicly on ArcGIS Online. This provides two modes of applicability: web-based and mobile. There are two ways that this can be done with the current version of PARTNER. The ideal option would be allowing the officer to generate their own route through an Esri web application. This would involve sharing PARTNER as a geoprocessing service on a hosted portal. PARTNER can then be implemented in the user interface as a custom widget for the officers to identify the crime to be targeted. Using the method will also bypass any issue with the current CAD system by the FPD ingesting the data as the processing and visualization will be hosted on the application. Government Furnished Computers are highly regulated with where the system can browse on the internet. However, it is possible to get the website "whitelisted" for regular access or the design of the application be inclusive of mobile use to mitigate the safe listing process.

Alternatively, if the desired approach is using a mobile-friendly option, the routes can be shared as a web route rather than exporting PARTNER as a service. These routing layers are organized with group-sharing permissions and accessed through the mobile application ArcGIS Navigator. With this process, an additional step to PARTNER would be included to write the output route with directions to a group with directions enabled. This will allow the officer to retrieve the routes and query for a route with the officer's name in the metadata. While this does not offer a computer-based option, it will provide the officer with turn-by-turn directions to complete the route.

Conclusion

The proposed solution to develop a law enforcement patrol route providing geospatial evidence was achieved through PARTNER's methodology. Through streamlining multiple geoprocessing tools and techniques, crimes can be defined within an area in a way that allows for rapid visualizations and analytic decision-making beyond a hotspot study. Additionally, PARTNER remains independent of a police officer's own intuition for an area. This then enables both the geospatial evidence and the police officers to work in tandem to determine the most effective route through an area.

Upon completing this tool, a demonstration was provided to the City GIS/IT team for Fredericksburg city. PARTNER demonstrated a customizable routing solution capability that can be rapidly fielded for use in many environments. From the discussion during the presentation, it was identified that PARTNER can also be used to create combined crime correlation hotspots for routing. This was done by altering only the SQL expression in the user interface element. This discovered dynamic ability can allow a police officer to identify and route multiple crime hotspots using the *OR* operator. Alternatively, with the *AND* operator, the areal units can be assessed with a finer variable query. The *AND* operator will then identify only the hotspots where all crimes selected are higher than average.

The dynamic capability within this tool can increase the overall utility of the historical analysis being leveraged into the police patrolling tactics. PARTNER demonstrates an automation and evidence-based conclusion in a user-friendly geospatial tool for the emergency services community.

Appendix

1. Definitions of Patrol Types

Preventive Police Patrol: "Traditional preventive patrol is defined as the routine movement of uniformed officers by vehicle or foot through delineated geographic areas. Patrols of this type usually have five goals: deterrence of crime, apprehension of criminals, satisfaction of public demands for services unrelated to crime, development of a sense of security and confidence in the law enforcement agency, and recovery of stolen property." (Szynkowski, 1981).

Team Policing: "A community-oriented policing strategy that was first introduced in the 1970s as a response to the perceived failures of traditional policing models. The strategy emphasizes collaboration among officers and between police and community members to prevent crime and promote public safety. Under the team policing model, officers are organized into teams or units responsible for specific geographic areas or types of crime." (McKee, n.d.)

High and Low Visibility Patrol: These two types of patrols impact the degree of which the community is aware of the patrol. High visibility is where the officers involved want the community to be aware of what is occurring and law enforcement response/involvement. Low visibility is where the officer is being more discreet. This is also best applicable to instances where an officer does not want to be seen and may use unmarked cars, covers, and discreet communications (Newman, 1974).

Decoy Patrol: "Using plainclothes surveillance, decoy tactics, and statistical analysis for changing deployment, the unit attempted to apprehend suspects who were committing a crime. The unit used two techniques in this effort: decoy and blending. Using the decoy technique, a police officer is disguised as a potential crime victim and placed in an area where he or she is likely to be victimized. While decoy tactics are used in response to particular crime/victim patterns, blending techniques are employed to allow the police officer to move freely on the street. The primary objective is to effect quality arrests with no increased danger to police or citizens." (Beene, 1992)

Split-Force Patrol: Officer force is divided between two primary initiatives, patrol, and response. This is built to allow a constant force of patrol with the additional support of response officers that can either action calls and complaints or pick up on the patrol duties should the primary be taken away from the patrol process to answer a call (Cahn & Tien, 1980).

2. Geocoding attempts and results

The table required to be geocoded was twenty tables of three to five thousand records. This presented a large data problem to the project that incurred a high cost for the project analysis or created an issue with the geocoded data size. Below are some options explored for converting the crime data obtained from the FPD into a workable table.

ArcInsight [6]*:* ArcInsight is a tool on the ArcGIS Online portal with a license. One of the options within the tool is to geocode tables to display on a map. This option was used, and the output created two different tables: one with point locations displayable on the map and one with the attribution. Within the ArcInsights, the two tables were joined, but there is no way to maintain that join outside the ArcInsight environment intuitively. When exported, the two tables do not have a key field to conduct a join on. The attribution is a crucial element for the analysis. This option was a free geocoding service with no limit on the batching size. Future iterations of PARTNER may require this to be the option for establishing the map.

Geocodio: This tool is a free online geocoding service after a user signs up. This option provided accurate geocoding after minor table manipulation; however, there is a limit to the geocoding batch size. This service allows for 500 features to be geocoded at a time per table. In the study for Fredericksburg, the data was parsed into tables containing three to five thousand features. To make Geocodio work, the tables need to be further parsed to increase the overall time spent manipulating the data. The attempt did produce accurate geocoded tables at zero financial cost to the analyst.

Feature Manipulation Engine: Feature Manipulation Engine (FME) is a standard tool analysts use for processing and geoprocessing data. When the crime data was ingested, various error codes were presented. This may be a feasible option, but a solution was not reached for this study.

Other Options: Various other free options were attempted to geocode the tables, which included Geoapify, GitHub, Cvs2Geo, and others were attempted. The most frequent issue was the batch sizes per table. Between 300-500 records are assessed as the standard size per geocoding process for the free options. It was determined that this was not a feasible option for this study. When using the ArcPro geocoding service, a cost is incurred through using Esri Credits. To mitigate the overall cost, the tables were filtered on selected crimes viewed in Figure 3

[6] ArcInsights | Documentation: ArcGIS Insights is an analytics workbench that allows you to perform iterative and exploratory data analysis. You can answer questions with data from ArcGIS, Excel spreadsheets, business databases, and more by simply dragging the data to perform analysis.

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