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Visualization of Spatial Relationships in Mobility Research: A Primer

Final Report

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As always any errors in the document are the sole responsibility of the authors.

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Abstract

The mapping of crime has been done for hundreds of years. Early studies mapped values across areas with choropleth maps or the specific locations of events using point maps. More recently, some researchers have become interested in developing spatial typologies of crimes that incorporate the relationship between offender and victim residence and the location of the crime. However, little explicit attention has been given in the criminological literature to the various methods available for visualizing the information contained in spatial typologies such as mobility triangles. This primer fills that gap by focusing on cartographic techniques available to (1) visualize the movement of offenders and victims among neighborhoods and (2) depict the relative relationships among locations that are captured in mobility triangle data.

Introduction

The mapping of crime data has a long and varied history. Early mapping efforts focused on where the criminals lived (Quetelet, 1842; Shaw & McKay, 1942) or where the crimes were committed (Boggs, 1965; Schmid, 1960a; Schmid, 1960b). These studies used a choropleth map to visualize the patterns of criminal residence and crime location.[1] A choropleth map shows the boundaries of areas and shades the areas by the amount of the analysis variable present, the darker the shading the greater the amount. Other researchers were interested in developing spatial typologies of crimes that incorporated the relationship between offender residence and the location of the crime. Burgess' (1925) classification of juvenile delinquency events as either neighborhood or mobility was the first work of this kind. Much later, Normandeau (1968) expanded the initial two category spatial typology to its present five categories. However, criminologists have given little consideration to the various methods available for visualizing the information contained in mobility triangles and other analyses of travel behavior.

This primer fills that gap by focusing on cartographic techniques that could be used to better visualize the information contained in a mobility triangle analysis. Capturing the dynamic elements of the convergence of victims and offenders in space and time often requires a combination of traditional techniques such as graduated symbol, pie chart, and choropleth maps with lesser known ones such as flow maps. This primer provides an overview of the techniques available to (1) visualize the movement of offenders and victims among neighborhoods and (2) depict the relative relationships among locations that are captured in mobility triangle data.

Mobility Triangles

Before discussing ways to visualize mobility triangles, a more in-depth introduction to both the method itself and the data involved, is warranted. Mobility triangles are formed from three locations: offender home address, victim home address, and site of the crime. The relative spatial relationships among the three locations constitute the basis of the typology and can be represented in terms of social coincidence or metric distance.

Traditional mobility triangles are classified using social coincidence within a set of socially derived boundaries. These boundaries most often consist of census delineations, such as census tracts or census block groups, or neighborhoods. The spatial coincidence among offender residence, victim residence and homicide location is compared to determine the classification as one of five possible types of mobility triangles (Exhibit 1). For example, if all three of the locations are in the same neighborhood, there is complete spatial coincidence and thus the triangle is classified as a neighborhood mobility triangle. Three of the four classifications involve some degree of social area coincidence. For example, if the victim neighborhood is the same as the location of the homicide but the offender neighborhood is different, it is classified as an offender mobility homicide. Only total mobility triangles involve a complete lack of neighborhood coincidence (i.e., they occur in three different neighborhoods). Distance mobility triangles, on the other hand, use an interval distance cut-off (e.g., .5 miles) to classify the relationships. If each of the distances between the three locations were greater than the cut-off value, the triangle would be classified as a total mobility triangle.

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[1] See Harries (1999) for an excellent beginning level introduction to mapping crime.

Exhibit 1: Traditional Mobility Triangle Typology

Neighborhood Location	Triangle Type
1. Homicide = Offender = Victim	Neighborhood Mobility Triangle
2. Homicide = Victim and Homicide <> Offender	Offender Mobility Triangle
3. Homicide = Offender and Homicide <> Victim	Victim Mobility Triangle
4. Homicide<>Victim and Homicide<>Offender and Victim=Offender	Offense Mobility Triangle
5. Homicide<>Victim and Homicide<>Offender and Victim<>Offender	Total Mobility Triangle

Although the two typologies are very similar, one uses a static nominal level comparison and the other a dynamic, interval level comparison. The traditional mobility triangle typology has five categories constructed from the relationships among neighborhoods with set boundaries. A distance mobility triangle has the five traditional categories plus three more (Exhibit 2). The additional categories stem from the differences in the logic involved. In the traditional typology of an offender mobility triangle, the victim and location neighborhoods must be the same and the offender and location neighborhoods different. Thus, by definition, the offender location neighborhood and victim location cannot be the same. However, in a distance typology, the criterion for classification is the distance between each of the three locations. Thus, there are three comparisons to be made – victim to homicide (inside or outside cut-off), offender to homicide (inside or outside cut-off) and victim home to offender home (inside or outside cut-off); each of these comparisons can be true or false (as opposed to traditional triangles where the comparison is between the neighborhoods in which each location might fall). There could be instances where the victim may live within the cut-off distance to the homicide location, and the offender may live outside the cut-off but the victim to offender distance could be inside the cut-off or outside the cut-off. This scenario would require two distinct types of offender and victim mobility triangles rather than just one, as is the case when using the traditional triangle typology.

Exhibit 2: Distance Mobility Triangle Typology

Triangle Type	Criteria
1. Neighborhood Mobility Triangle	HomicideToOffender < cut-off distance HomicideToVictim < cut-off distance VictimToOffender < cut-off distance
2. Offender Mobility Triangle/ Local Residence	HomicideToVictim < cut-off distance HomicideToOffender >= cut-off distance OffenderToVictim < cut-off distance
3. Offender Mobility Triangle/Non-Local Residences	HomicideToVictim < cut-off distance HomicideToOffender >= cut-off distance OffenderToVictim > cut-off distance
4. Victim Mobility Triangle/Local Residences	HomicideToVictim >= cut-off distance HomicideToOffender < cut-off distance OffenderToVictim < cut-off distance
5. Victim Mobility Triangle/Non-Local Residences	HomicideToVictim >= cut-off distance HomicideToOffender < cut-off distance OffenderToVictim > cut-off distance
6. Offense Mobility Triangle	HomicideToVictim > cut-off distance HomicideToOffender > cut-off distance OffenderToVictim < cut-off distance
7. Local Event/Non-Local Residences	HomicideToVictim < cut-off distance HomicideToOffender < cut-off distance OffenderToVictim > cut-off distance
8. Total Mobility Triangle	HomicideToOffender > cut-off distance HomicideToVictim > cut-off distance VictimToOffender > cut-off distance

In the time since the original research on mobility triangles, the value of opportunity theories of crime such as routine activity theory (Cohen & Felson, 1979), lifestyle theory and environmental criminology (Brantingham & Brantingham, 1981) as aids to understanding crime patterns has become widely recognized. These theories emphasize the role of human spatial behavior in bringing together motivated offenders and suitable targets in environments that are conducive to crime. As the use of opportunity theories and spatial classification systems such as mobility triangles has increased, so has the need for cartographic techniques to aid in understanding the data.

This primer provides a wide-ranging exploration of techniques for the cartographic representation of mobility as it relates to criminal events. Data describing homicide events, victims, and offenders in Washington, DC, illustrate the different cartographic techniques. The primer takes an applied perspective using many examples to illustrate how and when particular cartographic techniques can aid in the visualization of data involving multiple locations and/or movement. Applications to both research and practice are discussed.

Since the goal of this primer is to provide an introduction to visualizing flows and spatial relationships among locations, it begins with a general discussion regarding the role of maps and available cartographic techniques.[2] The first section explains the data used in the primer and sets out a framework for organizing the various cartographic techniques available. The next section provides examples to demonstrate the types of questions that can be answered through the examination of mobility data at a variety of scales. Specific techniques for depicting locations, symbolizing proportions and relationships, and representing flows are all addressed in turn. Many practitioners, particularly homicide detectives and patrol, will be especially interested in the final section that focuses on the homicide situation in one neighborhood. The two appendices offer technical overviews of software and data formatting. Appendix 1 reviews three software products available to produce flow maps and provides valuable information to those who are ready to use flow maps in their analyses. Appendix 2 provides more explicit directions on how to create an origin and destination matrix. In sum, the primer offers the first attempt to address the challenges of visually representing information from multiple location data sets such as those used in a mobility triangle analysis.

Objectives of the Primer

After reading this primer the user should

- Know what types of mapping techniques are available and when each is appropriate for a particular analysis.
- Be familiar with how to symbolize specific map types and the pros and cons inherent in choices made by the mapmaker.
- Be able to articulate the types of questions that can be answered using each type of map.
- Be familiar with different types of software available to construct flow maps and their relative advantages and disadvantages.
- Know how to symbolize the relationships revealed by mobility triangle classification.

[2] There are a variety of introductory cartography books that offer both a breadth and depth of basic cartographic principles that is beyond the scope of this document (Dent, 1999; Robinson, 1995; Slocum, 2005).

Cartographic Representation of Mobility Triangles: An Applied Perspective

Maps are models of reality. As models they are, by definition, simplified representations of the world. At the same time, maps are also powerful analytical and communication tools because they can be used to summarize large volumes of information. However, like all tools, maps as communication devices are only as good as their creators. It is the analyst/mapmaker who controls which aspects of the map are minimized and which are emphasized through choices of cartographic technique (i.e., point, line or area); symbol types, colors and sizes; and general map design. These choices directly impact the message communicated to the map reader. The following discussion examines several different types of cartographic techniques that address various aspects of mobility triangle data and speaks to how they can be used, either singly or together, to communicate information and expose relationships.

The conceptual approach to the various cartographic display techniques is detailed in Exhibit 3. The figure depicts three types of techniques, point, line and area that are pertinent to visualizing the information captured in mobility triangles. The position in relation to the origin of the graph is meant to dually symbolize: (1) the most suitable type of cartographic technique to use at a particular scale; and (2) the type of feature most often used to represent a particular type of mobility triangle data. Point maps are located close to the origin of the graph for two main reasons.[3] First, they represent the type of event symbol employed (i.e. a point) when the distance traveled by both offender and victim is very short (i.e., close to zero). Second, they are best used with large-scale maps showing a neighborhood or portion of a city. Choropleth maps are farther out from the origin on both axes because they are good for showing distributions across areal units. They can symbolize offender or victim journey to crime and are best at city to regional scales (e.g., to show the average length of journey by neighborhood). Finally, line maps showing flows can convey the movements of offenders and victims between specific neighborhoods, cities, or states. The flexibility of flow maps earns them a spot at the center of the graph. In general, the appropriate technique for a particular map is driven by three factors:

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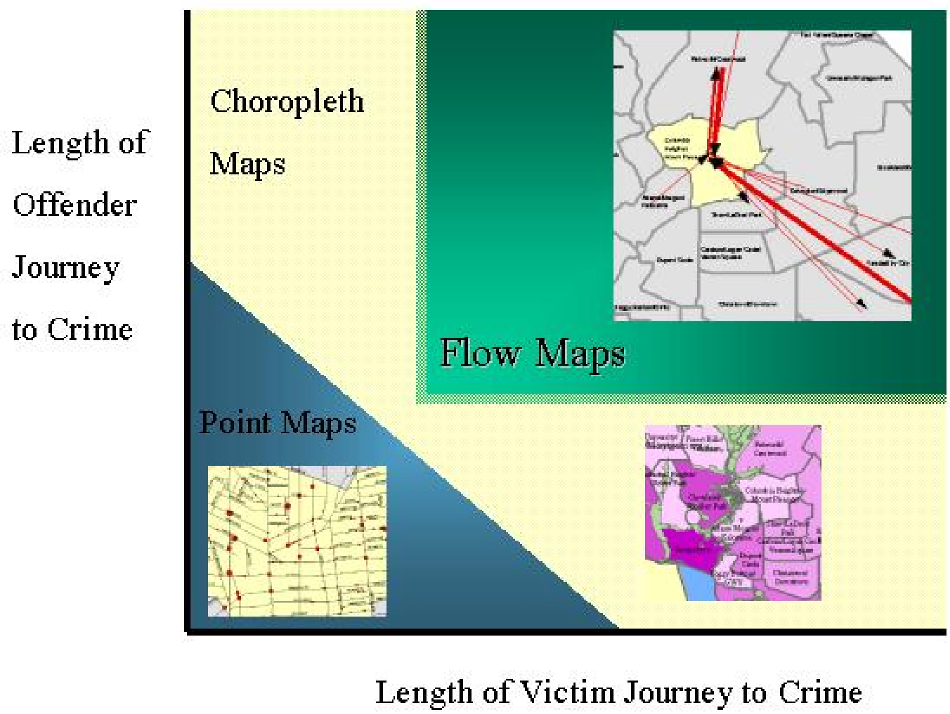
3 The terms ‘point map’, ‘pin map’ and ‘common dot map’ (Dent, 1999) all refer to the same general type of map.

(1) the type and availability of data, (2) the scale, and (3) the question to be answered. The next few paragraphs provide examples of each type of mapping in relation to those three factors.

Exhibit 3: Classification of Cartographic Display Techniques



Location data that consist of addresses are good candidates for point mapping. An important type of point map is the graduated symbol map. On a regular point map, each symbol represents one event and they are all the same size. Graduated symbol maps, on the other hand, have only one symbol to represent all events at a particular location; the size of the symbol depicts the number of events. Point maps can be employed at a large scale (e.g., neighborhood) or a regional-scale. The trade-off is in the level of detail that can be communicated effectively. Usually, it is straightforward to depict the exact locations of events on a large-scale map.[4]

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[4] Most crime mapping involves one jurisdiction or one part of a jurisdiction. Thus large-scale maps are those that depict a very small area such as a neighborhood while small-scale maps are larger than a county. One drawback to point maps, even at a large scale, is that multiple crimes at the same location are impossible to distinguish. Graduated symbol maps address this issue by having the size of the symbol represent the number of events at the same location.

However, the same events on a regional-scale/small-scale map are helpful only for showing the overall distribution of locations because the individual symbols overlap and are difficult to distinguish from one another. The type of question being answered is always an important consideration and should guide the choice of technique. If the goal of the map is to provide information about the distribution of a type of event across a city, then a point map may be the appropriate tool. For example, creating a point map of home addresses of victims would be a quick way of visualizing concentrations of victim residences that should lead to further analysis. Specific to mobility triangles, when examining events in which both offender and victim trips have zero distance (e.g., crime occurs at the home that victim and offender share), point mapping techniques provide an excellent visualization of the distribution of those locations.

Both choropleth and flow maps offer convenient and powerful methods for representing data at the city or regional scale. These types of maps are especially helpful when offenders, victims, or both parties, have made longer trips to the site of the event because they enable the aggregation of information. Choropleth maps (also known as area maps) allow the representation of relative quantities of offenders, victims, and crime locations across areas. The greater the concentration, the darker the color used to depict the area on the map. Because areas are different sizes and can contain different base populations, it is important to map only normalized data (e.g., densities, percentages etc.) rather than totals.[5] Otherwise, the map can provide incorrect information. For example, when mapping burglaries the number of housing units in an area affects the total number of burglaries. Thus, the number of housing units should be used to normalize burglary data before it is mapped, so the distribution of burglary incidents relative to targets is accurately shown. Choropleth maps can also be applied to characterize differences in quantities. For example, the difference in the import/export of offenders and victims can be represented. However, the analyst should make the purpose of the map clear. Area-based symbol maps are also a good alternative at this scale and offer the ability to show the distribution of a variable within each area. When applied in conjunction with flow maps (explained below), choropleth maps can summarize both aggregate flows of offenders and relative ratios of offenders and victims on the same map.

[5] Additional design decisions that are critical to creating choropleth maps have been covered in aforementioned introductory texts and will not be reiterated here.

Flow maps provide unique information that is difficult, if not impossible, to adequately visualize using other cartographic techniques or a matrix. This type of map is specifically designed to represent dynamic flows of people or goods between areas (Tobler, 2004a; Tobler, 2004b). Data for flow maps comes in the form of origin and destination totals (Exhibit 4). Each cell in the table represents the number of trips made between the two neighborhoods. For example, nine individuals traveled from Neighborhood 2 to Neighborhood 4 (see shaded cell). Flow maps can be used at a variety of scales but are most effective at the city, regional, or country level to depict overall flows between areas. This type of map excels at answering questions about connections between particular areas and about the extent that a phenomena is internal versus external. For example, 60% (n=20) of the trips originating in Neighborhood 1 also ended in Neighborhood 1, indicating a local pattern. Far more effort has gone into developing techniques for point and choropleth maps (Dent, 1999; Harries, 1999) than flow maps.[6] These endeavors have gone a long way to improving the readability and accuracy of the information depicted on maps and can be used to inform the creation of flow maps.

Exhibit 4: Example Origin and Destination Matrix

	DESTINATION			
ORIGIN	**Neighborhood 1**	**Neighborhood 2**	**Neighborhood 3**	**Neighborhood 4**
Neighborhood 1	20	5	8	0
Neighborhood 2	7	14	6	9
Neighborhood 3	12	16	4	3
Neighborhood 4	2	13	15	7

An Introduction to the Example Data Set

Overview of Examples

The different techniques for visualizing spatial relationships among locations are illustrated through a homicide data set. The data set includes the location of the homicide as well as the home addresses of both victims and offenders. As noted above, a variety of cartographic techniques are available to visualize these data and their suitability varies by the scale of the analysis. The following sections examine each type of cartographic technique in turn at a small

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6 One notable exception is the body of work by Waldo Tobler (2004a; 2004b) on flow visualization.

scale (e.g., District of Columbia or metropolitan region). Then a sample analysis of homicide in the Columbia Heights/Mt. Pleasant neighborhood cluster is provided to illustrate how those same techniques can be applied at a large scale. By using the same data set and displaying it in different ways, the following examples provide a good introduction to the potential effects of map-making decisions on the message of the map.

Overview of Data

When analyzing data that represent multi-location phenomena, such as mobility triangles, the analysis data set is usually a subset of the entire set of incidents. This occurs because one or more of the three locations, homicide event, victim home address, and suspect home address are not known. For instance, since the offender information is not known, no homicides for which there has not been an arrest can be included. This introduces a certain amount of bias into the sample since mobility triangles only include homicide events in which an arrest was made. The analysis set is reduced even further if either of the other two locations do not geocode successfully since all three locations must geocode for the event to be included in the mobility triangle analysis.[7]

The sample data for the primer consists of the 4,534 homicides that occurred in Washington, DC, over the 13-year period, 1990-2002. Of those homicides, 3,972 victim home addresses and 3,293 offender home addresses were successfully geocoded. When the geocoded locations were linked to find events with all three locations available, 2,773 homicide triads (representing 2,139 unique homicide events/victims) remained. These numbers do not add up neatly because a homicide can have more than one offender but all three locations had to be successfully geocoded in order for the triad of locations to appear in the data set. After all the geocoding and joins, the primer's data set represents approximately 47% of all homicides that occurred during the study period.

The study area includes the District of Columbia, Maryland, and Virginia but the focus is on homicides that occurred in the District of Columbia (DC). The home addresses of homicide

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[7] It is possible to analyze what Block, Galary and Brice (2004) call dyads. Dyads are location/victim home address and location/offender home address pairs. Since these cannot be mobility triangles they are not specifically addressed in this analysis. However, cartographic techniques such as point and flow maps could be used to visualize dyads.

victims and offenders were included if they lived in the study area. While the study area of homicide location (i.e., DC) is compact, covering only 61 square miles, the study area for victims and offender home addresses was much larger, including both Maryland and Virginia in addition to DC. According to the decennial census, the population of DC was 572,059 in 2000. In the same census year, Maryland had a population of 5,296,486 and Virginia 7,078,515.

General, Multi-Scale Analyses of Mobility Triangle Data

This section details the types of information that can be gleaned from mobility data by using different cartographic techniques to visualize the data across multiple scales. Three different types of analyses are illustrated. The first section examines how point data contained in mobility triangles can be displayed. Next, the relative distributions across neighborhoods are examined with choropleth maps. Finally, the dynamic exchange of individuals across space and time via flow maps is discussed.

Depicting Locations

The most basic cartographic technique is using points to show the distribution of events. Point maps require information about the physical location of the homicide and victim and offender home addresses; they are very good at communicating the spatial pattern of those locations. In the case of mobility triangles, there are three related locations which can be symbolized in a variety of ways.

Questions That Can Be Answered By Point Maps

- Where do offenders live?
- Where do victims live?
- Where are crimes occurring?
- What is the relative location of homicide to offender and victim home addresses?
- Where do the victims live who were victimized in a particular neighborhood?
- Where do the offenders live who committed crimes in a particular neighborhood?
- What is the distribution of different types of mobility triangles?

Examples

Related to mobility triangles, point maps enable the visualization of any one or all three, of the locations that make up the triangle. For instance, the distribution of home addresses of homicide victims (Exhibit 5) or offenders (Exhibit 6) could be shown, as could the pattern of homicide locations (Exhibit 7). All three of these maps indicate the highly clustered nature of homicide events and consistently reveal six major groupings across DC. These clusters are in north central, central, southern southeast, central southeast and northern southeast.

Exhibit 5: Point Map of Victim Home Addresses

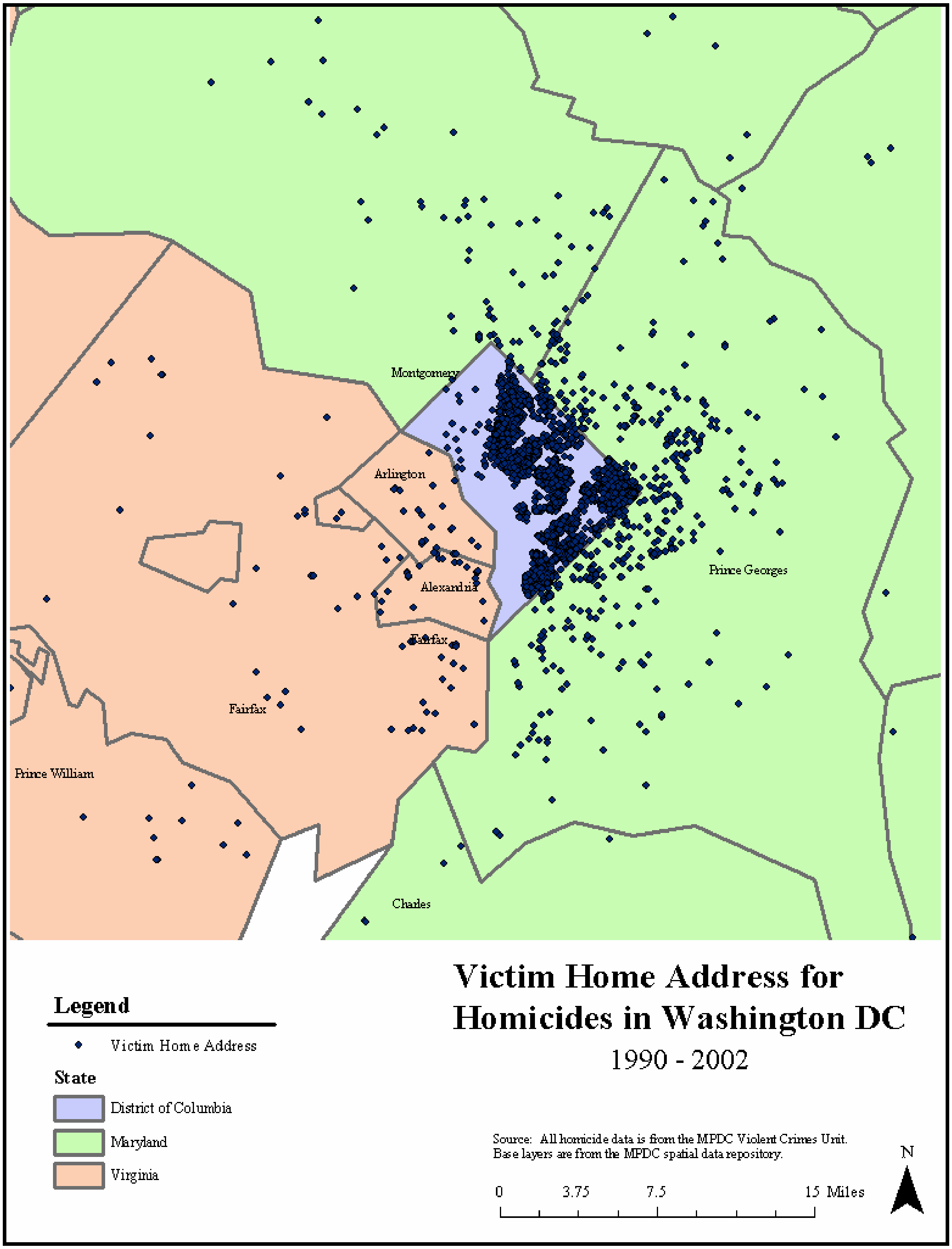


Exhibit 6: Distribution of Homicide Offender Home Addresses

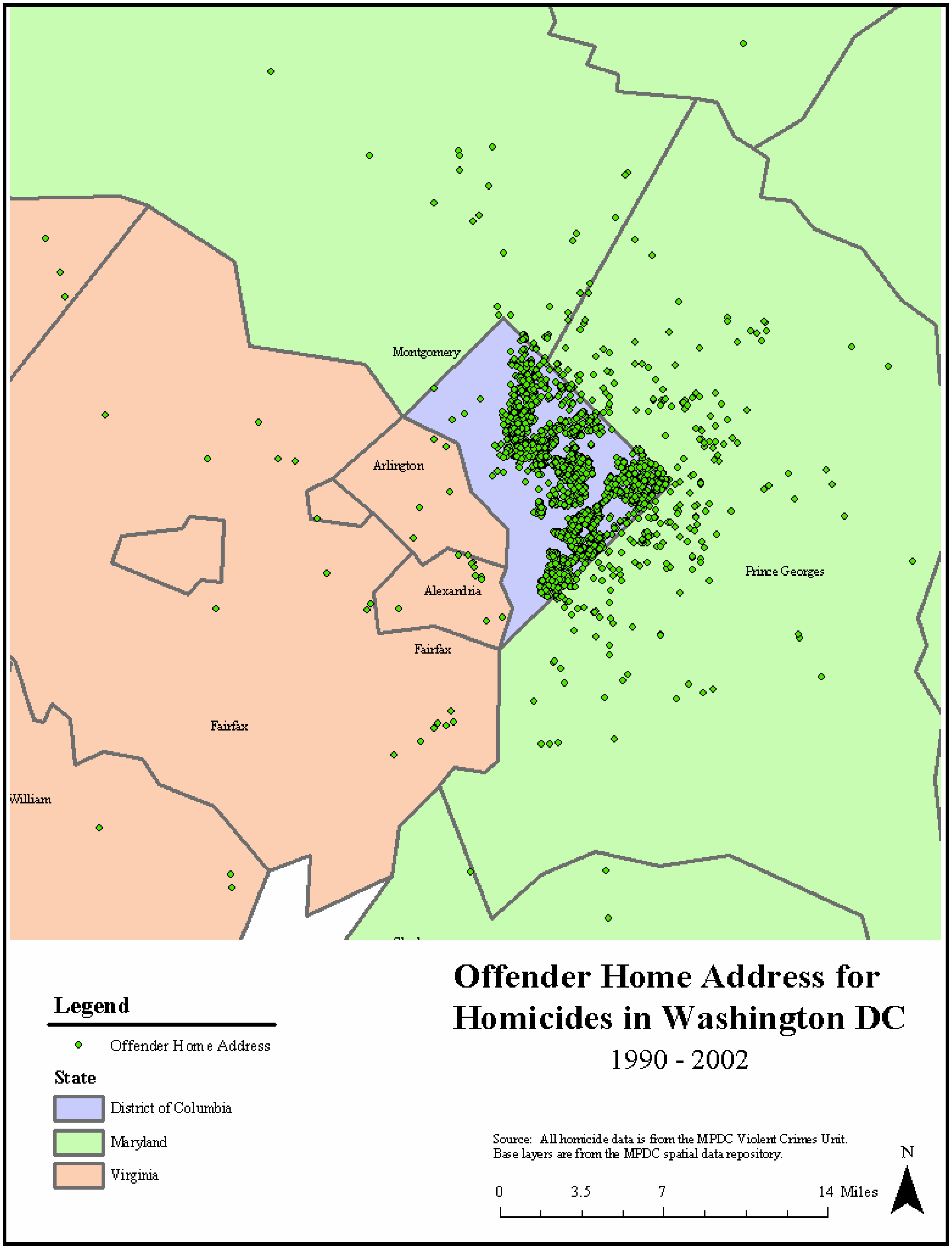
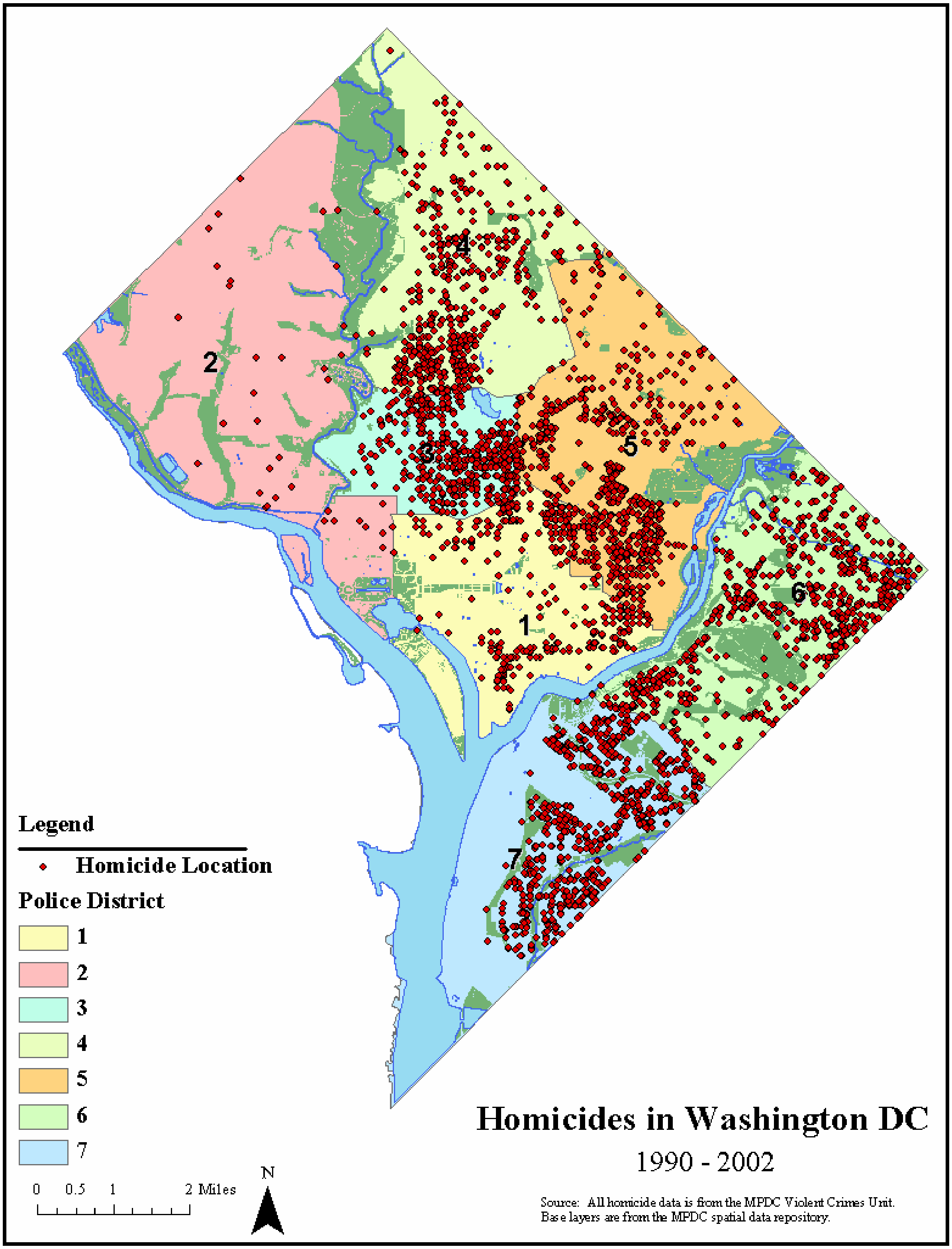


Exhibit 7: Distribution of Homicide Locations



Point maps are also helpful when the goal is to depict the three locations important to one specific homicide (Exhibit 8). This type of map makes it easier for investigators or jurors to 'see' how the different locations are related. Alternatively, crime analysts are often more interested in recognizing patterns that may be helpful to understanding the homicide problem. To this end, creating a map of the locations of the homicides where the symbol type or color represents the type of mobility triangle may be very useful (Exhibit 9). Locations of homicides that are part of different types of mobility triangles are easily visible. For example, the cluster of total mobility triangles between 13^{th} and 16^{th} Streets NW and along Newton, Monroe, and Park could be examined in more detail and provide the foundation for problem solving activities (see red ellipse on map).

Exhibit 8: Primary Addresses Associated with a Particular Homicide Event

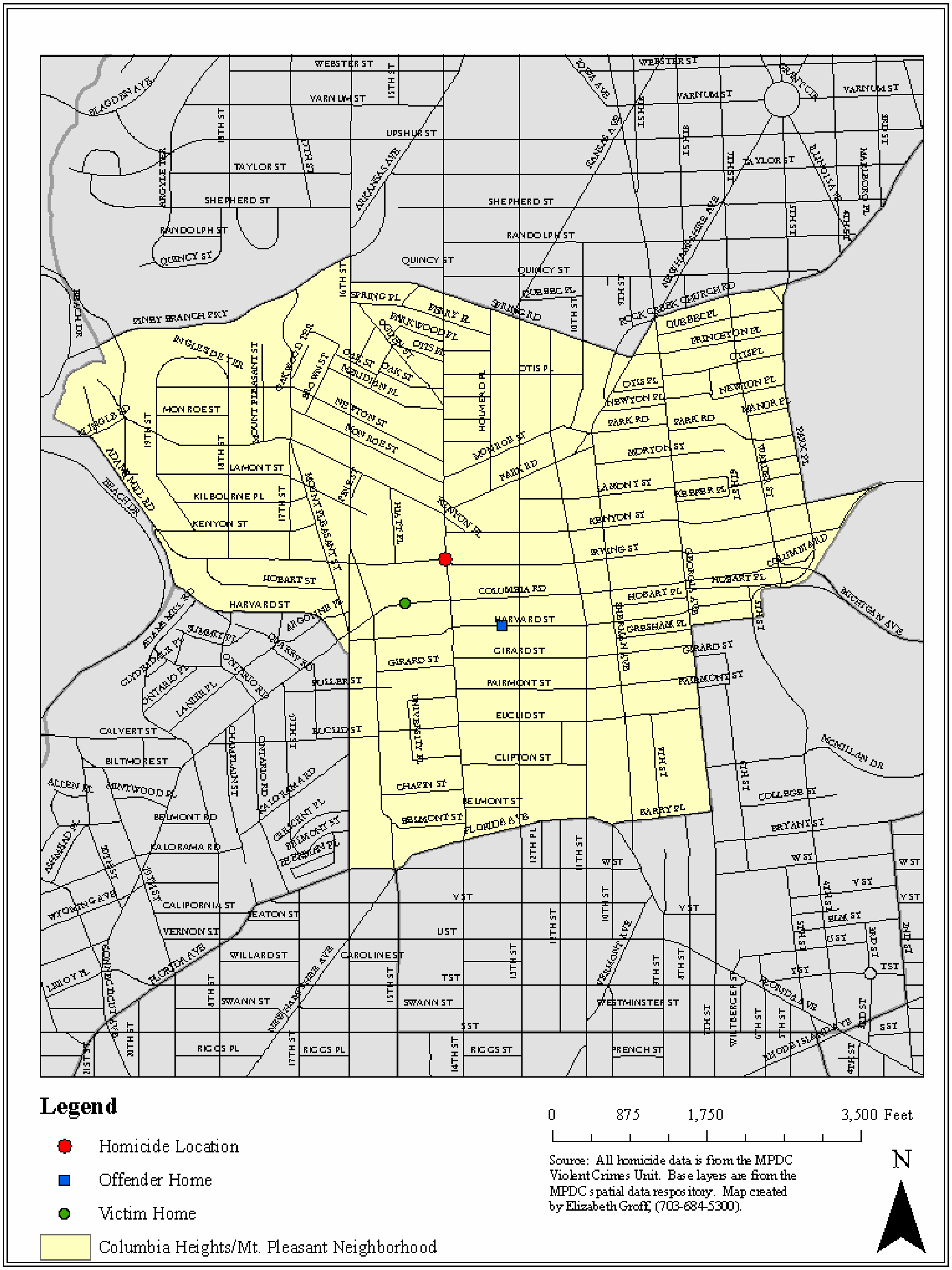
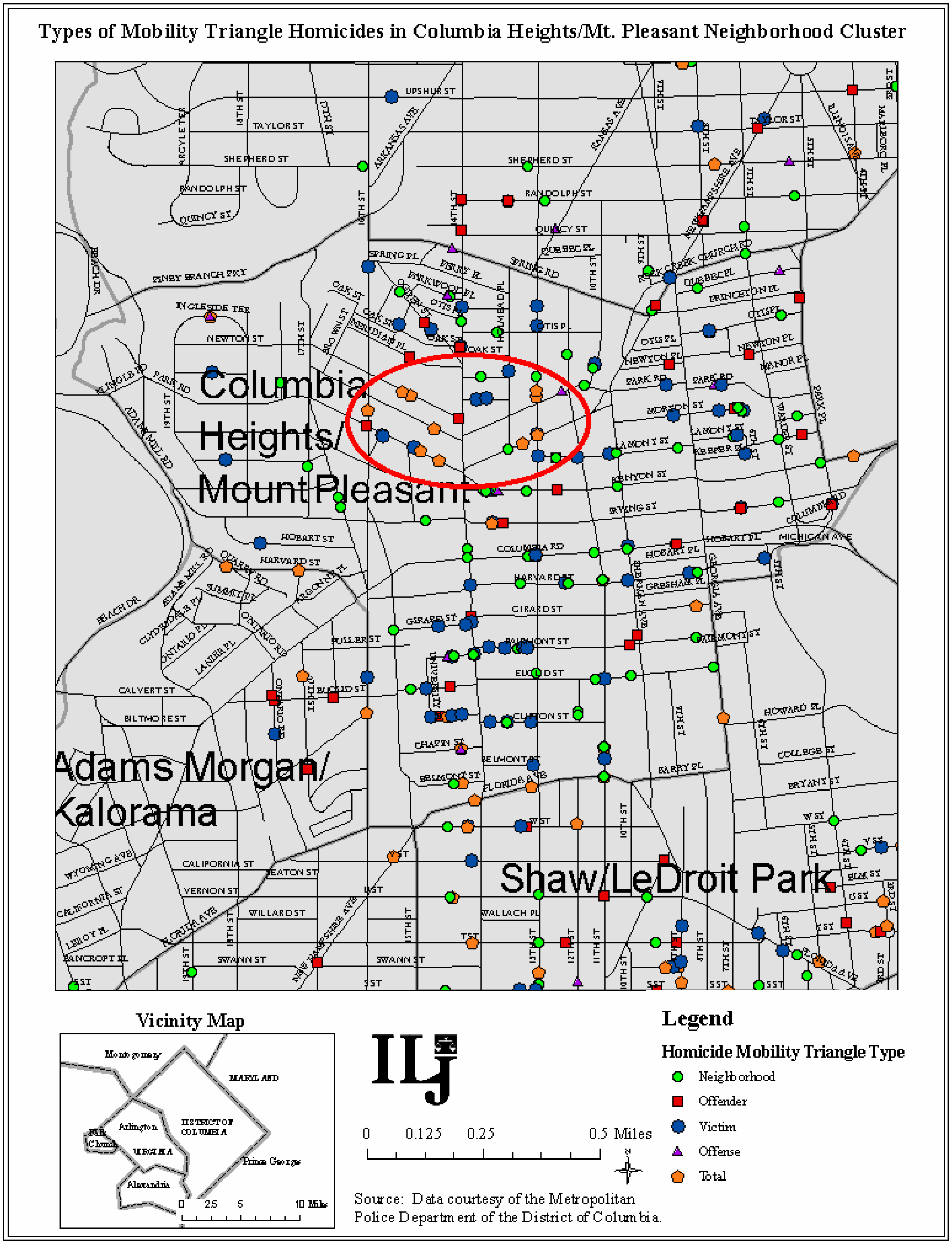


Exhibit 9: Highlighting Patterns of Triangle Types



Another point-based approach focuses on homicides in a particular neighborhood and only displays the locations of associated victim and offender home addresses (Exhibit 10). This map shows the origins of both victims and offenders involved in Mt. Pleasant/Columbia homicide events. The two maps offer a broad overview of patterns and clearly show origin patterns that are very similar for both victims and offenders. By changing the scale of the map, it is possible to examine the patterns within Mt. Pleasant/Columbia and in the immediate area (Exhibit 11). Once again, the origin patterns are very similar for both victims and offenders. In addition, the maps clearly show that many of the offenders and victims involved in homicides live within the neighborhood.

Symbolizing Proportions and Relationships

One of the goals of any descriptive typology is to achieve a better understanding of how things are related by classifying them. Since mobility triangles are just such a typology (i.e. they classify locations related to a homicide by their social or relative distance from one another) questions regarding the spatial distribution of triangle types become important. This section discusses two types of maps for symbolizing proportions and relationships; area-based symbol maps using pie charts and choropleth maps. Symbol maps with pie charts are an excellent method for showing the relative distribution of triangle types across neighborhoods. The pie chart depicts the proportion of each type of mobility triangle in that neighborhood. Choropleth maps are good at representing the concentration of a single classification type (e.g., neighborhood mobility triangles) across all the areas. One special type of choropleth map is called a difference map. Difference maps are handy for showing change over time and relative proportions within an area.

Questions That Can Be Answered By Choropleth and Symbol Maps

- Do offenders from one neighborhood tend to offend in a particular set of other areas?
- Which neighborhoods have the highest proportions of particular types of mobility triangles?
- What is the relative distribution of offender mobility triangles across all areas?
- Are there neighborhoods that are net exporters of offenders or victims?

Exhibit 10: Triad Locations Associated with a Specific Neighborhood: Regional View

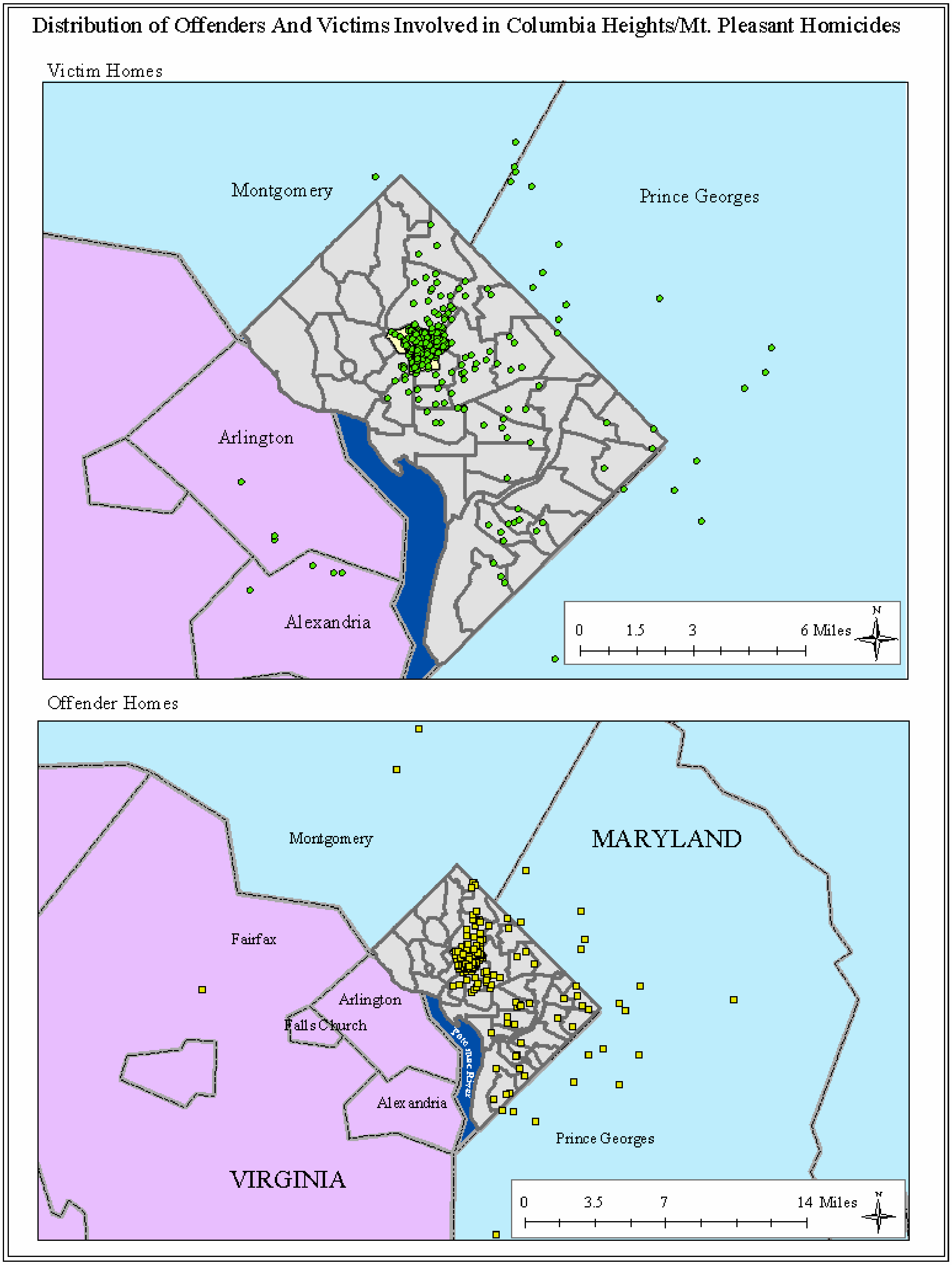
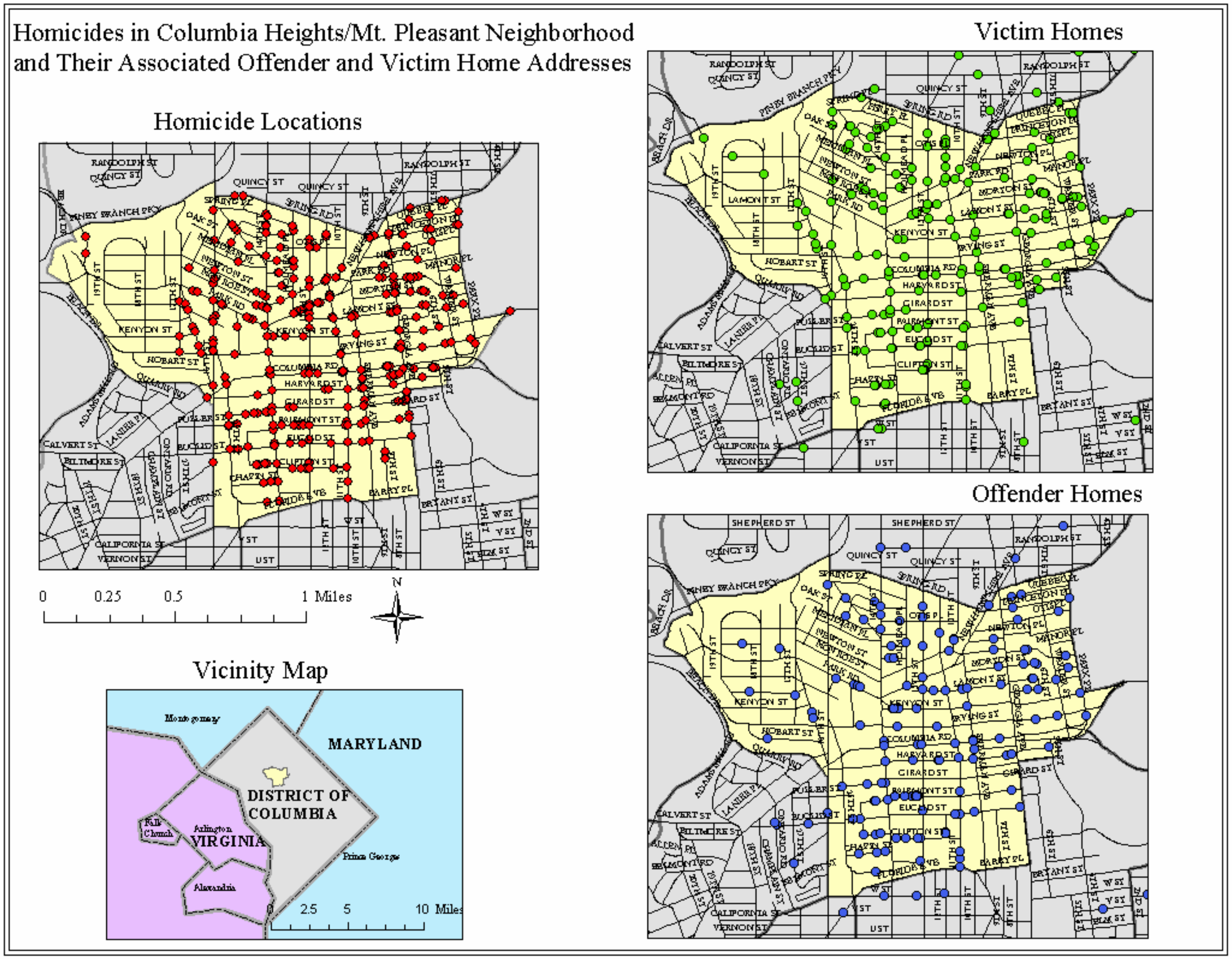


Exhibit 11: Triad Locations Associated with a Specific Neighborhood



Statistical Symbols: Pie Charts and Graduated Circles

Two cartographic techniques for representing data are pie charts and graduated circles. Pie charts communicate the relative proportions of each type of classification found in a particular area. Graduated symbols represent the number of events at a specific location. In Exhibit 12 pie charts convey the proportion of each type of traditional mobility triangle found in a particular neighborhood, making it easy to spot which neighborhood clusters have a large proportion of neighborhood and offender triangles. In both neighborhood and offender mobility triangle classifications the victim resides in the neighborhood. Thus, it is the residents of a neighborhood who are being killed rather than nonresidents. The pie charts make it easy to visually add together the green (i.e. neighborhood triangles) and red sections (i.e. offender triangles) of the pies to identify neighborhoods such as Eckington/Edgewood, Trinidad/Ivy City and Fort Lincoln where over half of the victims are neighborhood residents (see Exhibit 13 to find out area names).

Graduated symbol maps are convenient for depicting multiple events at the same location. As mentioned earlier, simple point symbols for the same address draw on top of one another making it impossible to tell how many events occurred at an address. Exhibit 14 demonstrates how graduated symbols can show the concentration of homicide events within the Mt. Pleasant neighborhood cluster. While there are many single events along 11th Street NW, there are many more multiple event locations on 13th and 14th Street. The next logical step, to pursue this matter further, would be to physically inspect the social and environmental milieu along those three streets (e.g., proximity to drug markets, types of land use and business) to explain the difference in pattern.

Exhibit 12: Relative Distribution of Triangle Types Across Neighborhoods

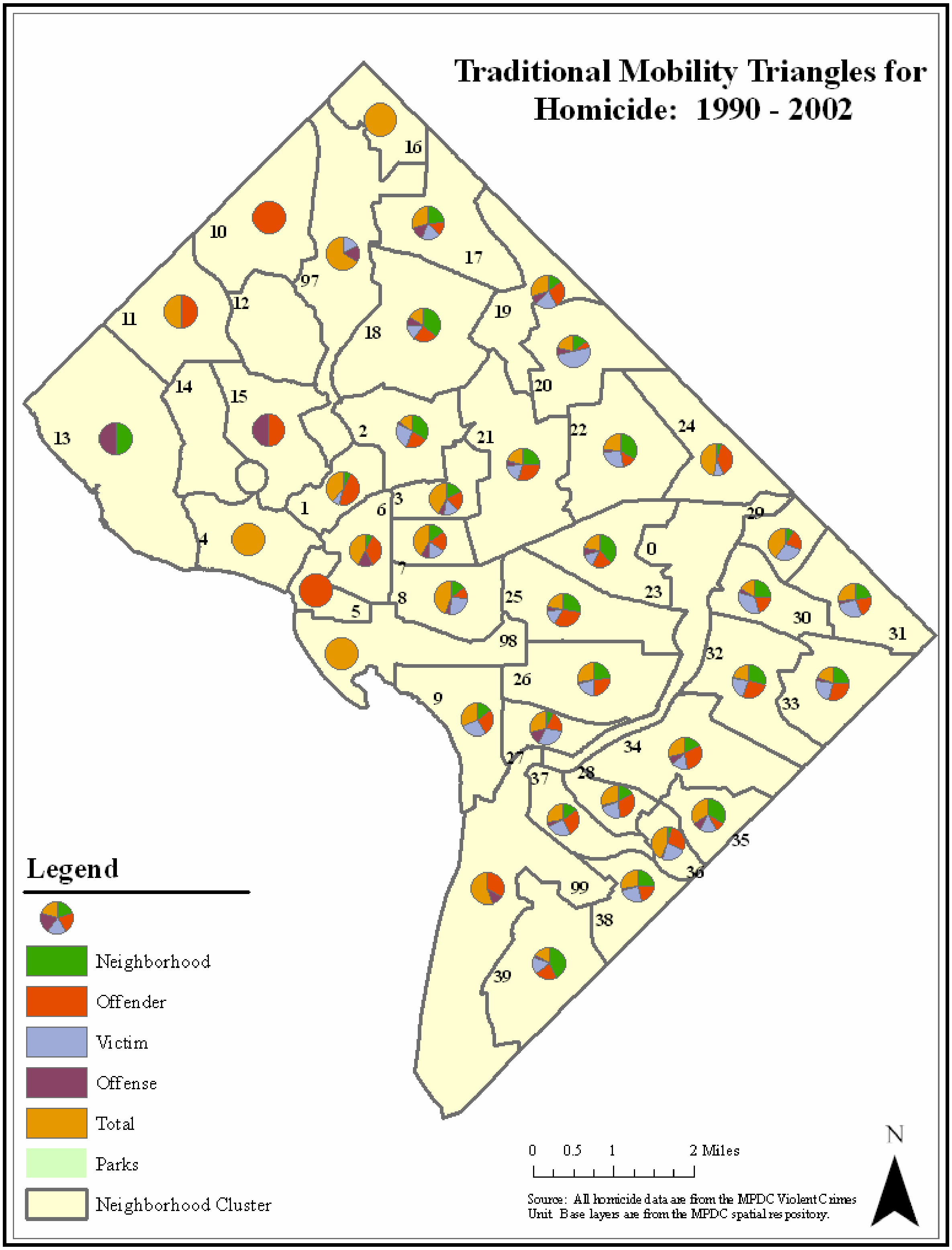
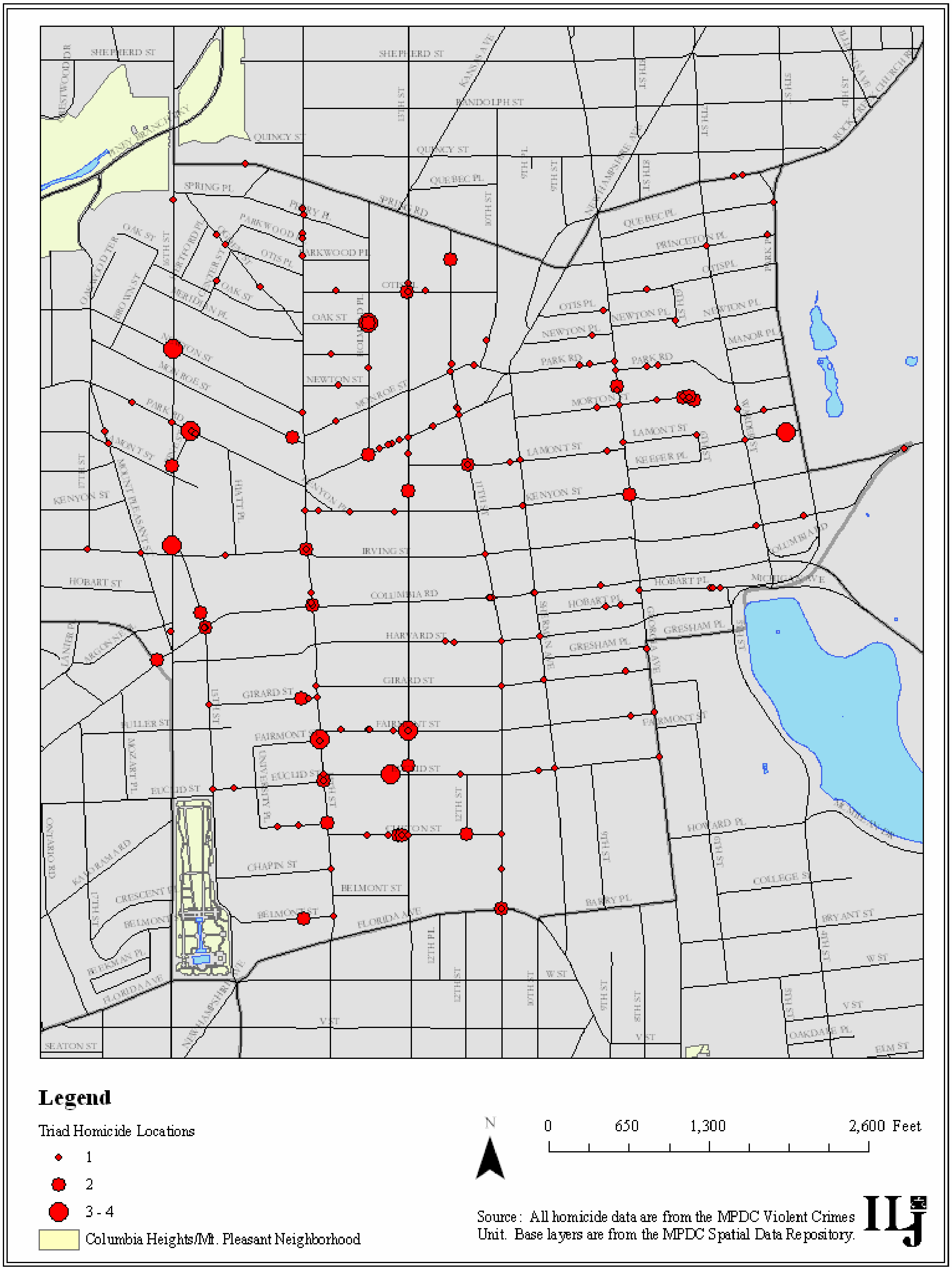


Exhibit 13: Neighborhood Name Reference Table

Cluster Id	**Neighborhood Name**	Cluster Id	**Neighborhood Name**
Cluster 1	Adams Morgan/Kalorama	Cluster 22	Brookland/Brentwood
Cluster 2	Columbia Heights/ Mount Pleasant	Cluster 23	Trinidad/Ivy City
Cluster 3	Shaw/LeDroit Park	Cluster 24	Fort Lincoln
Cluster 4	Georgetown	Cluster 25	Kingman/Stanton Park
Cluster 5	Foggy Bottom/GWU	Cluster 26	Historic Capitol Hill
Cluster 6	Dupont Circle	Cluster 27	Navy Yard
Cluster 7	Cardozo/Logan Circle/Vernon Square	Cluster 28	Historic Anacostia
Cluster 8	Chinatown/Downtown	Cluster 29	Eastland Gardens/Kenilworth
Cluster 9	Fort McNair/ SW Waterfront	Cluster 30	Mayfair Central
Cluster 10	Chevy Chase	Cluster 31	Deanwood/Lincoln Heights
Cluster 11	American University/Friendship/Tenleytown	Cluster 32	River Terrace/Greenway
Cluster 12	Forest Hills/Van Ness	Cluster 33	Benning/Marshall Heights
Cluster 13	Foxhall	Cluster 34	Fairlawn/Twinning/Fort Davis
Cluster 14	Cathedral Heights/Glover Park	Cluster 35	Hillcrest/Naylor Gardens
Cluster 15	Cleveland/Woodley Park	Cluster 36	Woodland
Cluster 16	Colonial Park	Cluster 37	Barry Farm
Cluster 17	Brightwood/Takoma Park	Cluster 38	Douglass/Shipley
Cluster 18	Petworth/Crestwood	Cluster 39	Congress Heights/Washington Highlands
Cluster 19	Fort Totten/Queens Chapel	Cluster 97	Rock Creek Park
Cluster 20	University/Michigan Park	Cluster 98	Mall
Cluster 21	Eckington/Edgewood	Cluster 99	Waterfront

*Areas labeled with a ‘0’ are not neighborhoods or identifiable entities such as the Mall, Rock Creek Park etc.

Exhibit 14: Graduated Symbol Depiction of Homicides in Columbia/Mt. Pleasant



Choropleth Maps

Choropleth maps are frequently used to depict aggregate data for areas (Dent, 1999; Harries, 1999; Rengert, Piquero, & Jones, 1999). These maps are very good at conveying the relative distribution of a phenomenon across a set of areas. Typically, the darker the color, the more of a mapped phenomenon exists in an area. Because the size of areas usually varies widely, this technique is usually used with rates or densities.[8] The most straightforward application of choropleth mapping to mobility triangle data is to examine the relative concentration of a single type of triangle across all the neighborhoods. Exhibit 15 illustrates a choropleth map in which neighborhoods are shaded by the percent of homicides within a neighborhood that were classified as belonging to an offense mobility triangle (victim and offender lived in a different neighborhood than where the homicide occurred).[9] Choropleth maps can be used to compare the percentage of mobility triangles of each type for every neighborhood. Exhibit 16 shows the concentration of mobility triangle types across all neighborhoods on one page, with each type of mobility triangle on a separate map. The individual maps represent the proportion of a triangle type in a neighborhood. This requires a technique that Tufte (1983) refers to as small multiples. The analyst creates a series of maps that are identical except for the variable being displayed. Small multiples make comparison across maps easier. For instance, it is easier to tell which of the neighborhoods have higher percentages of victim and neighborhood mobility triangles. The small multiples also facilitate comparisons between mobility triangle types. For a good illustration, compare the distribution of victim and neighborhood mobility triangles in Exhibit 16 with the pie charts used in Exhibit 12. While the relative proportion within a neighborhood is clear on both maps, it is more difficult to make comparisons among neighborhoods and proportions of homicide mobility by type on the pie chart map than on the choropleth map.

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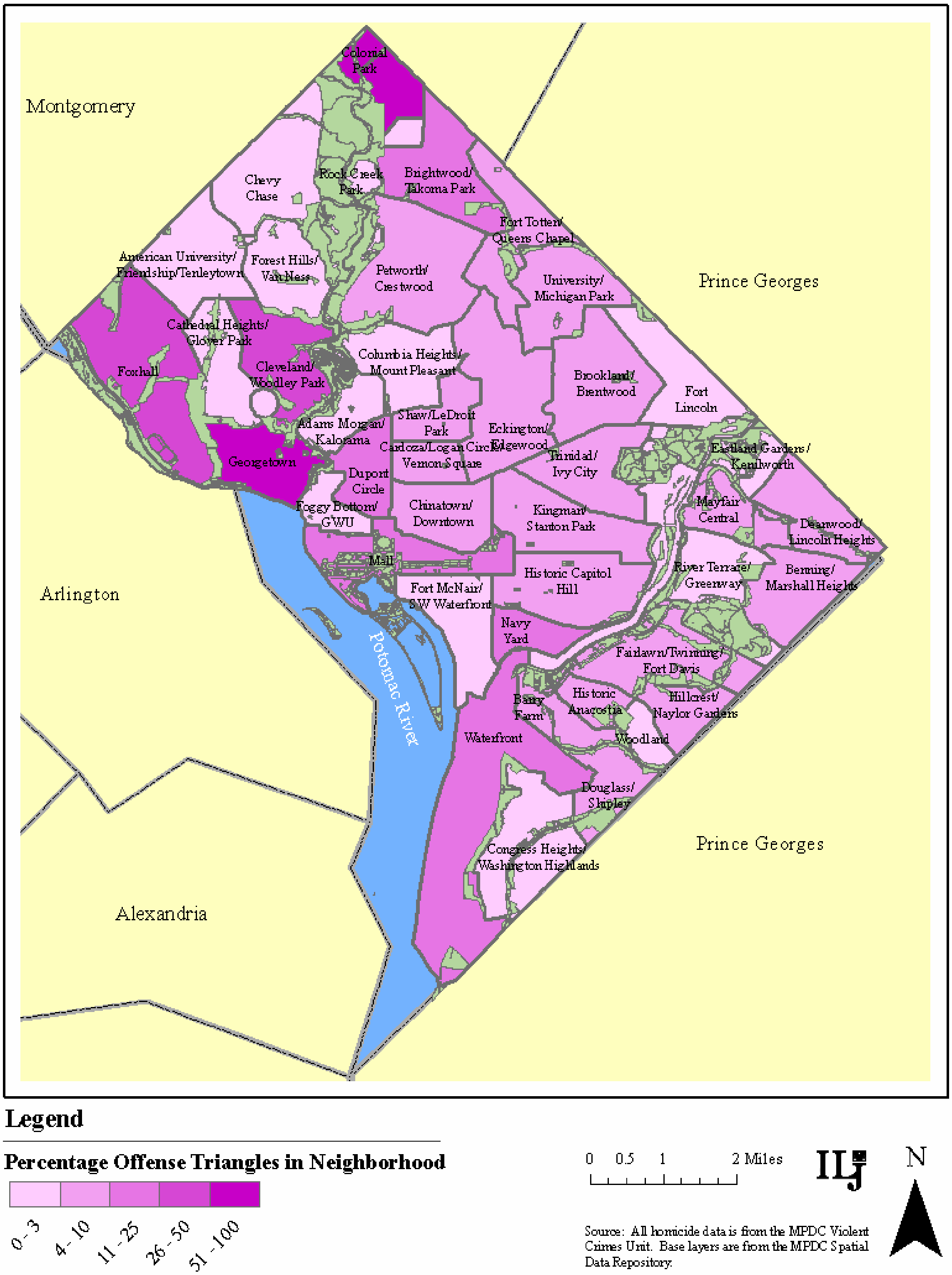
[8] Please see Harries (1999, 46-48) for an excellent discussion of the pitfalls related to the use of population for crime data. In addition, the normalizing variable should be pertinent to the data being mapped. For example, the total number of housing units is a better denominator then total population when normalizing burglary data.

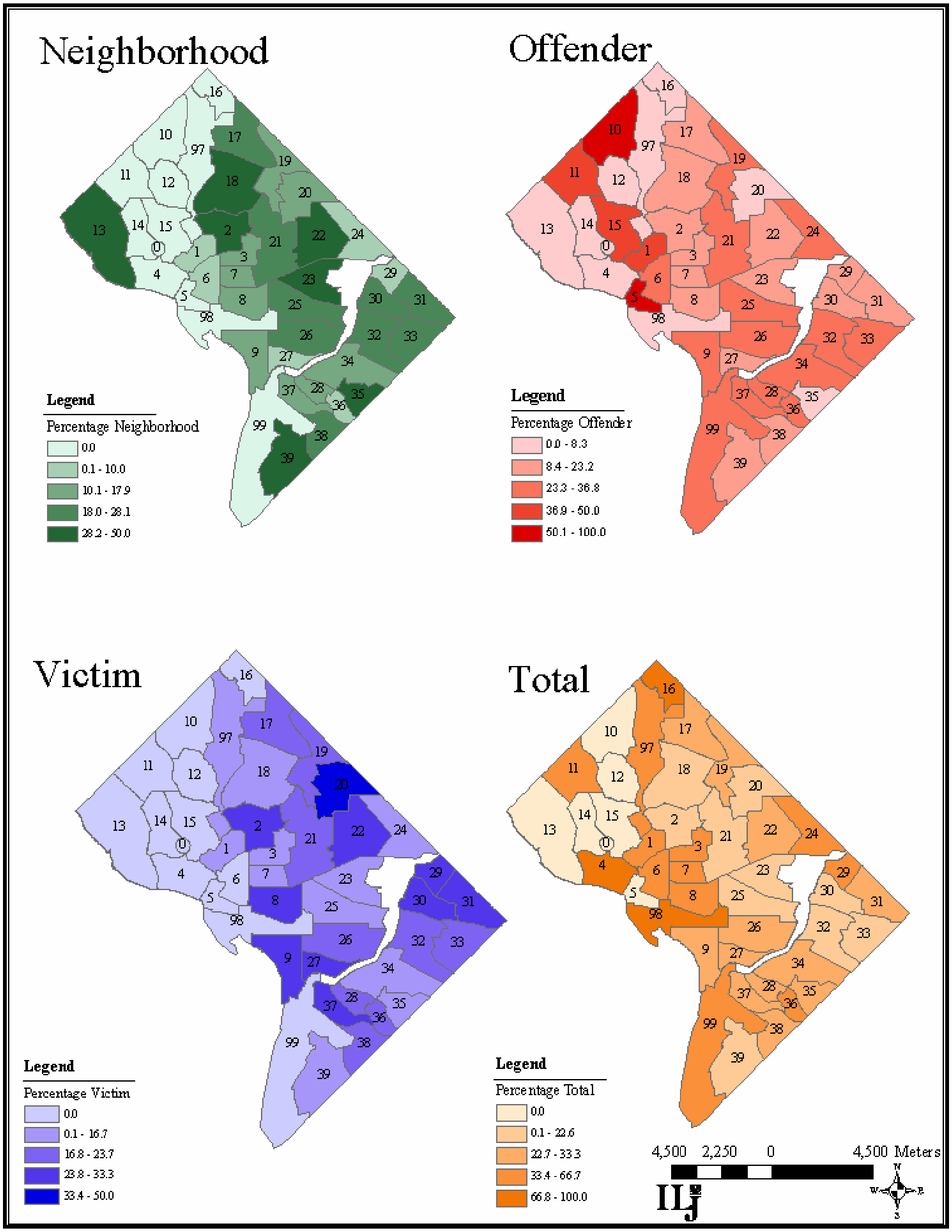
[9] Presenting offense mobility triangles using this technique does have a drawback. The map shows the proportion of the total events that are offense mobility triangles but the total number of homicides in a neighborhood affects this statistic. For example, if there were two homicides in a neighborhood and one of them was an offense mobility triangle then the proportion would be 50%. Proportions in neighborhoods with only a few homicides are most affected.

Exhibit 15: Characterizing Variation of a Single Type of Mobility Triangle Across All Neighborhoods



Source: All homicide data is from the MPDC Violent Crimes Unit. Base layers are from the MPDC Spatial Data Repository.

Exhibit 16: Using Multiples to Compare Distributions of Triangle Types Across Neighborhoods



By focusing on either offenders or victims, additional maps can be created to examine the journey to crime. For example, one such map could highlight an origin neighborhood and then shade all the other neighborhoods by the percent of total events committed by offenders from the origin neighborhood. Turning to the example neighborhood of Columbia Heights/Mt. Pleasant, there were a total of 258 offenders who lived in the Columbia Heights/Mt. Pleasant neighborhood. Exhibit 17 illustrates an offender journey to crime map that depicts where those Columbia Heights/Mt. Pleasant offenders committed their homicides. Remember, the numbers on the map identify the neighborhood cluster (Exhibit 4). The highest proportion (approximately 70%) committed their homicides in their home neighborhood of Columbia Heights/Mt. Pleasant. The next most popular neighborhood for Columbia Heights/Mt. Pleasant offenders is the adjacent neighborhood of Petworth/Crestwood (18). The map also makes it easy to identify three other neighborhoods with strong offender connections specifically, Shaw/LeDroit Park (3), Trinidad/Ivy City (23) and Kingman/Stanton Park (25).

The relative inflow and outflow of offenders and victims contains potential clues to the structure of homicide. Exhibits 18 (victims) and 19 (offenders) show the results of shading each neighborhood by whether it is a net importer or exporter of victims or offenders.[10] Neighborhoods that are net importers are shaded in red and those that are net exporters are shaded in green. A vicinity map is included to show the data for Maryland and Virginia. Columbia Heights/Mt. Pleasant and Historic Capitol Hill are the two highest importers of victims and also rank in the top tier of offenders imported. The maps indicate both victims and offenders are traveling to those neighborhoods. At the opposite end of the spectrum, Congress Heights/Washington Highlands neighborhood and Prince Georges (PG) County are the two highest exporters of offenders and victims. One reason for this is because PG County is so much larger, both physically and population-wise, than any individual neighborhood cluster.[11] Even so, there is a definite core/periphery phenomenon at work. Neighborhoods on the eastern outer edge of DC tend to export offenders while those more toward the center and western edge of DC import them. The same pattern holds true for victims. Unfortunately, these maps do not convey either the existence of connections between neighborhoods or the strength of those connections. However, flow maps can be used to identify and convey those types of relationships.

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[10] In general, it is not sound cartographic practice to map absolute values, however, the purpose of this map (and of Exhibit 19) is to depict the absolute magnitude of difference between two quantities.

[11] This comparison is somewhat biased since the number of offenders imported by Prince Georges County is not known and would affect the net figure used. Of course this is true of the net for all neighborhoods since the DC residents who kill or are killed outside of the District are not in the analysis.

Exhibit 17: Homicides Committed by Columbia Heights/Mt. Pleasant Residents

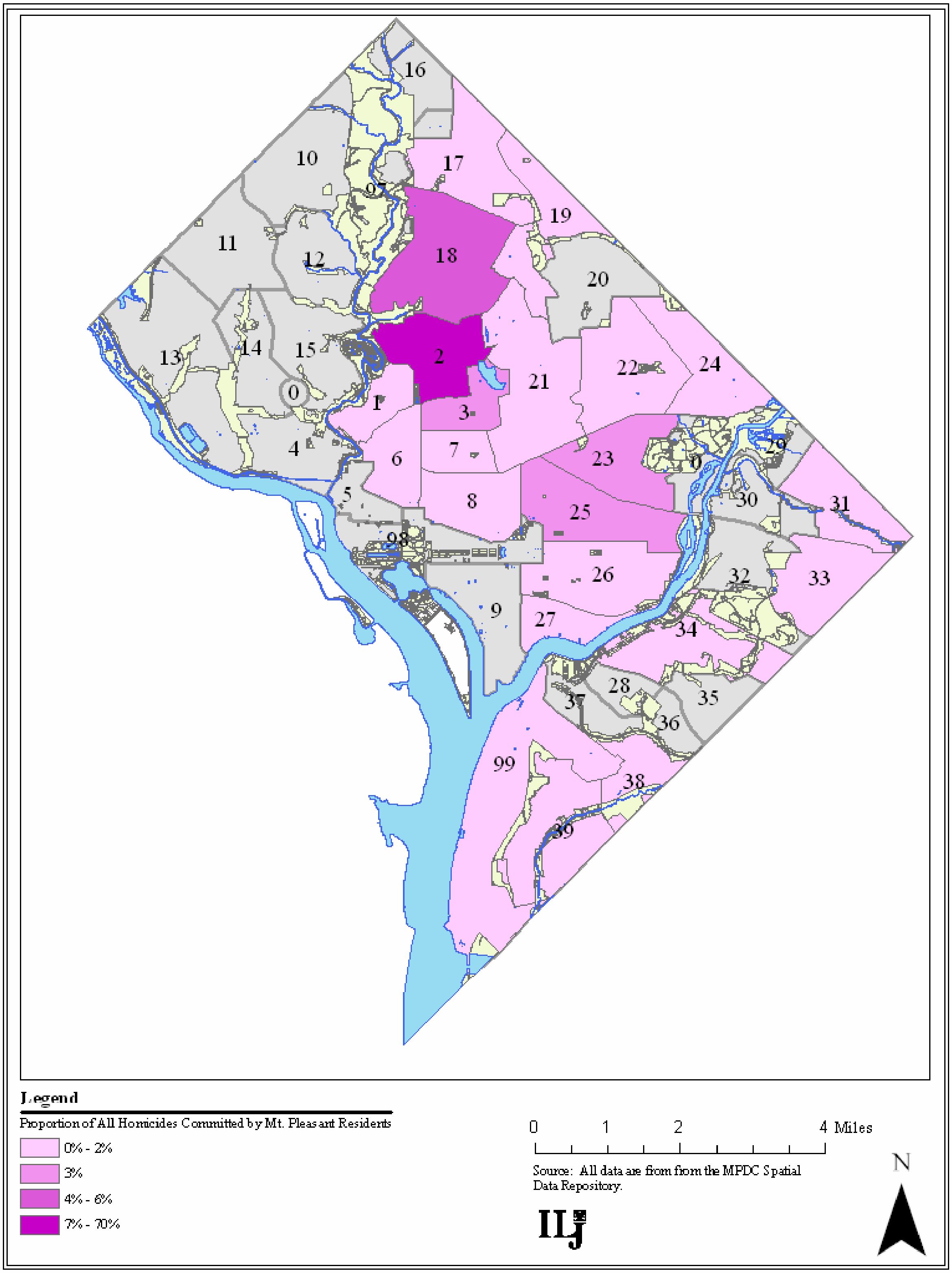


Exhibit 18: Using Choropleth Mapping: Showing Net Export of Homicide Victims

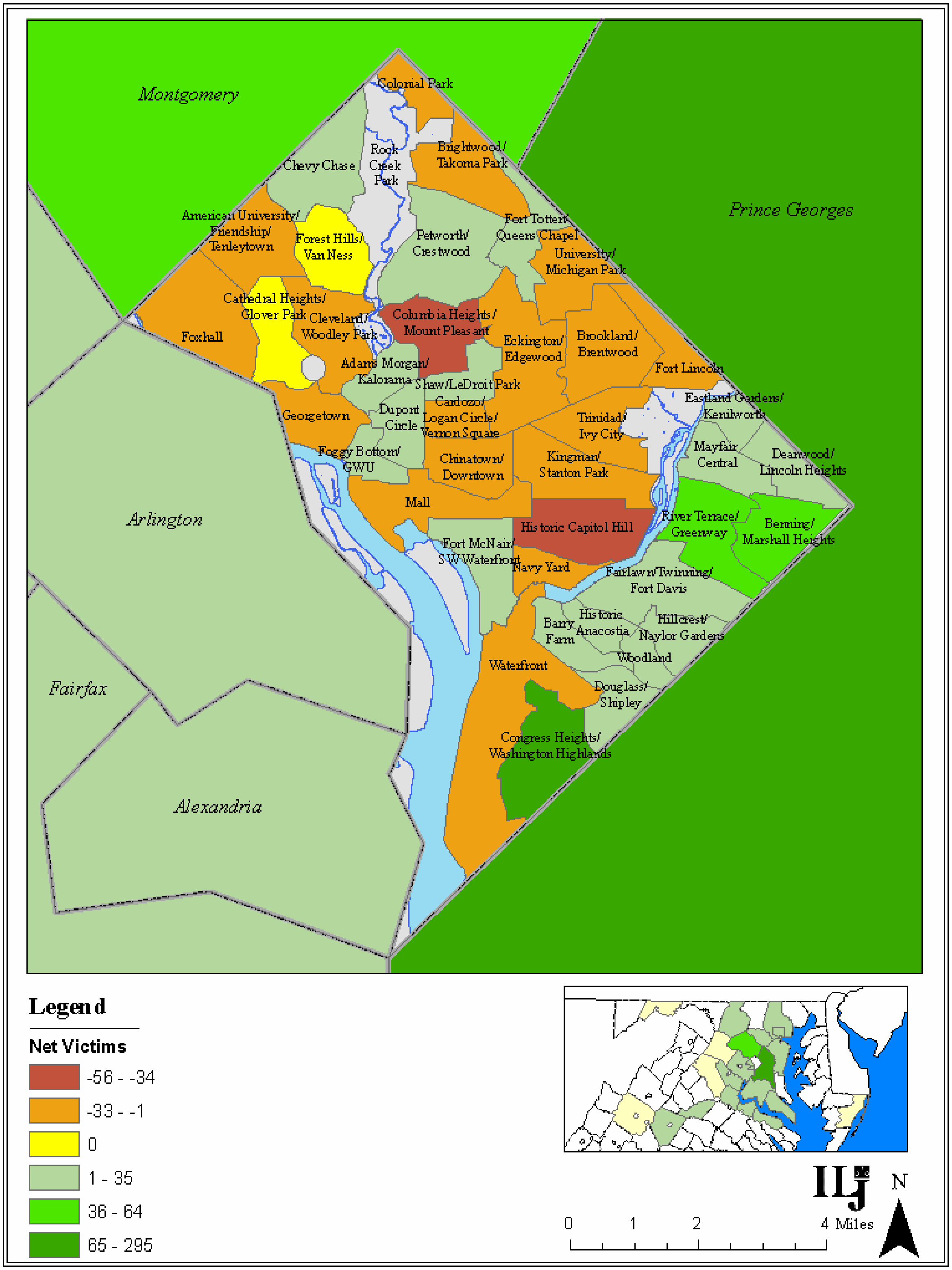
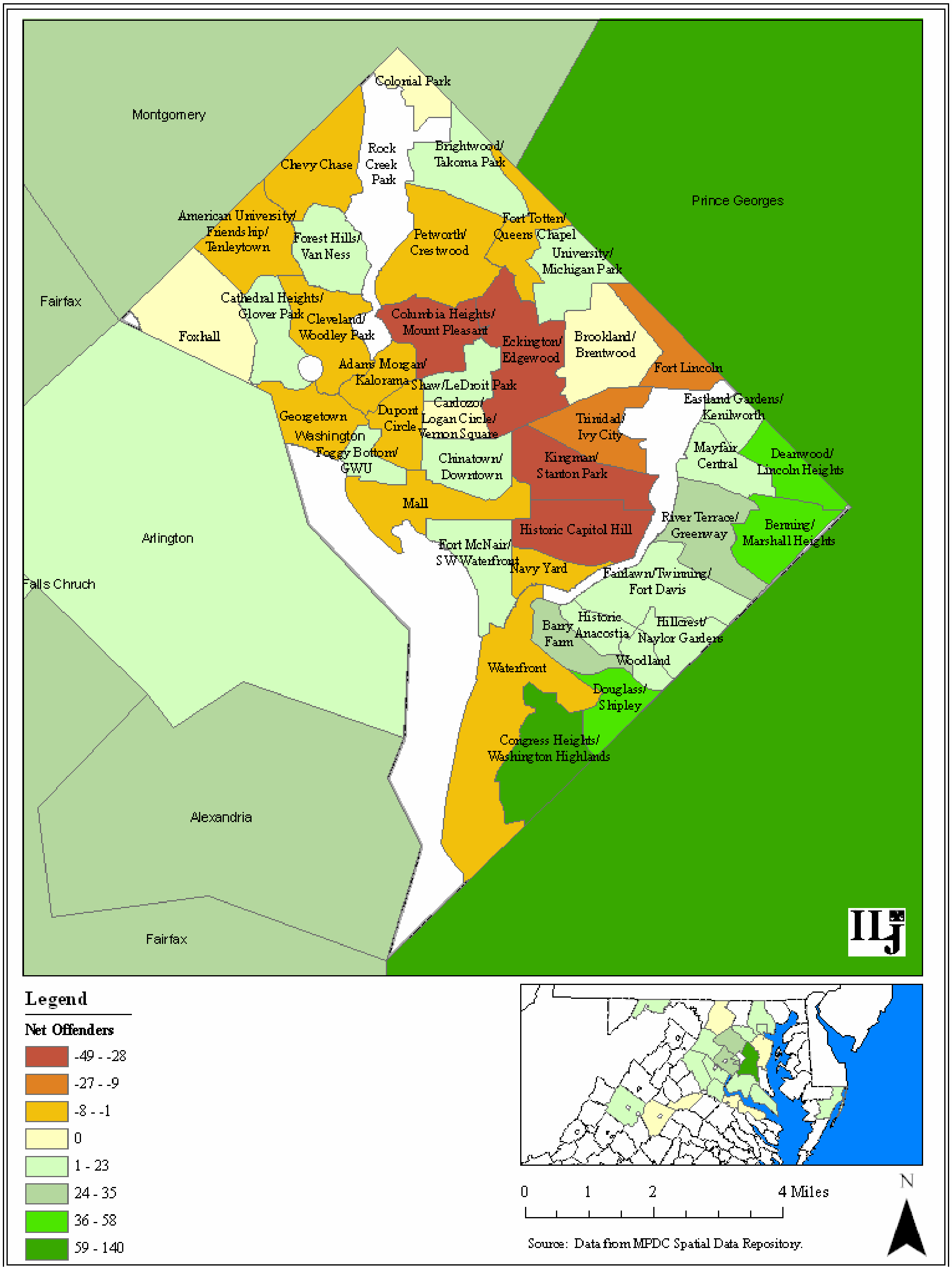


Exhibit 19: Using Choropleth Mapping: Showing Net Export of Homicide Offenders



Representing Flows

Minard's map of troop movements created in the mid-1800s is widely acknowledged as the first example of flow maps (Tobler, 2004b; Tufte, 1983). Minard used arrows to represent the flow of troops from one area to another. The thickness of the arrow represented the number of troops involved and the arrowhead depicted the direction of flow. This allowed a large volume of data to be presented in visual form. The same basic technique is still in use today. However, today's maps are computerized and consequently, the ability to generate flow maps using software is necessary for the technique to gain greater usage. Appendix 1 discusses three possible software programs to generate flow maps.

There have been a variety of efforts to visualize 'interaction' among areas in criminology. Early results on the journey to crime were reported in tabular format (Rengert et al., 1999). As more geographers became interested in the subject, maps in which lines connected the origin (offender residence) and destination point (crime location) became more common (Brantingham & Brantingham, 1984; Costanzo, Halperin, & Gale, 1986; Lenz, 1986). Some work has been done with using choropleth maps to display the results of a mobility analysis (Groff, 2002). However, the area of visualization of relationships is ripe for exploration. One cartographic technique that is underutilized consists of desire line maps, a type of flow map (Dent, 1999; Harries, 1999; Tobler, 2004a; Tobler, 2004b). In a desire line map, a line represents the flow between an origin and a destination but there is no attempt to model the actual route followed (e.g., along a street network). Instead, the lines are drawn to represent a connection between the two points with the thickness of the line representing the total interaction. In this way, flow maps provide a unique visualization of spatial connections important to the supply of victims and offenders.

The knowledge of origin and destination places is particularly important for depicting travel behavior because they provide points to which trips can be aggregated.[12] While it is possible to depict lines that represent every trip, the resulting map is of little use since it is impossible to distinguish important aggregate flows and/or patterns. This is a similar problem to

[12] The aggregated information can be input into travel demand modeling software for additional quantitative analysis (Levine, 2005).

the one encountered with point maps, displaying all the points does not reflect the locations with more than one incident and the large number of points makes it difficult to discriminate patterns. In addition, when many points or lines are symbolized, it is hard to distinguish among symbol types. For point maps these challenges are addressed through the use of graduated symbols to represent quantities at locations and/or choropleth maps that summarize area totals. In the case of victim and offender travel, lines can be drawn between a target neighborhood and all neighborhoods that supplied offenders or victims. The thickness and color of the line represent the quantity and type of flow (e.g., case percentage and import vs. export).

Questions To Be Answered With Flow Maps

- How much homicide is local?
- Are victims and/or offenders being attracted to an area?
- Do victims from a particular neighborhood tend to become victimized in a particular neighborhood?
- If we want to reduce the homicide rate in a particular neighborhood, where should we concentrate our efforts to identify and warn off probable offenders?

Total Flows

One of the most straightforward applications of flow maps is to examine the overall pattern of movement among areas. Exhibit 20 shows the aggregate flows of offenders among all the areas included in the study. By only including flows of 5 or more offenders, the legibility of the map is improved dramatically over a complete depiction of offender travel. While drawing all the flows is visually impressive and conveys a sense of the connectedness of the areas, it is impossible to learn anything concrete and the map is essentially illegible. One of the most striking features of Exhibit 20 is the dominance of Prince Georges County among all adjacent counties in supplying offenders. Given the relatively short distances of most travel to crime, we expect to see most of those trips to areas adjacent to or close to the boundary between DC and Prince Georges, as is the case. However, a significant portion of the offenders are involved in homicides in the inner DC neighborhoods.

Flow mapping techniques offer important information about the origins of offenders but do not depict the number of offenders who are neighborhood residents. A more comprehensive picture of homicide emerges if choropleth mapping is used to add information about the number of offenders who lived in the neighborhood and therefore are not represented in the flows on the map. In Exhibit 21, choropleth and flow mapping techniques are applied on the same map to compare the number of offenders traveling to a particular neighborhood, with the proportion that are residents the number of same map. The same type of map can be created to better understand flows of victims among neighborhoods in the study area (Exhibit 22).

Exhibit 20: Suspect Flows Among Neighborhood Areas

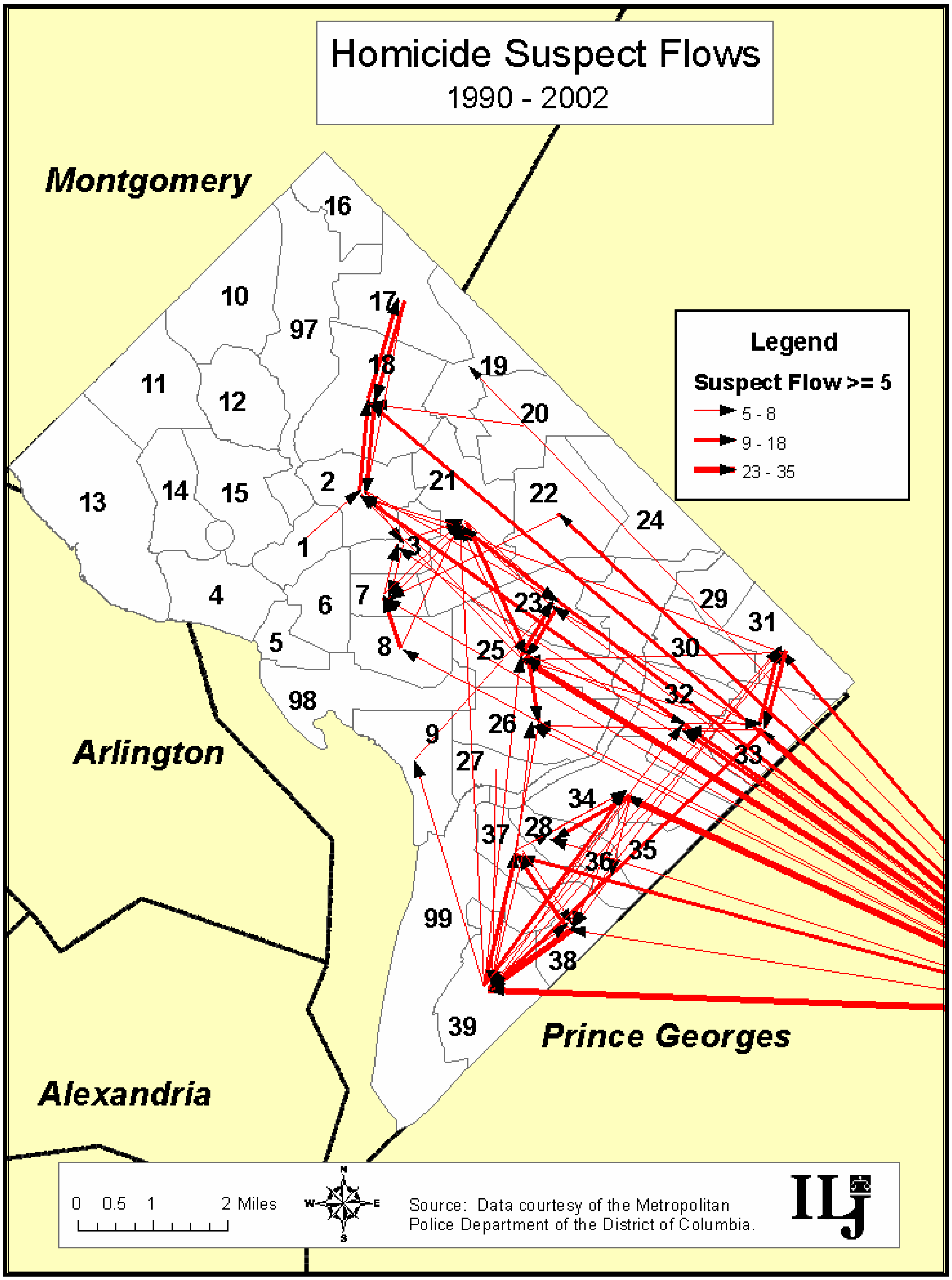


Exhibit 21: Intra–DC Flows and Concentration of Resident Offenders

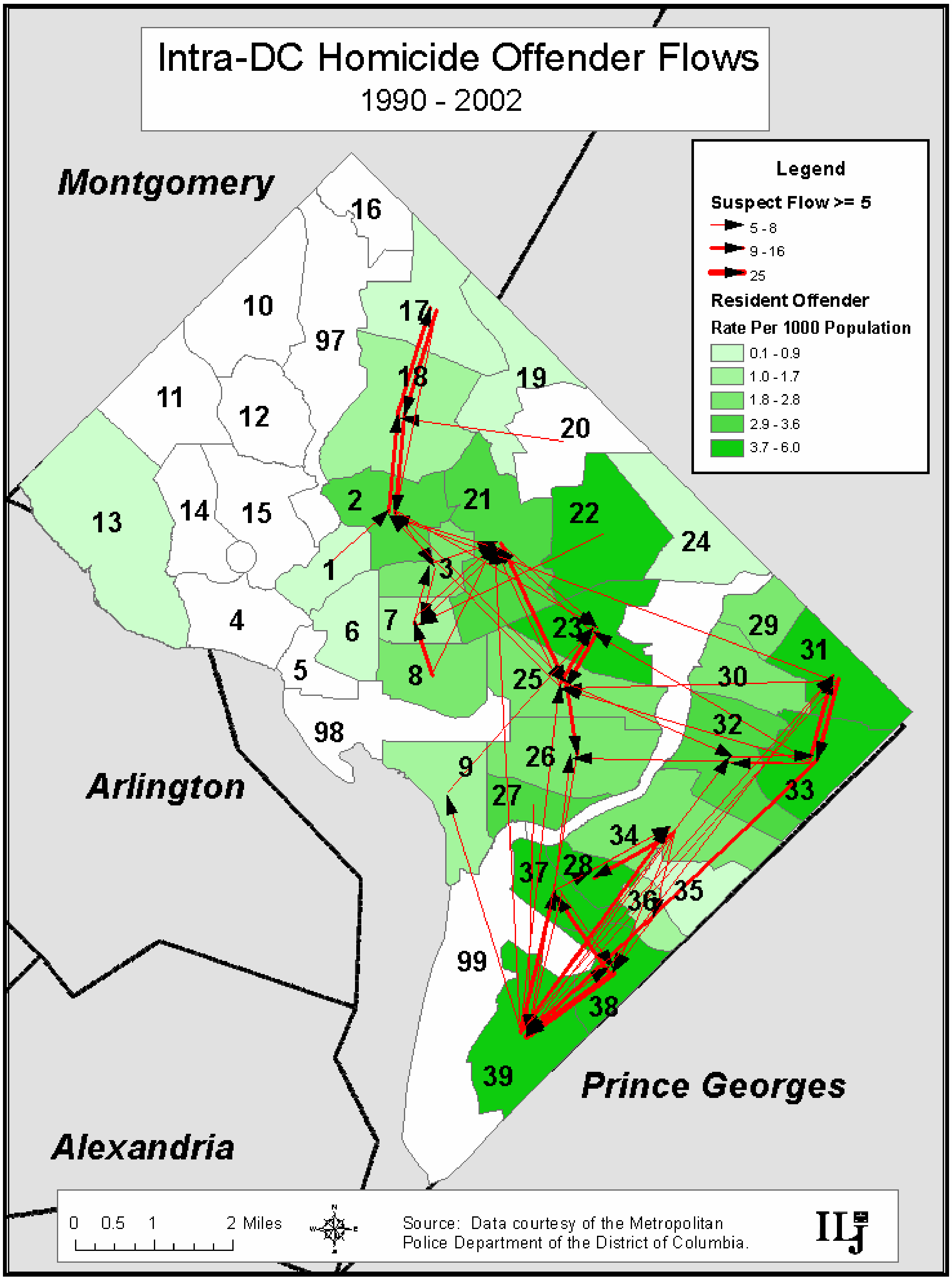
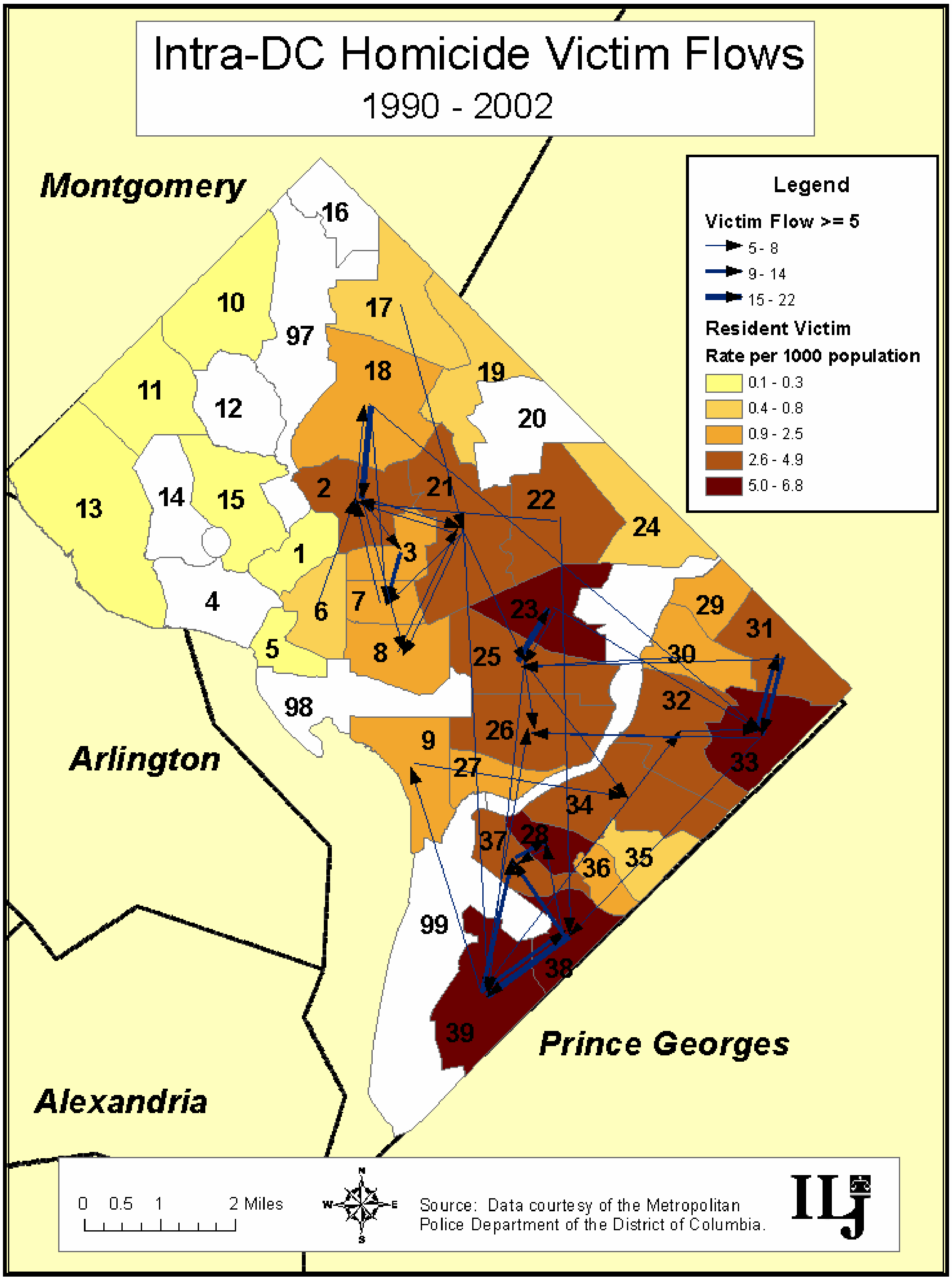


Exhibit 22: Intra-DC Victim Flows and Resident Victims



Flow Mapping for Neighborhood Crime Prevention

Policing and crime prevention initiatives are often undertaken at the neighborhood level. Flow mapping can be used to inform those efforts by isolating the flows into and out of a particular neighborhood. Exhibit 23 demonstrates this technique for the Columbia Heights/Mt. Pleasant neighborhood. However, Exhibit 23 provides only part of the information needed, the flows of offenders between neighborhoods. Another important factor is the number of offenders who kill in their own neighborhood. The text added to the map makes it possible to convey that over half of homicides in Columbia Heights/Mt. Pleasant involve neighborhood residents (56% of victims and 61% of offenders reside in the neighborhood) indicating a predominantly local problem. The symbolization on the map also informs the reader that an adjacent neighborhood, Petworth/Crestwood, supplied 15 or 16 of the offenders and between 14 and 22 of the victims. Prince Georges County is the other large contributor (15 offenders and 14 victims).[13]

These examples offer a brief glimpse of the techniques available for visualizing travel data in the form of flows. The possibilities for slicing data in myriad ways and then using these techniques to map it out are virtually limitless. One obvious refinement is to disaggregate data sets and examine more homogenous subsets. These subsets could represent motive, victim or suspect characteristics, place characteristics, or time of day. For example, one analysis would be to focus on gang or drug-related homicides. Another could address homicides that occur over a particular time of day. Finally, the subsets could be sliced more thinly to yield only the drug-related homicides that occur between midnight and six in the morning. These types of analysis illustrate the significant advantages to using flow mapping to better understand the convergence of victims and offenders.

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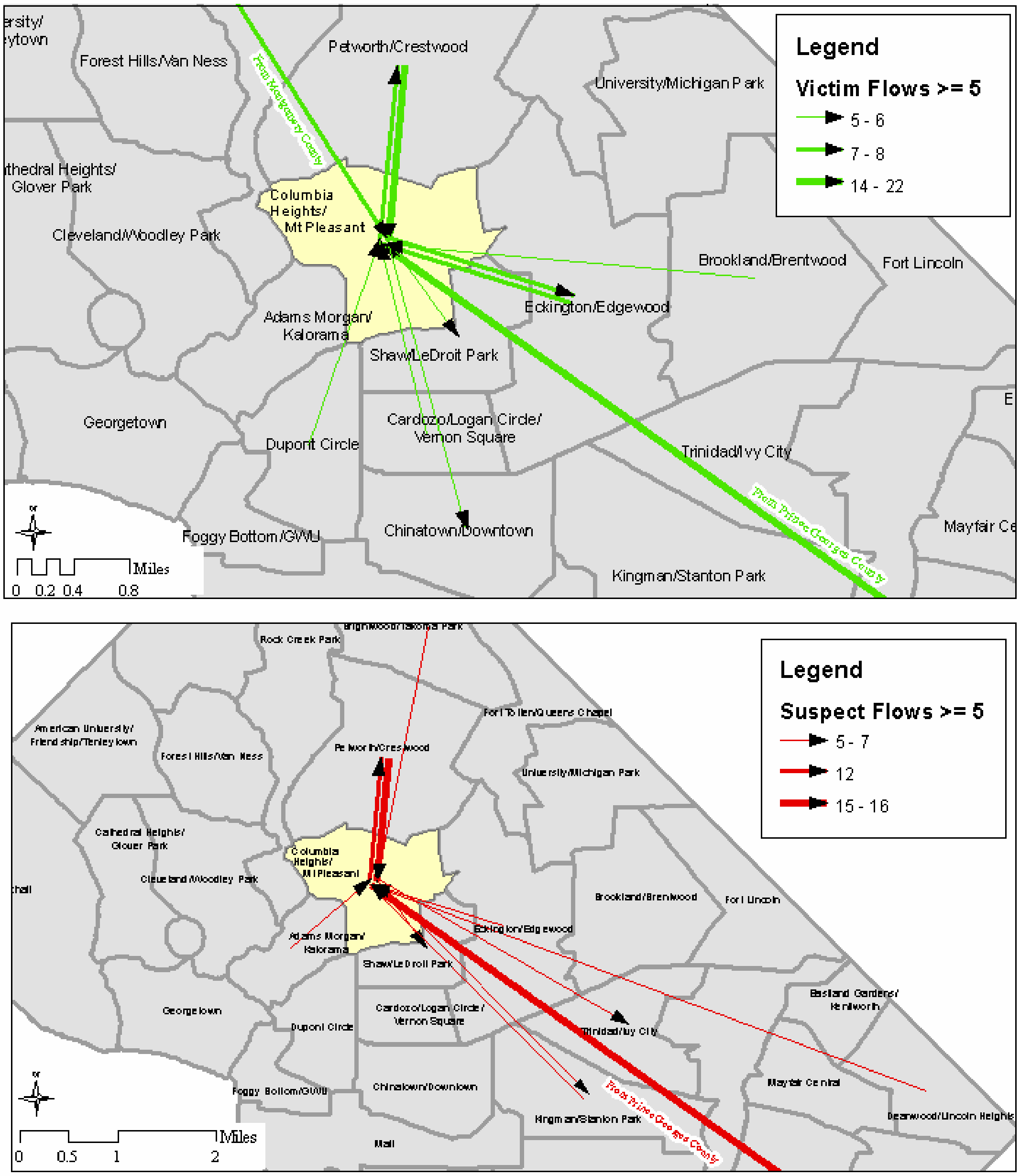
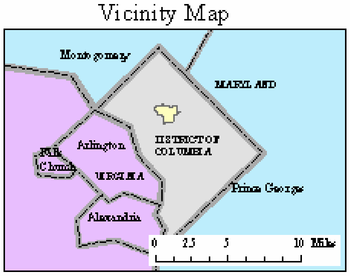
[13] At this point it would bear repeating that these data represent 13 years of homicide events. Thus, the applicability to preventing homicides is more limited. These techniques have greater applicability to more frequently occurring crime types that generate more events over a shorter period.

Exhibit 23: Victim and Offender Flows: Columbia Heights/Mt. Pleasant



Vicinity Map



Columbia Heights/Mt. Pleasant Neighborhood Summary

- 61% (n = 150) of offenders lived in the neighborhood
- 56% (n = 139) of victims lived in the neighborhood

Source: Data courtesy of the Metropolitan Police Department of the District of Columbia.

ILJ

Specific Neighborhood Level Analysis of Mobility Triangle Data: An Example

This section details the types of information that can be gleaned from mobility data when the focus of the analysis is describing the problem in a single neighborhood. A sample analysis of the Columbia/Mt. Pleasant neighborhood is provided to illustrate large-scale mapping techniques. The Columbia/Mt. Pleasant neighborhood cluster is near the geographic center of DC. It is 52% Black and its inhabitants reported a median household income of $30,523 in 2000. The District, as a whole, had a greater proportion of Black inhabitants (60%) and a slightly higher median household income of $30,727. Almost 17% of DC residents, but 25.6% of Columbia/Mt. Pleasant residents, were below the poverty level in 2000. A higher proportion of residents in the subject neighborhood are renters (59%) than in the District (54.6%) and they tend to have less residential stability. In Columbia/Mt. Pleasant, 58.5% of residents have lived in the neighborhood less than five years as compared entire District's rate of 47%.

With approximately 8% of the city's residents, the Columbia/Mt. Pleasant neighborhood accounted for approximately 9% of the city's homicides. More specifically, there were 416 homicides committed in the Columbia Heights/Mt. Pleasant neighborhood cluster over the study period. The home address of 372 (89%) victims and 289 offenders were successfully geocoded for those homicides.[14] However, there were only 199 homicides for which all three locations were known. These homicides produced 247 triads (9% of all triads for DC). In other words, the 199 homicides occurred in the neighborhood for which the victim's home address was known and one or more offenders were arrested. For these 199 homicides, 247 offenders were arrested; 162 homicides had one offender, 29 had two offenders, 5 had three offenders, and 3 homicide events had four offenders. The average distance traveled for victims killed in the neighborhood was 2.07 miles (Exhibit 24). The average offender's journey to commit the murder was shorter, only 1.67 miles, but the medians were almost identical. Both offenders and victims lived closer to location of the homicide than they did to one another. These distances are shorter than the

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[14] Each victim is considered a unique homicide. For victims, 89% of victim home addresses were successfully geocoded. Offender information is more complicated. A single homicide can have more than one offender. Thus, the number of offender home addresses used in the study represents offenders who were arrested (which could be more than one per homicide) and whose home address was successfully geocoded (70%). This does not represent the percentage of homicides for which there was an arrest.

citywide averages and medians. Exhibits 25 and 26 have the average distances by type of crime and how they compared with DC as a whole. While victims in the study neighborhood tend to travel shorter distances than homicide victims on the whole, those who were involve in homicides with drug-related and retaliation motives were the exception. Victims of drug-related homicides traveled slightly further in the study neighborhood than DC drug-related victims in general. There was no difference in victim travel distance for retaliation homicides. Offenders from Columbia Heights/Mt. Pleasant traveled shorter distances than other offenders across all motives.

Exhibit 24: Euclidean Distances Traveled by Homicide Participants: Mt. Pleasant vs. DC (in miles)

	Columbia Heights/Mt. Pleasant Homicides	All DC Homicides
Victim Distance		
Mean	2.07	2.63
Median	.37	.54
Offender Distance		
Mean	1.67	2.59
Median	.36	.72
House to House Distance		
Mean	3.2	4.3
Median	1.2	2.0
Total Distance		
Mean	6.9	9.6
Median	2.8	4.9

Exhibit 25: Euclidean Distances Traveled by Homicide Victims by Motive: Mt. Pleasant vs. DC (in miles)

	District of Columbia			Columbia Heights/Mt. Pleasant		
Motives	Number	Mean (SD)	Median	Number	Mean (SD)	Median
Argument	1687	2.34 (7.06)	.43	156	1.88 (4.48)	.26
Domestic violence	203	1.30 (2.90)	.00	13	1.46 (3.72)	.00
Drug-related	946	2.74 (7.61)	.62	90	2.93 (6.21)	.69
Gang-related	469	1.91 (2.57)	.72	49	1.94 (3.43)	.58
Retaliation	751	2.09 (6.12)	.58	52	1.82 (3.27)	.58
Robbery	647	3.50 (6.64)	.97	57	2.02 (3.42)	.25

Exhibit 26: Euclidean Distances Traveled by Homicide Offenders by Motive: Mt. Pleasant vs. DC (in miles)

	District of Columbia			Columbia Heights/Mt. Pleasant		
Motives	Number	Mean (SD)	Median	Number	Mean (SD)	Median
Argument	1687	2.60 (9.62)	.63	156	1.85 (2.94)	.43
Domestic violence	203	1.55 (2.85)	.09	13	.001 (.006)	.000
Drug-related	946	2.84 (7.84)	.81	90	1.88 (3.02)	.44
Gang-related	469	2.73 (10.18)	.97	49	1.97 (2.48)	.89
Retaliation	751	2.67 (9.30)	.90	52	1.73 (2.77)	.61
Robbery	647	2.39 (4.66)	.93	57	2.27 (3.37)	.49

However, strict travel distance cannot characterize the qualitative aspects of places in the same way that social distance does. In this case, social distance is represented by neighborhood.[15] There are a couple of different ways to analyze social distance. One way involves using the distribution of mobility triangles to characterize the social distance of participants. For the Columbia Heights/Mt. Pleasant neighborhood, 33.6% (n=83) of the homicides involved participants from within the neighborhood. The next most frequent type involved victims from outside the neighborhood (Victim mobility) and offenders from inside the neighborhood with 27.1% (n=67). In about 22% (n=55), the offender came in from outside the

[15] The literature on the importance of neighborhood as a representation of the social milieu is too extensive to be reviewed here. Please see the following sources for an overview of this topic (Bursik & Grasmick, 1993; Hunter & Suttles, 1972; Sampson, 1985; Tita & Griffiths, 2005b).

neighborhood. The most infrequent types of homicides were the Total mobility triangle with 14.6% (n=36) and Offense mobility with 2.4% (n=6). These results lend support for characterizing the problem in Columbia Heights/Mt. Pleasant as essentially a local one, especially as far as offenders are concerned. In over 60% of the homicides, the offender lives in the neighborhood.

Another approach would be to examine the origins of the victims and offenders who were killed in the neighborhood (Exhibit 27). Over half of the offenders (63%) and victims (60%) lived and died or committed murder in the Columbia Heights/Mt. Pleasant neighborhood. The next two largest contributors of both victims and offenders were the adjacent neighborhood cluster to the north, Petworth/Crestwood and Prince Georges County, Maryland. The adjacent neighborhood cluster, Eckington/Edgewood to the east, was the third largest contributor with 2% of offenders and 3% of victims.

A final strategy would be to examine the net flows of offenders and victims to identify neighborhoods that tend to export offenders or victims (see Exhibit 23). From the map and Exhibit 27 it is clear that the homicide problem in Columbia Heights/Mt. Pleasant is largely a local one. Looking back at Exhibits 18 and 19, they show the neighborhood also produces more offenders and victims than it gets from outside. Exhibit 17 provides a more nuanced view of where offenders from Columbia Heights/Mt. Pleasant are committing their homicides. Identification of the areas among which homicide participants travel provides critical information on the extent of homicide participants' prior interaction and may generate leads useful to homicide investigators.

Identifying the type of homicide problem in a neighborhood also has direct implications for prevention efforts. Neighborhoods that are exporters of offenders would be good candidates for programs geared toward offenders (e.g., employment or education programs). In terms of prevention strategies, victim awareness programs could be held in the neighborhoods that tend to provide victims. Data regarding flows of victims and offenders can provide important information for prevention (i.e., where services are needed) and for investigation (i.e., where potential offenders might live).

Exhibit 27: Relative Contribution of Offenders and Victims to Homicide Events in Columbia Heights/Mt. Pleasant Neighborhood

	District of Columbia	Offenders	% of Offenders Contributed	Victims	% of Victims Contributed
Cluster 1	Adams Morgan/Kalorama	5	1.7%	3	0.8%
Cluster 2	Columbia Heights/ Mount Pleasant	181	62.6%	223	59.9%
Cluster 3	Shaw/LeDroit Park	5	1.7%	5	1.3%
Cluster 6	Dupont Circle	3	1.0%	6	1.6%
Cluster 7	Cardozo/Logan Circle/Vernon Square	3	1.0%	5	1.3%
Cluster 8	Chinatown/Downtown	3	1.0%	7	1.9%
Cluster 9	Fort McNair/ SW Waterfront	1	0.3%	0	0.0%
Cluster 16	Colonial Park	1	0.3%	0	0.0%
Cluster 17	Brightwood/Takoma Park	5	1.7%	3	0.8%
Cluster 18	Petworth/Crestwood	18	6.2%	29	7.8%
Cluster 19	Fort Totten/Queens Chapel	2	0.7%	3	0.8%
Cluster 20	University/Michigan Park	1	0.3%	2	0.5%
Cluster 21	Eckington/Edgewood	7	2.4%	12	3.2%
Cluster 22	Brookland/Brentwood	4	1.4%	5	1.3%
Cluster 23	Trinidad/Ivy City	0	0.0%	3	0.8%
Cluster 24	Fort Lincoln	0	0.0%	1	0.3%
Cluster 25	Trinidad/Ivy City	6	2.1%	5	1.3%
Cluster 26	Fort Lincoln	3	1.0%	1	0.3%
Cluster 28	Kingman/Stanton Park	1	0.3%	3	0.8%
Cluster 30	Historic Capitol Hill	1	0.3%	1	0.3%
Cluster 31	Navy Yard	6	2.1%	1	0.3%
Cluster 32	Historic Anacostia	2	0.7%	0	0.0%
Cluster 33	Benning/Marshall Heights	1	0.3%	2	0.5%
Cluster 34	Fairlawn/Twinning/Fort Davis	1	0.3%	1	0.3%
Cluster 36	Woodland	0	0.0%	2	0.5%
Cluster 37	Barry Farm	1	0.3%	3	0.8%
Cluster 38	Douglass/Shipley	2	0.7%	0	0.0%
Cluster 39	Congress Heights/Washington Highlands	4	1.4%	3	0.8%
	Maryland				
	Charles County	0	0.0%	1	0.3%
	Montgomery County	2	0.7%	1	0.3%
	Prince Georges County	19	6.6%	20	5.4%
	Montgomery County	0	0.0%	10	2.7%
	Virginia				
	Alexandria	0	0.0%	4	1.1%
	Arlington County	0	0.0%	3	0.8%
	Fairfax County	1	0.3%	1	0.3%
	Prince William County	0	0.0%	1	0.3%
	Warren County	0	0.0%	1	0.3%
	TOTAL	289		371	

Discussion

The convergence of victim and offender continues to be an important research area. Many of the previous studies examining convergence make use of the offender residence, victim residence, and location of the crime, which together create a triangle. The earliest studies tended to focus on whether the offender and victim resided in the neighborhood in which the event occurred. Subsequent studies expanded the typology into a five category classification still in use today (Tita & Cohen, 2001; Tita & Griffiths, 2005a). These studies have clearly indicated that the spatial typology of homicide varies by other characteristics of the homicide (e.g., motive) and that homicide typologies are not homogenously distributed across space. However, scant attention has been paid to the visualization of these spatial typologies. The previous sections address this lack of information by summarizing a variety of visualization techniques for application with mobility triangle data.

As noted earlier, the goal of this primer is not to introduce already well-known cartographic techniques that have been thoroughly explained in basic cartography texts, but rather to stimulate thought about how these techniques could be applied to mobility triangle data. With the exception of flow mapping, the techniques discussed are available 'out of the box' from current geographic information software. The ability to draw lines between origins and destinations, however, is only available through specialized add-ons to GIS or custom programming. In order to address this challenge and facilitate the use of flow mapping by practitioners, Appendix 1 discusses the relative advantages and disadvantages of three different programs capable of producing flow maps. Appendix 2 gives an overview of the data preparation necessary to produce an origin-destination matrix. As a whole, this primer offers the first attempt to address the lack of information available to guide the cartographic representation of multi-location data.

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Appendix 1: Software Comparison

Three different software packages for producing flow maps are reviewed.[16] Two of the three packages are free, CrimeStat and Tobler's Flow Mapping software. The third is ESRI's ArcGIS Arcview® product. It is included because it contains a visual basic program that generates the lines for flow maps in Arcview®. A brief description of each product is given and their advantages and disadvantages relative to flow mapping are discussed. The goal of this section is to provide an overview of the different software packages for new users.

CrimeStat

Cost

Free.

How to Obtain

Can be downloaded from the Crimestat home page at http://www.icpsr.umich.edu/NACJD/crimestat.html.

Ease of Use

The voluminous user guide for CrimeStat III, version 3.0 goes far beyond software documentation and into the realm of broad introduction to spatial statistics and modeling (Levine, 2005). Of course, by definition the more flexible and full-featured a program is, the more complicated it tends to be. CrimeStat is no exception. However, the developer has provided an organized user interface that groups similar types of analysis under the same tab. Once the user has taken the time to familiarize themselves with the options, the program is relatively straightforward.

Basic Steps

CrimeStat contains several different methods for characterizing flows. Two are discussed here. One way is through the Journey-to-Crime Module located under the "Spatial modeling" tab (see Chapter 10 of CrimeStat manual for complete information). This method requires that you define a primary file. While under the "Spatial modeling" tab, click on the "Journey-to-Crime" sub-tab. The steps to create the lines are as follows:

1) Click on the box "Draw crime trips".
2) Click on the button "Select data file". This opens another window in which you can select the origin x, origin y, destination x, and destination y fields from your file.

[16] There are probably other utilities that have been developed to accomplish the same goal. These three packages were chosen because they are free and easy to install (CrimeStat and FlowMapper) or they were developed as part of this research effort (ArcGIS extension).

3) Click on the “Save output to” button to name an output file and choose a file format for the lines.
4) Open your preferred GIS package and display the lines.

Another method available within CrimeStat, “Trip Distribution” is under the Crime Travel Demand Module. Chapter 14 of the CrimeStat manual has extensive information regarding this method and the data formats required. The Trip Distribution method automatically assigns point locations to polygon centroids and computes the number of trips between zones. At least two files (and possibly three) are involved in the process. One file contains the origin and destination x,y coordinate pairs for the events. A second file contains the centroids for the polygons to which you want the origin points aggregated. A third file (which could also be the second file) contains the centroids for the polygons to which you want the destination points aggregated. Under the sub-tab Trip Distribution do the following.

1) Click on “Calculate observed origin-destination trips”.
2) Fill in the information about the origin and destination files (the polygon centroid you defined as the primary file earlier). Choose fields to use for the origin-id and the destination-id. Picking a unique identifier is recommended.
3) Click on the button “Select data file”. This allows you to choose the data file(s) to use in the analysis. The data file(s) should have the x,y pairs for the origin and destination locations.
4) By clicking on the “Save observed origin-destination trips,” “Save Links,” and “Save points” you can save a file of the trips, a file of the lines and a file of the polygon centroids.
5) Open your preferred GIS package and display the lines. Since the last field in the table, PREDTRIPS, contains the number of trips between two locations (in this case offender to victim) the graduated line symbol techniques described can be used with this file also.

Symbolization Capabilities

There are no mapping capabilities within CrimeStat but you can save files in several different formats (e.g., MapInfo, ArcView and AtlasGIS) for use in GIS. The output file from the Journey To Crime Module supplies only the lines representing a trip. The output file from the Crime Demand Module supplies the lines and the number of trips between two locations. The resulting cartographic layers must be symbolized within a GIS. The ‘look’ of the maps will therefore be determined by the GIS package chosen and the skill of the analyst. If ArcGIS® is used as the GIS package, all the standard cartographic capabilities are available to symbolize data generated by CrimeStat.

Drawbacks

Crimestat does take some effort to learn. Most of the effort necessary is to understand the statistics that are being used so they can be used correctly. The software design is also complex but in conjunction with the excellent user guide is easily mastered. For those who are still intimidated, there are workshops offered over the course of the year at

Inter-University Consortium for Political and Social Research (ICPSR) at the University of Michigan and the National Institute of Justice's Mapping and Analysis for Public Safety (MAPS) conference.

Tobler's Flow Mapping Software

Cost

Free.

How to Obtain

Can be downloaded from the Internet. FlowMapper home page is at http://www.csiss.org/clearinghouse/FlowMapper/ and there is a link to download the software, documentation and sample data sets.

Ease of Use

The software comes with documentation in the form of a comprehensive Help menu and a PowerPoint (converted to pdf) that serves as a User Guide. These documents contain step-by-step instructions on using the software. The ease of use is highly dependent or the user's data. Files that are already in a matrix format can be imported easily. Users do not have to know how to use a GIS.

GIS users who want to use FlowMapper will run into a challenge when converting GIS files into the format that FlowMapper requires. Getting the files into the correct format (i.e., a matrix) can be time consuming. Fortunately, Dr. Waldo Tobler has added a series of programs and accompanying documentation to the FlowMapper website that greatly facilitates the process. In addition, recent development efforts have made FlowMapper functionality available to users of ArcGIS 9.x via download at the same site.

Regardless of original data, in the end two files are necessary to map flows, 'centroids' and 'origin-destination matrix.' A 'location names' file, while not required, is extremely helpful for identification of specific areas.

Basic Steps

Since the documentation that comes with Flowmapper is so comprehensive, this section concentrates on giving an overview and providing detail where the documentation was less complete. In order to use the program, four files can be loaded into the software; two of the files are required and the other two are for display purposes. The required files include the place coordinates (centroids of the polygon) and an interaction table that contains data about the flows. The display files consist of one file of the place names (with identifiers that match the corresponding centroids) and another that has the boundaries. These files make it easier to interpret the origins and destinations of the arrows because they label the areas and show their boundaries.

As mentioned earlier, Dr. Tobler has created a series of programs that make it easier to get data into a format that FlowMapper can use. Those programs make the following paragraphs obsolete but they remain in this document for reference by individuals who are not able to make use of the new programs.

If the user's data is in text file format, the directions in the FlowMapper manual are sufficient to get the data into FlowMapper. This next section is only pertinent if the user is working with ArcGIS®. In that case, getting the centroids and location name files created is still fairly straightforward. To get the centroids, just use the AddXY toolbox in ArcMap and then export the data to a .txt file, comma delimited. Open the file and sort the file so that it is in a particular order (e.g., alphabetically). Then delete all fields except the x and y fields. The sort order is important because only the x and y fields remain in the file so they must be sorted in the same order as the location names file. For the location names file, simply use the same, sorted file but this time delete all fields except the name and save as an approved file type (once again space delimited with no headings).

The creation of the origin and destination matrix from two individual files is more complex. While there are several methods for getting data in matrix form (e.g., obtaining it that way from the data source or writing a program), the steps to one method that does not require programming are provided next.

1. Run a crosstabs analysis on the areas in SPSS and paste output file into Excel spreadsheet.
2. Check the number of areas in the crosstabs matrix against the file with all potential areas (they must match).
3. Make sure you delete the totals columns and all the headers
4. Then save as a .csv file
5. Open Wordpad and edit out all the commas and replace with spaces or utilize the new programs for data conversion.
6. Save file as a .txt file.
7. Read into Flowmapper

At this point all the necessary files are in Flowmapper and are ready for analysis. The documentation on how to create flow maps is very complete and need not be repeated here.

Symbolization Capabilities

FlowMapper can depict gross flows, net flows, and simultaneous two-way flows. In addition, the user can choose to show flows from all places to all places or limit the map to flows to and/or from only one place.

The user can obtain information about features on the map by clicking on them. Clicking on a flow line gives the magnitude (volume) of the flow, and clicking on a place reveals its identity. An automatic threshold option is available. In addition, centroid sizes can turn into label placement indicators. Two examples of maps generated by FlowMapper follow this section (Exhibits 1-1 and 1-2).

Drawbacks

The only real drawback for users who have matrix data in hand is the limited non-flow symbolization capability. Most critically, the inability to label areas makes it difficult to identify the areas that are connected. Tools to enable labeling of areas and other features would make a valuable enhancement to the package. One workaround for this issue is to add labels to the image in a separate graphics program (e.g., Corel Paint).[17]

The following drawbacks pertain mainly to individuals who are using GIS files or do not have a data matrix. The most time-consuming drawback for GIS users is the multi-step process to get GIS data into the application. A process that has been made much easier through the use of the new data conversion programs on the FlowMapper website. The remaining drawback is the inability to use existing GIS layers in the same map. The program would be greatly enhanced if it had the ability to use a wider variety of GIS files with a minimum of data transfer steps. Geographic features make it easier for map users to orient themselves and thus are valuable additions to any map. Dr. Tobler has suggested the use of a shp2mif converter program that produces ASCII text files. Once the header information is deleted, the list of coordinates can be imported into FlowMapper. Please contact Dr. Tobler directly for this program.

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[17] The authors are indebted to Waldo Tobler for this suggestion.

Exhibit 1-1: Flows of Offenders from Columbia Heights/Mt. Pleasant to Other Neighborhoods

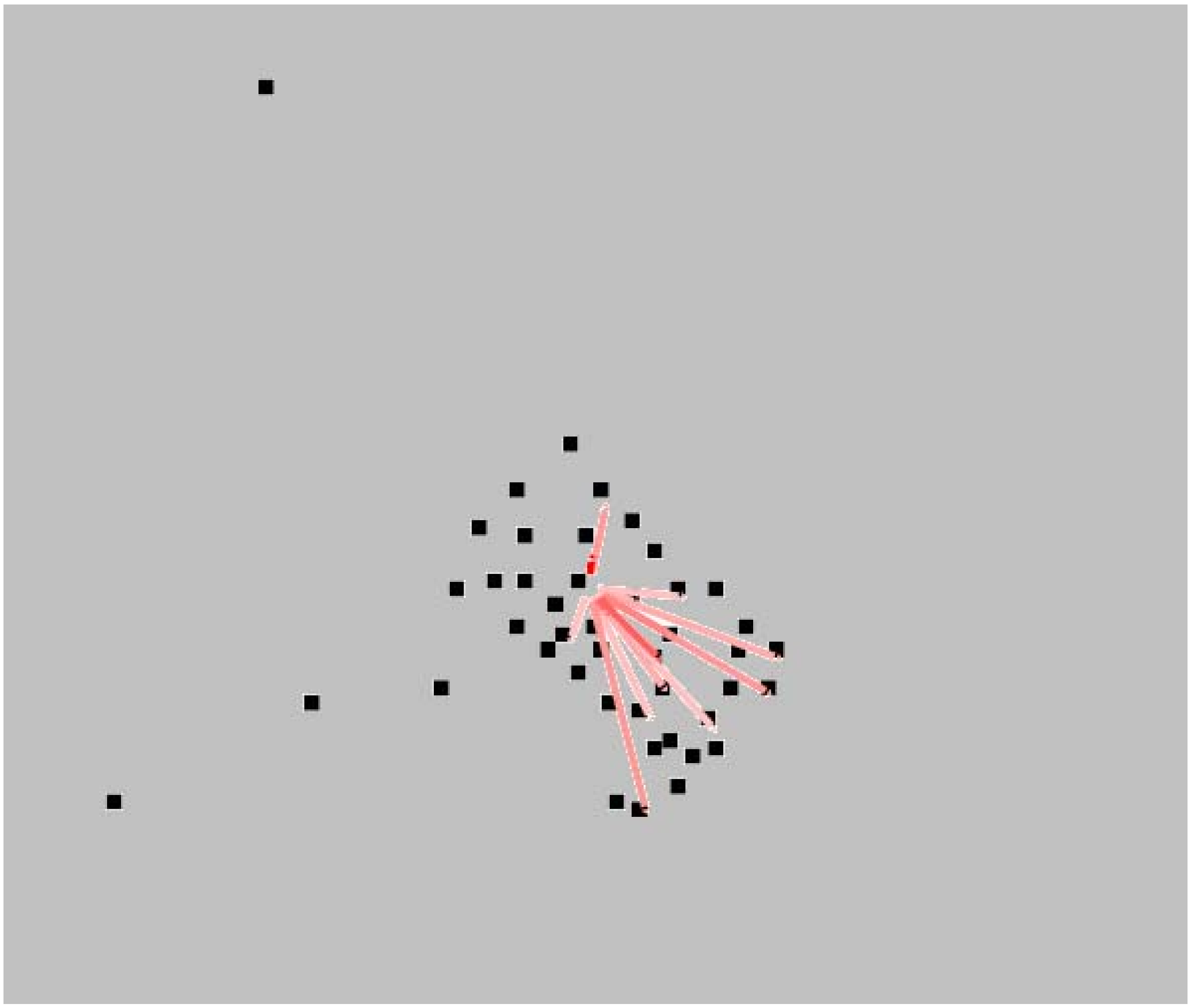
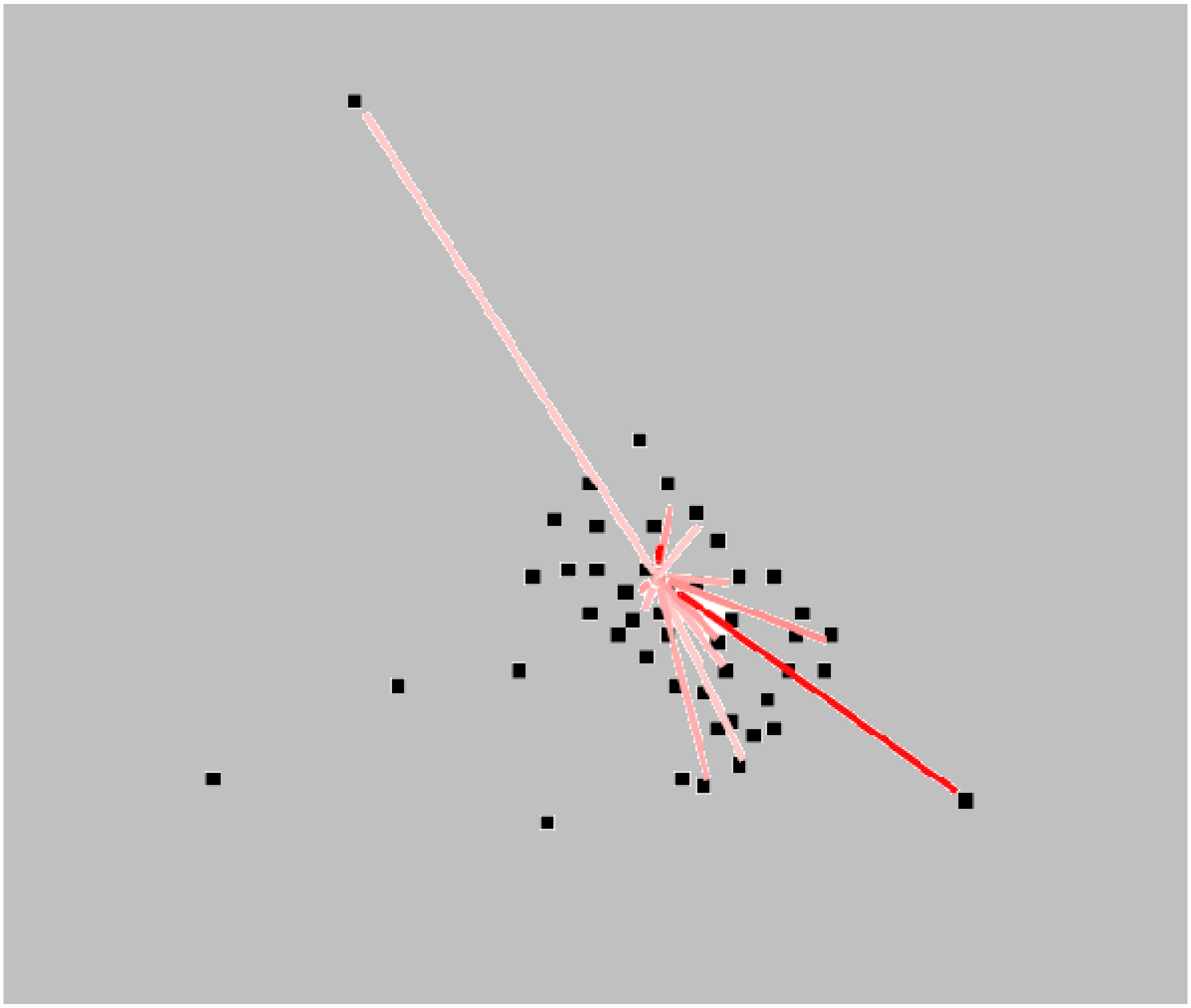


Exhibit 1-2: Flows of Offenders to Columbia Heights/Mt. Pleasant Neighborhood from Other Areas



ArcGIS®

Cost

Must purchase a license for ArcView©. The tool to generate lines between locations is free.

How to Obtain

Go to www.esri.com or contact a local ESRI office for the software license. The .dll is available from the National Institute of Justice.

Ease of Use

If you have a basic grasp of ArcView 9.0, using the additional tool to generate the lines is very straightforward. Symbolizing the lines can be as simple or as complicated as the user desires. Symbol functionality is contained in the main ArcMap product and is available through label and legend options.

Basic Steps

To use the generate lines tool you must first register the .dll file. This can be done by opening two file explorer windows. In the first one browse to c:\windows\system32 and scroll down till you see regsvr32.exe. In the second window open it to where your GenerateLines.dll is located. Drag and drop the generatelines.dll onto regsvr32.dll. You should get a message that it was registered successfully. There are three additional steps necessary to actual use the generate lines tool. The steps are (1) adding the tool to your project, (2) using the generate line tool, and (3) symbolizing and labeling the lines. These directions assume that you have already created your matrix file that contains the flows for victims and offenders (see Appendix 2 for a more detailed explanation). The first step is to add the generatelines.dll to your project. This step makes the tool available for your use. Go to the "Tools/Customize" menu item… and choose the "Commands" tab. Use the "Add From File" button at the bottom of the pop-up to navigate to where you have stored generatelines.dll. Choose the file in the dialog box and click "Open". You will get a message that you are adding the class clsLineTotals. Click "OK". Scroll down the commands list until you see the tool labeled DTC in the left pane, click on it. The GenerateLinesBetweenNeighborhoods button will appear in the right pane. Left click on the description and drag it to your preferred location on the tool bar. Now the tool is ready to use.

Using the tool is very simple. Just click on the tool and one dialog box opens. The dialog box allows you to navigate to the suspect and victim matrices and specify where to save the new line shapefiles that are created. You can also fill in the minimum number of trips between zones that are included. If you only have a few zones or a few incidents, you may want to use all of them. On the other hand, if you have many trips (as is the case with the sample data set) you may want to use a threshold to make the resulting display easier to read. Experimentation with the data is the best way to find the lowest, readable threshold.

Symbolization of the lines is done through the layer properties. The program creates one line per relationship that exists. So if a total of 10 offenders travel from Capitol Hill to Petworth and another 5 offenders travel from Petworth to Captiol Hill there will be two lines drawn between the two neighborhoods, one for each direction of flow. However, they are drawn on top of one another so it looks like one line. All the tools necessary to symbolize the lines (e.g., to offset the lines so you can see both and/or use graduated symbols to represent the lines) are available in ArcView®. To access the tools, simply right click on the layer to be symbolized and choose "Properties" from the list. In the dialog box choose the "Symbology" tab.

<u>To use graduated line sizes</u> – In the leftmost pane, under "Quantities" choose "Graduated Symbols". Then in the "Fields" section choose the field that contains the flow totals. Click on the "Template" button to change the line color.

<u>To use an arrowhead</u> – Click on the "Template" button and then on the "Properties" button to get to the advanced properties. Under Type: choose "Cartographic Line Symbol". Then click on the "Line Properties" tab to set the offset and the direction of the arrow. By clicking on the "Properties" button under "Line Properties" and then the "Symbol" button on the subsequent screen, you can change the size and color of the head of the arrow.

<u>To show a subset of flows</u> - The ability to control which flows are displayed can be accessed through the use of a "Definition Query". This allows the user to focus in on all the flows to and from a particular area or areas.

<u>To display the value associated with a flow arrow</u> - The individual lines can be labeled by using the "Labels" tab. The options to symbolize text are too numerous to cover here and are well documented in the on-line help.

Symbolization Capabilities

The setting to control the flow threshold is especially handy since it allows the user to only show flows above the threshold. This makes the output much more readable. As mentioned above, there are a variety of symbolization capabilities for the arrows that control color, width, and type of arrowhead, if one is used. There are limitations with the default arrow line symbol but the option to create your own custom line symbols to use is available.

The flows can be displayed with other geographic layers to provide additional context. For example, streets, parks, and water features could be added to the map to assist the readers in orienting themselves. Or another variable could be symbolized using choropleth mapping in addition to the flows on the same map (see earlier examples of showing the number of individuals who lived in the same area rather than traveling).

Drawbacks

The major drawback to this tool is the arrowhead symbol that comes with the software. It does not display well unless the arrowhead is very large. If the arrowhead is large it causes other visualization issues. This tool would be more accessible if incorporated into the core Arcview® software.

Appendix 2: Constructing the Data Matrix for a Flow Map

The first step in creating a flow map is assembling a matrix of origins and destinations. The value in each cell represents the number of trips between the two areas. Said another way, the number indicates the strength of the relationship as expressed by the frequency with which victims and offenders travel between the two areas.

One possible way to construct such a table is to use a spreadsheet (e.g., EXCEL) or statistical program (e.g., SPSS, Stata, etc.) to create a crosstabs table from the homicide location neighborhood and the home address neighborhood fields. This operation is performed twice, once for the suspect flows and again for the victim flows.

Exhibit A-1: Raw Crosstabs Table (Unbalanced)

	Location of Homicide				
Home Address	Cluster 1	Cluster 2	Cluster 3	Cluster 4	…n
Alexandria					
Arlington					
Cluster 1					
Cluster 2					
…n					

If the incident areas are not the same as the residence areas, you will have to insert rows containing zero values to balance the matrix. For example, the data used here had information about victims and offenders who traveled to DC but did not have the corresponding information regarding DC residents who traveled to the surrounding areas because the study did not include homicides that occurred outside of DC (Exhibit A-1). Consequently, the rows need to be manually added so the matrix is balanced. In Exhibit A-2, rows were added to represent Alexandria and Arlington as possible locations even though there was no data about homicide incidents in those areas.

Exhibit A-2: Balanced Crosstabs Table

	Location of Homicide				
Home Address	Alexandria	Arlington	Cluster 1	Cluster 2	…n
Alexandria	0	0	1	4	>=0
Arlington	0	0	0	1	>=0
Cluster 1	0	0	10	2	>=0
Cluster 2	0	0	3	5	>=0
…n	0	0	>=0	>=0	>=0

Appendix 3: Computer Program

One computer program was written to automate the drawing of the lines to depict flows between areas. How to use the generatelines.dll is describe in the ArcGIS® section of Appendix 1: Software Comparison. The generatelines.dll program is delivered with this document.