WHAT DO THOSE DOTS MEAN? MAPPING THEORIES WITH DATA

by

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Abstract: *Criminologists have expanded their use of maps as the costs of mapping have plummeted. Using two cases of drug dealing, this paper examines the way in which theory influences how we interpret maps. The first study is a hypothetical case using fictitious data; the second, an actual case using real data. We show that when the explicit theoretical content of maps is low, it is difficult to interpret the data. As the theoretical content of maps increases, their utility increases. We show that theory also enhances the utility of computer algorithms designed to find point clusters on maps. The implications for crime control and prevention practitioners and researchers are discussed.*

INTRODUCTION

We axe experiencing a revolution in the use of mapping in criminology and criminal justice research. The proliferation of easy-to-use, high-speed mapping software that runs on inexpensive personal computers has contributed to this revolution, just as easy to use statistical software contributed to the use of increasingly advanced statistical tools for the study of crime. Much attention has been focused

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on the variety of data that can be placed on maps and the methods of mapping that can be used (for useful summaries, see Block et al., 1995, or McEwen and Taxman, 1995).

Though mapping a variety of data using advanced software can help criminologists understand crime patterns, our ability to use maps effectively depends as much on how we incorporate theories in the maps of data. This paper describes why it is critical that we pay more attention to theory when using maps. The thesis is that adding explicit conjectural information to maps provides insights that are not available if one maintains a strict empiricist perspective. Though this papers emphasizes research applications of mapping, there are important parallel implications for the application of mapping to crime control and prevention operations.

THEORY, DATA AND METHOD IN MAPPING

Science advances through a complex interplay among speculation, observation, and method. This is no less true for criminology than it is for economics or physics. The simple paradigm we were taught in our first undergraduate research course stated that we entertain a hypothesis, derive some expected observable consequences from the hypothesis, compare the actual observations to these expectations, and then assess the meaning of the differences between our expectations and our observations. We might abandon the hypothesis if our expectations are dashed, amend it if our expectations are merely bruised, or celebrate it if our observations meet our expectations.

Though this process is overly simple, it does highlight the interplay among method, data, and theory. Theory is deeply imbedded in the data we apply to criminological questions. Indeed, to have a question about crime suggests that something is not as one expects. An expectation implies a theory. That we collect data — an expensive, time-consuming, and often difficult undertaking — suggests a theory about crime and a desire to find support for it, or a reason to choose an alternative theory. In the absence of an explicit theory, an implied theory guides the research. A researcher cannot know what data to collect, how to collect it, and how to analyze it without a theory (explicit or implied). A researcher without any theoretical guidance will find it impossible to determine the meaning of any data collected and will not be able to describe what was learned.

The decision to select a particular research method is also laden with theory. If the theory implies a linear relationship between two variables, then ordinary least squares regression might be useful.

But if the theory rules out a linear relationship in favor of a non-linear function, then an analysis method in accord with the theory needs to be selected. If a researcher is interested in the evolution of a crime pattern, he or she would use time-series analysis. Maps are only of use if we are interested in a phenomena that produces spatial patterns of crime.

Mapping crime data is a scientific enterprise, but it is often done without an explicit theory. The researcher plots crime points on a map or shades areas of the map in accordance with the presence or frequency of some attribute. In the absence of an explicit theory, the researcher must be acting on the implicit theory that space is related to crime. If the researcher maps political boundaries (police beats, council wards, city boundaries, or state lines), he or she implies that these boundaries matter in some way. If the researcher plots crime data on a street grid, he or she is stating that the pattern of the streets has some relationship to the crimes plotted.

It might be argued that there is no implied theory; that the streets, for example, are drawn as a reference for the reader and not because the researcher assumed there was a relationship between streets and crime patterns. This may be a valid explanation for the work of a police crime analyst who needs to direct patrol attention to a small area with a big crime problem. But it is not a valid explanation for the researcher communicating to an audience who will never visit the area. Few readers of the researcher's map are likely to visit the areas mapped; these readers want to know what the map tells them about areas in other cities and neighborhoods. If the researcher does not expect the street layout to help explain the crime pattern, or is not interested in testing the hypothesized relationship, then plotting the crimes on a blank page would be as meaningful as plotting them on the street grid. In other words, everything displayed on a map should be of theoretical importance.

The absence of explicit theories in crime mapping makes it difficult to interpret the data. This is particularly true when individual events are plotted. These are the simplest maps because the researcher has not aggregated the data. But they are also the most confusing. If data are aggregated by area and the frequencies of events in areas are compared, it is obvious what the maps are trying to show — some areas have more crime events than others (either absolutely or relative to some other factor, such as population). But when points are plotted it is not certain what is being examined. Should we be looking for clusters of dots? If so, how many dots and how close should they be to one other to make a cluster? Or should we be looking at the association of crime dots with other features drawn on the map? If so, which features should be shown and how close do the dots have to be to the feature to demonstrate an association? Whether we are looking for clusters or associations with features, how do we separate systematic patterns from chance or random patterns?

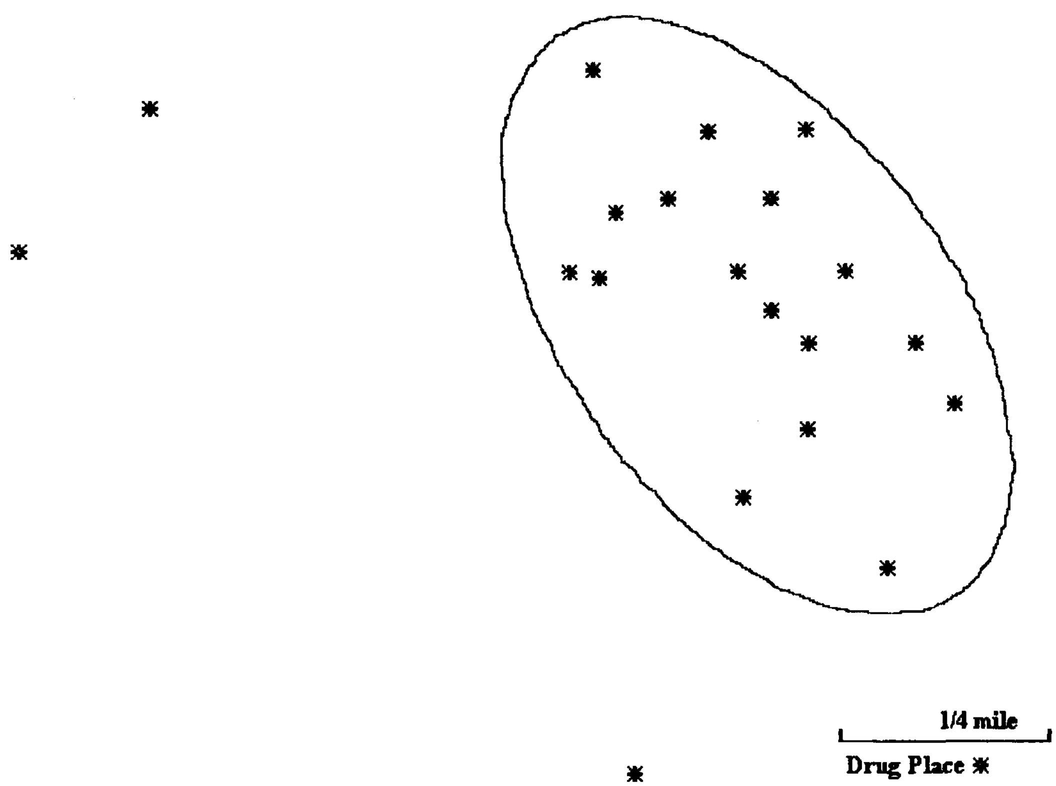
There are no methodological answers to these and similar questions; the answers depend on the theory being examined. And if the researcher has not been precise in describing his or her theory, readers can draw differing interpretations from the same map displays, regardless of the methodological tools used. As we will see later, methodological aids for interpreting spatial patterns plotted on maps are far more useful when an explicit and powerful theory is applied than when implicit and weak theories are used. Methodological tools, such as the example used later in this paper, are like carpentry tools; there are appropriate and inappropriate situations for their use, and there are different tools for different purposes. But ultimately, the quality of the finished product built will depend less on the tools than on the plans for the thing being built (as well as the skill of the user). This is not an evaluation of any general-purpose analytical tool but of the plans.

MAPS OF A HYPOTHETICAL AREA

To illustrate the role of theory in mapping, we will look at a series of maps of a fictitious area in a hypothetical city. In this example we will look at plots of drug locations. We will assume that these data came from narcotics investigation arrest reports, citizen calls over a drug tip phone line, and patrol officers reports, and that the data shown represent known sites of persistent drug dealing. In other words, we are going to assume that the data are reasonably valid indicators of drug dealing locations and that we can safely ignore data validity issues. We will examine the same hypothetical data pattern on a series of maps where the theory has been made increasingly explicit. Thus, we will hold the data set constant, vary the theory and examine how this influences our interpretation of the maps.

Figure 1 is a theory-free map (ignore the ellipse, we will come back to it later). It shows the dots on a featureless terrain. We see that there is a cluster of drug sites toward the upper right. What this means is unclear. The only context shown in this map is the distance scale, which tells us that the dots are relatively close together. But by itself, the scale does not provide sufficient context to interpret the map. That Figure 1 makes little sense is not surprising, but it reminds us that without a context data is meaningless.

Figure 1: A Theory-Free Map



How can this context be shown? We cannot map everything. Many interesting attributes cannot be mapped because they are not part of an easy-to-use database. But even if they were and we tried to map all these features, the map would be hopelessly cluttered and would be as uninterpretable as Figure 1. Some contextual features are irrelevant and could be left off of the map. But which features are irrelevant? The choice of the features that describe the relevant context depends on the theory being examined. To interpret the dots we need a theory so we can display the relevant context and leave out the irrelevant context.

Under what circumstances is it preferable to display data on a virtually blank map? Consider a researcher studying the covariance of two crime types in a large area. A map with just the outline of a city would show the borders of the data collection area. The researcher would plot the data for the two crime types on this featureless terrain. Since the researcher is interested only in whether the two crimes are found at the same locations, features like streets and police precinct boundaries would be irrelevant to the question being examined, would clutter the graphical display, and would make the map more difficult to interpret. There are many examples of featureless maps in criminological research. Canter (1995) and LeBeau (1995) use featureless maps to examine drug markets and police calls for service, respectively. Reboussin et al. (1995) discuss the use of "mapless mapping" to examine spatial relationships between the locations of rapists' homes and crime scenes. Since they are using data from several different cities, there are no features common to the areas used by the rapist. These examples show that when the theory being examined does not include spatial features and the data provides its own context, only the data needs to be shown on the map and little else needs to be displayed.

Even when spatial features are central to the theory, featureless maps may be useful. Brantingham and Brantingham (1995) display isopleths for crime in Burnaby, British Columbia. The authors label the places "under" the peaks of the isopleth surfaces to illustrate how crime concentrates at these locations. They do not show the streets of this city or other features. Clearly, many of the features we commonly associate with maps are not needed for some applications.

However, for most criminologists an important function of maps is to show how crime is related to spatial features. Which features should one select to show on the map? And which features should one leave off? To answer this question, we will continue with the hypothetical case we began with in Figure 1. Figure 2 shows the same dots we saw earlier on Figure 1, but superimposed on a street grid. The fact that a street grid is used (instead of elevation contours, soil type, or land use patterns, for example) suggests that the researcher feels that street layouts matter (and elevation, soil, and land use do not) for understanding the pattern of drug dealing places. If the researcher did not think that the street pattern was somehow important for understanding the pattern of drug locations, then any street configuration would be equally meaningful. Three types of streets are shown (side streets, arterials, and highways) with three line sizes because this is theoretically important. If street size was unimportant then the streets could be shown using only one line width. We can further explore the relationship between theory and map features by examining another set of features on Figure 2.

Figure 2: Map with Street Grid

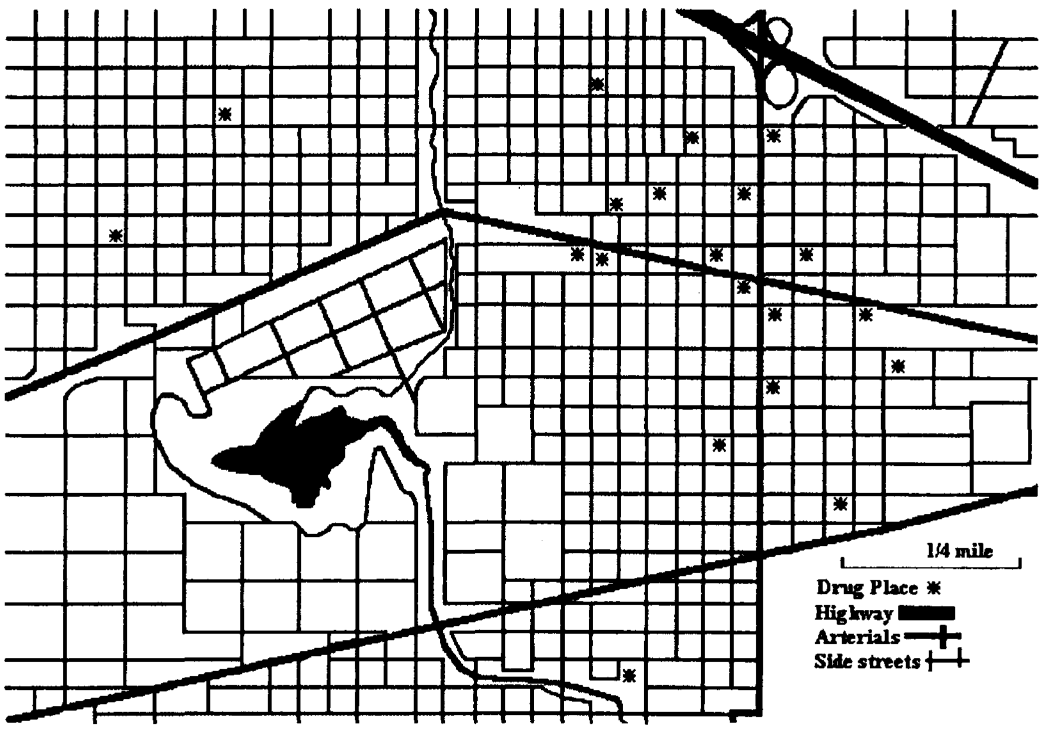


Figure 2 also shows a lake and two rivers. How are they related to the spatial organization of drug dealing? The water features are related to the street configuration. Many streets end at the rivers, and other streets bend around the lake. So the possible relationship between water features and drug dealing is mediated by the street pattern. If this is the hypothesis that the researcher is interested in, then it makes sense to include the water features on the map. However, many other topographical and land use features also influence street configurations, and these are not shown. But if the researcher is only interested in showing the relationship between street patterns and drug dealing, then there is no useful purpose of showing the features that influence street patterns. These features just clutter the map and distract the reader from the hypothesis being examined. For this reason, the water features have been deleted from subsequent maps of this area. As we will see, deleting these theoretically irrelevant features does not reduce our ability to interpret the map. If anything, removing the water features makes it easier to see the patterns we are interested in because there are fewer distractions.

We can see at least two patterns on Figure 2. First, the map shows the cluster of dots we noted originally, along with the three outliers (one toward the bottom and two toward the left of the map). This cluster is centered roughly around the intersection of two arterial streets. Another pattern visible is the relationship between the large streets and the dots. All of the drug locations are within three blocks of an arterial street, with two exceptions (a dot to the left and top, and another toward the center and top). Two of the outliers to the original cluster (Figure 1) fit this pattern, and one dot that was part of the original pattern is an outlier to the second pattern. Clearly, the pattern of dots observed depends on the expectations of the observer. Similarly, which dots are part of patterns and which are outliers depend on the expectations observers brings to the map. When the theory is explicit (e.g., all drug dealing should be close to arterial streets), the researcher and the reader can examine the same pattern. But when the theory is not clearly stated (e.g., street patterns provide structure to drug dealing), the reader and the researcher may be examining different patterns.

There are a variety of analytic tools that researchers can use to study spatial data. These procedures are useful for addressing a variety of questions, for example: Are these dots part of a single cluster? Are the events found in one area related to events found in nearby areas? Do spatial patterns change over time? Regardless of the question, the utility of the procedure will depend on the explicitness and power of the theory being examined.

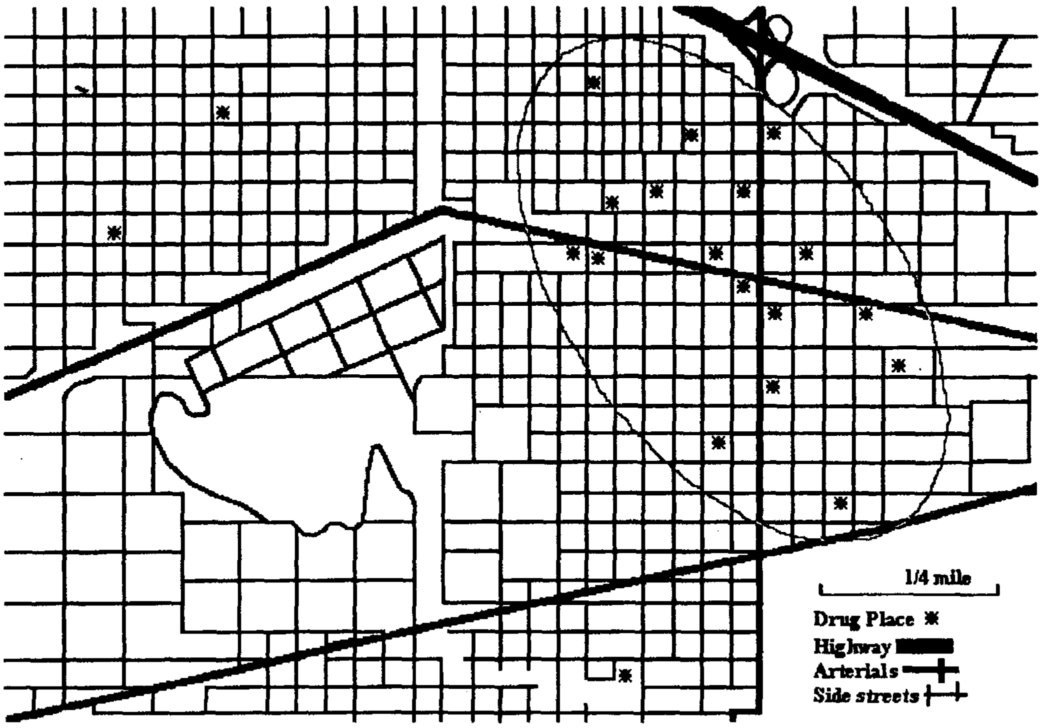
To illustrate this point we will focus on one type of question: Does this set of points represent a meaningful cluster? Let us focus attention on the original cluster of dots noted in Figure 1. Is this observed cluster centered on the intersection of the two arterial routes in Figure 2, or is this just our imagination? Recently, there have been attempts to develop decision rules for defining clusters of crime events. Buerger et al. (1995) describe a manual procedure that employed computer maps and direct observations of potential clusters to draw "hot-spot" boundaries for use in a randomized experiment (Sherman and Weisburd, 1995). A similar set of decision rules has been used by Weisburd and Green (1995a, 1995b) to study drug markets. This manual approach has the advantage of using a great deal of information, much of it not available on computer files or easily mapped, to create precise boundaries. Additionally, the borders of these clusters can enclose odd and complex shapes. The drawback is that the approach is time-consuming and requires many subjective decisions (Buerger et al., 1995).

Another approach is to fully automate the cluster-finding process by using a computer algorithm. The Illinois Criminal Justice Information Authority (ICJIA) has developed an easy-to-use software program (STAC) that allows us to detect point clusters (Block, 1995). This tool can help us interpret the dots on maps by offering a non-substantive standard for what a cluster means. By non-substantive we mean that the interpretation is not based on crime theory but is instead drawn from a mathematical algorithm that will identify clusters of points (representing anything) on a map. Though the ICJIA developed this software to assist police agencies detect crime patterns, it can be useful for research (see, for example, Rengert, 1995 and Block and Block, 1995). Because it is well-known and widely used, we will use STAC as an example from which make general statements about the relationship between spatial theory and analytical tools for examining spatial data.

Returning to Figure 1, if the ellipse were the result of an algorithm like STAC (it was in fact drawn by hand to mimic what such an algorithm would produce), then how much more information was added to what we can learn from Figure 1? The answer is, very little. We can see that some dots are inside the ellipse and some are outside. But absent map features the ellipse is not much more helpful than the dots by themselves. The problem is not with the analytic tool, but with the lack of contextual information for interpreting the analysis results.

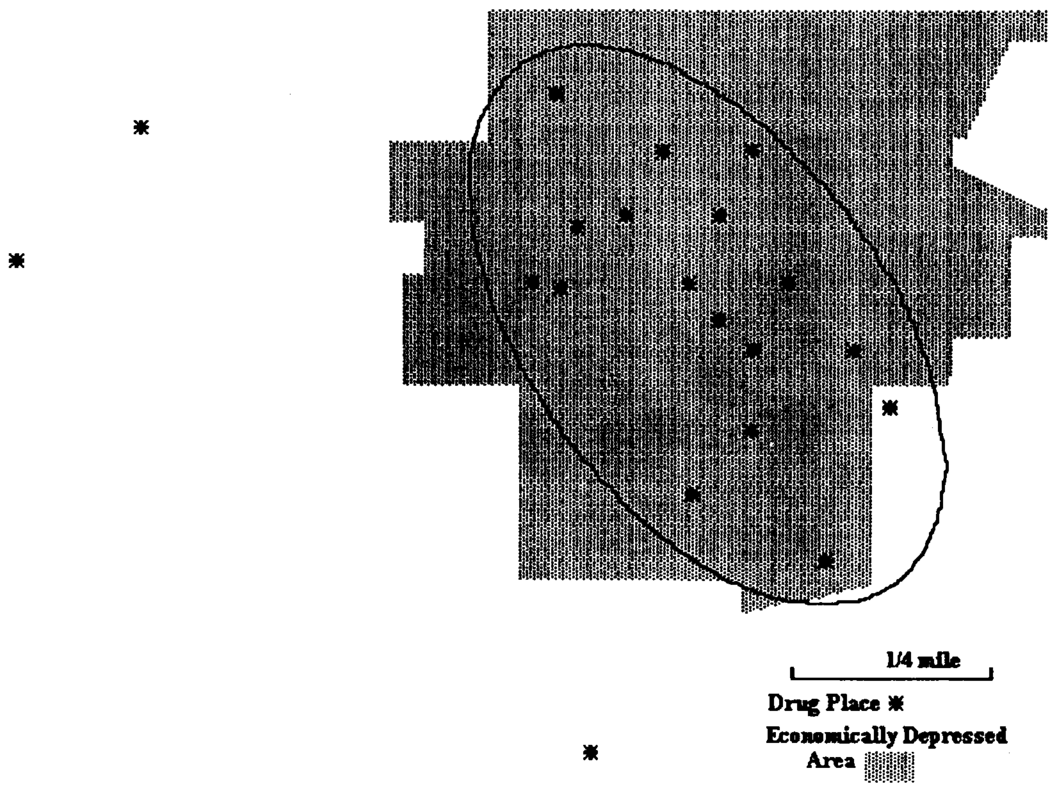
Figure 3 displays the dots, streets and ellipse. Now the ellipse provides some guidance. With the streets added, the ellipse suggests that the cluster is centered on the intersection. If the researcher had begun with a theory that drug locations cluster around intersections, then this ellipse would be evidence in support of that hypothesis. The ellipse also draws attention to another intersection of arterial streets that does not have a cluster of dots. This might suggest a deficiency in the original theory (e.g., intersections may be important for understanding drug markets, but why are some intersections involved and not others?). Thus, the value of such algorithms is tied to the use of theories. In the absence of a theory, such algorithms will add less to understanding the data being mapped than would be the case if a theory had been used. Clearly, the problem is not with the analytical tools being applied or the data being examined, but with the amount of theory being used.

Figure 3: Map with Street Grid and Ellipse



If we had another theory, however, the ellipse might not be as useful. Consider Figure 4. Here the researcher shaded an area of the city that is economically depressed. The theory being examined here is that economic investment in an area is associated with drug sites (no streets are shown because they are unimportant to this particular theory). We see at once that most of the dots fall within the economically depressed area. Four dots are outside the economically depressed area (the three outliers noted above and another dot on the extreme right). The ellipse is less useful here because it captures one of the outliers and suggests that the cluster is larger than it really is. The utility of the algorithm could be enhanced if the theory was more precise (e.g., explaining which parts of the economically depressed area are particularly vulnerable to drug dealing locations). But the theory is weak in that it does not explain how the dots are clustered or scattered within the shaded areas. Though the ellipse draws attention to large parts of the economically depressed area that are outside its boundaries, there are some areas within the ellipse that are without drug dealing places. This is an example of a theory being too weak for the statistical tool being used. The value of these types of algorithms depends on the precision, or power, of the theory. A more powerful theory would make the cluster-finding algorithm more useful.

Figure 4: Map with Poverty Area and Ellipse



The power of a theory is directly related to the patterns that are ruled out by the theory (Popper, 1992). Theories that permit fewer patterns are more powerful than theories that permit many. What we would like to do with maps is to specify where the dots should not fall and where they should. Let us see how this might work with a more detailed theory of drug market places, a theory that considerably restricts the allowable dot patterns. In other words, there are few dot patterns that are consistent with the theory compared to the many possible dot patterns that are inconsistent with the theory.

The theory we will use is based on a general model of illicit retail marketplaces (Eck, 1995). Though the theory covers a variety of consensual crimes, we will only describe it in reference to retail drug dealing. The theory asserts that there are only two ways to sell drugs. The first method, to sell to acquaintances or people vetted by acquaintances, reduces the dealers' and buyers' risk of theft and arrest. But it also reduces the number of sales that can be made by sellers and the shopping opportunities for buyers. This is called a "network market."

The second way of marketing drugs is for dealers to sell to strangers and for customers to buy from strangers. This style of drug market is called a "routine activity market." This strategy increases drug market participants' risk of theft and arrest, but allows sellers to make more sales and buyers to have more sources of drugs. To reduce their risks, buyers and sellers will meet where they both feel safe. This will occur in areas with which they are both familiar. Buyers and sellers will be familiar with these areas because they transact many of their legitimate routine activities in them. Routine activities such as shopping, playing, learning, working, and commuting are usually located along busy arterial routes. So are large multi-family apartment complexes. Many people, some of whom participate in drug transactions, will be familiar with these areas. Since both buyers and sellers will be familiar with these areas, drug dealing will take place along these routes. Locations near arterial routes let sellers "advertise" to passing customers that they are open for business.

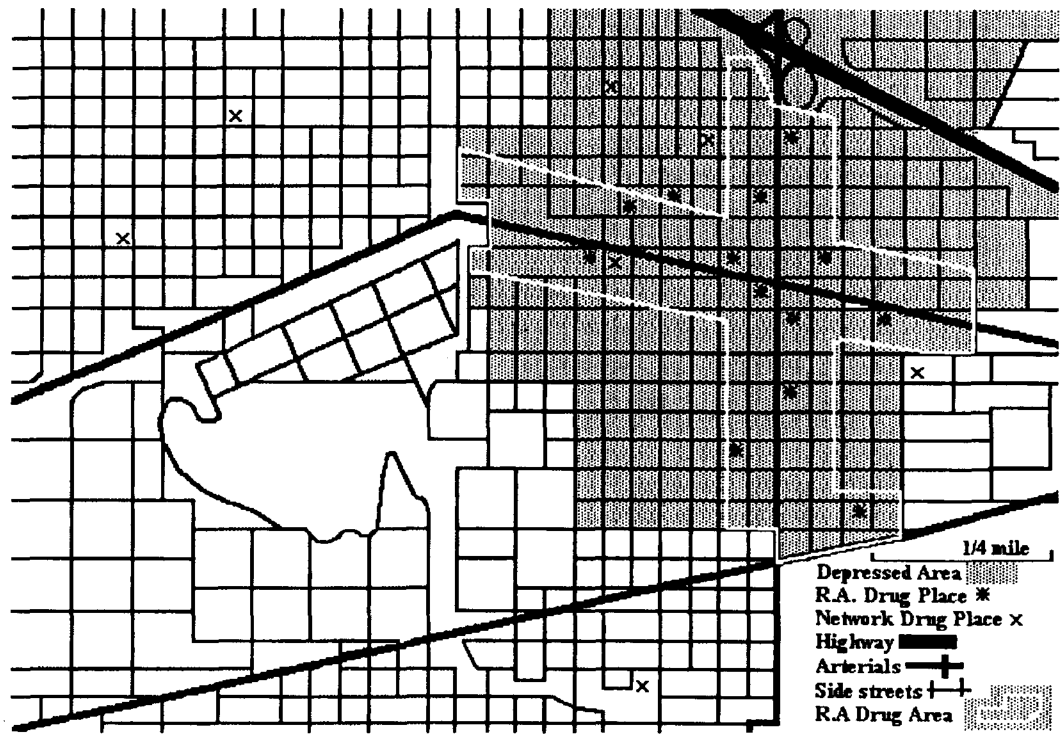
Network dealing will take place over a much larger area and will not necessarily be concentrated along arterial routes. This is because the participants know one other, which reduces their risks and thus the need to seek familiar areas. It also reduces sellers' need to advertise: buyers can call dealers and arrange to meet, or buyers can contact the sellers through intermediaries or by other means.

Routine activity market dealing is not just limited by arterial routes. Because routine activity sales operations will draw many customers, dealers must be at locations where property owners and managers will not bother them. Thus, they will be concentrated where place management is the weakest. And place management will be weakest, according to this theory, in economically depressed areas.

Network marketplaces will not necessarily be located in economically depressed areas because the risks of detection by place managers is lower. There are fewer people coming and going as a result of the network drug trade, and there is less need to sell from a single location. Any location will serve as long as buyers and sellers can make contact through their network to arrange exchanges at mutually satisfactory locations.

This implies that the two types of drug markets will have two different spatial patterns. Network places will be widely scattered and will display little clustering. Routine activity market places will be concentrated along arterial routes through economical depressed areas.

Figure 5: Map with Explicit Theory of Drug Dealing Places



If this theory is mapped along with the drug sites we might get a display like that shown in Figure 5. Here the researcher has noted the two differing drug sales types as specified by the theory. The Xs represent network dealing sites, and the dots represent routine activity marketplaces. Street sizes are theoretically important and are displayed on the map. Similarly, the economically depressed area is shown. Finally, the map shows the boundaries for the routine activity market area. The boundaries in Figure 5 are draw roughly a block and a half from the arterials. The theory does not say how close these boundaries should be to the arterials, so the boundaries drawn are somewhat arbitrary. A more powerful theory might specify the boundaries or a gradient around the arterials, perhaps based upon knowledge of drug users' search behaviors.

Interpreting the meaning of the dots is relatively simple because the theory tells us what we should expect. In this hypothetical example the theory is supported. The network Xs are widely scattered, in and out of the economically depressed area, near and far from arterial routes. The routine activity dots are within the market boundaries, with one exception.

The theory also tells us what dot patterns we should not expect. It rules out routine activity sites outside the economically depressed areas. Thus we can answer a question raised when we examine Figure 2: Why isn't there a cluster of dots around the lower intersection of two arterials? The answer is that much of the area around this second intersection is outside the economically depressed area. The theory also rules out routine activity market dealing far from arterials. There are no clusters of drug dealing in large parts of the economically depressed area (see Figure 4) because much of this area is far from arterial routes. Finding routine activity dealing sites outside the predicted boundaries would be grounds for seriously questioning the theory.

How useful would an algorithm for drawing ellipses around clusters be for examining this theory? First, we would want to analyze the two types of markets separately. For the network marketplaces, we would expect to see either a single very large ellipse encompassing most of the map, a set of many small ellipses each containing few points, or no ellipse at all. Any of these outcomes would suggest that it is difficult for the algorithm to identify a meaningful cluster.

Second, for the routine activity marketplaces, we would want to compare the orientation of the ellipse drawn around the dots to the orientation of the two arterial routes. This theory suggests a cross-shaped pattern (in the area shown in this example). Ideally, we would see two intersecting ellipses — one with its main axis going up and down, and the second with its main axis going left to right. The axes for the ellipses should be close to and roughly parallel to the two arterials. Unfortunately, a single ellipse cannot describe this shape (Block, 1995). This suggests that alternative mapping tools should be used. In this example, plotting iso-crimes may be more useful (Zepp, 1989).

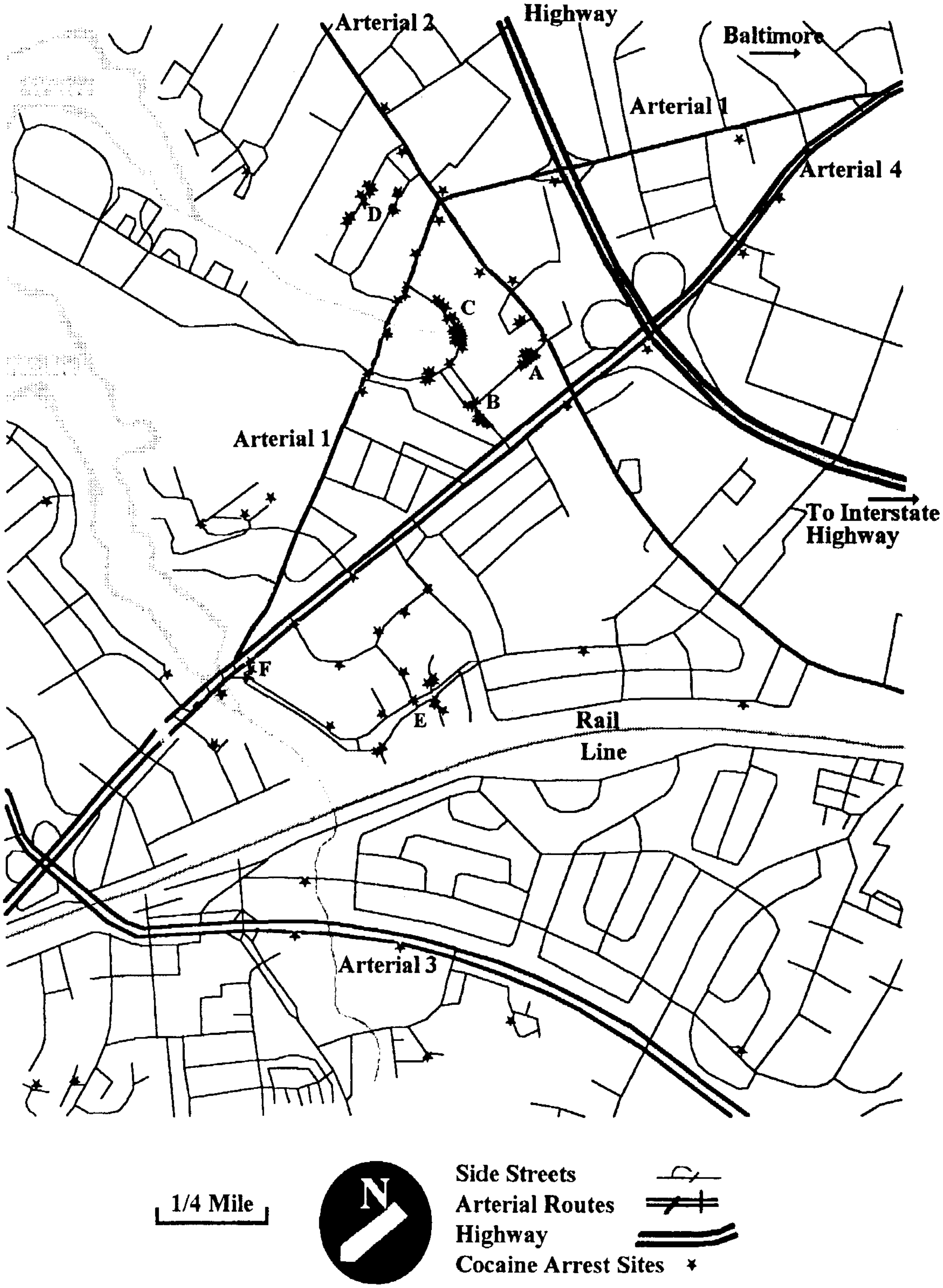
MAPS OF AN ACTUAL CASE

In the preceding case we looked at maps of a hypothetical area. Invented examples are useful because they allow one to examine just the factors one is interesting in without complicating the discussion with extraneous factors that create unexplainable loose ends. In short, these examples make the world pure and simple. But things are seldom this simple. Therefore, it is useful to examine a real-world case.

The actual case comes from an area in Baltimore County, MD. The maps were produced by the Baltimore County Police Department's Planning Division using Maplnfo.[1] The dots (stars on these maps) represent the locations of arrests for the sales and distribution of cocaine. We must note, therefore, that though the first hypothetical case mapped persistent drug locations with multiple indicators, in this actual case we are using a single indicator so that any specific dot may or may not represent a persistent dealing location. Nevertheless, patterns of arrest sites many indicate zones where drug dealing may be found, even if the precise location of each dot cannot be interpreted as evidence of persistent dealing at that place.

Let's begin by assuming we know nothing about this area but we are interested in the relationship between street patterns and drug dealing. Under these circumstances we might produce Figure 6, which displays a wide scatter of dots. Several patterns are evident. There are several tight clusters in the upper center of the map. These have been labeled A, B, C, and D. Cluster C is particularly large. Two other smaller clusters at the center of the map, E and F, are also notable. Though we may be interested in clusters, we can also see that most of the dots (including those in the six clusters just mentioned) are: (1) on arterial routes; (2) within two blocks of an arterial; or (3) on streets that loop off and back onto arterials. All four of the arterials have cocaine dealing arrest sites along them. Finally, there are a few widely scattered deviant cocaine arrest sites that do not fit this larger pattern. They can be seen at the bottom and left edge of the map.

Figure 6: Drug Arrests and Streets

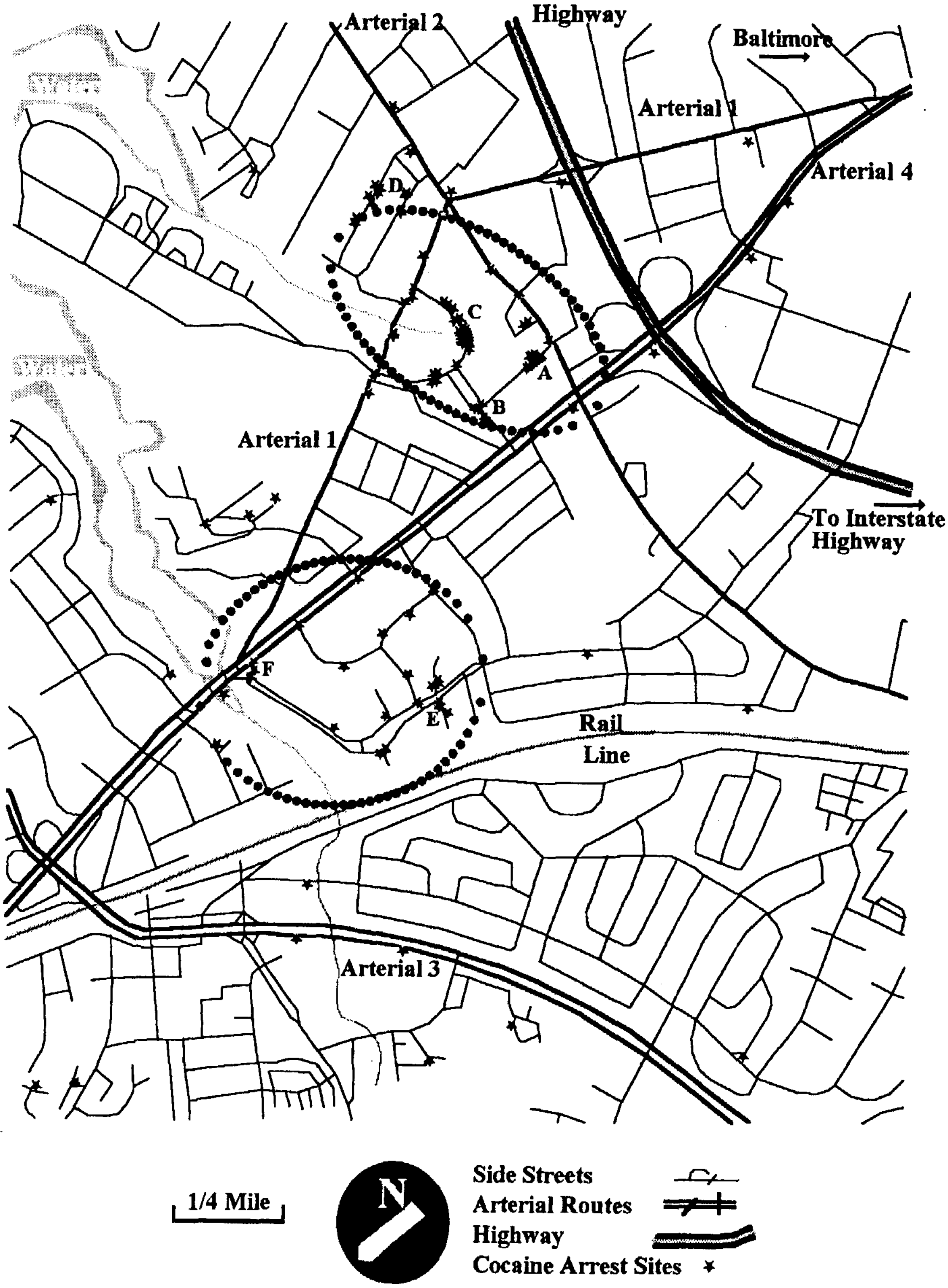


This map supports the theory that drug dealing is associated with street patterns. Nevertheless, the map reveals several deficiencies with this simple theory. Though most cocaine sites are associated with arterials (either on them or within easy access), there are many stretches of arterial routes without cocaine arrests. In addition, there are many street segments within two blocks of an arterial without cocaine arrests. Further, there are many short loops off and on to arterial routes with no cocaine arrests. The clusters at A, B, C, D and F can be explained using this simple theory, but it is more difficult to explain cluster E. In short, there are many theoretically high-risk locations for drug dealing that do not have obvious clusters.

More context is needed to better understand what the drug arrest pattern on this map shows, and this requires showing more features. Of the many possible features we could show on a map, which should we choose? Notice that the two ellipses are located near two inlets to the Chesapeake Bay. In the absence of a theory, we could create an ad hoc hypothesis that drug dealing concentrates around water courses. Perhaps drug dealing in Baltimore County is associated with water courses or branches of the Chesapeake Bay, but this would not help us understand drug dealing in San Diego, or New York, or Tulsa, or Kalamazoo, or most other areas. Though ad hoc speculation can be useful, we require something more — a generalizable theory. The water course hypothesis seems too arbitrary, an accident of what the Maplnfo program used by the Baltimore County Police Department happens to print and the peculiar topography of this part of the county. What widely applicable theory could we use to find information we could add to these maps?

If we apply the theory of illicit retail marketplaces to Figure 7, we find that the pattern of cocaine dealing sites (both where they are found and where they are not found) becomes more interpretable and the ellipses become more helpful. Much of the cocaine dealing in this part of Baltimore County is sold in routine activity markets, some of which are open-air street markets. The area is only four miles from the eastern border of Baltimore via arterials 1 and 4 that cut across the top and bottom of the upper ellipse and the top of the lower ellipse. The highway on the top right of maps 6 and 7 connects into the interstate highway circling the city. The area has a mixture of middle- and working-class residences, along with a variety of businesses. The economy of this area used to be primarily industrial, but the number of manufacturing jobs has declined. There is a substantial recreational industry in the area, concentrated around the Chesapeake

Figure 7: Drug Arrests, Streets and Ellipses



Bay. Though the entire area is not economically depressed, neither is it thriving and there are pockets of poverty.

Three of these pockets of poverty are found in three low-rent, large, multi-family apartment complexes. Two of these complexes are well-known for being poorly managed, and the third has undergone some changes in 1988 to improve property management (Carson, 1995a). According to the theory of illicit retail marketplaces, routine activity marketplaces should be located in areas where place management is weak and near arterial routes or major activity nodes. These complexes are shown in Figure 8.

Clusters A, B, and C are in the Village of Tall Trees. This complex has 828 residential units, in 105 buildings divided among 38 separate owners. Some owners have a single building, and some own many buildings. Buildings owned by a single person are often not adjacent to each other but are scattered throughout the complex. So if one place manager is diligent, poor place management by adjacent owners can undercut their efforts. Rents are low throughout the complex, but rentals are handled by each owner individually. If a person is evicted from one building they can move to a nearby building (Carson, 1995a, 1995b).

The street layout of Tall Trees contributes to its suitability as a site for drug dealing as can be seen in the sketch shown in Figure 9. This map is not to scale, but illustrates the location of clusters A, B, and C in relation to the streets within the complex, the parking lots, and external arterial routes. Dot cluster A is on an arterial route and includes a parking lot. Cluster B is at an intersection within the complex that gives ready access to three arterial routes (one to the north of the complex, one to the south, and another to the east). Cluster C is on a horseshoe street that provides easy exit off and onto a major arterial route to the south of the complex. Probably as important is the concentration of parking lots near cluster C. The ability of cocaine buyers to drive in, meet a dealer, and then leave seems to contribute to the drug problems of this area. In fact, from January through November 1994, 76% of the drug arrests in Tall Trees were of people who were not residents of the complex. In one eight-hour survey of vehicles in the complex, less than 6% belonged to residents of Tall Trees (Carson, 1995b).

Figure 8: Drug Arrests, Streets, Ellipses and Apartment Complexes

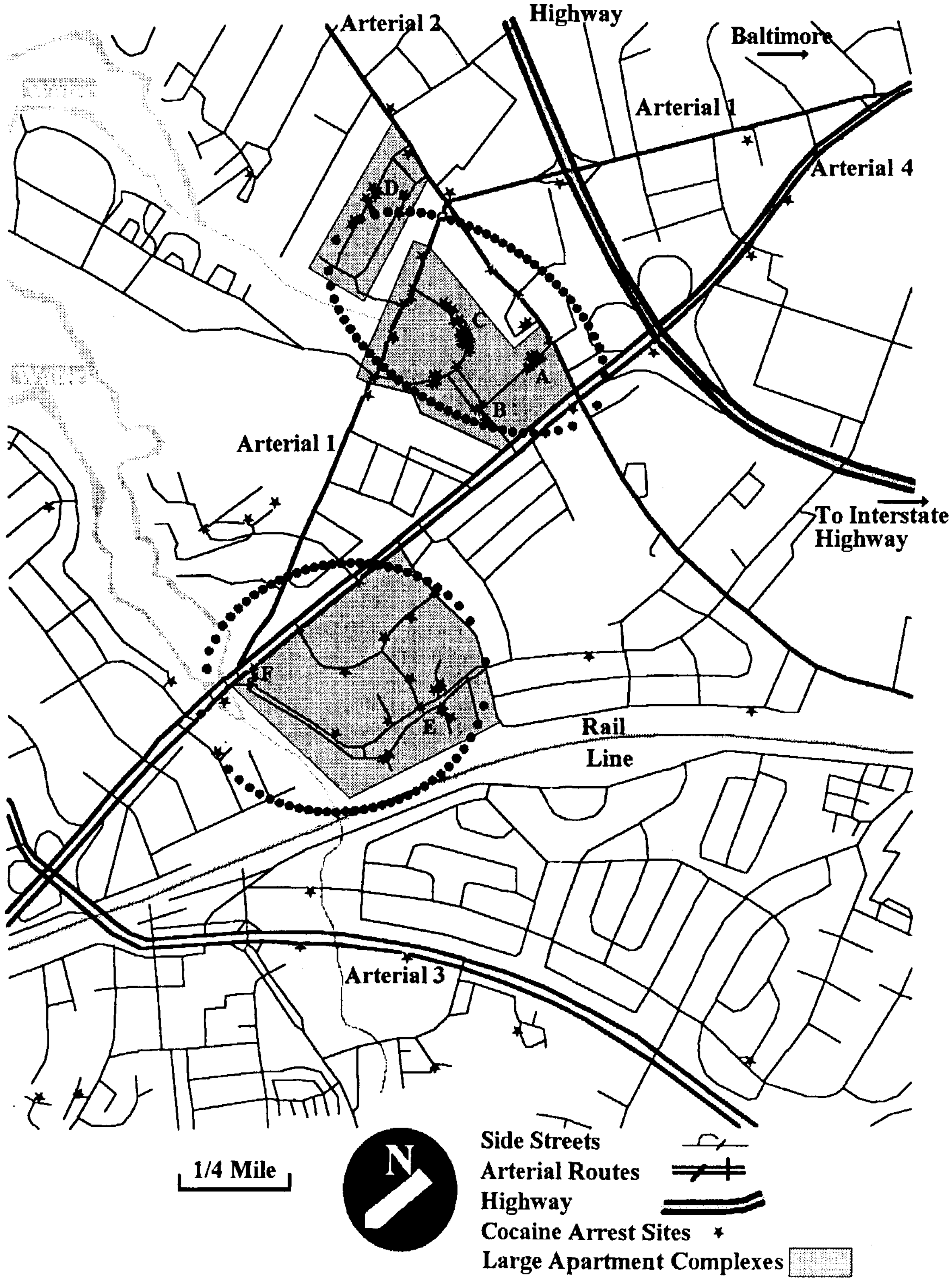
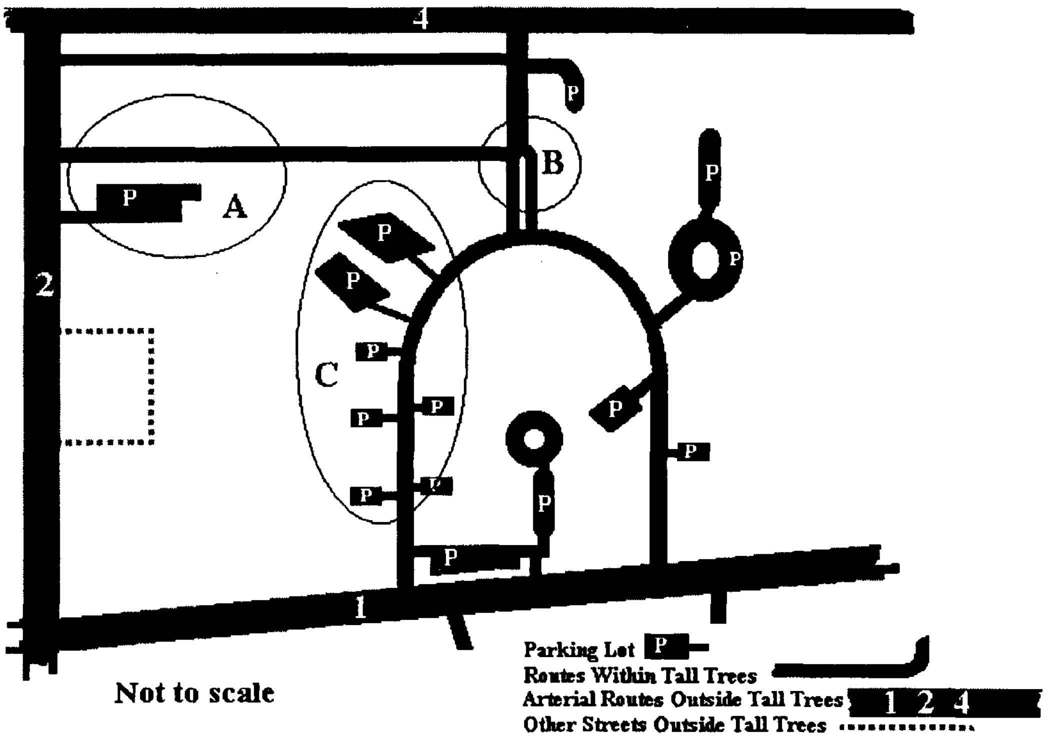


Figure 9: Detailed Street Layout of One Apartment Complex



Clusters E and F (on Figure 8) are in the Riverdale Village Apartments. This complex is in an advanced stage of decay. It has 1,100 units, but half are vacant and a third are closed. The complex had the highest percentage of code violations of any other multi-family apartment complex in the county. Unlike Tall Trees, Riverdale has a single owner, who lives in New York (Carson, 1995a). Drug buyers can easily drive through Riverdale, though not as conveniently as through Tall Trees. Cluster E is located at the back entrance to Riverdale. Cluster F is located at the front entrance, and on a major arterial route. The road connecting F and E is the major route through the complex, and directly connects arterials 1 and 4 to the north with arterial 2 (on the map) and arterial 4 (off of the map) to the south.

There is another low-income apartment complex in the area, Kingsley Apartments. These apartments are located at cluster D. This complex is not as badly managed as Tall Trees or Riverdale (Carson, 1995a), but its 312 units serve a low-income clientele. All tenants at Kingsley receive some form of federal rent subsidy (compared to 10 and 7%, respectively, of the renters in Tall Trees and Riverdale (Carson, 1995a). Though 55% of the cocaine arrests in the precinct came from these three apartments, only 9% came from Kingsley (36% came from Tall Trees and 10% from Riverdale) (Carson, 1995a, 1995b). Like the other two apartment complexes, it is convenient for drug buyers to come by entering from one arterial route and to go by leaving another.

If one set out to test the theory of illicit retail marketplaces, then STAC is particularly useful. The ellipses shown in Figure 8 provide evidence supporting this theory. The ellipses highlight at least two of the three areas that are predicted to have drug dealing. The one apartment complex partially missed by an ellipse is the best managed of the three. Without detailed information of the management practices of other properties in the area, but not shown on the map, we cannot be certain that there are no other properties that are theoretical candidates for drug dealing sites but that have no evidence of drug dealing. Figure 8 does not provide a complete test of the theory. Still, when we examine this actual case, we see the same relationship we explored with the hypothetical case; the more theory we bring to the data, the more interpretable the map and the more useful the analytic procedures.

IMPLICATIONS

In this paper, we have shown that theory changes how we interpret the data displayed on maps by changing what features we display on them. The map conveys the theory we are examining. This implies that we should display all of the relevant theoretical concepts, along with the data and any annotations that help us interpret the data and the theory. It also implies that anything that is not a theoretical concept or data, or does not help us interpret the theory or data (e.g., labels), should be left out.

We have seen that as the theoretical content of maps is increased, the easier it is to make sense of the data. Spatially organized data plotted on a blank page provide little information. But the same data, when plotted on maps annotated with increasingly powerful theories, become increasingly interesting and useful. This implies that the more precisely the researcher can specify his or her expectations of where the dots should and should not be found, before the dots are placed on the map, the more useful the map will be once the researcher plots the observations. If the researcher can say that the dots will only be found in a very few specific areas, or clustered around specific features, then the actual dot displays will be more useful than if the researcher only expects to find some clustering in unspecified areas. In the first instance, the researcher will know if the data are confirming or disconfirming his or her expectations. In the second case, the researcher will only learn that some clustering occurred or did not occur.

These findings also apply to procedures designed to find dot clusters using non-substantive computer algorithms. In the absence of a powerful theory, these procedures can find clusters but what these clusters mean is unclear. When the same procedure is applied to the same data but in light of a more powerful theory, the utility of such algorithms increases. These algorithms may be more useful for theory testing than for their original purpose — finding dot clusters in the absence of any expectation of where the clusters should be found (Block, 1995). In fact, Block and Block (1995) use the STAC cluster-finding algorithm to test hypotheses about the relationship between clusters of liquor-related crimes and of taverns and liquor stores in Chicago. Analytical techniques are not substitutes for powerful theories. Instead, they are complements (also see Block, in this volume).

We have restricted our attention to research applications of maps. Do the lessons of this discussion apply to operational uses of maps, by police departments, for example? The answer is yes. Maps 6, 7 and 8 illustrate this point under two different conditions. In the first condition, the police department is unaware of the pattern of cocaine sales arrests in this part of the county.[2] If the head of the narcotics section wanted to find out where the biggest drug problems are located, then Figure 6 would show several small clusters where a great deal of enforcement activity had taken place. Figure 6 suggests that there are at least six separate problems. In this scenario, where the police are in relative ignorance of what is taking place, the map suggests that further investigation is required to determine what could be done to address the problem. If STAC ellipses were drawn around these clusters, the resulting map (Figure 7) would suggest that there are two large clusters of seemingly related dots. Note that a police agency that has such limited information about the areas it serves could hardly be called community-oriented or problem-oriented. Thus, the type of mapping described in this scenario is probably typical of a traditional police agency that simply uses maps to augment its crime analysis function.

In the second scenario, the police are very aware of the cocaine problems in this part of the county, and they know about the involvement of the apartment complexes shown in Figure 8. The ellipses provide a different, and potentially more valuable, type of information under these conditions. Because the algorithm that drew the ellipses uses a procedure independent of the problem being investigated, the police could use Figure 8 as evidence that the Village of Tall Trees and the Riverdale Apartments have peculiarly high levels of drug selling activity. This evidence may be useful in presentations to community groups, and regulatory agencies, or in civil court proceedings. Note that the same map does not present good evidence that the Kingsley Apartments are a particular problem.

Police agencies taking a problem-oriented approach (Goldstein, 1990) would probably find this method useful. It is not uncommon for police officers to identify a troublesome location (e.g., a bar, convenience store, bus stop, movie theater, entertainment arcade, or liquor store), and to become convinced that many of the crimes near (but not necessarily on) the location arise because of the way the place is used. Is this claim justified? How can the officers test this hypothesis in a manner that would be convincing to an independent observer (senior commanders, community groups, the owner of the location, or a court, for example)? Plotting ellipses for the crimes in question is one method. If the ellipse showing a crime hot spot encloses the target location, this is evidence that the location may be a cause of the problem. If the ellipse does not enclose the target site, this is evidence that the location may not be responsible for the problem. Additional evidence may be required to make a strong case, depending on the circumstances, who the police officers are trying to convince, and the rules of evidence (if any) used by the independent observer. A rough analogue of the use of cluster-finding algorithms is the use of physical evidence in investigations. Most physical evidence is more valuable for verifying (or ruling out) an already-identified suspect than for identifying an unknown offender (Eck, 1983).

If the police do not know much about the area then they cannot form a testable hypothesis. This is the case in most situations when the police look for fast-breaking crime patterns so they can focus enforcement activity on a troubled area — by means of saturation patrolling, decoy operations, surveillance, or other tactics. Though the crime maps and even cluster-detection algorithms may be useful for these operations, these mapping techniques are probably more useful when officers already have a good understanding of the area in question.

This suggests that the police, like researchers, should pay as much attention to criminological theories as they do to the data they examine (dots) and the methods they apply (maps). Several eminently useful theories have direct application to research and operational mapping. These theories try to explain why crimes occur under specific circumstances (event theories) rather than try to explain why some individuals become criminal offenders and others do not (offender theories) (Eck and Weisburd, 1995). Routine activity theory (Felson, 1994) describes how criminal events are linked to everyday routines in society. Offender search theory (Brantingham and Brantingham, 1981) attempts to explain how offenders select crime targets. Both theories try to explain how crime is distributed in space and time. Rossmo (1995a) has used offender search theory to help police investigators solve serial homicides and rapes. The theory of the geography of illicit retail markets (described earlier) is based in large part on these two perspectives (Eck, 1994, 1995). Two applied theories used by the police and others interested in reducing crime events draw on routine activity theory and offender search theory. Problem-oriented policing (Goldstein, 1990) demands greater analysis of problems, and maps are particularly helpful in this regard (Rossmo, 1995b). Situational crime prevention (Clarke, 1992) seeks to find methods to block opportunities for crime. Often maps are useful for understanding the opportunities for crime and the development of methods for blocking these opportunities (see Matthews, 1992 and 1993, for example).

In summary, the investment in mapping technology and databases can be greatly enhanced if combined with an interest in theories of criminal events. The more explicit and precise analysts (researchers and practitioners) can state their expectations of the dot patterns, the greater their ability to interpret the observed dots and the more useful the maps will become.

♦

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NOTES

1. The maps from Maplnfo were scanned and the digital images edited to make the original map more legible. The arterial routes and highways were widened. When the arterial and highway enhancements obscured a cocaine arrest dot, the dot was moved slightly to the side of the street so it would still be visible. Two water features (a river and a creek flowing into the Chesapeake Bay) were deemphasized and annotations and labels were added. Finally, the areas of the apartment complexes were shaded.

2. In reality, the police department and other county agencies are working together to address a host of problems in the three complexes described in this paper.

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