THE INFLUENCE OF STREET NETWORKS ON THE PATTERNING OF PROPERTY OFFENSES

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Abstract: *This paper reports the results of a study that explored the relationships among property crime, the accessibility of street networks and the concentration of potential targets. It is hypothesized that the design of street networks Influences how people move about within a city and, consequently, their familiarity with specific areas. It was further argued that property crimes occur In known areas with attractive targets. Consequently, areas with the most complex road networks and the fewest common destination points should have the lowest levels of property crime. Using an ex post facto research design in two suburban municipalities, the study compared the relative amount of property crime in each street segment with that segment's relative accessibility, traffic volume and quantity of potential targets. Both road network complexity and traffic flow were found to be of substantial importance. Crime was higher in more accessible and highly used areas and lower in the less accessible and less used areas. The concentration of potential targets was highly related to accessibility and traffic flow and to overall property crime totals. The findings clearly point to the importance of the urban background created by cities through zoning and*

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road network development. The study also suggests that traffic barriers and road closures can be used as effective crime prevention techniques In only a limited number of situations. The situations should, however, be predictable when opportunities and the spatial decision processes of offenders are considered co-Jolntly.

INTRODUCTION

Municipalities have recently become interested in the prospects for controlling crime through the introduction of traffic barriers and traffic flow controls. Cities as different as London (Matthews. 1902). Chicago (America Planning Association, 1093). Miami Shores. FL (Cromwell and Zahm. 1991) and Delta. British Columbia (Sheard. 1991) have begun to experiment with the use of street barriers, parking prohibitions and other impediments to traffic flow. The idea is to create dead-ends, cul-de-sacs, and neighborhoods that are difficult to enter by motor vehicle in the expectation that the levels of crime on such streets and in such neighborhoods will be reduced. The rationale for these practical experiments tends not to be explicitly defined. However, there is a good basis in the theories underlying environmental criminology (Brantingham and Brantingham, 199 lb; Herbert and Hyde, 1985) and situational crime prevention (Clarke, 1992) for thinking that modifications of traffic flows, conditioned by the distribution of opportunities and offenders created by zoning practice and other urban design decisions, can have substantial impacts on a city's crime patterns.

This study examines how the accessibility of street networks and the sets of potential targets located on them affect the offender's search for targets as reflected in officially recorded crime. The research was conducted in the two suburban municipalities of Maple Ridge and Pitt Meadows, British Columbia. CAN, and it used 1979 crime data obtained from the Royal Canadian Mounted Police (RCMP). The following premises describe the basic nature of this study:

(1) Street networks can physically influence how people move about within a city. Street networks can also influence the way in which people become familiar with certain sections of a city.

(2) Property crime generally occurs within an offender's regular activity space. Property crime should be highest near the areas that offenders are most familiar with or frequently travel through.

(3) If travel frequency decreases as road complexity increases, then the areas with the most complex roads and the buildings on the

least accessible streets should have the lowest amounts of property crime.

(4) Planning practices tend to concentrate high-volume land uses on accessible roads in uncomplicated parts of the street network.

(5) Consequently, those streets known by large numbers of people will be part of the least complicated sectors of the street network and will also contain large numbers of potentially attractive targets for crime.

(6) Overall, aggregate crime patterns should cluster crimes along highly accessible main roads with a concentration of potential targets.

To test these premises, an ex post facto research design was developed that compared the relative amount of property crime on different types of street segments. These street segments were differentiated by their accessibility and traffic flow. The analysis also tested for the potential attractiveness of the different types of structures and land uses found on the street segments. The development of the research design was influenced by a similar study conducted in Minnesota by Bevis and Nutter (1977). and is supported by more recent research that explores street complexity and the attractiveness of targets (Brantingham and Brantingham. 1081; Taylor and Nee, 1988; White, 1990; Cromwell et. al., 1991; Sheard. 1991).

Opportunity and Awareness

Much of the current research in environmental criminology has considered only the objective site characteristics of opportunities. While this is important, it does not explain the cognitive process by which criminals evaluate the suitability of targets or become aware of potential targets. Whether or not a criminal is highly motivated, some target search process must normally precede the commission of a crime. This search process is often affected by objective site characteristics and by the criminal's perception of what constitutes a good or bad opportunity. The search may also be influenced by the limitations imposed by the physical environment and the searcher's knowledge of that environment. Criminals' knowledge about the environment and its opportunities for crime, their awareness spaces, largely depend upon their routine activity patterns. Those areas that criminals frequent probably form the dominant portion of their awareness space. Most targets are selected from within a criminal's awareness space. Property crimes should occur disproportionately in those same areas in which criminals carry out their routine patterns of activity (Cohen and Felson. 1979: Brantingham and Brantingham. 1984; Rengert and Wasilchick, 1985; Felson, 1987; Cromwell, et. al.. 1991).

It is clear from the criminological literature that the environmental opportunity structure influences criminal activity patterns (e.g.. Boggs. 1965; Letkemann. 1973; Cohen and Felson. 1979; Rengert. 1980. 1991; Heal and Laycock. 1986; Barlow, 1990; Mayhew, 1990; Hope. 1991; Clarke. 1992). This influence stems from both the physical limitations that the environment imposes upon the individual and the cognitive representation (awareness space) that the individual has of the environment. It is the potential polarity of these two forces that has made it difficult to measure a target's probability of being victimized.[2] Two measures are needed: an objective measure of the relative risk, and some measure that will account for the subjective component or awareness that criminals have of different opportunities.

The work of Boggs (1965) and of Harries (1991) and others has established that an objective measure of the relative risk of crime based on a measure of the distribution of opportunities can be critical to understanding crime patterns.[3] However, this research has left open the question of how to measure or quantify the relative risk of crime due to a criminal's awareness space. It is not sufficient to think of opportunities only in terms of objective realities. For instance, two houses with similar physical features and similar lot and block sitings in similar neighborhoods would normally be counted as presenting equal opportunities to a particular burglar. However, if one of these houses was not in a burglar's awareness space and the other was. then they could not really be considered as representing equal criminal opportunities since the unknown house would most likely not be discovered by that burglar during a search for a target. This means that, as Rengert (1980:21) put it: "...the relative magnitude of an opportunity is proportional to its relative degree of accessibility which will partially determine its probability of being exploited."

Street networks influence the mobility patterns of people (Brennan. 1948; Lee. 1970; Lowe and Moryadas. 1975; Thomson. 1977). The paths by which criminals regularly travel influence their awareness of potential targets (Brantingham and Brantingham, 1984, 1991b). Awareness and knowledge of areas could be considered in three broad categories: areas close to home, work, school or any other place where a person spends a fair proportion of his or her daily activities; those places passed regularly in the course of routine activities; and those areas that are very similar in almost all urban areas (Brantingham and Brantingham. 1903b).

The personally known areas around home or other routine activity nodes might be isolated by the structure of the street network from major flows of people and may be known to relatively few persons. Such areas would fall into the awareness spaces of fewer potential offenders and would be less likely targets of crime. Those crimes that do occur in such areas are likely to be committed by insiders—persons who belong to or routinely frequent the neighborhood. Work on residential burglary (Brantingham and Brantingham, 1975) found strong support for this: The interior parts of residential areas had much lower burglary rates than the border zones which were known to persons from several residential areas.[4]

Areas along major travel paths are known by many persons and, consequently, by more potential offenders. Such areas are in the awareness spaces of more potential offenders because offenders, like everyone else, spend most of their time in routinized, non-criminal activities that are shaped by the ways in which the physical environment channels movement around the city. Crime ought, then, to be concentrated on or near major highways. Yet crime, fortunately, has not saturated the urban environment, and while crime may be concentrated on or near a major road, not all major roads are sites for a lot of crime.

The next section explores how street patterns can influence the movement patterns of criminals and how these patterns can affect the decision process in target selection. It should be noted that street networks should have the greatest impact on crimes committed by people who learn areas by motor vehicle rather than on foot. Streets are paths for both those in vehicles and those on foot. But pedestrians also use designated pathways where vehicles cannot go. and sometimes make paths through parks, yards, gardens, apartment grounds and other non-public places where they ought not to go. Therefore, the "street" network available to the pedestrian is larger than the physical street network available to someone in a motor vehicle.

It is important to remember that the distribution of criminal opportunities is also shaped by the road network. High traffic volumes mean high numbers of potential individual victims. Moreover, the owners of commercial properties generally try to locate where they can be seen by a maximal number of potential customers. Consequently, through natural commercial interest, abetted by official land use planning and zoning practices in most cities, businesses locate on or near major roads. In turn, major roads in modern cities, for obvious driving safety reasons, tend to be uncomplicated and predictable in design. Altogether, road networks influence the location of some potential targets and the aggregate size of agglomerated awareness spaces.

Street Design and Crime

The idea that there is some sort of relationship between streets and crime has been around for a long time. Edward I tried to control crime in England more than seven centuries ago by controlling road design through the Statute of Winchester of 1285 (Plucknett. 1960). Several authors have noted how the criminal areas or rookeries of nineteenth-century London were deliberately broken up through the placement of new streets as part of a broader program for slum clearance and the improvement of traffic circulation (Dyos. 1957; Tobias, 1972). Victoria Street, for instance, was deliberately designed to break up the Westminster rookery; while New Oxford Street was constructed through the heart of the infamous Golden Lane rookery. Ferri (1896:123) argued that "High roads, railways, and tramways disperse predatory bands in rural districts, just as wide streets ... [prevent] robbery with violence, concealment of stolen goods, and indecent assaults."

Yet the advent of better transportation networks has not always historically coincided with reduced amounts of crime. For instance. Glyde (1856) found that the highest rates of crime for medium-sized towns in Suffolk during the mid-nineteenth century occurred along the major highways. This seems to be a common phenomenon even today. Several scholars have found higher crime rates on or near major traffic arteries (Angel. 1968; Luedtke et al.. 1970; Wilcox. 1973; Duffala. 1976; Beavon, 1984; Brantingham and Brantingham. 1984; Greenbergand Rohe. 1984). Moreover, public transportation systems concentrate people (including potential offenders) near potential targets for crime (including transit riders and staff) at transit stops and nodes (Brantingham. Brantingham and Wong, 1990. 1991).[5]

Relationships between streets and crime were also observed by the Chicago School sociologists. Burgess (1916:726) concluded that one of the most important factors in understanding delinquency was the proximity of youths to business streets. This relationship was further expounded by Burgess (1925b: 152) in his discussion of the structured relationships between the locations of the homes of offenders and victims and the locations of delinquent events. Shaw and McKay (1942) also found spatial proximity to criminal opportunities to be an important empirical element of the pattern of delinquency in the cities they studied, although this observation has tended to get buried by the more sociologically appealing aspects of social disorganization theory (Brantingham and Jeffery, 1991:232).

The crime-producing and crime-reducing potential of street network systems and their associated land uses was. for the most part, forgotten by social scientists and urban planners alike for half a century. A review conducted by Appleyard and Lintell (1972:84). two urban planners, in the early 1970s complained that "studies of urban streets have concentrated almost exclusively on increasing their traffic capacity with no parallel accounting of the environmental and social costs." In subsequent research on "livable streets," Appleyard (1981) examined residents' views about local crime problems but did not examine actual crime patterns. In fact, much modern planning tends to view traffic as evil, and follows an anti-urban bias, often associated with Wirth (1964), in separating streets with cars from pedestrian pathways.

The first contemporary urban planner to develop a theory linking crime to street use was Jacobs (1961), and this was only by inference. In her theory of crime control she explicitly outlined three themes. First, Jacobs stressed that a clear distinction must be made between public and private space. Second, appreciating that a great deal of crime takes place in public space, Jacobs emphasized the need for informal surveillance of that space. She argued that citizens must become vigilant and become "the eyes of the street." Third, she believed that areas with few people around tend to suffer more crimes because there are no witnesses. Consequently, Jacobs stressed that cities should be planned so that there is always moderate activity in public areas such as sidewalks, parks and streets. She did not, however, consider the roles of street networks and land uses in shaping offenders* selections of targets. She did not consider that criminal offenders behave non-criminally most of the time.

The idea that street design could influence crime was expounded by Newman (1972). He contended that the existing fabric of city streets can be subdivided in order to create territorially defined units. As the territorial subdivision of streets in an area increases, the residents can better recognize interlopers who do not belong in the area. Territorial subdivision is also likely to increase the territorial protectiveness of people who do belong to the territorial subdivision. One aspect of an increase in territorial behavior is an increase in surveillance. Both phenomena, Newman argued, will contribute to a reduction in crime.

Newman offered empirical support for his contentions in a second book. *Community of Interest* (1980). One of the studies in this book examined the privatization of streets in St. Louis. MO. According to Newman, in order to arrest the social decay of their neighborhoods, a few residents of St. Louis banded together to buy back their streets from the city. The citizens of these private streets legally own and maintain them, taking back this responsibility from the city. The distinguishing features of these private streets, as outlined by Newman, are: each street is blocked off at one end to prevent through traffic; and ownership of each street right-of-way by the residents is guaranteed by a deed of restriction attached to all property abutting the street. The closing-off of streets, argued Newman, reduces pedestrian and vehicular traffic, and apparently creates a psychological effect that encourages residents to think of their own street as their neighborhood or "home turf." For Newman, the closing of streets was really an attempt to exclude outsiders from the neighborhood.

In order to test whether these private streets had lower crime rates than public streets, Newman examined three matched comparisons. He concluded that even though each street showed some idiosyncrasies in criminal behavior, the private streets suffered less assault, purse snatching, vandalism, theft from autos and theft of auto accessories than their matched public streets. The only exception to this pattern was the crime of burglary. Newman offered two explanations as to why burglary appears to be an anomaly:

> First, physical closure and institutionalized ownership may make a stranger more obvious and residents more watchful, but it may do little to clandestine entry into a structure from the rear alleys and yards, which, although privately owned, are often only minimally fenced. Second, the very status of the private streets (composed of middle-class single family homes) compared with adjacent public streets (composed of lower-income multifamily homes) may serve to label the private streets as lucrative targets for burglary [Newman, 1980:142].

Although the ideas of Jacobs and Newman have received a lot of public attention, they did little to explore the empirical relationship between street design and crime.[6] Moreover, subsequent studies have found that their concepts of territoriality and surveillance seem to be related more to

fear of victimization than to actual risk (Greenberg and Rohe, 1984; Taylor et al., 1984; Taylor. 1988). Partially inspired by the earlier work of both Jacobs and Newman, criminal justice planners Bevls and Nutter (1977) conducted what is probably the first empirical study of street network design and crime. The previous work of Jacobs and Newman had accentuated the importance of street layouts and building designs Intended to make residents work together against outside criminals, without giving much thought to the problem of criminal insiders (Brantingham and Brantingham. 1993a. 1993b). Bevis and Nutter (1977) emphasized a different theoretical perspective.

They postulated that street layout can alter crime in ways other than by increasing territorial!ty and surveillance on the part of residents. From interviews with prisoners. Bevis and Nutter found that burglars prefer to be familiar with the areas they victimize, and to select targets that are convenient for both access and departure. This would mean that burglars are probably less familiar with, and find less attractive, those areas that are somewhat isolated or inaccessible. They also noticed that some of the early cognitive mapping literature (e.g., Moore and Golledge. 1976) suggested that less accessible streets are traveled less by non-residents than are more accessible streets. This led Bevis and Nutter (1977:4) to hypothesize that "houses and apartments along less accessible streets will not be as familiar to nonresident criminals and will not be as frequently burglarized as will housing along more accessible streets." This hypothesis was further supported by interviews with police, who suggested that there are fewer crimes on cul-de-sacs and dead-end streets than on through streets. It is important to note that Bevis and Nutter did not try to think of all criminals as outsiders or non-residents. Crimes are committed by both residents and nonresidents, but some areas are known to both while some areas are known only to residents or insiders.

Bevis and Nutter (1977) utilized an accessibility typology of six street types to examine the spatial distribution of crime in Minneapolis. MN. They found a noticeable pattern of lower residential burglary rates in housing located on blocks with lower accessibility, and an upward trend that relates increasing street accessibility with rising crime rates. They also found that census tracts with highly permeable street layouts are statistically associated with high residential burglary rates. These areas are more easily known by residents and non-residents. The permeability of census tract areas was determined by using a beta measure derived from graph theory.[7]

In the intervening years, there have been a number of other approaches used to analyze the relationship between street networks and crime. Apparently unaware of the work of Bevis and Nutter, White (1990) discovered a strong relationship between neighborhood permeability—as measured by the number of access lanes leading from traffic arteries into neighborhoods—and burglary rates. Environmental psychologists have maintained a continuing interest in the topics of areal awareness, spatial knowledge and path-finding behavior, which point toward an understanding of criminal target selection through the analysis of travel paths (e.g.. Gifford. 1987: O'Neill. 1992).

Brantingham and Brantingham (1978. 1981. 1991b. 1993a, 1993b) considered some of Bevis and Nutter's ideas in developing their own theoretical model of crime-site selection. That model uses the concepts of opportunity and motivation, and ties them together with the concepts of mobility and perception. Basically, the Brantinghams' theoretical model posits that criminals engage in a search for their targets or victims. The intensity of this search will depend upon how highly motivated they are to commit a crime. In order to evaluate and select targets, criminals will use their previous knowledge of the environment (learned either through experience or through social transmission); this knowledge base is known as a criminal's awareness space. This theoretical model led Brantingham and Brantingham to conclude deductively that, among other effects, there should be less crime on dead-end streets and cul-de-sacs than on streets that offer greater accessibility. Moreover, the target search should normally be strongly shaped by the character of the road network. As they put it:

> In order for a crime to occur, the criminal has to locate a target or victim in his awareness space. A criminal's awareness space will change with new information and as a result of searching. The expansion of an awareness space will most probably occur in a connected fashion; the borders or edges of currently known areas will be explored, first. In exploring new areas, the potential offender will find it easier to penetrate areas with predictable road networks. Areas with grid street layouts are more predictable than areas with winding roads, cul-de-sacs, or dead ends [Brantingham and Brantingham, 1991b:51].

RESEARCH STUDY

It has been suggested that street networks influence the mobility patterns, awareness spaces and target choices of criminals, particularly those using automobiles or street-level public transit. Criminal mobility, awareness spaces and target choices are difficult to measure on both practical and ethical grounds.[8] Still, the empirical traces of those phenomena should be visible in the spatial patterns of crimes known to the police. A research study using the crime traces found in police records was designed to determine whether property crimes are positively associated with street accessibility and. secondarily, with the density of potential targets on accessible streets. Unlike the Bevis and Nutter (1977) study, this research looked at all property offenses, not just residential burglary.

The study was conducted in the municipalities of Maple Ridge and Pitt Meadows. British Columbia, CAN. These two small suburban satellites of Vancouver were selected for four reasons:

(1) This geographic region is isolated from surrounding communities by two major rivers. This feature is important because it minimizes the number of streets that are shared with other municipalities and reduces potential displacement of crimes by offenders.

(2) The street network system of this area was sufficiently varied in nature. It provided a diverse sample of street segment types. Many municipalities offer no range in street segment types: Older communities were often developed in a typical grid-like fashion, while newer suburbs have often been developed almost completely in complicated "organic" styles featuring many cul-de-sacs in residential areas.

(3) Transportation in these municipalities is dominated by private motor vehicles. Road networks should, conceptually, have a higher impact in such areas than in areas where movement patterns are dominated by pedestrians or by rail transit systems.

(4) The local RCMP detachments and city planning departments were very supportive and cooperative.

The unit of analysis for the study was the street segment. A street segment or block, for the purposes of this study, was operationally defined as that portion of a street that is between two intersections.[9] An ex post facto research design was developed that compared the relative amount of property crime on street segments. Each street segment was identified by its street name, and by its high and low address. Data were collected on the location or address of every officially recorded incident of bicycle theft, auto theft, theft from auto, burglary, other property theft and willful damage recorded by the police in the two municipalities over a one-year period. The locations of these property crimes were aggregated to their spatially corresponding street segments.

Street segments were differentiated by their relative vehicle accessibility and traffic flow. Information was also collected about the nature of development on the street segments. An interval measure of street accessibility was developed based upon the number of "turnings" into each street segment. Figure 1 shows eight examples of different ways in which street segments can be connected. Each direction from which a person in a vehicle can enter or exit a street segment counts as one turning. The usual range for this accessibility variable (TURNS) is from one to six. Only 30 of the 1.575 street segments under study were found to have an accessibility factor of 1; because of their small number they were grouped with the next highest accessibility-factor grouping for statistical analysis. Street segments were also classified according to the level of traffic on them. The traffic flow variable (FLOW) identified streets in a hierarchical fashion (i.e.. "feeder." "minor artery." "major artery" and "highway"), according to a classification scheme used by city planners. Table 1 gives a cross tabulation of street accessibility (TURNS) by street flow (FLOW). As might be expected, artery and highway street segments have more turnings than feeder segments.

Controlling for Opportunities

Multivariate statistical techniques are used to analyze the relationship between street accessibility (TURNS and FLOW) and the amount of property crime.[10] Despite use of these statistical techniques, it cannot be overemphasized that a statistical analysis will not rule out alternative or complementary explanations, especially those that introduce additional variables as common causes of the variables under consideration. As has already been discussed, the most theoretically important variable to consider is that of "opportunity." If more reported property crime occurs on highly accessible streets, this may simply be due to the fact that there are more opportunities on more highly accessible streets. Stores and their associated parking areas are typically located on or near major streets. In addition, apartment buildings are frequently built near major roads to segregate land uses and to reduce traffic risk in single-family residential areas. High access roads generally, under current zoning practices, carry

Figure 1: Accessibility Measure: Operational Definition

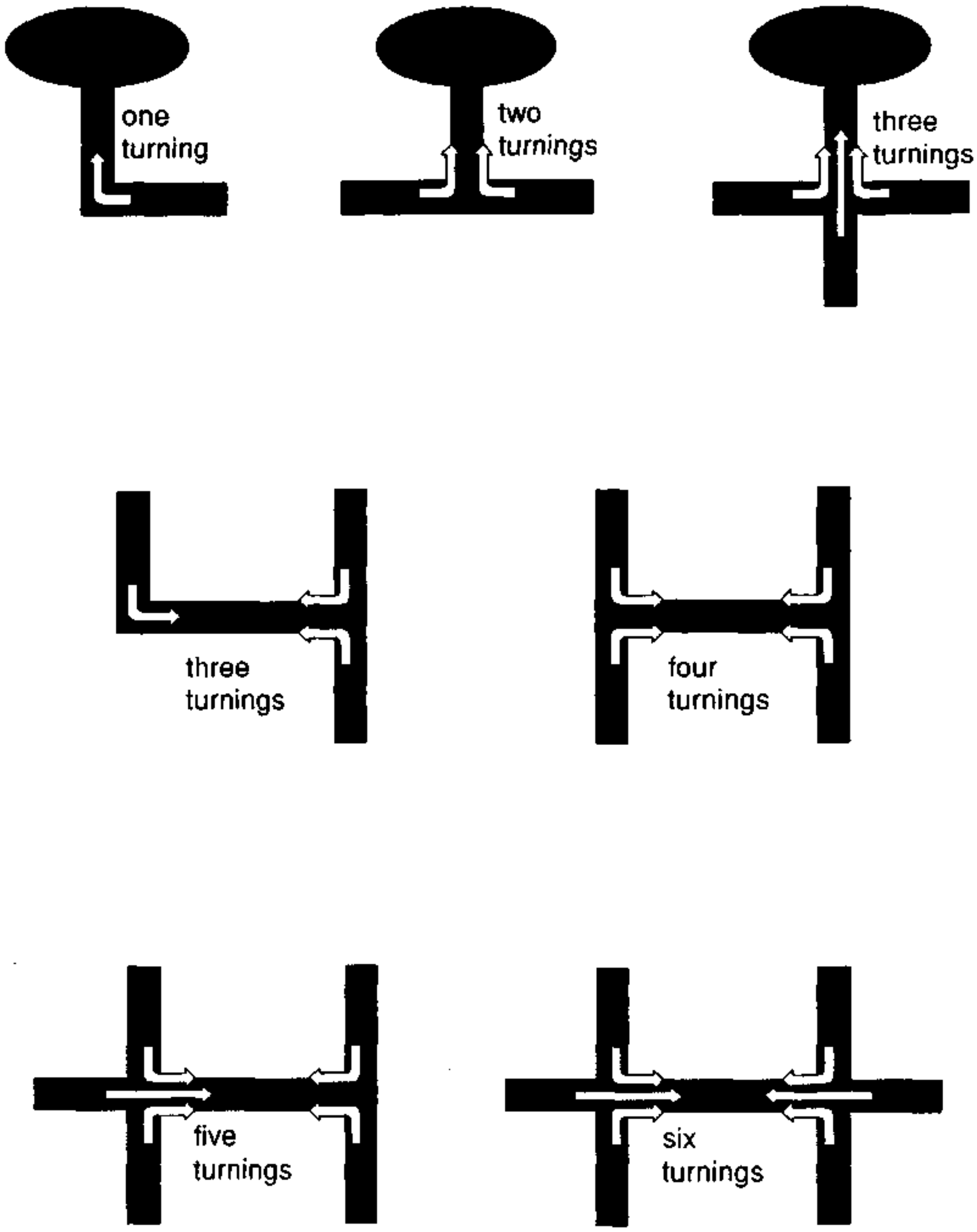


Table 1: Cross-Tabulation of Street Flow by Accessibility (Turns)

	NUMBER OF TURNS						
	1	2	3	4	5	6	Total
Feeder	30	271	258	427	243	108	1,337 84.9%
Minor Artery	0	4	5	65	41	11	126 8.0%
Major Artery	0	0	3	28	30	7	68 4.3%
Highway	0	2	2	17	14	9	44 2.8%
Total	30 1.9%	277 17.6%	268 17.0%	537 34.1%	328 20.8%	135 8.6%	1575

high concentrations of crime targets and criminal opportunities as well as high volumes of traffic.

Information was collected about the type of potential criminal opportunities on each street segment. Tax assessment data, which contain legal descriptions of every individual property in the study area, were used to identify opportunities. Computerized tax assessment data were cross-matched according to the high and low address of each street segment. The following information was obtained:

/. Actual land use, collapsed into the following categories:

1. number of single family dwellings;
2. number of duplexes,
3. number of multi-family homes (i.e., apartments, row housing. conversions, high rises, residential hotels, etc.);
4. number of units from multi-family homes,
5. number of mobile homes;
6. number of civic and institutional buildings;
7. number of transient accommodations (e.g.. hotels, motel and auto courts [with and without pubs], campgrounds, seasonal resorts, etc.);
8. number of commercial establishments;
9. number of farms:
10. number of industrial sites; and
11. number of vacant lots.

n. Average lot size for each street segment (in square feet) of the above building types.

III. Average value for each type of property on each street segment.

IV. Average Improvement value (assessed value of each building) of each type of property.

When using multivariate statistical techniques there are basically two methods by which one can consider the importance of the location of opportunities. One method is to construct a crime rate (crime per opportunities). Descriptively, this method is often quite meaningful. The other method requires opportunities to be statistically controlled as independent variables. In this latter method the dependent variable (crime) is entered into the multivariate equation as a numerical count rather than as a rate. The argument in favor of this latter method is that often in environmental criminology the indiscriminate use of denominators has produced rates that are of limited utility (Harries, 1991). For example, if auto theft rates are calculated with such different denominators as resident populations, or registered cars of resident populations, or parking spaces or vehicles parked in an area during a 24-hour period, the results are different and have different meanings. For most operational and prevention purposes, volume counts are the important figures. Problem spots are more easily identified.[11]

A careful analysis of the conceptual difficulties surrounding the concept of opportunity reveals that at least two questions have to be answered before using objective measures of opportunity as denominators: (1) What is an opportunity? and (2) Are all opportunities equal? In this study, six different property crimes are examined. It might be feasible to use the number of building units as a statistical control. But in the analysis of a crime such as breaking and entering, it does not make any conceptual sense to use it while analyzing other crimes such as bicycle or auto theft. Since building units were the only type of opportunity for which environmental data could be collected, the number of possible denominators that could be used was very limited.[12]

To further complicate matters, there is the question of whether different types of opportunities should be treated equally. Different opportunities will have different rates of risk, and treating them as equivalent units (e.g., commercial units and mobile homes) may be tantamount to adding apples and oranges together. Furthermore, even identical opportunities may have different rates of risk depending upon their physical location or ease of accessibility. For instance, in another Vancouver-based study. Butcher (1091) found that, due to their easier accessibility, apartment units on ground level floors were more vulnerable to burglary than were apartments located on higher floors. Although most criminological research treats apartment buildings as having unitary risks throughout (e.g.. Coleman, 1089), not all units within an apartment building are at equal risk. Ground-floor locations dominate apartment building risk figures. But if physical location is the only difference among apartments, should they be considered to be at equal risk?

Weighting factors may be produced to create equivalent units for comparative purposes in the future, but with the current state of knowledge about the environmental opportunity structure, it is not possible. Because of these various difficulties in using opportunity variables as denominators, this study opted for using them as independent variables in the multivariate analysis.[13]

Analysis of Street Accessibility

In order to test the accessibility measure (TURNS), a series of one-way analyses of variance were conducted for each of the six property crimes and for the total amount of reported property crime. Table 2 gives a summary of these statistical analyses. This table shows that the accessibility measure used in this study was related to all of the property crimes except bicycle theft. It is not surprising that a crime like bicycle theft, which is largely committed by young juveniles, displays spatial patterning that is different from other property crimes. The distribution of bicycles in the physical environment probably contributes to this difference. Bicycles will tend to be found in areas where children congregate (e.g., parks and schools), and this distribution of targets may bear no direct relation to the accessibility of streets, but it does have a more direct relationship to the paths followed by children. Children are the likely "criminals" in most suburban bicycle thefts. Children are less tied to street networks as they move about.[14] If children commit most of the offenses. it is not surprising that there is no relationship between this type of crime and formal street patterns. Bicycle theft might have been tied to the actual paths and accessibility network for children, as well as to their flow volume. Analysis of the childrens' path network was beyond the scope of this study, but is clearly a needed step. Sheard (1991) has begun the analysis of children's pathways in another Vancouver suburb. He found that the introduction of new pedestrian pathways connecting the ends of cul-de-sacs created the equivalent of through roads for pedestrians. These new pathways brought increased volumes of property offenses to the connected cul-de-sacs. Sheard arranged the closing of several of these new pathways and documented an almost complete elimination of property crimes in the adjacent, reestablished "real" cul-de-sacs.

Although Table 2 shows statistically significant relationships for all the property crimes, with the exception of bicycle theft, the directional relationship between accessibility and crime has not yet been explored. The group means of each property crime show a distinct pattern, again with the exception of bicycle theft. It appears that as street accessibility increases, the number of reported property crimes also increases. To show this trend, the group means of each property crime were plotted against the number of turnings and Pearson product-moment correlations were calculated. Table 3 summarizes the results of this correlational analysis. This table shows that there is an almost perfect linear relationship between the accessibility variable (TURNS) and property crime. Figure 2 graphically depicts this relationship for the total amount of property crime.

Table 2: Relationship Between Accessibility and Crime (One-Way Analyses of Variance)

TYPE OF CRIME	F-RATIO	SIGNIFICANCE
Bicycle Theft	1.570	0.1799
Auto Theft	6.545	0.0000
Theft From Auto	7.208	0.0000
Property Theft	6.665	0.0000
Willful Damage	10.421	0.0000
Break & Enter	9.735	0.0000
Total Crime	10.483	0.0000

*Degrees of freedom: between=4, within=1570.

In order to evaluate the concurrent effects of street accessibility (TURNS) and street flow (FLOW), a two-way analysis of variance was performed. The analysis showed that both factors have a statistically significant linear relationship with total property crime at the street-segment level of aggregation. In addition, there is a significant two-way interaction between the two factors. Those blocks with both high accessibility (TURNS) and a high street flow (FLOW) have a disproportionately greater amount of crime. However, the predictive power of these data at the individual street segment level of aggregation is relatively low, as very little of the variation in the crime rate is explained by these two factors (R^2 = 0.15). The relatively low percentage explained is related to the non-saturation of suburban areas with crime. Some highly accessible and high-flow street segments experienced little or no crime. The accessibility and flow help define aggregate awareness spaces, that is, the space from which crime targets are chosen. But, as previously described, the elements making up the set of potential targets on particular streets should also influence the amount of crime experienced, and in these communities some of the high-access, high-flow segments had few targets.

Table 3: Relationship Between Accessibility and Crime (Pearson Correlations)

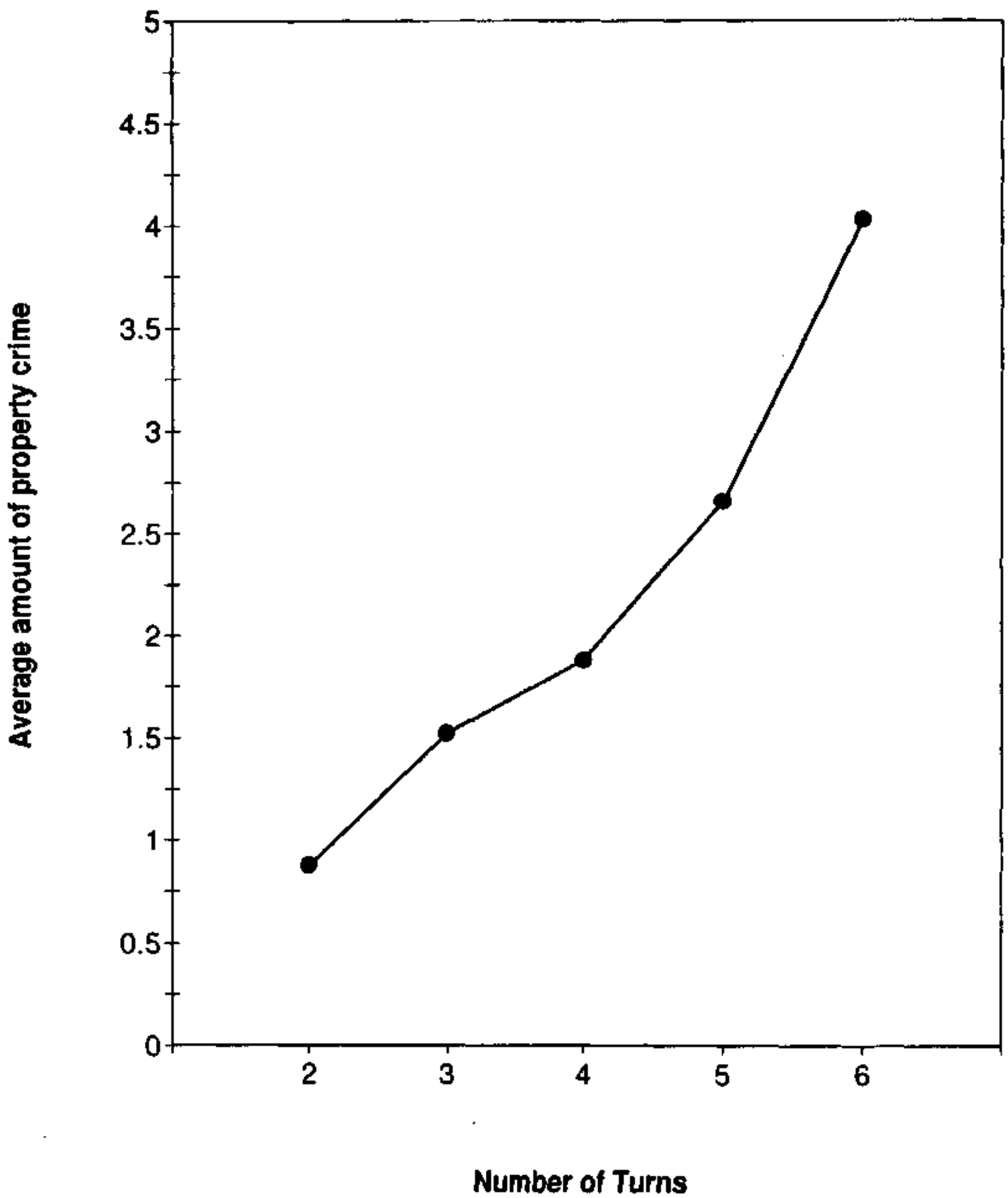
TYPE OF CRIME	r	R^2	SIGNIFICANCE
Bicycle Theft	.07510	.00564	.45223
Auto Theft	.89466	.80042	.02019
Theft From Auto	.95327	.90873	.00602
Property Theft	.98462	.96947	.00114
Willful Damage	.93659	.87721	.00949
Break & Enter	.97039	.94149	.00306
Total Crime	.97126	.94335	.00291

To develop a stronger predictive model and to control for the possible effects of other choice variables, an analysis of covariance was performed. The question that then arose is what variables to select as covariates given the large number of independent variables available in the environmental data set that was developed. To try every potential combination of covariates to obtain the best predictive model was not feasible. To resolve this problem, a stepwise multiple regression analysis was first used to search out a strong combination of independent variables that predicted the amount of property crime on each segment.[15] The five opportunity variables that were uncovered using this regression procedure were the following:

(1) NUMCE—the number of commercial establishments on each block.

(2) TAXTA—the average improvement value of transient accommodation on each block.

Figure 2: Number of Turnings by Total Crime



(3) HISCH—a dummy variable: whether or not there is a high school on a street segment.

(4) TAXAP—the average improvement value of any apartments on each block.

(5) NUMAP—the number of apartment buildings on each block.

These variables were then used as statistical controls in an analysis of covariance performed to assess the influence of opportunity variables, as well as of accessibility and street flow on crime volumes.

While not included in this analysis, but consistent with the complexity of actual criminal behavior, the set of appropriate opportunity variables might be different in analyses of specific crimes. This study looked at total property offenses. A study restricted to residential burglary, as was Bevis and Nutter's (1977), might find different opportunity variables that worked well. When looking at aggregate property offense patterns, opportunities are reasonably related to the presence of large numbers of people (potential offenders and victims), and to a large number of potential property crime targets (buildings, automobiles, portable property in homes, visible property in stores, etc.).

In an analysis of covariance the researcher has the choice of entering the factors into the equation first, entering the covariates first, or entering both of them simultaneously. In this study the two factors were entered into the equation first, since the factors are causally prior to the covariates on a theoretical level. Before criminals can select specific opportunities they must first travel to a specific location. The accessibility and street flow variables are indicators of travel routes. Causally, travel along these routes must occur prior to the selection of opportunities by criminals, that is, the routes become part of a potential criminal's awareness space, restricting the set of known targets.

Analysis using offenders (Rengert and Wasilchick, 1985; Cromwell et al., 1991) is necessary to explore the full search pattern. This analysis was restricted in the same sense that the phrase "I always find it in the last place I look" describes a restricted search process. Opportunity variables, which reflect the number and attractiveness of potential targets, were entered into the model after the two factors. By entering the two factors into the model first, they are given the chance to explain as much of the variance as possible. This procedure conforms, as much as possible, with a crime-site selection model in which the target area is chosen (or routinely experienced) first, and a specific target is then chosen from within the selected area. Note that the overall strength of the model is not changed by adopting this procedure. When the covariates are entered into the model, the new variables adjust for the variation that was attributed to the two factors. Stated another way, the covariates might be considered indicators of characteristics that identify the existence of good targets in known places. The covariates are not necessarily independent of the accessibility and flow factors and, in fact, under the basic environmental model should be interrelated.

The covariance model that was developed by this procedure can be seen in Table 4. In this model both street accessibility and street flow are statistically significant. There is also a significant interaction between the two factors. In this model the two factors account for 14.7% of the variance. While the covariates account for the majority of the variance in the model (54.6%), the two factors cannot be easily dismissed as unimportant. Not every potential target is always victimized, even in what are probably well-known, well-traveled parts of a municipality. Overall, the covariance model explains 69.3% of the variance, which is quite high for a model based upon such a low level of aggregation.

Table 4: Accessibility vs. Street (Analysis of Covariance)

Source of Variation	Sums of Squares	df	Mean Square	F	Significance
Main	6085.38	7	869.34	99.12	0.0000
- TURNS	807.31	4	201.83	23.01	0.0000
- FLOW	4406.70	3	1468.90	167.49	0.0000
Covariates	22541.30	5	4508.26	514.04	0.0000
- NUMCE	5859.74	1	5859.14	668.14	0.0000
- TAXTA	8640.48	1	8640.48	985.21	0.0000
-HISCH	3390.41	1	3390.41	386.58	0.0000
- TAXAP	1731.16	1	1731.16	197.39	0.0000
- NUMAP	1644.80	1	1644.80	187.54	0.0000
Two-Way Interaction	863.41	11	78.49	8.95	0.0000
Explained	29490.08	23	1282.18	146.20	0.0000
Residual	11822.24	1348	8.77		
Total	41312.32	1371	30.13		

The results of this analysis of covariance are descriptively displayed in Table 5. This multiple classification analysis (MCA) table shows how the mean of each category, for the two factors, was affected when the covariates were used as statistical controls. The mean of each category is expressed as deviations from the grand mean (2.2 property crimes per block). By examining the column of unadjusted means one can see a distinct pattern. As accessibility and street flow increase, so does the amount of property crime. The street accessibility measure (TURNS) shows that blocks that have only two turnings average 0.95 reported property crimes (2.2 minus 1.25). while at the other end of the spectrum blocks with six turnings average 5.27 reported property crimes (2.2 plus 3.07). The volume of traffic measure (FLOW) likewise shows the same linear pattern, as the amount of reported property crime ranges from 1.52 for the lowest volume flow to 11.91 for the highest volume flow. This table is useful in showing the relation between the factors and the covariates in a descriptive fashion, but does not provide accurate coefficients for a predictive equation because of the weak interaction effect between the two factors.

The effects of the two factors on one another can be seen in the second column, which adjusts for the influence of the other independent factor. Note the changes in these values: The effect of each factor reduces the value of the other factor. Although the variation is reduced, the ordinal pattern produced by both factors is still maintained. That is. as street accessibility or street flow increases, so does the amount of reported property crime. This, of course, is consistent with a weak interaction effect.

The third column in the MCA table adjusts for the effects of the five covariates as well as the two independent factors. The two factors still maintain the same linear pattern. However, each group's deviation from the grand mean is greatly reduced, as would be expected given that the covariates are attempts at measuring attractive opportunities. This would have little or no impact only if crime occurred in an irrational, random pattern and there was no such thing as target suitability. The street accessibility measure (TURNS) ranges from 1.78 property crimes for blocks with two turnings, to 2.42 property crimes for blocks with six turnings. The street flow measure (FLOW) ranges from 2.05 for the lowest street volume flow, to 3.32 for the highest street volume flow. This third column shows that once the covariates are included, there is a much more limited difference between the different segment types. Accessibility and the flow are related to covariates that measure the number and tax value of apartments, the number of high schools and commercial establishments, and the tax value of motels and hotels. Neither the number of turnings nor the traffic flows explain crime independently when consid-

ered conjointly with the covariates and when all crimes are considered together. Conversely, although not tested in an analysis-of-covariance model, the opportunity covariates will not function independently of the turnings and flow factors.

Table 5: Accessibility vs. Street Flow (Multiple Classification Analysis)

Variable and Category	N	Unadjusted		Adjusted for Independents		Adjusted for Independents and Covariates	
		Dev'n	Eta	Dev'n	Beta	Dev'n	Beta
TURNS							
2	269	-1.25		-0.72		-0.42	
3	229	-0.64		-0.18		-0.11	
4	482	-0.13		-0.26		0.15	
5	289	0.80		0.39		0.15	
6	103	3.07		2.43		0.22	
			0.20		0.14		0.04
FLOW							
1	1143	-0.68		-0.62		-0.15	
2	119	1.46		1.27		0.68	
3	67	2.80		2.50		0.69	
4	43	9.71		9.12		1.12	
			0.36		0.33		0.06
Grand Mean				2.20			
Multiple R^2					0.15		0.69
Multiple R					0.38		0.83

This interrelationship is hardly surprising given the fact that traditional North American land-use zoning places apartments, shops, high schools, bars, motels and other high activity land uses on or near main arterial roadways, or near exits from major limited-access highways. Road networks influence zoning, but zoning also influences the design of road networks. Road networks, traffic flows and zoning together influence the locations of certain types of developments, and, consequently, substantially influence where crimes occur. Accessibility and traffic flows, when considered independently, have an impact on crime location; but it is an impact that, when considering all property crimes, is highly interrelated with the location of potential targets or opportunities on arterial roads.

Future studies should explore more specific crimes. They should also try to determine the relative importance of planning and zoning decisions in fixing the location of specific types of targets, as well as their impact on the general development of awareness spaces through road network and public transportation planning. For example, assaults that take place in bars obviously occur in areas zoned for such commercial use (Wikstrom, 1985:256-258; Roncek and Pravatiner, 1989; Roncek and Maier. 1991). Research should begin to explore whether bars on the most accessible roads or clustered in areas together are in the awareness spaces of more people, attract more people from further distances, and produce more assaults (do strangers engage in more assaults than people who know each other?) and more drinking and driving offenses.

CONCLUSIONS

The results of this study demonstrate that criminal opportunities are at different risks in the environment depending upon their location. It was shown that, all other things considered equal, opportunities have a greater likelihood of being exploited if they are on relatively accessible and frequently traveled streets. These observations support the theoretical supposition that property offenders engage in a spatially patterned search behavior in the selection of their targets. Property offenders will commit crimes within their routine activity spaces. In the aggregate, this means that property crimes are most likely to occur on street segments which are highly accessible within the road network, have higher levels of traffic (or people) flows, and include attractive targets such as apartments, bars, high schools or motels.[16] In this aggregate analysis of property offenses, opportunities in accessible areas dominate the pattern of criminal events.

Through modern city planning practices, local and regional governments unknowingly create the opportunity network for crime. This last point is particularly important since it indicates a need for more intensive research on the spatial mobility of offenders and on what attracts them to targets. Some offenders stay close to home or to work or school. Some travel rather far in locating targets. Whether close or far away, all offenders travel some distance to reach potential targets, even if only across a room.

This study provides information that may prove useful for cities as they try to make decisions about introducing road barriers to reduce crime. In those cities and those parts of cities that are already fully developed, the effective use of traffic barriers for crime prevention depends on careful situational crime analysis. It is important to establish what the crime patterns are, to determine who is probably committing the crimes in the area being analyzed, and to assess why they are probably doing it. It is particularly important to assess how criminals are moving around in the city generally and in the area under analysis in particular. In a high-crime area, where most offenders live close to the places in which they commit their crimes and in which most people travel on foot most of the time, cutting off car traffic will have little preventive effect. Using traffic barriers to reduce accessibility to low-crime areas will also have little preventive effect. Reducing car access to an area will only have an impact if there is some crime on non- arterial roads and most of the crime is committed by outsiders. Reducing accessibility to non-arterial roads would likely reduce problems there. It certainly would not reduce crimes already occurring on or near main roads.

Reducing crime through road design and reduction of area accessibility should have its greatest impact in planning and developing new areas. The road network can, if properly designed, deflect the flow of outsiders without the use of walls or gates. A well-designed road network can even influence the travel network of local residents, both on foot and in automobiles. Pedestrian pathways in new areas should be considered as part of the general road network, particularly for children and adolescents, at the design stage. Because criminal behavior peaks at a young age, opportunistic crimes may be highly related to travel paths for youth.

Through their planning and development decisions, cities cluster targets and restrict or increase accessibility to them. Cities create the backdrop for crime through their control of roads, commercial development, housing, building costs and transportation networks. While restricted to two very suburban municipalities, this study does indicate that the backdrop created by cities cannot be treated simplistically. though its effects probably vary by crime type. Crimes committed by persons who walk between destinations will probably follow quite different patterns from crimes committed by those who drive or take public transit. Blocking roads to create dead-ends and restrict traffic flow may reduce residential crime committed by neighborhood outsiders who travel by car, but not crimes committed by local youths moving on foot (Cromwell and Zahm, 1991; Sheard. 1991; Matthews, 1992). Blocking roads into residential areas will not reduce crime on main roads; it may in fact increase it by focusing outsiders on a few roads and a limited set of targets. Clustering the housing of those with restricted income on high-access roads may increase the opportunities for crime and consequently the volume of crime. From a design perspective, the spatial mobility patterns of potential offenders help show where much greater care should be taken to increase quasi-official surveillance, or to include site and situation design that reduces easy opportunities. The analysis of the use of roads as well as the placement of targets should become part of standard situational crime prevention, for both reducing existing crime problems and avoiding problems in the planning of new developments.

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NOTES

1. Cohen and Felson (1979) argue that criminal acts require a convergence in space and time of likely offenders, suitable targets and the absence of capable guardians against crime. They found that the dispersion of activities away from households and families increases the opportunity for crime and thus generates higher crime rates. The absence of capable guardians against crime is probably one of many variables that influence a criminal's perception of what constitutes a good opportunity.

2. See Fattah (1991) for a detailed analysis of victimization patterns, and Pease (1992) for post hoc estimation of future victimization rates.

3. In her study. Boggs (196 5) demonstrated that simple resident population denominators, in crime-rate ratios, can produce distorted pictures of crime distributions. She noted that crime rates should form probability statements and should therefore be based on the risk or target group appropriate for each specific crime category.

4. See, also. Herbert and Hyde. 1985; Walsh. 1986.

5. Travel patterns and the activity centers associated with travel destinations such as bars, high schools, shopping centers or business districts are related quite strongly to where crimes occur. See Bullock, 1955; Engstad, 1975; Brantingham and Brantingham, 1981; Poyner. 1983; Coburn. 1988; Roncek and Pravatiner, 1989: Sherman et al., 1989; Block, 1990; Roncek and Maier, 1991.

6. Jacobs (1961) and Newman (1972, 1980) have also received much methodological criticism. See, for example, Mawby. 1977; Mayhew, 1979; Poyner, 1983. 1988.

7. The beta index is a connectivity measure that relates the number of paths in a graph to the number of vertices in a graph. The formula is JJ = *e/v*, where e is the number of edges and *v* is the number of vertices in the graph. See: Brantingham and Brantingham, 1984:243; Brantingham et al., 1992.

8. See Cromwell et al.. 1991 for an excellent example of a study that did try to get at the decision patterns of active burglars directly, and that also provides thoughtful treatments of the practical and ethical constraints on this type of research.

9. This means that intersections can only be end points of a street segment. An intersection was defined as the point where a street ends, or where two or more roads meet or cross. This definition of a street segment is roughly similar to Ralph Taylor's idea of a "street-block," but without the implication that it is necessarily a behavioral setting as that idea is understood by environmental psychologists. See Taylor, 1988:129.

10. The analysis included data for every street segment and for all reported property crimes. At one level, no statistical analysis is necessary since no inferences are being made from sample data to a population. Statistical analysis was performed, however, because the measures of association are helpful in sorting out relationships. Statistical significance does not take on its traditional meaning in this analysis.

11. Analysis of this type is not without problems. Particular care has to be taken to avoid finding a linear relationship in what might be bi-modal or might be shaped by a few extremely high values.

12. Vehicle registration data were not available at the required level of aggregation under legal privacy protection rules. No agency purported to have a listing of bicycles by address, much less anything like a count of other forms of personal property.

13. In the next section a multiple regression analysis was performed. An examination of the residuals from this analysis showed that its distribution was quite leptokurtic. or far more peaked than the normal curve (Blalock, 1972:98). Upon investigation it was discovered that this condition was caused by the large number of street segments on which no crime had occurred. To correct for this condition, all those segments with no buildings were dropped from further analysis. The rationale for this decision was that street segments with no opportunities should have no crime. A one-way

analysis of variance confirmed this hypothesis (F- ratio = 20.3, F-prob = 0.0, df = 1,1573). The deletion of these 203 segments that had no buildings on them greatly reduced the leptokurtic character of the residual distribution. The two-way analysis of variance that is being discussed in the main text was performed after dropping these buildingless street segments.

14. This is so because children, who move about on foot or by bicycle but who do not drive motor vehicles, travel pathways—shortcuts—through urban spaces from which motor vehicles are barred: paths through parks; across neighbors' yards; along semi-closed access lanes; along pedestrian greenbelts and bicycle paths. Viewed more broadly, this point suggests very different access and crime patterns in Manhattan and Queens because of the relative total proportions of movement keyed to pedestrians and automobiles in the two boroughs.

15. The stepwise procedure was used because there was no a priori reason for ordering the opportunity variables. A forward stepwise procedure was used with inclusion levels. The order of inclusion is determined by the respective contribution of each variable, based upon the partial Fs, to the explained variance. The maximum number of independent variables that could be entered into the equation was set at five; a minimum partial F-ratio for any given variable to enter into the equation was set at F = 5.0; and a minimum tolerance level was set quite high at t = .75 to reduce the effects of multicollinearity.

16. While we recognize that such areas may also constitute transitional zones that may well include residents who are, in Wikstrom's terminology, "socially loaded" and therefore have high potentials for offending, this is not simply another way of saying that crimes occur where offenders live. Although it is true that a Pareto function model of distance decay can be used to describe the simple distribution of offenses in relation to the location of an offender's home, the literature is clear than offenders often journey substantial distances to offense sites and that these journeys tend to be pulled along major roads toward city centers. See, for example, Baldwin and Bottoms, 1976: Brantingham and Brantingham. 1984; Wikstrom, 1985; Costanzo et. al., 1986; Lenz, 1986; Rand, 1986; Rhodes and Conly. 1991. This is a way of saying that crimes occur where certain kinds of land uses cluster in accessible locations.

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