

## LAND USE AND VIOLENT CRIME

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**Keywords:** land use, violent crime, spatial analysis, ecological theories

### Brief biographical paragraphs

John Ottensmann is a professor in the School of Public and Environmental Affairs at Indiana University-Purdue University Indianapolis and serves as the director of urban policy research for the Center for Urban Policy and the Environment. He received his undergraduate degree from the University of Wisconsin at Madison and the Ph.D. in City and Regional Planning from the University of North Carolina at Chapel Hill. His research focuses on the spatial organization of urban areas, the spatial dimensions of public policy, and the use of analytical models to understand these issues. He has done applied public policy research for a variety of organizations and has published articles in a diverse range of scholarly and professional journals.

Thomas D. Stucky is Interim Director of Indiana University's Center for Criminal Justice Research and an Associate Professor of Criminal Justice. Professor Stucky earned his Ph.D. in Sociology at the University of Iowa in 2001. His scholarly interests are at the intersection of politics and criminal justice, specifically the relationship between politics and crime/policing at the city level, and state level trends in imprisonment and correctional spending. He is also interested in the continuing development of the systemic social disorganization theory, and among other things the relationship between land use, the physical environment and crime. He has authored two books, and journal articles appearing in *Criminology*, *Journal of Quantitative Criminology*, *Journal of Research in Crime and Delinquency*, and *Justice Quarterly*, among others.

This is the author's manuscript of the article published in final edited form as:  
Stucky, T. D., & Ottensmann, J. R. (2009). Land Use And Violent Crime\*. *Criminology*, 47(4), 1223-1264. <http://dx.doi.org/10.1111/j.1745-9125.2009.00174.x>

## **LAND USE AND VIOLENT CRIME**

Although research has shown specific land uses to be related to crime, systematic investigation of land uses and violent crime has been less common. This study systematically examines links between land uses and violent crime and whether such links are conditioned by socioeconomic disadvantage. We employ geocoded UCR data from the Indianapolis police department and information on 30 categories of land use, and demographic information from the 2000 census. We use land use variables to predict violent crime counts in 1000 X 1000 feet grid cells using negative binomial regression models. Results show that, net of other variables, specific land uses predict variation in counts for individual violent crimes and aggregate rates. Some nonresidential land uses are associated with higher violent crime counts, whereas others are associated with lower counts. Specific land uses also condition the effects of socioeconomic disadvantage on violent crime. Implications for routine activities/opportunity and social disorganization/collective efficacy theories of crime are discussed.

## INTRODUCTION

Consideration of the relationship between land use and crime has a long history in criminological research, dating back at least to the early studies in the Chicago school (Burgess, 1916; Shaw and McKay, 1972[1942]). Land uses are discussed in a variety of lines of research including Jacobs' (1961) and Newman's (1971) early work on urban landscapes and crime, Brantingham and Brantingham's (1981) crime pattern theory, routine activities/opportunity theories (Cohen and Felson, 1979; Kennedy and Forde, 1990), hot spots research (Loukaitou-Sideris, 1999; Sherman, Gartin, and Buerger, 1989; Weisburd, Bushway, Lum, and Yang 2004), and research on crime prevention through environmental design (CPTED) (Eck, 2002; Felson, 2002; Jeffrey, 1976, 1977; Lab, 1992; Plaster-Carter, Carter, and Dannenberg, 2003).<sup>1</sup>

Despite this longstanding, periodic attention to land use (Duffala, 1976; Fowler, 1987; Greenberg and Rohe, 1984; Greenberg, Rohe, and Williams, 1982; Ley and Cybriwsky, 1974; Lockwood, 2007; Smith, Frazee, and Davidson, 2000; White, 1932; Wilcox, Quisenberry, Cabrera, and Jones 2004), until recently it has not figured prominently in research on several mainstream ecological theories. Thus, land use is completely absent from anomie/strain research and most tests of social disorganization/collective efficacy theories (but see Sampson and Groves 1989).<sup>2</sup>

Research also frequently focuses on a few specific land uses such as taverns (Roncek and Maier, 1991; Roncek and Pravatanier, 1989) or schools (LaGrange, 1999; Roncek and Faggiani, 1985; Roncek and LoBosco, 1983), or combines land use information into indices (McCord, Ratcliffe, Garcia, and Taylor 2007; Wilcox et al., 2004), or single measures of "mixed" or nonresidential land use. For example, Sampson and Raudenbush (1999) include a measure of "mixed land use" but find no effects of the measure on crime, whereas Cahill (2005) finds significant effects of mixed land uses on crime. These conflicting findings may result from treating different land uses

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<sup>1</sup> See also Murray (1983), Roncek (1981), Taylor (1998), Taylor and Gottfredson (1986), Taylor and Harrell (1996) for overviews of physical environment and crime.

<sup>2</sup> See Brantingham and Jeffrey (1981) for a discussion of this issue with respect to social disorganization theory.

similarly. If not all land uses produce crime, then combining such measures risks masking potentially opposite effects on crime. For example, commercial establishments may be associated with higher crime because they place potential offenders and targets in proximity with regularity. But do industrial areas, which likely place fewer offenders and targets in proximity, also create similar opportunities for crime? To date, few studies have *systematically* examined links between particular land uses and violent crime.<sup>3</sup>

Many studies have assumed that land uses have direct effects on crime irrespective of social context. Thus, the effect of “nonresidential” land uses is expected to be the same in advantaged or disadvantaged areas. Such an assumption seems unwarranted because the potential for land uses to create opportunities for crime likely depends on the willingness and/or capacity of occupants of an area to exercise social control (see Merry, 1981; Smith, Frazee, and Davison, 2000; Wilcox et al., 2004), which are also likely to vary based on the relative advantage or disadvantage of a neighborhood. Thus, a few recent studies have argued that the effects of land uses on crime are likely conditional on the socioeconomic characteristics of the area (Smith et al., 2000; Wilcox et al., 2004). Yet, these studies considered a limited number of land uses, and either focused on a single crime, or employed subjective land use measures. Therefore, additional systematic consideration of the conditional effects of land use and socioeconomic disadvantage seems warranted. The current study advances research on land use by systematically exploring whether and how a wide variety of objectively-measured land uses and several violent crimes are related, and by exploring whether land uses and socioeconomic disadvantage have independent or conditional effects on violent crime. Following a discussion of existing research on land use and crime, we discuss the data and methods used in the current study. Then we discuss the results of negative binomial analyses of the links between land uses, socioeconomic and demographic factors, and geocoded UCR violent crime counts

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<sup>3</sup> Several recent studies have examined links between land uses, neighborhood deterioration, and actual or perceived disorder such as Kurtz, Koons, and Taylor (1998); McCord et al., (2007); Taylor, Koons et al., (1995); Wilcox, Quisenberry, and Jones (2003).

in 1000 X 1000 feet square grid cells in Indianapolis, Indiana. We close by discussing the implications of the current study for systemic social disorganization/collective efficacy and routine activities/opportunity theories of crime.

### **LAND USE AND CRIME**

Although studies of land use have appeared sporadically for decades, there appears to be a renewed attention to land use in recent years. Recent studies have focused on land use, usually from two broad perspectives—routine activities/opportunity theories and social disorganization/collective efficacy theories.<sup>4</sup> Developed in 1979 by Cohen and Felson, routine activities theory suggests that the daily activities in which citizens engage—going to work, school, and church—differentially place potential offenders and potential targets in close proximity, which leads to variation in crime victimization. From this perspective, a crime is more likely to the extent that motivated offenders and suitable targets meet in the absence of a capable guardian. Thus, studies incorporating land use have focused on how particular land uses such as bars (Roncek and Maier, 1991; Roncek and Pravatanier, 1989) or schools (LaGrange, 1999; Roncek and Faggiani, 1985; Roncek and LoBosco, 1983) can increase crime by regularly placing offenders and victims in proximity in the absence of guardianship. For example Roncek and Maier (1991) found that areas with bars tend to have higher violent and property crime (UCR index offenses), net of sociodemographic factors. Similarly, LaGrange (1999) examined the effects of malls and schools on minor crimes for a one-year period in Alberta, Canada, from a routine activities perspective. She argued that schools and malls place many people who don't know each other (malls) or are at a crime prone age (schools) together. Using data “enumeration areas” (subunits of census tracts) from Edmonton, LaGrange found that malls and public high schools, rental units, rooming houses, and vacant lots all increase criminal mischief and damage to parks and transit areas.

The opportunity approach suggests that different land uses are likely to create different

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<sup>4</sup> One recent study (McCord et al., 2007) focuses on Brantingham and Brantingham's crime pattern theory.

opportunity structures for crime, by influencing the mix of motivated offenders, potential victims, and the presence or absence of capable guardians. So a church is likely to create a very different set of social interactions that seems much less likely to place offenders and victims in proximity (in the absence of guardianship) than commercial activities. Yet, as noted above, many studies create aggregate measures of land uses as if all nonresidential land uses can be assumed to similarly increase opportunities for crime (Cahill, 2005; Sampson and Raudenbush, 1999) or focus on a few specific land uses (LaGrange, 1999; Roncek and Faggiani, 1985; Roncek and LoBosco, 1981; Roncek and Maier, 1991; Roncek and Pravatanier, 1989). Therefore, a study which allows for investigation of the independent effects of a variety of land uses is warranted.

Other recent studies of land use and crime have employed the social disorganization/collective efficacy perspective. Developed from the Chicago School tradition and Shaw and Mckay's landmark study (1972 [1942]), social disorganization theory posits that community crime rates vary because social structural factors such as poverty, ethnic heterogeneity, and family instability, impede the ability of residents to maintain informal social control in the neighborhood (see also Bursik, 1988; Sampson and Groves, 1989). Although most social disorganization studies focus on *social* ecology, some studies also consider land uses (Lockwood, 2007; Sampson and Raudenbush, 1999; 2000; Wilcox et al., 2004). Some argue that mixed or nonresidential land uses impede the ability of residents to maintain social control by increasing street traffic which increases the number of strangers in an area and reducing residents' ability to tell locals from outsiders (Gardiner, 1976; Greenberg, Rohe, and Williams, 1982; Kurtz, Koons, and Taylor, 1998; Taylor et al., 1995; Wilcox et al., 2004), or by increasing actual or perceived neighborhood deterioration, disorder, or incivilities (Kurtz et al. 1998; McCord et al., 2007; Taylor et al., 1995; Wilcox, Quisenberry, and Jones 2003).<sup>5</sup>

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<sup>5</sup> Others argue that mixed land uses can be beneficial. Jacobs (1961) argued that mixed land uses are crucial because they keep people in areas throughout a day. Thus, there are constantly "eyes on the street." Expanding on Jacobs' work, Newman (1972) developed the concept of 'defensible space.' Newman suggested that territoriality (the degree to which an area appears to be "owned") and natural surveillance are factors that would likely affect an offenders'

Consistent with this logic, Lockwood (2007) examines the influences of retail/commercial and public/institutional, and recreational land uses on robbery, aggravated assault, and simple assault rates in 145 census block groups in Savannah, Georgia. Lockwood (2007) finds that both commercial and public land uses are significantly positively associated with simple assault, aggravated assault, and robbery rates.<sup>6</sup> Additionally, the author finds that recreational land uses are significantly positively associated with robbery rates. Yet, Lockwood's analysis focuses only on a few very broad categories of land uses, the study has a small sample size, and the study only considers direct effects of land uses on crime.

Recently, theorists have begun to suggest combining social disorganization and routine activities theories (Smith et al., 2000). Such an approach would suggest that crime rates will vary based both on how frequently routine daily activities place offenders and targets in proximity, and the willingness or capacity of others to intervene to maintain social control.

Consistent with this logic, two recent studies have suggested that the effect of land uses on crime may be conditional on the socioeconomic characteristics of the neighborhood. If socioeconomic disadvantage (a structural antecedent of social disorganization) is generally associated with lesser levels of informal social control, *ceteris paribus*, then the crime generating potential of land uses will likely vary depending on the level of disadvantage in an area. Consistent with this, Smith et al. (2000: 516) found that "[s]ocial disorganization attributes of a face block combine with land use factors to affect the probability that street robbery will occur." Specifically, the authors found that the influence of hotels/motels, and bars/restaurants/gas stations on robbery was greater as the number of single parent households in a face-block increased, whereas the influence of

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choice of whether or not to commit a crime in a given area. He argued that physical characteristics can give the impression that space will be defended and therefore reduce the likelihood of crime. In addition, if people feel they own a space, they will be more likely to exercise informal social control over it and as a result, crime will be lower. Evidence on the utility of defensible space is mixed (Mawby, 1976; Merry, 1981; Taylor, Gottfredson, and Brower, 1980, 1984).

<sup>6</sup> The author also noted having examined homicide rates but no results were presented for these analyses.

multifamily structures, bars/restaurants/gas stations, and vacant/park lots on robberies decreased with distance from the center of the city. Although promising, these findings are specific to robbery and include primarily commercial kinds of land uses.

Similarly, Wilcox et al. (2004) suggest that the effect of land use on crime might be conditional on the socioeconomic characteristics of the area (see also Wilcox, Quisenberry, and Jones, 2003). Wilcox et al. (2004) examined the linkages between specific land uses and burglary, assaults, and robberies in 100 Seattle neighborhoods. The authors argued that certain types of land use will lead to greater difficulty in maintaining informal social control because of the greater amount of “public” space and the larger number of strangers. Wilcox et al. (2004) also argued that certain types of land use are more likely to be associated with physical deterioration or incivilities, which could lead to more serious crimes (i.e., broken windows logic). The authors found that the effects of businesses on burglary and playgrounds on robberies and assaults were conditional on the relative level of population instability. Yet, the effects ran counter to their expectations. Wilcox et al. (2004) had predicted that some land uses would be *more* likely to be associated with crime in unstable areas. Their analyses showed just the opposite to be true. They speculate that such land uses in unstable areas may encourage greater monitoring by parents at playgrounds and the police or business owners for businesses in unstable areas. Yet, this study only considered a few land uses, relied on a small number of census tracts, did not control for crime or disadvantage in surrounding areas, and employed subjectively determined land use measures.<sup>7</sup>

In sum, although land use measures have periodically been incorporated in criminological studies, most studies have assumed that nonresidential land uses independently increase opportunities or decrease the potential for informal social control. Recently, authors have suggested that opportunity and informal social control may have conditional effects on crime. Consistent with this

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<sup>7</sup> Respondents were asked a series of questions regarding the presence of nine land uses within three blocks of their homes.

logic, two recent studies (Smith et al., 2000; Wilcox et al., 2004) have considered conditional effects of land uses and disadvantage on violent crime. Yet, each has limitations that suggest the need for additional research. Therefore, a systematic study of the effect of objectively-measured land uses on a variety of serious violent crimes that considers the conditional effects of land uses and disadvantage seems warranted.

## **DATA AND METHODS**

The data for this study come from three sources, the Indianapolis Police Department (IPD) Uniform Crime Report (UCR) data for 2000-2004, land use data from the Indianapolis Department of Metropolitan Development from 2002, and 2000 Census data.<sup>8</sup> Crime data for the study covers the IPD service area, which is approximately the Indianapolis city boundaries before city-county consolidation in 1970.<sup>9</sup>

### **UNIT OF ANALYSIS**

The units of analysis for this study are 2,142 1000-foot square grid cells overlaid on the (IPD) service area. Grid cells only partially included within the boundaries have been excluded from the analysis because only some crimes in them would have been reported to IPD. One advantage of this approach is that the grid cells are much more homogeneous than larger units such as census tracts or block groups. Although other units such as census blocks or face blocks (e.g. Smith et al., 2000) might have been chosen, each would present significant problems for allocating the crime data (See Appendix 1 for additional discussion of the use of grid cells rather than census-based boundaries). Maps 1 and 2 illustrate the IPD service area relative to Marion County, Indiana, and the grid cell approach taken in the current analysis.

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Maps 1 and 2 about here

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<sup>8</sup> Although these data could be subject to concerns over causal order, it seems unlikely that in the short run changes in crime are unlikely to cause changes in land use.

<sup>9</sup> The 2000 population of the IPD service area was 322,212. This population is comparable to that for other large central cities in the Midwest, such as Pittsburgh, PA (334,563), Cincinnati, OH (331,285), and St. Louis, MO (348,189).

## DEPENDENT VARIABLES

In this analysis, we use geocoded UCR data for the IPD service area from 2000-2004 to examine the violent index offenses (murder and non-negligent manslaughter, rape, robbery, aggravated assault) individually and as a violent crime index.<sup>10</sup> We focus on violent crimes because, by definition, these require an offender and a target to interact. For each crime, the count of incidents per cell was determined. The crime locations were geocoded from address information, so that crimes could be located as accurately as the nearest street address.<sup>11</sup>

## SOCIOECONOMIC VARIABLES

To determine whether land uses influence crime net of socioeconomic variables, and whether their influence on crime is conditioned by disadvantage, it is necessary to control for relevant socioeconomic predictors of violent crime. Therefore, we include the socioeconomic characteristics of the areas in which each of the grid cells are located. Values of the sociodemographic variables have been estimated for each grid from the 2000 census. To estimate the grid cell values the blocks and census tracts were intersected with the grid cells and the values of blocks and tracts split by the grid cells were apportioned to the cells based on the proportion of the area of the block or census tract within the cell. Block data from Summary File 1 were used for the estimation of those

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<sup>10</sup> The homicide variable includes homicides from 1992 to 2004 to increase stability of estimates. Preliminary analyses also considered homicides from 2000 to 2004 with similar results.

<sup>11</sup> IPD did not provide information on the geocoding success rate for the UCR data that were provided or describe the geocoding procedures used. However, the dataset included a small number of records (less than 1%) for which no geocoded coordinate information was provided. Some of these records included “UNKNOWN” in the address field, while others included addresses that apparently could not be successfully geocoded. Based upon this, one might infer that the geocoding success rate exceeded 99 percent, though we cannot definitively conclude this, which would be a very high success rate. IPD uses the street database of the Metropolitan Emergency Communications Agency, which handles 911 dispatching for geocoding. This is an extremely comprehensive and accurate database, which would contribute to a very high geocoding success rate. Further, IPD has full-time personnel devoted to “cleaning” the UCR data and puts considerable effort into the UCR dataset so that the crime locations accurately reflect the locations of the crimes as opposed to the locations to which the officers initially responded. This is evidenced by the time delays associated with the release of the UCR data. While IPD makes their officer incident report data available within 24 hours, the UCR data are not available until approximately 4-5 months later. This suggests attention to developing accurate address information that could make the high geocoding success rate plausible.

characteristics reported at the block level: population, Hispanic population, African-American population (all persons reporting at least one race African-American), number of female headed households, number of occupied housing units, and number of owner-occupied housing units.

Block group data from Summary File 3 were used for the estimation of those characteristics obtained from the long-form (sample) questions: population change from 1990 to 2000, number of persons foreign born, number of persons aged 16 and over in civilian labor force, number of employed persons, number of persons for whom poverty status was determined, and number of persons below the poverty level. It should be noted that there can be a number of grid cells in each block group in some cases (see Map 3). Therefore, because these block group characteristics represent an aggregation across the area within each block group, the much smaller grid cells may in some cases depart from this average.

Previous research has shown that many social structural predictors of crime such as poverty, unemployment, and family disruption are often highly correlated. Therefore, following previous research (Land, McCall, and Cohen, 1990; Parker and McCall, 1999), using principal components analyses, we created a *disadvantage index* which included the following indicators: percent poor, percent unemployed, median household income, and percent female-headed households. Factor loadings ranged from 0.68 to 0.83. Social disorganization theory and research has focused on the difficulty of maintaining social control in unstable neighborhoods (Wilcox et al., 2004). Therefore, we developed a *stability index*, consisting of the percent of housing units that were owner-occupied, the percent that is foreign born, and the percent of the population that had not moved for five years.<sup>12</sup> Factor loadings on this index ranged from 0.66-0.82. In addition, the percentage of the population that is African American and the percentage Hispanic in the cell are included. To control for the

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<sup>12</sup> Alternative specifications that included only the percent of owner-occupied residents or percent of population that had not moved in the previous five years produced similar results to those reported in tables 2 and 3.

possibility that greater counts of violent crime will occur in a cell simply because more people live in an area, we control for the cell population (Land et al. 1990).

## LAND USE VARIABLES

Prior research has considered several land use categories. The land use data available for Indianapolis included parcel-based data on land use in 2002 obtained from the Indianapolis Department of Metropolitan Development. Each parcel was assigned a land use in one of the following categories: Residential (0 – 1.75, 1.76 – 3.5, 3.6 – 5, 5.1-8, 8.1-15, over 15) units per acre, Commercial (office, retail/ community, heavy, downtown mixed), Vacant, Agriculture, Industrial (light, heavy), Hospitals, Schools, Cemeteries, Churches, Utilities, Parks, Water, Unknown or under development, Village mixed use, Airport-related mixed use. Land use parcel information was intersected with the grid cells to obtain the portions of each parcel within each grid cell and summarized to produce the total area of the land in each grid cell devoted to each land use type. Then for each land use type, the percentage of the land area of the grid cell in the land use type was determined.

Preliminary analyses examined both presence of land use and the percentage of the cell devoted to each land use. Following extensive examination of land uses empirically and through review of previous research, the following set of land uses were included in the models described below.<sup>13</sup> Consistent with prior research suggesting that schools can be associated with higher crime, we include a categorical variable to indicate the presence of a *school land use* in the cell. Categorical variables were included for the presence of *hospitals* and *cemeteries*. If nonresidential land uses are associated with higher crime, one might expect that hospitals would be associated with higher crime because they bring many strangers together. Conversely, cemeteries could be associated with fewer violent crimes because they are unlikely to place offenders and targets in proximity.

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<sup>13</sup> All land use percentage variables were expressed as a percentage of the total non-road land use with the exception of the residual land use variable which was expressed as a percentage of the total area of the cell.

Examination of prior research suggests that commercial businesses are likely to be associated with higher crime (Smith et al., 2000) by frequently placing offenders and targets in proximity. Likewise, vacant land has been posited to be associated with higher crime (Greenberg et al., 1982; LaGrange, 1999; Ley and Cybriwsky, 1974), presumably through increased opportunity in the absence of guardianship or informal control. Although some have argued that industry, as a nonresidential land use, could be associated with higher crime (Lockwood, 2007), others suggest that industry might be associated with lower crime (Felson, 1987). In addition, some studies have found parks or recreational land uses to be associated with crime (Lockwood, 2007; Wilcox et al., 2004). Although, not studied in other research that we are aware of, water is a feature of many cities, whether in the form of rivers, lakes, or retention ponds. We anticipate that water would reduce the opportunity for violent crimes, although the areas around water may be areas with lower guardianship or informal social control.<sup>14</sup> To explore these effects individually, commercial businesses, industry, vacant land, parks, and water land uses were all included and expressed as percentages of the total land area in each cell.<sup>15</sup>

Some studies have also shown that high density housing can create anchors for disadvantage and crime (McNulty and Holloway, 2000). Therefore, a categorical variable was also created to capture the presence of high density residential land use within a cell (defined as 8 or more units per acre). Additionally, the presence of through traffic streets may increase crime by increasing street traffic and the presence of strangers (Greenberg et al., 1982). Therefore, we include a continuous variable that captures the sum total of the length of major roads in each grid cell. Thus, if a cell had one major road running through the entire cell, the value of the variable would be 1000.

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<sup>14</sup> One reviewer suggested that we examine buffers around water because beaches may bring large numbers of people together and increase opportunities for crime. We agree that this would be appropriate in some areas, however, in our study there are no large bodies of water with beaches.

<sup>15</sup> Despite the ability to examine many specific land uses, data were limited in some ways. In the dataset, there were four broad categories of commerce that provided no opportunity for further disaggregation. Thus, in this study we are unable to distinguish taverns from other commercial establishments.

Finally, we include a variable that captures the percentage of remaining land uses as a control variable. This *residual land use* variable includes the percentage of total land area devoted to agriculture, utilities, railroad rights-of-way, rights-of-way, village or airport mixed uses, under development, other, and unknown.<sup>16</sup> (See table 1 for variable means and standard deviations and Appendix 2 for variable correlations.)

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Table 1 about here

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## MODELING STRATEGY

Perhaps not surprisingly due to the size of the grid cells, the distribution of the dependent variable is highly skewed. Especially for homicide and rape, many cells have zero counts. Therefore, a Poisson distribution is more appropriate for count data (Greene, 2000; Osgood, 2000, Osgood and Chambers, 2000). Because Poisson models assume that there is no residual dispersion left to explain once the explanatory variables are included, we employ negative binomial models (which include a dispersion parameter) in the analyses reported below.<sup>17</sup> We limited the analysis to cells with a population count greater than zero. Combined with missing information on some independent variables for some cells, this caused a 7.7% reduction in the sample size from 2,142 to 1,956.

Because cells can be contiguous, the crime data can be expected to exhibit spatial autocorrelation, producing spatially correlated errors in the normal negative binomial models. Indeed, calculation of a Moran's (1948) I statistic for all crimes discussed below confirmed statistically significant ( $p < .001$ ) spatial auto-correlation.<sup>18</sup> To address this, we develop spatial autoregressive models by including a spatial lag variable in the model (Fotheringham, Brunson and

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<sup>16</sup> We are grateful to anonymous reviewers for this suggestion.

<sup>17</sup> The advantage of including this parameter in the model is that when there is no over-dispersion in the model, the parameter estimate is 0 and the negative binomial model reduces to the Poisson model.

<sup>18</sup> The Moran's I statistic was calculated using Anselin's GeoDa version 0.9.5-i. Significance was calculated using the random permutation procedure with 999 permutations. Results were substantively similar using the Queen or Rook contiguity.

Charlton, 2000). For the weight matrix, we include the eight adjacent cells surrounding each grid cell, producing a spatial lag variable that is the average of the counts for the specific crime in those adjacent cells.<sup>19</sup> The multivariate models reported in tables 2 and 3 were estimated using maximum likelihood methods in SAS Proc Genmod.

## RESULTS

### BIVARIATE RESULTS

To determine whether land use and crime are related, it seems reasonable to examine the data before moving on to regression equations. Figure 1 shows the percentage departure from the overall cell average for homicide, rape, robbery, and aggravated assault counts by the presence or absence of industry within a cell. Thus, the horizontal axis represents a cell with average counts of each offense. Cells containing industrial land uses have between 15 and 25% fewer violent crimes than the overall cell average, whereas those without industry experienced 5 to 15% higher than average homicides, rapes, robberies, and aggravated assaults. Of course, this figure does not control for other factors such as population and disadvantage.

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Figure 1 about here

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Figure 2 shows the percentage departure from the overall cell average count for each violent crime based on levels of disadvantage and the presence or absence of commercial land uses within the cell. The left two sets of columns represent cells with below average levels of socioeconomic disadvantage, whereas the right two sets represent cells with above average levels of disadvantage. From the left, the first and third groups of columns are cells without commercial land uses, whereas the second and fourth groups of columns are cells with commercial land uses present. Figure 2 suggests that the effects of commercial land use and disadvantage on violent crime may be

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<sup>19</sup> A recent example of the use of a spatial lag model for addressing spatial autocorrelation in the prediction of crime rates is Wang (2007).

conditional. For example, as one might expect, violent crimes are lowest in advantaged areas with no commercial land uses and highest in disadvantaged areas with commercial land uses. Yet, robbery is substantially higher in advantaged areas with commerce than disadvantaged areas with no commerce, whereas the reverse is true for homicide. From a social disorganization perspective, one might expect that both robbery and homicide would be higher or lower in areas with similar levels of disadvantage. Though not accounting for other factors, taken together, these figures suggest that land uses and crime are related but in potentially complicated ways.

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Figure 2 about here

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## NEGATIVE BINOMIAL REGRESSION ANALYSES

Turning to multivariate examinations of land use and crime, tables 2 and 3 present the results of negative binomial regression analyses of the effects of land uses and socioeconomic variables on the violent crime index and homicide, rape, robbery, and aggravated assault counts for 1,956 cells in Indianapolis. Table 2 considers main effects of a variety of land uses on individual violent crimes and an aggregate index of violent crime. Table 3 presents conditional effects of land uses and disadvantage on the violent crime index which combines cell counts for murder, rape, robbery and aggravated assault.

To examine overall model fit, a likelihood ratio test was calculated. The likelihood ratio is computed as two times the difference between the log-likelihoods of the models being compared. This difference is then compared to the  $\chi^2$  distribution. The degrees of freedom for the test equal the difference in the number of parameters between the two models being compared (Osgood and Chambers, 2000). In tables 2 and 3, each model is compared to a model with only an intercept and dispersion parameter. Calculating the likelihood ratio test for each of the equations in tables 2 and 3 shows that all models are significant at the .001 level.

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Table 2 about here

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Turning to the effects of individual variables, as one might expect, in all equations in table 2, the spatial lag variable is significant, showing that violent crime is positively correlated with violent crime in adjacent cells. Population size is also significantly positively related to all violent crimes for all equations, and the percentage of the population in the cell that is African American is significantly positively associated with all violent crimes except rape. The percentage of the population that is Hispanic in the cell is significantly positively related to the violent crime index, aggravated assault, and homicide, but not rape or robbery. The index of population stability is significantly negatively related to all violent crimes except robbery ( $p < .10$  for homicide).<sup>20</sup> Consistent with prior research, the socioeconomic disadvantage index is significantly positively related to all violent crimes in table 2 ( $p < .001$ ). However, as we will see in table 3, the effects of socioeconomic disadvantage on violent crime are conditioned by certain land uses.

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Table 3 about here

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Turning to the effects of specific land uses on violent crime, the presence of high density residential units in the cell (8 or more units per acre) was significantly positively ( $p < .001$ ) associated with all violent crimes in table 2, even controlling for population size and socioeconomic disadvantage. There appears to be something about such units that is associated with all types of serious violent crime, even controlling for the other factors in the model. Apparently high density housing units promote serious violent crime.

The percent of a cell devoted to commerce is significantly positively related to all crimes in table 2 except homicide, even net of the other factors in the model. From a routine activities

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<sup>20</sup> We tested numerous interaction effects with land use variables and the stability index but none were significant.

perspective, one would expect this result because commercial activities increase the frequency of offender and target contacts in the absence of capable guardians, *ceteris paribus*. The percentage of a cell devoted to industry is significantly negatively related to the violent crime index, robberies, and aggravated assaults, marginally negatively related to rape ( $p < .10$ ), but is unrelated to homicide in table 2. Although some would suggest that all nonresidential land uses are associated with higher crime, these results suggest that this is not always the case. From the routine activities perspective (Felson, 1987), these results make sense because industrial areas are not likely to attract large numbers of potential offenders, although they are not likely to be areas where large numbers of capable guardians are present. Although to our knowledge, no research has considered whether water and crime are related, we included water to be systematic. The percent of water in a cell was significantly negatively related to the violent crime index, robbery, and aggravated assault ( $p < .05$ ), but unrelated to homicide or rape. This suggests that water in an area decreases the number of violent crimes, most likely by decreasing the opportunities for offenders and victims to interact. We also examined whether the length of major streets in the cell influenced violent crime, net of the other factors in the model. As expected, we found that the lengths of major streets in a cell were significantly positively associated with violent crime overall and individually in all equations in table 2. Additional major streets likely increase the number of strangers in an area, and, *ceteris paribus*, increase the number of potential offenders and victims in an area, which may also make it more difficult to maintain informal social control. Additional major streets also increase the number of entry and exit points, which may make areas more attractive for offenders (see White, 1990 for a discussion of research on neighborhood permeability).<sup>21</sup>

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<sup>21</sup> We also considered a binary variable indicating the presence of major streets and a continuous variable that captured the total percentage of the land in a cell devoted to streets, highways, and interchanges. Both alternative specifications produced similar main and interaction effects to those reported in tables 2 and 3. We are grateful to anonymous reviewers for suggesting alternative specifications to probe the robustness of this relationship.

The presence of a cemetery in the cell was significantly negatively related to homicide and robbery ( $p < .05$ ), and marginally negatively related to the violent crime index ( $p < .10$ ). Thus, it appears that cemeteries reduce some kinds of crime, possibly by suppressing the number of potential offender-victim interactions. School land use was significantly negatively related to homicide ( $p < .05$ ), and marginally negatively related to rape ( $p < .10$ ), but unrelated to robbery, aggravated assault, or the violent crime index. These mixed findings contradict prior studies that have shown schools to be related to crime. Perhaps the explanation lies in a limitation of the current data. School land use includes all types of educational institutions, including public and private elementary and secondary schools and colleges and universities. Presumably public high schools might be more likely to be related to serious violent crimes than private elementary schools.

The presence of a hospital in a cell was also unrelated to violent crime in all equations in table 2. We had expected that hospitals might attract both offenders and victims and therefore increase the potential for violent crimes. Yet, unlike commercial areas, hospitals do not appear to be associated with violent crime. In addition, contrary to some prior studies (Lockwood, 2007; Smith et al., 2000), the percent of a cell devoted to park related land use was significantly negatively associated with aggravated assault ( $p < .01$ ) and marginally negatively related to homicide ( $p < .10$ ), but unrelated to the other violent crimes in table 2. Such a finding is somewhat surprising because one might expect parks to increase interactions between potential offenders and targets, in the absence of guardians and be areas where informal social control would be lower. Finally, the percent of vacant land in a cell was marginally positively related to robbery in table 2 ( $p < .10$ ) but unrelated to the other crimes. One explanation for this may be that in this context, vacant land means that there is no structure on the land, which can mean very different things depending on the context surrounding the vacant land. Thus, a vacant lot in a brand new subdivision is likely to have very different implications for violent crime than a vacant lot surrounded by boarded up buildings.

Finally, the residual land use category that we included was significantly negatively associated with the violent crime index, aggravated assault, and robbery, but not rape or homicide.<sup>22</sup>

#### THE CONDITIONAL EFFECTS OF LAND USE AND DISADVANTAGE ON VIOLENT CRIME

Table 3 considers whether the influences of land uses and disadvantage on violent crime are conditional. To avoid reporting on multiple analyses, we limit these analyses to the overall violent crime index and those results where there were consistent interactions between land uses and disadvantage (although numerous other interaction terms were examined). In general, the main effects of the control variables on violent crime are consistent with expectations and remarkably stable across the five equations reported in table 3. Specifically, the spatial lag variable, cell population, socioeconomic disadvantage, percent Black and percent Hispanic are all significantly positively related to the violent crime index, and the stability index is significantly negatively related to violent crime in all equations as expected (disadvantage is marginally significant in equation 1). In addition, the main effects for several land uses including high density housing, percent commercial, percent industrial, percent water, and the binary variable for the presence of a cemetery and the length of major streets variable achieve significance in all equations in table 3, and are in the expected direction. Parks, schools, hospitals, and the percentage of vacant land in a cell were unrelated to the violent crime index in all equations in table 3.

Turning to the examination of interaction effects, equation 1 of table 3 includes an interaction term for the presence of high density residential units and disadvantage, which is positive and significant ( $p < .01$ ). Thus, the effect of disadvantage on violent crime is conditioned by the presence of high density housing. Figure 3 illustrates the predicted number of violent crimes expected at

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<sup>22</sup> The substantive findings from tables 2 and 3 are similar whether this variable is included, excluded, or the sample is limited to cases with less than 20% of land uses in this miscellaneous category. Few cases (8.4%) had more than 20% of total land area in this category and many were already excluded because they also had zero population.

various levels of the disadvantage index depending on the presence or absence of high density residential units in the cell (assuming the cell contained no schools, cemeteries, or hospitals and other variables were at their means). Even in highly advantaged areas (i.e., the left side of the figure), areas with high density housing have somewhat higher expected numbers of violent crimes. However, as the area becomes more disadvantaged, the effect of high density housing on violent crime becomes more pronounced. Interestingly, predicted violent crime counts in highly advantaged cells with high density housing are only slightly lower than predicted violent crime counts in extremely disadvantaged areas with no high density housing. Thus, it appears that high density housing is associated with higher violent crimes but especially so in disadvantaged areas.

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Figure 3 about here

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Equation 2 includes an interaction term between the percent of a cell that is commercial and the disadvantage index. The significant negative interaction term ( $p < .001$ ) means that commercial land use actually blunts the relationship between disadvantage and violent crime. Figure 4 illustrates predicted violent crime counts in a cell at varying levels of disadvantage and percent of the land use that is devoted to commerce (with no high density housing, schools, cemeteries, or hospitals in the cell, and other variables at their means). In extremely advantaged areas (the far left side of the figure), crime is expected to be lowest in cells with no commerce and increase substantially as the percentage of the cell devoted to commerce increases. Yet, as disadvantage increases, the additional violent crimes one would expect with increasing commercial land use becomes much less. In extremely disadvantaged areas (the far right side of figure 4), the predicted number of violent crimes in the cell increases only slightly as the amount of commerce increases.<sup>23</sup> Several possibilities might

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<sup>23</sup> To probe whether this conditional relationship depended on the type of commercial activity, we ran additional analyses including the available subcategories of commerce. We found identical results for three of the four subcategories of commerce: office commercial, retail/community commercial, and heavy commercial, but not downtown mixed commercial land uses (which are only present in a small number of cells). Thus, although the

explain this finding. First, it could be that commercial activities in advantaged areas bring relatively larger numbers of motivated offenders than in disadvantaged areas where more of these offenders might already be located. Or it could be that commercial activities in advantaged areas are associated with much more attractive targets for offenders. Although we can only speculate without additional data, the current results challenge the notion that commerce is invariably associated with higher crime regardless of the socioeconomic context.

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Figure 4 about here

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Equation 3 includes the interaction term for the percent industry and disadvantage, which is significantly negative ( $p < .001$ ), meaning that industry blunts the impact of disadvantage on violent crime. Figure 5 illustrates predicted violent crimes at various levels of percent industry in a cell and disadvantage (net of the other variables as noted for figure 4). When there is no industry in a cell, there is a strong positive relationship between disadvantage and predicted violent crime counts. Yet, as the percentage of the cell devoted to industry increases, the relationship between disadvantage and violent crime lessens. If the percentage of the cell devoted to industry is two standard deviations above average, the predicted violent crimes are similar regardless of the level of disadvantage. It could be that industry provides a buffer against the increasing violence one would expect in more disadvantaged areas, by reducing opportunities for offenders and targets to come together, or it could be that the presence of industry increases informal social control by increasing the number of law-abiding citizens in an area. Of course, this is only speculation without individual-level data. These results suggest that physical environment and social ecology interact to produce crime.

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Figure 5 about here

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category of commerce is somewhat broad, it appears to be the case that most types of commercial activity are conditionally related to violent crime as reported for the broader category in Table 3.

Equation 4 includes the interaction term between the length of the major roads in the cell and disadvantage, which is significant and negative ( $p < .001$ ). Figure 6 illustrates the predicted number of violent crimes one would expect at various levels of the disadvantage index and road lengths in the cell (with no schools, cemeteries, or hospitals in the cell, and other variables at their means). In advantaged areas, areas with long segments of major roads would be expected to have more than twice as many violent crimes as those with no major roads. Yet, in disadvantaged areas the difference between predicted violent crime counts in cells with no major roads or long segments of major roads is much smaller. The explanation for this may be similar to the presence of commerce. It could be that major roads create additional avenues for motivated offenders to enter and exit areas (see White, 1990). Or it could be that areas with major roads make informal social control more difficult. In advantaged areas this might overwhelm social control capacity, whereas in disadvantaged areas there is likely to be limited informal social control capacity to overwhelm. Or it could be that in disadvantaged areas with major roads, citizens are especially vigilant because of the larger number of people. Those in advantaged areas might not feel a similar need to be vigilant and therefore be more vulnerable (see Wilcox et al., 2004 for a similar argument).

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Figure 6 about here

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So what are we to make of these results? Clearly, we cannot assume that the effects of land uses on crime are unconditional, which may explain some of the inconsistent findings of previous studies that have typically only examined main effects of land uses (or as Smith et al., 2000 note, fail to find interaction effects with larger units of analysis). Such findings suggest that it is important to re-examine the reasons we would expect land uses to matter for crime. Prior studies have generally focused on either increased opportunities or reduced informal social control (separately) as the mechanisms by which land uses influence crime. These results are consistent with the notion that

opportunity and informal social control interact to produce variation in violent crime in urban areas. Of course, we can only speculate on these issues without additional data that is beyond the scope of the current study.

#### CHECKS FOR ROBUSTNESS

To examine the robustness of the findings reported in tables 2 and 3, we conducted a number of additional analyses. First, equation 5 of Table 3 shows that the reported effects remain when all interactions are included. Second, it is important to note that numerous additional interaction effects were tested for land use and socioeconomic characteristic combinations (e.g., hospital, schools, water, vacant land, and cell population by disadvantage interactions, as well as interactions with the stability index), and none were consistently significant. We ran sensitivity analyses for the effects of specific variables. For example, to explore whether the results were influenced by the inclusion of cells with few residents, when models were restricted to cells with 20 or more residents or 50 or more residents, substantively similar estimates were produced. We also ran models that employed mean substitution to replace missing data and found only two differences from those reported in tables 2 and 3. In some models, parks became statistically significantly negatively associated with violent crimes and the stability index declined to non-significance in some models. Otherwise substantive conclusions were identical to those reported.

To investigate the potential that outliers might influence the significance of land uses, for the 1000-foot cell models we restricted the analyses to cells with less than 80 percent devoted to industrial, water, or park uses, and found similar results. We observed no obvious outliers for any of the dependent variables. We ran models limiting the sample to cells with less than 20 percent of residual land uses and found similar results to those reported here.

We conducted analyses using 500 X 500 feet cells and these results showed that the effects of specific land uses such as percent commercial and percent industrial interacted with the level of disadvantage in an area to produce violent crime variation. Thus, substantively similar conclusions

about the direct and conditional impacts of land use and disadvantage were reached with smaller units of analysis (and a much larger N).

We also conducted analyses which calculated socioeconomic variables with the 2000 census area characteristics within a ½ mile radius of the cell rather than the cell itself. Again, substantively similar results were produced regarding the direct and conditional effects of land uses and disadvantage on violent crimes. Finally, we calculated a spatial lag variable of the disadvantage index, and models which controlled for the average level of disadvantage in the 8 surrounding cells (in a 3 X 3 grouping of cells) produced results substantively equivalent to those reported in table 3.

### **DISCUSSION AND CONCLUSIONS**

Some prior research has suggested that land uses and crime are related, although studies have tended to focus on specific land uses and generally investigated only main effects of land uses. The current study moved beyond prior research by considering main and conditional effects of a variety of land uses on several serious violent crimes. Using socioeconomic and land use information for regular shaped 1000 X 1000 feet cells in the IPD service area we found that specific land uses are related to a violent crime index of UCR reported crimes, and homicide, rape, robbery, and aggravated assaults, net of the variables typically included in violent crime models. Specifically, we found that commercial activity and high density residential land uses were associated with higher violent crime counts, whereas cemeteries, water, and industry were associated with lower counts for some violent crimes. Thus, it does not appear that all nonresidential land uses are associated with higher crime. In addition, the influences of several land uses on violent crime counts were conditional on the socioeconomic characteristics of the cell. Specifically, we found that the effects of busy roads, high density residential units, commerce and industrial land uses on violent crime counts all depended on the disadvantage index (and vice versa). Yet, high density residential units enhanced the impact of disadvantage on violent crime, whereas commerce, industry, and busy roads dampened the effect of disadvantage. Thus, both residential and nonresidential land uses can increase or decrease crime but

their effects depend on the socioeconomic context surrounding them.

In addition to confirming the importance of land uses for explaining violent crime, net of socioeconomic variables, the current study has implications for both systemic social disorganization/collective efficacy theories and routine activities/opportunity theories. As we noted earlier, there has been exploration of land use-crime relationships at least since the early days of the Chicago school. For example, Shaw and Mckay's classic discussion of transition zones shows that land uses are systematically related to social (dis)organization. They noted that the highest delinquency areas were those that were in close proximity to industrial or commercial areas. Yet, Shaw and Mckay (1972[1942]: 143) dismissed the notion that land uses caused delinquency:

There is, of course, little reason to postulate a direct relationship between living in proximity to industrial developments and becoming delinquent. While railroads and industrial properties may offer a field for delinquent behavior, they can hardly be regarded as a cause for such activities.

Consistent with this, subsequent research and theorizing in systemic social disorganization has primarily focused on *social* ecology rather than land uses and so, with few exceptions (Sampson and Raudenbush 1999, 2004; Smith et al. 2000; Taylor, 1997; Wilcox et al., 2004), mainstream research on social disorganization/collective efficacy (Morenoff, Sampson, and Raudenbush, 2001; Sampson and Groves, 1989; Sampson, Raudenbush, and Earls, 1997) has excluded land use variables. Yet, the current study suggests that Shaw and Mckay may have been incorrect to presume that land uses themselves would be unlikely to have independent effects on crime (see also Brantingham and Jeffery, 1981). One of the key findings of the original Shaw and Mckay study was that neighborhoods tended to have stable rates of delinquency despite changes in their racial and ethnic composition over time. They interpreted this to mean that neighborhood social structural characteristics created some enduring constraints on the ability of neighborhoods to generate informal social control. It seems quite likely that they undersold the importance of how the enduring

*physical* characteristics of neighborhoods also structured social interactions in patterned ways that created opportunities for delinquency—which is even suggested by the reference to industrial areas as “offering a field for delinquent behavior” in the quote above. Given the relatively stable nature of land use configurations in areas over time, it seems likely that some of the observed stability in neighborhood delinquency rates was due to the enduring physical characteristics of the neighborhoods. Of course, this speculation goes beyond the findings of the current cross-sectional study but our results suggest that theorists explicitly need to bring physical structure back into social disorganization/collective efficacy theories.

This study also suggests that the focus on the breakdown of social institutions in systemic social disorganization theory may be overly narrow. In addition to being amorphous, difficult to measure social constructs, social institutions such as religion, education, and the economy have tangible physical manifestations that structure social interactions in patterned ways. Thus, the importance of education or commerce may not only be in how it influences the capacity for informal social control but also in how the physical land uses associated with such activities structure social interaction and, as a result, opportunities for crime.

The current study also suggests that theories focusing on the breakdown of social institutions only tell part of the story. Ecological theories such as social disorganization and institutional anomie theories also need to focus on social institutions at work and the complex interplay of social institutions that generate particular land use configurations. Students of urban politics are keenly aware that zoning and resulting land use configurations are not natural phenomena. Therefore, the placement of certain land uses is intimately tied to how neighborhoods can or fail to mobilize to say “Not in My Back Yard” to some land uses perceived as undesirable. Or, conversely, how well neighborhoods mobilize to create or maintain desirable neighborhoods through zoning or code enforcement can have important effects on crime (see Bursik, 1989).

The findings of the current study also have implications for land use planners. For example, it

appears that busy roads and high density housing can produce additional violent crime but busy roads have more of an impact in advantaged areas whereas high density housing has more of an impact in disadvantaged areas. It also appears that industry may be a buffer against violence, especially in disadvantaged areas.

This study also suggests new avenues of development for routine activities/opportunity theories of crime. For example, land uses are mentioned in Sherman et al.'s (1989) seminal work on "hot spots" (see also Kennedy and Forde, 1990). Such stability of crime hot spots was recently confirmed in Weisburd et al.'s (2004) study of crime trajectories of street segments in Seattle. Yet, such work is too often ad hoc. Hot spots, however, don't simply appear at random, nor do they result solely from the socioeconomic characteristics of the neighborhood. They are the result of how particular land uses structure the routine activities of daily life and social interactions in patterned ways. Therefore, small area research would benefit from additional consideration of how to systematically include land use information and how such land uses structure social interactions and opportunities for crime. Including land use information could help to make sense of how routine activities and the corresponding opportunities for crime come together in a structured way to move beyond the empirically-driven approaches often taken in such research.

The findings of the current study also provide additional evidence supporting the integration of social disorganization and routine activities theories. For example, Smith et al. (2000) began to empirically integrate routine activities and social disorganization theories in their study of robbery in face blocks (see also Wilcox, Land, and Hunt, 2003; Wilcox, Quisenberry, and Jones, 2003, 2004). Although such a study is a good beginning, more theoretical work is necessary to fully integrate situational and ecological theories, which is likely the best way to capitalize on the strengths of both.

Despite the contributions of the current study, some limitations should be noted. One weakness of the current study is the inability to distinguish within certain categories of land uses. For example, the current data could not distinguish liquor establishments from other kinds of commercial

businesses or elementary schools from high schools. Future research needs to examine more closely the extent to which different kinds of commercial activity increase violent crime more than others. A second limitation of this study is that we did not have access to data on property crimes. We did, however, find fairly consistent effects of land uses across violent crimes. Future research should consider whether the effects of land uses found in the current study also apply for property crimes such as burglary and theft. A third limitation of this study is that it is cross-sectional. Given the stability of land use configurations, it seems unlikely that crime is driving land uses (at least in the short-term). Yet, future research should examine long term dynamic models of land use and crime. We were also unable to measure informal social control, incivilities, or opportunity directly in the current study. Therefore, our study cannot address such issues. Fully explicating the role of land uses in generating violent crime awaits a study that can incorporate measurements of these key intervening variables. Finally, our study only includes land use information from one city. Although there is little reason to believe that the kinds of land uses examined here would have different effects in other cities, and the data analyzed here come from a fairly typical older large Midwest city, such comparisons with other cities in future research would help clarify the generality of the findings of the current study.

In sum, we find that specific land uses affect violent crime, and the effects of such land uses on violent crime vary depending on the socioeconomic disadvantage in the area. We believe that such results suggest important revisions to existing ecological and situational theories are necessary to incorporate land uses into theoretical models. Land uses also may provide a way to integrate ecological and situational models to develop a fuller explanation of crime.

**Table 1. Univariate Statistics for Variables Used in Multivariate Analysis (N=1,956).**

<b>Variable</b>	<b>Mean</b>	<b>Std. Deviation</b>	<b>Minimum</b>	<b>Maximum</b>
<b>Violent Crimes per Cell</b>	10.3	14.08	0.00	114.00
<b>Homicides Per Cell</b>	0.55	1.08	0.00	8.00
<b>Rapes Per Cell</b>	0.57	1.04	0.00	11.00
<b>Robberies Per Cell</b>	4.36	7.76	0.00	67.00
<b>Agg. Assaults Per Cell</b>	4.88	6.79	0.00	61.00
<b>Cell Population</b>	154.27	111.27	1.00	760.46
<b>Percent Black</b>	40.46	37.15	0.00	100.00
<b>Percent Hispanic</b>	3.86	5.82	0.00	54.41
<b>Stability Index</b>	0.0316	0.94	-5.39	2.19
<b>Disadvantage Index</b>	0.00	1.00	-3.54	3.25
<b>Hi Density Residential (y/n)</b>	0.79	0.41	0.00	1.00
<b>Commercial Percent</b>	10.19	18.73	0.00	100.00
<b>Industrial Percent</b>	10.78	23.23	0.00	100.00
<b>Water Percent</b>	0.92	6.34	0.00	83.37
<b>Major Road Total Length</b>	74.89	855.39	0.00	4742.0
<b>Cemetery in Cell (y/n)</b>	0.03	0.16	0.00	1.00
<b>School in Cell (y/n)</b>	0.13	0.34	0.00	1.00
<b>Hospital in Cell (y/n)</b>	0.03	0.18	0.00	1.00
<b>Park Percent</b>	3.28	12.32	0.00	100.0
<b>Vacant Percent</b>	5.60	10.86	0.00	98.50
<b>Residual land Use Percent</b>	5.04	11.72	0.00	100.00

**Table 2. Negative Binomial Regressions of Land Uses and Socioeconomic Variables on UCR Violent Crimes in 1000 X 1000 Feet Grid Cells in Indianapolis (N=1956).**

	<b>Violent crime</b>	<b>Homicide</b>	<b>Robbery</b>	<b>Aggravated Assault</b>	<b>Rape</b>
<b>Intercept</b>	-0.2060* (0.1014)	-3.2321*** (0.2166)	-1.272*** (0.1367)	-0.7147*** (0.1099)	-2.3109*** (0.1953)
<b>Spatial Lag</b>	0.0305*** ( 0.0030)	0.1846** ( 0.0633)	0.0563*** ( 0.0068)	0.0877*** ( 0.0062)	0.2737*** ( 0.0633)
<b>Cell Population</b>	0.0042*** (0.0003)	0.0037*** (0.0005)	0.0046*** (0.0004)	0.0033*** (0.0003)	0.0035*** (0.0005)
<b>Percent Black</b>	0.0048*** (0.0007)	0.0141*** (0.0014)	0.0038*** (0.0009)	0.0046*** (0.0008)	0.0008 (0.0013)
<b>Percent Hispanic</b>	0.0097* (0.0041)	0.0195** (0.0063)	0.0018 (0.0050)	0.0138** (0.0043)	0.0094 (0.0061)
<b>Stability Index</b>	-0.0629* (0.0289)	-0.0905+ (0.0527)	-0.0406 (0.0373)	-0.0971** (0.0307)	-0.1112* (0.0507)
<b>Disadvantage Index</b>	0.2687*** (0.0298)	0.3302*** (0.0539)	0.1993*** (0.0374)	0.2925*** (0.0326)	0.3099*** (0.0532)
<b>Hi Density Residential (y/n)</b>	0.5922*** (0.0641)	0.7182*** (0.1601)	0.6296*** (0.0867)	0.5603*** (0.0738)	0.5432*** (0.1444)
<b>Commercial Percent</b>	0.0150*** (0.0014)	0.0044 (0.0027)	0.0230*** (0.0018)	0.0050** (0.0015)	0.0050* (0.0025)
<b>Industrial Percent</b>	-0.0037** (0.0013)	-0.0043 (0.0029)	-0.0035* (0.0017)	-0.0049** (0.0015)	-0.0051+ (0.0027)
<b>Water Percent</b>	-0.0137** (0.0041)	-0.0000 (0.0072)	-0.0178** (0.0060)	-0.0150** (0.0047)	-0.0111 (0.0087)
<b>Park Percent</b>	-0.0012 (0.0020)	-0.0037+ (0.0022)	0.0004 (0.0026)	-0.0057** (0.0022)	0.0013 (0.0035)
<b>Major Roads Total Length</b>	0.0004*** (0.0000)	0.0002*** (0.0000)	0.0005*** (0.000)	0.0003*** (0.0000)	0.0003*** (0.0000)
<b>Cemetery in Cell (y/n)</b>	-0.2830+ (0.1453)	-0.6800*** (0.3616)	-0.6688** (0.2139)	-0.0922 (0.1574)	-0.5161 (0.3557)
<b>School in Cell (y/n)</b>	0.0179 (0.0618)	-0.3023* (0.1188)	-0.0075 (0.0801)	0.0670 (0.0657)	-0.1990+ (0.1121)
<b>Hospital in Cell (y/n)</b>	0.0289 (0.1148)	-0.1438 (0.2039)	-0.0762 (0.1518)	0.0245 (0.1197)	-0.0780 (0.1882)
<b>Vacant Percent</b>	0.0021 (0.0023)	0.0075 (0.0038)	0.0051+ (0.0030)	-0.0001 (0.0025)	0.0051 (0.0040)
<b>Residual Land Use Percent</b>	-0.0085*** (0.0021)	-0.0026 (0.0040)	-0.0080** (0.0028)	-0.0089* (0.0023)	-0.0042 (0.0040)
<b>Dispersion</b>	0.5763 (0.0255)	0.3587 (0.0640)	0.8206 (0.0414)	0.5298 (0.0291)	0.4202 (0.0701)
<b>Log Likelihood</b>	38933.8***	-1112.2***	10335.0***	10888.7***	-1299.2***

Note: Standard errors in parentheses, + p < .10, \* p < .05, \*\* p < .01, \*\*\* p < .001 (2-tailed tests).

**Table 3. Negative Binomial Regressions of Land Use and Socioeconomic Variable Interactions on UCR Violent Crimes in 1000 X 1000 Feet Grid Cells in Indianapolis (N=1956).**

	Equation 1	Equation 2	Equation 3	Equation 4	Equation 5
<b>Intercept</b>	-0.2445* (0.1019)	-0.1768+ (0.1010)	-0.1815+ (0.1014)	-0.1918+ (0.1013)	-0.1742+ (0.1016)
<b>Spatial Lag</b>	0.0295*** ( 0.0030)	0.0301*** ( 0.0030)	0.0298*** ( 0.0030)	0.0306*** ( 0.0030)	0.0288*** ( 0.0030)
<b>Cell Pop.</b>	0.0042*** (0.0003)	0.0041*** (0.0003)	0.0041*** (0.0003)	0.0042*** (0.0003)	0.0041*** (0.0003)
<b>Pct. Black</b>	0.0046*** (0.0007)	0.0047*** (0.0007)	0.0046*** (0.0007)	0.0047*** (0.0007)	0.0044*** (0.0007)
<b>Pct. Hispanic</b>	0.0090* (0.0041)	0.0099* (0.0041)	0.0099* (0.0041)	0.0102* (0.0041)	0.0099* (0.0041)
<b>Stability Index</b>	-0.0720* (0.0290)	-0.0676* (0.0286)	-0.0622* (0.0288)	-0.0642* (0.0287)	-0.0735* (0.0287)
<b>Disadvantage Index</b>	0.1129+ (0.0605)	0.3308*** (0.0325)	0.3116*** (0.0317)	0.3422*** (0.0362)	0.2982*** (0.0676)
<b>Hi Density Residential (y/n)</b>	0.6357*** (0.0652)	0.5984*** (0.0638)	0.6015*** (0.0640)	0.5791*** (0.0641)	0.6242*** (0.0647)
<b>Commercial Pct.</b>	0.0150*** (0.0014)	0.0139*** (0.0014)	0.0150*** (0.0014)	0.0145*** (0.0014)	0.0138*** (0.0014)
<b>Industrial Pct.</b>	-0.0035** (0.0013)	-0.0040** (0.0013)	-0.0032* (0.0013)	-0.0039* (0.0013)	-0.0035** (0.0013)
<b>Water Pct.</b>	-0.0137*** (0.00401)	-0.0149*** (0.0041)	-0.0133** (0.0041)	-0.0131** (0.0040)	-0.0139*** (0.0041)
<b>Park Pct.</b>	-0.0009 (0.0019)	-0.0016 (0.0020)	-0.0015 (0.0020)	-0.0013 (0.0020)	-0.0016 (0.0020)
<b>Major Roads Total Length</b>	0.0004*** (0.0000)	0.0004*** (0.0000)	0.0004*** (0.0000)	0.0004*** (0.0000)	0.0004*** (0.0000)
<b>Cemetery in Cell (y/n)</b>	-0.2789+ (0.1449)	-0.2866* (0.1448)	-0.2915* (0.1450)	-0.2964* (0.1445)	-0.2993* (0.1439)
<b>School in Cell (y/n)</b>	0.0097 (0.0618)	0.0051 (0.0617)	0.0201 (0.0617)	0.0201 (0.0617)	0.0060 (0.0615)
<b>Hospital in Cell (y/n)</b>	0.0348 (0.1150)	0.0334 (0.1140)	0.0168 (0.1145)	0.0549 (0.1144)	0.0414 (0.1138)
<b>Vacant Pct.</b>	0.0018 (0.0023)	0.0016 (0.0023)	0.0016 (0.0023)	0.0016 (0.0023)	0.0008 (0.0023)
<b>Residual Land Use Percent</b>	-0.0081*** (0.0021)	-0.0083*** (0.0021)	-0.0085*** (0.0021)	-0.0087*** (0.0021)	-0.0083*** (0.0021)
<b>Disadvantage* Hi Density Residential</b>	0.1864** (0.0633)				0.1296* (0.0657)
<b>Disadvantage* Pct. Commercial</b>		-0.0059*** (0.0012)			-0.0046*** (0.0013)
<b>Disadvantage* Industry Pct.</b>			-0.0052*** (0.0013)		-0.0049** (0.0013)
<b>Disadvantage* Road Length</b>				-0.0001*** (0.0000)	-0.0001* (0.0000)
<b>Dispersion</b>	0.5749 (0.0254)	0.5671 (0.0252)	0.5714 (0.0253)	0.5704 (0.0254)	0.5599 (0.0249)
<b>Log Likelihood</b>	38938.1***	38945.1***	38941.8***	38940.3***	38926.3***

Note: Standard errors in parentheses, + p < .10, \* p < .05, \*\* p < .01, \*\*\* p < .001 (2-tailed tests).

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## **APPENDIX 1. DISCUSSION OF GRID CELLS AS THE UNITS OF ANALYSIS**

We chose 1000-foot grid cells as the units of analysis because other units of analysis presented a variety of problems. An obvious choice for this type of spatial analysis would be census subdivisions, either census tracts or block groups, which are familiar and widely used. We felt that these were inappropriate for the current study for several reasons. First, these units are relatively large and would have very significant heterogeneity in terms of land uses, reducing the ability to distinguish the relationship between land use and crime. Second, because these units are defined to have (very roughly) equal populations, they vary significantly in terms of land area, further confounding the analysis of the spatial relationship between crime and land use. A final issue arises from the fact that the boundaries of these units are generally streets. The UCR data have all been geocoded to street centerlines. The geocoded locations are not offset to the side of the street on which the address is located. This is reasonable because incidents can literally occur in the middle of the street, with the address being used to identify location on the street as opposed to a parcel on either side of the street. For crimes occurring on streets that form the boundaries of these units, ambiguity would exist as to which tract or block group the crimes should be assigned.

Because census tracts and block groups are so widely employed in spatial analysis, there is a tendency to assume that these are somehow “natural” units. Such an assumption seems potentially problematic. Census tracts have been defined locally to be somewhat homogeneous areas. However, this is limited by the constraints of establishing census tracts with roughly comparable populations meeting the census criteria and tracts were often delineated decades ago. Such tracts may have been relatively homogeneous when created but less so now, given population changes over time. For block groups, no claim is made that these subdivisions reflect natural areas. They are defined for administrative convenience by the Census Bureau.

Using census blocks would provide areas more appropriate for reducing the heterogeneity of land use. However, the use of these units is highly problematic given IPD’s assignment of the crimes

to the street centerlines. Nearly all of the crimes would be assigned to the boundaries between the census blocks, creating difficulties in consistently assigning the crimes to census blocks.

Perhaps the most reasonable “natural” units for analysis, suggested by one reviewer, would be face blocks, single street segments of blocks. For areas with regular, rectangular blocks, these are relatively well-defined units. However, in areas with irregular street patterns, the definition of the face blocks becomes more ambiguous. Because of the structure of the UCR crime data provided by IPD, many crimes have been geocoded to street intersections. This raises the ambiguity of assigning those crimes to the (typically four) face block street segments at the intersection. Our use of grid cells largely solves the problem of assigning the geocoded crimes to the correct unit. Though it is possible that a grid cell boundary could intersect with a crime location, the probability of an *exact* intersection is extremely small.

The major argument for using the grid cells as opposed to census tracts or block groups is to reduce the heterogeneity of land use within the units of analysis (Map 3 shows a comparison of block groups with the grid cells for Marion County). This cannot, of course, address potential issues in the heterogeneity of socioeconomic characteristics within the units of analysis for which the census reports those characteristics. Socioeconomic characteristics are necessarily derived from the census data and are estimated for the grid cells by making the assumption that the characteristics are uniform within the census units. However, for those characteristics available from the full-count, census block data, block data were used to estimate grid cell values. The assumption is made only of homogeneity within the small areas of the blocks, not the larger block group areas. For those characteristics from the sample data, reported at the block group level as the smallest unit (foreign born, lived in same residence, unemployment, poverty, and household income), the assumption is necessarily being made of homogeneity within the block groups for estimation for the grid cells.

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Map 3 about here

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**Appendix 2. Bivariate Correlation Matrix for 1000 X 1000 Feet Cells, N=1,956.**

	1	2	3	4	5	6	7	8	9	10	11	12	13
<b>1. Violent Crime</b>	-												
<b>2. VC lag</b>	.58*	-											
<b>3. Homicide</b>	.57*	.40*	-										
<b>4. Hom lag</b>	.44*	.73*	.46*	-									
<b>5. Rape</b>	.60*	.41*	.35*	.29*	-								
<b>6. Rape lag</b>	.49*	.81*	.30*	.54*	.38*	-							
<b>7. Robbery</b>	.89*	.44*	.39*	.30*	.46*	.39*	-						
<b>8. Robbery lag</b>	.50*	.91*	.29*	.55*	.37*	.74*	.44*	-					
<b>9. Agg Assault</b>	.87*	.58*	.54*	.46*	.50*	.47*	.57*	.44*	-				
<b>10. Aggass lag</b>	.57*	.92*	.41*	.72*	.38*	.70*	.37*	.68*	.63*	-			
<b>11. Cell Pop</b>	.48*	.50*	.31*	.29*	.38*	.48*	.35*	.45*	.50*	.46*	-		
<b>12. % Black</b>	.19*	.25*	.35*	.54*	.06*	.08*	.09*	.12*	.23*	.29*	.02	-	
<b>13. % Hispanic</b>	.20*	.21*	.06*	.02	.19*	.28*	.20*	.23*	.15*	.15*	.24*	-.25*	-
<b>14. Stability</b>	.32*	-.36*	-.16*	-.20*	-.25*	-.33*	-.28*	-.36*	-.27*	-.31*	-.26*	.08*	-.38*
<b>15. Disadvant.</b>	.33*	.42*	.36*	.53*	.24*	.37*	.20*	.28*	.36*	.46*	.08*	.47*	-.05*
<b>16. Hi Den Res.</b>	.26*	.32*	.20*	.26	.20*	.31*	.17*	.23*	.29*	.34*	.43*	.02	.12*
<b>17. % Commer.</b>	.20*	.07*	.01	-.03	.05*	.01	.30*	.14*	.06*	.02	-.19*	-.03	.08*
<b>18. % Industry</b>	-.19*	-.18*	-.13*	-.15*	-.13*	-.14*	-.15*	-.16*	-.18*	-.17*	-.41*	-.15*	.21*
<b>19. % Water</b>	-.05*	-.04	-.01	.01	-.03	-.05*	-.05*	-.06*	-.04	-.02	-.12*	.05*	.04
<b>20. % Park</b>	-.06*	-.03	-.01	.03	-.03	-.03	-.06*	-.06*	-.06*	-.01	-.13*	.09*	.02
<b>21. Major Road</b>	.28*	.07*	.09*	.04	.14*	.03	.31*	.05*	.19*	.07*	-.08*	-.05*	.05*
<b>22. Cemetery</b>	-.08*	-.06*	-.05*	-.02	-.06*	-.07*	-.07*	-.08*	-.06*	-.03	-.12*	.02	-.04
<b>23. School</b>	.01	-.02	-.04	-.03	-.02	-.03	-.01	-.03	.03	-.01	.04	-.01	.03
<b>24. Hospital</b>	.02	.05*	.01	.01	.02	.03	.01	.04	.03	.05*	-.02	-.02	.03
<b>25. % Vacant</b>	.01	.03	.10*	.14*	.02	.02	-.02	-.02	-.03	.05*	-.04	.18*	-.04
<b>26. % Resid. LU</b>	-.07*	-.03	-.04	.01	-.04	-.01	-.06*	-.02	-.07*	-.03	-.19*	.01	.01

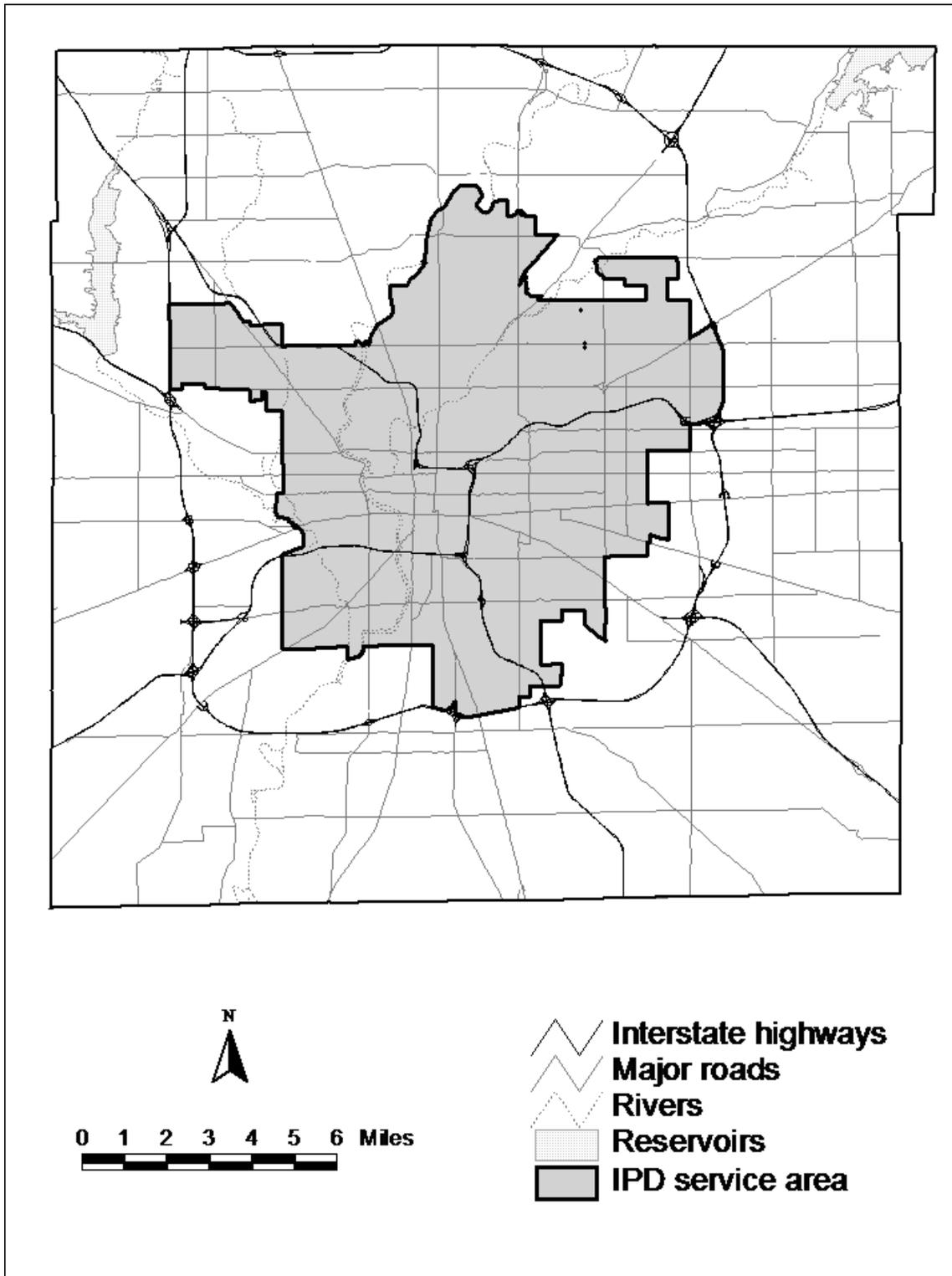
\* p < .05, two-tailed test.

**Appendix 2. Bivariate Correlation Matrix for 1000 X 1000 Feet Cells, N=1,956.**

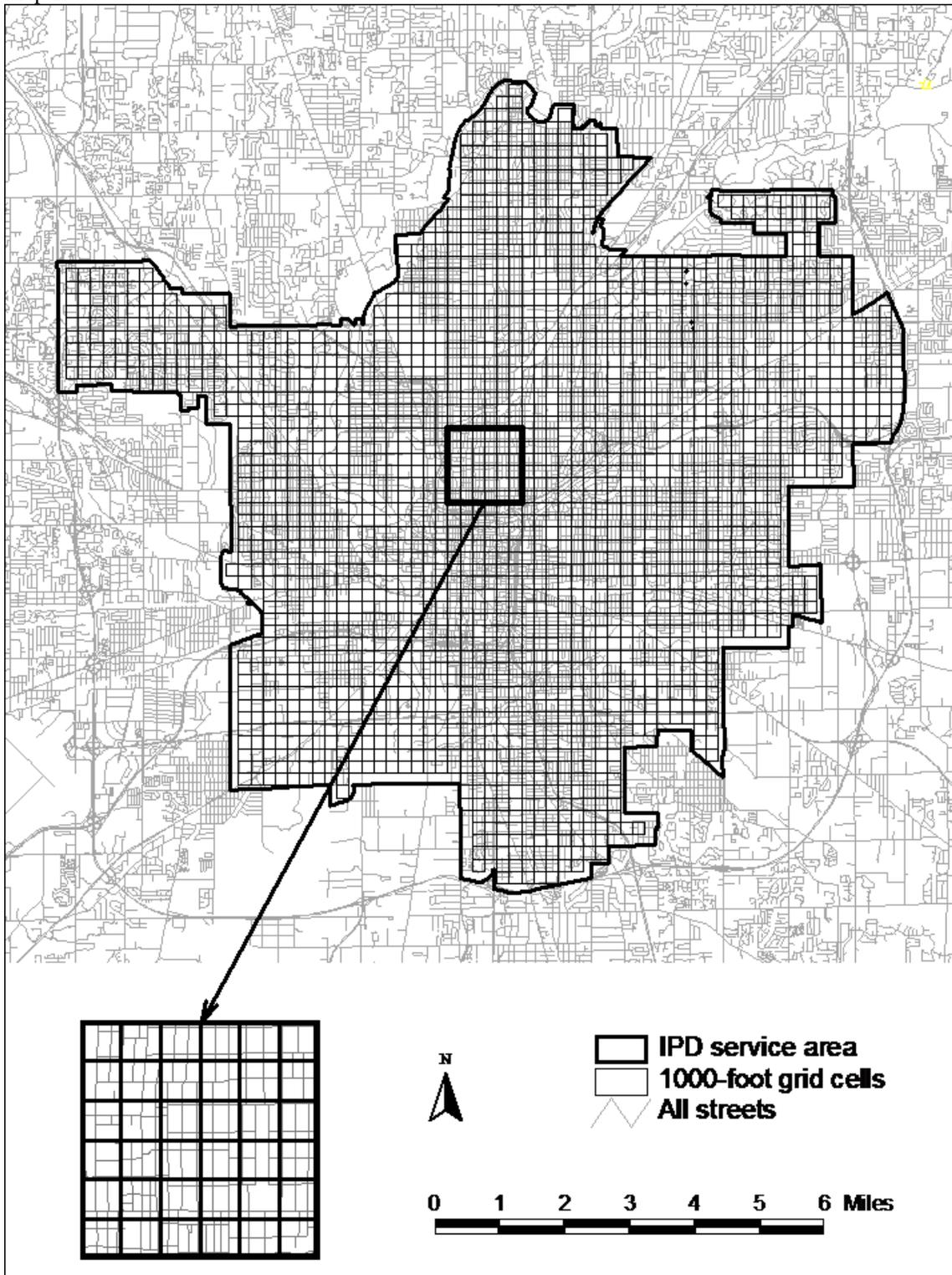
	14	15	16	17	18	19	20	21	22	23	24	25	26
<b>15. Disadvant.</b>	-.28*	-											
<b>16. Hi Dens Res.</b>	-.12*	.18*	-										
<b>17. %Commer.</b>	-.23*	.03	-.13*	-									
<b>18. %Industry</b>	.09*	.11*	-.25*	-.07*	-								
<b>19. %Water</b>	-.11*	.04	-.08*	-.05*	-.02	-							
<b>20.% Park</b>	.03	.06*	-.01	-.08*	-.10*	.02	-						
<b>21. Major Road</b>	-.17*	.02	.04	.34*	.05*	.04*	-.01	-					
<b>22. Cemetery</b>	.03	-.02	-.01	-.04	-.02	-.02	-.01	.01	-				
<b>23. School</b>	-.15*	-.02	-.03	-.06*	-.13*	.07*	.02	-.01	-.04	-			
<b>24. Hospital</b>	-.17*	.06*	-.02	.01	-.04	-.01	-.01	.06*	.01	.01	-		
<b>25. %Vacant</b>	-.01	.23*	-.01	-.01	-.01	-.03	-.07*	.01	.01	-.06*	-.02	-	
<b>26. % Resid. LU</b>	-.14*	.13*	-.09*	-.01	.06*	.05*	-.05*	-.01	-.02	-.03	.01	-.01	-

\* p < .05, two-tailed test.

Map 1.



Map 2.



Map 3.

