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Friction of distance, violent crime and murder rate

Reginald Arkell, AICP, rltp.ra@att.net

Abstract: "Friction of distance" in human geography holds that increasing separation between locations within the built environment imposes costs in the form of money, time, effort, and negative externalities such as stress and crime. This study considered the ability of land use and roadway travel characteristics together as a viable way to estimate the known relationship of distance in terms of suburbanization with violent crime measured by murder rates in primary cities for 147 of the largest U.S. metropolitan statistical areas (MSAs). Methodologies consisted of multivariable cross-sectional ordinary least squares (OLS) linear and quantile regression. Development of multiple models revealed that MSA-weighted population density consistently held statistically significant inverse relationships with primary city murder rates; elasticities ranged from -0.18 to -0.31 at the mean. The proportion of residents near city centers also had similar associations at smaller elasticities. Respective measures of urban area freeway lane kilometers per 100,000 primary city population and urban area per capita vehicle kilometers traveled each as sole suburbanization independent variables had elasticities of 0.12 and 0.40 without substantively compromising model strength. Average annual hours of delay per auto commuter and number of vehicles per primary city square kilometers had similar elasticities while increasing prognostic accuracy of certain models. Statistical significance of the suburbanization independent variables was as high as eight out of nine quantiles. Extenuating support is given to theories of urbanism, metropolitan expansion, spatial mismatch, and social disorganization as friction of distance exacerbates detrimental inner-city conditions known to facilitate violent crime.

Keywords: freeway lane kilometers, murder rate, suburbanization, vehicle kilometers traveled, violent crime, weighted population density

1 Introduction

The 2015 violent crime rate (offenses per 100,000 population) for primary cities (alternatively referred to as core or central cities) of the 100 largest U.S. metropolitan statistical areas (MSAs) was more than a four-fold increase compared to 1950. The murder rate increased about 80% during the period (Federal Bureau of Investigation, 1951, 2015). Violent crime rates in U.S. primary cities of the 100 largest MSAs have consistently been up to and more than twice that of suburban areas in the 1980s through 2018 (Bodah et al., 2021; Kneebone & Raphael, 2011). Further, violent crime rates generally decreased with distance from urban cores. However, the gap between central city and suburban violent crime rates declined during the period. This was due in part to a substantial drop in central city arrest rates (Bodah et al., 2021). U.S. violent crime rates both overall and in large cities increased for years after the mid 1950's before peaking in the 1980's when they began to fall for more than two decades (Friedman et al., 2017; Justice Research and Statistics Association, 2000). Yet, violent crime and murder rates in large cities have varied widely during this decline (Friedman et al., 2017).

There is a lack of consensus in the literature regarding causes of decreasing U.S. non-violent and violent crime during recent decades. Some researchers have framed possible

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reasons pursuant to the routine activities theory (Cohen & Felson, 1979) which explains crime via 3 concepts: motivated offender; increased opportunities; and lack of oversight or guardianship (Baumer & Wolff, 2012; Farrell et al., 2014; Tcherni-Buzzeo, 2018). Farrell et al. (2014, p. 438) organized explanative hypotheses into 17 categories with security improvements seemingly most promising (see Appendix A).

Blumstein and Wallman (2006) analyzed numerous studies of U.S. violent crime rates and gave most credibility to rising incarceration rates, which were likely responsible for up to one-fourth or more of the drop in violent crime. They found other factors to be less convincing and relatively minor.

Within human geography, "friction of distance" posits that greater spatial separation between elements of the urban landscape introduces increased expenditures—financial, temporal, and physical—alongside negative side effects such as psychological strain and crime. Studies have demonstrated the association between decreasing racial segregation/spatial unevenness, and reductions in violent crime (Fabio et al., 2011; Light & Ulmer, 2010; Shihadeh & Flynn, 1996).

Studies have identified bidirectional links between the extent of suburbanization, via various measures of population spread, roadways, and violent crime rates in primary cities as discussed in the background and theory section below. Measures include population density, primary city/MSA population ratios, population size, proximity to major thoroughfares, traffic issues, and commuting patterns. Consensus on the legitimacy of these metrics varies. The extent that travel volume as measured by vehicle kilometers traveled, number of registered vehicles per square kilometers, or other innovative metrics combining land use and transportation features are related to and driving crime due to the friction of distance has not been fully analyzed.

The strong interdependent relationship between land use and transportation has been exhaustively studied for decades. Research has demonstrated that urban design, population density and land-use diversity are moderately and consequentially associated with travel demand (Cervero & Kockelman, 1997; Ewing & Cervero, 2010; Handy et al., 2005) and transportation costs (Litman, 2021a). Proliferation of the automobile is strongly associated with suburbanization (Kopecky & Suen, 2010), consistent with the natural evolution theory of urban development (Mieszkowski & Mills, 1993). Personal combined housing and travel expenditure burdens tend to increase with geographic spread (Center for Transit-Oriented Development & Center for Neighborhood Technology, 2006).

The most important contribution of this paper to existing literature is the extent that broader transportation metrics, either separately or together with established suburbanization measures or other land-use descriptors, are related to violent crime rates in U.S. MSA primary cities due to the friction of distance. The caveat being that incremental change was measured through simultaneous testing of indicators across a large standardized sample of 147 MSAs. A related contribution is the potential role that these metrics have in the conceptual structure of these associations (e.g., background conditions, mediators, independent structural drivers). The topic is of high interest to the public and politicians due in part to the following violent crime issues: declining trends in recent decades, pandemic era and location-specific spikes, media coverage, police-related shootings, terror-inspired attacks, mass shootings, sniper attacks, and the number of citizen demonstrations. Further, the study is critical in understanding transportation's associations with violent crime as solutions are considered for modernizing the U.S. interstate highway system (Transportation Research Board, 2019; Unger et al., 2010). The paper next discusses the pertinent literature and theories related to suburban growth and violent crime. This is followed by materials and methods, results of the analyses, and discussion/conclusion. References to crime are assumed to include both violent and property crime unless labeled as one or the other.

2 Background and theory

2.1 Highways and population decentralization

Previous research on the interrelationship between transportation, geographic population shifts, and well-being provides groundwork for understanding any association between suburbanization and violent crime. A study of the Chicago region found no empirical relationship between the timing of highway construction and urban decentralization but concluded that a contributory effect was possible (Sen et al., 1998). Yet, highway plans were in place prior to much of the suburbanization (City of Chicago, 1939). A critique by the Center for Neighborhood Technology (1999) of Sen et al. (1998) mapped timeframes of Chicago area expressway construction and new suburban residential development to show both interdependence and that the latter appeared to follow the new roadways in certain areas.

Baum-Snow (2007a, 2007b) concluded from analysis of U.S. cities for the period of 1950-1990 that one new highway penetrating a central city could be expected to reduce its population by up to 18%. In a follow-up study, Baum-Snow (2020) found that, for the period 1960 to 2000, new MSA highways decentralized 14% to 16% of primary city working inhabitants and 4% to 6% of jobs. Cox et al. (2008) cast doubt on the Baum-Snow (2007a, 2007b) research, which has been countered by Baum-Snow (2008). One of the criticisms by Cox et al. (2008) was that other factors were predominantly responsible for suburbanization such as rising incomes, automobile usage, and changes in production.

Mothorpe et al. (2013) found that each 1.6 kilometer (km) [mile (mi)] of expressway in the vicinity of an urbanized area (UA) in Georgia reduced agricultural land by 468 acres during the period 1945-2007. Voss and Chi (2006) studied Wisconsin urban and rural areas for the period 1965-1995 and determined that improved highways (four-lane conversions) had a modest positive causal effect on population growth within 16-32 km (10-20 mi).

Guerra et al. (2025) demonstrated that major urban arterials and expressways in the U.S. are overbuilt. The authors estimated net welfare gains of about $28 billion per year from a 10% reduction in urban roadway capacities due to the higher benefits of more productive land uses. Alternatively, new urban highway capacity equates to social costs exceeding social benefits by at least a factor of four (Guerra, 2025). Other studies have found a broad range of net impacts both positive and negative without considering the full spectrum of social costs (Bhatta & Drennan, 2003; Boarnet, 1997). Similar analyses found that average returns on highway investments have at least equaled costs in the worst-case scenarios (U.S. Department of Transportation, 2019).

2.2 Built environment and violent crime

There is extensive literature on the interplay between various changing aspects of urbanization, including inherent alterations to transportation infrastructure and mode choice, relative to stressors and crime. These are summarized here to present the knowledge base, issues, and gaps.

2.2.1 Metropolitan expansion

Wirth's (1938) theory of urbanism outlined how city size, density and heterogeneity were seemingly positively associated with social disorder, personal disorganization/mental issues, and crime. The reasoning being that potential differentiation in terms of culture, personal traits, and opinions resulted in segregation and transitory habitats. The separation, diversity, and sheer numbers resulted in weakened ties of affinity, neighborliness, and acquaintanceship. Nervous tension, friction, frustration, and conflict followed. Thus, large cities required the most public investment in social control to substitute for these voids (Wirth, 1938). Skogan (1977) described this phenomenon as the “normal model” of crime and social control. He analyzed 1946-1970 data for the 32 largest U.S. cities to test this hypothesis regarding crime rate. Findings were that places with large/dense populations and racial heterogeneous characteristics had the highest crime rates. However, he found this was a relatively new trend occurring in the post-World War II period with White migration to suburban areas.

Skogan (1977) argued that the exodus from core cities created a much larger stratification of settlements that had only existed previously within city subcommunities at a much smaller scale. This new stratum, otherwise known as suburbanization, resorted population by race and class with White and affluent persons moving out of cities followed by jobs and amenities. The poor, Black people and other minorities were left in central cities with diminished employment and rising crime. Skogan (1977) found that the associations of both population density and racial heterogeneity with primary city crime were low or negative until the early 1950’s when they subsequently became positive, rising over time. The association between city population size and crime during the study period was minor and negative from about 1951-1961 (Skogan, 1977).

Studies analyzing U.S. city/MSA data varying from 1970-1990 found that the resulting segregation of poverty, minorities and other disadvantaged populations in central cities from more affluent residents, employment and related amenities moving to suburban locations was a substantive factor in explaining central city crime rates (Cullen & Levitt, 1999; Morenoff & Sampson, 1997; Shihadeh & Ousey, 1996). These demographic patterns have caused continual and substantive disparities in tax rates and public services (Bahl et al., 1992; Berry, 2021; Frey, 1979). Shihadeh and Ousey (1996) identified the suburbanization-crime association as an externality of urban restructuring. This occurred pursuant to metropolitan expansion theory, which suggests that exurban development transfers resources, employment, and people out of central cities. Comparably, findings were also in line with the spatial mismatch hypothesis, evolved from Kain (1968), which states that job suburbanization and housing segregation separated minority populations from employment opportunities.

In short, the consensus is that market-driven urban expansion that does not account for the externalities of reduced accessibility from increased travel distance leads to higher crime. This does not discount Wirth’s theory of urbanism that cities before rampant suburbanization had major issues with disfunction and high crime (Jacobs, 1961). Indeed, the relationship between metropolitan expansion and crime appears bidirectional in terms of causality (Bradford & Kelejian, 1973; Burnham et al., 2004; Jargowsky & Park, 2008).

2.2.2 City-suburban commuting patterns and boundaries

Research has theorized that the suburbanization-crime association was due in part to the routine/daily movement of population to dominant primary cities from suburbs to access employment and amenities (Gibbs & Erickson, 1976; Stafford & Gibbs, 1980). This ostensibly served to inflate primary city crime rates by expanding such opportunities. Stults and Hasbrouck (2015) found that additional daytime population in central cities from commuting had a statistically significant positive relationship with both actual and artificially inflated crime rates. Farley and Hansel (1981) and Farley (1987) hypothesized that the commuting relationship may be an arbitrary result from the effect of the central city-suburb boundary location and that relative deprivation is the more plausible explanation for inner city crime. The borders purportedly influenced central city crime as core municipalities with larger areas had higher percentages of land and populations outside of high-crime central areas (Farley & Hansel, 1981; Farley, 1987).

Zimmer (1976) documented how suburban population increased at a rate of about four to five times that of growth in central cities from 1950-1970. Most of the relatively small central city growth came from annexations, which previously had been the favored method to accommodate urban expansion. In 1910 and 1970, 75% and 45% of the respective urban populations lived in central cities (Zimmer, 1976). By 2010, central city populations only comprised about one-third that of UAs (U.S. Bureau of the Census, 2010). Thus, while central city boundaries are arbitrary, there has been a radical long-term settlement shift across political boundaries to suburban locations.

2.2.3 Population density

Jargowsky and Park (2008) documented conflicting studies on the association between simple population density and crime before 1980 with a positive relationship more common. For example, neighborhood congestion accompanied by conditions such as deprivation, crowding within dwelling units, and violent subcultures leads to higher crime (Booth et al., 1976; McCarthy et al., 1975). Yet Pressman and Carol (1971) found no correlation between population density and crime.

Conversely, different measures of population density have since been found to be associated with crime. Klovers (2006) analyzed 1970-2000 data for 53 U.S. cities and their suburbs and found that rising crime was influenced through bidirectional decreasing population densities and associated increases in poverty concentration. Jargowsky and Park (2008) used 2000 U.S. city/MSA data to analyze the relationship between suburbanization and both violent and property crime measured at the metropolitan level. They concluded that suburbanization and lower population densities increased crime in metropolitan areas through economic and social isolation of central city neighborhoods, as defined by social disorganization theory (Jargowsky & Park, 2008).

Hipp and Roussell (2013) analyzed 2000 data using block group weighted population densities and population of the macro-environment for UAs within a 32 km (20 mi) radius of U.S. core city center points. Findings showed a more robust nonlinear association between crime and these devised variables than the linear association with the conventional population and population density metrics. Relationships were either positive or negative depending upon the type of crime analyzed (Hipp & Roussell, 2013).

Thus, population density has a complex relationship with crime due to contextual factors. As espoused by Jacobs (1961), it is very plausible that conventional urbanism characterized by clustered populations with mixed land uses securely overseen by crowdsourced “eyes on the street” is an important factor. Thus, weighted population density could be an appropriate measure of clustering and distance when controlling for other variables.

2.2.4 Major roadways

In the first study of its kind, Calamunci and Lonsky (2025) established that construction of a new expressway in U.S. counties caused a respective 5% and 8% increase in violent and total crime in those localities during the period 1960 to 1993. A major caveat is that the positive effect was only evident in counties with low pre-existing police forces. The authors posit that increased economic activity from highways created more opportunities for crime but were not a major factor in the crime wave that paralleled expressway construction.

Other studies have found a positive relationship between proximity to expressways and crime (Jarrell & Howsen, 1990; McCutcheon et al., 2016; Rephann, 1999). Agnew (2020) found that new motorways in Ireland were associated with a 10% increase in burglary rates for newly connected communities. Wuschke et al. (2021) discuss the literature linking various urban features including major roads with certain crime specialties. Their analysis of two Canadian suburban communities found that large urban arterials accompanied by major shopping districts tended to have the highest crime rates including violence. Thus, there is a consensus of the literature that proximity of crime to major roadways is positively associated due to the opportunities that such mobility provides. Mobility can potentially be measured to quantify the relationship in a variety of ways.

2.2.5 Traffic

The extent of any relationship between traffic itself and violent crime was examined. Loader (2025) discussed studies showing how proliferation of the automobile has facilitated criminal behavior both via extended mobility and the theft of vehicles themselves. Beland and Brent (2018) documented the various literature on the link between traffic congestion and mental health issues in the form of stress, aggression and domestic violence. Literature has demonstrated the positive association of crime including violence with traffic offenses, and accidents (Brace et al., 2010; Giacopasi & Forde, 2000). Studies have found associations between increased traffic enforcement and lower robbery rates (Sampson & Cohen, 1988; Wilson & Boland, 1978). Researchers have demonstrated positive relationships of tetraethyl lead and air pollution near expressways with violent crime (Curci & Masera, 2018; Filippelli et al., 2005; Herrnstadt et al., 2015). Thus, ample evidence shows that increased traffic intensity and volume leads to or is associated with diminished mental health and air quality. Such stressors lead to criminal tendencies which increase further with mobility lacking in traffic enforcement.

2.3 Background and theory summation

In summary, a positive relationship has been demonstrated between the number of urban expressways and population decentralization. Albeit there is debate on the causal influence of those highways and the extent they impacted net welfare. It is relatively clear that causality in the suburbanization and crime interrelationship is bidirectional. Suburbanization appears to be more than a background factor while exhibiting traits as both a mediator and structural driver of crime. The arbitrary nature of city boundaries may be a quandary for measuring the crime association in terms of primary city/MSA population ratios and commuting patterns. Research on the association of population density and crime has found both positive and negative relationships. Weighted population density may provide more precision. There is evidence and consensus of positive links between violent crime and traffic congestion, reckless driving, expressway-induced pollution, and lax traffic monitoring by police. Suburbanization is clearly related to propagation of the automobile/increased travel demand and crime due to enhanced geographic access, urban decay, and physical separation of inner city populations and economic opportunities. This evidence is consistent with the aforementioned theories of urbanism, metropolitan expansion, spatial mismatch, and social disorganization. The friction of distance or costs of travel include time, energy, and other resources which generally rise with lower population densities. Studies appear scant concerning potential interrelationships between land uses and more precise quantitative transportation measures with violent crime in primary cities.

3 Materials and methods

3.1 Conceptual framework

Based upon the literature review, the theoretical structure guiding the empirical modeling approach is that violent crime as measured by murder rate is both a cause and a result of various sociological factors. Figure 1 presents the foundational conceptual interrelationship. Urbanism in the form of cities facilitates crime from the inherent opportunities created by bringing people together. Hence, a coherent causal chain follows. Crime leads to metropolitan expansion as residents seek quality of life improvements away from turmoil. In turn, suburbanization as quantified by different land-use measures, is also a cause of crime due to the friction of distance. Increases in travel cause rising transportation costs and unpriced negative externalities such as congestion and emissions which can result in net welfare losses (Arkell, 2021). Thus, the spatial mismatch of land uses would initially appear to be a mediator to crime which is then aggravated by the resulting transportation requirements. The combination transitions the effect to that of a structural driver of crime. The friction created from distance is then exacerbated further via stress in the form of inner-city decay and associated sociological breakdowns. These include broken families, homelessness, unemployment, drug use and other disfunction leading to additional crime.

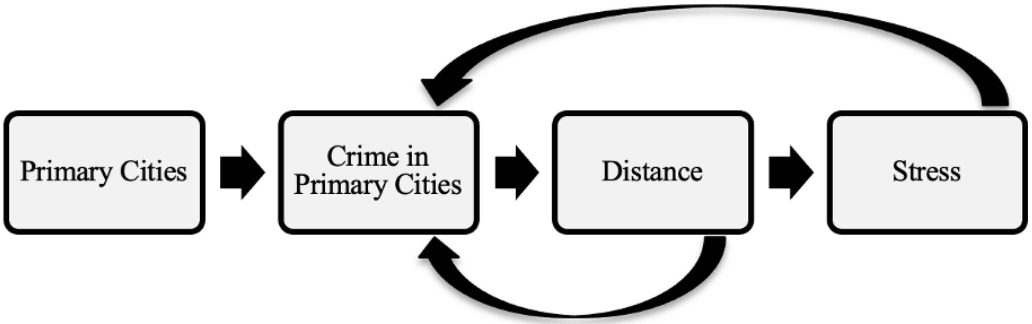

Figure 1. Crime and distance conceptual causal flow

The study's cross-sectional empirical design captured differences in variables, including measures of land use and transportation form, to determine associations with murder rate. The method was a set point in time reflecting a culmination of past decisions. Therefore, a broader use of metrics were available for testing than past studies at the expense of sacrificing causality insights.

3.2 Dependent variable

The 2015 data for primary cities were collected from the FBI Uniform Crime Reporting (UCR) Program. This resource is appropriate as it has been in place since 1930 and virtually all U.S. municipal, county and state law enforcement agencies participate in the program. There are limitations in UCR data accuracy and some gaps exist. Gramlich (2020) analyzed 1995-2019 Bureau of Justice Statistics and FBI data and found that less than 50% of violent crimes were reported to police. Researchers consider murder rate a more accurate indicator of violent crime as it is subject to less manipulation (Boylan, 2023; Gramlich, 2020). Thus, murder rate (i.e., number of offenses per 100,000 in primary city population) consisting of murder/nonnegligent manslaughter or the willful nonnegligent killing of one human being by another (Federal Bureau of Investigation, 2015) was used as the dependent variable instead of violent crime rate. Data were from primary city police departments and did not include crimes handled by state, county, and university police for offenses within municipalities.

3.3 Suburbanization metrics

The following describes the suburbanization-related transportation and urban form metrics that were tested for potential associations with murder rates in primary cities. First, population spread was differentiated by primary city/UA residency ratios from proportions of UA populations at various distances from urban centers (i.e., primary city centers). In relation, population clustering was identified in the form of density and weighted density. Second, efforts were made to integrate such measures with distinct metrics for both the built transportation network and the amount of vehicular travel. Thus, to expand upon existing literature, measures such as UA freeway lane km per primary city 100,000 population (freeway capacity), UA per capita vehicle km traveled (VKT), and number of vehicles per primary city square km were critical elements analyzed in the study. The purpose of the approach was to capture dynamics of the interrelationship between land use and transportation relative to suburbanization in an effort to predict murder rates. A longitudinal approach was prohibitive, mainly due to the lack of localized per capita VKT data when much suburbanization occurred before 1989. There is also an absence of historic vehicle registration data at local levels. Similarly, limited availability of localized historic urban freeway lane km and metropolitan weighted population densities data posed challenges.

The period of data consisted mainly of 2015, with 2010 used for Census UA data (collected decennially) (Table 1 and Appendix A). This period can be considered representative of reported violent crime and murder in recent years, which was relatively consistent in the U.S. from 2010 through 2020 (FBI). It also avoids potential data oddities due to the pandemic. Independent variables of the built environment relative to urban form and transportation in Table 1 were used as proxies for suburbanization.

The known relationship between suburbanization and central city violent crime dictated that variables analyzed would not necessarily be at the same geographic scale. For example, measuring the proportion of UA freeway lane km per 100,000 population of both primary cities and incremental urban rings captures the dynamics of potential contributing factors occurring at different geographic scales. In other words, UA freeway lane km – whether measured in total or per 100,000 UA population - may have limited meaning to inner-city violent crime rates without considering the context of population levels near the urban core. A higher ratio is plausibly indicative of increasing suburbanization and/or urban dedensification due to wider spacing of the built environment resulting in stress to those inner-urban residents. Pearson Correlation coefficients ranging from 0.30 to 0.50 for proportion of UA freeway lane km per 100,000 population of both primary cities and incremental urban rings relative to primary city murder rate provided credence (Table 1, rows 1 and 3). Another illustration is metropolitan weighted population density, which measures the extent of urban and economic drift from central cities. The independent variables in Table 1 are indicators of inner-city stressors from increased travel due to both cost impacts on personal budgets and economic wellbeing in addition to the effects of congestion and pollution.

Table 1. Tested suburban independent variables and data sources

Independent Variables	**Source/Description**	**Pearson Correlation**[3]
UA[1] Fwy. Lane km / UA 100,000 Pop. @ 1.6-14.5 km (1-9 mi) Radius of CBD[1]	U.S. Fed. Hwy. Adm. (FHWA) 2015 Hwy. Stats. (HM-72), U.S. Census 2012	0.3047 to 0.3809
UA[1] Per Capita VKT	FHWA 2015 Highway Stats. (HM-72)	0.2418
UA[1] Fwy. Lane km/100,000 City Pop.	FHWA 2015 Highway Stats. (HM-72)	0.5036
UA Total Road km/100,000 City Pop.	FHWA 2015 Highway Stats. (HM-72)	0.3810
Primary City Vehicles Per Square km	U.S. Census 2015 ACS 5-Yr. Estimates	0.0390
UA Average Annual Hours Delay per Auto Commuter	Texas A&M Transportation Institute (2015)	0.1082
UA Per Capita Transit Annual Unlinked Trips	Federal Transit Administration 2015	-0.0262
Primary City Standard Pop. Density	U.S. Census 2015	0.0810
UA Standard Pop. Density[1]	U.S. Census 2010	-0.1451
MSA Weighted Pop. Density[2]	U.S. Census 2012	-0.0723
City Pop. / 100,000 UA[1] Pop.	U.S. Census 2015	-0.3743
Pop. @1.6-14.5 km (1-9 mi) Radius of CBD[1] / 100,000 MSA Pop.	U.S. Census 2012	-0.2578 to -0.3392
2015 Primary City Pop. Increase Per 100,000 from Commuting	U.S. Census 2015 ACS 5-Yr. Estimates (B08301; B08604)	0.2559

1. Urbanized Area (UA); Central Business District (CBD); Vehicle Kilometers Traveled (VKT).
2. Calculated by determining population density of each Census tract, weighting it by the proportion of residents in the MSA, and adding the totals.
3. Pearson correlation coefficient with 2015 primary city murder rates.

3.4 Hypotheses

The null hypotheses tested, were that each of the suburbanization independent variables in Table 1 do not have a relationship with the dependent variable of 2015 primary city murder rate and the slope of the population regression was zero. The alternative hypotheses were that each of these independent variables do have a relationship with primary city murder rate, and the slope of the population regression was not zero. The level of significance for the tests was 0.05, and assumed unless otherwise noted, with cases of 0.10 identified.

3.5 Methodology

Data were collected for 147 of the largest MSAs, associated UAs, and primary cities/counties within them. Primary cities were identified by municipalities with the largest populations and up to two others that had comparable numbers of residents. There were 123 MSAs with singular primary cities, 12 with two primary cities, and 12 with three primary cities (Appendix B). Thus, there were 147 observations in the sample size, which included 183 primary cities. Each case of an area with multiple primary cities entailed combining the data into one observation. By using this sample, primary cities were captured that had the highest potential for alternatives to personal vehicles such as public transportation and walking. Further, much of the prior city-level crime research has focused on more than 100 of the largest cities (Stults & Hasbrouck, 2015). The analytic methodology was multivariable cross-sectional ordinary least squares (OLS) linear and quantile regression. This approach was appropriate as, in addition to the aforementioned sampling procedure, scatter plot analyses showed all independent variables in the developed models had linear relationships with murder rates.

Construction of the models occurred in three stages. First, central city murder rates were regressed separately on the suburbanization independent variables in Table 1 to identify those having the strongest associations as supported by theory. Pearson correlation coefficients for these independent variables are in Table 1.

The second step entailed testing numerous multivariable models to identify controlling independent variables from Appendix A that together held theoretically rational and statistically significant ($p<0.05$) relationships with murder rates. This was done primarily through reverse stepwise regression. Appendix A identifies these by the aforementioned motivated offender, increased opportunities, and lack of oversight or guardianship categories. The dependent and independent variables were converted to log (ln) as appropriate to minimize data skew and improve normalcy. All variables in the models are considered ln unless otherwise noted.

The controlling independent variables used were: the ln sum of primary city other vacancy rate, family single head of household rate, and poverty rate (U.S. Bureau of the Census, 2015); primary city county premature deaths per 100,000 population (University of Wisconsin Population Health Institute, 2015); primary city murder clearance rate per 100,000 murders (non-ln to relieve endogeneity) (Murder Accountability Project, 2015); primary city population 65 years old and above per 100,000 (U.S. Bureau of the Census, 2015); and MSA regional price parities (U.S. Bureau of Economic Analysis, 2015). See Appendix C for an expanded discussion.

The third step consisted of investigating the potential for endogeneity, omitted variable bias, heteroscedasticity, multicollinearity, and other specification issues through standard econometric significance tests amongst variables and residuals in addition to scatter plot analyses.

4 Results

4.1 Analytical framework

Expanding upon the above methodologies, analysis using the control variables progressed with increasing complexity and validation techniques. Initial regressions limited the suburbanization measures to single variables to identify preliminary relationships with primary city murder rates. Next, the regressions combined multiple suburbanization independent variables to ascertain their interrelationships and potentially improve robustness of the models consistent with the aforementioned theories. Analysis then focused on the extent that the suburbanization variables contributed to model strength. Finally, quantile regression was performed to identify the extent that the relationships held throughout the range of murder rates.

4.2 Single suburbanization independent variable

Table 2 displays separate models of control variables and single suburbanization or land use and transportation independent variables from Table 1 found to have the most robust associations with murder rate. Three suburbanization independent variables (all exogenous) were found to have statistically significant ($p<0.05$) relationships with murder rate and had the following elasticities: metropolitan weighted population density (-0.20), UA freeway lane km per primary city 100,000 population (0.12), and per capita VKT (0.40) (columns 1-3). Three suburbanization independent variables (all endogenous) were found to have statistically significant relationships ($p<0.05$) with murder rate and had the following elasticities: primary city vehicles per 100,000 population (0.60), UA average annual hours of delay per auto commuter (0.21), and primary city population increase per 100,000 from commuting (0.15) (columns 4-6). For additional results, see Appendix D. Excepting UA standard population density, all of the suburbanization independent variables in Table 2 and Appendix D had the appropriate directional effects pursuant to the hypotheses. Land-use measures of increasing population density were associated with reductions in murder rate and increases in volumes of transportation metrics had the opposite relationship.

Table 2. OLS regression models of 2015 primary city murder rate – single land use/transport independent variable (N=147)

Independent Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Primary City Other Vacancy Rate + Poverty Rate + Single Head Family Household Rate	0.506* (0.041)	0.450* (0.048)	0.491* (0.041)	0.556* (0.050)	0.484* (0.042)	0.466* (0.044)
Primary County Premature Death	1.272* (0.236)	1.450* (0.239)	1.280* (0.237)	1.296* (0.241)	1.374* (0.236)	1.479* (0.240)
Age 65+ per 100K Population	-0.457* (0.172)	-0.422* (0.174)	-0.423* (0.171)	-0.415* (0.173)	-0.348* (0.174)	-0.455* (0.176)
(non-ln) Primary City Murder Clearance Rate	-6.17e-06* (1.67e-06)	-5.90e-06* (1.69e-06)	-5.76e-06* (1.67e-06)	-5.85e-06* (1.69e-06)	-5.43e-06* (1.68e-06)	-5.43e-06* (1.68e-06)
Metro Area Regional Price Parity	0.681* (0.104)	0.465* (0.085)	0.524* (0.084)	0.580* (0.094)	0.366* (0.099)	0.504* (0.085)
Land Use/Transport Variable (see Notes 1-6)	-0.198* (0.064)	0.123* (0.061)	0.403* (0.140)	0.601* (0.273)	0.209* (0.090)	0.152* (0.071)
Intercept	-18.638* (2.402)	-20.599* (2.320)	-21.001* (2.272)	-28.498* (4.056)	-21.498* (2.299)	-22.052* (2.341)
R^2	0.782	0.773	0.780	0.775	0.776	0.774
F-ratio	83.54	79.64	82.69	80.26	80.65	80.03
RMSE	0.419	0.426	0.420	0.425	0.424	0.426

Notes: Standard errors in parentheses; *$p<0.05$; **$p<0.10$; Gray shading depicts suburbanization variables

1. metropolitan weighted population density (exogenous)
2. UA freeway lane km per primary city 100,000 population (exogenous). Models using UA freeway lane km per 100,000 population at 1.6-14.5 km (1-9 mi) increments showed comparable elasticities and statistical significance for 1.6 and 4.8 Km (1 and 3 mi) ($p<0.05$) and for 3.2 km and 6.4-14.5 km (2 mi and 4-9 mi)($p<10$) (all endogenous)
3. per capita VKT (exogenous)
4. primary city vehicles per 100,000 population (endogenous)
5. UA average annual hours delay per auto commuter (endogenous)
6. primary city population increase per 100,000 from commuting (endogenous)

4.3 Multiple suburbanization independent variables

The suburbanization independent variables were tested in select combinations together as one independent variable (added lns), separately in the same models, and groupings of both (Table 3 and Appendix E). All models were very similar in terms of the overall goodness of fit, F-ratio, mean squared error (MSE), p-values, and exogenous variables. Table 3 displays the more robust models in terms of suburbanization variable statistical significance ($p<0.05$ except as noted) and R^2 among other metrics. The land use independent variable of metropolitan weighted population density had elasticities ranging from -0.18 to -0.31 (columns 1-5). Elasticities of the other suburban independent variables were as follows: 0.09 for UA freeway lane km per primary city 100,000 population + UA per capita VKT + primary city vehicles per square km (column 3); -0.10 for population within 1.6 km (1 mi) of primary city center per 100,000 metropolitan area population (columns 4 and 5); and 0.21 ($p<0.10$) and 0.25 for primary city vehicles per square km (columns 1 and 5). UA freeway lane km per primary city 100,000 population + UA per capita VKT + UA annual hours delay per auto commuter as one combined sole suburbanization variable had an elasticity of 0.14 (column 6). UA average annual hours delay per auto commuter was statistically significant with an elasticity of 0.23 (column 7). Primary city population increase per 100,000 from commuting was not found to be statistically significant when controlling for other suburbanization variables (see Appendix E). It also did not add substantive predictive power when combined with other transportation independent variables as a single measure.

Table 3. OLS regression models of 2015 primary city murder rate - multiple land use/transport independent variables (N=147)

Independent Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Primary City Other Vacancy Rate + Poverty Rate + Single Head Family Household Rate	0.476* (0.042)	0.498* (0.040)	0.460* (0.467)	0.493* (0.041)	0.466* (0.043)	0.519* (0.056)	0.507* (0.058)
Primary County Premature Death	1.413* (0.258)	1.219* (0.230)	1.396* (0.241)	1.160* (0.238)	1.390* (0.264)	0.950* (0.215)	1.009* (0.237)
Age 65+ per 100K Population	-0.466* (0.167)	-0.432* (0.167)	-0.487* (0.170)	-0.431* (0.170)	-0.470* (0.169)	-0.307** (0.177)	-0.298* (0.178)
(non-ln) Primary City Murder Clearance Rate	-5.67e-06* (1.62e-06)	-5.91e-06* (1.62e-06)	-6.16e-06* (1.65e-06)	-6.39e-06* (1.65e-06)	-6.07e-06* (1.64e-06)	-6.61e-06* (1.69e-06)	-6.39e-06* (1.71e-06)
Metro Area Regional Price Parity	0.565* (0.108)	0.560* (0.108)	0.626* (0.106)	0.644* (0.104)	0.641* (0.103)	0.585* (0.172)	0.491*† (0.201)
1st Land Use/Transport Variable (see Notes 1-7)	-0.308* (0.173)	-0.251* (0.065)	-0.180* (0.064)	-0.214* (0.064)	-0.286* (0.073)	0.144* (0.041)	0.129** (0.069)
2ndLand Use/Transport Variable (see Notes 1-7)	0.007* (0.002)	0.007* (0.002)	0.091* (0.044)	-0.103* (0.046)	-0.100* (0.045)	- -	0.082 (0.157)
3rd Land Use/Transport Variable (see Notes 1-7)	0.208** (0.127)	- -	- -	- -	0.247* (0.128)	- -	0.225* (0.096)
Intercept	-19.761* (2.625)	-17.082* (2.348)	-19.616* (2.422)	-16.372* (2.574)	-18.702* (2.819)	-25.149* (3.521)	-24.726* (3.653)
R^2	0.800	0.796	0.788	0.789	0.800	0.770	0.771
F-ratio	68.81	77.33	73.87	74.40	66.85	78.04	58.22
RMSE	0.404	0.406	0.414	0.413	0.409	0.430	0.431

Note: Standard errors in parentheses; *$p<0.05$; **$p<0.10$; Gray shading depicts suburbanization variables; †Primary city per capita household income used instead as a control variable as indicated below.

1. metropolitan weighted population density + (2nd) average annual hours delay per auto commuter (non-ln) + (3rd) primary city vehicles per square km (all exogenous)
2. metropolitan weighted population density + (2nd) average annual hours delay per auto commuter (non-ln) (all exogenous)
3. metropolitan weighted population density + (2nd)(UA freeway lane km per primary city 100,000 population + UA per capita VKT + primary city vehicles per square km) (all exogenous)
4. metropolitan weighted population density + (2nd) population within 1.6 km (1 mi) of primary city center per 100,000 metropolitan area population (all exogenous); Models using population within 3.2-14.5 km (2-9 mi) of primary city center per 100,000 metropolitan area population (all exogenous) all showed comparable elasticities with statistical significance as follows: 3.2 km (2 mi)($p<0.05$); 4.8 and 8.0 km (3 and 5 mi)($p<0.10$)
5. metropolitan weighted population density + (2nd) population within 1.6 km (1 mi) of primary city center per 100,000 metropolitan area population + (3rd) primary city vehicles per square km) (all exogenous); Models using population within 3.2-14.5 km (2-9 mi) of primary city center per 100,000 metropolitan area population (all exogenous) all showed comparable elasticities with statistical significance as follows: 3.2 and 4.8 km (2 and 3 mi)($p<0.10$)
6. (UA freeway lane km per primary city 100,000 population + UA per capita VKT + UA annual hours delay per auto commuter) (exogenous)†

7. UA freeway lane km per primary city 100,000 population + (2nd) UA per capita VKT + (3rd) average annual hours delay per auto commuter (all exogenous)†

4.4 Independent contributions to R^2

Table 4 and Appendix F show the direct proportional contribution of individual independent variables to R^2 when adding each last to selected models compared to the sum of these for all independent variables. This excludes combined effect of all variables, which is added separately and contributes substantially to R^2 from a range of 53% to 61%. Table 4 depicts the suburbanization independent variables with the most contributions to R^2. In each model, metropolitan weighted population density consistently added the highest amount individually with a range of about 4% to 8%. When this independent variable was individually modeled with other suburban independent variables, the combined predictive strength ranged from 6% to 12%. Average annual hours of delay per auto commuter (non-ln) added predictive strength of about 4% (columns 1 and 2). Other findings in Table 4: population within 1.6 km (1 mi) of primary city centers per 100,000 metropolitan area population added about 2% (columns 4 and 5); combinations of several transportation independent variables added about 2% (column 3); and primary city vehicles per square km added about 2% (column 5). For additional findings, see Appendix F.

Table 4. Contribution strength of independent variables to R^2

Independent Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Primary City Other Vacancy Rate + Poverty Rate + Single Head Family Household Rate	0.185 54.5%	0.225 60.7%	0.148 48.8%	0.216 58.8%	0.175 51.2%
Primary County Premature Death	0.044 12.9%	0.041 11.1%	0.051 16.7%	0.036 9.8%	0.041 12.1%
Age 65+ per 100K Population	0.011 3.3%	0.010 2.7%	0.012 4.1%	0.010 2.7%	0.012 3.4%
Primary City Murder Clearance Rate (non-ln)	0.018 5.3%	0.020 5.3%	0.021 7.0%	0.023 6.2%	0.020 6.0%
Metro Area Regional Price Parity	0.040 11.8%	0.039 10.6%	0.053 17.4%	0.059 15.9%	0.058 17%
1st Land Use/Transport Variable (see Notes 1-5)	0.026 7.6%	0.022 5.9%	0.012 3.9%	0.017 4.6%	0.023 6.6%
2nd Land Use/Transport Variable (see Notes 1-5)	0.012 3.5%	0.014 3.8%	0.006 2.1%	0.008 2.1%	0.007 2.1%
3rd Land Use/Transport Variable (see Notes 1-5)	0.004 1.1%	- -	- -	- -	0.006 1.6%
Total R^2 Individual Independent Variable Contribution	0.339 100%	0.371 100%	0.304 100%	0.368 100%	0.341 100%
Remaining Contributions of all Independent Variables Combined	0.460 58%	0.425 53%	0.484 61%	0.422 53%	0.454 57%
R^2 Total	0.800	0.796	0.788	0.789	0.800

1. Table 3, Column 1: metropolitan weighted population density + (2nd) average annual hours of delay per auto commuter (non-ln) + (3rd) primary city vehicles per square km
2. Table 3, Column 2: metropolitan weighted population density + (2nd) average annual hours of delay per auto commuter (non-ln)
3. Table 3, Column 3: metropolitan weighted population density + (2nd)(UA freeway lane km per primary city 100,000 population + UA per capita VKT + primary city vehicles per square km)
4. Table 3, Column 4: metropolitan weighted population density + (2nd) population within 1.6 km (1

mi) of primary city center per 100,000 metropolitan area population

5. Table 3, Column 5: metropolitan weighted population density + (2nd) population within 1.6 km (1 mi) of primary city center per 100,000 metropolitan area population + (3rd) primary city vehicles per square km)

4.5 Quantile regression

Quantile regression was performed to identify more refined associations of the suburban independent variables with primary city murder rate. Table 5 depicts six models that primarily maintained statistical significance (p<0.05) in the highest number of quantiles that were analyzed. The common suburbanization variable for all but one of these was metropolitan weighted population density as it maintained statistical significance in ranges of six to eight of nine quantiles and elasticities of -0.18 to -0.49 within those quantiles (rows 1, 3a to 6a). The coefficient values tended to decrease with larger quantiles and were never statistically significant in the 0.90 quantile. Compared to metropolitan weighted population density, transportation-related suburbanization independent variables tended to have smaller coefficient values and were less statistically significant throughout the quantiles. One exception was UA per capita VKT which as the sole suburbanization independent variable was statistically significant in 6 quantiles and had elasticities ranging from 0.42 to 0.80 within those quantiles (row 2).

Table 5. Quantile regression models of 2015 primary city violent crime rate (N=147)

	OLS					**Quantile**				
Model	**Mean**	**0.10**	**0.20**	**0.30**	**0.40**	**Median**	**0.60**	**0.70**	**0.80**	**0.90**
(1)	-0.198*	-0.285*	-0.224**	-0.219*	-0.241*	-0.213*	-0.190*	-0.193*	-0.189**	-0.072
	(0.064)	(0.117)	(0.121)	(0.019)	(0.085)	(0.076)	(0.76)	(0.090)	(0.109)	(0.105)
(2)	0.403*	0.797*	0.512*	0.469*	0.415*	0.223	0.440*	0.447*	0.276	0.154
	(0.140)	(0.261)	(0.261)	(0.196)	(0.196)	(0.151)	(0.199)	(0.179)	(0.218)	(0.193)
(3a)	-0.251*	-0.372*	-0.341*	-0.260*	-0.266*	-0.219*	-0.266*	-0.222*	-0.183*	0.079
	(0.065)	(0.104)	(0.127)	(0.103)	(0.094)	(0.074)	(0.079)	(0.077)	(0.092)	(0.112)
(3b)	0.007*	0.013*	0.009*	0.006	0.005	0.006*	0.007*	0.006*	0.006**	0.003
	(0.002)	(0.004)	(0.005)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
(4a)	-0.180*	-0.277*	0.220*	0.163**	-0.183*	-0.204*	-0.191*	0.199*	0.141**	-0.086
	(0.064)	(0.112)	(0.109)	(0.099)	(0.087)	(0.083)	(0.074)	(0.081)	(0.082)	(0.105)
(4b)	0.091*	0.071	0.091	0.074	0.130*	0.180*	0.112*	0.100**	0.108**	0.096
	(0.044)	(0.077)	(0.075)	(0.068)	(0.059)	(0.056)	(0.050)	(0.055)	(0.056)	(0.072)
(5a)	-0.214*	-0.291*	-0.307*	-0.215*	-0.259*	-0.229*	-0.236*	-0.190*	-0.120	-0.085
	(0.064)	(0.105)	(0.124)	(0.096)	(0.085)	(0.070)	(0.072)	(0.086)	(0.102)	(0.099)
(5b)	-0.103*	-0.102*	-0.097	-0.087	-0.144*	-0.066	-0.073	-0.072	-0.123**	-0.084
	(0.046)	(0.076)	(0.089)	(0.069)	(0.061)	(0.050)	(0.052)	(0.062)	(0.074)	(0.071)
(6a)	-0.286*	-0.486*	-0.342*	-0.356*	-0.303*	-0.272*	-0.299*	-0-223*	-0.263*	-0.154
	(0.073)	(0.132)	(0.118)	(0.116)	(0.096)	(0.091)	(0.078)	(0.095)	(0.101)	(0.098)
(6b)	-0.100*	-0.225*	-0.108	-0.116	-0.146*	-0.082	-0.056	-0.068	-0.080	-0.044
	(0.247)	(0.081)	(0.073)	(0.072)	(0.059)	(0.057)	(0.048)	(0.059)	(0.063)	(0.061)
(6c)	0.247*	0.440*	0.237	0.291	0.102	0.203	0.260*	0.209	0.371*	0.332**
	(0.128)	(0.229)	(0.205)	(0.202)	(0.167)	(0.159)	(0.135)	(0.165)	(0.177)	(0.170)

Note: Standard errors in parentheses; *p<0.05; **p<0.10.

G1. Table 2, Column 1: metropolitan weighted population density

G2. Table 2, Column 3: per capita VKT

G3. Table 3, Column 2: (a) metropolitan weighted population density + (b) average annual hours of delay per auto commuter (non-ln)

G4. Table 3, Column 3: (a) metropolitan weighted population density + (b) (UA freeway lane km per primary city 100,000 population + UA per capita VKT + primary city vehicles per square km)

G5. Table 3, Column 4: (a) metropolitan weighted population density + (b) population within 1.6 km (1 mi) of primary city center per 100,000 metropolitan area population

G6. Table 3, Column 5: (a) metropolitan weighted population density + (b) population within 1.6 km (1 mi) of primary city center per 100,000 metropolitan area population + (c) primary city vehicles per square km)

Average annual hours of delay per auto commuter (non-ln) was statistically significant in 5 quantiles (row 3b). A combined independent variable of UA freeway lane km per primary city 100,000 population, UA per capita VKT, and primary city vehicles per square km was statistically significant in three quantiles with elasticities ranging from 0.11 to 0.18 (row 4b). Population within 1.6 km (1 mi) of primary city centers per 100,000 metropolitan area population was statistically significant in two quantiles (elasticities of -0.10 to -0.14)(row 5b). The elasticities were -0.15 to -0.23 in those same variable quantiles (row 6b) with the addition of a separate third suburbanization independent variable of primary city vehicles per square km which was statistically significant in three quantiles (elasticities of 0.26 to 0.44)(row 6c). For additional findings, see Appendix G.

5 Discussion and conclusion

Ceteris paribus, the land-use variable metropolitan weighted population density and several transportation-related suburbanization variables were all found to be associated with murder rate in a variety of models with similar overall predictive strength. Metropolitan weighted population density had the strongest relationship with elasticities at the mean ranging from -0.18 to -0.31, unsummed contributions to R^2 of 4% to 8%, and statistical significance that held within six to eight of nine quantiles. Addition of the transportation-related variables resulted in total suburbanization contributions to R^2 of 6% to 12%, higher at the upper end than three of five control variables. When tested as the sole suburbanization variables in models, UA freeway lane km per primary city 100,000 population and UA per capita VKT were statistically significant and had respective elasticities of 0.12 and 0.40 (Table 2, columns 2 and 3). The following suburbanization variables (elasticities noted) required modeling more than one together to achieve both valid statistical significance with murder rate and contributions to model strength: primary city vehicles per square km (0.25)(Table 3, column 5), average annual hours of delay per auto commuter (0.23)(Table 3, column 7), and number of residents per 100,000 metropolitan population within 1.6-3.2 km (1-2 mi) of city centers (-0.10) (Table 3, columns 4 and 5).

A likely explanation for the findings is that low weighted population density becomes a mediator during metropolitan expansion by setting the land-use patterns that aggravate inner city stressors related to violent crime due to the friction of distance. This includes neighborhood diversity losses of clustered residents, businesses, and economic activity which lowers informal social control or shared accountability (Ludwig, 2025). These conditions are consequently exacerbated by responding traffic and its negative externalities of increased congestion, accidents, travel costs, pollution, and excessive mobility. Thus, suburbanization becomes a factor in violent crime. Nevertheless, the foundational aspect of weighted population density would appear to explain its dominance in the quantile regressions. Conversely, intensities of the transportation-related follow-on reactions as measured by the quantile regressions may vary more by cities and regions based upon a host of factors such as location quotient or employment diversity, education, regional culture, and other quality of life issues.

Broader societal problem severities are likely more highly associated with violent crime. This may explain declining land use and transportation variable predictive murder rate strength and statistical significance in higher segments of the quantile regressions. In relation, differences in urban structure at neighborhood levels could pose complications not fully addressed in the research methodology. For example, weighted population density can be beneficial in one neighborhood when accompanied by diverse amenities. Conversely, a lack of such features serves to emphasize the downside of crowding which can facilitate criminal activity. Further, a small number of deficient neighborhoods could have substantive impacts on the murder rates of primary cities.

Contributions of the suburbanization variables to R^2 were relatively small compared to the combined control variable of primary city other vacancy rate + poverty rate + single head family household rate. The generally higher marginal influences on R^2 by weighted population density compared to the transportation measures is consistent with the quantile regression findings. Nevertheless, these findings must be interpreted with caution as they can be sensitive to specifications of the models and correlations amongst the independent variables.

There are several contributions of this study to the literature that can aid policymakers. First, newly identified innovative groupings of land use and transportation data are legitimate measures for the established relationship of suburbanization with violent crime as measured by murder rate. While causality was not established, the findings lend further credence to the conceptual structure and established bidirectional nature of suburbanization and crime. Second, areas heavily invested in expressways and personal vehicular travel may experience relatively higher violent crime in central cities. In relation, UAs in conventional suburbanization form risk similar outcomes without offsetting measures to mitigate impacts to central cities.

A third contribution to the literature is that increasing populations at incremental distances of about 1.6-3.2 km (1-2 mi) from their primary centers per 100,000 UA population had statistically significant associations with lower murder rates (Table 3, columns 4 and 5) while the proportion of UA populations within primary city boundaries did not have such relationships. In relation, the tentative finding that primary city population increases per 100,000 UA populations from commuting were associated with murder rates (Table 2, column 6) may be reflective of auto-oriented UA's with heavy traffic and its negative externalities. The association did not hold true when controlling for other suburbanization metrics. These commuting patterns are substantively correlated with UA freeway lane km per primary city 100,000 population (Pearson correlation coefficient of 0.459). This counters past research that temporary increases in primary city populations from commuting were due to increased opportunities or targets for crime (Gibbs & Erickson, 1976; Stafford & Gibbs, 1980; Stults & Hasbrouck, 2015). The findings align more with Farley and Hansel (1981) and Farley (1987) that relative deprivation is the overall explanation for violent crime and that any association of city/UA population ratios is due to the arbitrary nature of municipality borders. All the findings align with the Wirthian normal model of urbanism, metropolitan expansion theory, spatial mismatch hypothesis, and social disorganization theory.

An incidental finding which adds to the literature is that primary city murder clearance rates in all models held statistically significant negative associations, which likely reflects in part the success of hot spots policing or the focus of law enforcement in high-crime districts (Committee to Review Research on Police Policy and Practices et al., 2004; Smith et al., 2024; Zimring, 2012).

A shortcoming of the research is that it does not reveal other insight on declining murder and violent crime in recent decades or its escalation during the pandemic era. Longitudinal data were not used to measure relationships over time. Therefore, the associations are prognostic and cannot be considered causal. Reverse causality is certainly evident conceptually and empirically. Endogeneity was identified in certain models summarized in section 4.2 which was addressed in the more intricate models outlined in section 4.3. Omitted-variable bias cannot be ruled out completely despite the multitude of independent variables considered and applied validation techniques. Unfortunately, pertinent UA/primary city data were unavailable, particularly freeway lane km, UA VKT, and vehicle registrations, during early proliferation of the automobile. A recommendation is to build upon the cumulative research by developing credible data estimates back to about 1950 or earlier, if possible, when crime began to escalate.

In terms of public policy, authorities should use caution as the study findings are correlational and not causal. It is recommended that local governments consider the social costs of crime in central cities within their regions before making decisions to expand major thoroughfares and borders of municipalities in exurban and suburban areas. The 2021 Infrastructure Investment and Jobs Act and the 2022 Inflation Reduction Act allocated planning and capital funding for expressway removal to address past harms. Other proposals put forth in recent years such as VKT fees and optimal kilometer pricing to address air, noise, and water pollution hold promise in reducing travel demand (Congressional Budget Office, 2011; Litman, 2021b, 2021c). Optimal road usage charges that address all social costs, including violent crime, would likely reduce further low-density urban spread and could help revitalize primary cities. However, other policy choices may be necessary to meaningfully impact primary city murder rates given the permanency of existing urban physical form.

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Author contribution

The author confirms contributions to the paper as follows: all tasks: Reginald Arkell.

Appendix

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