A Micro-Spatial Analysis of the Demographic and Criminogenic Environment of Drug Markets in Philadelphia

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Few studies have combined factors related to social disorganisation and factors related to opportunity theory at the microspatial level, with most studies aggregating to the block group or census tract. This study disaggregates block group census data in and around the vicinity of locations believed to encourage outdoor drug markets in Philadelphia, Pennsylvania, USA. A location quotient analysis finds that drug arrests cluster within a block or two of many suspected crime generators/attractors. Results from a zero-inflated Poisson model suggest some land use variables and factors associated with social disorganisation can help predict the location and size of drug markets; however, at the city level only retail alcohol outlets remained significant when combined with the social disorganisation-related variables, as a predictor of drug markets. The article discusses a number of potential reasons for these findings.

Illicit drug markets can be thought of as commercial enterprises, not unlike legitimate businesses, with their need to be situated in 'business-friendly' environments. To be successful, drug markets must be located in areas that contain, or can attract, a sufficient number of customers, and because they are illegal and often undesirable, they must be located in communities that either tolerate or are unable to resist their presence (Eck, 1995; Olligschlaeger, 1997; Rengert, 1996). Socially disorganised areas are believed to be business-friendly environments for drug markets because they are prone to contain sufficient numbers of drug users in their population, while also lacking the resources or social efficacy to prevent the establishment of the illegal trade.

To further increase the business return, drug markets may benefit from being in close proximity to certain facilities within neighbourhoods that might attract illicit drug users. Particular businesses and activity nodes (for example, liquor outlets, pawnshops, drug-treatment centres, and subway stations) located near socially disorganised areas are theorised to provide opportunities for drug markets in two ways. First, they may serve as anchors for the routine activities of drug users drawing local

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addicts to particular blocks, and second, because some nodes, such as subway stops and bus terminals, may increase the number of potential customers at a drug market by bringing in drug users from outside the neighbourhood. This suggests the possibility of predicting the location of drug markets within the urban landscape using two approaches, one based on the socioeconomic characteristics of neighbourhoods, and the second based on specific land-use structures that encourage drug markets within those neighbourhoods.

A number of studies have tested the relationship of drug markets to socially disorganised neighbourhoods. Other studies have mapped drug markets and measured their proximity to certain theorised criminogenic locations, essentially either crime attractors or crime generators (Brantingham & Brantingham, 1995a). In this article, we combine these approaches using a methodology recently employed by Rengert, Ratcliffe, and Chakravorty (2005). In the study that follows, we replicate their variables where possible and build on their previous study of Wilmington, Delaware (a city of some 70,000 people) with a case study in Philadelphia, Pennsylvania, a city of nearly 1.5 million. We use the same two-stage spatial analysis technique that combines socioeconomic, area-based characteristics derived from the census with variables that indicate proximity to crime-enabling locations.

One question that arises from the earlier study is whether the measures of proximity of drug markets to criminogenic features hold for a different urban area. For example, the Rengert et al. (2005) study found that drug arrests clustered 400 ft from taverns. There has been insufficient research to determine if these values are equally applicable beyond Wilmington, Delaware, and this study adds to the existing body of work by reporting the values for Philadelphia. Second, the earlier study reported results of the main study for a small, relatively homogenous city. The replication provided in this article explores whether the relationships hold for a city with a population larger by an order of magnitude.

After reviewing recent spatially based drug market studies, the article presents two analyses. The first is a location quotient analysis of the opportunity-based factors and their relationship with drug arrests, and the second employs a zero-inflated Poisson (ZIP) regression model in order to explore interrelational effects with socioeconomic factors across the urban environment. To achieve the ZIP model analysis, it is necessary to combine area-based variables derived from the census (for example, female-headed households in a block group) with point-based variables (addresses) derived from the locations of crime generators and attractors. In doing so, the analysis avoids many of the inaccuracies associated with the usual point-in-polygon approach (most noticeably the modifiable areal unit problem, see Chainey & Ratcliffe, 2005; Openshaw, 1984) by employing a more spatially accurate buffer technique centred on individual criminogenic locations. We begin by reviewing the literature on the spatial locations of drug markets.

The Locations of Drug Markets

Social disorganisation and routine activities are the two dominant theories used to explain the spatial distribution of crime in urban environments (Andresen, 2006). Since the 1800s (Guerry, 1833; Mayhew, 1862; Quetelet, 1842) it has long been found that variables that approximate measures of social disorganisation at the

neighbourhood level provide a good correlation with crime rates. Socially disorganised neighbourhoods have been shown to be ineffective in thwarting illegal activity due to a lack of social efficacy (Bursik, 1988; Dunlap, 1992; Shaw & McKay, 1942) resulting in a tendency for drug markets to cluster spatially in these areas (Forsyth, Hammersley, & Murray, 1992; Kleiman, 1991; Olligschlaeger, 1997). Using census data as proxy measures for social disorganisation at the neighbourhood level, researchers have found that socially disorganised neighbourhoods typically suffer from high unemployment rates, a high rate of female-headed households, low education levels, high minority population, and high residential turn-over (see for example, Bursik, 1988; Gottfredson, McNeil, & Gottfredson, 1991; Shaw & McKay, 1942). Thus, the theory runs that areas with high levels of these factors should be more likely to suffer a drug market because they are unable to garner enough formal and informal resources to successfully combat them.

Recent studies of social disorganisation have explored the immediate local environments of social disorganisation at scales finer than the commonly-used census tract (Griffiths & Chavez, 2004). For example, Tita and colleagues (Tita, Cohen, & Engberg, 2005) interviewed gang members in Pittsburgh, Pennsylvania to identify their 'set space': the location at which they met, hung out, and conducted business. Regressing these individual awareness maps to variables associated with social disorganisation, they identified the best predictors of gang locations as places with weakened capacities for informal social control. The street block has also been the focus of longitudinal research. In their study of crime over many years at the street block level of Seattle, Washington, Weisburd and co-workers found that over a 14 year period, only 4% to 5% of blocks (street segments) accounted for 50% of all incidents (Weisburd, Bushway, Lum, & Yang, 2004). However, what is common to many studies is that even when individual address data are available, the need to explore census variables necessitates aggregation to the census tract or block group level (for example Tita & Griffiths, 2005). In this research, we are able to subdivide census areal units and explore a more appropriate proximity-based model that examines social disorganisation around drug markets.

Social disorganisation alone does not predict a drug market. Many lower income and socially disorganised inner-city neighbourhoods have no drug markets. Research on individual drug addicts shows they tend to have not completed their high school education, are unemployed, have low formal income levels, and are members of minority ethnic groups (US Department of Health and Human Services, 1993), all characteristics that are not uniformly distributed within urban areas. A successful drug market must therefore be located in or near a neighbourhood that has the potential to generate sufficient numbers of drug users, as defined by these variables, or be easily accessible to drug users arriving from other locations (Eck, 1995). This means a drug market must be spatially located in a community where drug sales would be least disturbed by area residents and business owners and one that already contains, or can attract, enough drug users with cash available. In other words, social disorganisation is not necessarily sufficient for the development of a drug market: it also requires sufficient (business) opportunity.

Opportunity has traditionally been linked to routine activities theory as the mechanism by which offenders are made aware of criminal possibilities (Brantingham & Brantingham, 1993; Clarke & Felson, 1993; Jeffery & Zahm,

1993; Robinson, 1999). Early articulation of routine activity theory considered the process working for predatory crime at the neighbourhood level (Cohen & Felson, 1979); however, more recent work has extended the application of the interplay of a motivated offender and suitable target in the absence of a capable guardian in a number of ways, not least by including a wide variety of crime types (Felson, 1998) and by localising the spatial scale to more refined than the neighbourhood or census tract (Groff & LaVigne, 2001; Ratcliffe, 2006; Rengert et al., 2005). At this spatial extent, there are a number of land use features in the environmental backcloth of the city that have been suggested as encouraging, and providing the opportunity for, drug markets, as the next paragraphs summarise.

Environmental criminology research has shown that areas suffering from high levels of crime are often easily accessible to offenders via transportation corridors, including major streets, subways systems, and bus lines (Brantingham & Brantingham, 1991). Given that many drug users are unemployed with low income levels, the public transport network enables drug users to access a wider variety of locations, including those that contain drug markets. A drug market may therefore prosper from a location near a transportation facility because of the improved access it provides to its customers. This would be especially true if the customers of the drug market were from outside the immediate area as opposed to being residents, attending either an *export* or *public* drug market, employing Reuter's terminology (Reuter, 2000).

In the urban environment some land uses may add to the likelihood that drug users and addicts will congregate in the area, increasing the customer base and resulting in the likelihood of a drug market setting up nearby. A number of studies have shown that neighbourhoods surrounding alcohol sales outlets, including taverns and liquor stores, suffer higher crime levels (Roncek & Maier, 1991; Roncek & Pravatiner, 1989), while Sherman and colleagues (1989) reported that liquor outlets are closely associated with 'hot spots' of crime. Additionally, it is known that drug users frequently combine alcohol and drug use and many suffer from concurrent addictions (Best et al., 2000; Wadsworth, Moss, Simpson, & Smith, 2004). Therefore, drug markets should benefit from being located near alcohol outlets.

Addicts need cash to purchase drugs, suggesting that drug markets may profit from locating near cash-providing businesses such as pawnshops and cheque-cashing centres. Anderson (1999) notes that pawnshops located in the low income neighbourhoods of Philadelphia are used by thieves to convert stolen goods into fast cash with few questions asked, while also identifying cheque-cashing stores as the community banks of the poor and disconnected. Furthermore, homeless shelters are likely to increase the number of drug users in a neighbourhood, given that studies have documented the high drug use among many of their residents (Gelberg, Linn, & Leake, 1988; Snow, Baker, & Anderson, 1989). Drug-treatment centres also draw users to an area and therefore increase the potential customer base for a local drug market. Thus, it may be beneficial for drug markets to position themselves near pawnshops, cheque-cashing centres, homeless shelters, and drug-treatment centres in order to increase access to customers.

In summary, factors associated with social disorganisation are theorised to be also factors associated with the establishment of illegal drug markets; however, urban features relating to crime generators and attractors may also increase the opportunity to sell drugs to customers because potential customers are drawn by

these land uses and urban facilities. As pointed out by Smith, Frazee, and Davison (2000), a number of studies have in recent years articulated this version of theoretical integration to explain victimisation rates. In particular, the study by Smith and colleagues explored interaction effects between social disorganisation and routine activities in explaining street robbery in a midsize south-eastern US city with a study that employed the spatial scale of the street face block (Smith et al., 2000). Smith reaffirmed the validity of an integrated theoretical model when explaining a different crime type (vehicle theft), albeit in apparently the same city using the same spatial scale, while working with Rice (Rice & Smith, 2002).

Given the potential relationships outlined above between demographic and land use factors and drug markets, this article tests the hypothesis that variables drawn from the census that have been used by researchers to approximate measures of neighbourhood social disorganisation, and opportunity-based factors (including cheque-cashing stores, pawnshops, liquor outlets, and homeless shelters) may together determine where these markets will be located. Specifically, we seek to replicate the study by Rengert, Ratcliffe, and Chakravorty (2005) with a larger, more heterogeneous study area. This replication will fulfil two important functions: first, it will explore whether the measures of proximity (how close to a location drug arrests cluster) encountered in the Wilmington study are similar to the Philadelphia region, and second, it will determine whether the relationships discovered in the first study hold when tested on a much larger and more heterogeneous research area. Furthermore, it provides an alternative approach to the use of face blocks when exploring crime within census divisions and tracts, as employed by Smith et al. (2000) and Rice and Smith (2002). The next section describes the data sources employed in this study.

Data Sources

The dependent variable for this study consists of all drug sales and possession-for-sales cases recorded by the Philadelphia Police Department for the City of Philadelphia, Pennsylvania (USA) during the years 2002 and 2003. These 13,499 incidents are referred to hereafter as drug arrests. While police arrest data are, to a considerable degree at the individual record level, a facet of operational dynamics, in aggregate they are a generally reliable proxy measure of the locations of outdoor drug markets, at least in terms of easily available official data. Recent work by Warner and Coomer examining the validity of police arrest data as an indication of local drug market locations resulted in findings that 'suggest that arrest rates for drug trafficking are reasonably valid indicators of the relative level of visible drug trafficking among neighbourhoods' (Warner & Coomer, 2003, p. 133). To complement the drug arrest data, variables commonly associated with the incidence of social disorganisation were collected at the census block group level from the 2000 US Census. The researchers recognise that these are not social disorganisation variables, but are proxy measures of social disorganisation commonly employed in the research literature. These variables consisted of median household income, percentage female-headed households with children under age 5, percentage renter-occupied households, percentage households with residents who had lived in the same house for less than 5 years, percentage vacant residences, percentage

TABLE 1

Descriptive Statistics of Social Disorganisation Variables at the Census Block Group Level

Variables n = 1816	Mean	*SD*
Med Household Income ($ × 1,000)	30.5	16.9
% Female-headed HH with children under 5 years	3.80	5.90
% Renter occupied	38.8	23.7
% In same house for less than 5 years	36.7	17.3
% Vacant residences	11.5	11.0
% Unemployed males 16–24 years	35.4	21.3
% Residents under 25 years without HS certificate	30.7	16.7
% Minority	61.1	38.1

unemployed males 16 to 64 years old, percentage of residents over 25 years with less than a high school education, and percentage minority population. These variables formed the social disorganisation-related independent variables for the study. Descriptive statistics for these variables are shown in Table 1.

The locations of facilities believed to be crime generators and attractors, as determined by the comparison study and literature review earlier, were sourced from a variety of locations. Local government sources, particularly the Philadelphia Police Department, provided addresses for many of these criminogenic locations, such as subway stops, liquor outlets, halfway houses, and homeless shelters. Other locations were geocoded by the research team from telephone book records (both hard copy and online) for facilities such as pawn brokers and cheque-cashing stores. Inevitably, some variables from the Wilmington study could not be directly replicated in Philadelphia. For example, Pennsylvania's Liquor Control Board licensee list does not distinguish business types into taverns and liquor stores, as used in the Rengert et al. (2005) study. By law in Pennsylvania, spirits and wine can only be sold in state-run liquor stores and fully fledged restaurants. Beer can only be purchased in personal quantities to take off premises or consumed on the premises in businesses that serve prepared food. We therefore use the term 'beer establishments' to include all sandwich shops, delis, corner markets, and taverns which serve prepared food and are licensed to sell beer for on and off-premise consumption (n = 146). State liquor stores have their own category as a potential drug-market enabling set of locations in this study.

In Philadelphia, drug-treatment centres are categorised as both residential (n = 14) and outpatient (n = 20) facilities. In the location quotient analysis that follows, these facilities are reported both as independent groups and as a merged group. The residential and outpatient facilities were merged for the final ZIP analysis. Addresses for these facilities were obtained from the City of Philadelphia Department of Human Services web site. Homeless shelters and halfway houses were also located from this source. Cheque-cashing centres and pawnshops were included in the analysis if they were so identified in either the online or hard copy phone books. Finally, the City of Philadelphia has 49 subway stations located within its city limits. These were also included in the analysis.

Location Quotient Analysis of Criminogenic Locations

The first step in the analysis was to determine if drug arrests were clustered around criminogenic locations (suspected crime attractors and generators), testing the theory that these facilities may directly or inadvertently support drug markets through services that they provide. This part of the analysis also serves as a check on the generality of a similar analysis in the Rengert et al. study. A location quotient was computed using ArcGIS, a geographic information system (GIS), for each category of facilities to answer this question. A location quotient is a technique used in regional science that has been previously applied to the criminal justice field (Brantingham & Brantingham, 1995b), and is calculated thus:[1]

$$LQ = \frac{c_i / a_i}{c_R / a_R}$$

Where

LQ = Location quotient
c_i = total amount of crime in a study area i
(where i is a sub-area of the larger region R)
a_i = the area of study area i
c_R = total amount of crime in the larger region R
a_R = the area of the larger region R.

In the current study, the location quotient is computed by dividing the density of drug arrests around selected features by the mean density of drug arrests found across the entire city. Location quotient values greater than one suggest that drug arrests

TABLE 2

Opportunity Buffer Location Quotients

Facility	*n*	0–400 ft	400–800 ft	800–1200 ft	1200–1600 ft
Cheque-cashing store	96	4.92	3.67	2.79	2.17
Beer establishment	146	6.77	3.36	2.35	1.67
State liquor store	53	2.50	1.89	1.82	1.88
Pawnshop	30	7.19	4.71	3.32	2.26
Halfway house	41	5.22	6.09	4.08	4.10
Homeless shelter	39	2.51	2.83	2.92	2.31
Subway station	49	4.58	2.47	1.86	1.48
Drug-treatment centre	34	2.77	3.59	4.13	3.15
Drug-treatment centre (residential)	14	1.32	1.74	2.63	2.26
Drug-treatment centre (outpatient)	20	3.61	4.72	4.93	3.21

Note: For each facility, the table shows the number of that facility in Philadelphia, as well as the location quotient values for four concentric buffers expanding from the facility at 400 ft intervals. Values greater than 1 indicate a greater density of drug arrests than would be expected from a uniform distribution across the city. Values of 2, for example, indicate that the density of drug arrests is twice the uniform city rate. Drug treatment centres, both residential and outpatient, were combined in the ZIP model analysis. All three location quotient values (residential, outpatient, and combined) are shown here.

cluster around the facility type. A location quotient value of two would suggest that the clustering is twice as dense as would be found if the drug arrests were spread out uniformly across the entire city. Location quotients were computed for multiple 400-ft buffers or 'doughnuts' around each facility, each band expanding 400 ft from the previous one. This distance is approximately equal to the length of one city block in Philadelphia. Location quotient values for the buffers around the various categories of locations are shown in Table 2.

On examination of Table 2, two distinct patterns become clear. The first pattern shows that drug arrests cluster immediately within 400 ft of cheque-cashing centres (LQ = 4.92), beer establishments (LQ = 6.77), pawnshops (LQ = 7.19), and subway stations (LQ = 4.58). Steadily decreasing location quotient values are found when moving further away from these facilities suggesting that drug markets are attracted to the vicinity of these businesses and facilities. In particular, the beer establishment figures are noticeable. The significant clustering of drug arrests within one block of beer establishments declines rapidly within a block or two of the locations suggesting a microclimate where drug and alcohol problems co-locate.

The second distinct pattern in the location quotients shows a possible place management effect (Eck, 1995) on drug arrests clustering around halfway houses, homeless shelters, and drug-treatment centres. The area immediately surrounding these facility types (0–400 ft) has a lower location quotient value than of the distance bands. The peak for halfway houses is in the 400–800-ft buffer (*LQ* = 6.09), and in the 800–1200-ft buffer for both drug-treatment centres (*LQ* = 4.13) and homeless shelters (*LQ* = 2.92). One possible cause for these findings may be due to the intervention of staff and managers at the locations trying to prevent drug sales from occurring in front of the facility. Alternatively, clients fearing they will be ejected from the programs may be limiting the amount of drug activity conducted on the specific block where the facility is located. The high location quotient values around each facility, however, are still evidence of above-average clustering of drug arrests around these criminogenic facilities.

The location quotients are a simple and effective method with which to explore the clustering of drug arrests in the immediate vicinity of certain crime attractors and generators. However, while the location quotients offer evidence of clustering, they do not offer an explanation other than the immediate environmental criminological one. The second part of the analysis attempts to integrate polygon-based socioeconomic indicators related to social disorganisation with these land use/opportunity-related findings. To do this, the buffers with the highest location quotient values are retained for the second part of the analysis.

The reason for retaining the highest location quotient value buffers is because this is the area that is most likely to contain the dominant drug markets in the region. Nearby drug markets may exist (as evidenced by location quotient values greater than one in other buffers); however, they may be secondary markets that feed on the periphery of the primary market location that has the most business (measured here as arrests). The highest location quotient value buffers are retained for further examination as representing these primary drug markets.

The Spatial Analysis Framework

The location quotient analyses provide support for the theory that drug markets cluster near certain criminogenic locations. However, as stated earlier, the location quotient analysis is unable to incorporate any of the sociodemographic variables needed to integrate the social disorganisation component of our study. The location quotient analysis is however useful for establishing at what distances from each facility drug arrests are most highly clustered. For example, drug arrests cluster within 400 feet of pawnshops, but from 400 ft to 800 ft for halfway houses.

Conceptualising crime in proximity to locations allows us to change the nature of the spatial analysis framework. In other words, rather than thinking of crime clustering at a point (such as a liquor store) we can think of the crime cluster as an area (defined as a polygon or circle surrounding the liquor store with a radius of 400 ft). In this way the crime cluster areas in our analysis become circles with a 400-ft radius (also known as a buffer) for beer establishments, subway stations, pawnshops and cheque-cashing centres, and as a doughnut (with the hole in the centre) for halfway houses in a boundary that begins at 400 ft from each location and extends out to 800 ft, and for homeless shelters and drug-treatment centres with a boundary that begins at 800 ft and extends out to 1200 ft. By changing the geography of crime-attracting features from a point-based model to an areal one, the crime attractor/generator geography is now compatible with the polygon-based geography of the US Census.

The areal approach is preferable to simply counting the number of each type of facility within a block group because census geography is not designed for the examination of crime. Census geography is primarily designed to facilitate census collection and while it does attempt to mirror neighbourhood boundaries, this is only as a secondary consideration. Census boundaries run down streets and through intersections, the very same intersections that are often the *loci* of drug markets. By simply counting the facilities in a block group, we run the risk of falling foul of the modifiable areal unit problem (MAUP), a spatial analysis predicament that can happen when the results of a spatial analysis are dependent on the arrangement and size of the units of analysis (Chainey & Ratcliffe, 2005, p. 151). Because census boundaries are administrative in purpose, they rarely reflect the underlying pattern of criminal offending. The distribution of offences within an areal unit will change if different units of analysis are employed, such as census tracts, block groups, or police beats (Openshaw, 1984; Unwin, 1996). As a result, a more adaptive geography is required to minimise these problems. While Rice and Smith (2002) adapted street blocks into areal units and counted crime events to those units, their approach does not resolve the MAUP satisfactorily. Although they used a non-census geography approach, they aggregated criminogenic locations to face blocks that intersect at street corners — the precise location where many street drug markets exist. By using location quotient buffers we circumvent the intersectional issues that likely occurred with the Rice and Smith analysis, and while not eradicating the MAUP completely, the use of areal units rather than a point-based approach minimises many of the locational issues.

The use of buffers, while parsimonious, does not solve all of the spatial problems. Buffer rings around facilities do not nicely coincide with block group boundaries

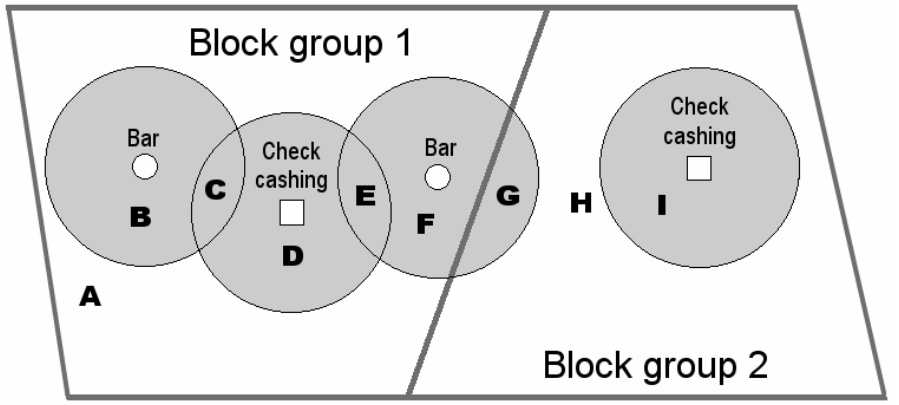

FIGURE 1

Establishment of new geographic units to explore the relationship between census variables and non-census areal patterns.

Source: Rengert, Ratcliffe & Chakravorty (2005, p. 154). Reproduced with permission of Criminal Justice Press.

from the census. This creates an analytical problem of finding an appropriate mechanism to merge these two data sources effectively. This problem can be resolved through the use of a GIS. Within most GIS programs there is a union facility that allows the merging of polygons. In our case, we used ArcGIS, a product of the ESRI Corporation, though buffer and union tools are available in most common GIS packages. We replicated the approach employed by Rengert et al. (2005) and show an example figure (Figure 1) from their work.

Figure 1 shows two neighbouring census block groups (#1 and #2) as white areas with a grey border. Within these block groups are four crime attractors, two bars and two cheque-cashing stores. Each of the crime attractors has a 400-ft buffer shown as a grey disc. As can be seen in Figure 1, these discs partially intersect with each other and all of the discs intersect with the block groups. In this way, the area of the two block groups has been subdivided into nine separate parcels (A through I) based upon the four buffers shown. Parcels A and H lie outside facility buffer rings while the remaining parcels (B, C, D, E, F, G, and I) lie within buffer rings. Note that parcel G was originally part of parcel F but the latter was subdivided into two parcels because it overlapped into block group 2. Two parcels, C and E resulted from overlapping buffer distance rings. Thus, three types of parcels have been created: (a) those not within range of a crime attractor (A and H), (b) parcels within 400 ft of one attractor (B, D, F, G, and I), and (c) parcels within 400 ft of two facilities (C and E). Each newly created parcel therefore contains a unique combination of criminogenic location proximity measures and census variables. The attribute data for each new parcel contains a binary indication of proximity to each type of facility as well as all of the census data from the census block group within which it resides.

In our study we combined the highest location quotient buffers for eight facilities with census demographics from the 1816 block groups within the city of Philadelphia. The eight types of facilities were cheque-cashing stores, beer establishments, state

liquor stores, pawnshops, halfway houses, homeless shelters, subway stations, and drug-treatment centres. These were drawn from the theory-based literature review covered earlier in the article. The result of the unions of the eight types of facilities and the city's block groups was a mosaic of 5101 new, smaller parcels, or geographic units, many unique to each other providing a customised geography with which to explore the crime rates within. Each unit contained its own demographic data, a 0–1 binary value to indicate whether or not it was within the maximum location quotient range of a facility, and a count of drug arrests within the unit. See Figure 2 for an example mosaic of the new geography created for this analysis.

ZIP Model Analysis

To analyse the newly integrated spatial units we used a zero-inflated Poisson (ZIP) model. Because the distribution of the drug sale events in the new geographic units contained a large number of units with no drug arrests, the ZIP model was preferable to a number of alternative analytical techniques due to its specific ability to cope with a high frequency of zero-count analytical units. Of the 5101 spaces formed during the buffering and unioning, 3296 (64%) had no drug arrests within them. The mean drug arrests per new unit was 2.65, with a standard deviation of 9.38. The new spatial units had a mean size of 0.067 square km, with a standard deviation of 0.244 square km.

The ZIP model has other advantages. It is a two-part process that provides two different sets of prediction coefficients. The first part of the model is a binary logistic or 'hurdle' model that predicts the likelihood that a geographic unit will be a member of a group of locations that will never have a drug market. This, in essence, is the hurdle that must be overcome for an area to have a drug market. This part of the analysis attempts to categorise areas into those that have the potential to contain a drug market (as defined by drug arrests) and those that are not deemed to have such potential. The second part of the ZIP model identifies which variables are significant in predicting the size of the drug market, if a drug market has the potential to exist. In other words, the model identifies which variables are significant in creating suitable environments in which drug markets have the capacity to exist, and it identifies a potentially different set of variables which indicate the conditions necessary for markets to flourish. With our integrated study, these variables can be drawn either from the variables that represent social disorganisation conditions or from the binary variables that indicate proximity to a crime attractor or generator.

The independent variables for our study included the binary indicators of being in a high location quotient area, census variables as shown in Table 2, a spatial lag variable to account for spatial autocorrelation and an area size measure to control for differences in the size of the geographic units. The spatial lag variable is used to control for the possibility that the arrest rate in one area is influenced by the arrest rate in neighbouring areas and, in our model, was constructed as a single order, rook-contiguity lag measure of arrests in adjoining units. It is in effect a measure of the causal influence of police and offender behaviour in neighbouring areas.

The model produces two output tables (which will be discussed in the next section) and some descriptive statistics. Of the latter, the Vuong test is a measure of

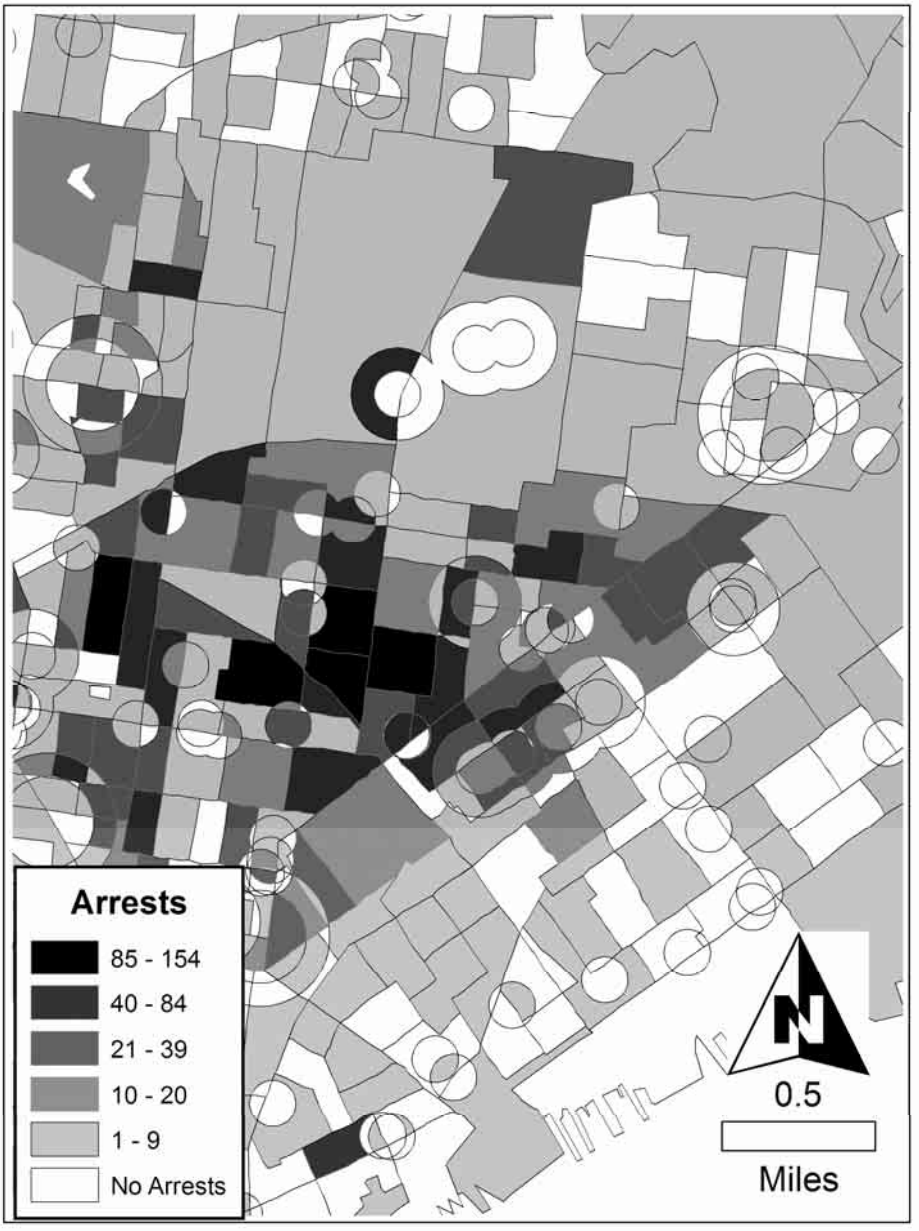

FIGURE 2
Example of the new geographic units from North Philadelphia.

the suitability of the zero-inflated model compared to a regular Poisson model. With a Vuong test statistic of $z = 15.36$ ($p < .001$), the ZIP model was shown to be significantly preferable for dealing with the zero-inflated data. Model statistics indicate that the inclusion of the independent variables significantly improved predictions on the outcome over the constant-only model ($p < .001$). Premodel tests indicated multicollinearity was not a problem.

Results

As stated earlier, the first half of the ZIP analysis predicts the likelihood that each variable is significant in either constraining or allowing an area to move from being unlikely to sustain a drug market to being likely to containing an outdoor drug market. In Table 3, positive values for coefficients imply that the variable acts as a constraint on the development of drug markets. In other words, the value predicts the likelihood that the geographical unit will be in the always-zero count group (while this seems counter-intuitive for the type of study presented here, this is the standard way that ZIP model results are presented). Conversely, negative and significant values suggest that the variable is important in predicting the environment for a drug market.

TABLE 3

ZIP Logistic Model Predicting Placement in Areas With No Drug Arrests

Predictor	*b*	*SE*	*Z*	Significance
Cheque-cashing stores	.6073093	.1287985	4.72	.000
Beer establishments	.6010026	.1162816	5.17	.000
State liquor stores	.6820344	.1736666	3.93	.000
Pawnshops	.4102938	.184829	2.22	.026
Halfway houses	.4848869	.1230515	3.94	.000
Homeless shelter	.6684536	.1091788	6.12	.000
Subway stations	.3120724	.1542508	2.02	.043
Drug-treatment centres	1.313411	.1637586	8.02	.000
Med income ($ × 1000)	.0059058	.0039537	−1.64	.100
% female-headed HH w/children	.0118932	.0046816	−2.54	.011
% renter occupied	.0042014	.0018603	2.26	.024
% unemployed males	−.005689	.001884	−3.02	.003
% vacant	.5910206	.3174643	−1.86	.063
% in-house < 5 years	.0077513	.0022797	3.40	.001
% minority	−.0063053	.0013194	−4.78	.000
% without HS certificate	−.0086018	.0027008	−3.18	.001
Area (sq ft × 1000)	.0005768	.0001067	−5.41	.000
Spatial lag	−.1196491	.0107629	−11.12	.000
Constant	1.394485	.2423655	5.75	.000

The results in Table 3 show that none of the (believed) criminogenic locations (cheque cashing, liquor businesses, pawnshops, halfway houses, drug-treatment centres, or subway stations) were significant in predicting the initial location of a drug market when holding the social disorganisation variables constant, as their coefficients are all positive and predictive of geographic units containing zero drug arrests. Even though the location quotient analysis showed clustering of drug arrests at these locations, these effects seem to wash out when combined with the varying socioeconomic variables found across the city. On the other hand, the negative coefficient values for percentage female-headed households, unemployed males, residents over 25 years without a high school education, and minorities in the population, indicated that these social disorganisation-associated variables were predictive of geographic units containing drug arrests, when holding all other variables constant. The greater the hypothesised degree of social disorganisation, as identified by the percentages of these proxy variables, the higher the likelihood the geographic unit would contain at least one drug arrest.

Surprisingly and contrary to expectation, the percentages of renter-occupied dwellings and households with occupiers living there for less than 5 years had positive coefficients, indicating that higher levels of these variables predicted units

TABLE 4

ZIP Regression Model Predicting Drug Arrest Count

Predictor	*b*	*SE*	*Z*	Significance
Cheque-cashing	−.3956469	.0384926	−10.28	.000
Beer establishments	.0977508	.0291069	3.36	.001
State liquor stores	−.3858296	.0674566	−5.72	.000
Pawnshops	−.3105341	.0561268	−5.53	.000
Halfway houses	−.033346	.0332752	−1.00	.316
Homeless shelter	−.3229771	.0376221	−8.58	.000
Subway stations	.1021459	.052828	1.93	.053
Drug-treatment centres	−.1652597	.0577511	−2.86	.004
Med income ($ × 1000)	−.000022	1.27e-06	−17.31	.000
% female-headed HH w/children	.0088193	.0013391	6.59	.000
% renter occupied	−.0038903	.0005653	−6.88	.000
% unemployed males	−.0018322	.0004859	−3.77	.000
% vacant	−.136521	.0942033	−1.45	.147
% in-house < 5 years	−.0002774	.0007092	−0.39	.696
% minority	.005748	.0004444	12.93	.000
% without HS Certificate	.0178642	.0007254	24.63	.000
Area (sq ft × 1000)	−.0000285	4.99e−06	−5.71	.000
Spatial lag	.0361977	.0007024	51.53	.000
Constant	1.365513	.0723315	18.88	.000

with no drug arrests. Median income and the percentage of vacant residences did not attain statistical levels of significance.

Table 4 presents the results of the second part of the analysis, the regression prediction of the number of drug arrests (essentially the predicted size of a drug market) in a geographic unit. Many of the criminogenic facilities that demonstrated clustering from the location quotient analysis demonstrate a negative impact on the size of a drug market in areas that were deemed to have the potential to sustain a market; in other words, in areas that were not predicted to be in the always-zero group. These included cheque-cashing stores, state liquor stores, pawnshops, halfway houses, and drug-treatment centres. If the statistical limits are relaxed slightly, proximity to a subway station is found to be a predictor of an increase in the size of the drug market ($p = .053$). Proximity to beer establishments is shown to increase the size of a drug market, holding all other variables constant.

On the demographic side of the model, increases in the proportions of female-headed households, residents over 25 without a high school education and minorities, were all positively related to the number of drug arrests found in a geographic unit. Neither the occupants' length of residence nor the number of vacant properties were significant and, interestingly, the percentage of housing units occupied by renters and the percentage of unemployed males had a negative impact on the number of drug arrests. As expected from theory, as the median household income in a geographic unit increases, the number of drug arrests decreases.

Discussion

The main aim of the study was to combine demographic indicators that suggest social disorganisation with the opportunity-related crime generators and attractors derived from routine activity theory. A second aim was to replicate as much as possible the study by Rengert et al. (2005). Inevitably, it was not possible to exactly replicate their study, and the authors recognise that the current study has a number of limitations. First, Philadelphia, Pennsylvania is a significantly larger city than Wilmington, Delaware with greater heterogeneity of population characteristics and land use. Second, the method of licensing liquor outlets in Pennsylvania is different to Wilmington and resulted in different classifications of liquor outlets. Potential errors in the spatial analysis may have also derived from inaccuracies of the geocoding of criminogenic locations or drug arrests. While a number of the criminogenic locations were checked by the researchers, the drug arrest data were provided by the Philadelphia Police Department as X and Y geographical coordinates. In the absence of specific addresses it was not possible to corroborate the specific drug arrest sites, or related geocoding error rates. The Philadelphia Police Department was one of the earliest innovators of crime mapping in the US and the department continues to maintain a sophisticated geocoding process that has been fine-tuned over many years, while still being respondent to changes in the city's geography. That being said, while this study has attempted to minimise the negative impacts of the MAUP, there are inevitably still issues associated with this most pernicious of spatial problems. Furthermore, there are inherent limitations with the use of census data, which are well known within the research community. In particular, the assumption that demographic factors, such as unemployment rates, are equally distributed within a

census tract or block group is known to be problematic though irresolvable in a study such as this due to the limitations of data confidentiality requirements. As a reviewer of this article also pointed out, census variables do not indicate other unobservable factors (not measured in this study) that may influence the opportunity structure in the spatial units, such as abandoned buildings and other microvariations in the urban mosaic that may drive social disorganisation.

Importantly, because this was a cross-sectional study, we cannot say anything for sure about the direction of the relationship between the criminogenic land uses and drug markets. The investigated theories suggest it would be advantageous for drug markets to locate near certain land uses, but it is probably not beyond speculation that some land uses may locate near drug markets for the reciprocal advantages the drug markets may provide.

The analysis shown here demonstrates the tip of a potentially significant analytical iceberg. We have limited the analysis to factors related to routine activities and social disorganisation variables in a fairly limited fashion. Being spatially located within a high location quotient area was indicated with a Boolean operator rather than with a variable that represented the number of bars or pawnshops (for example) in the area. Furthermore, due to page constraints and the desire for clarity, interaction analysis among the land uses was not attempted. This would have required 28 first order interactions (a*b), before even considering potential multiple interactions (a*b*c). While we believe this has helped to keep the findings and methodology parsimonious, there are clearly opportunities for additional research in this area.

When the study results were examined, we were surprised that the criminogenic impact of the crime generators and attractors, so clear from the location quotient analysis, did not generally sustain through the ZIP model in the direction expected. The first part of the study explored the potential for areas to contain drug markets. Examination of Table 3 showed that all of the crime generators/attractors were significant; however, they were significant in predicting the likelihood that the geographic unit would not contain drug arrests.

There are two plausible explanations for this, one methodological and one theoretical. The first relates to the geographic unit of analysis. While the location quotient confirms a high number of arrests within a buffer, repeatedly slicing off a buffer or doughnut into smaller pieces due to the intersection of block group boundaries or other buffers is likely to increase the segments of the buffers that have no arrests. For example, consider a buffer that had 10 drug arrests. This number of arrests would contribute to a high location quotient value. But the likelihood of repeat arrests at one or two key locations means that the drug arrests would cluster within the buffer. Slicing the buffer into five pieces is more likely to create one piece with 10 arrests and 4 pieces with no arrests rather than an even distribution of 2 arrests per slice.

A second possible cause for this finding is the huge impact that sociodemographics has to play in the establishment of drug markets in Philadelphia, overshadowing any criminogenic effect of the facilities. If this is the case then this finding is important because it adds significantly to the previous work in this area. Previous studies cited earlier have tended to find support for social disorganisation and its integration with routine activity theory, with greater emphasis on the strength of

social disorganisation. However, it may be that in Philadelphia sociodemographics are the dominant mechanism to determine the possible development of drug markets and there is little role at all for opportunity as a factor in the establishment of drug markets. It may therefore be that the search for socially disorganised neighbourhoods may be a driving factor in the choice of location for drug dealers and that, while locating near a criminogenic land use is of value in attracting customers, it is not a primary motivation for the establishment of a dealing location.

The demographic variables related to social disorganisation factors display an interesting pattern in the prediction of drug market potential. As expected, with increases in the percentage of female-headed households with children, unemployed males, vacant properties, residents who did not complete high school and minority residents, the likelihood of the area being free of drug markets declined. Given the relative lack of influence of opportunity factors, this may be suggestive of the spill-over process referred to by Rice and Smith (2002, p. 327) whereby offenders from the area are arrested for drug dealing on a variety of blocks in an area, drawn more by the general level of social degeneration in the neighbourhood rather than by the proximity to specific features of the urban land use environment.

Interestingly, as the percentage of households occupied by renters or by people who have lived in the same house less than five years increased, the chance of the area containing a drug market declined. One possible reason for this unexpected finding may be the recent resurgence of downtown living in Philadelphia over the past ten years. The Center City area of Philadelphia has seen a resurgence in young, middle-class professionals drawn by property tax abatements and rapid growth in quality apartment construction. The area currently accounts for a high number of transient, but wealthy residents and is expected to contain 10% of the city's residents within the next few years. One of the aims of this research was to establish if there were differences between Wilmington, Delaware, and a larger conurbation, and this may be one of those differences.

Table 4 presented the results of that part of the analysis that predicted factors that would increase the size of drug markets where they existed. The results were mixed for the crime attractors and generators. Cheque-cashing centres, state liquor stores, pawnshops, homeless shelters, and drug-treatment shelters were found to have an inhibiting effect on the size of drug markets, where drug markets were likely to exist. It is difficult to come up with a causal explanation for this. The findings from the study suggest that proximity to a subway station is likely to increase the size of a drug market, though we recognise that with a p value of .053, this result falls just outside of the generally agreed definition of significance. Beer establishments were found to operate in the expected direction such that where a drug market had the potential to exist; being within a block of a beer establishment was a significant predictor of an increased number of drug arrests. This provides further indirect support for the common research finding that drug users are polyusers and often mix alcohol and drugs (see e.g., Rengert, 1996).

As shown in Table 4, most, but not all demographic variables were related to the size of drug markets as theorised. Contrary to expectations, increases in the percentage of rental households were associated with smaller drug markets, which may be due to the Center City resurgence as described above. Additionally, the results showing that the size of drug markets decrease as the percentage of unemployed

males increases suggesting that, at least in Philadelphia, the economic explanation of drug market locations takes precedence over that of social disorganisation, in some situations. That is, some areas have such high levels of unemployed males that the neighbourhood does not have sufficient financial resources to sustain a large drug market. Although their finding was not statistically significant, Rengert et al. (2005) found this same result in their study of Wilmington, Delaware.

The social disorganisation principle reasserts itself in the remainder of the findings in Table 4, in that drug markets tend to be larger in size when the local population has greater percentages of racial minorities, female-headed households with children, and people who did not complete high school. As expected, as median household income increases, the size of drug markets decreased. Although the demographic variables used in this study are proxy variables for social disorganisation and are not social disorganisation measures per se, there is considerable support for the concept of social disorganisation and its relationship to drug markets in this study.

One of the different features of this study was the combination of social demographic and opportunity-related facilities to predict the location and size of drug markets. When explored at the city level, the social disorganisation variables appeared to respond more in the manner expected from theory. Yet we know from the location quotient analysis that there is clustering around opportunity-related, criminogenic locations. The spatial lag variable reinforces the notion from the location quotient analysis that drug arrests cluster in Philadelphia. The significance and high z value for this variable indicates that areas with high numbers of drug arrests are likely to be surrounded by other high drug arrest areas. The most likely explanation is that not all opportunity facilities within a category are as bad as each other. When aggregated to the city level, facilities such as beer establishments, pawnshops, and subway stations show evidence of drug arrest clustering. In reality, it is likely that there are good and bad liquor establishments, good and bad pawnshops, and subway stations that are located in areas unlikely to have drug markets. When concurrently analysed within the ZIP regression model, the influence of criminogenic locations (except beer establishments) is overshadowed by the greater consistency of demographic variables as predictors of drug market arrests across the city. The strength and importance of social disorganisation as the driving mechanism for the development of drug markets has been reinforced by this study.

Conclusion

In this analysis we were able to successfully combine social disorganisation factors derived from block group census data with point data (addresses) consisting of drug arrests and crime attractors and generators into a new geographic unit structure. This new unit of spatial delineation was more descriptive of the data in question and resulted in both a higher number of units (5101 compared to 1816 census units) and more precise spatial units than block groups alone would have allowed us to analyse. The use of a zero-inflated Poisson analysis allowed us to determine which factors were important to the location of a drug market, as well as which factors were related to its size, by employing a methodology first presented by Rengert et al. (2005). It offers a more precise instrument for evaluating spatially based

demographic and criminogenic locations in a regression equation to determine their combined impact on crime events.

In trying to explain patterns of drug market arrests, this study directly compared factors associated with social disorganisation and factors associate with routine activities theory. In doing so the article sought a more robust direct comparison of theories, as advocated recently in this journal by Weatherburn and Lind (2006). The results add weight to the argument that more strategic measures are required to tackle drug markets in urban areas. The strength of the variables that stand as proxy measures of social disorganisation articulate much about the force of the relationship between neighbourhood decline and criminal opportunities. However, it is too early to negate the power of land use and opportunity structure in relation to criminogenic environments from this study. This is only the first replication of the Wilmington study, and further methodological and theoretical development is undoubtedly warranted.

Endnote

1 It should be noted in equation 1 that we use area as the denominator; however, studies of other crime types may replace the area measures with more appropriate denominators. For example, a study of residential burglary could use the number of housing units (available from the census) as a better choice of denominator.

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