Environment and Planning B: Planning and Design 2014, volume 41, pages 000 – 000

doi:10.1068/b120068p

Modelling urban crime through workforce size: a test of the activity support concept

Lorena Montoya
Department of Services, Cyber-security and Safety, University of Twente, PO Box 217, 7500AE, Enschede, The Netherlands; e-mail: a.l.montoya@utwente.nl
Received 14 December 2012; in revised form 5 January 2014; published online 22 October 2014

Abstract. Crime has not figured strongly in urban planning agendas, it has been more of an afterthought. The consequences of this are property losses, psychological impact, high insurance premiums, and large police forces. There has been a gradual shift from the study of the offender to that of the victimized object. Most design-related efforts have been directed at the building and few at the neighbourhood or city level. There are opposing views regarding the effect of land use on crime. This research studies the relationship between the extent of economic activities and services and five types of crime using data from Utrecht in Holland. The findings show that (a) a relationship does exist, (b) the effect of some sectors is constant across crime types, and (c) some activities have a positive relation whilst others a negative relation with crime. The implications of these findings for planning and crime prevention are discussed.

Keywords: land use, activity location, environmental design, urban planning, crime prevention

Background

Urban planners are faced with the need to strike a balance between numerous and sometimes conflicting objectives. These objectives are not always afforded the same importance. Among several reasons that explain this are the efforts by pressure groups wishing to put their theme high on planning agendas. A good example is the sustained environmental lobbying. Other reasons include research gaps which cause some themes to receive low attention or are dropped altogether from planning consideration. The field of crime prevention provides a good example of a theme where some research gaps exist and these result in crime prevention having a somewhat lower profile within the field of urban development planning. There exists a failure of people or organizations to think about future crime risks or they have buried and untested assumptions about what causes crime. Risk assessment is not enough; it should be followed by a crime impact assessment of a type resembling the environmental or health equivalent (Ekblom, 2001). This paper aims to contribute empirical material in the field of crime prevention by environmental design, which would constitute a key component of such an impact assessment.

Throughout the world a considerable amount of research effort has been devoted to understanding criminality (ie, the offender). Extensive research has taken place on the reasons that lead people to become criminals, such as poverty, social disadvantage, parenting practices, and school performance. Conversely, considerably less effort has been directed towards 'situational crime prevention' (Clarke, 1980; 1997), which aims to modify the immediate conditions in which crimes are committed (Tilley, 2009); hence it addresses crime rather than criminality. Findings by Sherman (1995) support the view about the need to move away from the offender as the focus of research. He found that future crime is six times more predictable by the address (ie, location) of the occurrence than by the identity of the offender. Moreover, Coupe and Blake (2006) consider that focusing on the offender alone might lead

to ill-founded conclusions. In their view, low detection rates, such as those of burglary, hamper the compilation of representative samples of criminals. However, situational crime prevention has detractors, since some argue that it merely displaces crime (ie, change of location). Displacement clearly matters, but its risks have been overstated and it is not always malign (Tilley, 2009). Moreover, diffusion of benefits (ie, unexpected reduction of crime in areas not directly targeted by a situational preventive action), can bring considerable added value, but has been often overlooked (Clarke and Weisburd, 1994). According to Weisburd et al (2006), crime displacement is small and diffusion of benefits is more likely.

During the last decade 'crime science' has emerged in response to the need to broaden the approach. Crime science promotes a transdisciplinary approach where the contributing fields include criminology, sociology, psychology, geography, architecture, industrial design, engineering, biology, epidemiology, computer science, and mathematics (Laycock, 2005). Crime science view is that by the convergence of disciplines more substantial gains will be obtained in the field of crime prevention. In many countries research into the effect of building characteristics on crime and disorder has led to the development of 'secure-by-design' guidelines, regulations, and certification schemes. Neighbourhood and urban design lag somewhat behind in this respect. Crime prevention through environmental design (CPTED) (Jeffery, 1971) concepts (ie, territoriality, access control, surveillance, image maintenance, activity support, and target hardening) are widely used by practitioners in the design and redesign of neighbourhoods. CPTED states that the proper design and effective use of the built environment can lead to a reduction in the fear and incidence of crime and an improvement in the quality of life (Crowe, 2000). CPTED is founded on various theories that are explained later in this section. The empirical evidence currently available of CPTED's effect at the neighbourhood and urban level is limited, inconclusive, and even criticized.

The lack of a 'secure-by-design' approach to neighbourhood and urban design implies property loss, the psychological impact of victimization, indirect costs such as high insurance premiums, and high policing costs. Additionally, this omission results in costly remedial design modifications made a posteriori. The absence of this consideration during the design process is explained by the lack of a substantial body of research on the role of smaller-scale (ie, urban or neighbourhood) design on crime. Theory is needed that includes both the structural characteristics of each area and the dynamic social exchanges that occur within these areas (Fagan and Davies, 2000). This topic is relevant for the urban planning community since opposing views exist regarding the effects of land uses on crime. Some argue (Petterson, 1997; Poyner and Webb, 1991) that in neighbourhoods, opportunities for crime are reduced by increasing the range of activities in both spatial and temporal terms. Hence mixed land-use patterns contribute to a safer, more vital public realm (Zelinka and Brennan, 2001). The Charter of New Urbanism encourages mixed land-use. It states that many activities of daily living should occur within walking distance in order to allow independence to those who do not drive, especially the elderly and the young (CNU-Members, 1996). In addition, it states that civic, institutional, and commercial activity should be embedded in neighbourhoods and districts, not isolated in remote, single-use complexes. There are others who express negative views. Reynald (2011), for example, found that in the Netherlands mixed land use increased property crime whilst Kurtz et al (1998) found that it increased calls to emergency services. Cozens (2011) argues against mixed land use since he considers that different land uses are associated with both different types and different levels of crime in diverse and dynamic ways.

Several underpinning theories and concepts are relevant in the field of crime prevention through environmental design: social disorganization, rational choice, routine activity, anchor point, crime pattern, directional bias, defensible space, eyes on the street, critical crime-intensity zone, crime habitats, and crime attractors/generators/detractors/neutral.

Social disorganization theory [see Rubington and Weinberg (2003) for an extended discussion] argues that not only individual characteristics (ie, gender, age, race) but also residential location shape the likelihood that a person becomes involved in illegal activities (Park and Burgess, 1921). This theory is important because it states that 'place matters'. Moreover, distance (ie, 'as the crow flies') from a city centre is a factor that influences social and physical deterioration (Shaw and McKay, 1942). This approach was criticized because of its simplistic nature, in that it overlooked social, cultural, economic, and political characteristics. However, research shows that even after taking these characteristics into account, a 'proximity to city centre' crime effect exists (see, for example, Robinson and Rengert, 2006).

Rational choice theory argues that crime is a purposive action aimed at fulfilling the offender's ordinary needs for things, such as money, drugs, sex, freedom, and thrill. To meet such needs, decisions and choices have to be made and these are constrained by time and ability as well as by the availability of relevant information. According to this theory, an offender's decision-making process involves the weighing of reward against effort and risk (Cornish and Clarke, 2008).

The routine activity approach (Cohen and Felson, 1979) argues that offenders come across criminal opportunities as they go about their daily routine activities and make decisions about whether to take action. This theory states that a criminal act takes place when a likely offender converges in space and time with a suitable target (eg, a victim or property) in the absence of a capable guardian (eg, property owner, security guard). In other words, problems occur when offenders and targets come together and capable controllers fail to act (Eck and Clarke, 2003; Felson and Boba, 2010).

The anchor point theory of environmental knowledge acquisition (Golledge, 1999; Golledge and Spector, 1978) states that locations, features, path segments, or familiar districts 'anchor' cognitive maps and influence the encoding, storage, and decoding processes used when accessing stored information in a decision-making context. The work of Lynch (1960) should be mentioned, as he not only listed paths, boundaries, districts, and nodes but also argues that landmarks are among the structural elements of a city. Golledge and Stimson (1997) argue that when individuals analyze the time and cost of travel to an activity place there is often a directional bias. This bias is often related to a partiality for a particular place over other equally distant places because of some perceived quality of the preferred place. Landmarks are often noticed and remembered because of their dominance of visible form, peculiarity of shape or structure, or sociocultural significance (Golledge, 1999).

Crime-pattern theory integrates rational choice theory, routine activities approach, and anchor point theory. It explores the distribution and interaction of targets, offenders, and opportunities across time and space. Crime-pattern theory states that all individuals develop routine-activity spaces. Some areas within these spaces become better known than others. Criminal targets are usually selected from within an offender's awareness space. The awareness space consists of nodes, paths, and edges. Typical nodes include locations such as home, shops, places of entertainment, friends' homes, workplace, and school. The paths are the connections between the activity nodes. Edges are places where there is enough distinctiveness between one part and another that the change is noticeable. The edges create areas where anonymity is higher or where strangers are more easily accepted because they are frequently and legitimately present, while the interiors of neighbourhoods may constitute areas where strangers are uncomfortable and subject to challenge. According to this theory, crime clusters at high-activity nodes, along major paths, and along edges (Brantingham and Brantingham, 1993; 2008). Although crime-pattern theory integrates several earlier theories, it does not include the concept of directional bias.

The defensible space theory of crime prevention through urban design (CPTUD), (Newman, 1972; 1996) states that people perceive space as being either private, semiprivate, semipublic, or public and their expectations and levels of involvement in caring and protecting it vary across these types. CPTED adopted the concept of territoriality from CPTUD. In CPTED, territoriality is seen as the appropriation of space by legitimate users to discourage the presence of illegitimate users (Cozens et al, 2005). This appropriation takes the form of caretaking, feelings of ownership, or monitoring of activities (Brunson et al, 2001).

The eyes-on-the-street theory (Jacobs, 1961) states that the systematic zoning of areas for particular uses reduces the surveillance potential. Jacobs reached this conclusion after observing that in the inner city of Boston (USA), busy streets with a diverse mix of land uses provided more informal–natural surveillance. This theory is the basis for the activity-support concept of CPTED and its impact is clearly visible in the Charter of New Urbanism (CNU-Members, 1996). Activity support involves the generation of activity by ordinary citizens to discourage criminal action and, more specifically, the placing of 'safe' activities to serve as magnets for ordinary citizens who may act to discourage the presence of criminals (Cozens et al, 2005). The activity support concept has been translated by many into simply the encouragement of mixed land use. However, it does not aim to encourage activity in general but instead to identify 'safe' activities and locate them where these are likely to have a positive impact.

Angel (1968) made an important contribution because he discussed the issue of activity intensity or magnitude. He argued that certain critical levels of street activity and population density are linked to crime. In his view, when land-use intensity is very low, it follows that the crime level is low due to the scarcity of potential victims. As the intensity of land use increases, however, the number of potential targets grows sufficiently to attract potential offenders (ie, the critical crime-intensity zone). Beyond this point, the increase in the number of people provides a sufficient number of witnesses to deter offenders from committing crime. Other researchers have reported similar findings: for example, that busier streets with some pedestrian movement have reduced levels of recorded crime (Hillier and Shu, 1999; 2000).

The crime-pattern theory's key elements (ie, nodes, edges, and paths) can be classified into crime generators, crime attractors, crime detractors, and have no effect on crime. This classification is useful because it provides a framework for the formulation of crime-prevention strategies. Crime generators and crime attractors are places that become hotspots. Crime generators are nodes that attract large numbers of people for reasons unrelated to any particular level of criminal motivation they might have or the particular crime they might end up committing (eg, shops, entertainment venues, sports venues). Crime attractors are particular places, areas, neighbourhoods, or districts which create well-known criminal opportunities to which intending criminal offenders are attracted because of known opportunities for particular types of crime (eg, bar districts, prostitution strolls, drug markets, large shopping centres particularly those near major public transport exchanges, large and insecure parking lots in business or commercial areas). Also crime-neutral areas exist which neither attract intending offenders nor provide criminal opportunity that is too tempting to resist (Brantingham and Brantingham, 2008). Finally a crime detractor is an area that pushes offenders away or that contains few attractions (Kinney et al, 2008). Bernasco and Block (2011), for example, found that both pull and push factors exist in relation to robberies.

Finally, Felson (2006) argued that crime settings can be divided by the range of crimes they foster. A specific crime habitat invites a particular type of crime over a certain area. For example, a train station might be conducive mainly to pickpockets while a Dutch university might be conducive mainly to bicycle theft. A generic crime habitat, on the other hand, fosters many different crime types at a high rate in a particular area. Felson classifies generic

crime habitats into: (1) discrete edges, (2) connected edges, and (3) thick crime habitat. The notion of habitats is relevant because it explains why the edges between two neighbourhoods with a large number of abandoned sites are prone to high rates of different types of crime, particularly when such edges are interconnected via motorized public transport.

There are several limitations in the research literature which this research aims to address. The debate regarding the impact of mixed land use, with some claiming that it increases crime (Knowles, 2006; Town et al, 2004) while others that it decreases it (Bohl, 2000; Bothwell et al, 1998; Zelinka and Brennan, 2001), seems to be based largely on anecdotal rather than empirical evidence. 'Eyes on the street' may lead to increased surveillance, but it may also bring potential offenders to 'good' opportunities. Research is needed to clarify this issue in order to encourage a consensus for future planning. In addition, research frequently focuses on a few specific land uses, such as bars or schools, or it combines land-use information into indices or single measures of 'mixed land use'. If only some land uses produce crime, then combining such measures risks masking potentially opposite effects on crime (Stucky and Ottensmann, 2009). Therefore, there is a need to evaluate the impact of individual economic activities and services on different types of crime. Furthermore, no research seems to have included a measure of land-use size or intensity. Lastly, ambient population[(1)] should be accounted for and not only for the resident population (Andresen, 2011).

The general aim of this paper is to study the relationship between (a) economic activities and services and (b) crime. More specifically, the objective is to answer three questions while considering guardianship potential, target availability/attractiveness, offender potential, and the bias towards the city centre resulting from its touristic or historical appeal

1. Is there a relationship between (a) economic activities and services and (b) crime?
2. Do variations exist across different crime types? In other words, are increases in a given economic activity or service associated with decreases in one type of crime but with increases in another type of crime?
3. Which economic activities and services are statistically significant predictors of crime?

Method

Sample

Data from the Dutch city of Utrecht were used. Utrecht is the fourth largest city in the Netherlands. It is located 33 km southeast of Amsterdam and has an area of 9 930 ha. In 2011 it had a population of approximately 311 000 inhabitants. The city has 10 districts and 110 neighbourhoods. The median size of neighbourhoods is 47 ha, although in the most urbanized part of town these are as small as 4 ha, in size (ie, equivalent to a block of 200 x 200m). The data analyzed consisted of 7 years (2005–11) of statistics aggregated at the neighbourhood level (sample size of 770). The source of the data was the Municipality of Utrecht's website 'municipal monitor' (http://utrecht.buurtmonitor.nl).

Concepts

The frequency (ie, count) of recorded crime for several property and 'violence with the intent of theft' crime types constituted the dependent variables. The following specific crime types were analyzed: residential burglary, pickpocketing, mugging, theft of a car, and theft from car.

Time-budget surveys provide the best way to measure activity across a city. These surveys are unavailable at the neighbourhood level in the Netherlands and it is, therefore, necessary to

[(1)] The term 'ambient population' takes into account the movements of individuals through a given area and therefore depicts the population at risk. Therefore it, represents those present at a given point in time as opposed to the resident population which is what most studies take into account. The ambient population can be predicted on the basis of a time budget. However, time budgets are notoriously hard to establish and they are usually not available for small administrative units.

use other sources. The reasoning for using the number of jobs per sector rather than the number of establishments per sector is to capture the ambient population during working/school days since it is expected that the number of employees is related to the number of customers or visitors. The activity-related variables analyzed were the number of employees for each of the following economic activities or services: (a) agricultural; (b) construction; (c) financial; (d) health; (e) cultural, sport, and recreational; (f) retail and wholesale shopping; (g) lodging and dining; (h) transport and communications; (i) offices; and (j) other services.

Direct distance (ie, 'as the crow flies') in km to the cathedral was used to account for the bias towards historic/touristic landmarks. The cathedral in Utrecht is not only the centre of the old town but also, nowadays, it is a common meeting point for people on their way to entertainment or shopping activities.

Four 'control' variables were selected following a review of previous research (Bernasco and Luykx, 2003; Gould et al, 2002; Klerks and Kop, 2008; Reynald et al, 2008):
(1) Residential stability in the form of the average length of stay in years was used to represent guardianship.
(2) Due to the unavailability of income data at the neighbourhood level, the average house price/m^2 of built area in € thousand was used to depict target attractiveness.
(3) The percentage of unemployed persons with low education level was used to represent offender potential.
(4) Ethnic heterogeneity in the form of the percentage of ethnic non-Dutch was used to depict social cohesion.
Additionally, the study took population density and neighbourhood size (in ha^2) into account.

Analysis

The analysis was carried out at the neighbourhood level. There is literature available (eg, Fagan and Davies, 2000; Holloway and McNulty, 2003) that considers land use at that type of spatial unit (ie, above the microlevel).

The analysis consisted of four phases. First, descriptive statistics were developed to check whether the data met regression assumptions such as normality and multicollinearity.[(2)] Second, 'full' regressions (ie, with all variables) were performed for each type of crime using a multilevel negative binomial regression.[(3)] The group-level variable used was the neighbourhood defined by the Dutch Census Bureau (CBS) as an area of homogeneous land use.[(4)] Thirdly, on the basis of each regression, the predicted counts at a given value

[(2)] The variance inflation factor diagnostic statistic was used to verify that the variables chosen did not present multicollinearity.

[(3)] The multilevel approach was selected because the individual values were not completely independent; in other words, for a given variable values from the same neighbourhood were similar to each other. The average correlation between the variables measured on values from the same neighbourhood was higher than that of values from different neighbourhoods. Such a regression handles what would otherwise result in large biases in the standard errors, resulting in many spuriously significant results. The dependent variable measures frequencies (ie counts of crimes). Due to its over-dispersion (ie excess of observations with a count of 'zero'), the negative binomial regression model was used. In addition, the model was 'bootstrapped' to handle the skewness in the distributions of the independent variables. The bootstrapping procedure also has the advantage that it makes the interpretation of regression results straightforward (Erceg-Hurn and Mirosevich, 2008; Wright and London, 2009).

[(4)] Modifiable area units such as districts can cause a statistical bias, which can affect the statistical hypothesis tests. This problem has been widely acknowledged (see, for example, Harcourt and Jens, 2006; Openshaw, 1984). However, because the neighbourhood unit in The Netherlands is chosen on the basis of the principle of homogeneous land use, it is justifiable to conduct this analysis using this unit. Moreover, since criminology theory dictates the need to carry out crime analysis whilst controlling for the effects of sociodemographic characteristics, the neighbourhood unit is the smallest unit for which such information is publicly available and hence was the only viable unit for this research.

(eg, at 0, 10, 20, 30, government jobs per ha) were calculated.[5] Fourthly, to compare across crime types, the predicted counts were graphed for each economic activity and service based on their present minimum and maximum values (see table 1). Finally, regression models with the best predictors were elaborated for each crime type on the basis of the 'full' models. An iterative backward elimination process was carried out one variable at a time based on *p*-values. The best-fitting model was selected on the basis of Schwarz's Bayesian information criterion (BIC), which is a model selection tool.[6] A model with lower BIC value constitutes a better model.

The regressions illustrate the effect of each of the continuous independent variables on the dependent variable whilst controlling for the effects of all the other variables (ie, whilst taking all the other variables into account). The regression output could be, therefore, used to predict the effect of not only individual independent variables but also the combined effect of several of them.[7] For example, a planning authority could use the regression output to forecast the likely effect in a residential neighbourhood of an urban regeneration project for the conversion of a disused industrial facility into a shopping centre with shops and cafes or restaurants (see example in appendix A).

As mentioned in the Concepts subsection, because of the nature of the data used, the model is suitable for predicting crime during working/school days and is not suitable for predicting crime during weekends and holiday periods.

Results

Table 1 summarizes the results of the descriptive statistics of both the dependent and independent variables included in the analysis. First, a description of the findings regarding the 'margins' (ie, predicted counts) is presented, followed by a description of the final regression models. The 'full' regression models (see table in appendix B), which are those that include all the independent variables, show that the effect of the various sectors may or may not be homogeneous across crime types. For example (refer to figure 1), increases in the number of jobs in the educational sector are associated with (1) increased risk of residential burglary and pickpocketing, (2) reduced risks of theft from cars, and (3) have no effect on car theft.

Figure 2 shows that rises in the business workforce are associated with increases in the theft from cars but have no effect on the other crime types. It is important to view this graph together with the regression output because in some cases a trend exists but it might not be significant. For each crime type (and given the study's sample size) the regression shows whether there is enough evidence that a given activity is a significant predictor of a particular crime type.

The results of the 'compact' regression models (ie, the best fitting ones, consisting of the least number of variables), shows that (refer to table 2): (a) pickpocketing rises directly with the number of jobs on the transport and communication sector [an increase in one job/ha in

[5] The predicted count of a variable (ie, 'margins') is calculated whilst holding all other variables in the model at their means.

[6] This measure, as well as other similar ones such as the Akaike's information criterion (AIC), is not intrinsically interpretable (it is not meaningful to talk about their values being large or small per se); however, it is useful as a way of comparing models (Field, 2009). The BIC penalizes complex models, giving preference to simpler models, and is effective in keeping in line with the principle that models should be as simple as possible (theories and models should be parsimonious).

[7] For ease of interpretation, the regression results in table 2 (later) are presented on the basis of incidence rate ratios (IRR). However, to model a development scenario such as the one described below, regression coefficients are needed instead. The logarithm of IRR values represents the regression coefficient (ie β). The formula required to predict the expected counts is $\exp[(\beta_1+\ln\delta_j)+\beta_2 x_{2i}+\ldots+\beta_7 x_{7ij}]$ where the specific neighbourhood j has a given δ_j. For further information on multilevel negative binomial regression formulas, refer to Rabe-Hesketh and Skrondal (2012)

Table 1. Descriptive statistics of dependent and independent variables.

Variable	Mean	Standard deviation	Minimum	Maximum	*N*
Dependent variables					
Residential burglary	22.09	21.09	0	132	777
Pickpocketing	9.49	38.03	0	480	777
Mugging	3.94	6.97	0	92	777
Car theft	4.75	4.86	0	48	777
Theft from car	82.21	110.56	0	1340	777
Independent variables (jobs/ha)					
Farming	0.01	0.02	0	0.21	777
Industrial	0.90	2.00	0	16.22	777
Construction	0.74	1.15	0	10.30	777
Hotel and dining	2.18	7.01	0	56.24	777
Transport and communication	2.77	7.10	0	67.36	777
Business offices	8.91	17.80	0	134.12	777
Financial	1.60	7.28	0	76.61	777
Government	3.56	14.93	0	161.28	777
Education	3.98	10.97	0	107.33	777
Health	4.76	5.77	0	36.24	750
Culture, sport, and recreation	1.37	2.73	0	18.14	777
Commercial – retail/ wholesale	4.90	12.96	0	131.88	777
Others	1.41	2.91	0	23.76	777
Control variables					
Distance to city centre (km)	3.04	1.99	0.09	9.53	777
Average length of stay (years)	7.65	2.81	0	14.40	777
Unemployed with low education level (%)	1.42	1.72	0	22.73	766
Ethnic non-Dutch (%)	27.48	15.91	0	100	766
Average house price (1000 € per m^2 of built area)	3.31	0.98	1.28	7.74	719
Population density (inhabitants/ha)	66.62	47.93	0	189.86	777

this sector increases the amount of pickpocketing by a factor 1.032 or 3.2% (IRR=1.032)]. This implies that if the yearly pickpocketing rate of a neighbourhood is 2.20 per one hundred inhabitants, the effect of adding an extra worker on this sector would be a rise to 2.28 pickpocketing events per one hundred inhabitants per year; (b) residential burglary decreases inversely with the number of jobs in the culture, sport, and recreation sector (IRR=0.961); (c) mugging rises directly with the number of jobs in the hotel and dining sector (IRR=1.046). Additionally, mugging decreases with the distance from the city centre (IRR=0.761); (d) theft of cars decreases inversely with the number of jobs in the health sector (IRR=0.976), and (e) theft from cars decreases with the number of jobs in the farming sector (IRR=0.092) and also with jobs in the health sector (IRR=0.974). Furthermore, theft from cars decreases with distance from the city centre (IRR=0.839). In addition, it was found that no economic activity or service is statistically significantly associated with decreases in one type of crime but with increases in another type of crime. Finally, regarding the control variables (refer to table 2), the percentage of inhabitants who are 'unemployed with low education' level is the only variable that is a significant predictor of all crime types. The average house price

is a significant predictor of all crimes types except pickpocketing. Ethnicity is a significant predictor only for residential burglary and theft from cars. The density of inhabitants is a significant predictor of all crime types except mugging.

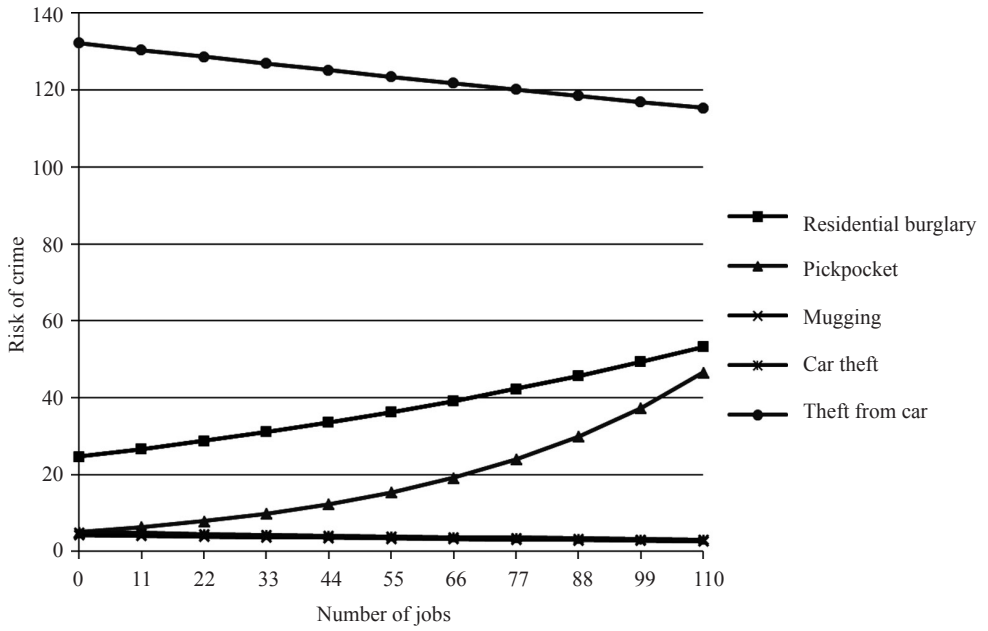

Figure 1. Predicted count of number of jobs the educational sector by crime type (whilst all other variables are held at their means).

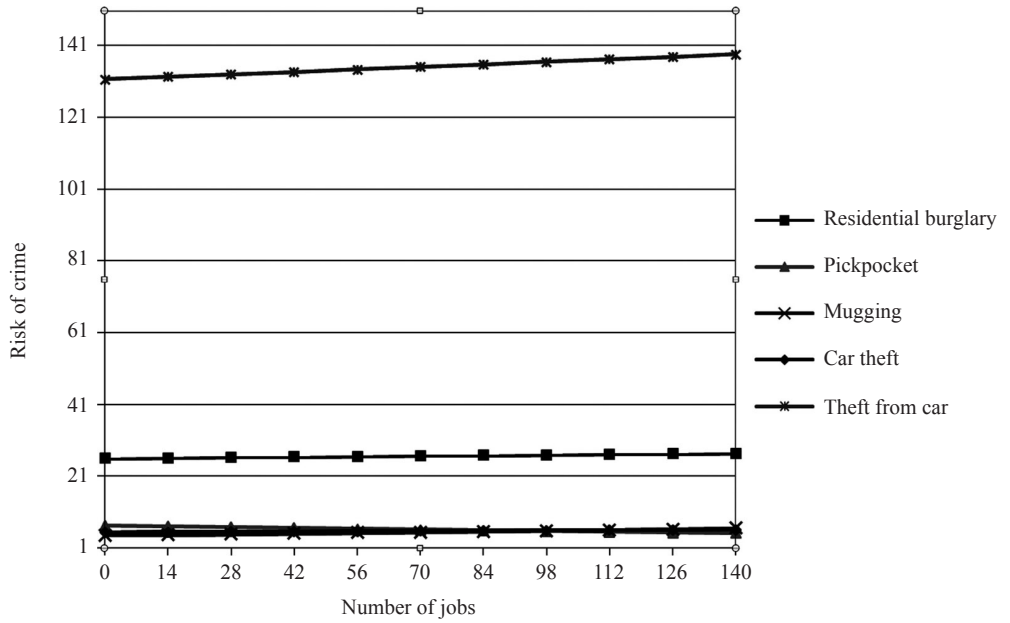

Figure 2. Predicted count of number of jobs of the business sector by crime type (whilst all other variables are held constant).

Application and synthesis

Three questions were addressed. The first is whether there is a relationship between (1) economic activities and services and (2) crime. It was found that for all five crime types, there is a relationship between at least one of the activities and crime. These findings suggest that crime potential should be a consideration in neighbourhood and urban planning.

Table 2. Multilevel negative binomial regression models (compact models).

	Residential burglary		Pickpocketing		Mugging		Theft of car		Theft from car	
	incident-rate ratio	standard error	incident-rate ratio	standard error	incident-rate ratio	standard error	incident-rate ratio	standard error	incident-rate ratio	standard error
Fixed-effects parameters										
Jobs farming (per ha)									0.092	0.097*
Jobs health (per ha)	1.013	0.010	1.022	0.015			0.976	0.011*	0.974	0.008**
Jobs culture, sport, and recreation (per ha)	0.961	0.017*								
Jobs transport and communication (per ha)			1.032	0.013*						
Jobs financial (per ha)			1.021	0.021						
Jobs educational (per ha)			1.023	0.015						
Jobs hotel and dining (per ha)					1.046	0.017**			0.973	0.016
Distance from historical centre (km)					0.761	0.032***			0.839	0.045**
Ethnic heterogeneity (%)	1.014	0.005**							0.990	0.004*
House price (€ thousand)	0.912	0.041*	1.080	0.068	0.708	0.055***	0.871	0.051*	0.798	0.041***
Unemployed with low education (%)	0.898	0.029**	0.851	0.058*	1.194	0.060***	1.167	0.043***	1.135	0.034***
Inhabitants (per ha)	1.013	0.002***	1.006	0.003*			1.005	0.002*	1.008	0.002***
Constant	3.985	1.006***	2.167	0.928 [a]	25.764	9.151***	17.255	8.550***	24.430	8.881***
Random-effects parameters										
ln*r*	1.181	0.183	0.804	0.223	1.652	0.224	2.240	0.409	0.534	0.198
ln*s*	1.591	0.247	0.134	0.161	0.906	0.152	0.829	0.162	2.117	0.291
r	3.257	0.597	2.235	0.498	5.215	1.170	9.398	3.848	1.706	0.338
s	4.907	1.211	1.144	0.184	2.475	0.377	2.292	0.371	8.307	2.422
Log-likelihood	−2425.97		−1422.99		−1484.52		−1588.56		−3268.02	

[a] p <0.10; *p <0 .05; **p <0 .01; ***p <0.001

N=693 (103 neighbourhoods)

Note. The inverse of one plus the dispersion is assumed to follow a beta(r,s) distribution.

In relation to the theoretical framework, these findings support the crime-pattern theory (Brantingham and Brantingham, 1993; 2008) in the sense that activity nodes play a role in determining where crime takes place. Moreover, support was found for Lynch's (1960) and Golledge's (1999) claims that directional biases towards historical landmarks exist. These findings also back the claims by the Charter of New Urbanism (CNU-Members, 1996), which considers that single-use development should be avoided. For example, if increases in the number of jobs in the culture, sport, and recreation sector are associated with decreases in residential burglary, residential-use-only neighbourhoods do not constitute the best option. This finding confirms the view of Cozens et al (2005), who believe that the placing of 'safe activities' can attract legitimate users who may act to discourage illegitimate users. This finding also supports the defensible space theory; Newman (1996) argued that people defend space which they identify as private or semiprivate. For example, in the Netherlands it is common practice that the residents (neighbours) are involved in the design of a park's playground area, including the selection of the actual objects (eg, benches, slides, swings). Such participation changes the perceived character of the park from 'public' to 'semipublic' or 'semiprivate'. This involvement in decisions which relate to public areas leads to a higher presence of neighbours in the surrounding area, increasing natural surveillance, and thereby reducing residential burglary. This finding raises the question of what should be the catchment area of essential services such as parks. Regarding activity intensity, the research does not support the view of Angel (1968), who claims that a 'critical crime-intensity zone' exists. A curvilinear relationship between crime and the individual economic activities or services was not identified in this study.

The second question is whether variations exist across different crime types. The analysis shows that, indeed, variations do exist across crime types although this is not the case for all the activities analyzed. Some activities therefore increase crime while others decrease it. This finding supports the view of Cozens (2011) who claims that different land uses are associated with both different types and different levels of crime in diverse and dynamic ways. This result is relevant because it leads to the issue of how to integrate such findings for the purpose of strategy formulation.

The third question is which economic activities and services are significant predictors of crime. The variable 'culture, sport, and recreation-related workforce' is the best predictor of residential burglary. The 'transport and communication-related workforce' is the best predictor of pickpocketing. The 'hotel and dining-related workforce' is the best predictor of mugging. The 'health-related workforce' is the best predictor of theft of cars. Finally, the 'farming' and 'health-related workforce' are the best predictors of theft from a car. A key finding is that some of these activities have a positive relationship with crime whilst others have a negative one. Therefore, it seems that neither of the polarized views which currently exist with respect to the relationship between land use and crime is justified. Stucky and Ottensmann's (2009) view that mixed land-use analysis masks potentially opposite effects on crime is not supported by this research. It is worth noting that the trend does exist but that it is not statistically significant. Further research is needed to study the impact of particular subsectors before producing a list of activities broken down into crime attractors, crime generators, crime detractors and crime neutral. For example, the effect on crime of a Dutch 'coffeeshop', an establishment where not only soft drugs are sold legally but where food and drinks are also sold, should be compared with that of ordinary snack bars, cafeterias, and restaurants.

It could be concluded, therefore, that there is crime-reduction potential by means of neighbourhood and urban planning, particularly land-use planning. A decision support system could provide planning officers with a tool to rank future development alternatives based on their criminogenic potential. Such a system is feasible because all the data used in

this study are readily available at the neighbourhood level. However, the design of such a system would inevitably include difficult decisions such as establishing a ranking of crimes according to their importance (eg, is residential burglary more serious than mugging?) The ranking of incident types is not a new idea since emergency call centres use incident-priority levels to prioritize the resources available to respond to calls. The weighting of crime types for the purpose of a decision-support system to rank urban development alternatives could be done on the basis of the value of property loss; alternatively it could be based on the psychological impact on victims, the costs of the physical improvements or adaptations, policing and criminal justice costs, or on a combination of all of these [see Welsh et al (2001), Roman and Farrell (2002), and van Soomeren and Wever (2004) for literature on cost-benefit analysis of crime-prevention measures]. Such a system could also constitute a tool on which to base a decision on whether or not to allow a land-use conversion (eg, given the characteristic of a neighbourhood, should a request to allow the conversion of a building from single-family residence into a night club be granted or turned down?) It would also allow neighbourhood watch programme participants to anticipate the effect of changes such as the closing of a major supermarket. Lastly, the system could also allow police departments to anticipate changes in hotspots resulting from changes in the environment and adapt their foot and vehicle patrols accordingly.

From a policy point of view, the findings show that the criminogenic impact of development should be a consideration during the early phases of the neighbourhood and urban design process. It is clear that this crime-potential assessment should be afforded the same importance as other planning tools currently deemed as mandatory and which aim to make cities more sustainable, such as environmental impact assessments. From a methodological viewpoint, the research findings illustrate the importance of avoiding generalizations in terms of both land uses and crime types.

Recommendations for further research

This research proves that a relationship exists, rather than that the economic activities and services cause crime. Further research would be needed to prove cause and effect. For example, one could measure crime before and after the opening of a particular economic activity (eg, supermarket) in the area where such activity will be located (ie, experimental area) as well as in an adjacent area and in a control area. In addition, a more detailed research could be carried out to develop catchment-size guidelines. Proximity of a site to a crime attractor or generator may increase the amount of crime there because it is located on the paths that lead towards and from the crime attractor or generator (Bernasco and Block, 2011). Such research could therefore model the incidence of individual crimes on individual buildings based on the intensity and also on the distance between them. Finally, the research by Coupe and Blake (2006) suggests that a further refinement could be made by splitting the dataset into two parts, for example, one for day and one for night using time information.

References

Andersen M A, 2011, "The ambient population and crime analysis" *The Professional Geographer* **63** 193–212

Angel S, 1968, "Discouraging crime through city planning", WP75, Institute of Urban and Regional Development, University of California at Berlekey, Berkeley, CA

Bernasco W, Block R, 2011, "Robberies in Chicago: a block-level analysis of the influence of crime generators, crime attractors, and offender anchor points" *Journal Research in Crime and Delinquency* **48** 33–57

Bernasco W, Luykx F, 2003, "Effects of attractiveness, opportunity and accessibility to burglars on residential burglary rates of urban neighborhoods" *Criminology* **41** 981–982

Bohl C, 2000, "New urbanism and the city: potential applications and implications for distressed inner-city neighbourhoods" *Housing Policy Debate* **11** 761–797
Bothwell S, Gindroz R, Lang R, 1998, "Restoring community through traditional neighbourhood design: a case study of Diggs Town public housing" *Housing Policy Debate* **9** 89–114
Brantingham P L, Brantingham P J, 1993, "Nodes, paths and edges: considerations on the complexity of crime and the physical environment" *Journal of Environmental Psychology* **13** 3–28
Brantingham P L, Brantingham P J, 2008, "Crime pattern theory", in *Environmental Criminology and Crime Analysis* Eds R Wortley, L Mazzerole (Willan, Cullompton, Devon) pp 78–93
Brunson L, Kuo F E, Sullivan W C, 2001, "Resident appropriation of defensible space in public housing: implications for safety and community" *Environment and Behaviour* **33** 626–652
Clarke R V G, 1980, " 'Situational' crime prevention: theory and practice" *British Journal of Criminology* **20** 136–147
Clarke R V G, 1997 *Situational Crime Prevention: Successful Case Studies* (Harrow and Heston)
Clarke R V, Weisburd D, 1994 *Diffusion of Crime Control Benefits: Observations on the Reverse of Displacement* (Criminal Justice Press, Monsey)
CNU-Members, 1996 *Charter of New Urbanism* (McGraw-Hill, New York)
Cohen L E, Felson M, 1979, "Social change and crime rate trends: a routine activity approach" *American Sociological Review* **44** 588–608
Cornish D B, Clarke R V, 2008, "The rational choice perspective", in *Environmental Criminology and Crime Analysis* Eds R Wortley, L Mazerolle (Willan, Cullompton, Devon) pp 21–47
Coupe T, Blake L, 2006, "Daylight and darkness targeting strategies and the risks of being seen at residential burglaries" *Criminology* **44** 431–464
Cozens P M, 2011, "Urban planning and environmental criminology: towards a new perspective for safer cities" *Planning Practice and Research* **26** 481–508
Cozens P M, Saville G, Hillier D, 2005, "Crime prevention through environmental design (CPTED): a review and modern bibliography" *Property Management* **23** 328–356
Crowe T, 2000 *Crime Prevention Through Environmental Design: Applications of Architectural Design and Space Management Concepts* (Butterworth-Heinemann, Oxford)
Eck J E, Clarke R V, 2003 *Classifying Common Police Problems: A Routine Activity Approach* (Criminal Justice Press, Monsey)
Ekblom P, 2001, "Future imperfect: preparing for the crimes to come" *Criminal Justice Matters* **46** 38–40
Erceg-Hurn D M, Mirosevich V M, 2008, "Modern robust statistical methods" *American Psychologist* **63** 591–601
Fagan J, Davies G, 2000, "Crime in public housing: two-way diffusion effects in surrounding neighbourhoods", in *Analyzing Crime Patterns: Frontiers of Practice* Eds V Goldsmith, P McGuire, J Mollenkopf, T Ross (Sage, Thousand Oaks, CA) pp 121–137
Felson M, 2006 *Crime and Nature* (Sage, Thousand Oaks, CA)
Felson M, Boba R L, 2010 *Crime in Everyday Life* (Sage, Thousand Oaks, CA)
Field A, 2009 *Discovering Statistics using SPSS* (Sage, London)
Golledge R G, 1999 *Human Wayfinding and Cognitive Maps* (Johns Hopkins University Press, Baltimore, MD)
Golledge R G, Spector A N, 1978, "Comprehending the Urban Environment: Theory and Practice" *Geographical Analysis* **10** 403–426
Golledge R G, Stimson R J, 1997 *Spatial Behavior: A Geographical Perspective* (Guilford Press, New York)
Gould E D, Weinberg B A, Mustard D B, 2002, "Crime rates and local labor market opportunities in the United States: 1979–1997" *Review of Economics and Statistics* **84** 45–61
Harcourt B E, Jens L, 2006, "Broken windows: new evidence from New York City and a five-city social experiment" *University of Chicago Law Review* **73** 271–320
Hillier B, Shu S, 2000, "Crime and urban layout: the need for evidence", in *Secure Foundations: Key Issues in Crime Prevention, Crime Reduction and Community Safety* Eds S Ballantyne, V MacLaren, K Pease (Institute for Public Policy Research, London) pp 224–248

Hillier D, Shu S, 1999, "New evidence on the relation between crime and space" *Planning in London, Designing for Secure Spaces* **29** 36–39
Holloway S R, McNulty, T L, 2003, "Contingent urban geographies of violent crime: racial segregation and the impact of public housing in Atlanta" *Urban Geography* **24** 187–211
Jacobs J, 1961 *The Death and the Life of Great American Cities* (Vintage Books, New York)
Jeffery C R, 1971 *Crime Prevention Through Environmental Design* (Sage, Thousand Oaks, CA)
Kinney J B, Brantingham P L, Wuschke K, Kirk M, Brantingham P J, 2008, "Crime attractors, generators and detractors: land use and urban crime opportunities" *Built Environment* **34** 62–74
Klerks P, Kop N, 2008 *Societal Trends and Crime-Relevant Factors: an Overview for the Dutch National Threat Assessent on Organized Crime 2008–2012* (Police Academy of the Netherlands, Apeldoorn)
Knowles P, 2006, "Designing out crime—the cost of policing New Urbanism", http://www.americandreamcoalition.org/safety/policingnu/policingnu.html
Kurtz E M, Koons B A, Taylor R B, 1998, "Land use, physical deterioration, resident-based control, and calls for service on urban street blocks" *Justice Quarterly* **15** 121–149
Laycock G, 2005, "Defining crime science", in *Crime Science: New Approaches to Preventing and Detecting Crime* Eds M J Smith, N Tilley (Willan, Cullompton, Devon) pp 3–24
Lynch K, 1960 *The Image of the City* (MIT Press, Cambridge, MA)
Newman O, 1972 *Defensible Space* (Macmillan, New York,)
Newman O, 1996, "Creating defensible space", US Department of Housing and Urban Development, Washington, DC
Openshaw S, 1984 *The Modifiable Areal Unit Problem* (GeoBooks, Norwich)
Park R, Burgess E W, 1921 *Introduction to the Science of Sociology* (University of Chicago Press, Chicago, IL)
Petterson G, 1997, "Crime and mixed use development", in *Reclaiming the City: Mixed Use Development* Ed A Coupland (Spon, London) pp 179–202
Poyner B, Webb B, 1991 *Crime Free Housing* (Butterworths, London)
Rabe-Hesketh S, Skrondal A, 2012 *Multilevel and Longitudinal Modeling Using Stata* (Stata Press, College Station, TX)
Reynald D M, 2011, "Factors associated with the guardianship of places: assessing the relative importance of the spatio-physical and sociodemographic contexts in generating opportunities for capable guardianship" *Journal of Research in Crime and Delinquency* **48** 110–142
Reynald D, Averdijk M, Elffers H, Bernasco W, 2008, "Do social barriers affect urban crime trips? the effects of ethnic and economic neighbourhood compositions on the flow of crime in The Hague, The Netherlands" *Built Environment* **34** 21–31
Robinson J B, Rengert G F, 2006, "Illegal drug markets: the geographical perspective and crime propensity" *Western Criminology Review* **7** 20–32
Roman J, Farrell G, 2002, "Cost-benefit analysis for crime prevention: opportunity costs, routine savings and crime externalities", in *Evaluation for Crime Prevention* Ed. N Tilley (Criminal Justice Press, Monsey, New York) pp 53–92
Rubington E, Weinberg M, 2003 *The Study of Social Problems* (Oxford University Press, New York)
Shaw C R, McKay H D, 1942 *Juvenile Delinquency in Urban Areas* (University of Chicago Press, Chicago, IL)
Sherman L W, 1995 *Hot Spots of Crime and Criminal Careers of Places* (Criminal Justice Press and The Police Executive Research Forum, Monsey, NY)
Stucky T D, Ottensmann J R, 2009, "Land use and violent crime" *Criminology* **47** 1223–1264
Tilley N, 2009 *Crime Prevention* (Willan, Cullompton, Devon)
Town S, Davey C L, Wooton A B, 2004 *Design Against Crime: Guidance for the Design of Residential Areas* (University of Salford, Salford)
van Soomeren P, Wever J, 2004 *A Review of Costs and Benefits Analysis in Crime Prevention in the EU Member States* (European Community, Amsterdam)
Weisburd D, Wyckoff L A, Ready J, Eck J E, Hinkle J C, Gajewski F, 2006, "Does crime just move around the corner? A controlled study of spatial displacement and diffusion of crime control benefits" *Criminology* **44** 549–591

Welsh B C, Farrington D R, Sherman L W, 2001 *Costs and Benefits of Preventing Crime* (Westview Press, Boulder, CO)
Wright D B, London K, 2009 *Modern Regression Techniques Using R: A Practical Guide for Students and Researchers* (Sage, London)
Zelinka A, Brennan D, 2001 *SafeScape: Creating Safer, More Livable Communities Through Planning and Design* (American Planning Association Planners Press, Chicago, IL)

Appendix A

Table A1. Crime-prediction example using coefficients (β) from full model (appendix B).

Variable	Scenario 1: residential	Scenario 2: residential plus shopping centre
Distance from historical centre (km)	4.0	4.0
Average length of stay (years)	15.0	15.0
Unemployed with low education (%)	3.0	3.0
Ethnic heterogeneity (%)	25.0	25.0
House price (1k €)	4.0	4.0
Inhabitants (per ha)	50.0	50.0
Jobs hotel and dining (per ha)	0.0	25.0
Jobs commercial, retail and wholesale (per ha)	0.0	100.0

Predicted count = $\exp[(\beta_1+\ln\delta_j)+\beta_2 x_{2i}+\ldots+\beta_7 x_{7ij}]$

Predicted count of residential burglaries for scenario 1

$$\exp[(1.020+\delta_j)+(4\times0.059)+(15\times0.009)+(3\times-0.015)+(25\times0.013)+(4\times-0.084)+(50\times0.14)]$$

Predicted count of residential burglaries for scenario 2

$$\exp[(1.020+\delta_j)+(4\times0.059)+(15\times0.009)+(3\times-0.015)+(25\times0.013)+(4\times-0.084)+(50\times0.014)+(25\times-0.019)+(100\times0.003)];$$

where the specific neighbourhood j has a given δ_j (table with δj values not included).

Appendix B

Table B1. Multilevel negative binomial regression models (full model).

Fixed-effects parameters	Residential burglary		Pickpocketing		Mugging		Theft of car		Theft from car	
	β	Standard error	β	Standard error	β	Standard error	β	Standard error	β	Standard error
Jobs farming (jobs/ha)	−0.801	1.046	−0.061	2.037	−1.324	2.458	1.436	1.490	−2.547	1.086*
Jobs construction (jobs/ha)	0.006	0.074	−0.025	0.064	−0.034	0.062	0.069	0.067	0.017	0.045
Jobs hotel and dining (jobs/ha)	−0.019	0.034	0.010	0.043	0.041	0.025	−0.019	0.040	−0.027	0.028
Jobs transport and communication (jobs/ha)	−0.004	0.018	0.024	0.022	0.023	0.019	0.000	0.024	0.005	0.016
Jobs business offices (jobs/ha)	0.000	0.004	−0.003	0.004	0.003	0.005	0.001	0.006	0.000	0.006
Jobs financial (jobs/ha)	0.001	0.017	0.018	0.020	0.000	0.019	0.025	0.023	−0.005	0.016
Jobs government (jobs/ha)	−0.005	0.009	0.001	0.005	−0.003	0.005	−0.005	0.006	−0.001	0.005
Jobs educational (jobs/ha)	0.007	0.014	0.021	0.015	−0.004	0.020	−0.005	0.024	−0.001	0.012
Jobs health (jobs/ha)	0.016	0.011	0.018	0.019	0.000	0.142	−0.025	0.013[a]	−0.026	0.009**
Jobs industrial (jobs/ha)	0.015	0.034	0.015	0.052	0.038	0.028	0.020	0.031	−0.010	0.024
Jobs culture, sport, and recreation (jobs/ha)	−0.028	0.032	0.037	0.037	−0.006	0.038	0.017	0.036	−0.019	0.029
Jobs commercial retail/wholesale (jobs/ha)	0.003	0.011	0.021	0.040	0.001	0.018	−0.002	0.019	0.000	0.015
Jobs—other services (jobs/ha)	0.012	0.020	0.012	0.028	−0.026	0.031	−0.025	0.025	0.008	0.029
Distance from historical centre (km)	0.059	0.061	0.076	0.107	−0.237	0.062***	−0.047	0.064	−0.192	0.066**
Average length of stay (years)	0.009	0.024	0.048	0.046	0.043	0.035	0.007	0.029	−0.012	0.019
Unemployed with low education (%)	−0.105	0.032**	−0.167	0.095[a]	0.175	0.066*	0.174	0.038***	0.128	0.031***
Ethnic heterogeneity (%)	0.013	0.005**	0.011	0.012	−0.009	0.007	−0.005	0.005	−0.011	0.005*
House price (€ thousand)	−0.084	0.046[a]	0.052	0.074	−0.382	0.089***	−0.156	0.064*	−0.215	0.054***
Inhabitants (per ha)	0.014	0.002***	0.005	0.004	0.002	0.002	0.001	0.002*	0.008	0.002***
Constant	1.020	0.431*	−0.141	0.910	3.194	0.741***	3.002	0.892**	3.337	0.474***
Random-effects parameters										
ln$r$	1.217	0.208	0.945	0.287	1.856	0.236	2.238	0.576	0.523	0.214
ln$s$	1.621	0.287	0.308	0.217	0.978	0.204	0.981	0.227	2.209	0.328
r	3.376	0.704	2.257	0.738	6.397	1.508	10.798	6.215	1.688	0.361
s	5.058	1.451	1.361	0.295	2.659	0.542	2.666	0.604	8.102	2.657
Log-likelihood	−2420.394		−1411.55		−1405.851		−1577.452		−3266.225	

[a]p <0.10; *p < 0.05; **p < 0.01; ***p <0.001.

N = 693 (103 neighbourhoods)

Note. The inverse of one plus the dispersion is assumed to follow a beta(r,s) distribution.