High Resolution Analysis of Crime Patterns in Urban Street Networks: an initial statistical sketch from an ongoing study of a London borough

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Abstract

In this paper we report some initial statistical results in a comparison of residential burglary and street robbery in the street network of a London borough, using space syntax to analyse the street network. The results are presented against a background of current issues in urban design under discussion between the New Urbanism movement and the design against crime community: streets or cul-de-sacs, mixed use, permeability, and density. A method of primary risk band analysis is proposed as the basis of a simple, repeatable methodology for the analysis of crime patterns in street networks.

1. New urbanism and defensible space

An increasingly animated debate is taking place between two schools of thought on how to design cities to minimise crime. The points at issue are aptly summarised by (Town & O'Toole 2005) in a table of six points where the 'new urbanist' position, as set out by Zelinka & Brennan in their 2001 book 'Safescape', is contrasted to the 'defensible space' position, originating in Oscar Newman's 1972 book 'Defensible Space' (Newman 1972).

On some of the issues, for example the dangers of rear or courtyard parking, or the risks introduced by footpaths and alleys, there is good recent evidence (including from space syntax studies) that the critics of New Urbanism are right. But on the main strategic issues of grid versus tree-like layouts, public versus private space, developmental scale, permeability, mixed use and residential density evidence of the appropriate precision is sporadic and inconclusive (for a review see Shu 'Crime in Urban Layouts', PhD thesis

	SafeScape	**Defensible Space**
Public vs. Private	Maximize commons to promote interaction and a sense of community	Maximize private areas to create defensible space; create a sense of community through smaller developments with fewer strangers
Uses	Mix uses to provide activity and increase eyes on the street	Mixed use reduces residential control and therefore increases crime
Streets and Footpaths	Encourage walking and cycling, increase surveillance through a grid street pattern	Limit access and escape opportunities to provide more privacy and increase residential control
Alleys	Face buildings toward alleys to provide eyes on the alley	Eliminate or gate alleys as they increase burglary and are dangerous for pedestrians
Autos	Build homes close to the street, forcing parking to be on the street or in rear courtyards	Autos are safest in garages or visible in front of the house; rear courtyards facilitate burglary
Density	High density to promote activity, sustain public transit, and reduce sprawl	Density creates vulnerability when it increases common areas or unsafe parking

Figure 214: Summary of design and crime issues (Town & O'Toole 2005)

University of London 2000). What is needed is high resolution analysis of crime patterns in urban street networks in which these issues are variables to begin to build the body of evidence needed to decide these issues. In this paper we propose such a high resolution technique. The unit of analysis is the segment of a street between junctions, and the technique combines space syntax analysis with Geographical Information Systems (GIS).

In contrast to most available crime analysis packages, which focus on the clustering of crime in particular locations, space syntax research has pointed to the importance of looking at non-clustered patterns, that is the kinds of locations in which certain kinds of crime occurred, but which are dispersed throughout the grid and so do not appear as clusters or 'hot-spots'. By combining space syntax with the data handling capabilities of GIS, a flexible method of analysis can be developed which works at the high resolution level required, but can also work at higher levels of aggregation such as the Output Area of the 2001 Census or the administrative divisions into wards.

Previous space syntax studies have confirmed some of the principles of the prevailing defensible space orthodoxy, but has also opened up a positive window on certain new urbanist propositions. For example, syntax studies of residential burglary have confirmed that when embedded in an urban street network, simple linear cul-de-sacs can often be the safest places, but that when the cul-de-sac is generalised into a design principle so that whole areas take the form of a hierarchy of cul-de-sacs, the effects can be quite the opposite (Hillier and Shu 2000, Hillier 2004). It has also shown that in residential areas, the streets that are most integrated - and therefore with more natural movement- are often safer than the more broken up spaces, but that where integrated streets have 'local vulnerability'; for example through 'secondary exposure' through alleys or adjacent open areas, or basement access, then integrated streets can become singularly vulnerable. We call these switches 'flip over effects' to express the idea that design variables do not act independently, but interact, so that all must be got right together if there is to be a genuine reduction in vulnerability. Equally complex results have come from looking at crimes against the person in urban areas, with patterns of crime shifting with time of day and thus with the presence of greater or lesser degrees of movement (Alford 1996).

But space syntax has not so far studied patterns of crime either at the much larger scales of the city and its multiplicity of socially and spatially differentiated areas, or with a full analysis at the high resolution level of the street segment. In this paper we seek remedy this deficiency by reporting the first results of a space syntax study of crime in the street network of an entire London borough, with 99,991 households and 263,464 people within its boundaries (according to Census 2001). We have been given access to a 5 year crime data base in which every crime has been located and by linking this to a space syntax analysis of the whole borough (in the context of its urban surroundings), and linking both to social and demographics data available from the 2001 census, as well as the Borough's own property database, we have perhaps the largest and best body of spatial, socio-demographics and crime data yet brought together in a single study. As an extra bonus, the fact that the London borough in question is largely made up of traditional housing on a street network, makes this data base ideal for posing the key current questions as to how street networks and their functioning shape the pattern of crime. But we should also issue a 'health warning'. The London borough in question is socially and ethnically highly varied, and differentiated physically between its inner, more 'inner city', and outer, more suburban, areas. Some of its centres are already known as high crime areas. We should be careful not to generalise its results prematurely, before a range of such studies have been made in different cities.

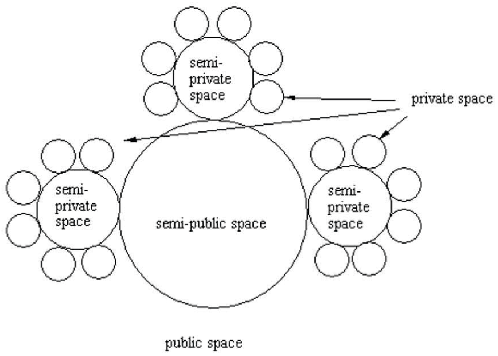

Figure 215: Newman's Hierarchy image.

2. Theoretical background: the other side of Newman

The key issue in the debate between new urbanism and defensible space is the relation between the dwelling and the public realm. Throughout the history of urbanism, this relation has been more or less direct, and it would not be an exaggeration to say that the very basis of urban form historically is dwellings opening on to linear spaces linked into network: the street network. In modern times, this relation has been broken twice: first by architectural modernism, especially in its social housing programmes (for a review see Hillier 1988); and then by Oscar Newman's hugely influential 'defensible space' concept, as summarised in figure 215, redrawn from page 9 of his book:

But in spite of the fact that his concept radically disrupts the dwelling-street relation, throughout his book, when talking about real cities, Newman again and again acknowledges the security benefits of well-designed streets with dwellings opening on to them: '...streets provide security in the form of prominent paths for concentrated pedestrian and vehicular movement' (op. cit p. 25)....'the street pattern , with its constant flow of vehicular and pedestrian traffic, does provide an element of safety for every dwelling unit' (p. 103). He criticises the modernist practice of closing off streets the make larger urban blocks, noting that 'An inhabitant returning home must leave the public street and wind his way through the undefined and anonymous grounds of the project to reach the front door of the building. He would have been much safer had he been able to go directly from street to front door, and safer still if the front door and lobby of his building faced directly onto the street'(p. 25). Later he adds: 'The interior of project buildings and grounds suffer the unique distinction of being public in nature and yet hidden from public view' (p. 32) and later still: 'Large super-blocks, at various densities, have been found to exhibit systematically higher crime rates than projects of comparable size and density that have city streets continuing through them'. There is also the reverse effect, that Newman acknowledges: that dwelling entrances on the street benefits the street and makes it more secure: 'The street comes under surveillance from the building, the building entries and lobbies under the surveillance of the street' (p. 15) 'The positioning of front entrances along the street provides them with continuous natural supervision by passers by; the residents within their houses, in turn, provide these passer-by with protective surveillance'. There is also a policing benefit: 'Well lit front door paths, with individual lights over the entrances, allow cruising police to spot at a glance any peculiar activity taking place on a row-street house'. And more generally: 'The street, without the continued presence of the citizen, will never be made to function safely for him' (p. 15).

One might then ask why Newman to universalise his defensible space concept. Several factors seem to have been involved. First, Newman's object of concern was not the city as a whole but the socially disastrous social housing estates that had been inserted in decades following the two post-second world war. Second, the idea of hierarchically ordered space was at the time the prevailing architectural orthodox, taught in architecture schools under the rubric of the need for a 'hierarchy of space from public to private', which seemed to be confirmed by the then fashionable, though now largely discarded, 'theory of human territoriality' (Hillier & Hanson 1984). Newman also thought we might need to move towards a city of hierarchically ordered enclaves as a kind of spatial counterweight to what he saw as the increasing openness, liberality and moral heterogeneity of modern societies, which he thought had diminished our powers to act as communities and inhibit crime.

Whatever the reasons, the problem situation has now changed. We are no longer pre-occupied with the need to fix past architectural errors, but to learn to design cities again. The 'other side of Newman', and how we link residential areas together to form a well-working and secure system, is a key part of this agenda. The aim of this paper is to open up research on this 'other side of Newman' from the point of view of urban security, and to begin to ask how far his many observations on the security benefits of well-working street networks can be supported by evidence. We also have the methodological aim of setting up simple and repeatable space syntax based methods of analysis for crime patterns in street networks, so that evidence can be accumulated on a consistent basis.

3. Redefining the urban crime problem

Understanding the relation between the urban street network and crime is not simply a matter of measuring properties of the street network and correlating them with levels of crime. Cities are highly differentiated spatial systems, with huge variations in movement and activity levels, built form densities and mixes of land use, from one part to another. These variations will inevitably influence crime rates, if for no other reason than that there are far more opportunities for crime in some areas than others.

But there is a more fundamental relation between the differentiation of urban areas and the street network. In their very nature, cities are dynamic, movement based systems, and movement is shaped in the first instance by the configuration of its street network (Hillier et al. 1993, Penn et al. 1998a 1998b, Hillier and Iida 2005). Through its configuration, the street network creates a basic pattern of movement flows, and these then shape land use choices, according to the need for different land uses to be close to or remote from movement. This sets in train a process that eventually gives rise to a city as a network of busy and quiet zones, focused on centres at different scales set against a background of the residential space which makes up the bulk of the city. The functional differentiation of the system has its origins in the configuration of the street network itself.

Evidence of this 'city-creating' process is easy to find in the Borough. If we compare segments with 1-5 non residential units with those without any, we find on average they lie on longer and more globally, but not locally, integrated lines. If we raise the threshold we find that on average segments with 5-20 non-residential units lie on much longer,

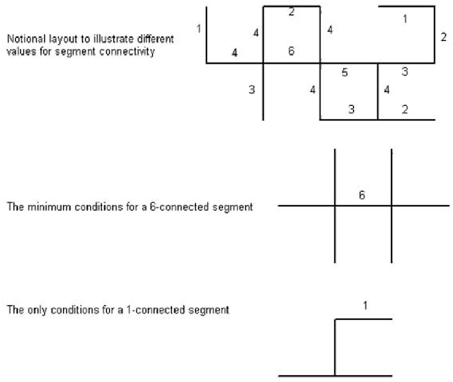

Figure 216:

much more connected, and on much longer and more globally integrated lines than those without, but also much more locally integrated and on much more connected lines. This is in accordance with the theory which expects that although small numbers of non-residential units such as shops may initially cluster at more globally integrated locations such as road intersections, more substantial development of non-residential 'live' uses such as retail requires local integration conditions also to be satisfied. (Hillier 1999) It should be noted that this is found even though we are not yet distinguishing between 'live', that is, movement dependent non-residential uses, such as retail and catering, and non-movement dependent uses. We can expect these differences to be even more marked when this distinction is made.

The implication of this is that the configuration of the street network and its land use patterns, together with the movement patterns which link one to the other, are all bound together in creating the city as a functionally differentiated system, with large fluctuations in the density of activities, buildings and movement rates from one area to the next, and even from one street to the next. The fact that all of these factors, each of which have been separately canvassed as being related to crime, are thoroughly inter-correlated through the process which creates the functionally differentiated city, warns us to take great care in using multivariate statistics to establish anything like a chain of causality between these factors and crime.

4. The street segment level

From the point of view of analysis in which the unit of analysis is the street segment, the implications of this process even more marked. Before we consider the syntactic properties which define how the segment is embedded in the larger scale spatial network, the segment has in itself certain basic properties, namely it connectivity, its length, and the number of buildings of different kinds and uses that lie on it. Segment connectivity normally has a value between 1 for the last segment in a cul-de-sac and 6 for a grid like layout, as shown in Figure 216:

Segment connectivity thus relates to access and egress (and so to potential escape routes), and it the key to the whole issue of grid-like versus tree-like layouts. Other prop-

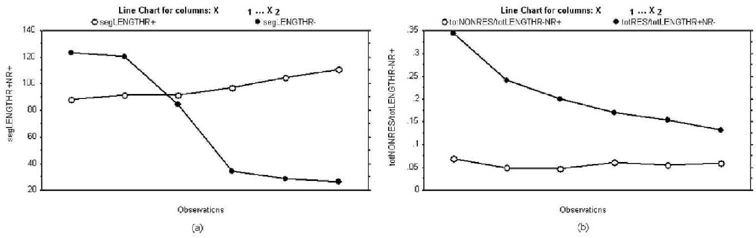

Figure 217: Segment connectivity and segment length.

erties can be derived form these basic properties: street density (the number of residential and non-residential units over its length), the ratio of residential to non-residential, and the relation of both to connectivity. By aggregating the data in bands according to their segment connectivity, and distinguishing segments with residential uses from those without and plotting both on a line chart (left below) in which increasing segment connectivity is left to right on the horizontal axial (Figure 217).

We find that for segments with residence (solid), greater length means more connectivity, but for segments without residence (nonsolid) greater length means less connectivity. The short, high connectivity segments (bottom right in the chart) are the 'high street' areas where an intensified grid with smaller blocks sizes is predicted by the theory. If we then look at linear density (right above) we find that on residential segments density decreases with increasing connectivity, while for non-residential segment linear density first decreases, then increases, though at a lower level compared with residential. Both charts illustrate the basic bifurcation that is found in all cities between residential and high street areas. High connectivity is found both on short segments in high street areas and on longer segments in grid like residential areas, as can be seen in Figure 218 and this is the outcome of the working of the spatial process by which cities become functionally differentiated into centres at different scales set against a residential background.

This is the heart of our problem. Because centres attract much higher levels of activity and density than the residential background, we must expect that, other things being equal, there will also be an increase in the incidence of crime in and around them. In this sense, we can say that the problem of urban crime arises directly from what cities are like and how they work. But what is the implication of this? Should we avoid creating centres? Or can we learn to understand the spatial, functional and crime dynamics sufficiently to be able to design them as safer places?

5. The concept of risk

The key concept is risk. Because town centres tend to have higher rates of crime does not lead us to believe that we should stay away from them. Our assessment of crime is, intuitively, and correctly, based on risk assessment. Suppose, for example, we need to walk from the tube to our homes late in the evening and we have a choice of routes, one a well-used route with, say, an average pedestrian movement rate of 400 people per hour and on which are were 40 muggings per year, and a poorly used route with an average movement rate of, say, 40 people per hour (common on a spatially segregated route) on which there were 10 muggings per year. We intuitively choose the route with the greater incidence of

Figure 218: Map of segment Connectivity.

mugging because the risk of an individual being mugged is in fact two and a half times less than on the poorly used route. Interestingly, this analysis is also to be found in 'the other side of Newman': Some commercial street corners, identified as safe, have records, showing up to three times more crimes than any other place in the immediately surrounding urban area. However, the number of pedestrians passing any point on a commercial street is over twenty times the average of surrounding streets and areas. The rate of occurrence may be higher, but the chance of occurrence per user may be lower' (Newman, 1972 p. 109).

But how can we make an analysis of risk which also allows us to make comparisons between different crimes. The question is made more complex by the fact that different crimes are facilitated or inhibited by different spatial conditions: pick-pocketing likes busy streets, burglars like secluded access, muggers need a supply of victims but as far as possible one at a time, and so on. Here, we take the two urban street related crimes which are the most common and which people most fear, residential burglary and personal street robbery, and suggest a relatively simple technique which we call primary risk band analysis for dealing with space structure, movement, densities and land use mixes in an interactive way.

We proceed in four stages: First, we look visually and statistically at the overall spatial patterning of the two crimes in the borough as a whole. We then discuss the problems of assessing risk and explain the technique of primary risk band analysis which enables us to set patterns of crime in a context of risk. We then analysed the spatial pattering of residential burglary and street robbery in turns. Finally, we discuss the results comparatively in the light of the main questions that are being debated between new urbanism and its critics.

Figure 219: Distribution of burglary.

6. Spatial distributions of the two crimes in the whole borough

We begin with the large picture. The spatial distributions for burglary and personal robbery are shown in Figures 219 and 220. Although broadly similar in certain aspects of regional distribution, they are quite different in micro-distribution. Burglary forms a dispersed pattern with variable densities from one area to the other, with the highest densities in the southern and eastern - and so more urban - areas, and the lowest in the northern and western, more suburban areas, as we would expect from the British Crime Survey. There are one or two clear clusters, but what is of greatest interest about the pattern is, first, the areal differentiation and overall dispersion of the pattern, and also the degree to which adjacent neighbourhoods vary markedly from each other in crime rates at quite a small scale, as can be seen more clearly in Figure 221, which maps burglary per unit of housing in 'Output areas' of about 125 dwelling units.

In striking contrast, the distribution of robbery is less dispersed and more clustered, with whole areas virtually without robbery. However, the clustering is not in patches, or polygons, but forms a distinctly linear structure. We should then think perhaps of 'hot lines' rather than hot spots. But since the linear pattern of robbery more of less follows the pattern of local spatial integration shown in Figure 222, and spatial integration is known to approximate movement patterns, it would seem likely that what we are seeing is that there is more robbery where there are more people. We will need to consider this carefully when assessing robbery risk in different types of location.

The greater concentration of robbery compared with burglary is shown by a simple statistic. Of the 7102 street segments in the borough, 4439, or 62.5%, have at least one residence on them and so can have a residential burglary. Of these 4439, 3080, or 69.4% actually have a burglary, leaving 30.6% free of burglary. Of the 7102 on which a robbery could occur, 2281, or 32.1%, have at least one robbery, leaving 67.9 free of robbery. 1643 segments, or 23.1% of all the segments or 37% or the segments with residence, have both

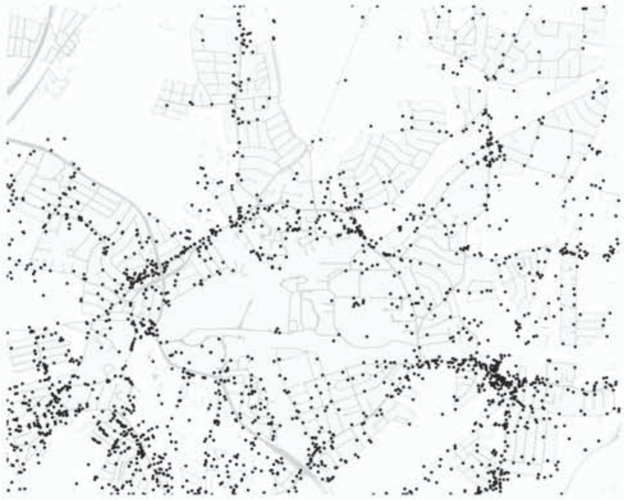

Figure 220: Distribution of robbery.

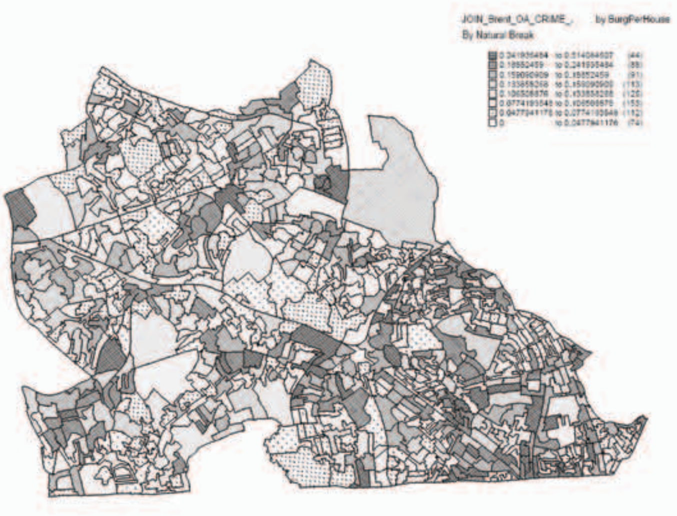

Figure 221: Burglaries per unit of housing in Census Output Areas.

Figure 222: local integration.

Table 25:

	Seglen	segconn	axlen	axcon	rad3	rad-14	rad-n	mnres	tax	k-segs
Burglary	115	3.9159	382	5.192	7.007	2.49	1.67	21.5	4.35	3080
Robbery	119	4.1261	432	6.072	7.33	2.54	1.69	19.25	3.26	2283
0-burglary	61	3.9838	325	5.241	6.949	2.45	1.65	7.05	3.21	1359
0-robbery	55	4.176	332	5.29	7.027	2.47	1.66	6.62	2.23	4819

at least one burglary and at least one robbery, 3253, or 45.8% have neither burglary nor robbery. So nearly half of the segments have neither crime over 5 years. At the other extreme, one segment has 75 crimes, 73 of them robbery.

Using the street segment as the unit of analysis, we can also discern some broad statistical patterns by comparing the spatial properties of segments on which the two crimes occur and do not occur (Table 1). If we compare average measures for the segments on which burglary occurs with those on which it does not occur, we find that, although the relatively small number of 1- and 2-connected segments (which include most cul-de-sacs) have the lowest average burglary rates (but see below), the 13000 burglaries on average occur on segments which are significantly (p - .0186) less connected that those without burglary.

This is unexpected, but of course these figures deal only with the street network, and do not taking into account the effects of footpaths or alleys. Even so, it is striking that the greater connectivity in the street pattern itself is associated with less, rather than more burglary.

We also find that the lines which segments with burglaries form part of are longer, but less connected than those without. This is again striking, because there is also a strong relation between line length and connectivity. The lines on which burglary occurs are also marginally more locally integrated, though not at a statistically significant level, and significantly more globally (radius-15) integrated than those without. Robbery also occurs in segments which are less connected, but significantly longer than those without, and also on lines which are both significantly longer and more connected hen those without, and significantly more integrated locally and globally. Comparing the two crimes, we can say that robbery is a significantly more integrated crime than burglary, and this is already clear from Figures 219 and 220.

7. Disaggregated analysis: the concept of primary risk bands

Our aim here, however, is to relate the pattern of crime to the micro properties of the street network, and to do this we must establish a unit of analysis and a rate. In previous studies of burglary (Hillier and Shu 2000) and robbery (Alford 1996), the unit of analysis has been the line. This is a rather gross element, which can differ quite considerably in spatial and functional properties along its length, so a more micro-scale element would be better. For burglary, previous syntactic studies have also used the single dwelling as the unit, with spatial differences of the street segment on which it lies assigned to the dwelling. This permitted the use of logistic regression to establish the burglary risk associated with each variable. However, for our present purposes, there is no robbery equivalent to this because the target is an individual rather than a building, and we cannot compare robbed and unrobbed people in the same way that we can compare burgled and unburgled dwellings.

The obvious micro unit of analysis is the street segment, which is already the basic unit of the spatial analysis of the street network. But this would only be meaningful if we could establish a rate for each crime for a segment, and this is highly problematical. For burglary, for example, however we define a unit of analysis above the level of the individual house - the segment, the street, the block, the administrative area, the geometrically defined quadrant, and so on - then a primary factor influencing the number of burglaries within that unit will be the number of residences, or targets, within the unit. This can be shown by considering a random pattern. If there is a random pattern of burglary - say by assigning each house a random number and using a random number selector to select 'burgled' houses - then as the number of burglaries increases there will be more in units with more residences. So in terms of absolute numbers it will appear that there are 'more' burglaries in units with more residences. If we then try to correct this by expressing burglary as a rate dividing the number of burglaries by the number of residences, then in the early stages of the process, and perhaps for much of the process, then units with more residences will appear to have lower rates, because the number of residences is now the denominator, and so each randomly assigned 'burglary' will contribute less to the 'rate', and it will appear that units with more residences have lower rates. We can show this graphically by simply plotting the count of burglaries per segment against the rate (number of burglaries over number of residences) for all street segments in the Borough (Figure 223).

We see that all the highest count segments have relatively low rates and all of the highest rate segments have relatively low counts. We cannot then use either meaningfully for statistical analysis. But if we try to standardise the number of residential units, as in the Output Areas of the 2001 Census for example, then we can only do so by sacrificing consistency in the spatial descriptors of our unit. Output areas often combine dwellings from main streets, a back street, and maybe also a cul-de-sac, so the spatial coherence of the unit is lost.

However, we can escape this problem by aggregating all segments with a given number of residential units, or within a certain band of residential units, and calculating a burglary

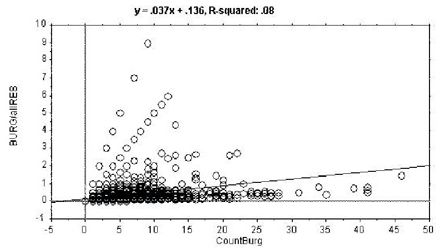

Figure 223: Count and rate of burglaries.

rate is for the whole group as the total number of burglaries over the total number of targets for that group. The number of targets on a segment is now a spatial condition for the unit, and so not involved in the rate calculation at the level of the segment. Because the number of targets on the segment is the most primitive expression of risk, grouping segments into bands according to the number of targets they represent is the natural way of aggregating the data since only in this way can this most fundamental dimension of risk contained within the data in a fully transparent way. We can call these aggregates primary risk bands, and note it is rather like taking all the segments that have the condition of having 1, 2, 3..... n residential units lying on them and treating them as an imaginary single line several kilometres long. This procedure will of course entail dangers, in that aggregating data in this way will also implicate other variables with which they are correlated, which could then operate as hidden variables in any subsequent analysis. However, since our aim will be exactly to investigate the relation between the 'primary risk' variable and other variables, this danger should be minimised.

We therefore aggregate the data into sets made up of segments with 1 dwelling (of which there are 328), with 2 (357), and so on up to 30 at which point we take pairs to keep samples large enough, and increasing the band size to maintain sample size, with a final band of 90+ (where there are only 34 segments, but with 3708 houses), we end up with a data table with 47 rows, most of which represent 1000+ houses, and those which do not have several hundred. We then for each band take the total number of burglaries and divide by the total number of houses, and so establish a true rate of burglary for dwellings lying on bands with different numbers of target residential units. We show the spatial distribution of the primary risk bands by plotting number of residential units on a segment map of the whole area as in Figure 224.

We can see that segments with the lowest number of residential units, tend to be found for the most part in high street areas (apart from the business estates), where the low number of residential units will be because there are large number of non-residential units, and in parts of the network where space is broken up, including in some social housing estates. In either circumstance, residential units will be relatively isolated, or sharing a segment with very few other residential units. The grey segments are those in which there are no residential units.

8. Primary risk band analysis of burglary

We then plot two things in the line charts below in which the horizontal axis is always the number of dwellings per segment, in each case taking moving averages with a period of 3

Figure 224: Map of residential unit count on segments.

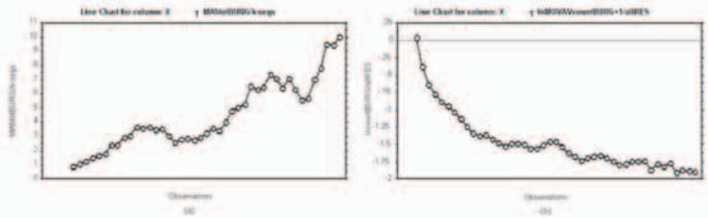

Figure 225: a: Count of burglary per segment; b: True rate of burglary.

to smooth out fluctuations and show the trend. In Figure 225 a below we plot the 'untrue' rate of the count of burglary per segment, and we find that, as expected, it increases with increasing numbers of dwellings on the segment, and reflects nothing more than that more targets means more burglaries. However, in Figure 226b, we plot the true rate for the risk bands, that is the total burglaries over the total dwellings for all segments for which the condition of that number of dwellings per segment holds, and find a very unexpected result: that burglary rates fall continuously as the numbers of targets on the segment increases.

The way this is calculated ensures that it cannot be an artefact of the numbers of dwellings on the segment, and so it must be a true result. In fact, it is a remarkable and basic finding, although it is presaged to some extent in the work of Shu (Hillier and Shu 2000), where it is show that risk decreases with number of intervisible neighbours, but on the whole line rather than on the segment. It means that on average burglary rates fall, more or less continuously, with increasing numbers of residential units on the segment. There is safety in numbers!

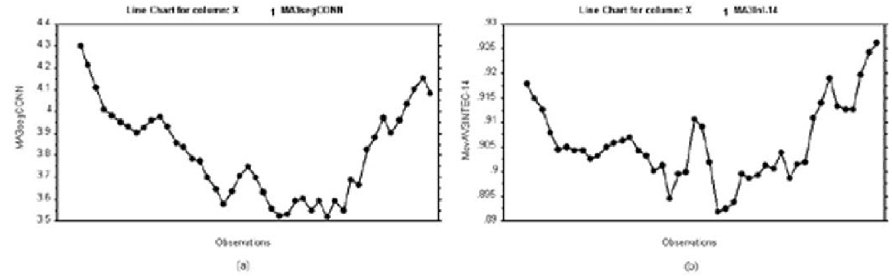

Figure 226: segment connectivity and b: Global integration in primary risk bands.

There are two possible interpretations of this. The first is natural surveillance: that more 'line neighbours' in your home segment provide increased surveillance, and that this deters burglars. The second is complementary to the finding of Bowers (Bowers, Johnson and Pease 2004) that the occurrence of a burglary in a location increases the probability of further burglaries in the vicinity of the first. If there were an upper limit to this process, then after a certain number of burglaries in a location, the location is seen as saturated and the risks increased, so the burglar moves on. This would raise interesting psychological questions as to how burglars identify 'locations' within which to select a target. The street segment is a natural locational unit in the same sense that a street is. Any upper limit to how frequently a burglar saw it as good sense to select targets in the same 'location', however defined, would imply greater 'safety in numbers' in that location. This finding suggests that burglars may identify street segments are locations.

Whichever interpretation is the case, it means that in an important sense, having more neighbours helps to keep you safe. The first consequence of adopting the primary risk band approach, then, is to bring to light a fundamental regularity in the spatial distribution of crime whose existence has been suspected before, but never demonstrated. On this basis, we can then explore the relation of this regularity to other spatial properties. For example, we already know that segment connectivity is found on both short and long segments. If we plot this for the primary risk bands (form left to right on the horizontal axis as before) find that there is high connectivity with few residences per segment, which falls to a low in mid-range, and then rises to high connectivity again for high residence segments. Figure 226 shows that the high connectivity segments are to be found both in the high street areas, where there are few dwellings because most units are non-residential and burglary rates are among the highest, and in some of the more integrated and grid like housing areas, where burglary rates are among the lowest.

We find Figure 226a above an even more striking fall and rise with global integration. This shows that although on average for the whole system segments with burglary are more globally integrated than those without, this average conceals a bifurcation in the data. Both high and low burglary rates are associated with integration; high in the integrated high street areas where there are few residential neighbours, and low in the integrated residential areas, where there are many line neighbours. This bifurcation can be shown graphically by a regression plot of integration against the true burglary rate for the primary risk bands as in Figure 227 below:

If we split the bands more or less evenly between the lower and higher residence bands and plot them separately (Figure 228a and 228b) we find that while for the low

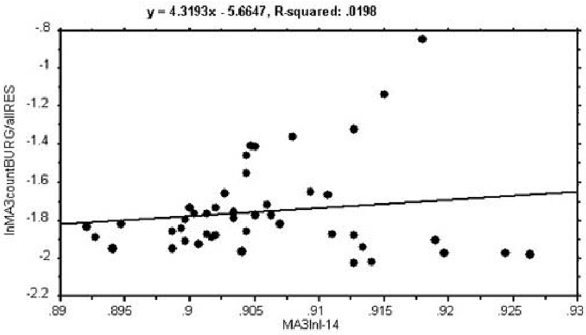

Figure 227: Global integration and rate of Burglary.

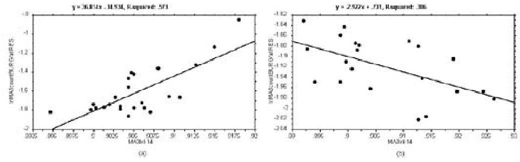

Figure 228: a and b: Burglary rate of higher and lower residence bands.

residence bands more integration means more burglary, for the high residence bands more integration - and so more natural movement - means less burglary, though less strongly. This would seem to explain why in previous studies of residential areas integration was generally found, other things being equal, to be associated with lower rates of burglary.

We can use the same approach to explore the impact of non-residential land uses on burglary. We find, for example, that although the average number of non-residential land uses increases more or less pro-rata with the increase in the number of residential units, the ratio of non-residence to residence falls consistently throughout the range, as in the left line chart below (Figure 229).

We also find that although segment connectivity and global integration fall then rise strongly with increasing dwellings per segment, the connectivity of the lines on which segments lie falls consistently, as in the right line chart above, and local integration follows a similar pattern, though in this case with a slight upturn in the high residence ranges.

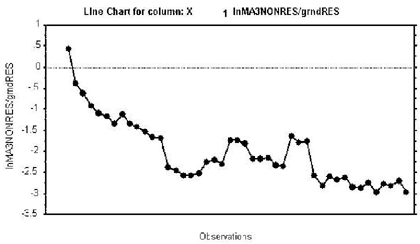

Figure 229:

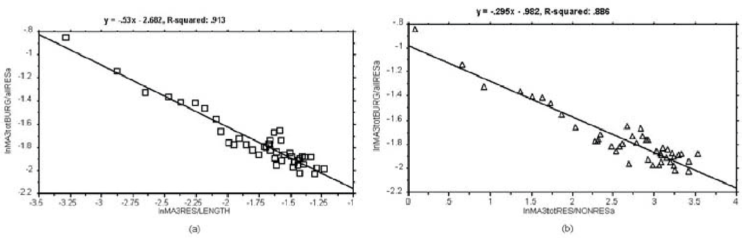

Figure 230: a: Linear density and b: ratio of residential to non-residential uses

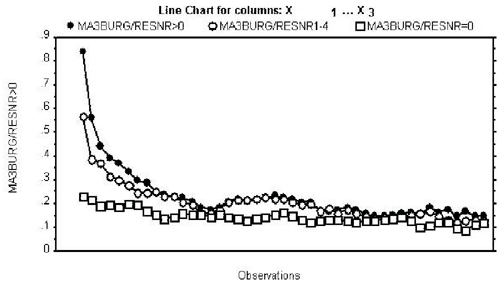

Figure 231:

This is consistent with theory, which relates the formation of local 'live' centres, based on movement dependent non-residential uses, to the co-incidence of local and global integration (Hillier 1999). Where global integration is not associated with local integration, then the ratio of residence to non-residence uses continues to rise in spite of the increase in the average number of residential units, and this is associated with low rates of burglary.

Two other basic segment variables correlate with the numbers of dwelling per segment, and so correlate also with reducing burglary rates. One is linear density, which is the number of dwellings over the length of the segment. The other is the ratio of residential to non-residential uses. Both in fact correlate with reducing crime more strongly that the simple number of dwellings (Figure 230a and b):

However, both also correlate very strongly with the number of dwellings, and threfore on this basis they cannot be seen as independent effects. However, two things can be said. On density, a multi-variate analysis of the relation between physical and social factors, such as house and tenure type, show that burglary per house in the 800 output areas in the Borough, show that terraced houses are the safest house type (and converted flats, flats in commercial buildings and semi-detached houses more vulnerable). This confirms the finding of the British Crime Survey finding though in this case the results is independent of tenure type or income level. But the same analysis also shows that higher density is associated with lower burglary rates independent of house type.

We can, however, use the current data to throw further light on the beneficial effect of higher ratios of residential to non-residential uses. By dividing the primary risk bands into those without non-residential units, those with 1-4 and those with any number and plotting them on then line chart in which increasing numbers of dwellings per segment run, as before, from left to right (Figure 231):

we see that while all three fall consistently with increased numbers of dwellings, where numbers of dwellings are small, segments with non-residential have much higher burglary rates, but with increasing number of dwellings the three trends converge as the ratio of residential to non-residential increases for the lines with either 1-4 or any number of non-residential. The differences do not quite disappear, but it suggests that it is the degree to which residential units outnumber non-residential that is critical. It also points again to the high vulnerability of small numbers of dwellings in strongly non-residential areas.

We see then that, for burglary, the relations between spatial and land use factors, with the implications of both for movement, are complex. Integration and segment connectivity are beneficial in more grid-like residential areas, but not in high street areas where dwellings are sparse and vulnerable. But this does not mean that mixing uses simply increases vulnerability. This is largely a function of the ratio of dwellings to other uses. Where the ratio of dwellings to other uses is high, the increased risk from other uses is small, though not negligible.

9. Primary risk band analysis of robbery

What then of robbery? We must first establish what we mean by primary risk. Whereas burglary is a crime against a fixed asset, whose numbers on segments remain constant, robbery is usually a crime against a moving person. This suggests two primary risk factors. The first is the length of time a moving person spends on a segment, and we can assume this will be, on average, a function of its length. We can call this time risk. The second is the number of potential victims moving on the segment. Risk of being selected as a target reduces with increases number of people on the segment. We can call this people risk. Both survive the randomness test. Random assignment of hypothetical robbery points to a map of urban routes (we do not need to consider the width of streets for this analysis, as movement take the general form of a thin linear trace) will eventually produce more points on longer segments. Selecting randomly moving people randomly as victims will also lead to higher number of victims on more populated segments, though of course as Newman remarks above, the rate will be lower. The same arguments that prohibit the use of segment by segment counts or rates then also prohibit the use of segment by segment robbery counts or rates. We will deal with the two kinds of primary risk factor in order, taking length first as this is measurable from a plan, whereas movement rates are not.

We first show that segment length is indeed a primary risk factor. We aggregate the robbery data into 45 segment length bands, initially at 5 metre intervals up to 100, then 10 to 250 metres and the increasing by larger interval to maintain total band length between 7000 and 26000 metres. We then count the number of robberies within each band and divide it by the number of segments. We find the rate rises consistently with increasing length (Figure 232a).

This shows that the time spent on a segment in moving through it is indeed a primary risk factor. However if we normalise to robberies per metre for bands by taking total robberies per band and dividing into total band length, we do not find, as we did with burglary, a consistent fall in rate but a sharp rise followed by and equally sharp fall, with another rise and fall in the higher ranges (Figure 232b).

How can this be explained? Very simply, it turns out. If we recalculate the bands as those without non-residential uses and those with non-residential uses, we find that the bands with zero non-residential uses do indeed fall consistently with increasing length, and

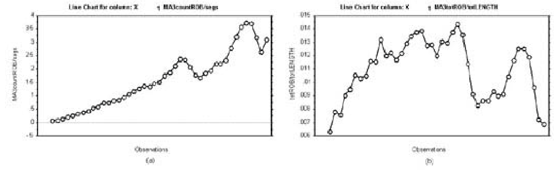

Figure 232: a: segment robbery rate in risk bands and b: normalised robbery rate in risk bands.

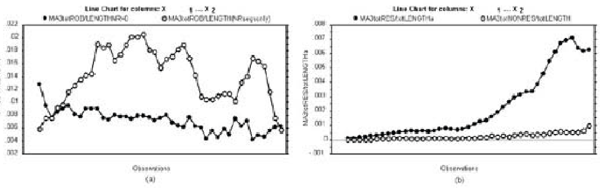

Figure 233: a and b

the rise and fall is wholly accounted for by the bands with non-residential uses (Figure 233a).

Since we know that segments with non-residential uses will in most circumstances be associated with higher movement rates, especially retail and similar movement dependent uses, this suggests that to explain the rise we need to take our second risk factor, people risk, into account. We cannot of course observe pedestrian flows in all the relevant segments, but we can make use of our extensive London data base on all day pedestrian (and vehicular) flows on over 367 street segments in 5 London areas to ascertain the average difference in pedestrian flows on segments with and without retail. Mean pedestrian movement on all 367 segments is 224.176 per hour. For segments without retail the rate is 158.476 for 317 segments, and for retail it is 640.714 for 50 segments. This means that the movement rate on segments with retail is 4.042 times those on segments without. The average robbery rate on segments without non-residential uses, as shown above left, is .0074, while the rate for segments with non residential uses is .0176, or 2.4 times as high. The rate of increase in robbery in the substantially less than the increase in movement rates, and dividing one into the other, so 2.4/4.042, we get 1.68, so that we can say in terms of people risk you are 68% safer on busier street segments with non residential uses than on those without. This of course is a very provisional figure, but it is probably a conservative one, in comparison, for example, with Newman's estimate quoted earlier. However, this show that it will be possible to combine people risk with time risk in assessing how the real risks of robbery are affected by the degree and mix of urban activity. But on present evidence, again, there seems to be safety in numbers!

10. Robbery space and time

But if the risk of robbery is affected by movement rates, what about the radical differences in movement rates at different times of the day and night? The differences in the diurnal patterns are clearly shown in the two images in Figure 234. The left image shows the daytime pattern of robbery in one of the high robbery neighbourhoods and the right image the night-time pattern. The night time pattern is much less dispersed and than the less numerous day-time pattern, and much more focused on the main arteries of the area. Could this be linked to movement, and, through movement, to spatial factors? It is possible of course that these time and space differences also relate to the type of robbery, including the degree of violence involved, and this issue will be looked at in the next phase of this research.

In what follows we first look at spatial factors associated with robbery by assembling the data into incidence bands (as opposed to risk bands), that is into bands on which 0, 1, 2 ...n robberies occur, and examining any shifts in spatial patterning.

We know first of course that incidence rises with increasing length of segment, as expected from the primary risk concept, as top left below. However, if we consider mean segment connectivity (we already know that robbery occurs on average on segments which are less connected than those on which it does not occur), we find that with increasing incidence, connectivity first rises but then falls sharply for the highest robbery segments, which although they constitute only about 1% of the segments, account for 17% of the robberies (Figure 235a). We find a similar pattern for both the connectivity of the lines on which the segments fall (Figure 22 b), and for their local integration (Figure 235d). The effect is less clear for global integration, and does not exist for line length, which increases and then stabilises with increasing incidence.

Since the incidence of robbery is known to vary with time of day, and since people risk conditions will also vary with time of day, could these be connected to the changing spatial patterns? We can explore this by dividing robberies into 3 hour incidence periods, and plotting incidence in the charts below from left to right starting with the O6-O9 morning period, and ending with the 03-06 late night period (Figure 236).

Figure 236 a shows that the peak is the 15-18 period, closely followed by the 21-00 period, and the 18-21 period. The 15-18 period includes much of the evening rush hour but there is no comparable peak around the morning rush hour (the robbers are still in bed!). However, the 18-21 and 21-00 are likely to be very different in terms of pedestrian movement, with more people around in the 18-21 period. So the 21-00 period is likely to be higher risk. The same almost certainly applies to the 00-03 period when there will be far fewer people, but nearly a many robberies, so a much higher risk. So the highest incidence period is early evening, but the highest risk is probably post-midnight.

Figure 236b shows the degree of concentration of incidents in specific locations by dividing the number of incidents into the number of locations. This shows that in the low incidence period there is a greater spread of locations, while in the high incidence periods a greater concentration. In Figure 23 c, we look at the mean length of segment on which robberies occur, and find a complex pattern, with 06-09 happening on shorter segments, 09-12 and 03-06 on the longest, but the peak periods dipping to shorter segments, and with the period 21-00 period of second highest incidence on the shortest segments (apart from the early morning period). The relevance of this is that shorter segments are often found where blocks are smaller in ‘live centre’ areas.

The pattern for segment connectivity (Figure 237d) is again different, with the early morning happening on the least connected segments and the highest risk post midnight period on much the highest. The early evening periods 18-21 is on lower connected segments than either of the periods before or afters, and much lower than the two night periods. The highest risk period is associated with then highest segment connectivity, and this again is suggestive in relation to the relative sparsity of people. Robbers use more

Figure 234: a: robbery pattern in first half of day and b: second half of the day.

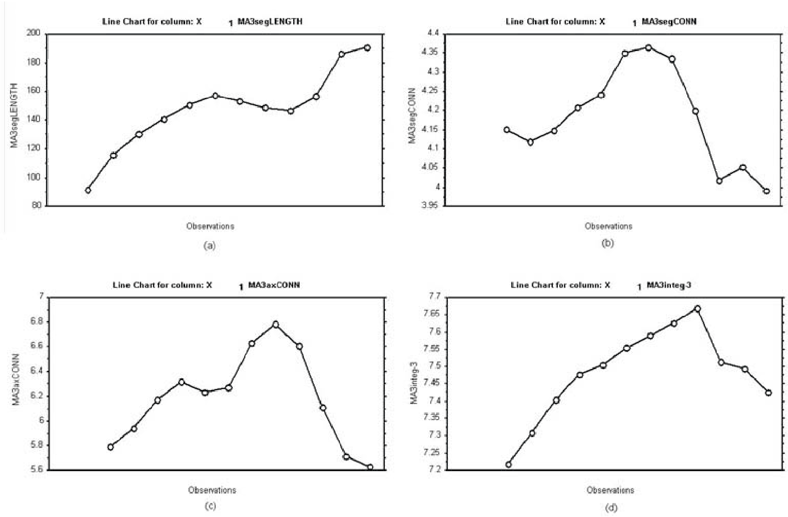

Figure 235:

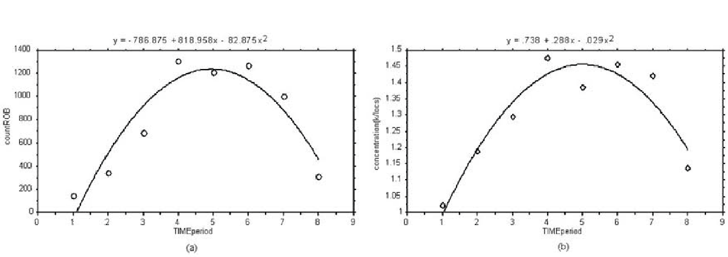

Figure 236:

connected segments when there are fewer people around.

Axial connectivity (Figure 237e) also yields an interesting pattern of fluctuation. The three peak periods all have strikingly lower axial connectivity than other periods, the midday period has the highest, and the night periods, including the highest risk periods, is also high. Again this is suggestive in relation to movement and visibility conditions, so the highest rates occur on less connected lines. The relation with axial length is similar but less pronounced, but with the peak robberies periods focussing on shorter lines of sight, and the midday and late night periods on longer.

The pattern with local integration (Figure 237f), which is normally the best predictor of movement rates, is similar and even more striking. Now the peaks are in the night periods: at night robbery goes to the most locally integrated locations, but retreats from them during the peak incidence evening periods, with morning through midday incidents rising towards a local integration peak at midday. This does suggest that the spatial characteristics of incident locations do really change with the presence of people in a systematic way.

The pattern with global integration (integ-14) is also striking (Figure 237g), though a little different. Global integration identifies the large scale structure of the area, and so by and large the centres and the links between them. It is very striking that the late afternoon evening peak periods tend to be in less integrated locations than the morning through midday periods, and the night periods, including the maximum risk period, in the most globally integrated locations. We can again conjecture that this could be related to robbery type, and its relation to movement rates. In Figure 237h, we see that incidence from the early morning on wards incidence increases with an increasing ratio of non-residential to residential uses in segments, with a strong peak in the final late night phase.

All the above measures are of the average spatial conditions under which crimes occur, and so do not deal with time risk rates. However if we substitute the time risk weighted measure of robbery per metre (total robbery on the incidence bands over the total length of segments in those bands) for the incidence measure and plot it by time of day, we find a pattern which is very similar to the incidence pattern, but now the peak has shifted to the late evening (21-00) period, because although the numbers of robberies is slightly less than the early evening peak, they tend to occur on shorter lines (Figure 238a).

We can also look at how the ‘space-time-risk for time periods’ co-varies with other factors. For example, it correlates very strongly with ‘concentration’ in few locations (Figure 237b), so higher incidence really does also mean less diffuse.

Even more strikingly, we find that there is a strong negative correlation with the integration variables, weakly with local, much more strongly with global, and strongest of all with intensity, a more complex integration type measure due to Hoon-Tae Park (Park 2005) $r^2 = .6008, .0239$ so significant). But the scatter is telling us something more interesting than the correlation (Figure 239). The ‘evening three’ peaks (high on the left) are occurring in spaces which are markedly less integrated than the average for robbery (thought still above the average for the whole system), while the late night/early morning low rate pair are in more integrated location. The only high rate associated with integrated locations is the early night 00-03 period which we also associated with the highest ‘people risk’. This pattern implies a clear message: don’t walk on main roads after midnight, but don’t leave them before midnight.

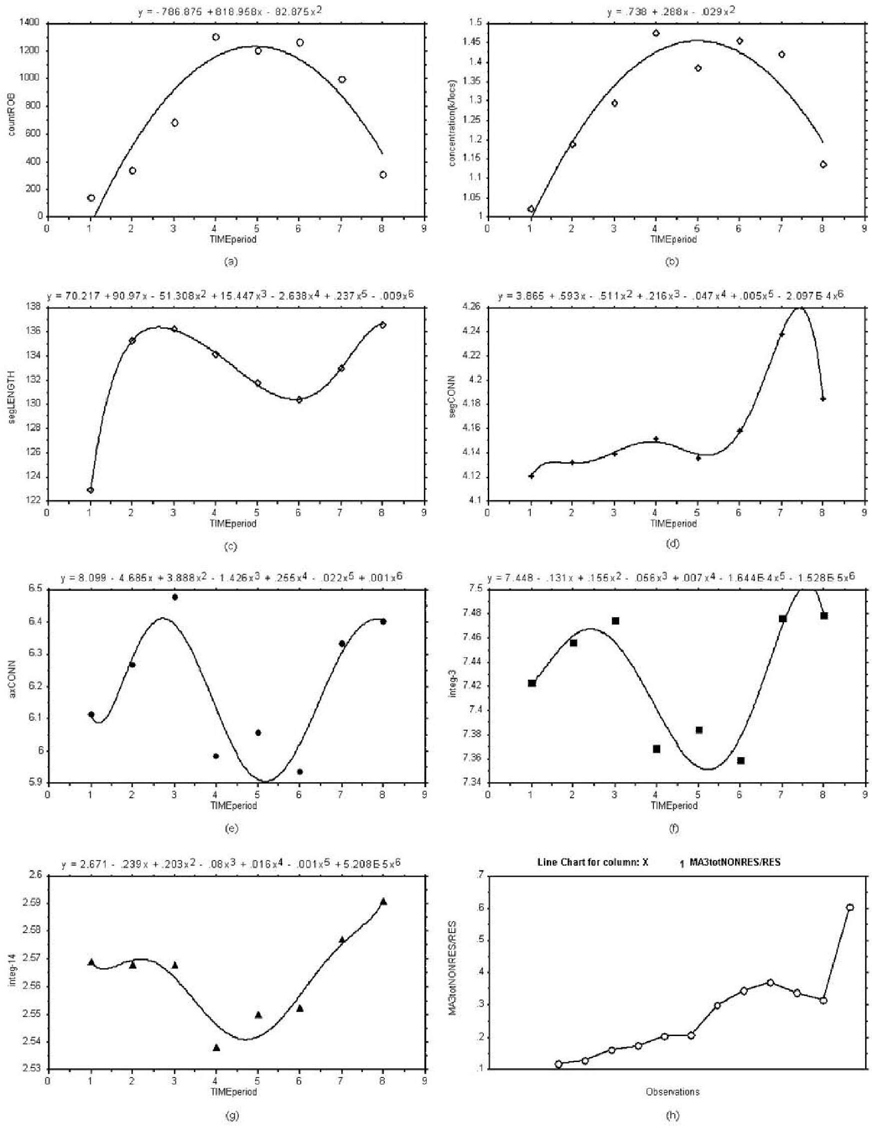
y = -786.875 +818.958x - 82.875x2
countROB
TIMEperiod
(a)
y = .738 + .288x - .029x2
concentration(k/locs)
TIMEperiod
(b)
y = 70.217 +90.97x - 51.308x2 + 15.447x3 - 2.638x4 + .237x5 - .009x6
segLENGTH
TIMEperiod
(c)
y = 3.865 + .593x - .511x2 + .216x3 - .047x4 + .005x5 - 2.097E-4x6
segCONN
TIMEperiod
(d)
y = 8.099 - 4.685x + 3.888x2 - 1.426x3 + .255x4 - .022x5 + .001x6
axCONN
TIMEperiod
(e)
y = 7.448 - .131x + .155x2 - .066x3 + .007x4 - 1.644E-4x5 - 1.528E-5x6
integ-3
TIMEperiod
(f)
y = 2.671 - .239x + .203x2 - .08x3 + .016x4 - .001x5 +5.208E-5x6
integ-14
TIMEperiod
(g)
Line Chart for column: X 1 MA3totNONRES/RES
MA3totNONRES/RES
Observations
(h)

Figure 237:

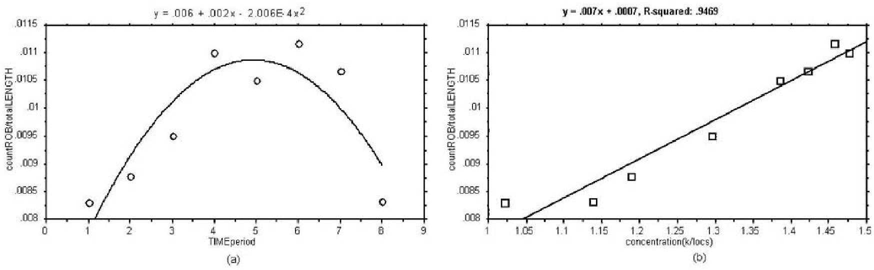

Figure 238:

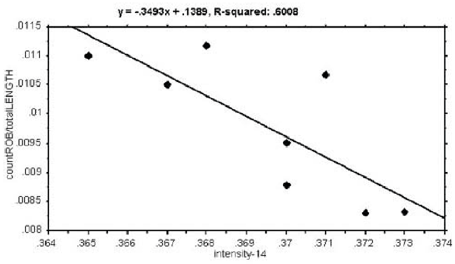

Figure 239:

11. Discussion

The aim of this preliminary statistical analysis has been to link the spatial and temporal patterning of crime with the spatial and temporal dynamics of the city and how it works. Although this is only the first stage of the research, we see that the inter-dependence of crime and space is much more complex and variable than is often believed. The results offer hope that with a more precise understanding of the relation between urban spatial dynamics and different kinds of crime, it will be possible to develop a more sophisticated approach to how to design city areas for urban levels of use without incurring penalties in terms of increased crime.

The most critical finding that has come to light in this study is the relation between spatial scale and the choice between grid like or tree layouts. In residential areas, the more dwellings that lie on street segment between junctions then, other things being equal, the safer you are from both burglary and robbery. This applies both to through streets and cul-de-sacs. For example, although the mean rate of burglary for 1 and 2 connected segments (which for the most part will be cul-de-sacs or cul-de-sacs) in the data is .105, against an overall average of .168 for all segments, cul-de-sacs with no more than 10 dwellings have a rate of .209 (calculated again as the total number of burglaries over the total number of dwellings in such segments, so the rate is a true one), while 6 connected (grid like) segments with more than 100 dwellings have a rate of .086, and the much larger number with 50+ have a rate of .142.

Social factors also play a role. By dividing the data into those with above average council tax bands (and so more valuable property), 6-connected segments with more than 50 dwellings per segment and higher tax band and no nonresidential, the burglary rate is.101, compared to .153 for the lower tax bands, and in general 6-connected segments with 50+ dwellings have a rate of .143, reducing to.124 with higher tax bands but rising to .191 for lower tax bands. Similar effects are found with increasing nonresidential uses. More affluent people survive better in a well-scaled, mixed use grid like layout than the less affluent.

A rather different story is found in cul-de-sacs. The overall burglary rate for 1-2 connected segments with 1-10 dwellings is .213 (51/239) for high tax, and .143 (86/599) for low tax. If we exclude those with non-residential the rate is even higher, at .241 for high tax (40/166) but lower, at .092 for (28/302) for low tax. High tax dwellings are more vulnerable in small cul-de-sacs, either than low tax dwellings, or high tax dwelling in grid like layout. In contrast, for 1-2 connected segments with 50+ dwellings, the rate for high tax is .068 (37/547) and for low tax .90, with non-residential making very little difference. So both high and low tax dwellings are more vulnerable in small cul-de-sacs with few dwellings, and much less vulnerable than large linear cul-de-sacs with many dwellings. We can also say that high tax dwellings are more vulnerable in small cul-de-sacs than in grid like layouts, even when these are mixed use, but for low tax dwellings the rates are similar. For both high and low tax, long linear cul-de-sacs are safe. The critical variable is the number of dwellings.

On the issues identified early on as being in contention between new urbanism and its critics - grid versus tree-like layouts, public versus private space, developmental scale, permeability, mixed use and residential density - certain observations can be made - though of course with the health warning about premature generalisation set out earlier. Since the six headings suggested in Figure 215 interact with each other, we will discuss them in turn using Town and Randall's heading, but mixing themes and drawing on other research where necessary.

11.1. Public versus private space

On scale and the effects of scale, the defensible space view seems clearly wrong. The idea that small groups of houses form better communities and so inhibit crime seems incompatible with the evidence either of the present study or previous studies. All the scale advantages seem to be with larger rather than the smaller scale, both for streets and cul-de-sacs. This is in keeping with the urban tradition. For both cultural and functional reasons, urban blocks in residential area were larger than those in the 'live centres', and so created larger segments between intersections. This still seem to be desirable today. Safescape also needs to take this into account. Residential areas are not like live centre areas, and need to be structured for adequate but not excessive levels of co-presence. Permeability is needed to structure movement, but is not beneficial when increased beyond the level and pattern needed to sustain adequate movement and co-presence. The maxim is that poorly used access is a hazard, as it provided opportunity without surveillance. In the same way, good space is used space, and if space it provided which does not work for everyday social use, then it is often used for anti-social uses (Hillier 1996). Residential areas and live centre areas are two different things and need to be designed differently. But we must distinguish between good connectivity in the street system which is beneficial, and the provision of permeability for its own sake, which reduces segment size and so increases vulnerability.

On grid like or tree like layouts two things are clear: first, that the benefits of cul-de-sacs come from embedding them in a street network, and making them large enough and linear enough to provide 'safety in numbers' and surveillance; and second that the more grid like parts of layouts, composed of 6-connected segments, can less vulnerable than more broken up, less connected layouts.

11.2. Mixed uses

Mixed use is context sensitive: it depends how you do it. The critical thing is that the more residential outweighs non-residential the better it tend to get. There is more crime in and around urban centres at all scales (we have yet to clarify the role of tube stations), and where this leads to isolated dwellings, or dwellings with very few neighbours, then this is associated with higher burglary. But to the extent that the ratio of dwellings to non-residential uses is increases - we might say to the extent that a residential culture is established - this disadvantage is very much reduced. We need to look at some high residence town centres, perhaps in France. Robbery rates are likewise higher in and around centres, but less than the increase in movement rates, so risks are reduced during the times when movement levels are good. Main streets are dangerous without good movement rates, as they are late at night, but when movement rates are good, the less integrated and less connected spaces associated with centres are the dangerous places.

11.3. Escape routes

Although footpaths and alleys are known to be crime hazards, this does not mean that high segment connectivity in the street network itself is a hazard. On the contrary, in many instances, high street connectivity in a more grid like layout is associated with low crime where the numbers of dwellings of segment are sufficiently large. If urban blocks are too small, so that there are fewer dwelling per segment - that is between the escape routes - then burglary tends to increase. In design, the issue of permeability must be linked to block size: the over provision of permeability with reduced block size will be hazardous. Overall, the idea that numbers of escape routes facilitate crime does not apply to the street system. Both burglary and robbery occur on average on less connected spaces than average. The 8 top robbery segments, which form .01% of the segments but which account for 4% of the robbery, have a mean connectivity of 3.625, well below the average for all segments of 4.16. 6-connected segments have lower average rates of robbery than 3-, 4- or 5- connected spaces.

11.4. Density

Because density interacts strongly with other key variables such as the number of dwelling on a segment, the effects of density have not yet been isolated as a specific variable in the present study. However, wherever residential density has been looked at as a variable, higher densities have been largely beneficial. On burglary, the increase in the number of dwellings per segment, which correlates with reducing rates of burglary, also correlates very strongly ($r^2 = .99$) with density (measured as the number of residences per unit length). On robbery, the ratio of dwellings to non-residential uses, which is associated with reducing robbery rates, also correlates strongly with residential density ($r^2 = .814$), though much less strongly in the higher density areas. But the trend is still beneficial. There is no evidence, in this or other syntactic studies, that it brings other disadvantages.

12. Conclusion

Overall, we can say that urban integration, and the increase in movement and levels of activity that it brings has a double effect; it can produce more natural surveillance and safety in numbers and so reduce crime; and it may mean than potential criminals also use integrated streets, and so make more accessible locations more dangerous. Both effects undoubtedly exist, and a key variable is the degree to which there is a residential culture in more active areas. Where it exists, crime risk is reduced, where is does not, risk is increased. But these benefits do not seem to pass through the intervening variable of community formation. They seem to be much simpler: effects of the ordinary co-presence of people that everyday movement and activity brings. A residential culture, it might be conjectured, is first a culture of civilised co-presence, and only second, and after due time, a culture of community formation. This, perhaps, is what made historic cities, which always brought heterogeneous population into dense patterns of contact, the civilised places they seemed to be. As both Jane Jacobs and Oscar Newman observed, a society which does not civilise its streets cannot be civilised.

The 'other side of Newman' the needs to be addressed by the design against crime community. The benefits that Newman saw in a well used network of streets linking the city together can real, and they largely depend on the presence of good numbers of dwellings on streets, and the fulfilling of certain design condition such as the sizing of blocks, the structuring of permeability, and maintaining a high ratio of residence to non-residence where uses are mixed. It has always been, and remains, unclear how breaking the link between residence and the street, as implied by the universalisation of the residential enclave, can lead to anything but an increasingly insecure public realm of our cities.

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