

Chapter 17

Case Studies in Crime Travel Demand Modeling

In this chapter, Richard Block and Daniel Helms present case studies in crime travel demand modeling for Chicago and Las Vegas respectively.

I. Travel Patterns of Chicago Robbery Offenders

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Some neighborhoods are dangerous others are safe. Crime clusters in specific areas. So too do criminals. Criminologists, police, and civilians have known this for nearly 150 years. However, relatively little research has been done on the travel patterns of offenders. Using a modification of standard transportation models, *CrimeStat III* allows police and researchers to describe and predict travel patterns based on four sequential models.

The object of research presented here is to test the usefulness and feasibility of CrimeStat's Crime Travel Demand model utilizing police reports of all robberies occurring in Chicago in 1997 and 1998 that had at least one known offender who lived in the city. In sum, the objectives of this study of robbery in Chicago were:

1. To test the *CrimeStat III* crime travel demand model in a mature central city.
2. To describe the travel patterns of robbery offenders based upon offenders home and location of incident.
3. To predict the travel patterns of robbers in 1998 based upon characteristics of the offender's resident neighborhood and the incident neighborhood and a gravity model of the relationship between the two..
4. To predict the travel patterns of robbers in 1998 based upon the patterns of 1997.
5. To assess the quality of the predictions and their value to the police.

Two Models: Econometric and Opportunistic

As outlined in chapter 13, a travel demand model is a four-step sequential model. The first stage is trip generation, whereby the number of crimes originating in a neighborhood and the number of crimes ending in a neighborhood are modeled. The second stage is trip distribution which is a model of the number of trips that go from each origin zone to each destination zone. The third stage is mode split, which models the number of trips for each zone pair (origin zone and destination zone) that travels by a particular

travel. The fourth, and final stage, is network assignment which models the likely routes taken by offenders in traveling between particular zone pairs.

This mapping of links assumes that travel decisions are based upon minimizing costs to get to a valued destination—as sort of geographic rationality. When I go to work, I weigh costs and benefits. I choose the route that will get me there quickest with the fewest problems. Early theories of criminology assumed that criminal activity was no different than other behavior. It was determined rationally. By extension, travel routes and crime locations are also determined rationally.

Trips of offenders are similar to any repeated activity. Most of our activities occur near where we live or work or on the path in between. This is our knowledge space. Trips within it maximize our efficiency and minimize costs. Daily purchases occur close to home with a rapid fall off with distance. But major purchases are an exception. They may occur far away. This distance decay can be generalized to travel cost decay. The more expensive in time, money, and distance, the less likely a trip will occur. Applied to robbery, most incidents occur close to home, but a bank robber might incur greater costs to find a good target. Most previous research has found that predatory criminals avoid incidents too close to home for fear that they will be recognized. Combined with distance decay, this creates a buffer zone of few criminal incidents (Rossmo, 2000).

Environmental criminology assumes that most activity occurs in a knowledge space that includes nodes of residence work and play and the routes between these (Brantingham and Brantingham, 1984,1990) However, the components of travel for criminals may not be the same as other people. For example, for someone with a full time job, getting to work as quickly as possible is important; time is money. For a jobless criminal, time may be less important.

Routine activities theory assumes that both targets and offenders choose their activities based on a weighing of costs and benefits. Offenders seek out targets in locations where they are likely to congregate (e.g. Bars at closing time, rapid transit stations). A crime occurs when an offender and a target converge in the absence of a capable guardian (Felson, 2002). The routine activities of offender may mostly be hanging out rather than rationally seeking targets. What is the basis of convergence? Chance or the decisions of offenders? Any potential robbers decision is effected by both chance and cost. Time and distance are both measures of cost. However, within a short distance of home time and distance costs are near to zero.

An alternative hypothesis is that robbers do not weigh costs and benefits of travel. Rather, they may see an opportunity for crime and take it. Because much of their day to day activity is near home, many incidents occur near the robbers's home. Travel patterns are irrelevant for these crimes. The number of robberies decline with distance from the offender's home because fewer of the robber's daily activities occur far from home. On the other hand, more professional robbers may seek out specific areas or locations where lucrative targets are found and may be willing to travel great distances.

In Chicago, an opportunistic robber's knowledge of good targets may be limited to the isolated area around his residence. In addition, trips within the area cost almost nothing, although other costs, such as risk of capture may be relatively high. The differences between Chicago and Baltimore County or between Chicago and its suburbs has to do as much with knowledge of the distribution of opportunities as with the cost of travel. Chicago's neighborhoods are so isolated that some offenders may have little knowledge of opportunities outside their resident area. The crime travel demand model holds that in the aggregate offenders appear to weigh costs and benefits. However, the data analyzed here says nothing about individual decisions. Decisions may be made with other factors not captured by shortest distance or time.

In one of the few studies of non-arrested robbers Wright and Decker (1997) found that most St Louis robbers are opportunistic and rob close to home. Rationality and careful cost calculation have little to do with their decisions. These are people who have a need for quick money. If they saw an opportunity near home, they would take it. Opportunities were most likely to occur as the potential offender and victim go about their daily routine activities. Many of them are close to home. Therefore, crime occurs close to home.

The closer to an offender's home that an incident occurs the more likely the incident results from a chance meeting. The further away that it occurs the more likely that it is planned. Part of the planning is transportation costs. Usually this is calculated in terms of income. It is difficult to do this for offenders. The best we can do is estimate travel time.

Crime Travel Demand Models in Chicago

The Offender Travel Model is a new application of the Travel Demand Model. The travel demand model has been in development since the 1950's. It is used in every metropolitan area in the United States. *CrimeStat*'s crime travel demand model was outlined in Chapter 13.

As applied to robbery in Chicago, description is as important as prediction. While the CPD has long collected information of the location of the incident and residence of the offender, these were not linked in any systematic way. In meetings with the department, credible descriptive maps, proved to be the most convincing reason to use the new *CrimeStat* travel demand module. Before a new technique is tested, its potential credibility must be demonstrated. Therefore, the last phase, in the Chicago Travel Demand Model emphasized both the predicted travel demand model and the observed travel of offenders.

Analysis of Chicago's Crime Travel Demand proceeds in three stages. The first step (trip generation) is a prediction of variables associated with the number of crimes originating in each zone and the number of crimes ending in each zone.

The second step is the prediction of links between zones based on zonal characteristics of incident locations and offender residences and a measure of the

attraction between the two zones. These predictive models are compared to the observed links and trips and the previous year's trips used as a prediction.

The mode split step was not run because of the lack of data. Unfortunately, the Chicago police data does not permit an analysis by different modes of transportation (see chapter 15). Data on whether the offender drove, walked, or rode rapid transit to the incident are not collected.

The final step is the description of probable travel routes from the offender's home zone to the incident zone based on shortest time or distance along a transportation network. The links modeled in the second step can be converted to a probable route between home and incident zones over a road network or a summary network load which aggregates travel of all offenders along a transportation network.

Data for the Study

Incident and Arrest Files

The analysis presented here merged information from many sources. This research is based on incident and arrest records from the CPD. Excluding O'Hare Airport, the city of Chicago is divided into 946 traffic analysis zones. Incidents are assigned to these zones for both residence location (the origin) and the crime location (the destination). These include all Chicago robberies in 1997 and 1998 that had at least one known offender who lived in Chicago. These were geo-coded by the address of the incident and all known offenders. Offenders who traveled longer distances are probably under-represented (Block, 2004). About 20% of all reported robberies are included. In 1997, there were 25,000 robberies reported to the police. Of these robberies, 4,636 resulted in the arrest of at least one Chicago resident. Including robberies with multiple offenders, there were 6,643 crime trips.

Traffic Analysis Zones

These incidents and offenders are counted in 946 Traffic Analysis Zones (TAZ). O'Hare Airport is excluded. Chicago's traffic analysis zones are mostly based on a uniform grid of 1/2 mile squares. These are not based on census tracts or other city divisions. However, some census data is available for these zones along with information on employment. About 100 of them have no census population and therefore are unlikely to include the residence of an offender. Land use, employment, population, and robbery incident and offender residence counts are available for all zones. Land use goes beyond the standard census measures to include characteristics from many data sources that might be related to crime. Among these are code violations, vacant parcels, fires, liquor licenses, pawn shops, entertainment venues, distance from the central business district

and other potentially criminogenic characteristics.¹ These traffic analysis zones are the units of analysis. Trips are defined from the center of a zone.

Chicago's Road Network

The base of Chicago's road network is a grid with 1/8 mile between blocks, a feeder street every half mile, and a main street every mile. Layered on top of this grid is a series of diagonal streets that tend to be major shopping streets and a relatively small number of expressways that converge at the edge of the central city. A semi-expressway, Lake Shore Drive, runs along the lakefront for 25 miles. Chicago has a well developed rapid transit system that, unfortunately, could not be included in the current analysis.

Two street networks were available for analysis:

1. **Modified TIGER Line File:** A mostly complete map of all streets and rail lines. Following police practice, the modified TIGER file allows for geo-coding in non-addressed areas, such as parks, by extending the base grid. All public streets are included, but one-way streets are not taken into account and the shortest distance may be on a route that no one would travel. Some areas of the city are not well mapped.
2. **Modeling network:** This includes Expressways, principal arterials and collector roads. Each road segment is uni-directional; that is, it expresses travel in only one direction. Thus, for a two-way road, there will be two records for every segment, one in each direction. This has the advantage that one-way streets can be examined since there will not be an opposite direction pair. On the other hand, a modeling network is less complete since minor streets are ignored. This type of map is useful for capturing trips that occur over a mile or more, but is not very useful for the many trips of less than 1/2 mile that occur in Chicago. It does take into account one-way streets. Using distance, the network will over-emphasize surface diagonal streets and will under-emphasize expressways.

One of the advantages of the modeling network is that street segments can be weighted by speed or travel time, rather than just distance. There are eight distinct time periods with the travel time on each segment by period being indicated. Each street segment can be weighted by its travel time in minutes during a specific time period (e.g.; 7-9 AM) to allow a more realistic description of travel behavior. Further, travel in opposite directions can be treated differently since travel times can be different for each direction. During rush hour, travel in one direction may be much quicker than travel in the other direction. Weighting by travel time will allow larger arterial roads and expressways to be

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In contrast to many cities, Chicago has a large population living in the central business district and lacks a ring of impoverished communities surrounding downtown.

chosen more since travel speeds will generally be faster on the larger capacity roads. This network tends to be most realistic for longer trips but, again, is not useful for very short 'local' trips since the local, neighborhood road network is not included. A greater percentage of the travel is on expressways.

Trip Generation

Using the arrest data, events were aggregated to the TAZ's by both the origins and the destinations. As expected, the distribution of crimes by origin zone and by destination zone were highly skewed. For example, 419 zones had no robberies originate in them while one zone had 27 origins and another had 24 origins.

A similar condition held for the number of crimes by destination. For example, 409 zones had no robberies occur within them while one zone had 24 crimes occur and two had 23 crimes occur.

Separate models of these incidents were developed at the zone level. The regression analysis tools in CrimeStat are excellent, but choosing regression predictors requires both skill and theory. Many explanatory variables were tested. The independent variables chosen for analysis were based on those previously found to be important predictors of violent crime in Chicago. Significant variables were:

1. POP2000 The most important was the 2000 population because the dependent variable was a predicted count of origins or destination. Other variables that were included were:
2. ETHNICPER The percentage of the dominant racial or ethnic group within the TAZ. Recent research (Sampson & Raudenbush, 2001) has found that racial isolation and poverty predicted high community levels of violence.
4. POVPERCENT The percent of the households below the poverty level. Sampson and Raudenbush (2001) found this to be a dominant variables explaining community disorder.
5. VENUE The number of entertainment venues (clubs, theaters, bowling allies) in a TAZ. This is information gathered from the MetroMix and the Reader in 2002. It was negatively related to the residence of the offender and was probably more a measure of perceived neighborhood safety than availability of targets.
6. PAWNSHOP The number of pawnshops is included in several regressions. A pawnshop is both a focus for potential targets and a good place to get cash.
7. VACANT: Count of vacant buildings in the TAZ. Perhaps this is an indicator of general neighborhood dilapidation (Broken Windows).

The variables that were not significantly related to origins or destinations included many that are typically related to travel demand including employment and distance from the central business district. In addition, variables that are often associated with robbery, such as counts of drug arrests, convenience stores, liquor licences, banks and currency exchanges were unrelated to origins or destinations after poverty and population were accounted for. Few TAZ characteristics that might attract an offender to commit a crime were significantly related to the number of robbery incidents in a TAZ. In general the results of the regressions and the resulting travel demand matrix supported the depiction of robbery in Chicago occurring in or near the offender's relatively isolated home neighborhood.

Poisson regressions for origin and destination zone counts for overnight trips were similar in 1997 and 1998. Tables 17.1 and 17.2 present the final Poisson regression models for the resident zone of robbers in 1998 and the location zones for robberies that occurred overnight. In all regression models, population had a positive relationship to the number of crimes, both origins and destinations. Similarly, the poverty variable and the ethnic homogeneity variable were positively related to the number of crimes, both origins and destinations.

Table 17.1

Final Overnight 1998 Robbery Origin Model

Data file:	Chicago TAZ with Time.dbf
Type of model:	Origin
DepVar:	Robbery Origins 8PM-5:59AM
N:	946
Df:	940
Type of regression model:	Poisson with over-dispersion correction
Log Likelihood:	-2011.35
Likelihood ratio(LR):	2962.73
P-value of LR:	0.0001
AIC:	4034.71
SC:	4063.82
Dispersion multiplier:	1.00
R-square:	0.443
Deviance r-square:	0.445

Predictor	DF	Coefficient	Stand Error	Pseudo-		
				Tolerance	z-value	p-value
CONSTANT	1	-2.072610	0.170828	.	-12.132746	0.001
POP2000	1	0.000235	0.000011	0.876420	22.156415	0.001
ETHNICPER	1	0.015786	0.001746	0.909463	9.042151	0.001
POVPERCENT	1	0.037134	0.002144	0.872974	17.321707	0.001
VACANT	1	0.016970	0.002528	0.835809	6.712064	0.001
VENUE	1	-0.115182	0.033458	0.933336	-3.442566	0.001

The pseudo-R-square values are reasonably good and an analysis of the residual errors do not reveal any major outliers. Given the large number of zones (n=946) the regressions predict variations in the count of origins and destination fairly well.

**Table 17.2
Final Overnight 1998 Robbery Destination Model**

Data file:	Chicago TAZ with Time.dbf					
Type of model:	Destination					
DepVar:	Robbery Destinations 8PM-5:59AM					
N:	946					
Df:	941					
Type of regression model:	Poisson with over-dispersion correction					
Log Likelihood:	-2041.56					
Likelihood ratio(LR):	2661.30					
P-value of LR:	0.0001					
AIC:	4093.11					
SC:	4117.37					
Dispersion multiplier:	1.00					
R-square:	0.380					
Deviance r-square:	0.474					
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Predictor	DF	Coefficient	Stand Error	Pseudo-Tolerance	z-value	p-value
CONSTANT	1	-1.946591	0.032370	.	-60.135432	0.001
POP2000	1	0.000218	0.000008	0.898680	26.418877	0.001
ETHNICPER	1	0.015913	0.000874	0.944910	18.201093	0.001
PAWNSHOP	1	0.335678	0.029184	0.954563	11.501940	0.001
POVPERCENT	1	0.035707	0.001888	0.989400	18.913079	0.001

Trip Distribution

After the two predicted models were developed, the trip distribution stage was modeled, in other words the number of trips that go from each origin zone to each destination zone (the trip distribution). The inputs were the predicted origins and predicted destinations for robberies in 1998 from tables 17.1 and 17.2.

The test of CrimeStat's crime travel demand module, began with analysis of 1997. Preparatory analysis indicated that 29% of robbery trips occurred in the offender's home zone. While the number of intra-zonal trips can be mapped and predicted, travel within a zone cannot be described.

Using observed crime trips, the number of trips from each zone to every other zone was calculated. Figure 17.1 depicts the volume of observed inter- and intra-zonal trip links in 1997. The zone shadings indicate the number of intra-zonal trips. The width of the links indicates the frequency of trip links. Impoverished areas of the west and south side dominate this analysis. Most inter-zonal links are quite short. Many begin in zones that

also have many intra-zonal trips. In Las Vegas and Baltimore County many links are associated with specific sites such as shopping malls or entertainment areas. Within the City of Chicago, the links lack a clear focal zone for incidents. However, few robbery trips are made to the central business district.

A trip distribution analysis includes both inter- and intra-zonal trips in a single analysis. The analysis is not of travel from home to destination, but from a home zone to a destination zone. For transportation planners inter-zonal trips are more important than intra-zonal trips because these predict changing transportation needs. The volume of within zone travel can be predicted but not specific routes. However, many Chicago robberies (29% in 1997, 26% in 1998) are intra-zonal.

Therefore, two techniques are tested to account for the many intra-zonal trips. In the first analysis, both inter- and intra-zonal overnight robberies trips are included in the same analysis. In the second analysis, to see whether different variables were predicting incidents close to the offender's home address from those further away, inter- and intra-zonal trips were analyzed separately. Ultimately, I concluded that there was little to be gained by separating the two types of trips.

Trip Distribution

The gravity model that underlies CrimeStat's trip distribution model assumes that travel between or within zones is dependent upon the offender pool, opportunities, and costs. Conceptually, this can be written as:

$$T(ij) = \alpha(\text{Offender Pool}) \beta(\text{Opportunities}) / \text{Cost}^\lambda \quad (17.1)$$

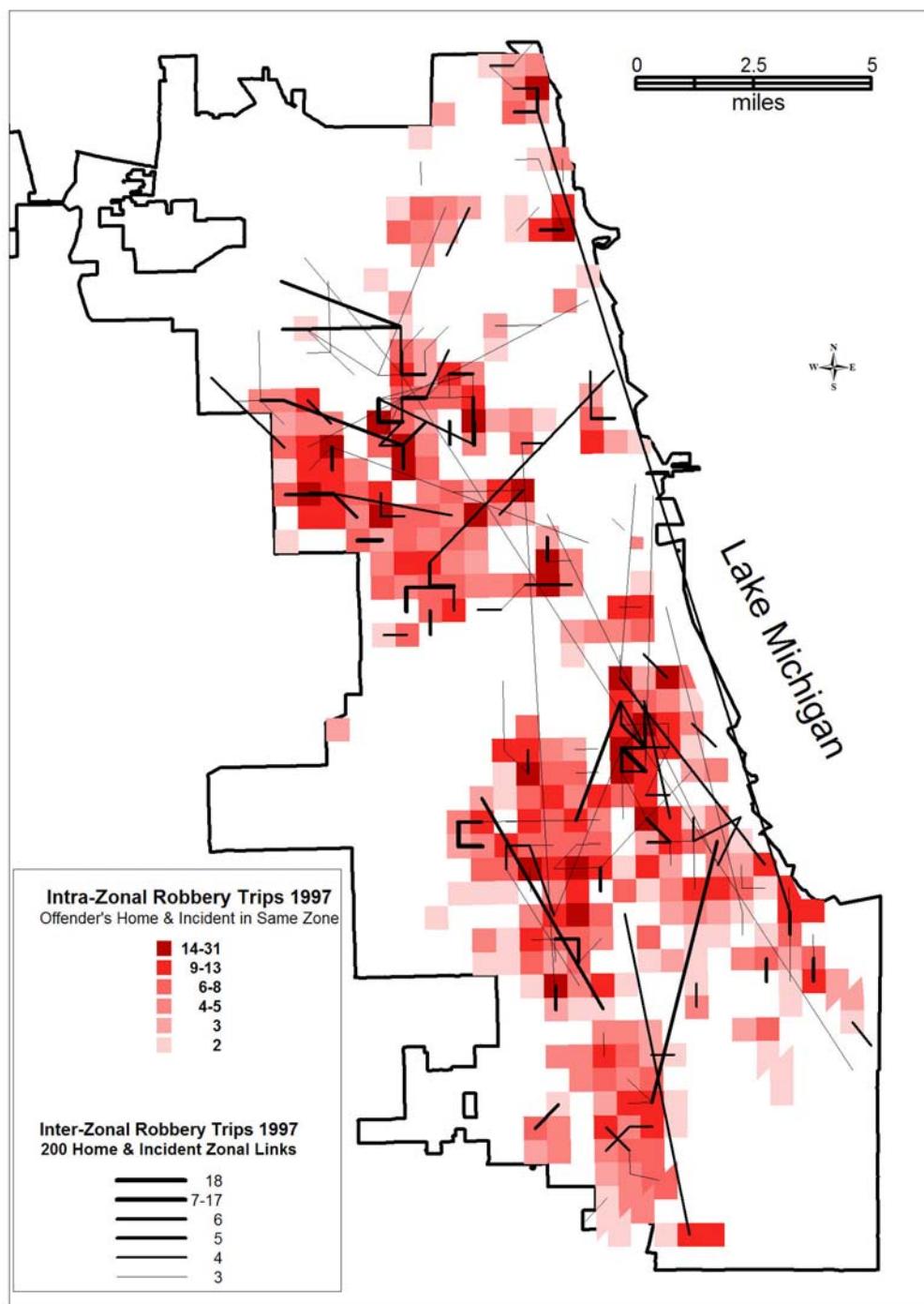
where α and β are coefficients and λ is an exponent. The impedance (or 'cost') component is modeled with a mathematical function. After experimentation, I found that the best impedance function was a lognormal distribution with a mean of 2 miles and a standard deviation of 5. The resulting model fit the actual trip length distribution quite well. The coincidence ratio was about the same for both the 1997 and 1998 comparisons (figure 17.2).

To graphically indicate the trips, straight lines are used to indicate links between zones and widths to indicate volume (figure 17.3). An inspection of figure 17.3, shows that many specific links were not well predicted. In general, the prediction underestimated very short trips but overestimated middle distance trips (2-4 miles).

Predicting 1998 Trips From 1997 Trips

From a police perspective, even the distribution of crime trips can be of value for tactical purposes and for planning interventions. However, the description of 1998 night time robberies travel demand was retrospective-done long after 1998. Can this distribution be successfully predicted? In time series analysis, the best prediction of one period is generally the period that immediately preceded it. In spatial analysis, this is also likely to

Figure 17.1:



Robbery 1997: Intra-Zonal & Inter-Zonal Links

Source: Chicago Police Department Cartography: Richard Block, Loyola University Chicago

Figure 17.2:

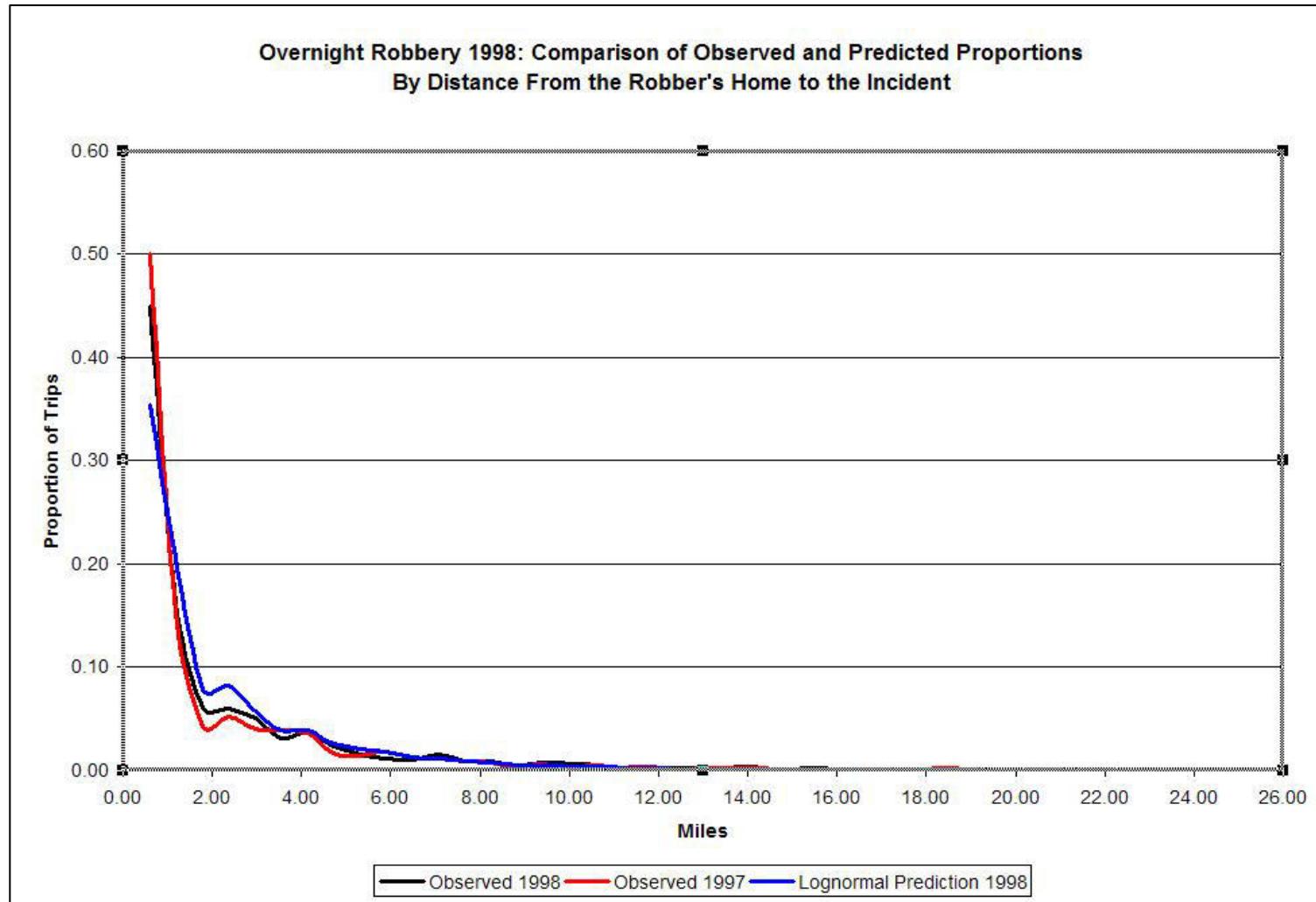
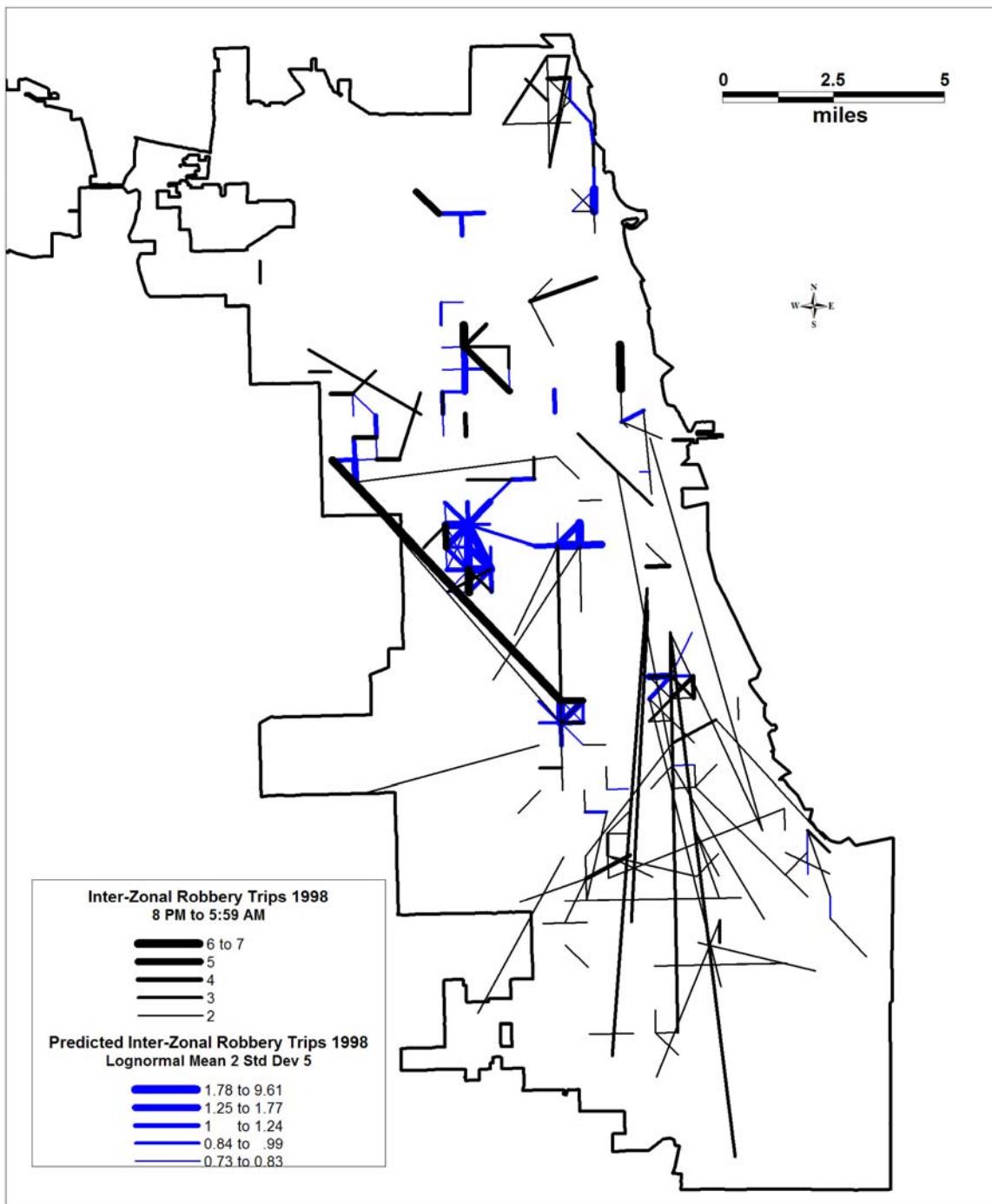


Figure 17.3



Observed & Predicted Overnight Robbery Links 1998

Source: Chicago Police Department

Cartography: Richard Block, Loyola University Chicago

be true, especially in a mature city. However, while neighborhood characteristics change slowly in Chicago, they do change. During the late 1990's many public housing projects were emptied and some were torn down. While few neighborhoods deteriorated, many gentrified. Any of these might cause a change in the distribution of robbery trips.

The 1997 observed robbery travel matrix was used to predict observed travel in 1998. *CrimeStat III*, in conjunction with a GIS and a statistical package, provides several comparison tools. Comparing 1997 and 1998, the fit is quite good. Including street segments that had no trips in either year, 55% of the trip links in 1998 were predicted by the trip links in 1997 ($r^2= .741$). The coincidence ratio of .86 for 1998 and the distance distribution in figure 17.2 above indicate a high degree of similarity. However, a comparison of the top 300 trip links illustrates that, while zones with many intra-zonal incidents are fairly well predicted, inter-zonal trips are not well predicted. Mapping these makes clear that 1997 inter-zonal links cannot accurately predict specific 1998 links (figure 17.4). However, specific links may be less important from a police perspective than knowledge of the frequency of offender travel on specific streets.

Predicting Overnight Robbery Trips

After selecting only those 1998 robberies that occurred from 8 PM to 5:59 AM, a zone to zone matrix was constructed. Unlike the analysis above, this matrix included both intra-zonal (31.5% of the total) and inter-zonal trips. As shown in Figure 17.5, zones with many intra-zonal overnight trips also had many inter-zonal trips. Intra-zonal links were widely dispersed throughout the city with an area of concentration on the west side, but there was no clear pattern.

Mode Split

Because of the lack of information about travel mode, the mode split model was not run. It is hoped that, with better information, this type of model could be run in the future.

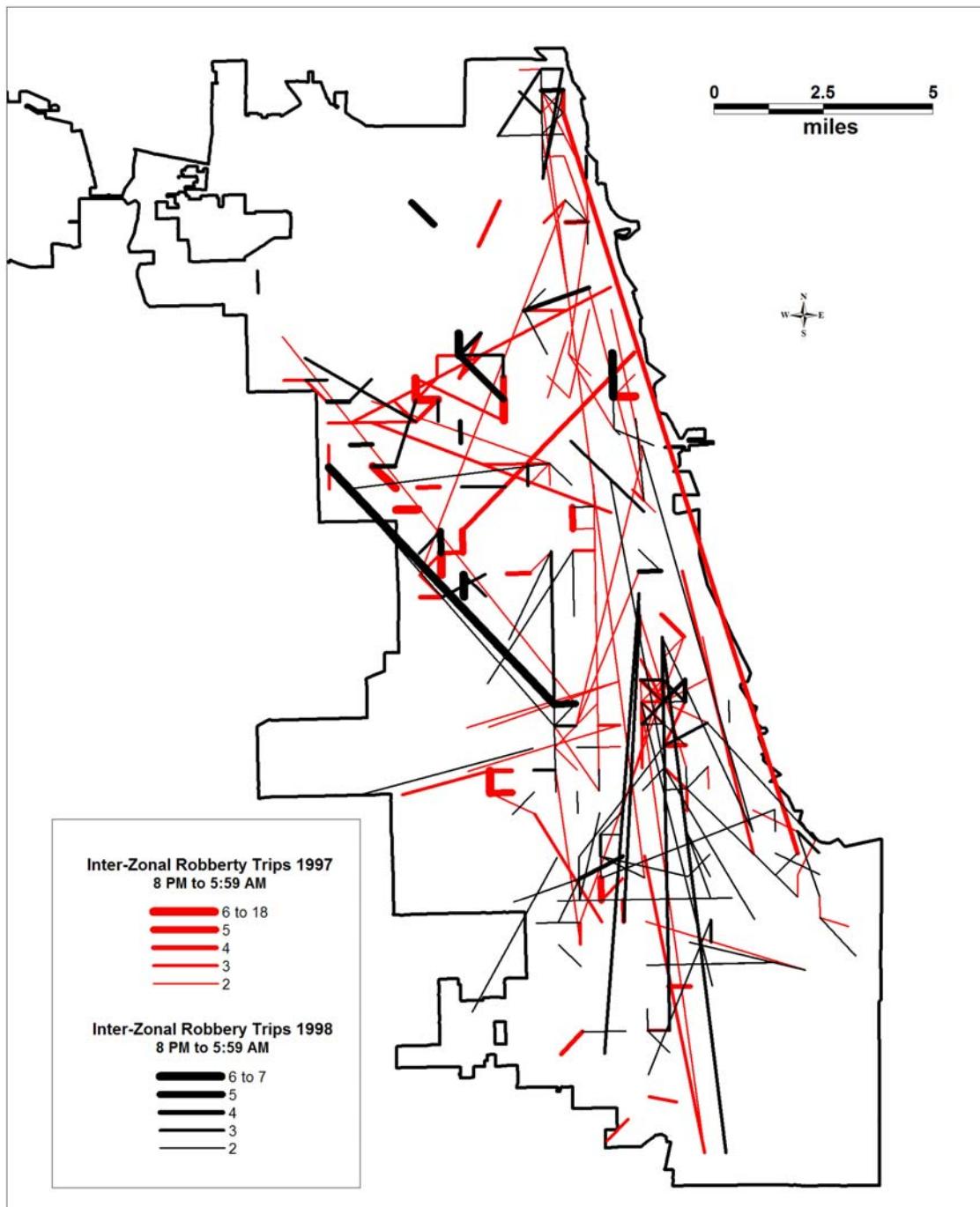
Network Assignment

The third, and final step, in the analysis was to examine the likely routes taken as well as the total demand placed on the road network. Network assignment is an especially useful tool for police work because it suggest possible locations for intervention. Because it is based on the actual street network, it is more concrete than a depiction of links. Therefore, I tested several ways to depict network assignment for 1997 robbery travel before proceeding to the 1998 analysis.

The network assignment routine in *CrimeStat III* outputs two results:

1. The shortest routes on a street network. For each zone-to-zone pair, the shortest path is calculated.

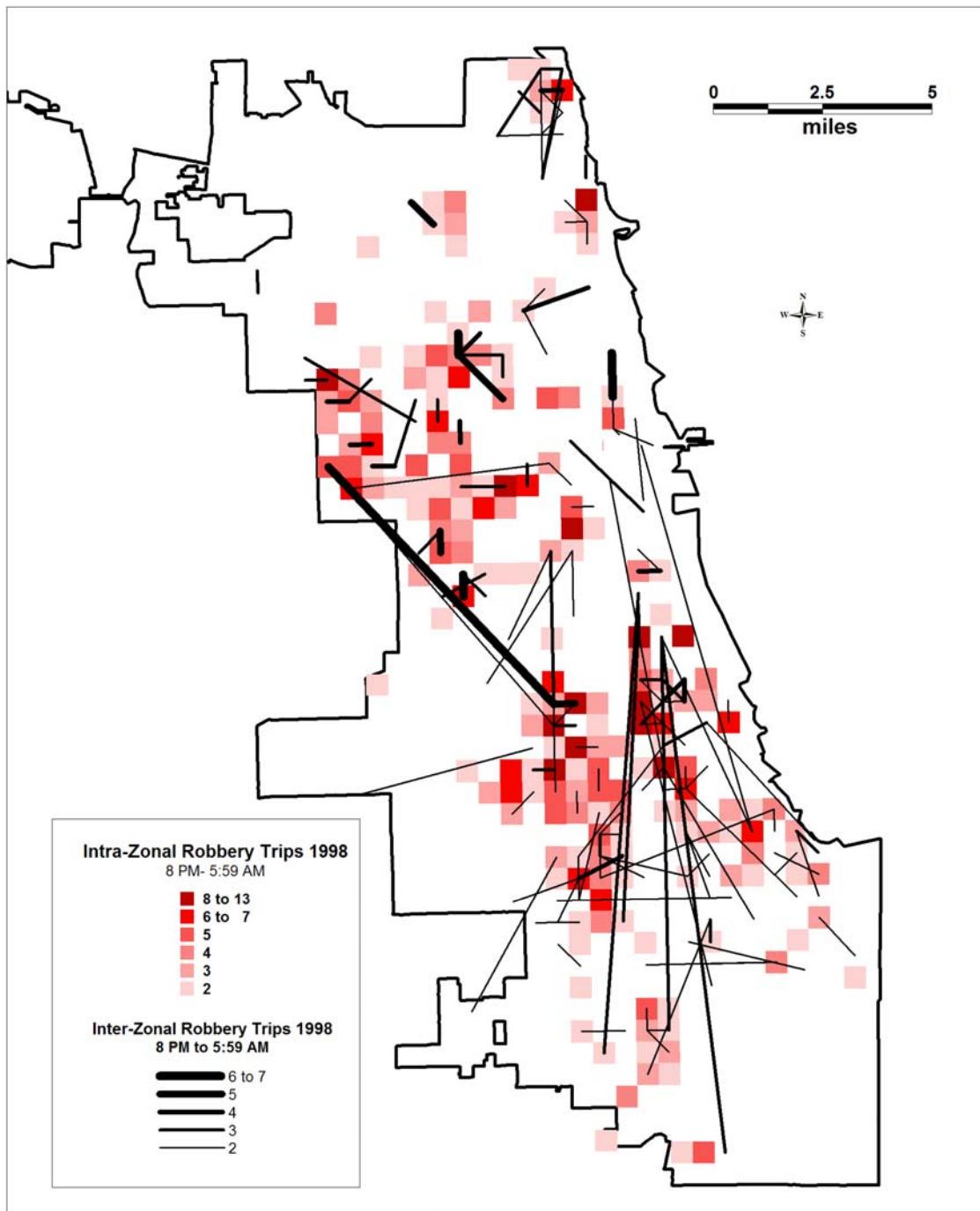
Figure 17.4:



Robbery 1998 & 1997: Observed Links

Source: Chicago Police Department Cartography: Richard Block, Loyola University Chicago

Figure 17.5:



Robbery 1998: Overnight Intra-Zonal & Inter-Zonal Links

Source: Chicago Police Department Cartography: Richard Block, Loyola University Chicago

2. The Network load. Network load counts the number of trips over each street segment regardless of origin or destination and sums these.

Both the shortest routes and the total network load can be based on time or cost rather than distance.

First, all inter-zonal robberies in 1997 were mapped along Chicago's street network by shortest distance. The 4000 trips were counted along each of Chicago's 51,000 street segments and mapped as a network load. As the width and color changes from blue to red in Figure 17.6, the number of trips that passed over a segment increases. However, this map is difficult to interpret and lacks credibility. Much of the load is along small side-streets. Diagonal streets are emphasized and expressways are ignored because they usually are not the shortest route in terms of distance. Also, travel in the wrong direction on a one way street is possible since only distance was used to calculate the shortest path. The CPD did not believe this to be a useful map.

The same inter-zonal links were mapped again along using the Chicago modeling network, but weighting segments only by distance (figure 17.7). While this resulted in a greatly simplified map, it still lacked some credibility. Expressways are rarely the shortest distance, therefore, their use is under emphasized. The algorithm results in an over emphasis on diagonal main streets. Some connected segments looked like a stair case following along Chicago's grid of main and secondary streets from one high incident neighborhood to another on the west and southwest sides.

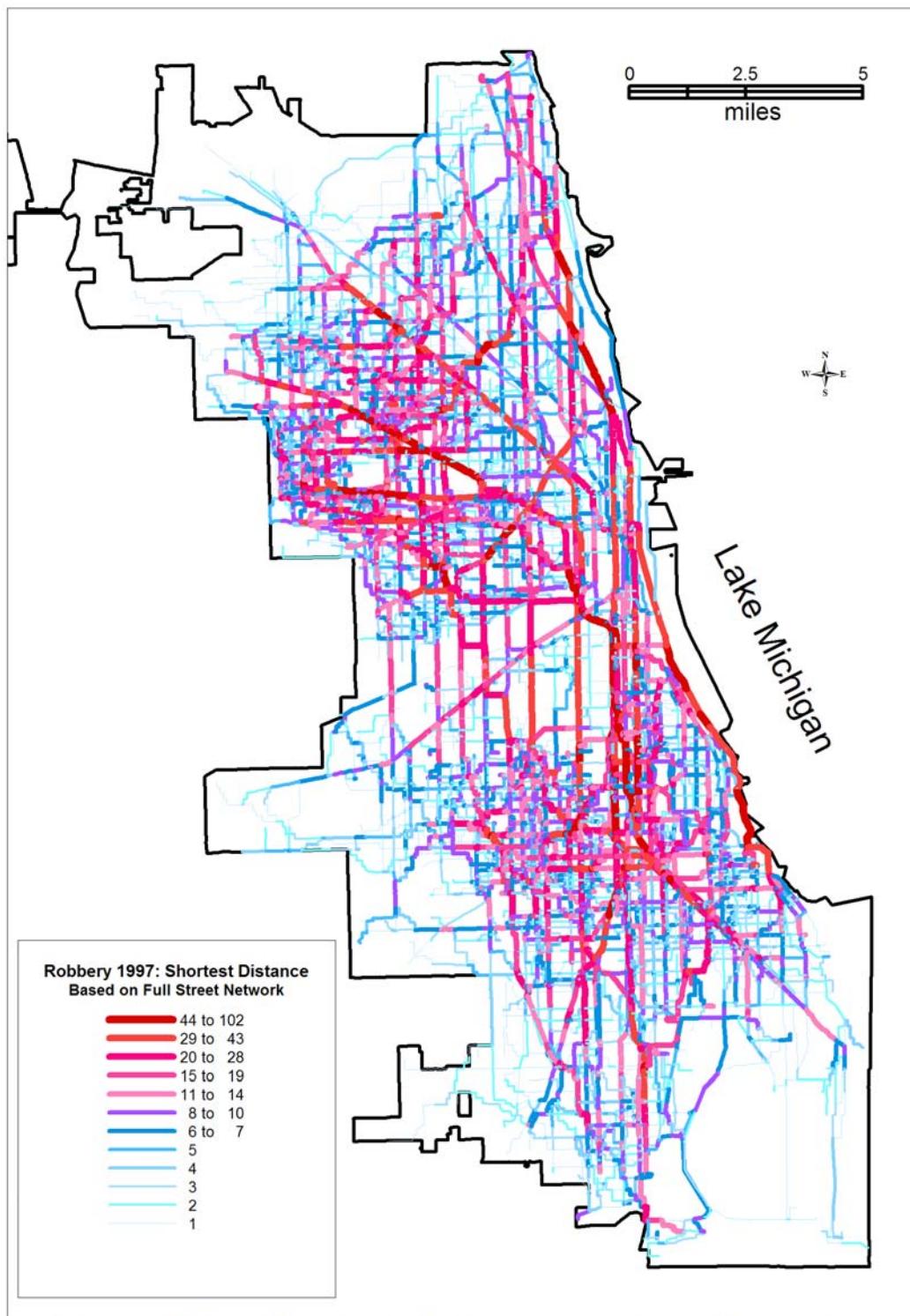
In other words, distance did not seem to be a good representation of travel routes. Given that police records include time of incident and travel time along Chicago's road network is available, and that *CrimeStat* allows for analysis by travel time, I re-conceptualized travel cost as shortest time rather than distance.

Shortest Time or Shortest Distance?

What does distance measure? Traveling ten miles during Chicago's evening rush is quite different than at midnight. However, the two blocks from my house to the nearest convenience store is unaffected by the time of day and little effected by the mode of transportation. While distance appears to be a straight forward measure, it is not. At close distance, it specifies knowledge space or the location of routine activities. Further from home, it is related to a lack of knowledge, but is also an inaccurate measure of the cost of travel. Better measures than distance are often available. All U.S. major metropolitan areas map travel time by time of day on major streets, feeder streets, and expressways using modeling networks (see chapter 16). These maps along with police data on time of incident can be combined to realistically describe shortest travel time rather than shortest distance.

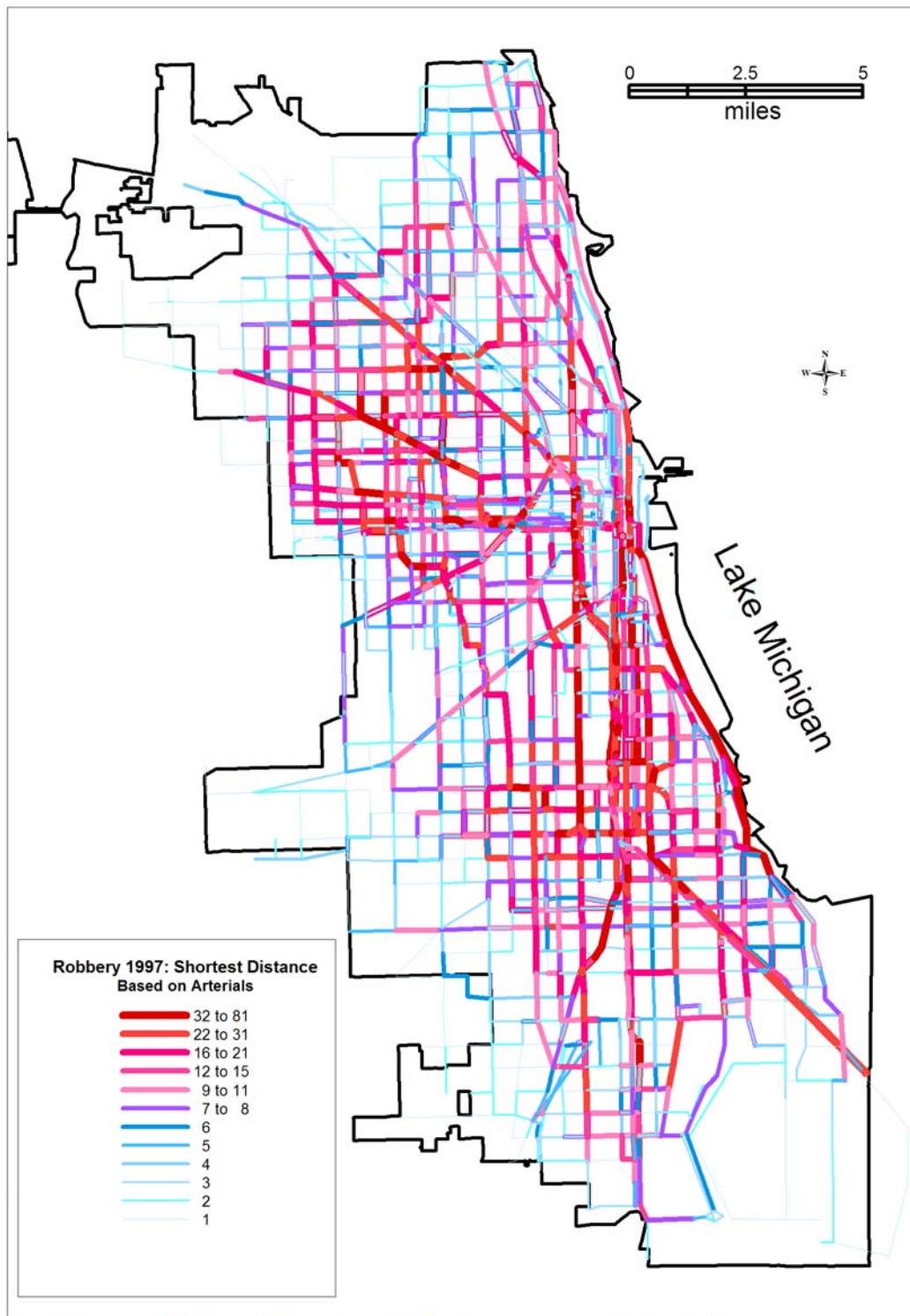
The Chicago Area Transportation Survey (CATS) divides the day into eight time periods based on travel demand. Whether a crime trip was intra- or inter-zonal was unaffected by time of day ($\chi^2=7.07$ sig=.421 in 1998). Not surprisingly, the robber's daily

Figure 17.6:



Robbery 1997: Shortest Distance on Street Network
Source Chicago Police Department Cartography: Richard Block, Loyola University Chicago

Figure 17.7:



Robbery 1997: Shortest Distance on Arterials
Source Chicago Police Department Cartography: Richard Block, Loyola University Chicago

travel cycle is different than the general population. In 1998, robbers show little demand for travel in the morning rush hour period (6 AM to 10 AM). Of the remaining trips, about half (46% in 1998) occurred from 8 PM to 5:59 AM. These overnight trips are the subject of the analysis presented here.

Overnight Robbery Trips

Overnight network load was mapped on Chicago's arterial roads according to both shortest distance (figure 17.8 left) and shortest time (figure 17.8 right). As before, the two maps are very different. Expressways are rarely included in the shortest distance between zones. Much of the travel is on diagonal surface streets. However, if time is taken into account, many of the trips are on expressways and on Lake Shore Drive. This is probably a more realistic description of longer distance trips.

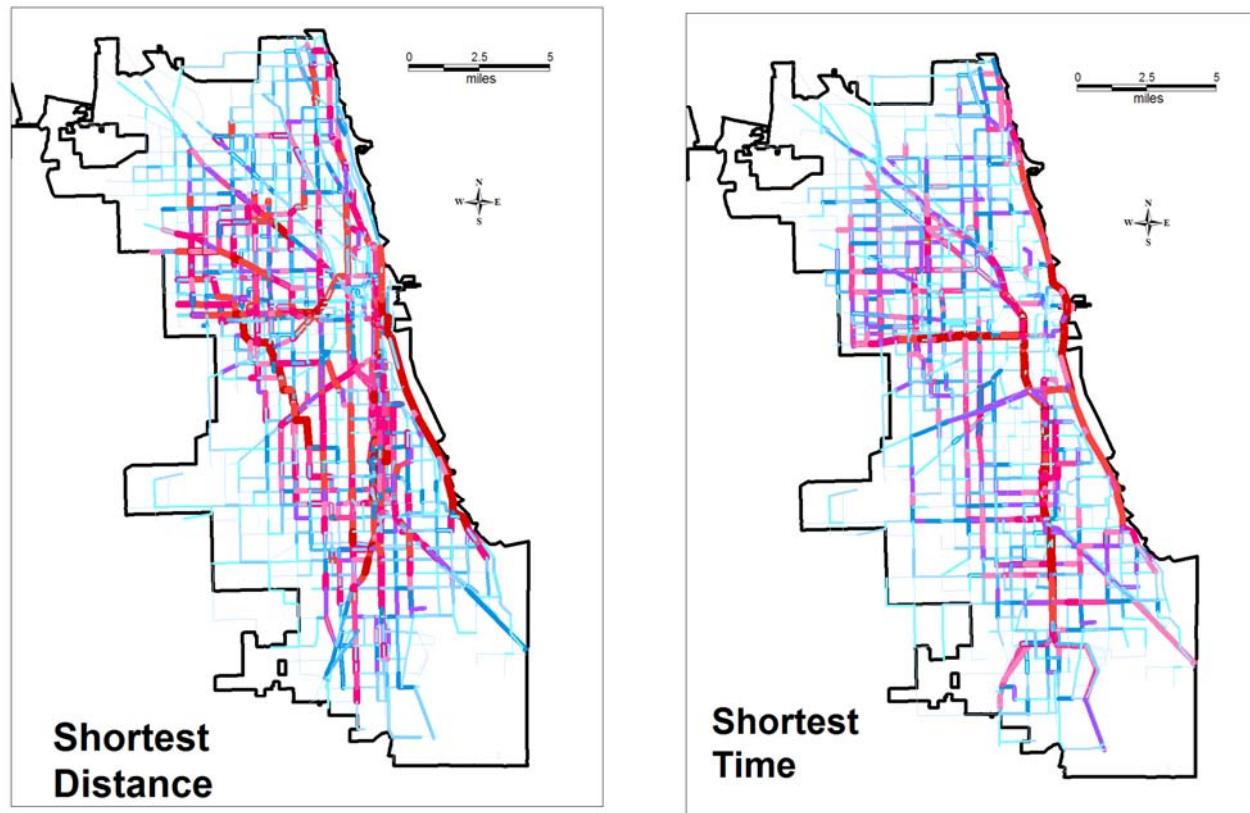
In moving from a complete street network to a simplified network using distance as an impedance to a time-based network, the description moves from an unrealistic and probably un-interpretable map to one that probably corresponds to the routes taken by offenders. Does this add to police knowledge? Of the 10,763 mapped segments in the network, 65.1% had no predicted trips assigned to them. Two percent of the road segments, those with 15 or more trips, contributed 20.2% of the 16,162 robber's movements across road segments. These were typically arterial roads or expressways. Nevertheless, by identifying these streets as those most likely to carry crime trips, these 'hot street' segments could become a focus for police patrol or for intervention to prevent crime.

Feasibility & Advantages

The police already collect information on the location and time of incidents and the home address of arrested offenders. Can this information be utilized to describe and predict the travel patterns of Chicago robbers? First, *CrimeStat*'s trip distribution module was used to describe zonal patterns of travel for all known 1997 Chicago robbery offenders. Around 30% of Chicago robberies are committed near to the offender's home. For these a zonal model cannot predict travel patterns. For other robberies, a time-weighted travel pattern resulted in a more credible description than one based on distance. However, even this description resulted in an over emphasis on travel along surface grid streets and diagonal streets rather than expressways.

The key to analyzing the robber's travel pattern is to reconsider the meaning of distance. Close to home or work, distance represents a knowledge space and an opportunity space, a place the offender knows in which he or she spends a lot time. This is an area where the benefits of knowledge may outweigh the costs of possible capture or it may simply be where the offender hangs out.. Further away, shortest distance is a poor representation of travel cost. In major metropolitan areas, a better representation is shortest travel time. Combining travel time of day with time of incident, results in a more realistic travel pattern.

Figure 17.8



**Robbery 1998, Offender Travel Network for Incidents
Occurring from 8 PM to 5:59 AM.
Shortest Travel Time & Distance Compared**

These intra- and inter-zonal links are, themselves, a new way to look at the relationship between offender and incident. However, they need some representation before they are useful to the police for tactical analysis or crime prevention. In my discussion with the Chicago Police Department, a network load map seemed to be most useful. Network load summarizes the number of crime trips that passed over each segment in a road network.

Limiting analysis to robberies occurring overnight (8PM to 5:59 AM), 1997 travel patterns were a good predictor of travel distances, intra-zonal robberies, and network load in 1998. However, 1997 travel patterns only weakly predicted specific links between traffic analysis zones. For 1998 incidents, a trip distribution model (using Poisson regression of the zonal count of robbers' homes and incident locations, and a impedance function) modeled the overnight travel links between home and incident. Substituting a lognormal impedance function - that better matched the observed overnight robbery pattern, resulted in predictions that were nearly as good as the 1997 observed travel patterns. A combination of these predictions with analysis of travel patterns over several years might eventually result in an excellent zonal prediction of crime travel patterns.

Crime travel demand analysis is complex and time consuming and requires a relatively powerful PC with a large memory capacity. Is it worth it? Yes. Information on crime trips is automatically gathered by the police, but it is not fully utilized. However, unlike transportation planners, police are generally concerned with the short term and with acute rather than chronic problems. They work on an existing street network rather than planning for the future. Crime travel demand models may better serve the police as short term descriptions rather than long term predictions and can probably be used to describe the effect of specific police interventions such as road blocks or drug interdictions. The crime travel demand model along with a GIS can identify hot street segments-those segments that are most likely to be on the travel routes of offenders and most useful for intervention to prevent crime.

For researchers, on the other hand, a crime travel demand model is a good way to ask long-term, structural questions. If the travel patterns remain relatively constant over time, then these relationships can be modeled using a limited number of variables. The result is a way to compare different metropolitan areas as well as a way to look at the same metropolitan area over different time periods. It's a framework for analysis that is broader than just a journey-to-crime type of description.

Limitations

There are also limitations to the model:

1. Only crimes with at least one known offender are analyzed. To the extent that offender travel patterns in unsolved crimes are different than those with known offenders, travel patterns will be misrepresented.

2. The model works best if records are gathered in such a way that the address of an offender home can be linked to the address of an incident.
2. The travel demand model assumes that the offender's home address is accurate. Offenders may not have a stable address or may give a false address.
3. The travel demand model assumes that offenders travel directly from home neighborhood to incident neighborhood; many probably do not.
4. The crime travel demand model is an aggregate model, not a individual one. It predicts travel from the center of one zone to the center of another. It cannot predict specific trips or the behavior of specific offenders and cannot predict travel within a zone.
5. The model must be crime and city specific. Chicago robbers were much more likely to attack close to home than those in Baltimore County or Las Vegas. Because these homes were distributed throughout the city, the travel patterns of Chicago robbers were much less focused on single target zones than in the other test sites.
6. The study of Chicago was limited to incidents that occurred in the city of Chicago. It does not model travel patterns of incidents occurring outside the city and can say nothing about them.
7. The data available from the Chicago Police Department did not allow for a test of travel mode used. It cannot be assumed that criminal trips use the same modes of transportation as non-criminal trips.

Conclusions: Chicago

Chicago is a city of isolated neighborhoods. Even nearby neighborhoods may be *terra incognita*. Crime travel follows the pattern of neighborhoods. In Chicago, many robberies occur very close to the home address of the offender. The crime travel demand model cannot analyze these crime trips because each zone is represented by a single point. In some impoverished neighborhoods, robbery is very common. An offender can opportunistically attack on any block. Even when offenders travel they tend to stay nearby their home neighborhood. The isolation of robbery in the a few neighborhoods results in a downtown that is relatively free of incidents and crime trips are relatively short.

Chicago is a mature city. Neighborhoods change slowly. Large scale changes in housing, poverty, or attractors do occur---the destruction of public housing, widespread gentrification and the replacement of rail yards with upscale housing. With these changes come new opportunities for crime and changing crime travel patterns. These may be predicted with the new crime travel demand module.

II. Application of Travel Demand Behavior Model on Crime Data from Las Vegas, Nevada

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Introduction

Strategic crime forecasting has for many years relied on a limited and simplistic suite of methods to predict approximately where future events may occur in broad strokes. Extrapolation of percentile change is probably the most commonly used means of forecasting future crime frequencies, based on the notion fundamental to all predictions, that the future will resemble the past. Unfortunately, this method is completely unable to cope with changes in the demographics, population, and social makeup of a jurisdiction.

For a number of years, innovative crime analysts and criminologists have looked to other disciplines outside the study of criminal behavior for methods of predicting how the future will unfold. Economics, epidemiology, meteorology, and biology have all offered significant contributions, as their more sophisticated and creative methods for foretelling future frequencies have been adapted to criminology with varying degrees of success.

Transportation modeling is the most recent external science to suggest potential means of predicting criminal behavior. The success of travel-demand modeling in the civilian world of transportation behavior has presented us with another possible technique which could be adapted to forecasting crime. Travel-demand modeling offers an algorithm for estimating not only how much activity will occur in a given region, but also how offenders will travel across the jurisdiction to commit their crimes. This model has been implemented in the *CrimeStat* software application for use against crime data.

In this study, we will review the application of this model against data from the metropolitan Las Vegas area over a period of three years.

The Las Vegas Metropolitan Area

The Las Vegas metropolitan area is comprised of Clark County, Nevada, and several independent municipalities within it. The Las Vegas Metropolitan Police Department (LVMPD) serves Clark County (in the capacity of a Sheriff's Office) as well as the City of Las Vegas (in the capacity of a municipal police department). Although the vast majority of the land area, population, and businesses within this area are policed by the LVMPD, there are three other significant jurisdictions: The City of North Las Vegas, the City of Henderson, and the City of Boulder City, each having their own police department.

In addition to these important sibling agencies, several other law enforcement agencies have overlapping jurisdiction within areas principally policed by the LVMPD: The Paiute Tribal Police, the Southern Pacific Railway Police, the Nevada Highway Patrol, US Air Force Security Police, US Air Force Office of Special Investigations, Federal Bureau of Investigation, Veteran's Administration Police, and others. Although these agencies perform valuable police functions, the LVMPD unquestionable deals with the vast majority of crime in the vast majority of locations, making it an attractive candidate for offender travel research.

In many ways, Las Vegas resembles an island. Surrounded by barren desert, with very few roads entering or leaving the city, it is an urban oasis in a sparsely populated desert wilderness, consisting of largely impassable terrain. This geographic position and isolation make Las Vegas highly interesting from the perspective of a transportation (or crime trip movement) modeler.

Another unique feature of the Las Vegas area is the highly transient nature of the population, which falls into three discrete categories:

1. First, the Resident Population consists of some one million persons, approximately 880,000 of which live in the jurisdiction of the LVMPD (the remainder being served primarily by Henderson and North Las Vegas). These permanent residents are the mainstay of the community and the source for demographic data used by the census bureau and planning agencies.
2. Second, we must consider the Visitor Population, consisting of some 35,000,000 - 40,000,000 persons per year. On any given day, between 100,000 and 500,000 visitors will be staying in the Las Vegas area - a critical factor in transportation, demography, and crime! These tourists sometimes act as crime importers (e.g., criminal street gangs from neighboring Californian cities often visit Las Vegas for weekend mayhem, or more professional criminal purposes); in most instances, however, they serve as a pool of prey for local criminals.
3. Third, and finally, there is a substantial Homeless Population in Las Vegas, drawn by the seasonally warm climate and the ease with which this city can be reached as a destination. Although not famous for a "friendly" attitude toward the homeless, these persons are protected by law enforcement in Las Vegas and are well served by many charitable social institutions and services. Because Las Vegas is also an easy place to sin, homeless individuals with drug, alcohol, and gambling addictions often gravitate here; the possibility of "winning big" and instantly reversing a life of misfortune also weighs in the consideration of many homeless who choose to make their base in Las Vegas. Although not a major source of annoyance as criminals, nor overly victimized by criminals, these persons do constitute a significant (although never well-measured) fraction of the local population, and

therefore of local crime statistics. However, due to the inability to accurately measure a "home" location for these persons when they do commit crimes, few of these have been represented in this study.

This study will focus on the criminal movement behavior of the resident population of the greater Las Vegas metropolitan area.

Source Data Provenance and Organization

Data concerning the Las Vegas metropolitan area was provided by the Las Vegas Metropolitan Police Department's Investigative Division. Often, researchers underestimate the severe difficulties and chronic shortcomings of law enforcement data. Thanks to a first-rate RMS, and a voluminous tactical database repository, the Las Vegas Metropolitan Police Department's data presented relatively few problems; however, geocoding accuracy issues, missing data fields from *modus operandi* tables, and erroneous arrestee home locations resulted in some difficulties. These had to be overcome before any analysis or testing of new methods was possible.

Crime report data for the LVMPD is maintained in an SQL-Server 7.0 database constructed by the Printrak (now owned by Motorola) company, makers of the Law RMS (LRMS) police records management system used by Las Vegas, among others. This repository currently houses many hundreds of thousands of crime reports, field interviews, and other critical police data in a well-organized, relational database.

Crime reports are filled out by either sworn officers (when taken in the field) or by station personnel (when reported in person at an LVMPD substation or city hall). These paper reports include ample MO detail and descriptive information in compartmentalized, "force-choice" fields, as well as substantial expository narratives. "Forced-choice" fields are also typically supplemented by "Other" options which can then be individually explained, to deal with very unusual crime behaviors, descriptions, or details.

At the end of each shift, officers submit their reports to their sergeant for review; after a quick check to ensure the most basic levels of data quality and integrity, the reports are then placed in a mailbox for pickup, which occurs several times each day and night. Reports are transferred by intradepartmental couriers to city hall, where they are collected by the Records Section. Professional data entry specialists then meticulously type each report into the LRMS database.

The data entry process includes several validation and error-trapping elements. These usually greatly enhance the completeness and accuracy of each report, but are sometimes bypassed by busy clerks. Perhaps the most significant validity check which can be bypassed is the address verification system, which performs a brute-force match against a "geofile" of known, valid locations. When a matching address is entered into the system, geographic coordinates and other useful data is automatically propagated into the file. Because many crimes do not occur at valid, documented physical street addresses (crimes

in remote or desert areas, or in new construction zones, or on buses or in taxi cabs, for example), however, data entry clerks have grown accustomed to overriding the address verification module. This is also sometimes done in the interests of speed and expediency, even when a valid, matchable address is provided in the crime report. When this happens, the resulting address must be cleaned using a data cleaning application prior to successfully matching in a geocoding operation. Once entered into the LRMS database, crime report information may be extracted through a variety of standard methods.

The LVMPD routinely downloads crime reports on a daily basis into an ATAC analytical database where crime analysts and investigators can examine and study the data without creating any drag on the primary server. The ATAC database is streamlined for analysis, and is much easier to query and analyze than the LRMS repository itself. The ATAC databases are Microsoft Jet-compliant relational database very similar to the MS Access 2000 database.

Data used for the Next-Generation Offender Crime Travel Model project were derived from records stored in several ATAC analytical databases created and maintained by the LVMPD Crime Analysis Section. These databases are archived by calendar year and by crime category. The archive dates for calendar year are assigned based on the year of occurrence. Crime categories are: Auto Crimes (including motor vehicle thefts, burglaries from motor vehicles, and criminal damage to automobiles); Burglaries (including all burglary statutes); Larcenies (including all Larceny/Theft statutes); and Personal (including all sexual offenses, assaults and aggravated assaults, robberies and home invasions, kidnappings, and homicides).

These databases contain MO, Persons, and Vehicles tables, related by event number. The MO table contains all information pertinent to the location, timing, category, and methods of each crime event; the Persons table all information on personal identification, description, and histories, not only for suspect and arrestees, but also victims, witnesses, reporting parties, etc.; the Vehicle table all information concerning any vehicles which may be involved in the offense, including descriptive and identification information, whether the vehicle relates to the criminals, victims, or has some other relationship to the crime.

For purposes of this project, the LVMPD authorized access and transmission of the contents of the complete ATAC database inventory for the Crime Analysis Section. Of the fifty-odd databases provided, the Personal Crimes databases for the years 1996 - 2002 were initially selected.

Data Screening

Three broad categories were selected from the complete data inventory provided:

1. Confrontational
2. Burglary, and
3. Vehicular crimes.

These intentionally disparate data were selected in the interests of increasing the latitude of the study. It was hypothesized that travel behavior would vary between these categories of events. Confrontational crimes included sexual assaults, robberies, kidnappings, and murders. These crimes were included in a single group as part of this initial appraisal of the effectiveness of travel-demand modeling on criminal behavior, even though it is obvious that the behaviors exhibited by offenders across these crime types are likely to vary. These crimes were grouped in spite of these likely differences because similarities in targeting behavior across these crimes might make them amenable to collective analysis; a hypothesis which can be tested using the techniques built into the travel-demand module.

Burglaries used in this analysis included both residential and commercial burglaries, but not burglaries from motor vehicles. Only crimes in which a building or property was illegally entered for the purpose of theft were included in this study, thereby eliminating the prolific larceny category.

Vehicular crimes included both auto thefts and burglaries from motor vehicles. "Carjackings" were not specifically included, but some auto thefts in which the modus operandi followed the confrontational "carjacking" pattern may have been included when specifically statutory designations were missing to differentiate these from more typical auto thefts.

Some operational definitions of these crimes are in order.

1. Sexual assaults used in this analysis included forcible rapes with victims of either sex, as well as any other physical, sexual abuse of another person of either sex - such as digital or objective penetration, fondling, etc. - and also open and gross lewdness (e.g., "flashing"). Statutory sexual seduction ("statutory rape") was excluded.
2. Robberies used in this analysis included all robbery-related statutes in the Nevada Revised Statutes (2002), including home invasions.
3. Kidnapping were included in confrontational crimes, but the application of kidnapping as a statutory offense by law enforcement in Las Vegas (and elsewhere) may be counter-intuitive to some readers. Kidnapping is often attached as an additional offense to other crimes, such as robberies or sexual assaults, in any case in which the victim is forcibly moved from one location to another. This practice is used primarily as an adjunct to prosecution, because kidnapping (unlike either robbery or sexual assault) is a federal crime, and in some cases may be easier to prove in court.
4. Homicides used in this analysis included all murder statutes, as well as all manslaughter statutes. No justified homicides were included.

Once the target crime categories have been defined, separate databases for each of the three categories were compiled. Although data for several years was made available, all but three years of data were excluded from the study. Data prior to 1997 was often relatively poorly maintained and prepared, and sometimes contained serious omissions which made it unreliable. Data for the year 2002 was incomplete when this study was commissioned. Although crime data for the years 1997 and 1998 was functionally reliable, socio-economic and transportation data for these years was not readily obtainable at the time this study commenced; since these data were necessary for implementation of this model, these years, too, were excluded from analysis. Therefore, only the years 1999, 2000, and 2001 were included in this study.

Because this study focuses on spatial relationships between crime event locations and criminal home locations, only solved crimes could be used. Crimes were included as "Solved" when an arrest was made - unfortunately, difficulties in obtaining data from the justice system and the long delays inevitable in the prosecutorial process made it impossible to identify crimes in which a conviction had been obtained; an arrest was the closest approximation to a reliable solution possible for this research.

Of those "solved" crimes in which an arrest was made, only those in which the offender's home address and the precise location of the crime itself were both known could be used. Even when crimes were closed by arrest, and adequate data was available to geographically plot and analyze the case, some have still been excluded. Instances in which the offender and victim both live at the scene of the crime have been excluded from these analyses, since no travel was involved; however, instances in which either party lived at the scene of the crime but the other did not have been retained. The reasoning behind this decision is that the decision to commit a crime at a given place does include the decision to commit a crime in one's own home. Therefore, the spatial travel (none) component of this decision should still be reflected in the model if we hope to eventually derive a valid statistical representation of offender travel behavior.

Also, crime in which the offender lived outside the study area (Clark County, Nevada) have been excluded in most cases - but not all. In some cases, "tourist" offenders may have been included when their temporary "base of operations" (i.e., local lodgings) have been recorded. In these instances, the hotel, motel, resort, or private dwelling they lived in has been used as a "home" location for purposes of originating a crime trip.

The number of cases usable for each category of crime varied significantly from year to year (table 17.3).

Table 17.3
Confrontational Crimes Available for Analysis

Year	Total Offenses	Usable Offenses
1999	5272	1080
2000	7560	1643
2001	3588	991

The large increase in number of offenses from 1999 to 2000 is difficult to explain; the following substantial drop (52%!) is even more troubling. A similar, but inverted, discrepancy emerges in the frequency of burglaries reported during those years (Table 17.4).

**Table 17.4
Burglary Crimes Available for Analysis**

<u>Year</u>	<u>Total Offenses</u>	<u>Usable Offenses</u>
1999	17234	2520
2000	12899	2040
2001	16403	2733

A final enigma, most significant of all, is obvious when we look at the frequency of auto crimes over the same three-year period (table 17.5).

**Table 17.5
Vehicular Crimes Available for Analysis**

<u>Year</u>	<u>Total Offenses</u>	<u>Usable Offenses</u>
1999	6871	646
2000	15025	1219
2001	8349	894

These disparities are hard to account for.

On the whole, 1999 had a middling number of auto thefts and confrontations, but a shockingly high number of burglaries; in 2000, on the other hand, the confrontations and auto thefts radically increased (the auto crimes by more than double!), but burglaries dropped notably. Finally, in 2001, confrontational crimes drop to the lowest levels (a staggering decrease), as do auto crimes, while burglaries leap up to nearly 1999 levels!

How can we explain these strange fluctuations? Given the large percentages involved, it's tempting to imagine some change in counting or reporting procedures in 2000; however, a scrutiny of the policies and procedures for the LVMPD does not seem to bear this out. Previous years (1996 - 1999) do not evince a similar wide degree of variation. The reason or reasons for these crime reporting "mood swings" remains unknown. Is there reason, therefore, to distrust these data?

For purposes of this study, the answer appears to be, "No." That is, the data used for these analyses should, even allowing for as yet-unexplained vagaries in reporting, comprise a representative sample of the reported crime activity in Las Vegas over these years.

Since forecasting the frequency of crime is a relatively minor component of the travel-demand model, these numeric sine-waves shouldn't cause us too much concern.

Instead, since the focus of this model is the effective explanation and representation of the distribution of crime trip generators and crime trip destinations (and, as a function thereof, of the crime trip paths between them), the frequencies themselves should matter little.

Reference Data

The Traffic Analysis Zone (TAZ) file for Las Vegas was selected as the optimum polygonal reference theme for this study (figure 17.9). This file was provided by the Metropolitan Planning Office for Las Vegas, the Regional Transportation Commission through the courtesy of David Granata, Senior GIS Analyst, himself an expert in transportation modeling through the use of geographic information systems (GIS). The data provided included historical data for 1999, 2000, and 2001, enabling more accurate modeling of the importance of various factors longitudinally across time. The TAZ dataset was provided in ESRI shapefile format, which is intrinsically legible to the CrimeStat application on which the model is to be built.

The TAZ shapefile includes information on housing, employment, income, population, road mileage, and a variety of subset data specific to particular types of employment (e.g., "Strip" jobs, Nellis Air Force Base employment, entertainment-related jobs, vacant properties, number of pawn shops, etc.).

An additional reference theme is needed to apply the final step in the travel-demand model, the network assignment method. The Major Street Centerline file (LVMAJSCL.shp) in ESRI shapefile format was selected (figure 17.10). Although only including arterial streets, freeways, and major thoroughfares, this transportation network layer is all that is needed to describe the vast majority of trips (of any sort) in Las Vegas. The addition of bus route information may prove a useful supplementary network to future analyses using this model.

Assignment of Crime Trips

Data from each year, by category, is assigned to a simple tabular database consisting of an identifying variable (Event Number as primary key), Origination coordinates (coordinates of the offender's home address, or local base of operations in the case of external offenders), and Destination coordinates (coordinates of the crime scene). These data were then combined into an *MS Access 97®* database for analysis using CrimeStat. Figures 17.11 and 17.12 shows the assigned origins and destinations.

Each origin-destination pair is termed a "Crime Trip." Following the reasoning of transportation modelers, it is understood that offenders do not leave their homes, travel directly to a crime scene to commit an attack, then return home. Instead, each "sortie" is likely to consist of several stages.

For example, a sexually predatory offender may get up in the morning, leave home, drive to work (stopping for coffee along the way), then go out to lunch before returning to the office, then on his way home depart from his usual route to drive through a residential

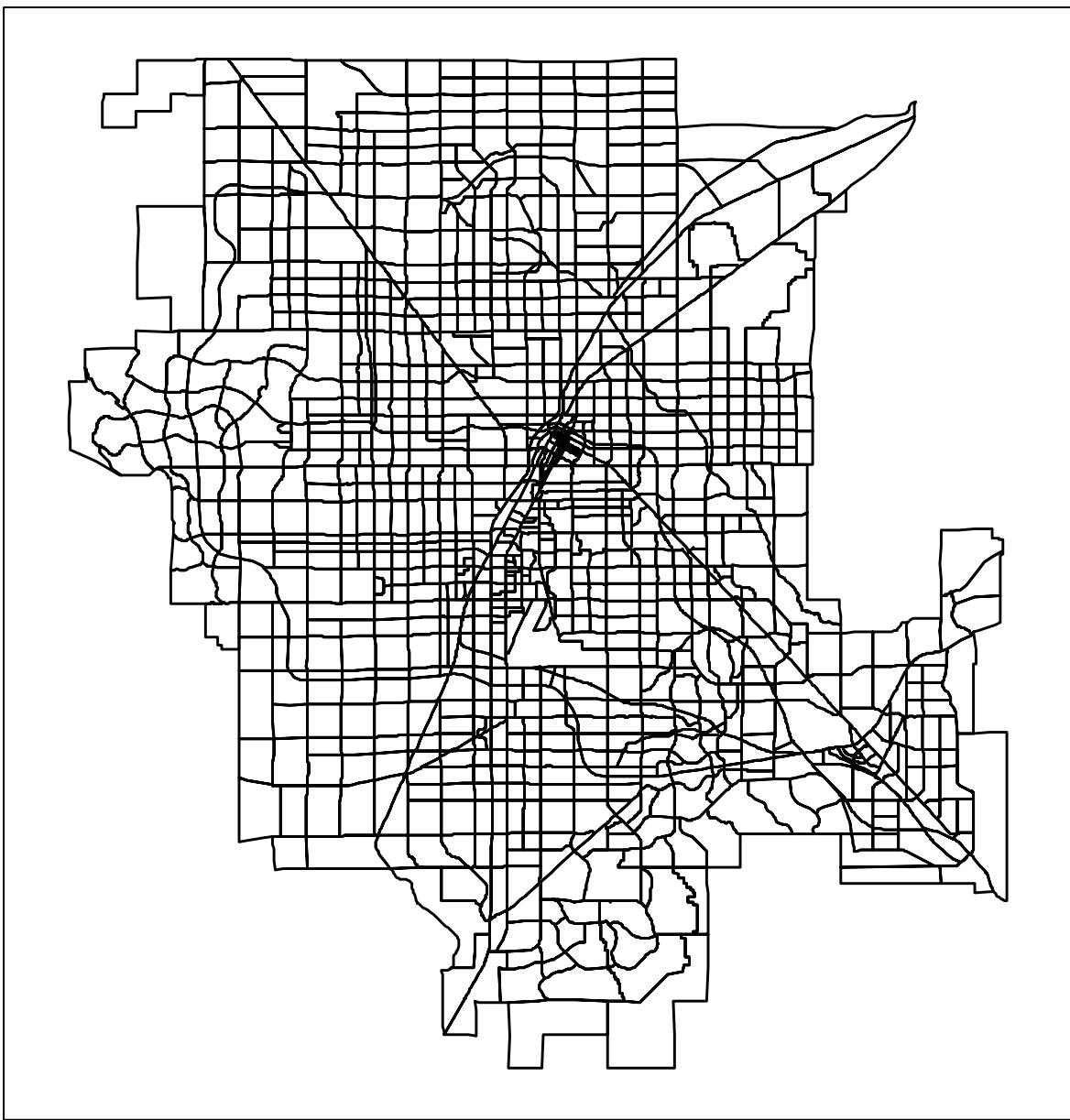


Figure-17.9: Traffic Analysis Zones in metropolitan Las Vegas

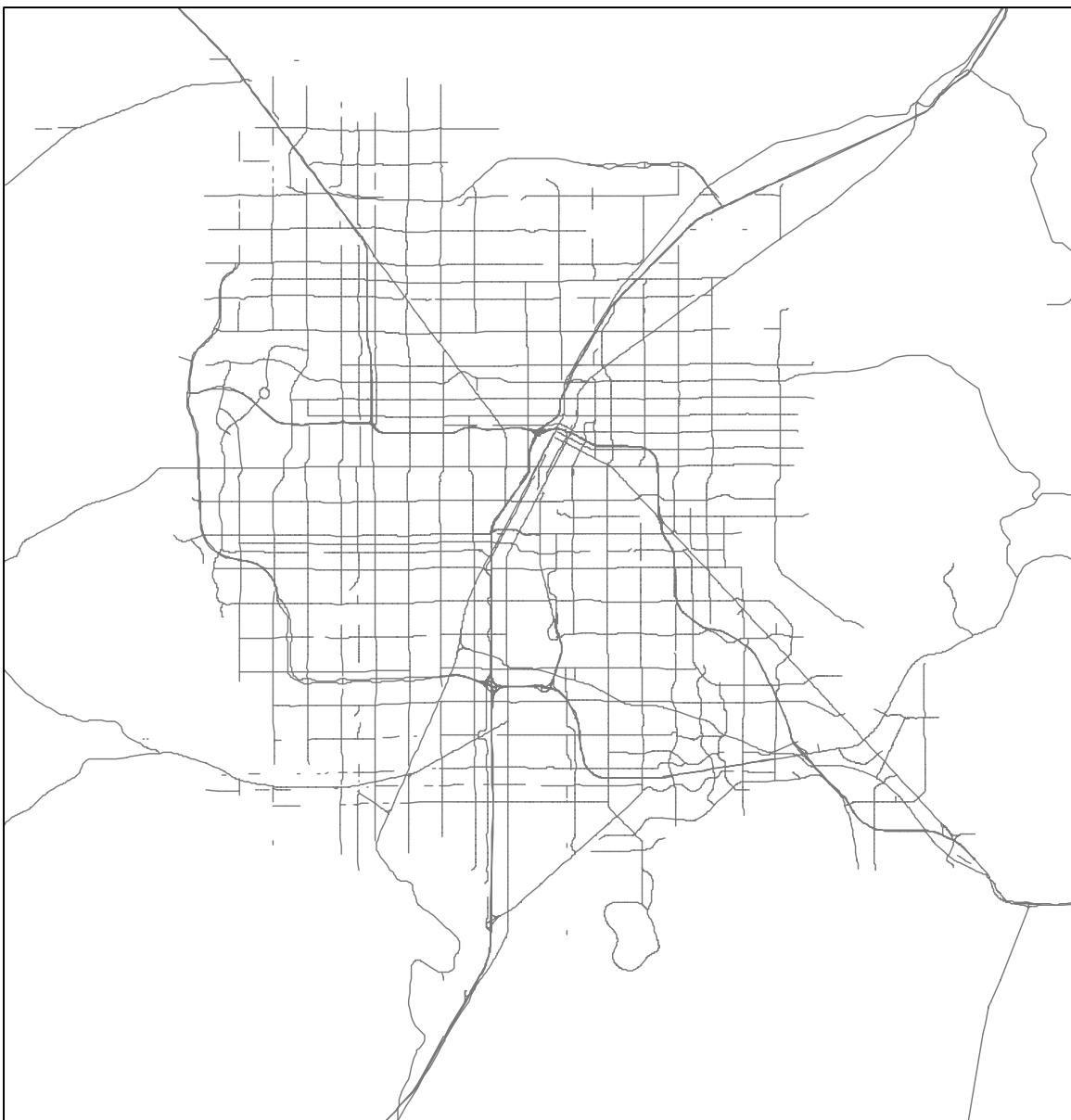


Figure-17.10: Las Vegas major street centerline network

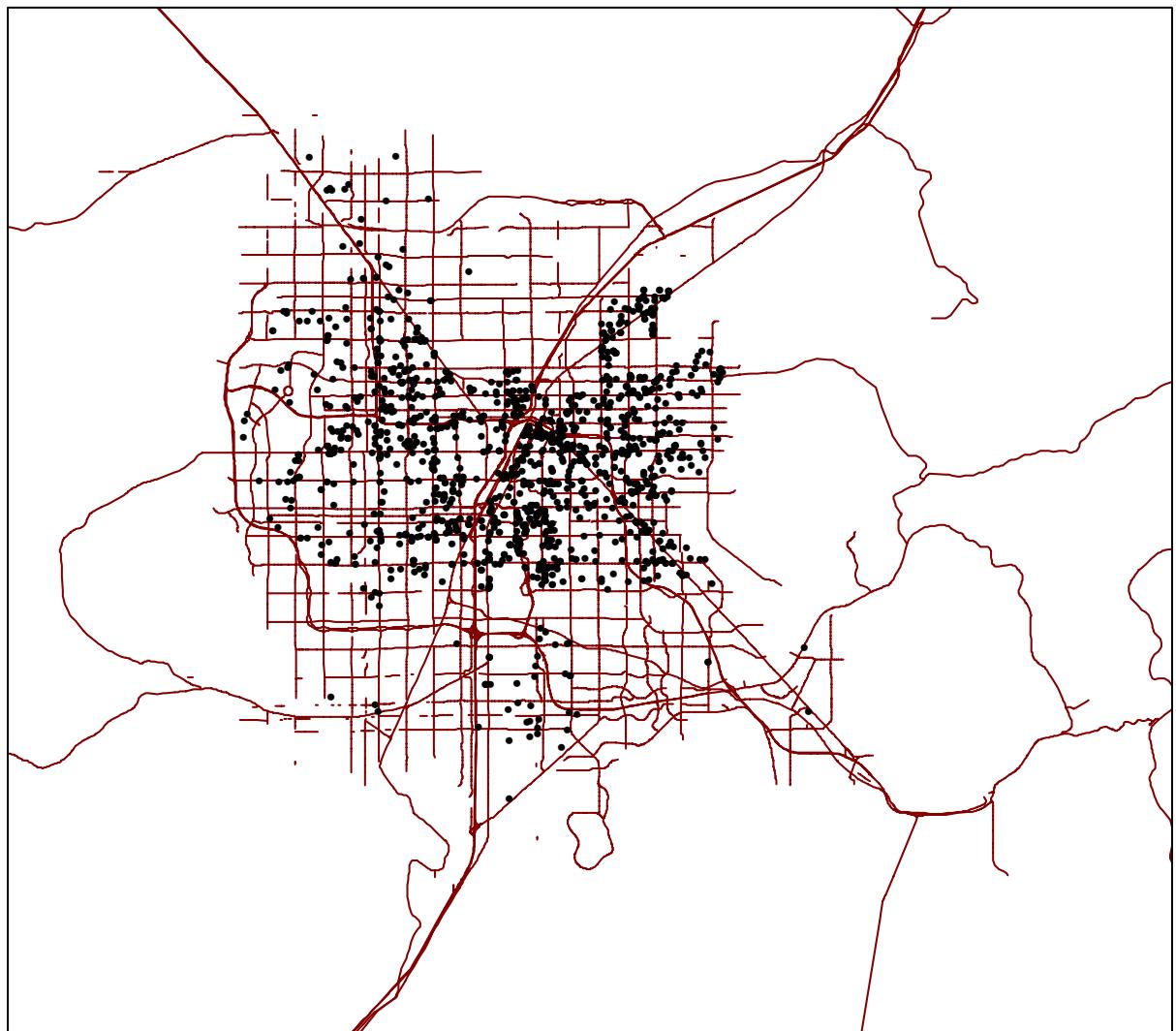


Figure 17.11: Crime Trip Origins (All Confrontational Crimes, 1999 – 2001)

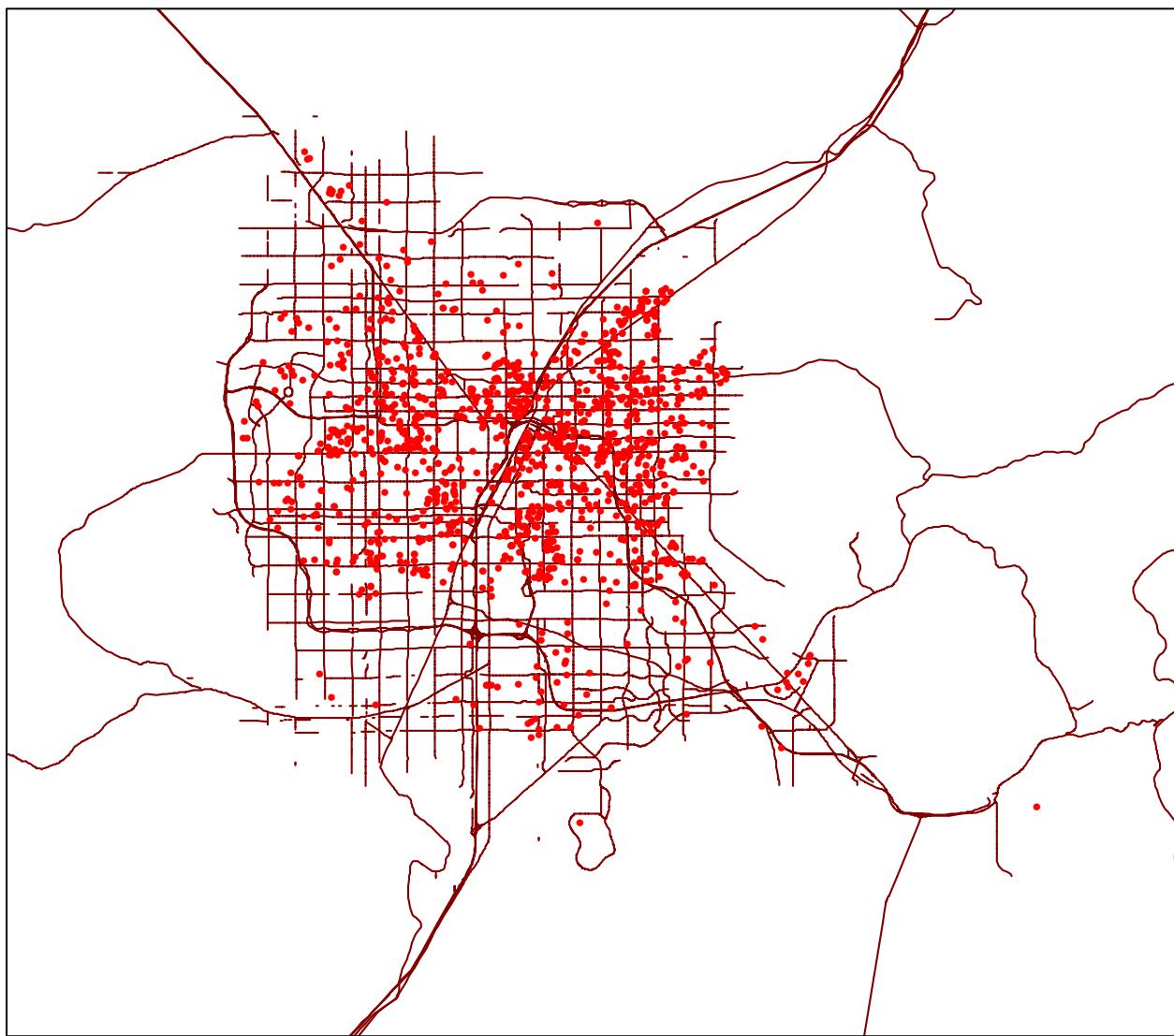


Figure 17.12: Crime Trip Destinations (All Confrontational Crimes, 1999 – 2001)

neighborhood, looking for targets for potential victims. If a promising target is observed, he may then commit an attack, then drive back toward his home area, stopping off for gas or at a drive-thru restaurant on the way, before parking at his house. Although this round-trip from home to home consists of multiple destinations, some of which are repeated throughout the day, the whole journey is considered to be a single "Crime Trip".

In some cases, a single offender was responsible for many crimes. When this happens, the single origin is paired with multiple destinations, resulting in separate Crime Trips. In other cases, one crime may be perpetrated by multiple offenders. When this happens, each offender's origin is paired with the single destination, again resulting in separate Crime Trips.

While it is possible to distinctly model each Crime Trip based on precise spatial locations, it is generally accepted to aggregate both origins and destinations to the centroid of each Traffic Analysis Zone. This enables the spatial assignment of TAZ variables such as income and population to the aggregate frequencies of both origins and destinations.

This assignment is performed in CrimeStat by centroid allocation - the nearest TAZ centroid is used to assign the TAZ data to each origin and destination. This method is faster and simpler than "point-in-polygon" spatial aggregation and assignment, but should result in comparatively few mistaken assignments due to unusual TAZ polygon shape or distribution. Since Crime Trip data is aggregated to the zonal level, therefore, the resulting analyses and forecasts are only applicable to this level and cannot meaningfully disaggregated to a more refined resolution.

The accepted travel-demand model framework contains a built-in "error factor" for external trips - that is, crime trips originating within the study area but having destinations falling outside the area, or, conversely, originating outside the study area but having internal destinations. These "external trips" were culled from the crime database during the data screening process; therefore, "External Zone" data is inapplicable to the trip generation stage of the analysis.

Trip Generation

Each origin/destination pair having been aggregated to the TAZ polygon layer, it is now possible to evaluate the relationship between socio-economic variables available in the TAZ database with the frequency of crime origins and destinations. This is accomplished through regression modeling, and may prove one of the most useful single features in the new modeling capabilities of the *CrimeStat* application.

There are two main regression options available in the software at present: Ordinary Least Squares (OLS) and Poisson. The Poisson estimation also includes a separate option which allows backward elimination of variables. This option, Poisson Regression with Backward Elimination, was the most effective of the techniques evaluated, resulting in consistently better visual fits to the data and lower residuals. This very useful

step examines each variable element suggested by the analyst for its predictive value as a coefficient in estimating the frequency of either origins or destinations by TAZ.

In every case, three variables within the TAZ database for Las Vegas proved consistently useful as predictive measures:

1. Income,
2. Population, and
3. Total Employment.

The measurable successfulness of these variables to account for the predictable distribution of both origins and destinations was somewhat counter-intuitive; it was suspected prior to the application of this model that other variables (in particular the number of pawn shops, the number of Strip employment opportunities, and the number of Nellis AFB employment opportunities) would be critical predictors of crime. In fact, however, all of these variables demonstrated strong multicollinearity with the three primary variables listed above. When these other, extraneous factors were excluded from the regression process, the effectiveness of the model's predictive capabilities was substantially improved.

A suggested and accepted travel-demand modeling techniques widely implemented by transportation planners is the adoption of "special generator" variables to explain unusual or unique factors implicit in some areas. It was expected that Nellis AFB, the Las Vegas Strip itself, and some other seemingly significant factors would likely fill the role of "special generator;" however, results indicated that none of these were as effective in a predictive or explanatory role as Income, Population, and Total Employment.

Latitudinal forecasting of crime trip origins and destinations performed fairly well; comparison of expected versus observed trip numbers did not match particularly well, but the relative distribution by TAZ was a very close match (figures 17.13-17.16).

Longitudinal forecasting of crime trip frequency by data from one year to the next year performed very poorly; this is probably an artifact of the still-unexplained drastic variation in frequency between the three years considered in this study. Results from other years, or other jurisdictions, may exemplify very different findings.

Side-by-side comparison of observed and predicted crime trip origins reveals some persuasive similarities, but significant discrepancies, also (figures 17.17 and 17.18). In general, relative proportions are very accurately described, but smaller-producing zones are somewhat underestimated (the model seems to perform better on zones with higher productions).

Side-by-side comparison of observed versus predicted crime trip destinations suggests that, proportionally, the model again performs very well, particularly on zones with higher production scores. Zones with very weak crime trip destination productions (of one or two crimes) are not as accurately depicted.

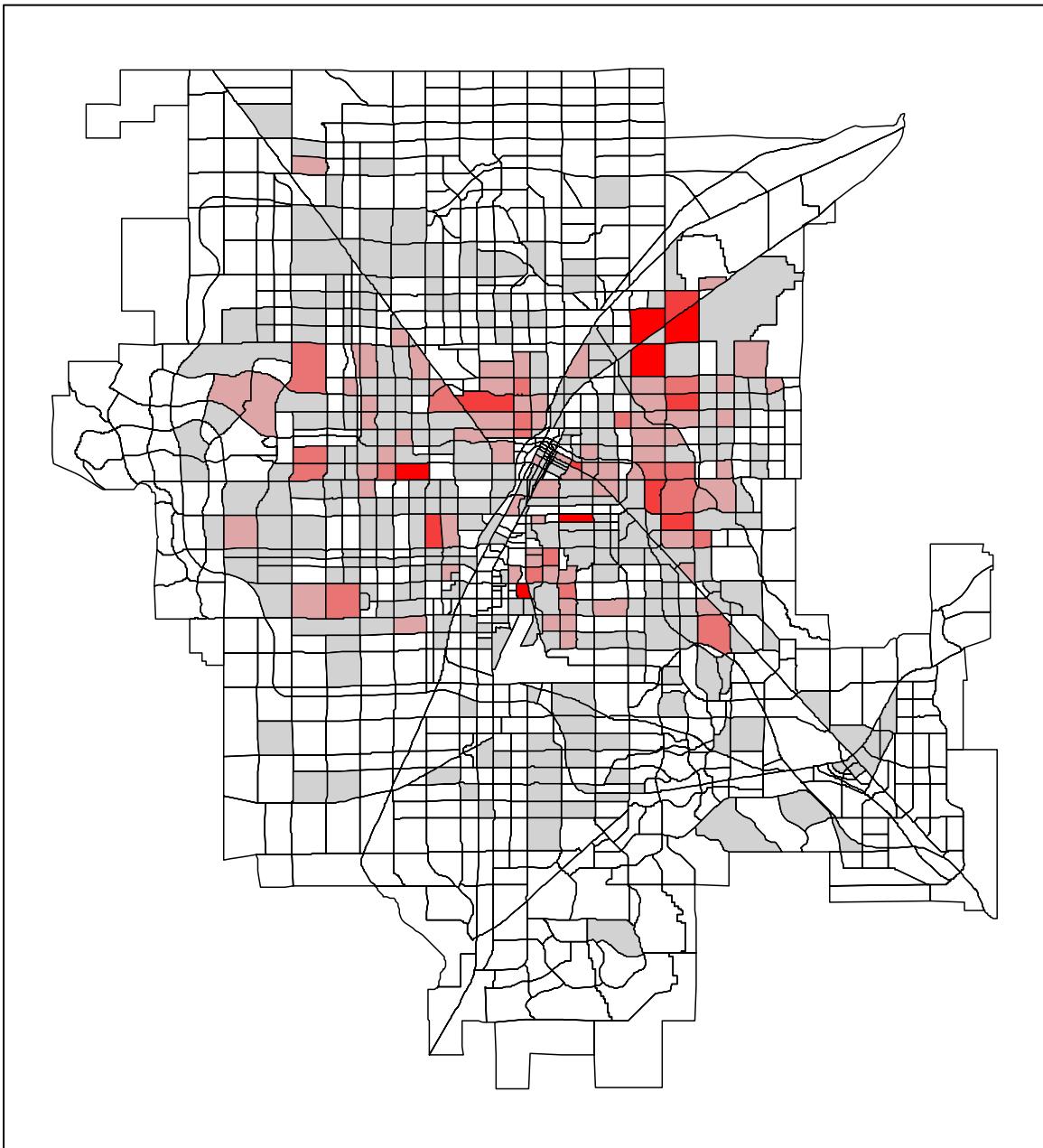


Figure 17.13: Relative equal-interval frequency distribution of actual crime trip origins

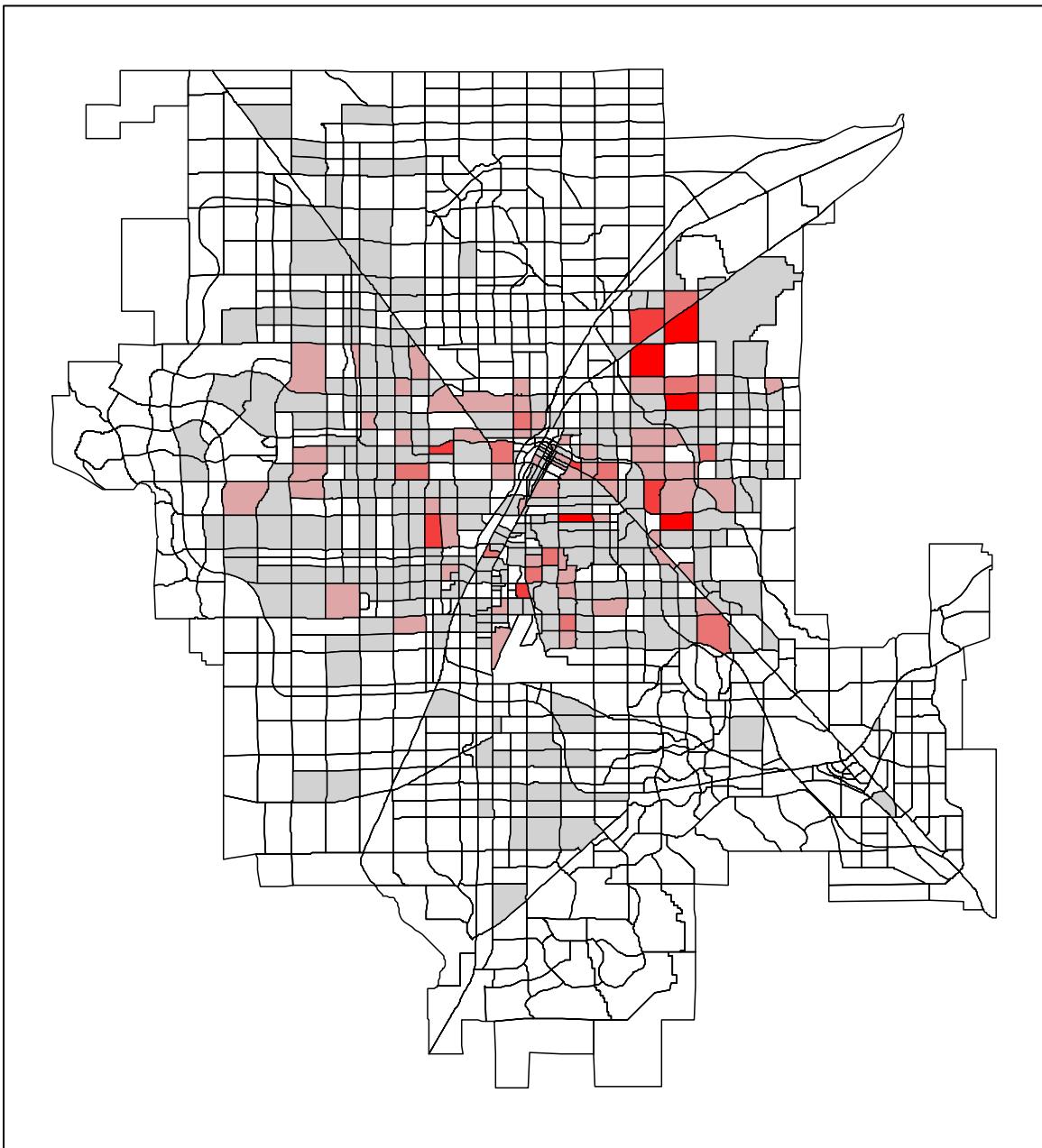


Figure 17.14: Relative equal-interval frequency distribution of actual crime trip destinations

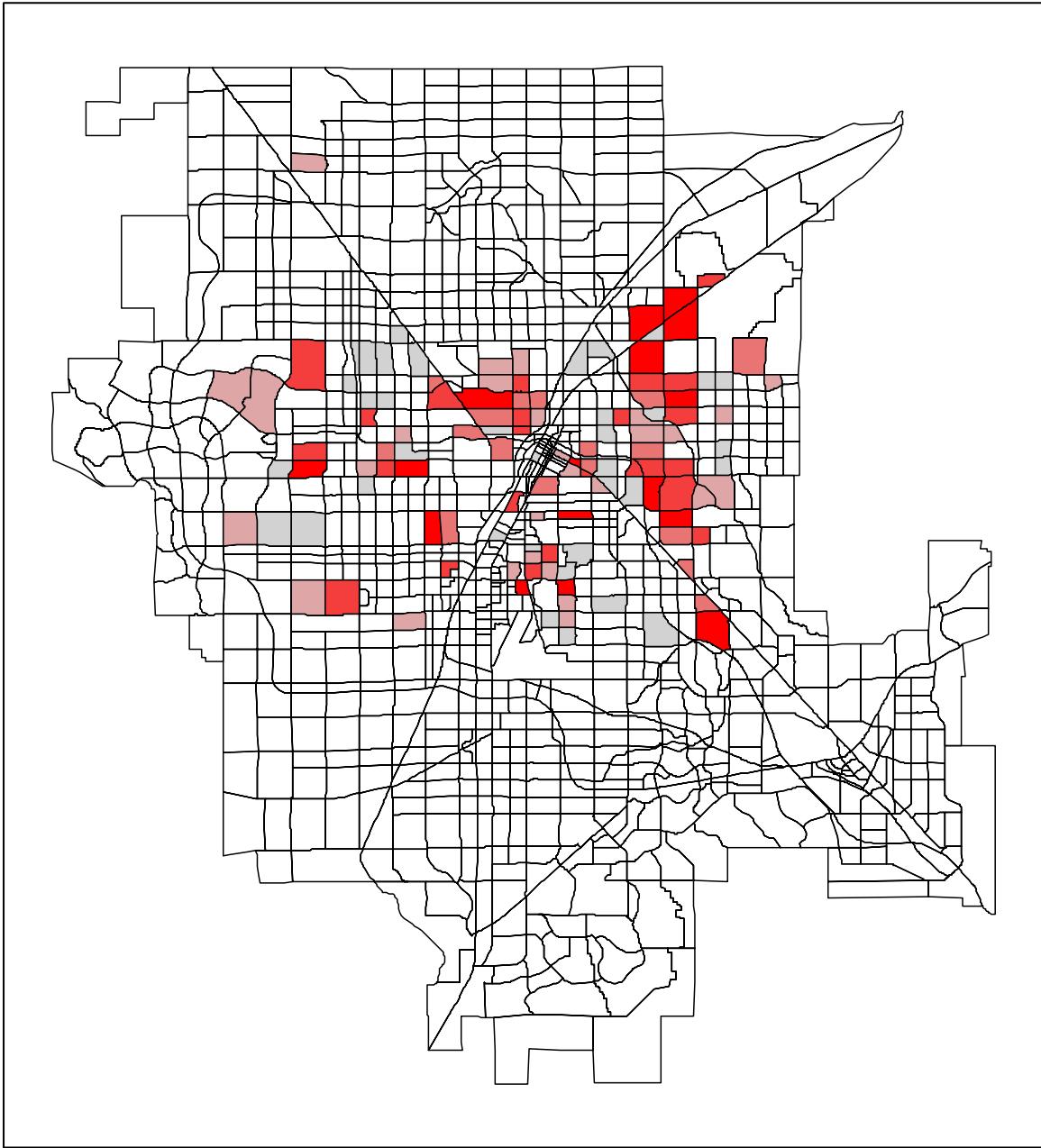


Figure 17.15: Relative equal-interval frequency distribution of predicted crime trip origins

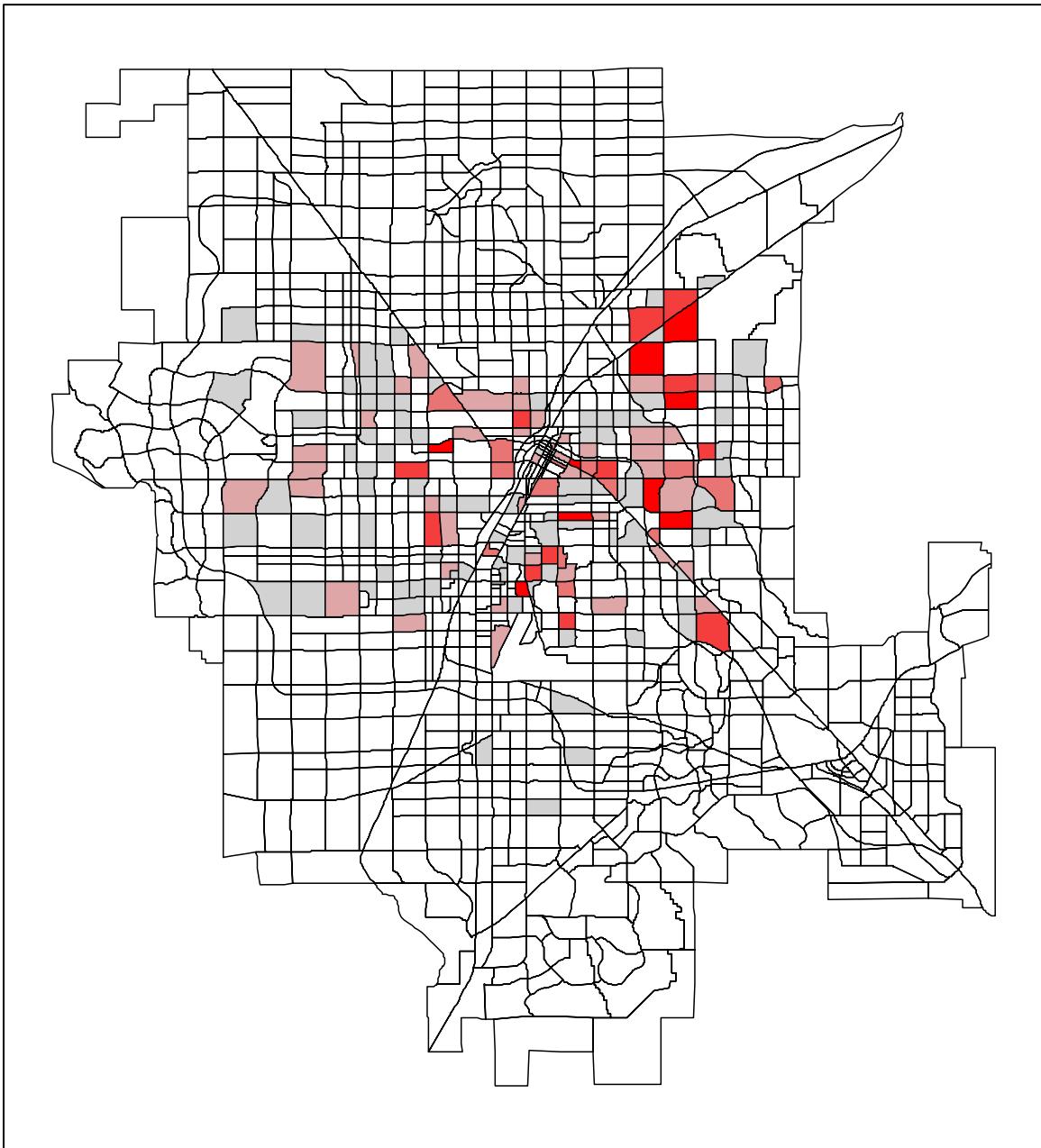
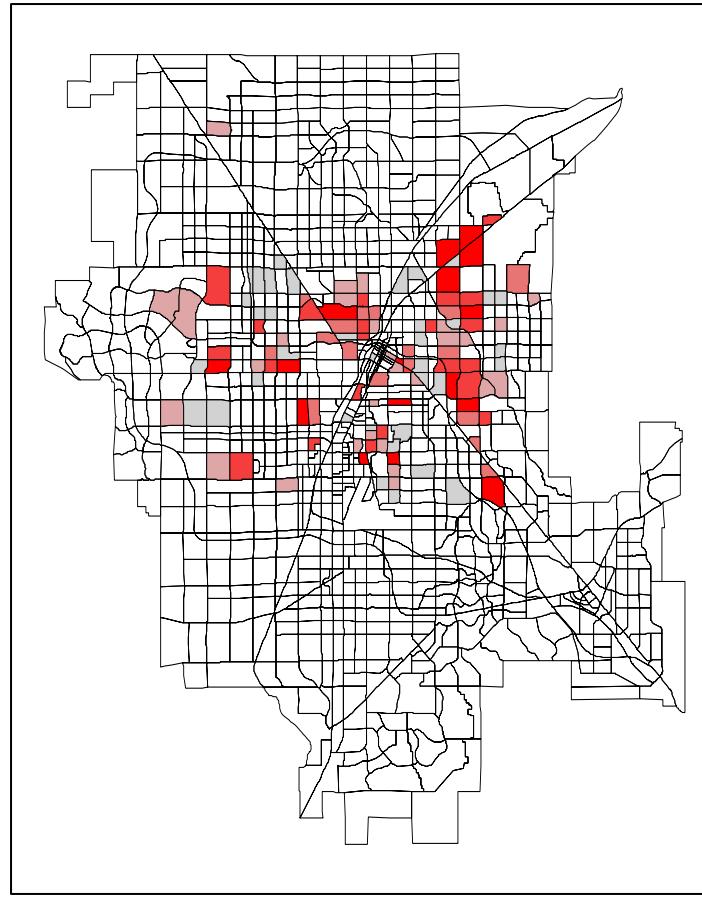
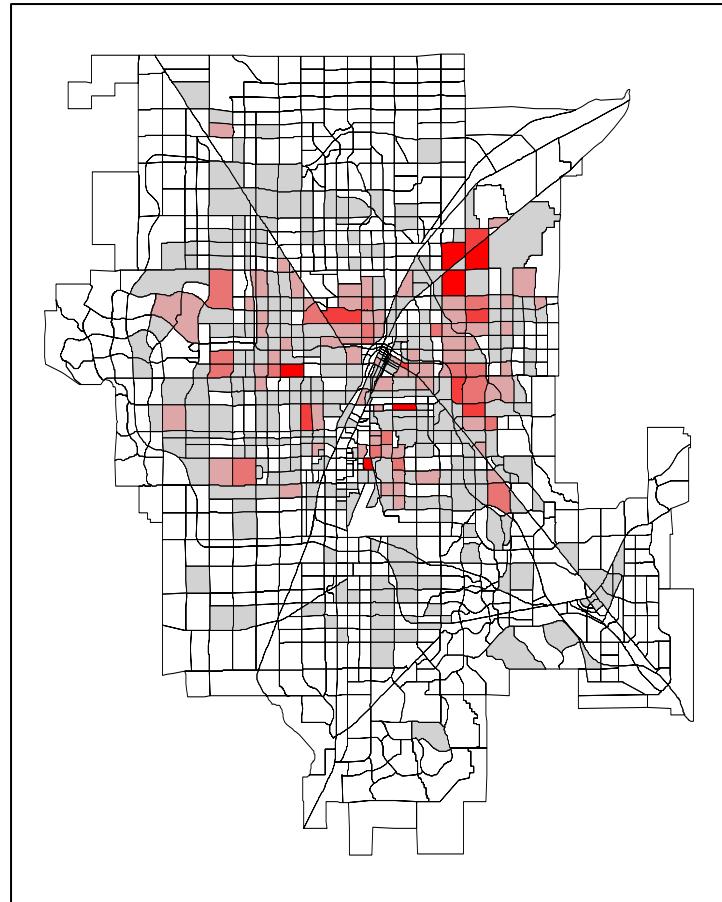


Figure 17.16: Relative equal-interval frequency distribution of predicted crime trip destinations



Figures 17.17: Comparison of observed (left) and predicted (right) origins

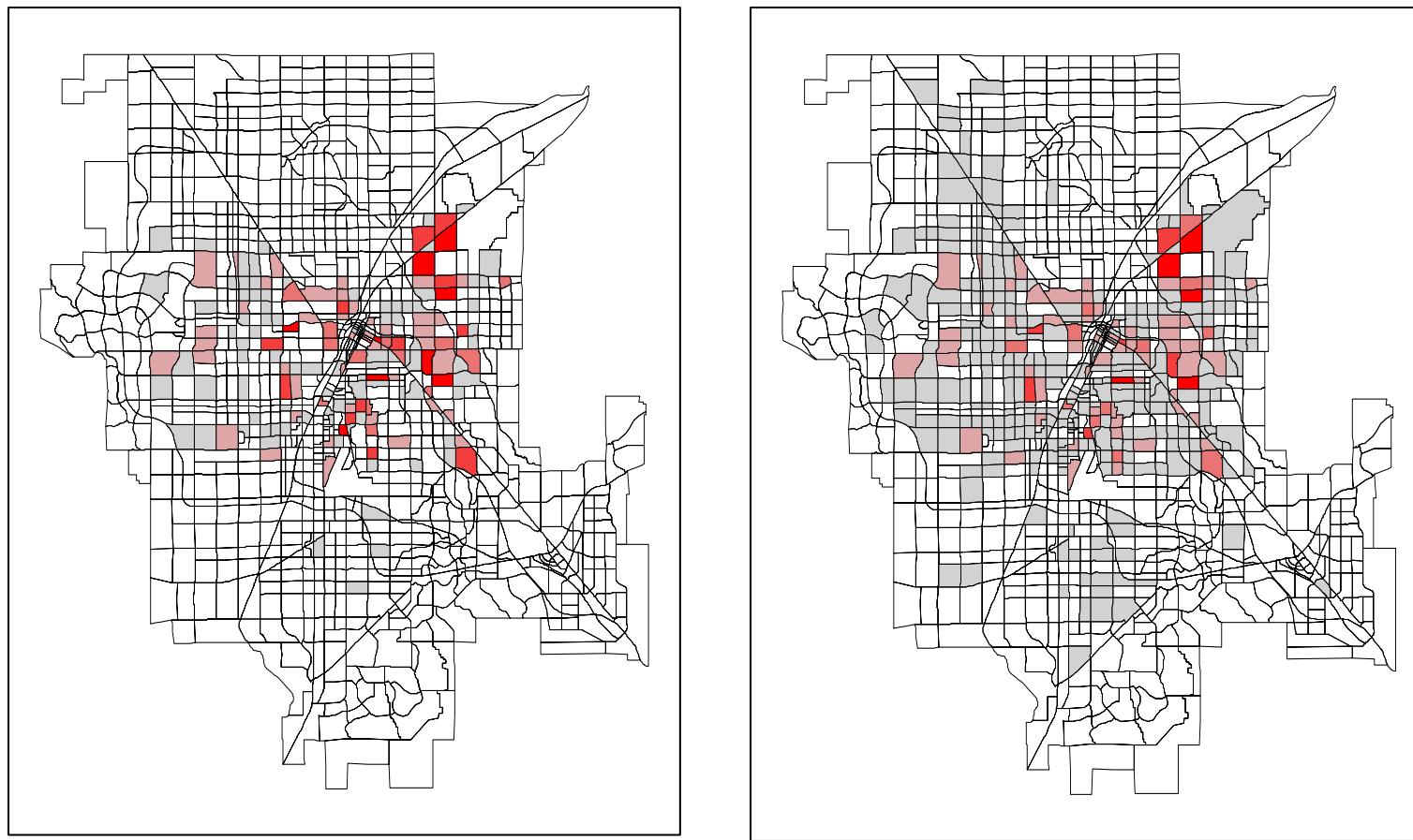


Figure 17.18: Comparison of observed (left) and predicted (right) destinations

Trip Distribution

Assignment of trip links between TAZ polygons performed very well (figure 17.19). Originally, some concern was felt that the assignment of crime events to TAZ centroids (rather than using the actual crime scene and home address coordinates) might result in significant distortion; however, this does not appear to have occurred. Compare the raw (actual) crime trip lines with the centroid-corrected trip lines to see how neatly they match (figure 17.20). The resulting distance decay and impedance functions perform perfectly well. There are almost no discrepancies visible to the naked eye.

Various impedance function calculations were attempted in the course of this study. Eventually, an adaptive (100-bin) normal interpolation with 100 minimum samples was selected as the best fit. However, a negative exponential impedance function also fit well, similar to the Baltimore County and Chicago models.

Intra-zonal crime trips - those having both origin and destination within the same TAZ - cannot be displayed as lines, since they have no length. Instead, they can be represented by points (figure 17.21). Inter-zonal crime trips, on the other hand, are better displayed by lines (figure 17.22).

Intra-zonal crime trips accounted for 42% of all crime trips overall, but only 12% of robberies, indicating a much longer "hunting range" for robbers; this may be in keeping with the hypothesis that the tourist corridors draw robbery crime trips as destinations which originate in other neighborhoods. More than 50% of sexual assaults were intra-zonal, indicating a shorter-than-usual hunting range for sexual attackers, who seem to prefer striking in their home neighborhoods.

Mode Split

Unfortunately, the mode split portion of the travel-demand model is the weakest element for the Las Vegas data.

Transportation modes across metropolitan Las Vegas are varied. Typical of a western city, the overwhelming majority of residents rely on private automobiles for transportation, as do many tourist visitors. However, this mainstay is supplemented by a robust bus system, as well as alternate personal transportation for short trips (i.e., walking, bicycling, or scooters). The picture of automobile transportation is somewhat muddled by the higher than usual dependency on taxi-cabs and limousines for transportation by out-of-state visitors.

Data provided by the LVMPD included a field called "Method of Departure" which was intended to contain information about how the offender departed the scene of the crime, which in turn would have been an effective way of calculating probable mode split for crime trips sampled. Unfortunately, this data field was blank in the overwhelming

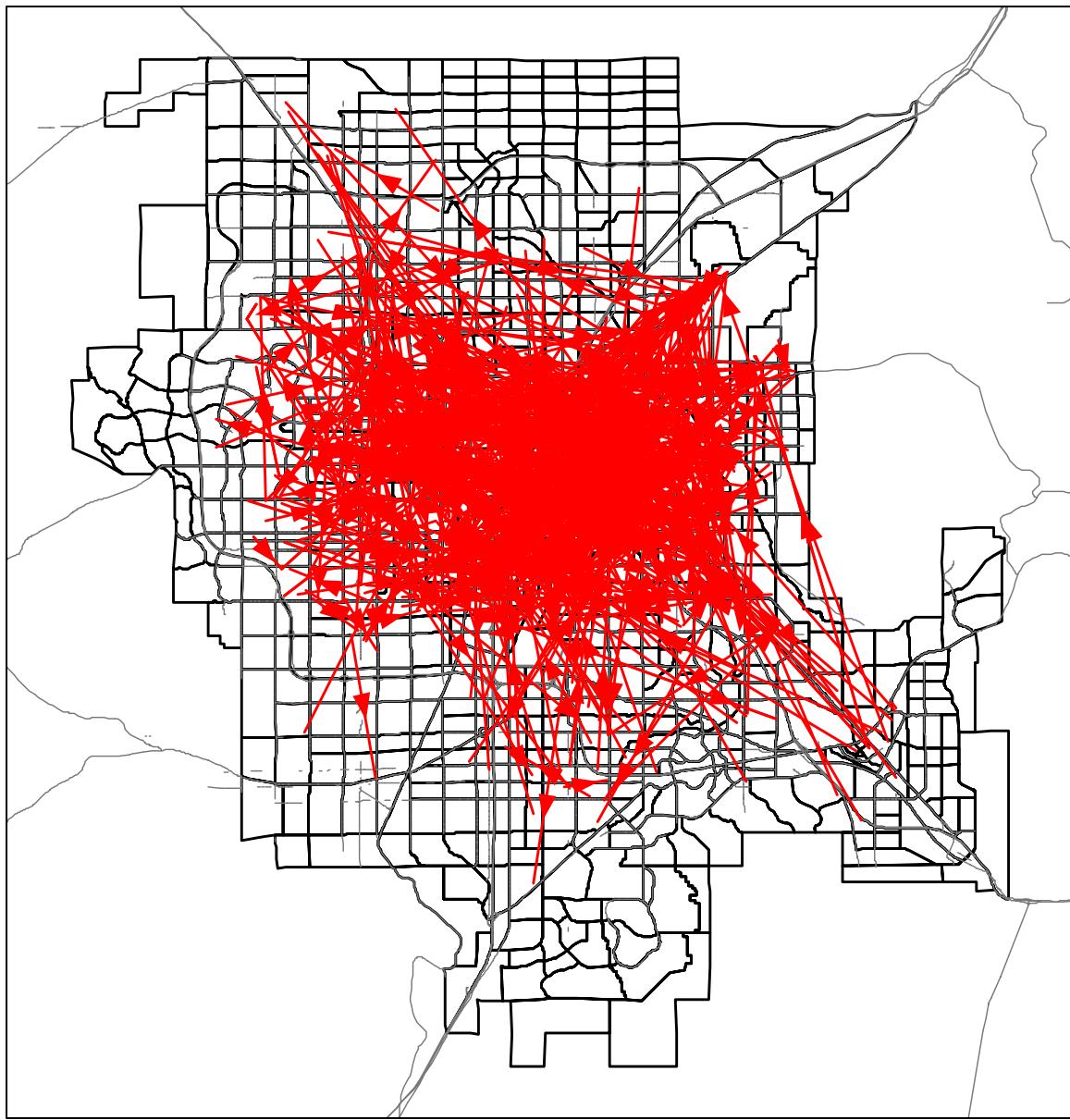


Figure 17.19: Raw Crime Trip Links

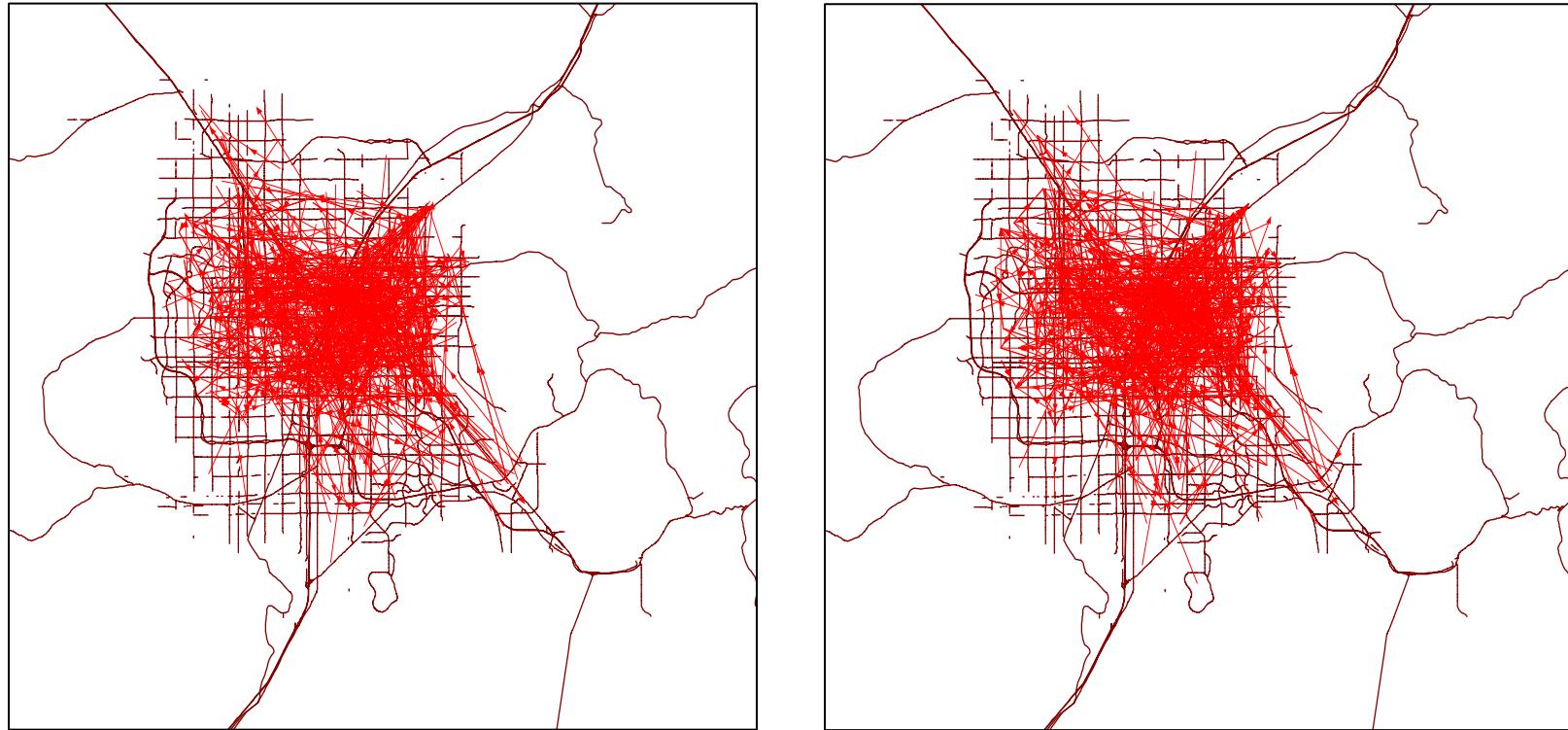


Figure 17.20: Actual (left) and Predicted (right) TAZ-centric crime trip links

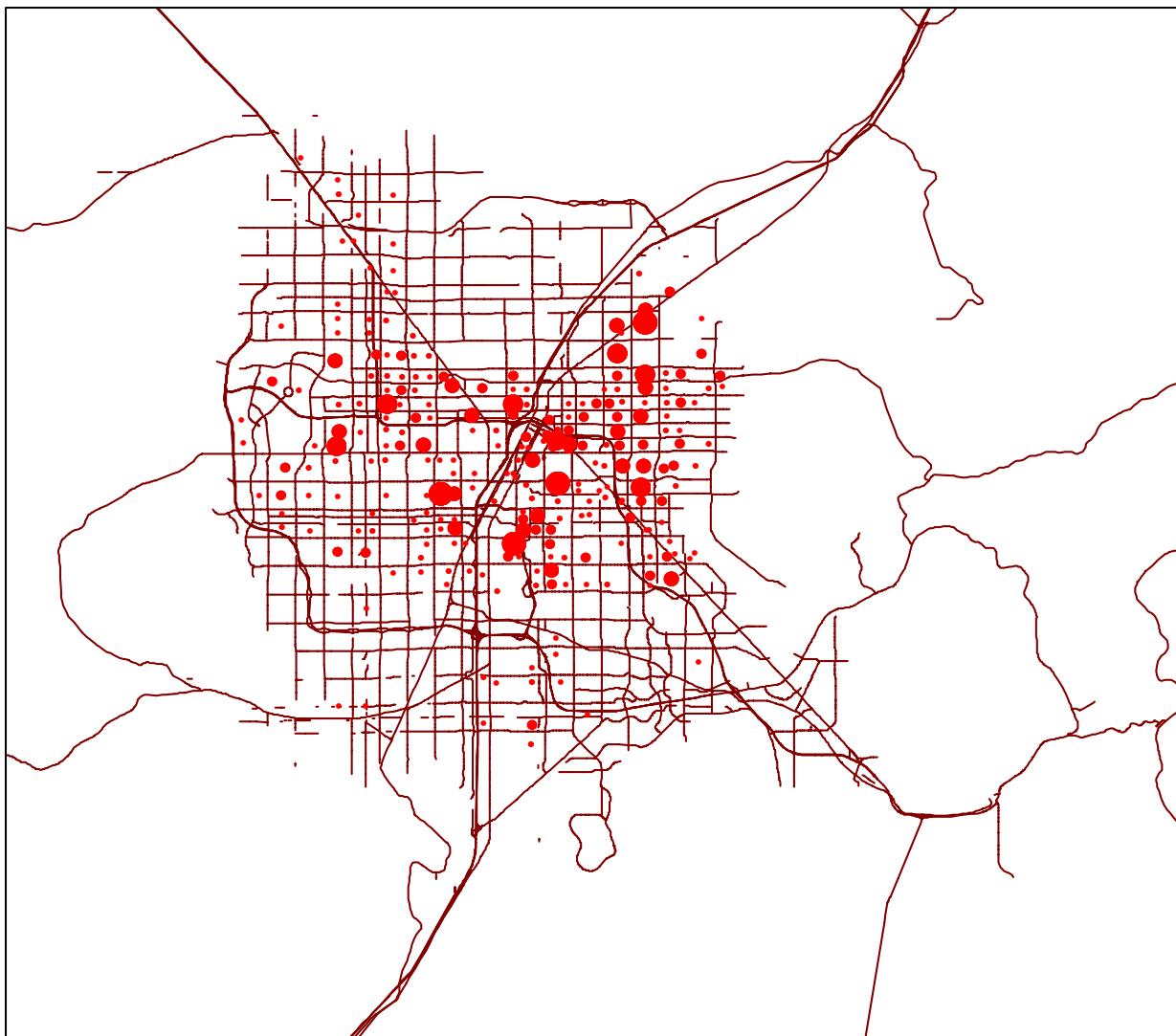


Figure 17.21: Predicted Intra-zonal crime trips



Figure 17.22: Top 100 predicted inter-zonal crime trips

majority of cases (approximately 4% contained entries, and only 75% of these - 3% overall - contained apparently valid data).

Therefore, any empirical estimation of mode split for these data requires inference from other data. For example, auto theft crimes may safely be assumed to use a car to provide transportation for at least some portion of the crime trip. In other cases, the plain-text narrative includes vehicle descriptions or statements about how the offender moved that were not distilled into the correct field. Unfortunately, the large volume of cases makes recovering information from these free narratives impractical for the small number of cases in which mode split information can beneficially be derived.

Due to this lack of reliable data, only two mode split options were included in this analysis: Walking and Driving. Default impedance functions proved very acceptable for both modes: Inverse Exponential for walking trips and Lognormal for driving.

Network Assignment

The complete street centerline (SCL) file for the metropolitan Las Vegas area was available in a routable format (topologically rectified ESRI Shapefile); however, this file proved prohibitively large and unwieldy for the A* shortest-path/least-cost algorithm implemented in *CrimeStat*. Instead of the complete SCL data layer, a layer consisting only of arterial streets and freeways was used instead. This major roads file proved adequate to neatly explaining the probable transportation path choices made by the top 100 and top 300 inter-zonal crime trips (figures 17.23 and 17.24).

In general, the visual goodness-of-fit for predicted crime trips improved as the category of crime was narrowed. Predictions from one year to the next remained weak, probably as a result of the as-yet-unexplained radical variance in crime frequencies across all studies categories; however, within discrete crime categories predictive capabilities were sometimes visually impressive.

Modeling Auto Theft Site to Recovery Site

In the case of auto thefts, an attempt was made to isolate the movement from vehicle theft site to vehicle recovery site, rather than use the theft site and offender home location as the destination and origin, respectively, of the crime trip. It was hoped that this variation of the travel-demand model for crime trip analysis might prove more useful for this type of data than home-based crime trips, partly because more accurate location information was available for recovery sites than for home locations, as well as because it was hypothesized that the theft/recovery "trip" segment might prove more representative than the home/theft trip.

Results for auto thefts appeared weak, with predicted crime trips much longer than the observed (figure 17.25). While the observed trips focused tightly on the central core areas and densely-populated residential zones, the predicted trips seemed to skirt the edges of the metropolitan area. This is possibly due to an implied over-emphasis on

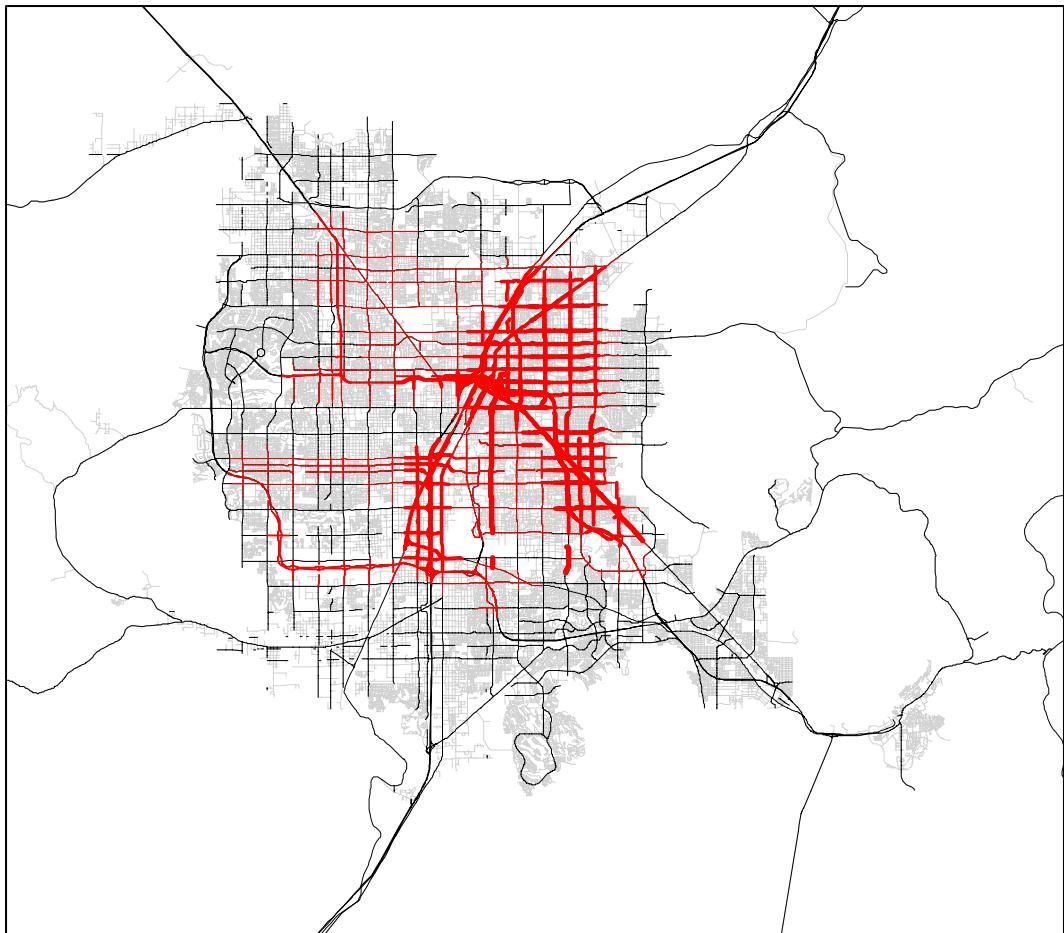


Figure 17.23: Top 100 Inter-zonal Crime Trips as allocated to Major Streets Network

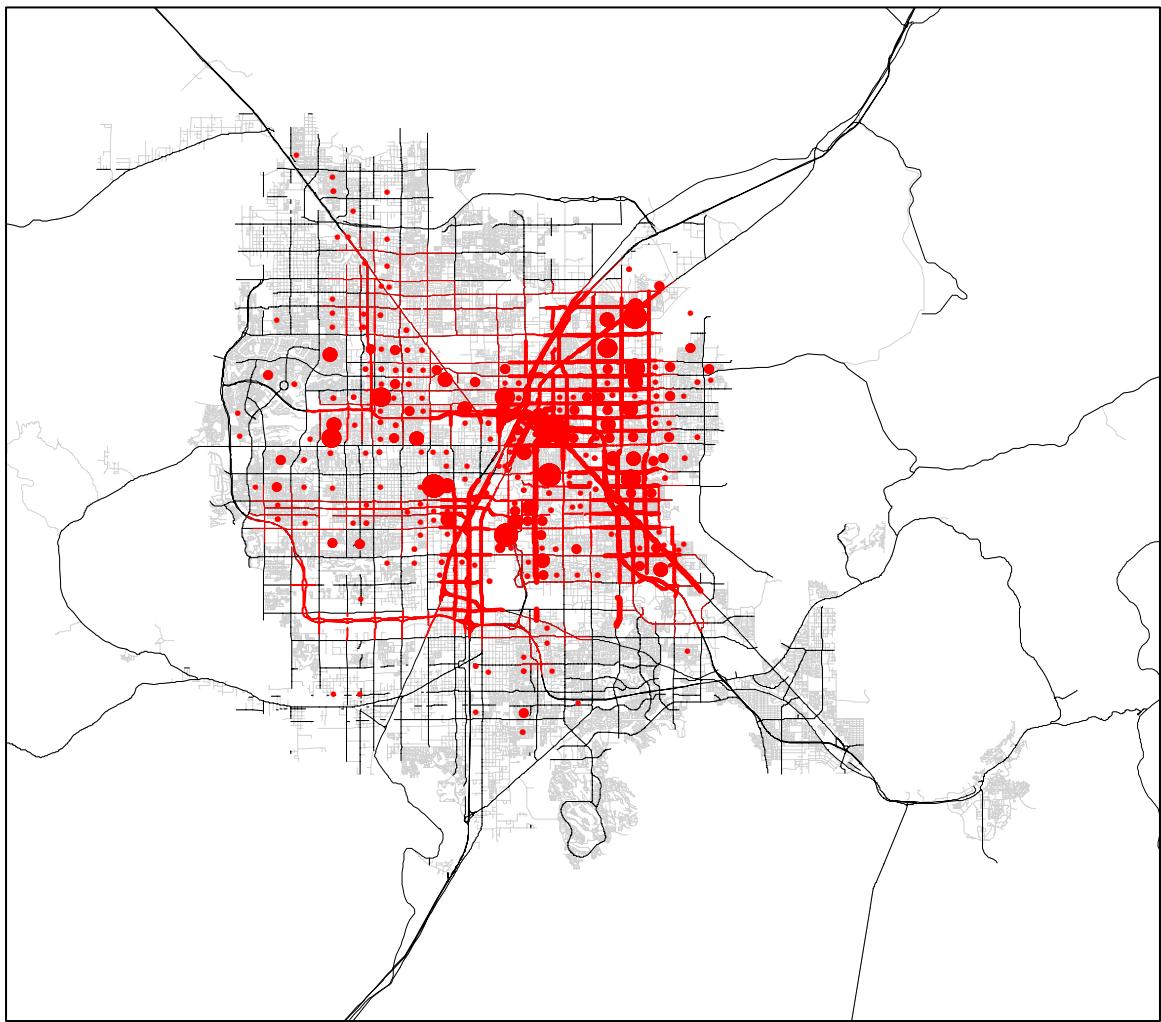


Figure 17.24: Top 300 Crime Trips (Intra- and Inter-zonal) as allocated to Major Streets Network

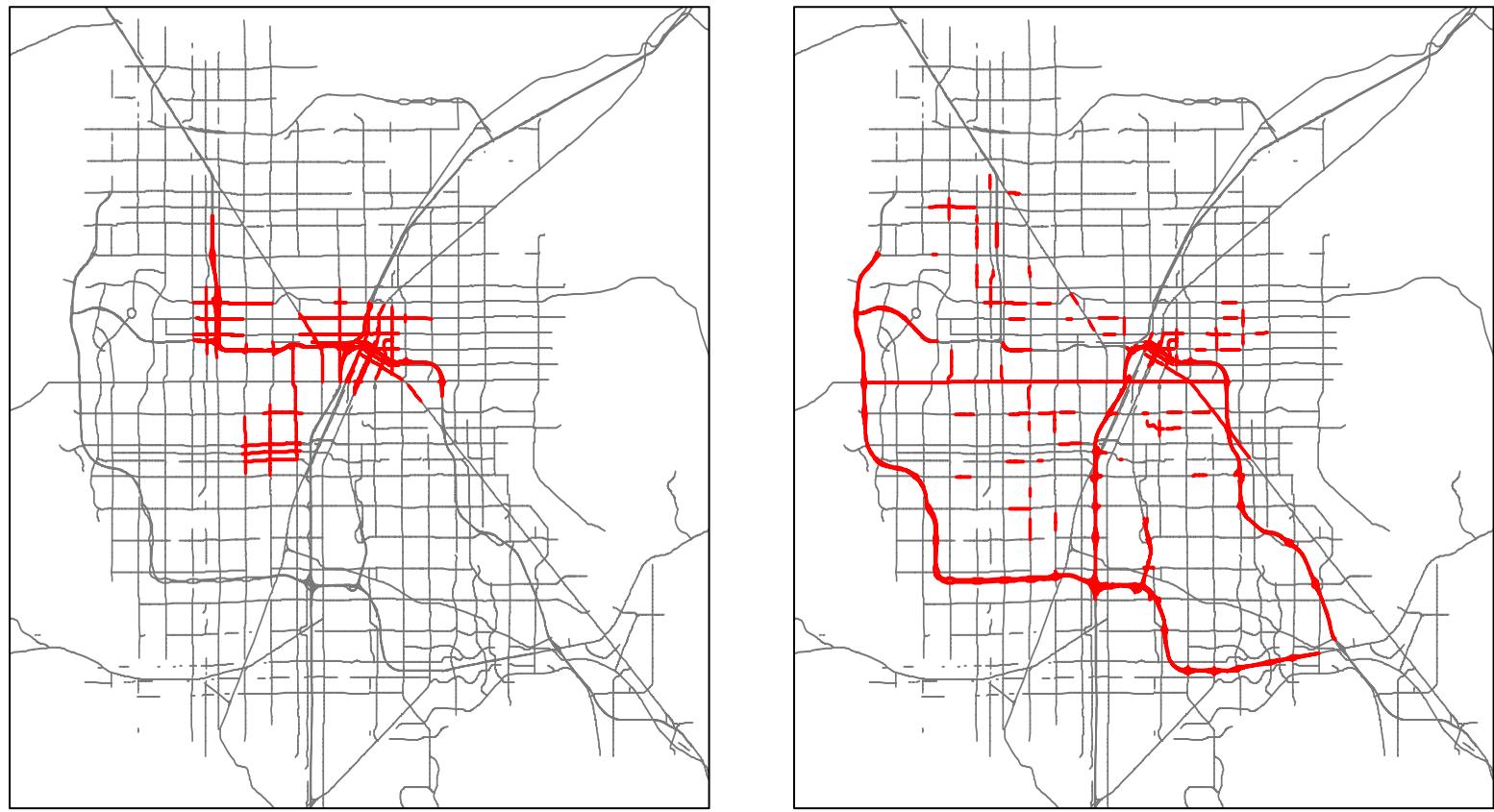


Figure 17.25: Observed (left) and Predicted (right) Top 100 Auto Theft Crime Trips as Allocated to Major Street Network

freeway travel which may be correctible with better network-allocation parameters. The median distance for observed crime trips was 2.3 miles.

Residential Burglaries

Differentiation of residential from commercial or auto burglaries was accomplished by three filtering criteria: Statute, Premise, and Zoning. Some specific Nevada Revised Statutes have been reserved for residential burglaries; burglaries in which these statutes were cited were therefore accepted as residential in nature. Categorical Premise type data was provided in the MO data for each crime; when this data explicitly noted a residential site, these cases were also accepted as residential.

Some burglaries didn't specifically include a residential statue or explicitly residential premise code; but were spatially located in areas of the jurisdiction reserved for residential rather than commercial, industrial, or other zoning purposes. These cases were therefore also accepted as residential in character.

Results for analysis of residential burglaries was more promising than for auto thefts, or for burglaries overall (figure 17.26). While, again, observed crime trips focused on the most densely-populated residential neighborhoods, and predicted crime trips were much longer and spread more far afield, this spread was much smaller than that seen in auto thefts and more closely conformed to the observed distribution. The median distance for residential burglary crime trips was 1.1 miles.

Sexual Assaults

The spatial distribution of sexual assault crime trips in many ways seemed to invert the problems seen in the predicted crime trips for auto thefts and residential burglaries. In the previous examples, an observed tendency toward centrality seemed to be confused with a predicted tendency toward dispersion toward outlying areas. In this case, however, a very nebulous, outlying distribution of observed crime trips (centering in three faint clusters around the perimeter of the central metropolitan region) was observed. The predicted crime trip distribution mistakenly emphasized central areas, and seemed to completely fail to predict the southeastern-most "cluster" of crime trips (figure 17.27).

The large median crime trip length for sexual assaults - 3.2 miles - may help explain the relatively poor predictiveness of these results. Different impedance functions will probably help improve the reliability of this model against these types of crimes.

Robberies

Robbery crime trips in Las Vegas appear to closely parallel the major gaming and transportation corridors running north to south through the center of the metropolitan area (figure 17.28). The visual fit of predicted against observed crime trips was most impressive against these cases. Although the predicted crime trip distribution appears more compact and centralized than the observed, the directionality and polarity of the two

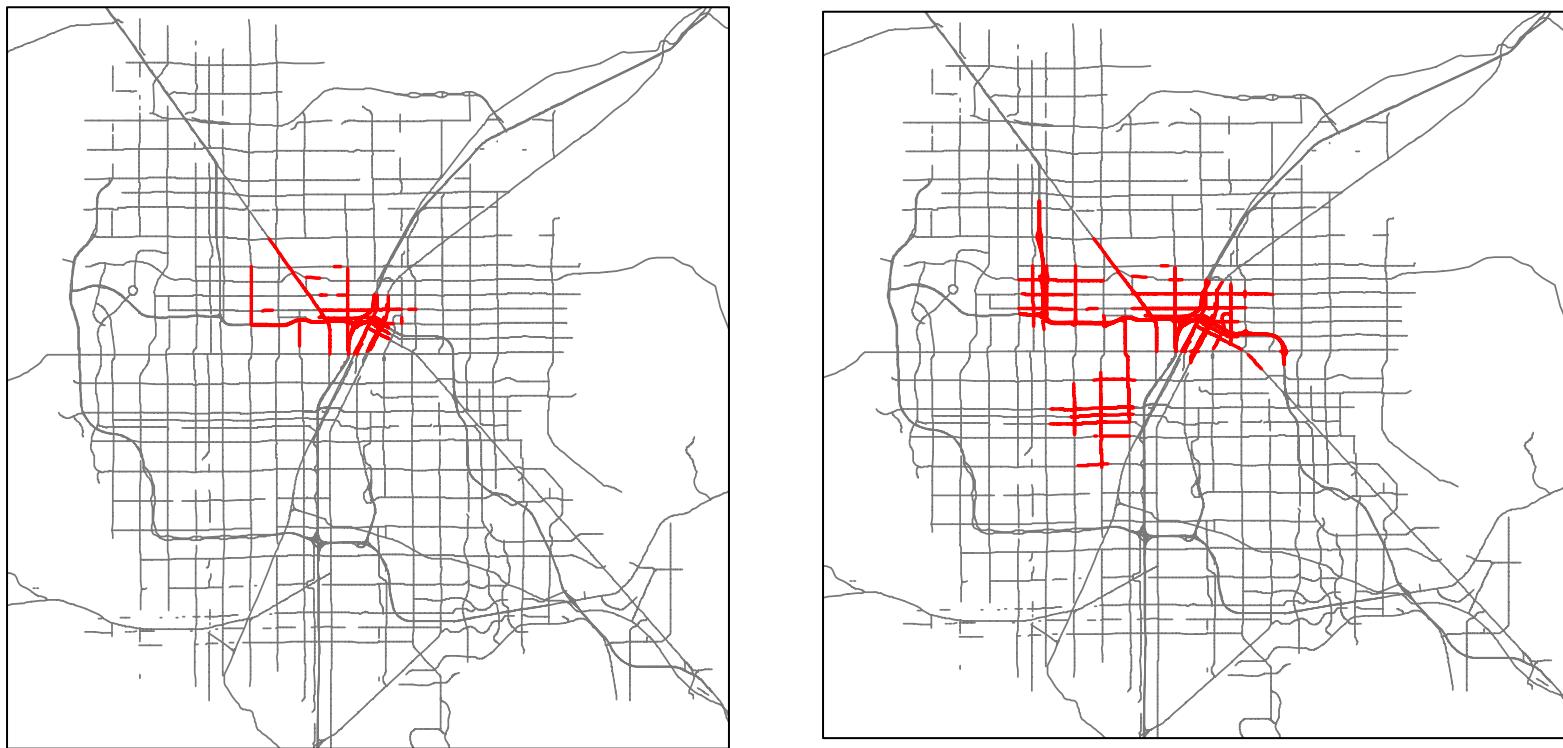


Figure 17.26: Observed (left) and Predicted (right) Top 100 Residential Burglary Crime Trips as Allocated to Major Street Network



Figure 17.27: Observed (left) and Predicted (right) Top 100 Sexual Assault Crime Trips as Allocated to Major Street Network



Figure 17.28: Observed (left) and Predicted (right) Top 100 Robbery Crime Trips as Allocated to Major Street Network

parallel nicely, and make a striking visual match. The median crime trip distance for robberies was 2.3 miles.

Conclusions: Las Vegas

Overall, the model appeared to perform well in some ways, but weaker in others. One of the most troubling problems facing the evaluation of the network assignment stage of the model is the lack of any good final metric other than visual approximation for determining the value of the resulting prediction. Some measurement of congruence is needed to make the determination of usefulness reliable and valid.

The first stage of the model - crime trip generation, is arguably the most useful to law enforcement. This elegantly simple model can readily be adapted to different types of data, and with the forthcoming inclusion of additional regression methods (specifically the negative binomial distribution model) to supplement the existing ordinary least squares (OLS) and Poisson variants, this feature is likely to remain useful for the foreseeable future.

The second stage of the model - crime trip distribution, is also potentially highly useful. The analysis not merely of where offenders live, or where crimes are committed, but of the travel and transportation decisions linking the two locations, may have significant repercussions for crime analysts. This type of analysis will be particularly useful for strategic and administrative analysts when recommending manpower allocation, beat boundaries and precinct/district configuration schemes, and assessing the impact of major developments such as transportation corridors, shopping malls, or sports complexes on the distribution of crime.

The mode split stage of the model was difficult to apply meaningfully to the Las Vegas data in this study, because of deficiencies in the data itself. Either transportation choice values were not recorded, or were recorded in irretrievable formats, making an empirical evaluation of offenders' transportation choice proclivities impractical. Failing the availability of empirical data, falling back on overall trends in public transportation choice are all that is possible for the analyst. Since it is possible that crime trips may be qualitatively different than other types of trips on which these statistical models have been based, further research is required to assess whether or not these standards will be applicable to criminal behavior.

The final stage of the model - network assignment, functioned mechanically as expected, but did result in some potentially weak results (such as overemphasis on the speed of freeways apparent in some results) which may be overcome with better mode split and network choice parameters.

One aspect of the model that caused for initial concern, the aggregation of crimes to the Traffic Analysis Zone polygon level, proved to have no significant impact on the resulting analysis. The TAZ structure seems admirably suited to analysis of this sort of movement - as indeed one might expect from its provenance.

The most successful predictive variables for estimating crime trip production, whether of origins or destinations, were infallibly Total Population, Total Employment, and Income. Inclusion of additional variables distorted rather than improved the predictive value of the model, most of the time with measurable multicollinearity which was not always apparent a priori.

With the mechanical aspects of the model - as implemented in the latest version of *CrimeStat*, complete and functioning correctly, it remains to be learned how to better calibrate and implement the model to make it an effective tool for law enforcement analysis and planning.