The G.R.A.B. Project: Geographic Robbery Analysis of Banks in the City of Tempe, Arizona

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This thesis has been presented to and accepted by the Office of Graduate Studies of the John Jay College of Criminal Justice of the City University of New York in partial fulfillment of the requirements for the Master’s of Arts in Criminal Justice.

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Abstract

The Geographic Robbery Analysis of Banks (GRAB) Project measures the spatial decisions of target selections for bank robbers in Tempe, Arizona from 2002-2006. Much academic research has been devoted to understanding the offender, but has often lacked target comparisons. This project holds offender characteristics constant, and examines the factors that comprise the geographic identity of each Tempe bank. These factors, called vulnerability variables, are tested on two levels: whether a bank is robbed, and how often a bank is robbed.

Through the use of desktop Geographic Information Systems (GIS) and crime mapping methodologies, bank and bank robbery data are analyzed for patterns. Density maps highlighting clusters of Tempe banks demonstrate that a small portion of banks account for a large portion of bank robberies. The banks found in this High Density Area are compared to banks outside of the area for differences in vulnerability variables. Additionally, robbed banks in this Area are compared to banks not robbed in the Area for potential explanations.

The results of this analysis demonstrate that significant differences exist between banks in this High Density Area and those outside of it. Banks inside the Area are statistically closer to the freeway. Additionally, banks in the Area that were not robbed lack a general uniformity in geographic variables exhibited in robbed banks. Policy implications based on these findings apply to banks and law enforcement. Banks should develop a more thorough awareness of the variables which potentially cause bank robbery at their locations. Law enforcement should develop more specific response plans

based on the vulnerability variables of each bank, and coordinate response based on the likely reasons the bank was targeted.

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Introduction

The Geographic Robbery Analysis of Banks (GRAB) Project seeks to understand the spatial decision-making of bank robbers. The project attempts to move beyond the classic post-conviction interview of offender methodologies, and analyze the variables that make offenders gravitate towards certain locations, and away from others. It is through the use of a desktop Geographic Information System (GIS) that the bank and bank robbery data is analyzed. The vulnerability variables studied are intended to provide insight to this phenomenon.

This has become a topic of interest as growth in the Crime Analysis field has inspired new, innovative approaches for understanding crime. As offenders adapt to technology, law enforcement must respond creatively. Traditional investigative procedures are not always applicable to the contemporary criminal. Further, when these methods are applicable, they can be aided by an analytical approach. This ideally leads to quicker identification and apprehension of offenders, as well as the linkage of additional cases. This process, known as tactical crime analysis, is gaining appreciation and attention in law enforcement.

Why Bank Robbery?

Bank robbery, relative to other crime, is very rare – two out of every one hundred robberies nationally are bank robberies (Weisel 2007). However, it is the attention that a bank robbery *earns* that makes it noteworthy. Similar to homicide, many bank robbery stories are broadcast on the news. Surveillance photos of the suspect are plastered on the television. People appear to be quite interested in bank robbers – movies are made (*Heat*, *Inside Man*), stories are glamorized (*Dog Day Afternoon*). There is something unique about not only the act of bank robbery, but the robbers themselves that interest the general public.

It may have something to do with the nature of the crime. A bank has special value in this society. It is a vault, in a literal sense, for our most prized possession – money. It is natural that anyone who violates the security of this vault be given serious attention. Furthermore, a bank physically represents trust, protection and security. People often view banks as hardened targets – impenetrable to invasion. The thought of breaching a bank's security piques the public's interest. It may also be a question of *why*? *Why* did that person decide to rob a bank? *Why* did they think they think they could get away with it? *Why* did they disregard the norms and laws of society? It could be quite simple. When notorious bank robber Willie Sutton was asked why he robbed banks he replied, "Because that's where the money is" (Sutton and Linn 2004). It may also be part obsession, and part fascination. While the jewel thieves and exotic art heists interest people, there is something special about a bank robber that commands our attention. In the world of robbery, bank robbery holds the crown.

Beyond the public response, there is a similar reaction to bank robbery from law enforcement. Bank robbery crime scenes are intense, crowded investigations. A vast amount of resources are dedicated to locating a bank robber. Federal (FBI) and local law enforcement investigate bank robbery, and the crimes often involve the use of numerous methodologies (DNA, fingerprints, SWAT, forecasting, etc) to arrive at a solution. Why not? It is the function of law enforcement to act on the behalf of the citizens, to respond to public demands.

Why GIS?

With new technology comes new opportunity for research, analysis and problem-solving. While mapping and the use of geography are not new skills per se, in the world of crime analysis GIS has been on the rise. As more law enforcement agencies are finding value in analyzing their data from a spatial perspective, analysis is coming to the forefront of police work. Further, as crime analysis proves its worth to investigations, new technologies offer innovative ways of approaching traditional problems.

The use of GIS is more than just the *en vogue* style of analysis. GIS allows for research that has previously received little attention. So it is with new technology that new questions are asked. Ideally, as these questions are answered, they lead to more questions and the process grows and evolves. As we gain more insight into the movement patterns of humans and the decisions that drive those movements, our analysis strengthens.

Given this focus on GIS and spatial movement, it is important to note that this project will not focus on the individual traits and qualities of offenders. The GRAB Project approaches bank robbery controlling for the offender. It is assumed that all the offenders are similar in that they made a conscious decision to rob a bank. The specific motivations behind this decision are irrelevant. What is relevant is once that decision was made, what influenced the target selection? What variables made a location attractive for bank robbery? It is in search of these answers that the GRAB Project seeks to analyze crime. Specifically, this study examines vulnerability variables for banks that *have* been robbed and those that have been robbed *multiple times*. It is important to keep these two dependent variables separate, as there are potentially different explanations for each. For example, the variables for a bank never robbed may be different than those for a bank that has been robbed, and both may be different than a bank robbed multiple times. Isolating and identifying these variables will ideally lead to a deeper comprehension of bank robbery.

Literature Review

Traditional police work has typically assumed a lack of cognitive decision-making on the part of the offender. This would imply that offenders did not take the time for adequate planning and research in target selection and methods of departure. While in some cases this remains true, by and large the offender has demonstrated the complexity and rationale of a determined, motivated individual. As technology and the means of apprehension have increased, so it appears that the reasoning and decision-making of the offender have also increased. To assume offenders lack decision-making only minimizes the potential crime prevention strategies available. Rather, to maximize crime prevention, understanding these decisions, both conscious and subconscious, matter. While the conscious data is often collected in the form of post-offender interviews, the unconscious has gone largely uninterpreted (possibly due to lack of an effective measure). However, steps are being taken to increase the depth of research in this area.

Studies have shown that offenders make conscious decisions when committing crimes. Petrosino and Kass (2000) observed that intelligent policy decisions should be made knowing this. Thus, the collection and analysis of information is the vital step in this process. This intelligence gathering is often done in the form of offender interviews. These are typically long after the fact, when the offender is incarcerated. This is often the basis for a decision model (Petrosino and Kass 2000). While making decisions based on data from previous cases is a positive step towards intelligence-led policing and data-driven decisions, this has often been the only data used to derive conclusions.

Given our advances in technology, collecting spatial data (and not just post-interview data) will further aid the informed decision-making process. Some researchers (TechBeat 2001) have begun to analyze crime series data in this fashion, with the intent of applicability to future similar data sets. The CATCH Program (Crime Analysis Tactical Clearing House), created by CMAP (Crime Mapping and Analysis Program) processes and analyzes crime data from around the country, and specifically focuses on the spatial components (TechBeat 2001). Such detailed research focusing on spatial movement has been the exception, not the norm.

Robbery studies typically seek to classify offenders. Petrosino and Kass (2000) classify convenience store robbers. Conklin (1972) defines professional, opportunist, addict and alcoholic robbers. Fortune, Vega and Silverman (1980) create situational or career robbers and Weisel (2007) defines professionals and amateurs. While the characteristics and distinctions of each system are unique, the theme is similar: grouping robbers into typologies for explanations and insight into their criminal behavior. There have been positive breakthroughs.

Such studies have been immensely effective in shedding light on the unknown – the criminal mind. Often it results in practical application of criminological theories that could otherwise go untested. Swope (2001) found that offenders will rarely commit crimes in geographic areas that are poorly known to them. An extension of Routine Activities Theory (Cohen and Felson 1979), this is the concept of Cognitive Spatial Awareness. Offenders are going to commit their crimes where the opportunity intersects with their known areas; these include normal routes for work, and proximity to their residence and recreational activities. While this does not explicitly relate to spatial patterns, it implicitly describes offender movement.

Interestingly, recent trends in bank robbery nationwide demonstrate that more females are becoming suspects, moving away from traditionally serving as lookouts (Thomas and Cook 2007). This is important to understand because it can drastically change the "profile" of a bank robber. This complicates the common typologies of offenders.

Markowitz and Salvatore (2005) applied Rational Choice Theory to crime target selection. Offenders will choose targets that maximize pleasure and minimize pain. Thus, they are open to situational opportunities that arise and possess an inclination to commit the criminal act. Crime becomes the result of an offender's ability to select targets that satisfy these requirements and avoid detection.

Other studies highlight the offender demographics and commonalities. Haran and Martin (1984) found that bank robbers in New York City are not a homogenous group at all, but are quite varied. While some of the consistencies were strong – lack of education, prior criminal record, menial employment, etc. – their main unifier appeared to be the inclination to rob banks. Interestingly, once this decision to rob a bank has been made (as it is consciously made at some point), Haran and Martin (1984) found there was little pre-planning associated with the crime. Weisel (2007) confirms this by finding that "many bank robberies are spontaneous and opportunistic crimes." It is research such as this that strongly suggests the influence of subconscious decisions in the process. Additionally, this research encourages the GRAB Project by recognizing the lack of uniform offender traits, and thus controlling for the individual. This creates the need to focus on the targets.

Matthews, Pease and Pease (2001) found varying reasons for bank robbers' target selection. In fact, while intentional repeat victimization occurred regularly, the logic behind these choices varied from robber to robber. This raises the question: If the rationale differs so much, should the focus for policy decision-making shift from the offenders to the targets? Despite the differences in offenders, the targets (for this study, banks) could yield some telling results.

This method has been dubbed a "location-oriented approach" (Cochran and Bromley 2002). It is a policy decision-making model seeking to maximize crime prevention efforts by understanding specific geographic locations, often referred to as "hot spots." Similarly, situational crime prevention focuses on the targets of crime. It does not seek to eliminate or change the motivations of the offender, but rather to make the target less appealing. In a Rational Choice sense of crime, this makes the pleasure less pleasurable and the pain more painful. These methods move away from the offender by controlling for them: all made a decision to commit a crime. The focus moves to the victim, and why he/she (or in this case, it) was chosen as a target.

There has been thorough research on target selection and crime. Weisel et al (2006) studied motor vehicle theft in a non-urban region. Their findings included that vehicle theft was significantly higher where there was a combination of high concentrations of rental housing and manufacturing/industrial areas. These results, which are less offender-specific and more target-oriented, create highly specific crime prevention strategies for the geographic area studied. This encourages unique approaches to specific areas.

Furthermore, Cochran and Bromley (2002) studied target selection as it relates to vehicle burglary. The study was based on victim perceptions of vehicle burglaries in a dense entertainment district. Identifying “hot spots” is essential in crime prevention. Specific areas warrant specific crime prevention models and decisions which maximize the areas’ potential. While the functionality of the term “hot spots” is debatable, the principle of this study is important: developing prevention strategies that are clearly applicable to a specific area.

Clarke and Goldstein (2003) discuss the use of hot spots. This type of analysis is beneficial to a degree. Hot spots are effective at identifying clusters, but they are not able to recognize the specific targets that make these spots *hot*. Rather, they suggest moving from hot spots to pinpointing risks, which requires a deeper appreciation of the data. In their study, an analysis of theft from cars in parking facilities, two key variables for pinpointing risks were parking lot decks and lot size. While these variables do not apply to the GRAB Project, the methodology is applicable: identify common factors that make targets distinguishable from one another, and thus a potentially more (or less) attractive target.

Perhaps one of the more in-depth studies of target selection specific to bank robbery is from Weisel (2007). Weisel finds that bank robberies occur disproportionately in urban areas. While this alone should come as no surprise (as most crime occurs disproportionately in urban areas), it is interesting to note that bank robberies often cluster where the banks are the most concentrated. This demonstrates that the *density* of banks in an area may be more important than whether it is an urban, rural or suburban location. Determining where the clusters of banks exist in an area may also reveal the most frequently victimized targets.

Further, Weisel (2007) is able to move away from the individual offenders by finding that banks have highly uniform security measures. In 2000, 98% of robbed banks had cameras and security systems. A majority of banks look alike: centralized entry, similar interior layouts and standard comforts for customers (and subsequently robbers). There has been no evidence that there is a single security practice that prevents bank robbery. Thus, it appears that since bank interiors are largely uniform, target selection could be based on other factors; specifically, geographic vulnerability variables.

Weisel (2007) creates two different typologies of bank robbers: professional vs. amateur, and solitary vs. multiple, and highlights their geographic target selection preferences accordingly. The “professional” bank robber typically seeks previous robbery locations, busy roads near intersections, multidirectional traffic and corner locations with multiple vehicle exits. On the other hand, “amateur” bank robbers often select targets based on previous robbery locations, heavy pedestrian traffic/proximity to dense residential areas, parcels without barriers and parcels with obscured egress.

“Solitary” and “multiple” offender typologies incorporate these decisions into their classification. It appears that a solitary offender is often an amateur, and the multiple offenders are often professionals. Weisel (2007) defines the solitary offender by seeking targets typically including:

- Open parcel, open to foot traffic
- Absent barriers (no fences, etc.)

- Alleys and pedestrian pathways
- Access to other commerce (i.e. strip malls)
- Escape routes which prevent being easily followed
- Obstructions blocking the view of possible escape routes
- Parcels open to dense residential areas or high pedestrian traffic

The common theme among these solitary traits is the ability to blend and go undetected by the common population while quickly fleeing the area. However, *too much* of any of these factors can hinder a robber. Targets that are too isolated are not favored, as are targets with too many pedestrians or heavy traffic, which slow the offender and force him or her to navigate through crowded spaces (Weisel 2007).

On the other hand, according to Weisel (2007), the “multiple” offenders prefer:

- Easy vehicular access (intersections, corner parcels, multiple egress points, multiple choices for departure)
- Two-way traffic with multiple lanes
- Busy streets, but not standstill traffic
- Proximity to major roadways
- Avoiding traffic signals

As with the professional to amateur comparison, some of these factors overlap, and some are very different. Despite some of these differences between groups of robbers, what this demonstrates is that space matters. It is the exterior of a bank that plays an important role in the robbery. Further, Weisel (2007) finds that

> Some bank features such as bank size, number of entrances, lobby size, and number of tellers may affect ease of escape;

> larger banks may have more exits and the greater hustle and bustle may mask both the robbery and the escape.

Additionally, it has often been assumed that target selection is a random decision. It is not. According to Weisel (2007) "…robbers select targets primarily based upon their concern with getting away from the robbery quickly." Spontaneous? Yes. Random? No. This concern is not based on the presence of alarms and cameras, as these have been established as a norm for a great majority of banks.

Prior and repeat victimization of a specific location also prove to be important. Repeat robberies at a location involving *different offenders* occur because it is the same features that attracted the initial robber (i.e. escape route, traffic flow) that are likely to attract additional robbers. The victimization risk of a robbed bank is much higher than an un-robbed bank. In fact, robbed banks are often surrounded by un-robbed banks (Weisel 2007).

However, research on the spatial decision-making of an offender can be taken further. These are the decisions that are absent of deliberation and second-guessing. These are not the decisions that will be revealed in an interview, but rather in the study of the offender's movement and behavior before, during and after the criminal event. Research has been done which applies animal movement theories in conjunction with spatial and temporal analysis to understand these motivations and factors guiding the offender (TechBeat 2001). This research, tested against real crime data and applied at various Police Departments around the country (including Tempe PD), uses theory from other scientific disciplines. Epidemiology, or the science of distribution and control of disease, is applied to crime patterns and trends. Animal movement, which studies the travel of predators, has relevance when tracking serial offenders. Even hydrology, the study of water flow, can be applied to traffic analysis, population densities and migrations, and demographics (Helms 2006, personal communication). The vehicle for applying these techniques becomes a Geographic Information System (GIS), which allows for the spatial analysis of relationships of multiple data sets.

The foundation for crime mapping has been solidified by many practitioners and researchers. Specifically, crime mapping seeks to add a spatial component to typically tabular data. This data is transformed into vectors – points, lines and polygons. Once displayed on a map, the data can be manipulated by graduating features (increasing or decreasing intensity based on the value of a variable), buffering (applying an area around data) and density (shading surface based on point data), among others (Boba 2005). These techniques allow for richer spatial analysis.

However, Eck et al (2005) demonstrate that crime mapping must be grounded in theory (place, street and neighborhood) to be effective. *Place theories*, or “low level” analysis, explain crime at specific locations. They address individual targets (point data) and require precise analysis and police response. *Street theories* examine crime on a street or block level. While police action is still precise, it moves beyond the dots and examines the lines. A common example is the patterns of prostitution. *Neighborhood theories* deal with larger areas. These polygons require more general responses, and due to their size, typically avoid specific target action. However, understanding the relationship of these theories is essential to any of their success. For example, place and street activity will influence the neighborhood police response.

To understand the geography of bank robbery, these principles must be applied and expanded upon. Goldsmith, Langer and Graff (2004) detail the basics of crime mapping, especially highlighting the common errors in geocoding and creating pin-maps. Often it is the quality of the data that creates problems in geocoding, which is the process of assigning a spatial position for previously non-spatial data. Further, they demonstrate that a pin-map should not be a final analytical product, but rather a starting point. In a simplified example in their study, crime data from the New York City Police Department is compared to census tracts. This allows for comparison of crime between areas.

Cohen (2006) demonstrated the ability to conduct reliable long-term forecasts using existing historical police data, demographic data and understanding seasonal shifts in crime trends. This type of location-oriented approach moves away from the individual offender and focuses on the targets victimized. Similarly, Corcoran, Wilson and Ware (2003) introduced neural networks and GIS to forecast short-term, high crime areas. The objective was to move beyond traditional police boundaries (which are often artificially created), and understand the true “hot spots” of crime. The results are encouraging, which further highlights the need for more spatial analysis of crime.

Segato (2004) demonstrates this potential, by comparing security measures of robbed banks to other banks in close proximity, in Padova, Italy. Crime mapping was used by selecting the comparison banks. The analysis found that bank robbers did not care about security measures. Similar to Weisel (2007), there appears to be an assumption of uniform security measures. Segato (2004) found that banks on street corners and banks with more than one entrance were more likely targets. Also, banks close to a freeway did not appear to be robbed more than those located away from freeways. This research introduces several variables to apply to Tempe, Arizona banks.

It is with this understanding of target selection, geographic decision-making, spatial movement analysis and GIS that this project approaches bank robbery. The following hypotheses are examined in the GRAB Project:

1. *Banks with optimal escape routes will be robbed more often than banks without*. Swope (2001) demonstrated the importance of offenders committing crimes where they are comfortable, and Weisel (2007) confirmed that the bank exterior is an important condition in offender decision-making.
2. *Robbed banks will be surrounded by banks that are not robbed*. This is based on Segato's (2004) finding that other banks in close proximity are not robbed, and Clarke and Goldstein's (2003) work regarding the specific targets within a crime hot spot.
3. *Banks which lack uniformity (relative to other regional banks) will experience less robbery activity*. Given Weisel's (2007) conclusion about robber comfort and uniform layouts, it would appear that a robber will choose a bank he or she is comfortable in.

Methodology

Introduction

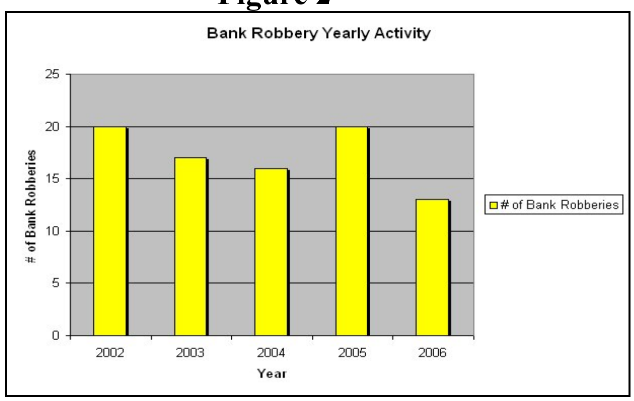
During the time period of January 1, 2002 through December 31, 2006 there were 89 bank robberies reported to the City of Tempe, Arizona Police Department. For the purposes of this study, 86 of these bank robberies are studied. The three bank robberies excluded from this research occurred at locations that no longer exist, thus limiting the analysis of the locations' current geographic vulnerabilities and hindering the application for future use. Of these 86 bank robberies, the yearly breakdown is displayed in Figures 1 & 2.

Figure 1

Year	# of Bank Robberies
2002	20
2003	17
2004	16
2005	20
2006	13

n=86

Figure 2

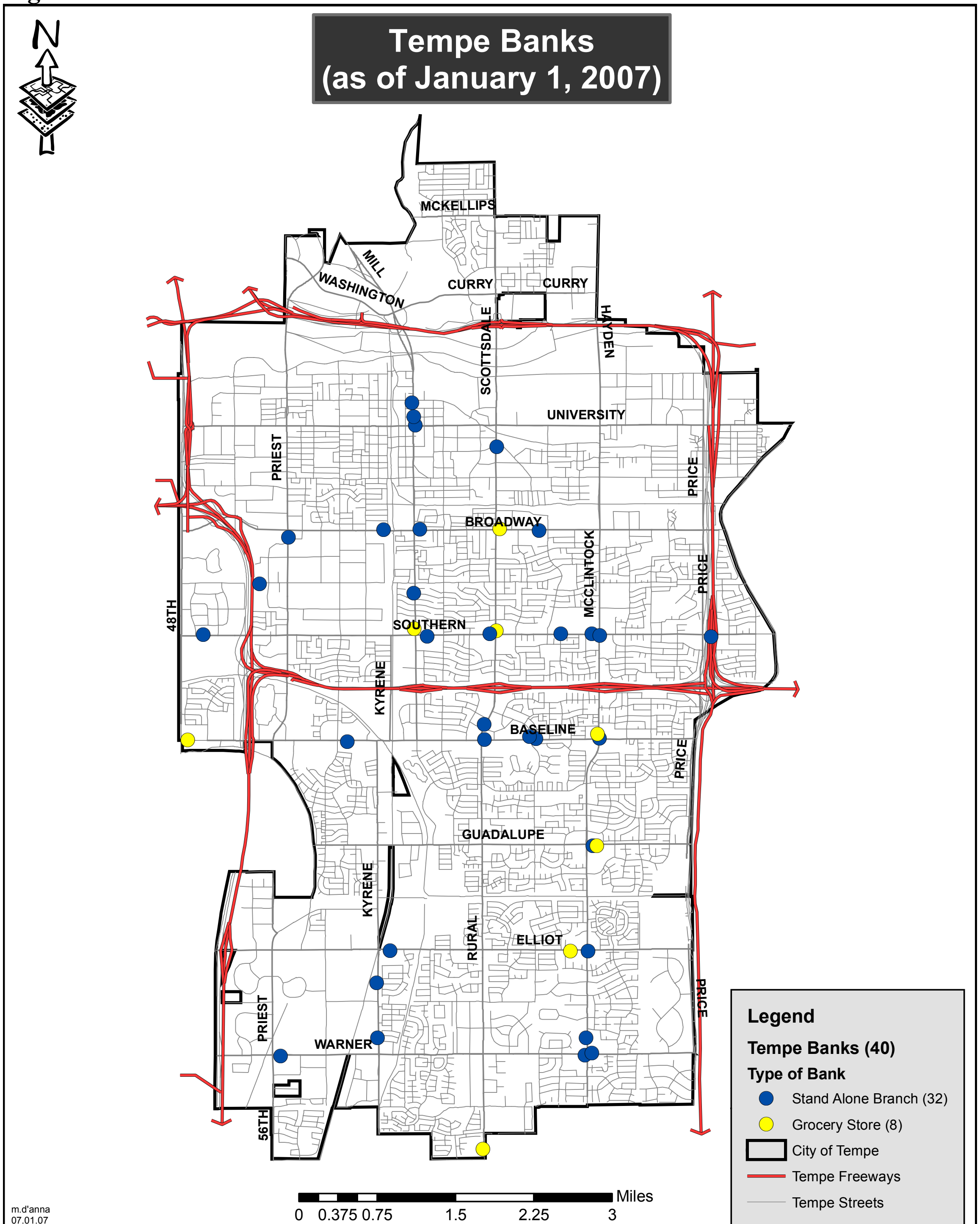


As of January 1, 2007, there were 40 banks in the City of Tempe. For the purposes of this study, a "bank" refers to all financial institutions, including banks, savings and loan, and credit unions (Weisel 2007). These 40 banks have been mapped and analyzed from a spatial perspective to reveal potential geographic vulnerabilities.

Mapping Banks & Robberies

There are several different (and effective) ways of mapping these crimes and locations. The first, and most simple, is a pin map. A pin-map utilizes vector-based data, which consists of points, lines and polygons. As its name suggests, this method places a single point on the map to represent the address of the location (historically it was literally a pin on a print map). All of the dots on this type of map are the same size. This map is effective for understanding *where* the 40 banks are located throughout the city, to a degree. One of the drawbacks to pin-mapping is that dots in close proximity to one another can overlap and even cover each other. However, one of the advantages is the ability to change the symbology based on a unique feature of the data's attributes. This groups the dots into different colors. In Figure 3, the 40 Tempe banks have been mapped and grouped according to the location type of the bank (grocery store or stand-alone). For the purposes of this study, a "grocery store" bank is defined as a bank located inside of a grocery store/supermarket. A "stand-alone" bank is one which is not in a grocery store/supermarket. Despite what its name suggests, it does not have to be a completely freestanding building, but may also include banks in strip malls and office complexes. This map establishes a foundation for spatial analysis by being able to quickly identify specific types of banks.

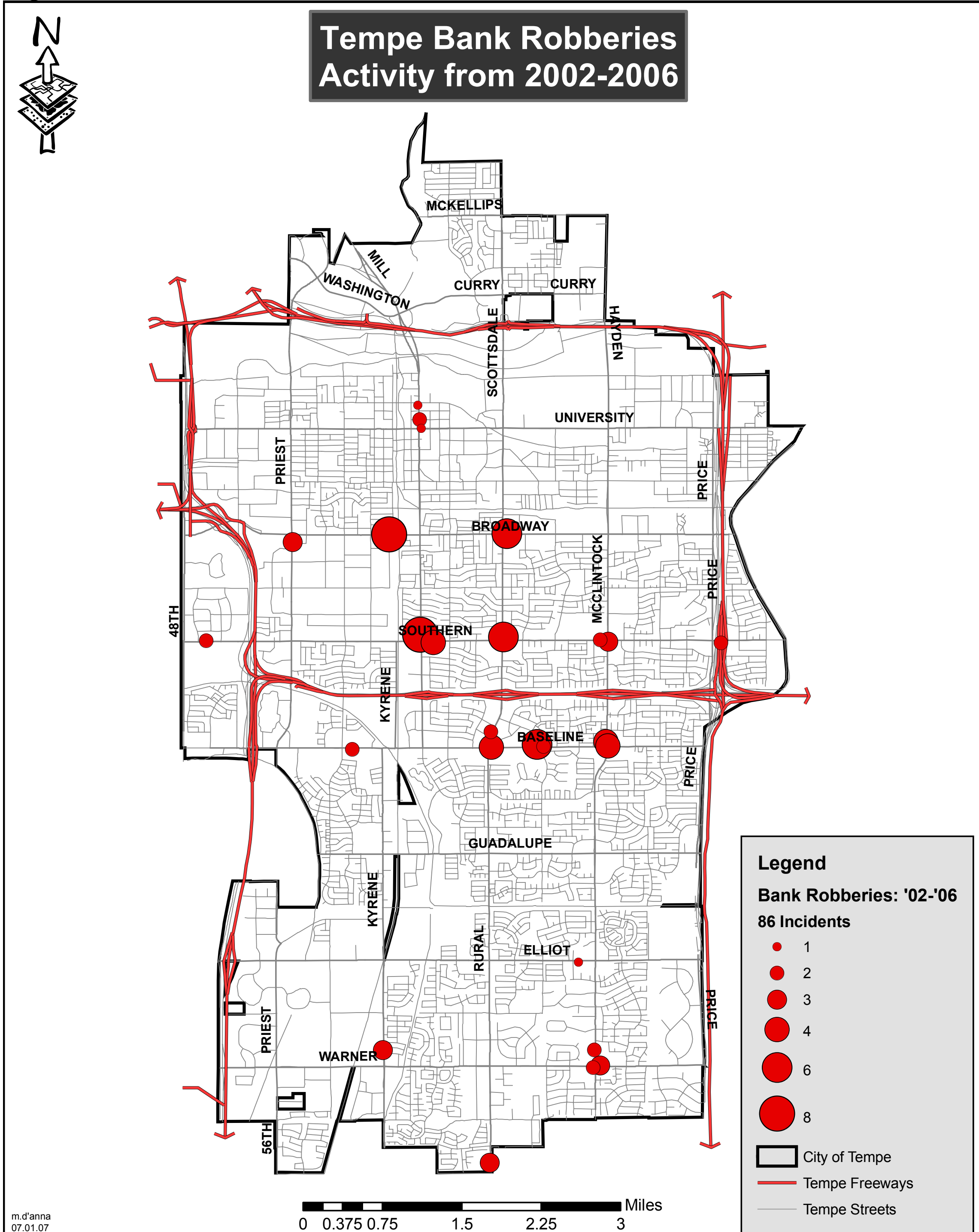
Figure 3



(addresses based on Police Department incident report & calls for service data and internet searches, n=40)

A pin map has also been created for the bank robberies. If the same methodology was applied here, a single dot would be placed at each robbery location. This type of symbology would be problematic because some banks are robbed more than once. This would create dots on top of dots; there would be no visual distinction between a bank that has been robbed once or robbed eight times. Thus, a graduated point map is created (Figure 4). This method proportionately increases the size of the dot based on the number of bank robberies that occurred at that location. This map is another step in data analysis, as we are able to visualize where and how frequently the bank robberies occur.

Figure 4



(incidents of reported bank robberies based on Police Department record management system & exclude robberies where the location no longer exists, n=86)

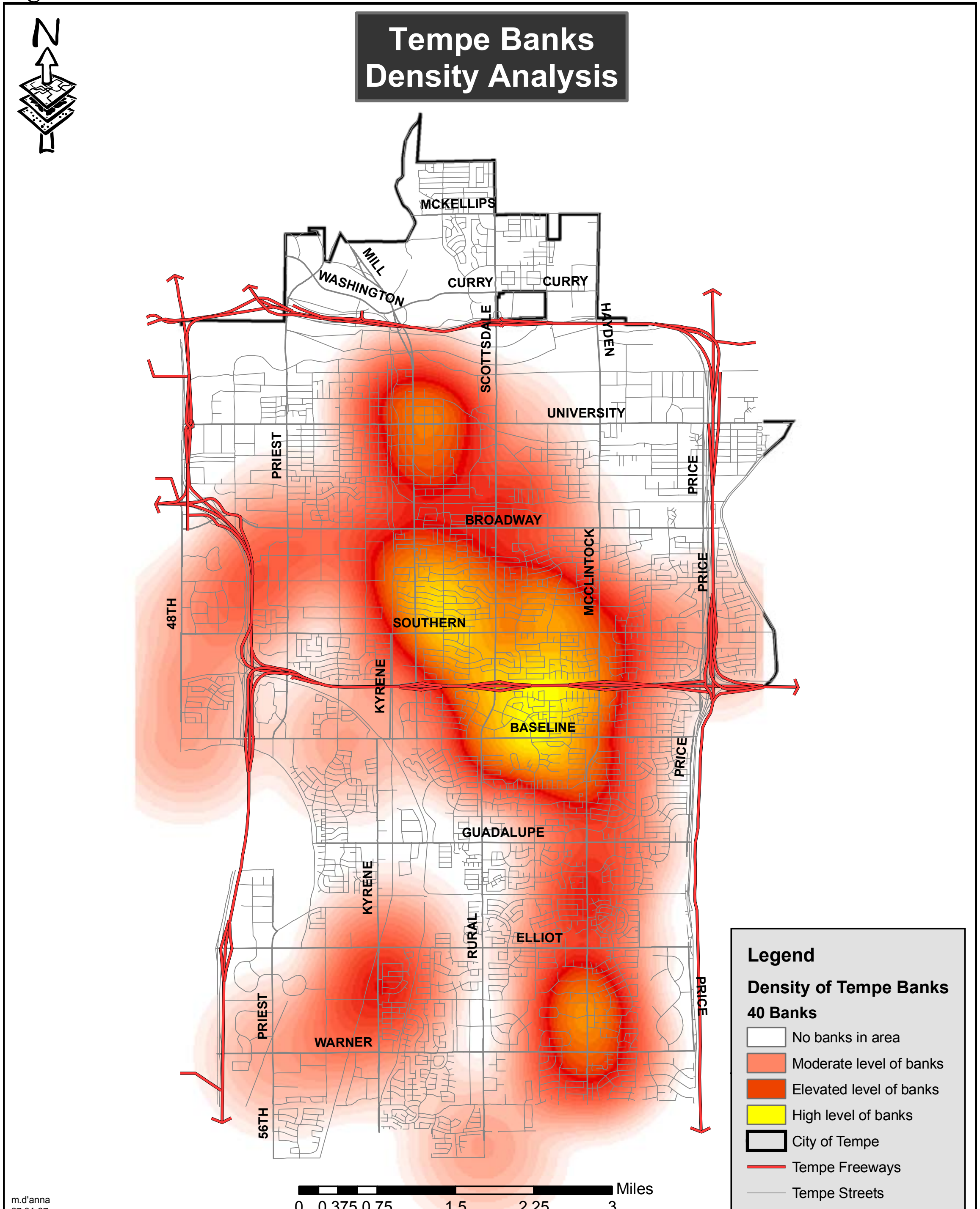
Early analysis on the data can be conducted. First, some banks in Tempe were not robbed during the time period (fourteen of the forty banks). Conversely, some banks were robbed as many as eight times in the five year period. Additionally, to the naked eye it would appear that the bank robberies are clustered, meaning a large portion of the robberies occur in a relatively small geographic area. To test this idea, density maps are created.

A density map (using the Spatial Analyst extension in ESRI's ArcMap 9.1) is based on raster images. A raster, unlike the vector-based maps in Figures 3 & 4, divides a given study area into a specified number of rows and columns, which create small boxes. This is similar to television resolution based on dots per inch (dpi). The more rows and columns (and subsequently more boxes) created, the sharper the detail. The point data is related to these boxes using a search radius. Each box in the raster searches for data within the range. Depending on each box's proximity to the data (in this case, bank or robbery point data), it is given a numeric score. This numeric score is translated into a color, and the entire color scheme is displayed on the map.

Before calculating the search radius, a decision about the cell size must be made. The cell size, created by the rows and columns of the raster, should ideally have a significant relationship to the underlying geography being analyzed. In this case, the average parcel size of Tempe was calculated, and the average frontage distance of an average parcel was used as the cell size.

Determining the search radius is arguably the most important part of creating a density map. Ideally, similar to the cell size, the search radius will be some sort of significant value related to the data being analyzed. For this study, the mean nearest neighbor statistic was used. The mean nearest neighbor is a measurement tool which calculates the distance of each data point to its closest point, compiles the values and finds the arithmetic mean. While this is not the only significant distance measurement possible, specific case work by the Tempe Police Department's Crime Analysis Unit has shown this value to be very effective and accurate in practical applications. Once calculated, the mean nearest neighbor value and the standard deviation are used as the search radius. In this analysis, the mean nearest neighbor plus two standard deviations was used in creating the search radius. Figure 5 demonstrates a density of the 40 banks in Tempe.

Figure 5



(density raster based on a cell size of 100 ft., using a study area created by bank point data plus a 10% buffer; search radius of 5565 ft, based on mean nearest neighbor of banks (1787 ft.) plus 2 standard deviations (1889 ft.))

At this point, it is possible to transform a raster into vector images. This is potentially helpful because it can create cut-off points for analysis. These cut-off points should be based on significant breaks in the data. These "breaks" are where there is a substantial increase or decrease from one value to the next. A histogram of the density raster highlights where the significant breaks in the data occur. Figure 6 is a sample histogram of Tempe Bank Density data, with highlighted significant break points. Creating vectors from these cut-offs is displayed in Figure 7. Three different breaks were discovered; these breaks were not based on equal intervals in the data but rather where the most significant changes (increases or decreases) occurred. The vector images, which are more advantageous for analysis, were created accordingly.

Figure 6

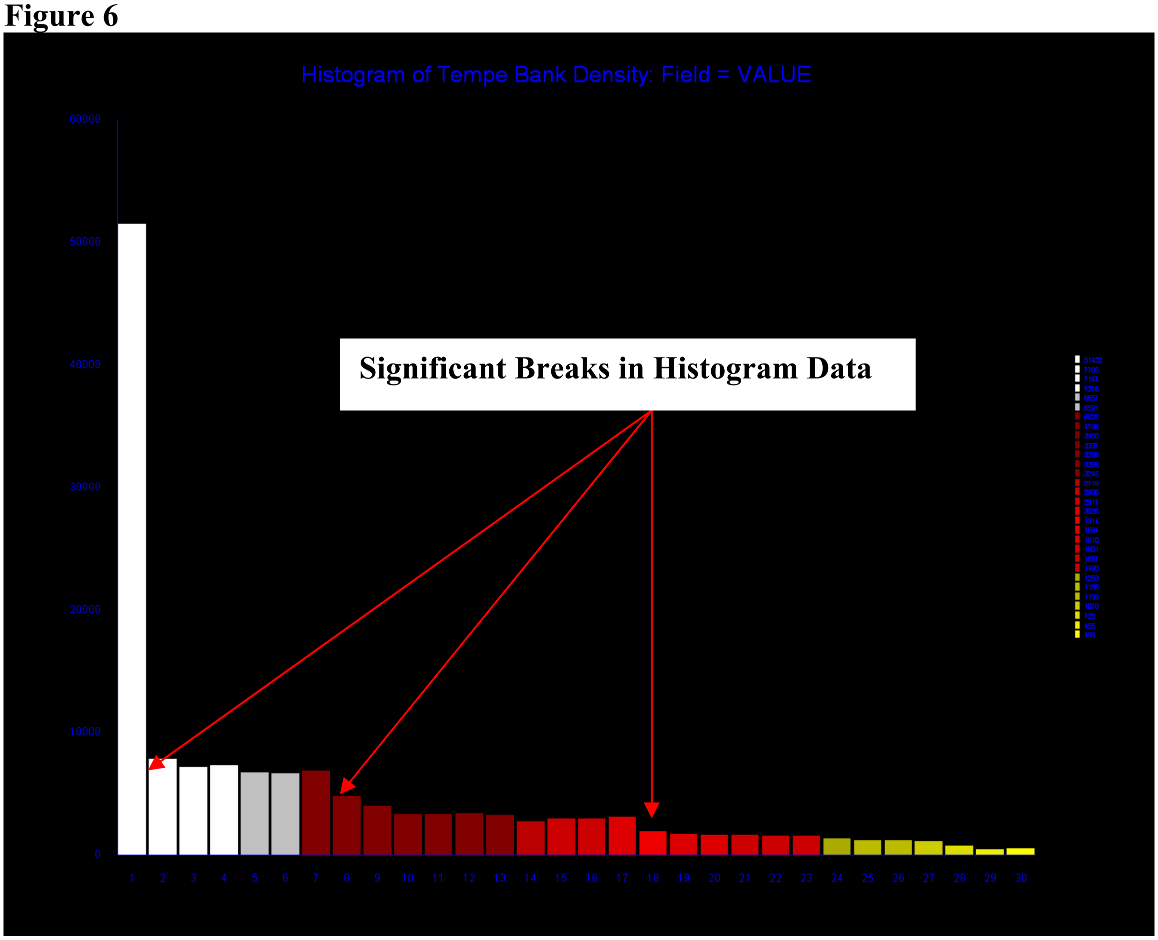
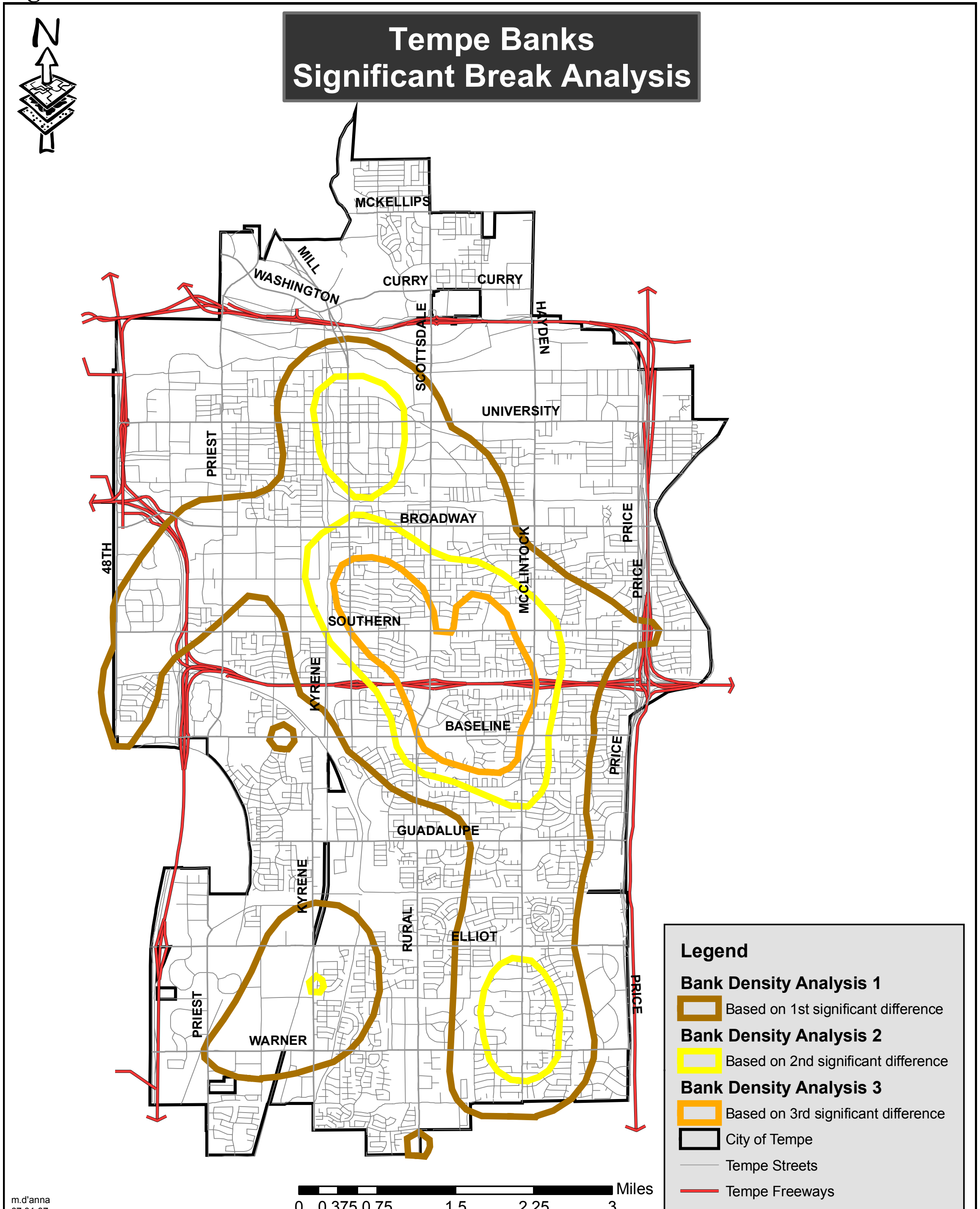


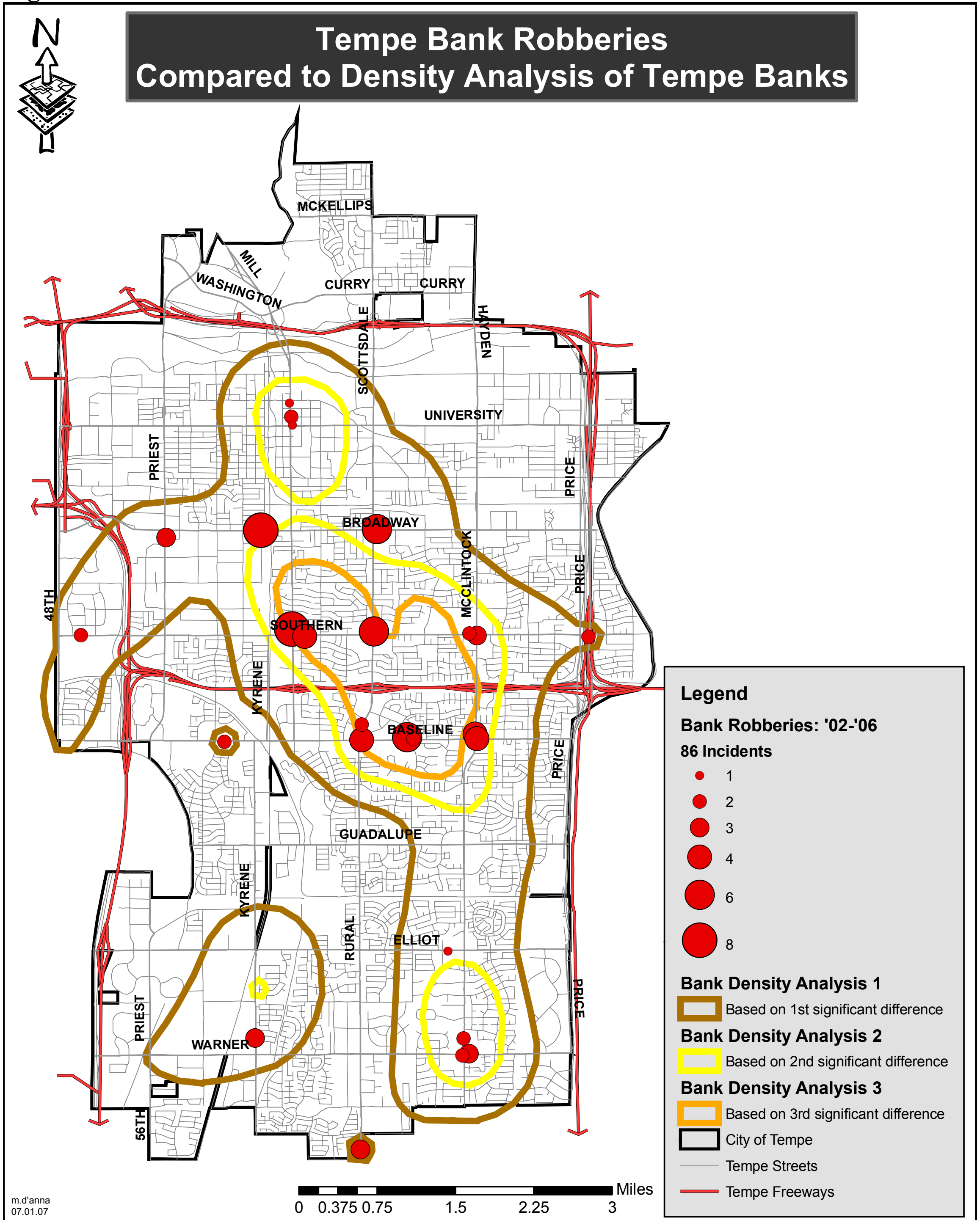
Figure 7



(density breaks based significant differences observed on histogram of bank density values; breaks were made not at equal intervals but where great increases or decreases in histogram were observed)

This process allows for the identification of potential clusters in the data. While very strong, the naked eye alone is unable to calculate with any mathematical certainty these clusters the same way statistics can. Thus, we are better able to understand the space and distance that the Tempe banks occupy, relative to each other. These vectors now show the clustering of banks in Tempe, displaying the densest areas of banks in the city. Furthermore, we can display the graduated point bank robberies over the density vectors of the banks. Figure 8 highlights where the bank robberies occur in relation to the density areas of the banks.

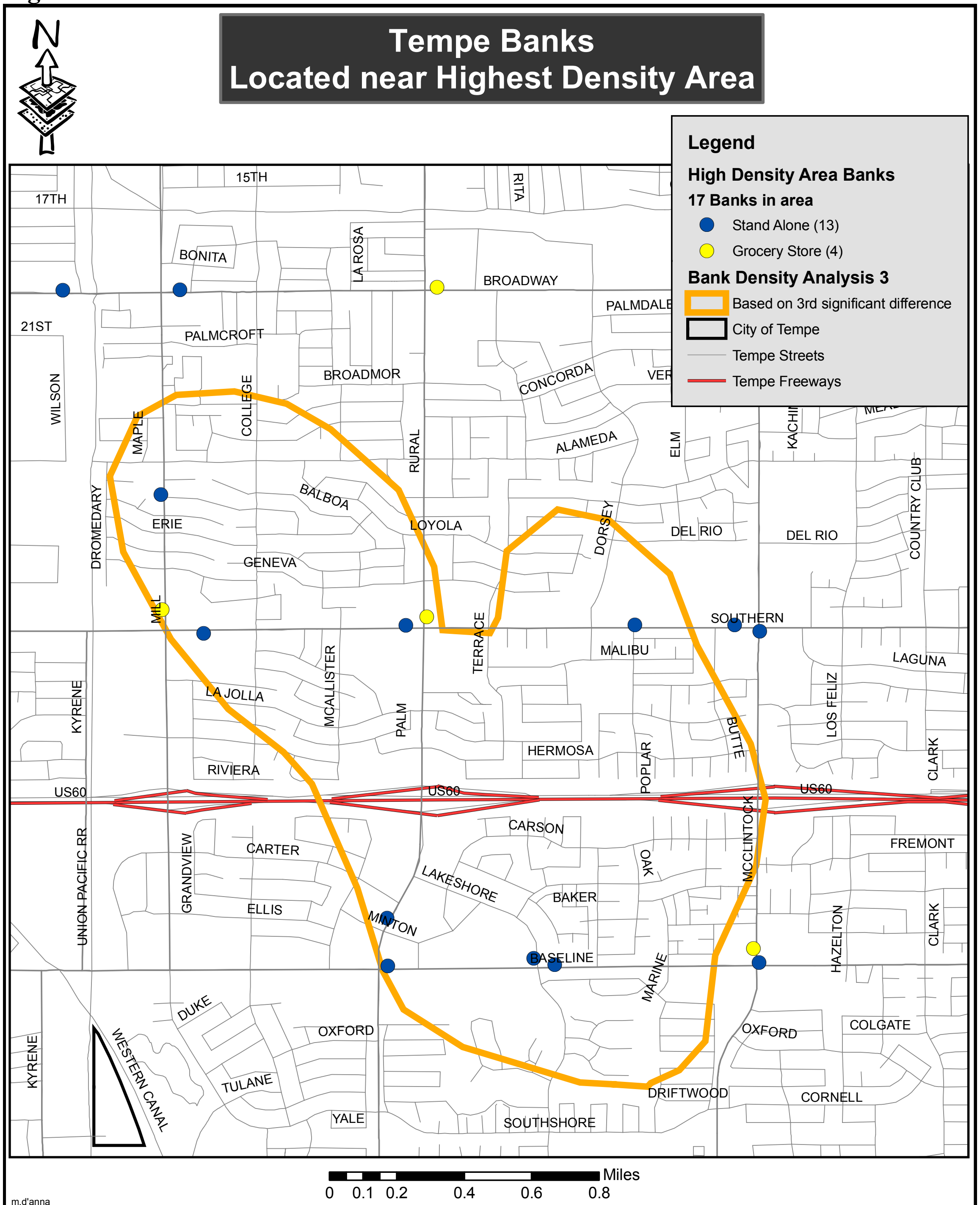
Figure 8



(density breaks based significant differences observed on histogram of bank density values; breaks were made not at equal intervals but where great increases or decreases in histogram were observed; incidents based on reported bank robberies, n=86)

This spatial analysis raises some interesting points. It appears that many bank robberies cluster around the densest areas of banks. In other words, a lot of the bank robberies occur in a crowded area of banks. In fact, when the map in Figure 7 is zoomed into the highest density area of the banks ("Bank Density Analysis 3," displayed in orange), there are seventeen banks within .55 miles of the highest density area. The banks in this area account for 42.5% of all Tempe banks, and the area itself accounts for only 5.6% of the entire city's area. Figure 9 zooms in and displays the seventeen banks which comprise this High Density Area (HDA).

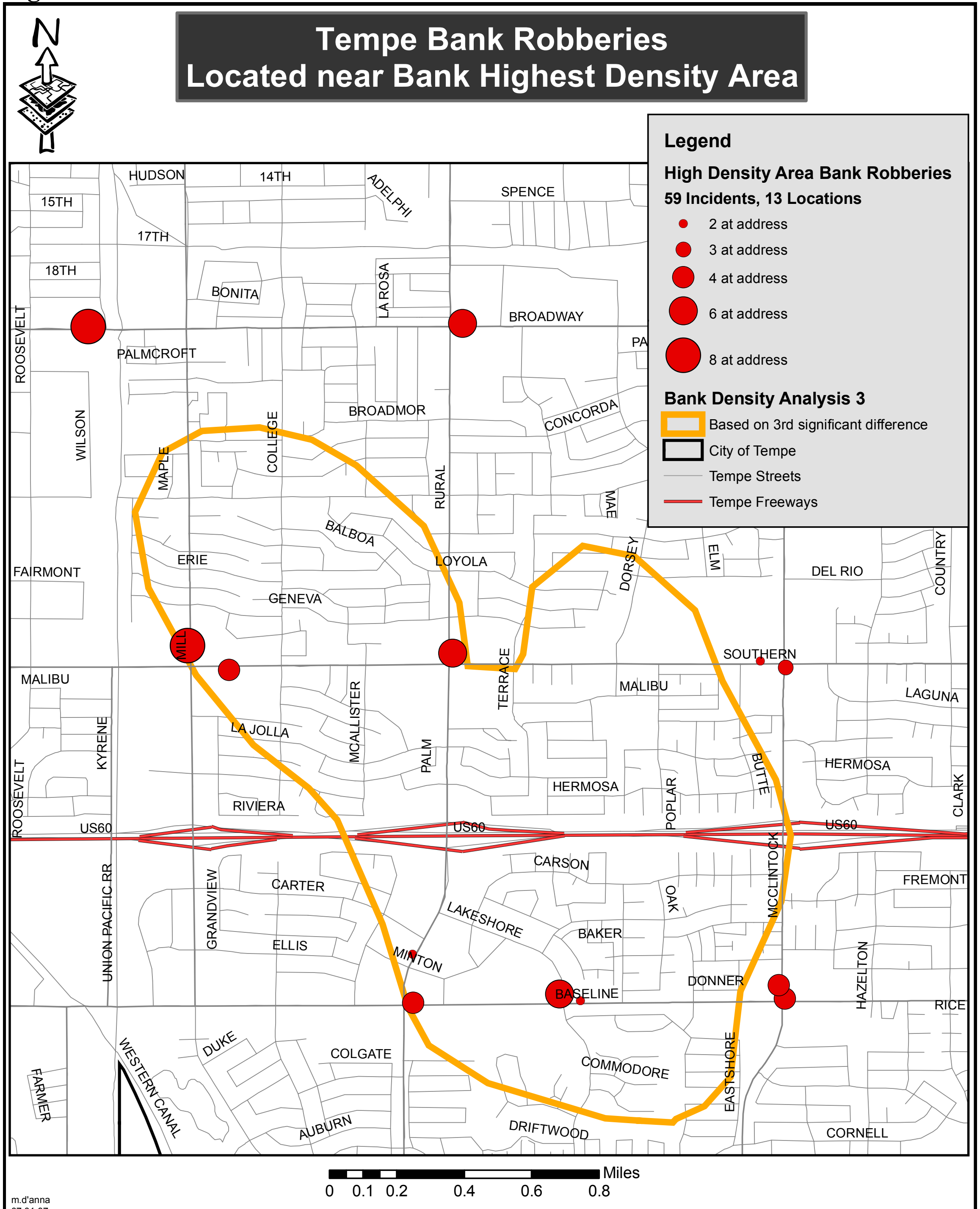
Figure 9



(highest density break based significant difference observed on histogram of bank density values, closest to top; banks in map were selected from all Tempe banks within .55 miles of high density area, n=17)

Of these seventeen banks in the HDA, thirteen were robbed during the time period of this study. These thirteen banks account for 32.5% of all Tempe banks. These banks were robbed a total of 59 times from 2002 to 2006, which accounts for 68.6% of all bank robberies. Thus, approximately 1/3 of Tempe banks account for more than 2/3 of the bank robberies. Figure 10 is the High Density Area overlaid by the graduated point data of the bank robberies in the area.

Figure 10



(highest density break based significant difference observed on histogram of bank density values, closest to top; bank robberies in map were selected from all Tempe bank robberies within .55 miles of high density area, n=59)

This raises a fundamental question: why do the banks in the high density area account for such a large portion of the bank robberies? At the heart of this question are the differences between a) the banks in this area and the other 23 banks in Tempe, and b) the banks robbed in this area and the other four banks not robbed, but in the dense area. This study focuses on the geographic vulnerability variables of Tempe banks, specifically related to these questions.

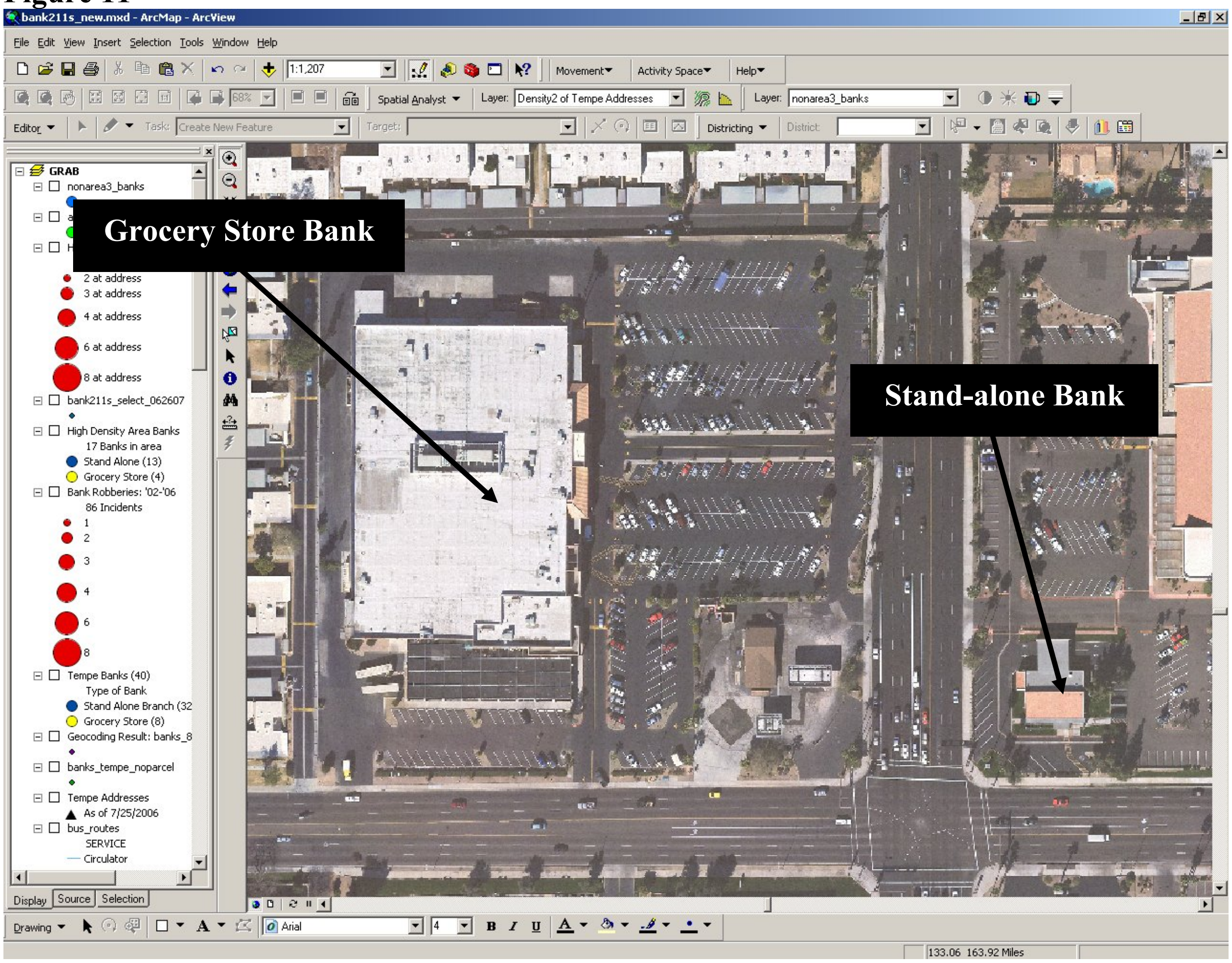
Geographic Vulnerabilities

Attempting to understand bank robbery in terms of geographic variables is potentially a daunting task. There are literally countless factors that could be examined. For the purposes of this study, the list must be narrowed to include only those that would appear most relevant to bank robbery. It is based on this concept of relevancy that these seven variables are chosen.

Location Type: Grocery vs. Stand-alone

This variable is seemingly obvious, but an initial analysis of the robbery data warranted further study. A grocery store bank has unique qualities absent in a stand-alone bank. A bank inside a grocery store is typically smaller than a stand-alone bank. With this smaller size, there is the potential for the perception of less security and more comfort for an offender. On the exterior, a grocery store bank typically has a large parking lot, which affords a robber more people to blend with and more places to hide. Weisel (2007) demonstrated the importance of this blend-ability for bank robbers. Given the standard chaos in a grocery store, a subtle robbery inside of a grocery store bank can go unnoticed with relative ease. In fact, in studying bank robberies during 2006 as a Tactical Crime Analyst, I found that in grocery store banks an adjacent customer can be completely unaware of a robbery occurring. Thus, the distinction of bank type is an important variable for understanding vulnerability. Figure 11 compares these differences in location type.

Figure 11

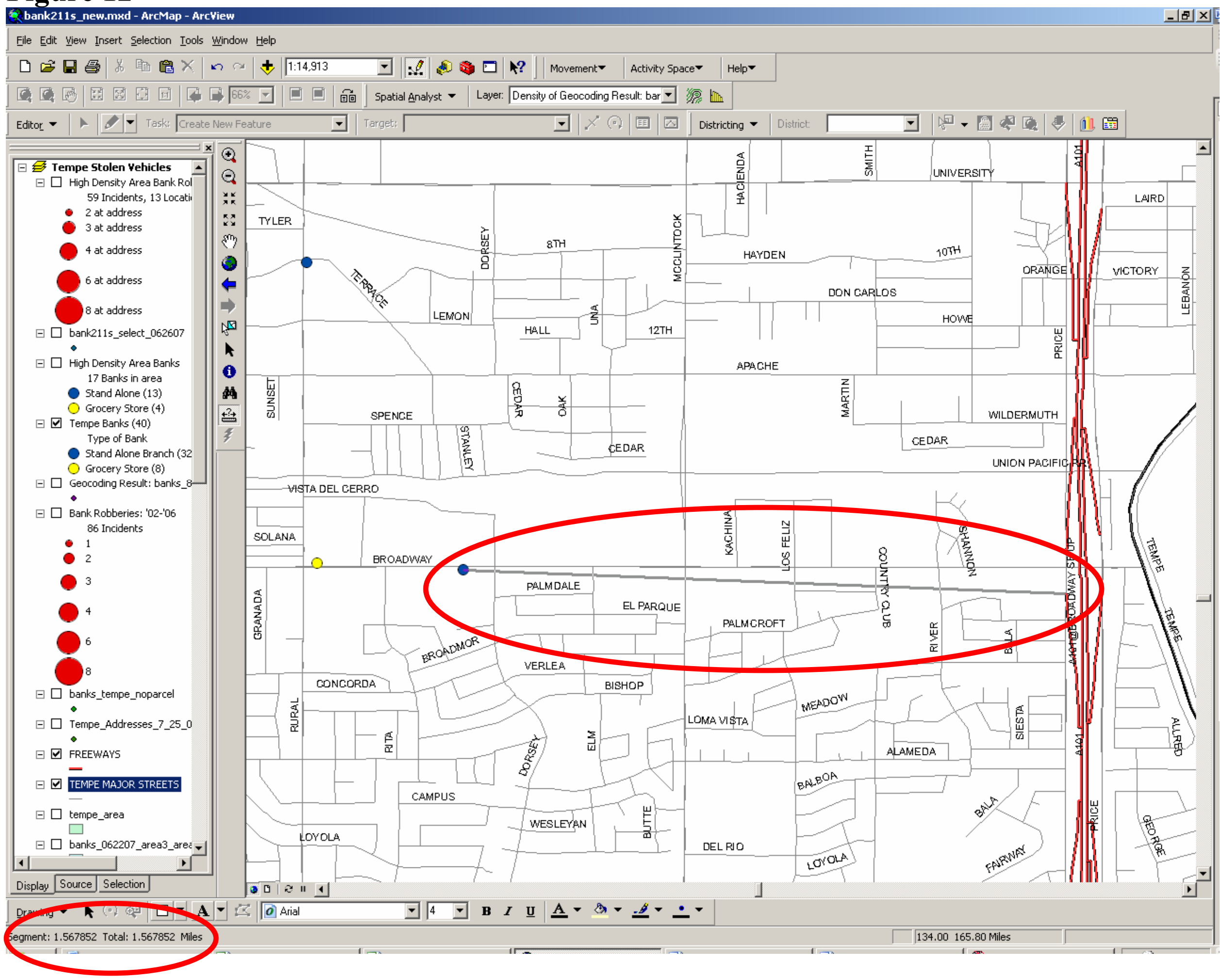


Distance-to-freeway

A bank's proximity to a freeway would appear to increase the potential for robbery. Tempe is a city bound and dissected by freeways. They allow quick access in, out and around the city, and make Tempe a major transportation portal for the eastern portion of Maricopa County. The proximity to a freeway increases the opportunity for a fast escape. It also allows for multiple options when fleeing the crime scene, in addition to the standard surface streets. A freeway presents unique challenges in attempting to locate a fleeing suspect, as speed and distance increase exponentially with time.

The distance of a bank to its nearest freeway was measured using Euclidean distances from the data point on the map to the nearest *entrance* to a freeway. This is important to note because while some banks were close to freeways, they were not close to actual on-ramps, thus negating their proximity as a reason for being targeted. Euclidean distance is the straight-line distance between two points. The alternative, Cost distance, measures distance using factors such as slope, street networks and land use (ESRI 2007). Euclidean distance was chosen over Cost distance because the City of Tempe largely lacks one-way streets, and multiple options for traveling to the same destination are the norm. Further, most banks are located on major streets and intersections, so often a bank's access to a freeway was a direct drive, from Point A to Point B. Thus, using Manhattan distances would not likely have changed the representation of the data. Figure 12 is an example of how the proximity to the freeway for a bank was calculated.

Figure 12

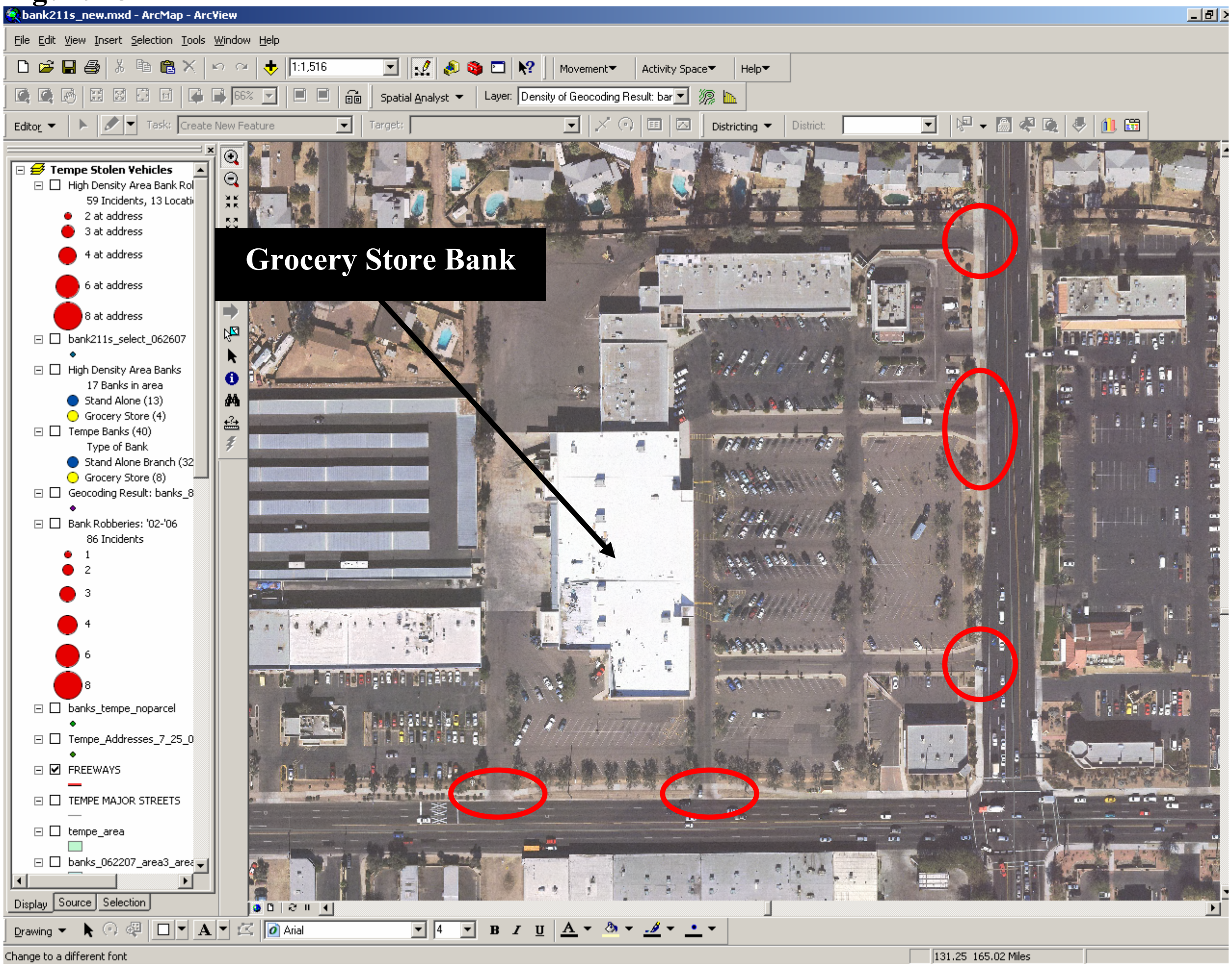


Parking lot egress

While the number of parking lot entrances and exits does not always correlate with the size of a parking lot, this often appears to be the case. Further, more egresses in a parking lot create more opportunities for alternative escape routes. Similar to distance-to-freeway, parking lot egress would appear to increase the options for a fleeing offender. Studies have shown that multiple options heighten a target’s vulnerability (Weisel 2007). Suspects appear to be drawn to locations with multiple avenues for exit. These targets have the potential to deceive anyone chasing them when fleeing. More parking lot egresses also give victims and witnesses a lower opportunity for seeing the suspect. Overall, more parking lot egresses would appear to give a bank a stronger likelihood of being robbed.

The number of parking lot egresses found at a bank in this study was based on the number of exits and entrances into a *bank's* parking lot. This was at times difficult to precisely calculate, as parking lots sometimes seamlessly transfer from one business to the next. This was most difficult when a bank is located either inside a grocery store or as a store in a strip mall. However, distinctions were made. As shown in Figure 11, the opening had to come from a parking lot that specifically fed into the bank. Through the use of barriers and parking islands, separate, unique parking lots were identified. While it may appear that there are as many as seven parking lot egresses at the bank in Figure 13, only five were counted, as the other two (not circled) were part of other parking lots.

Figure 13



Parcel size (area)

For this study, a parcel was defined as the tract or plot of land which a bank was constructed on. Parcel area was calculated and believed to be a variable worthy of study because there is the potential for patterns of large, small or average size bank parcels being targeted. Depending on the results, this analysis could yield several different conclusions.

<u>Large parcels</u> give an offender comfort in their size by allowing numerous access points and options for departure. This would, in theory, correlate to distance to freeway

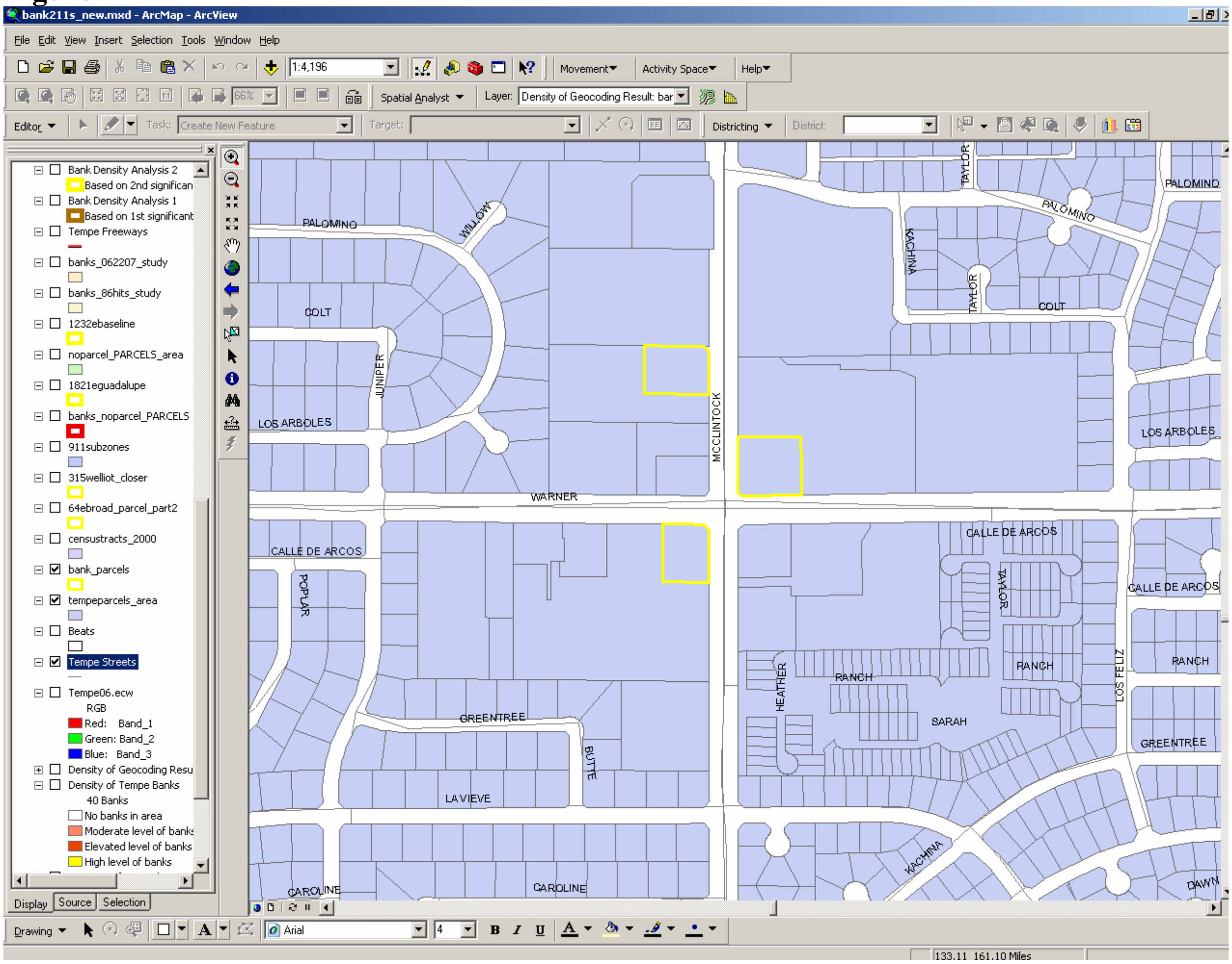
and egress measurements. It would also likely relate to location type, as most grocery stores are typically on large parcels. It would not relate to location type if there are a number of banks that are also on large parcels (i.e. office complexes) that experience different robbery activity.

Small parcels allow an offender to quickly flee the immediate property, thus favoring long-term comfort and blend-ability over short-term comfort. This would likely negatively correlate with the previous variables, but potentially have relationships with others to follow. A small parcel may not grant comfort via space, but may achieve it through more favorable access via exit (to streets, freeways, etc.).

Average parcels are exactly as they sound: average. They do not stand out as extremes and thus make themselves more frequently or less frequently targeted. This could demonstrate that parcel size is irrelevant to robbery. It could also suggest that average parcels are able to blend with other buildings and commerce, giving the offender comfort in their uniformity.

Figure 14 highlights three different bank parcels, each roughly the same size.

Figure 14



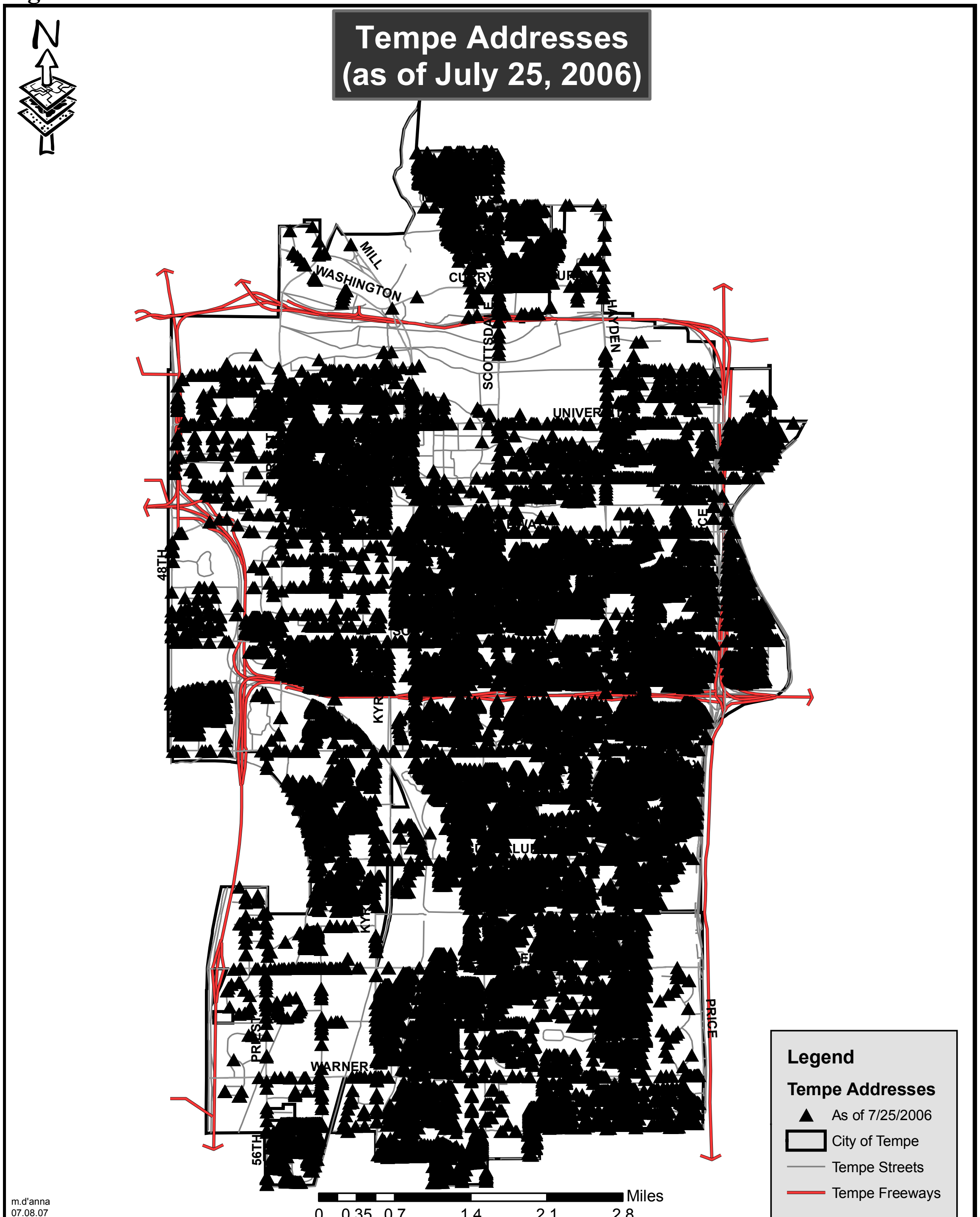
Surrounding area density

This variable is an application of Routine Activities Theory. To summarize, Routine Activities Theory states that crime occurs based on the combination of a likely offender, a suitable target and the absence of a capable guardian. These opportunities are presented in daily activities (Swope 2001). Therefore, the more addresses in an area, the greater opportunities for activity in an area. Activity in this study includes all human spatial movement, whether criminal or not. Bank robbery, one such product of this movement, would potentially have an increased likelihood of occurrence: the greater the density of an area, the greater the opportunity for a bank robbery. Density is defined as the measured quantity of an input throughout a landscape (ESRI 2007). In this variable, the input is address point data for the City of Tempe.

Conversely, there is the potential that the less dense an area, the greater the opportunity for a bank robbery. This would be a more isolationist approach; an offender would specifically look for a target away from dense areas of human activity. Swope (2001) labeled this a "density paradox:" while higher population densities offer more targets, they also offer more surveillance, witnesses and capable guardians. It is with these perspectives that density was explored.

In order to better understand the relative density for each bank, citywide population density was analyzed. This combines the concepts of density mapping with significant distances, nearest neighbor distances and the Routine Activities Theory of the clustering of offenders, targets and guardians. The address data used for these density calculations was based on a one-time data drop provided to the Tempe Police Department on July 25, 2006 from the United States Postal Service. The comprehensive address data contained apartment and office suite numbers, accounting for multiple units at one address. Figure 15 is a pin-map of all Tempe addresses.

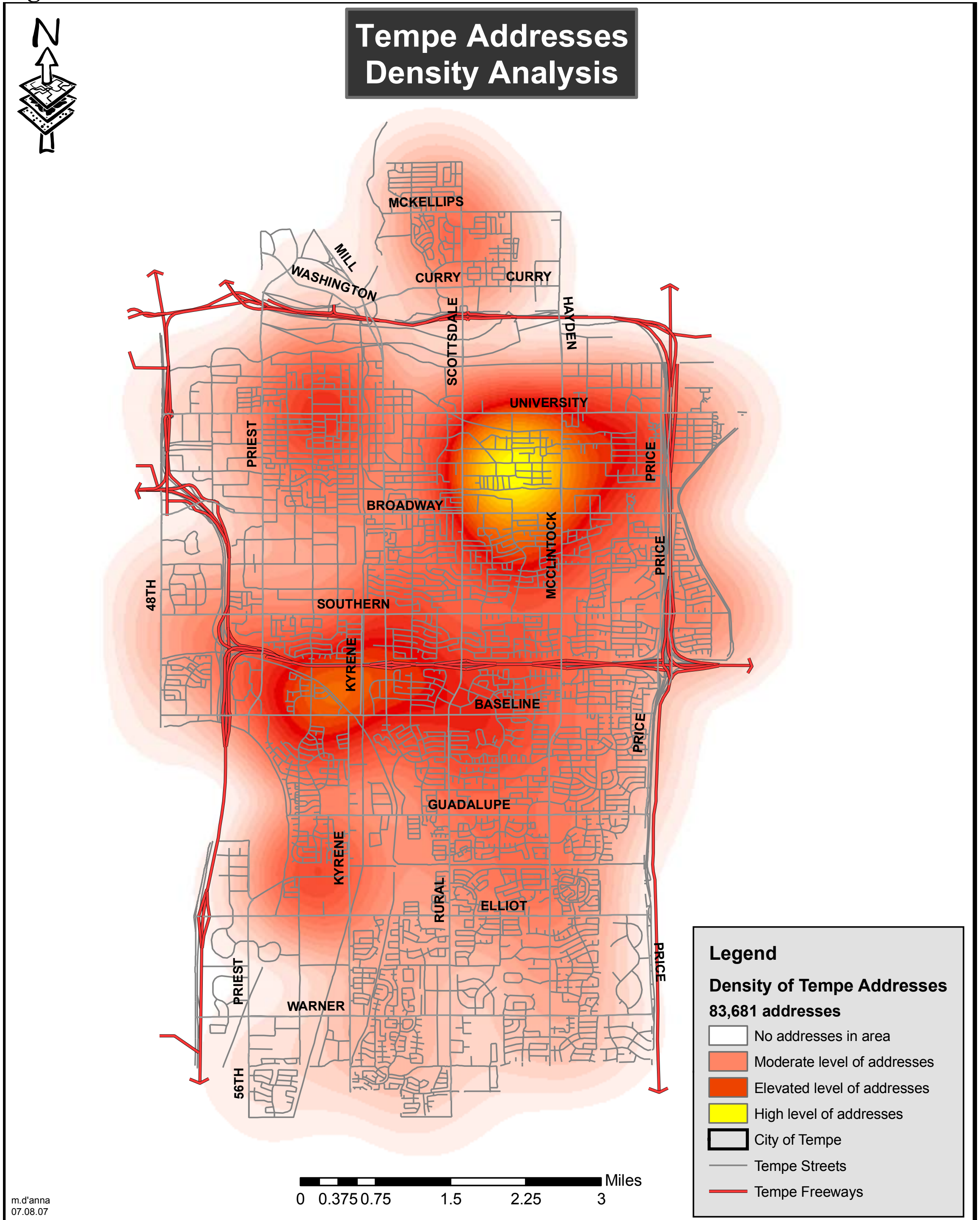
Figure 15



(address point data based on a one-time data drop from United States Postal Servce to the Tempe Police Department on July 25, 2006; data includes multiple addresses per point (i.e. apartment, suites & businesses) when applicable, n=83681)

Using a similar methodology employed for the density of Tempe banks, a density map was created for Tempe addresses. The mean nearest neighbor and the standard deviation of the bank data were used, as there were severe problems when attempting to calculate the nearest neighbor statistics on all 83,681 Tempe addresses. A density map is much more effective to understand and analyze than a pin-map is for this data. Additionally, we are able to see the effect that Arizona State University potentially has on the density of addresses in Tempe. While campus addresses are not considered part of the city, as off-campus living increases and urban building continues in the Downtown area of Tempe, there are clear effects on clusters of addresses (both commercial and residential). Figure 16 illustrates some of these density patterns.

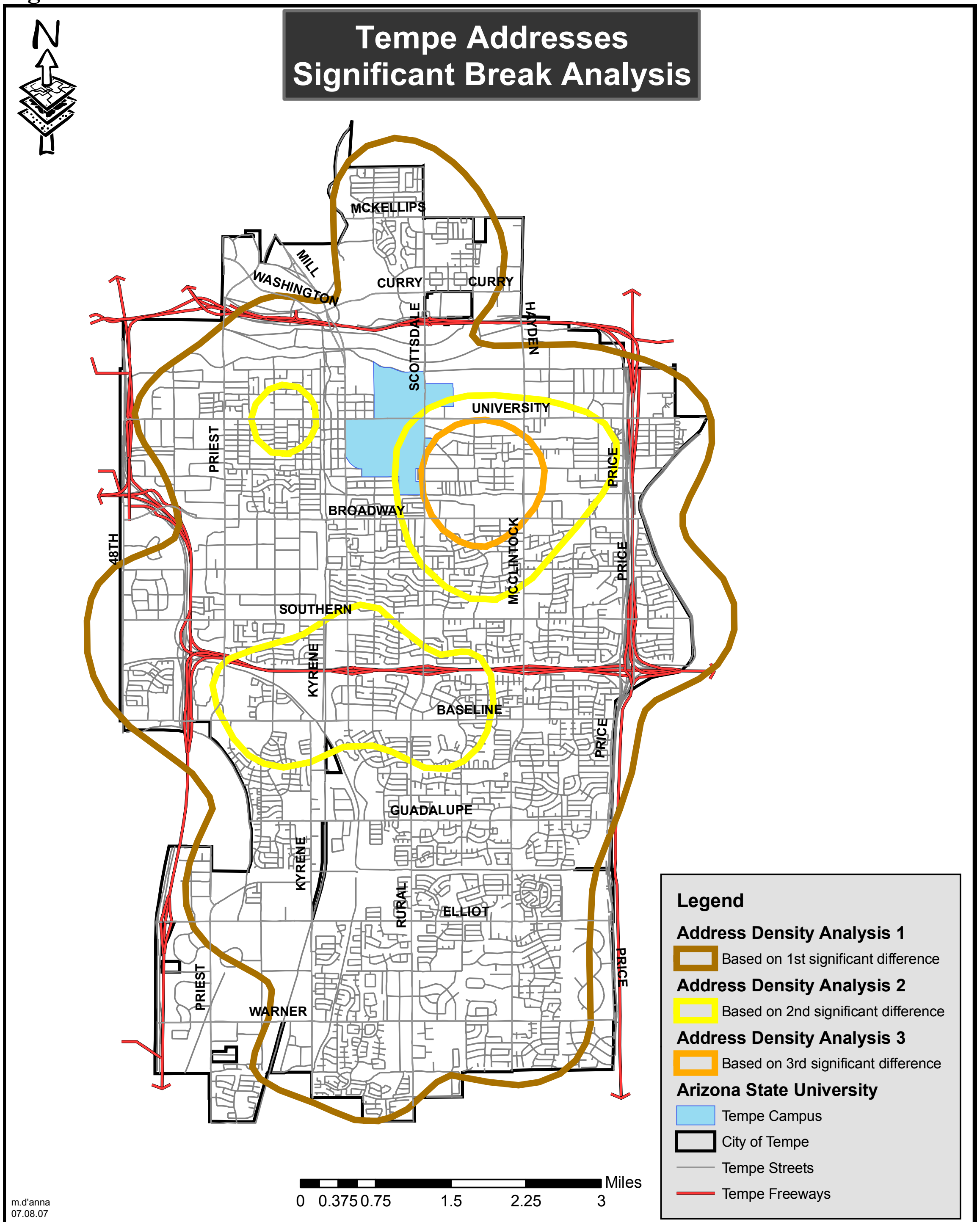
Figure 16



(density raster based on a cell size of 100 ft., using a study area created by Tempe address point data plus a 10% buffer; search radius of 5565 ft., based on mean nearest neighbor of bank data plus 2 standard deviations)

Similar to the bank density analysis, significant breaks in the histogram of the address data were found, and these "breaks" in the raster were transformed into vector images. Density areas were established. Figure 17 shows these breaks and the spatial relationship of Arizona State University and its potential effects on city density patterns.

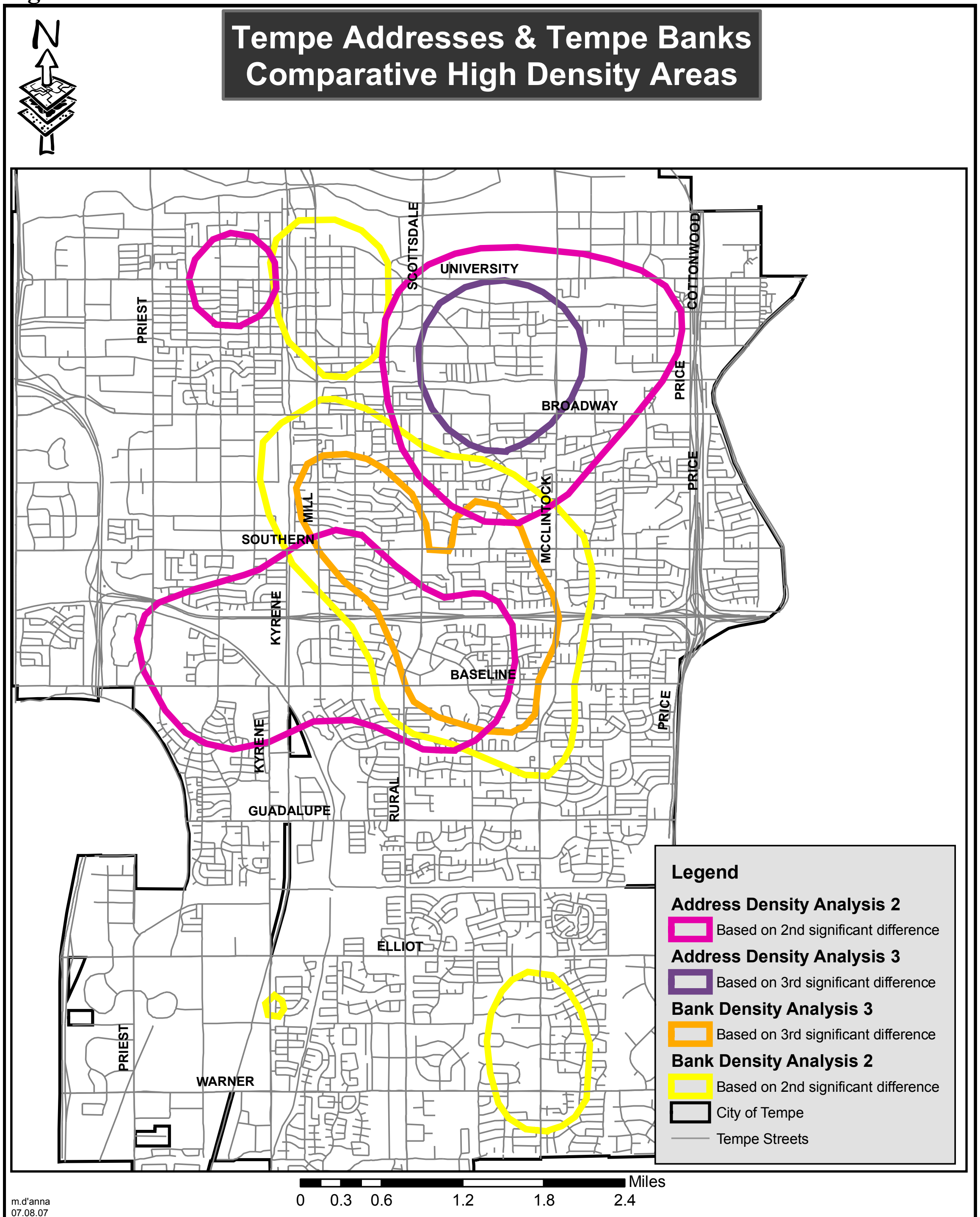
Figure 17



(density breaks based on significant differences on histogram of address density values; breaks were made not at equal intervals but where great increases or decreases in histogram were observed)

Once these areas were created, the address high density areas were compared to the high density areas for banks. Thus, Figure 18 highlights the two highest density levels (areas 2 & 3) for all Tempe addresses and the forty Tempe banks.

Figure 18



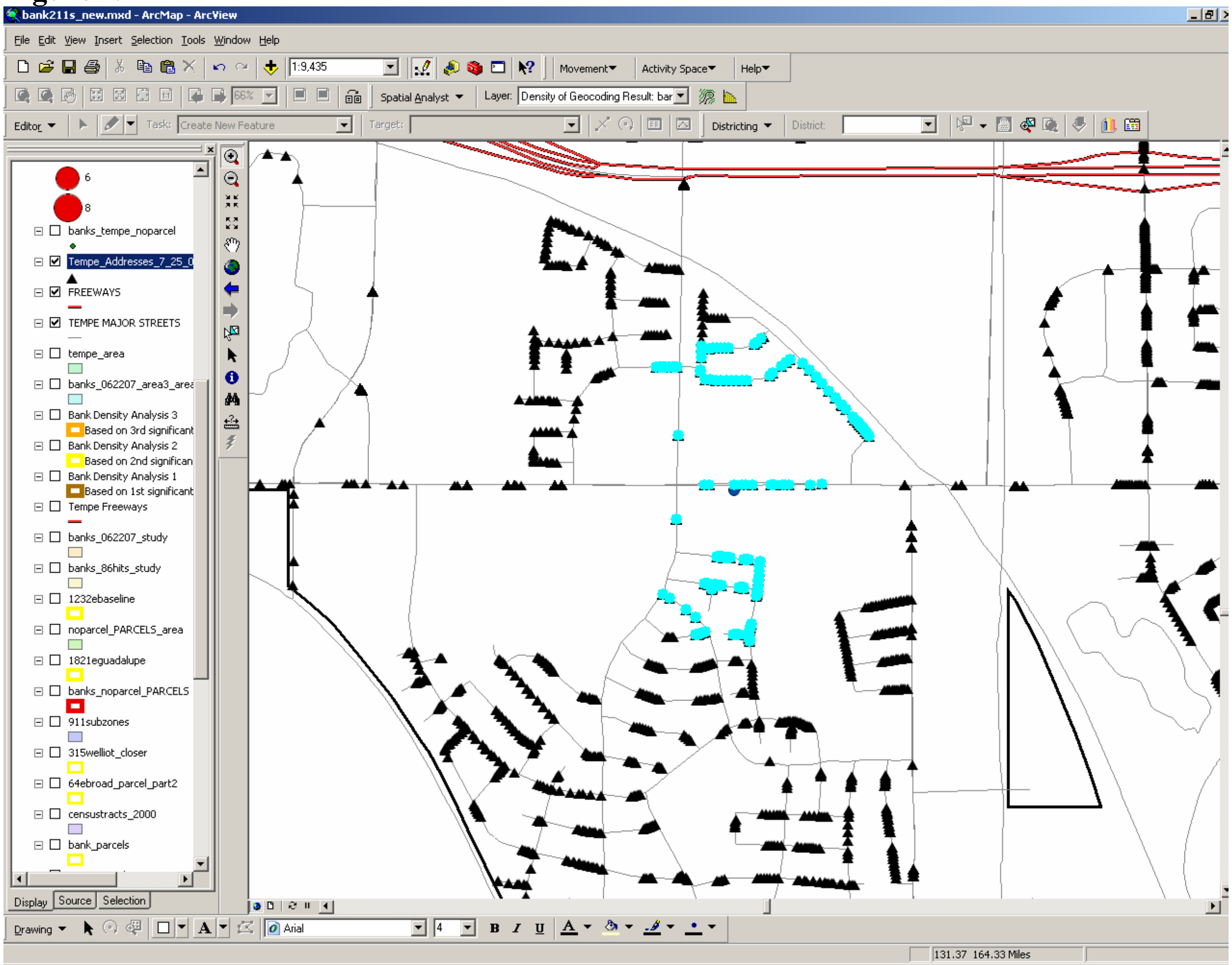
(density breaks based on significant differences observed on histogram of address density values & bank density values; the two breaks closest to the top for each data set are displated)

Interestingly, there is overlap between Area 2 of the addresses and Area 3 of the banks. Also, Area 2 of the banks comes very close to (0.072 miles), but does not intersect the high density area of the addresses (Area 3). Further, both High Density Areas do not intersect. At their closest points, they are 0.385 miles away from each other. Thus, based on these findings it would appear that banks in the Bank High Density Area may potentially have high density numbers when their surrounding area is calculated.

From here, individual bank densities were calculated for their potential to relate to bank vulnerability. A buffer was created around each bank of .25 miles. This arbitrary distance was based on street and neighborhood networks of the city of Tempe. This was carefully selected, as a search radius too large would go beyond the "immediate area." A search too small would not cover enough of the surrounding addresses, and not truly represent that bank's density.

Figure 19 demonstrates the physical addresses located within a ¼ mile of the selected bank. All surrounding Tempe addresses are displayed, but those highlighted in blue are the ones which fit the search criteria.

Figure 19



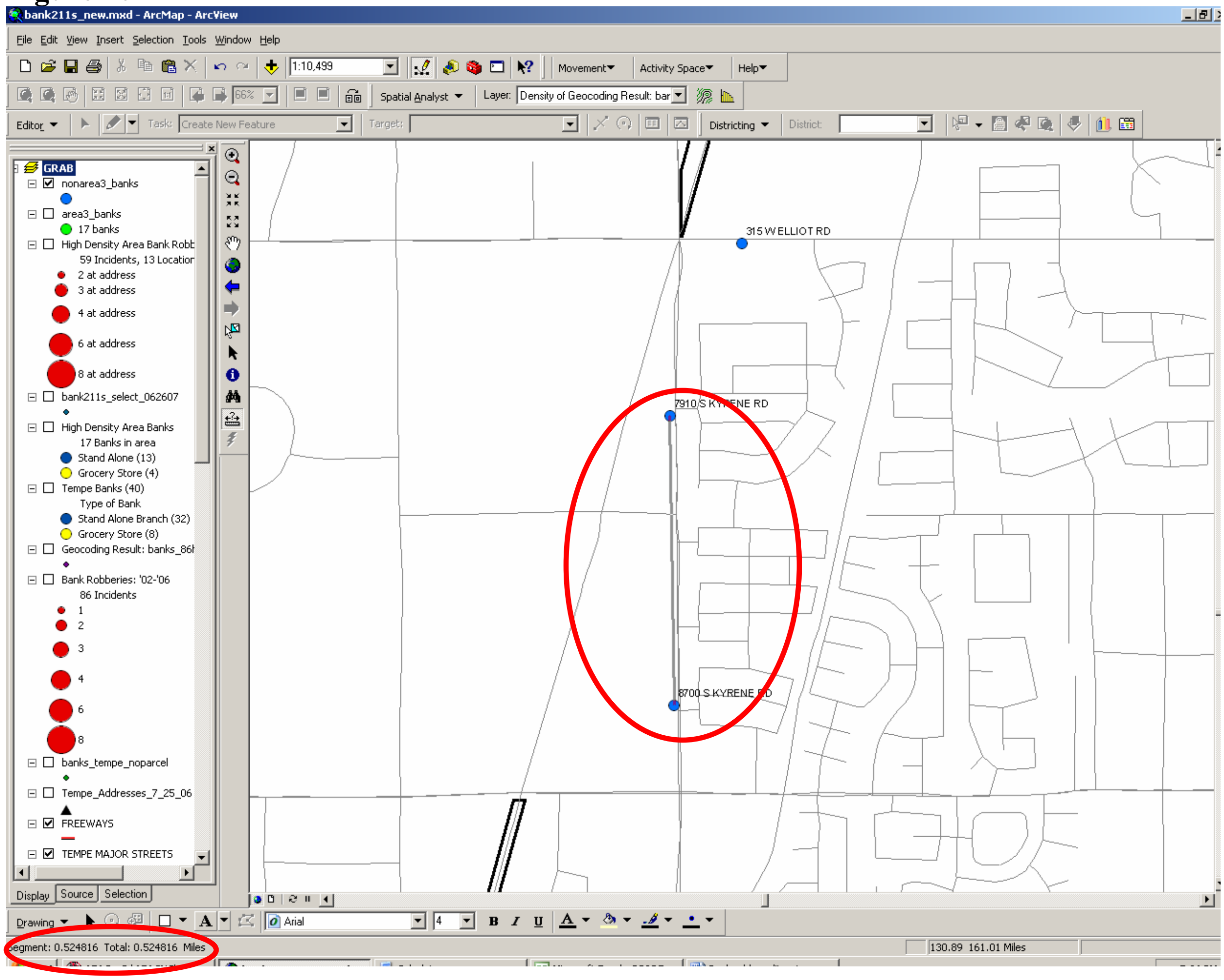
Nearest Neighbors

The concept of using the mean nearest neighbor as a study variable is that clusters of banks create a target-rich environment. It is theorized that such an environment is more conducive to bank robbery than isolated banks. Similar to the surrounding density variable, more “organized chaos” in a relatively small geographic area lends itself to greater target selection and a higher rate of bank robbery.

Additionally, this variable has the potential to show a “greater-risk bank.” This means that when comparing a bank to its next closest location, one may experience much more robbery activity than the other. The bank not being robbed is thus overshadowed and is not a victim, while the greater-risk bank is the common target. The bank being robbed is attractive to offenders more often and it is potentially deflecting attention away from a similar bank very nearby.

This calculation was based on Euclidean distance for reasons similar to calculating the distance-to-freeway. Specifically, there is a lack of one-way streets in Tempe, and often multiple options of travel for the same destination are available. Similar to the distance-to-freeway measurement, often during this calculation the Euclidean path followed an arterial street. Figure 20 is an example of a nearest neighbor distance.

Figure 20

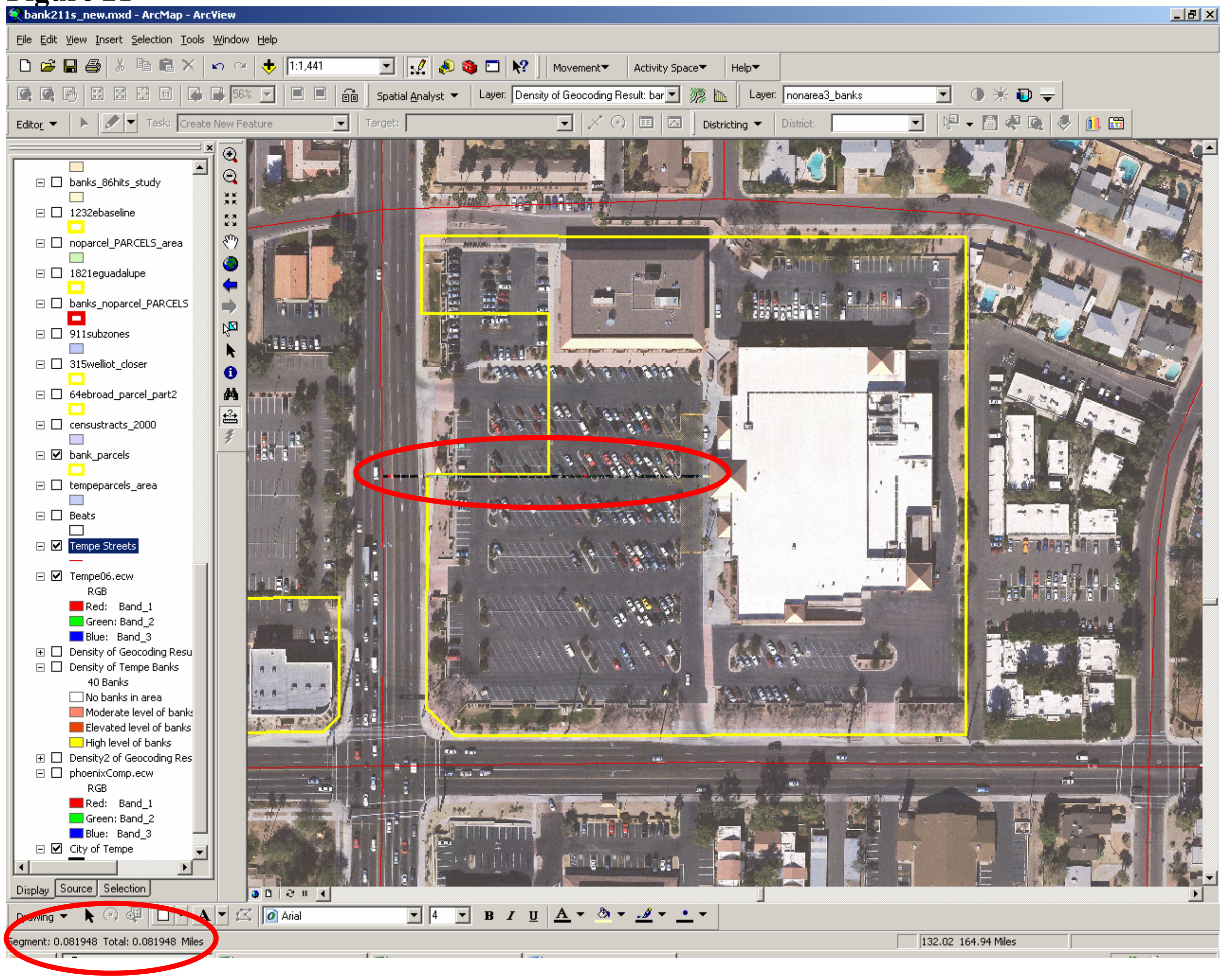


Building-to-street Distance

This variable was defined as the straight-line distance from the physical structure of the bank to its nearest point on the street centerline. This measurement begins within the parcel and extends out to the street. The theory behind this is to determine whether the physical layout has a relationship with a bank's robbery activity. This includes the size of the parking lot. A large parking lot gives space and options to an offender. A small parking lot lacks these features but may support a faster escape (through less internal traffic). In addition, a large building-to-street distance may suggest a small distance from the rear of the building to the parcel edge, which potentially interferes with alternative escape plans. Ideally, this measurement would be calculated in terms of “front door” distance, from street to bank. However, given the limitations of aerial photography and the subjective nature of determining a “front door,” the distance of building edge to street centerline was used to ensure accuracy and consistency.

However, the direction that a building *faces* was taken into account. Thus, the distance was calculated based on the front of the building to the street centerline. Furthermore, when locating the front of a building was still problematic, the distance was calculated based on the building edge to the street from which the address derives its name. For instance, for the bank at 2700 West Baseline Road, the distance was calculated from the building to Baseline Rd. Figure 21 is an example of this measurement.

Figure 21



Therefore, it is these seven vulnerability variables which were chosen for analysis: location type, distance-to-freeway, parking lot egress, parcel size, surrounding area density, nearest neighbor and building-to-street distance. Each variable offers unique potential for relationships between bank robberies and geography-based target selection.

Data Analysis

General

Figure 22 details the rankings for each bank's vulnerability variables, their mean rank and the number of robberies experienced in this time period. While it is tempting to immediately compare bank vulnerability rankings of locations in the High Density Area (HDA) to those that are not, it is essential to provide some preliminary correlations of all the Tempe banks. These findings could help understand expected results as banks in specific areas are compared.

Analyzing the relationship between bank type (stand-alone or grocery store) and its robbery frequency revealed a moderate positive correlation (r^2=.303). A bank in a grocery store tends to be robbed more often than a stand-alone bank. There appear to be great differences between the individual grocery stores banks, which a more in-depth analysis will likely reveal.

Conversely, a weak negative correlation was found between distance-to-freeway and the frequency of being robbed (r^2=-.131). A negative correlation in this variable confirms the notion that as the distance to the freeway for a bank decreases, the number of robberies at a location increase. Thus, despite this weak correlation score, it is the banks *closer* to freeways that are robbed more often.

When analyzing all forty Tempe banks a moderate positive correlation was found between the number of parking lot egresses and the frequency of being robbed (r^2=.334). As the number of egresses increases, the frequency of robbery also increases. This is not surprising, and confirms initial theories that offenders would select targets with increased options for flight.

Figure 22

Bank Name	HDA	Location	Freeway	Park. Lot	Parcel	Density	Near. Neigh.	Build-to-street	Mean	Robberies
1st Federal Credit Union	Yes	9	17	15	21	22	15	35	19	2
Desert Schools	No	9	37	15	17	1	35	20	19	0
1st National Bank	Yes	9	8	15	38	16	21	34	20	4
TruWest Credit	No	9	15	15	20	40	36	11	21	0
National Bank of Arizona	Yes	9	10	9	4	7	24	8	10	0
US Bank	No	1	30	9	9	12	16	17	13	1
1st National Bank	No	9	18	9	1	39	20	30	18	0
Chase Bank	Yes	9	6	15	11	8	33	13	14	2
World Savings Bank	No	9	28	35	32	20	27	27	25	2
US Bank	Yes	9	4	15	37	31	7	25	18	4
Bank of America	Yes	9	4	15	31	15	1	21	14	3
Bank of America	No	9	26	35	25	19	28	28	24	3
Washington Mutual	No	9	23	15	35	30	5	19	19	0
Chase Bank	No	1	20	1	2	29	6	2	9	0
Chase Bank	No	9	24	35	39	28	11	39	26	1
M&I Bank	No	9	14	15	34	26	25	32	22	3
Chase Bank	No	9	20	15	23	5	29	9	16	2
Arizona Federal Credit Union	No	1	11	3	10	35	37	24	17	0
Tempe Schools	Yes	9	22	9	13	24	2	7	12	0
Chase Bank	No	9	38	15	15	38	8	12	19	0
Bank of America	Yes	1	13	3	5	18	22	4	9	8
Wells Fargo	Yes	1	11	1	6	25	12	3	8	6
Arizona Central	No	9	1	15	22	34	40	18	20	2
Chase Bank	Yes	9	33	7	18	33	13	23	19	8
Chase Bank	Yes	9	2	9	29	4	32	22	15	2
Bank of America	Yes	1	3	3	8	21	9	6	7	4
Wells Fargo	Yes	9	15	15	16	10	17	14	14	6
M&I Bank	No	9	29	35	40	12	3	40	24	1
Wells Fargo	Yes	9	39	15	24	17	26	33	23	0
Bank of America	No	9	32	35	19	11	18	36	23	2
Compass Bank	No	9	25	15	27	9	23	29	20	0
Arizona Bank & Trust	No	9	35	15	12	37	10	38	22	0
Washington Mutual	Yes	9	6	15	36	23	14	37	20	0
Arizona Federal	No	9	19	15	28	3	39	16	18	2
Wells Fargo	No	9	27	35	30	27	19	10	22	2
Tempe Schools	No	9	35	9	7	32	30	15	20	3
Bank of America	Yes	9	8	15	26	6	4	26	13	4
Chase Bank	No	9	31	15	33	2	34	31	22	0
Wells Fargo	Yes	1	34	7	14	14	31	5	15	6
Bank of America	No	1	40	3	3	36	38	1	17	3

* Bank specific addresses are omitted for security reasons.

Parcel size, however, did not initially reveal any patterns in robbery activity. Correlating the parcel size of each Tempe bank and its robbery frequency revealed a very weak positive correlation (r^2=.003). In other words, there is virtually no relationship between the size of the bank parcel and the number of times it is robbed. There are several *potential* explanations for this lack of correlation:

- A majority of banks with a similar parcel size and inconsistent robbery frequencies
- Banks with a wide variety of different parcel sizes and consistent robbery frequencies

Regardless of which explanation is correct, at this point it appears that parcel size is not a good indicator of bank robbery activity.

Similarly, comparing the density of the surrounding area of each bank to its frequency of being robbed, there was a very weak positive correlation (r^2=.024). This attempts to show as the density in a bank's immediate area increases, so does its frequency of being robbed. However, the result is so weak that it is difficult to draw that conclusion. This is somewhat surprising, given the amount of overlap in the Density Areas observed in Figure 18. What appears to be occurring is the most dense and least dense banks are *not* being robbed. The two densest and four least dense banks all were not robbed. It is the banks that are *moderately* dense that are experiencing high bank robbery activity.

A correlation of nearest neighbor distances and the frequency of bank robbery yielded a weak negative relationship (r^2=-.132). Thus, there is a weak relationship between how close a bank is to other banks and how often it is robbed. This is interesting, as it suggests that as banks are found closer together, their robbery activity appears to increase. This supports early theories involving the density of all Tempe banks, and specifically, the creation of the HDA.

Finally, comparing the building-to-street distances of the Tempe banks to their robbery frequencies revealed a moderate positive relationship (r^2=.346). As a bank's distance from the street increases, the number of times it is robbed also increases. Similar to parking lot egress, this implies that a larger parking lot presents an offender short-term comfort in escaping the crime scene.

Figure 23 displays all the vulnerability variables and their correlation scores.

Figure 23

Correlation of Variable w/Robbery Frequency	r^2 value
Location Type (Grocery vs. Stand-alone)	0.303
Distance-to-freeway	-0.131
Parking Lot Egress	0.334
Parcel Size (area)	0.003
Surrounding Area Density	0.024
Nearest Neighbor	-0.132
Building-to-street Distance	0.346
Average Correlation score (absolute value)	0.182

The essential findings of these correlations are not causality, but that there are meaningful relationships between the frequency of being robbed and *some* of the geographic variables. Specifically, location type, parking lot egress and building-to-street distance, and potentially, distance-to-freeway and nearest bank neighbor demonstrate some interesting relationships. Analyzed broadly, this could suggest that banks inside of grocery stores with large parking lots possessing multiple points of egress that are close to the freeway as well as other banks are robbed more often and repeatedly than banks with a different geographic footprint. Additionally, based on these correlations, it appears that the density of addresses surrounding a bank and the size of the bank's parcel have virtually no relationship to its robbery frequency. This supports neither Routine Activities Theory nor the Density Paradox. However, these correlations do not explain the phenomenon of the high robbery numbers for banks in the High Density Area (HDA).

Comparative Data Analysis

Inside vs. Outside

Understanding the general trends in bank data for the entire city, tests were run to discover clear vulnerability differences of banks inside and outside the HDA. Using the initial correlations as a guide, these tests sought to further identify commonalities.

Comparatively, two of the total eight grocery store banks experienced no robberies in this time period. Both of these were located outside the HDA. Overall, the four grocery store banks outside the HDA accounted for 4 of 27 robberies outside the area, or 14.8 %. The four banks inside the HDA were all robbed. They accounted for 24 of 59 of the bank robberies in that area, or 40.7 %. These differences were found to be statistically significant ($t(6)=4.63$) at $p>.05$. This confirms (and exceeds) the previous correlations. Thus, it appears grocery store locations in the HDA are more likely to be robbed.

Distance-to-freeway, while a weak correlation on the citywide level, was stronger when further analyzed. The seventeen banks inside the HDA had a mean distance from the freeway of 0.69 miles, and the twenty-three banks outside the HDA had a mean distance of 1.01 miles. These distances were found to be statistically significant ($t(38)=2.38$) at $p<.05$. This further solidifies a previously weak negative correlation observed for all Tempe banks. This variable, along with location type, is potentially a reason for the high count of robberies in the HDA.

Interestingly, parking lot egress contradicted earlier analysis when examined within the HDA. The seventeen banks inside the HDA had a mean of 3 parking lot egresses. The twenty-three banks outside the area had a mean of 2.3 egresses. These differences were found not to be statistically significant ($t(38)=1.62$) at $p>.05$. Parking lot egress does not appear to be an explanation for the high robbery numbers inside the HDA. While there was a moderate positive correlation for all Tempe banks for this variable, it does not appear to account for the difference between areas.

Parcel size, which had virtually no correlation citywide, continued to not be a factor in this comparison. The seventeen banks inside the HDA had a mean parcel size of 142,649 feet, and the twenty-three banks outside the area had a mean size of 170,489 feet. This difference was not statistically significant ($t(38)=.39$) at $p>.05$. This result confirmed original correlation analysis, and demonstrates that parcel size does not appear to be a beneficial variable in comparison of the two areas.

Surrounding area density produced similar results. The seventeen banks inside the HDA had a mean density of 693 addresses, and the twenty-three banks outside the area had a mean density of 631 addresses, a difference not statistically significant ($t(38)=.42$) at $p>.05$. This confirms earlier correlations for the entire city; density does not seem to be a distinguishable variable when comparing banks and robbery frequencies, regardless of their HDA status.

The nearest neighbor statistics, in contrast, should reveal clear differences between the HDA and other banks. The seventeen banks in this area had a mean nearest neighbor of 991 feet, compared to a mean of 2860 feet for banks outside the HDA. This difference was statistically significant (t(38)=2.63) at p>.05. Thus, there is a difference in clustering. The HDA was based on the density of banks, so the banks in the HDA were expected to be closer (on average) to other banks. It appears that this distance may help explain high robbery numbers.

Finally, building-to-street distance appears affected by HDA status. The seventeen banks in the HDA had a mean building-to-street distance of .038 miles, and the banks outside the area had a mean distance of .028 miles. This difference was not statistically significant (t(38)=1.33) at p>.05. Despite a moderate positive correlation for all Tempe banks, those banks in the HDA are not statistically further from the street than those outside the HDA.

Figure 24 summarizes these findings.

Figure 24

Comparison of Banks in High Density Area vs. Banks outside of Area

Variable	t test score*	Result
Location Type	4.63	Statistically significant
Distance-to-freeway	2.38	Statistically significant
Parking Lot Egress	1.62	Not statistically significant
Parcel Size (area)	0.39	Not statistically significant
Surrounding Area Density	0.42	Not statistically significant
Nearest Neighbor	2.63	Statistically significant
Building-to-street Distance	1.33	Not statistically significant

(* two-tailed t tests for independent means)

Thus, when comparing banks inside the HDA to banks outside the HDA, there are three vulnerability variables that stand out as clearly significant – location type, distance-to-freeway and nearest neighbor. On average, banks in the HDA are closer to the freeway *and* are closer to other banks. However, four banks in the HDA were not robbed in this time period; a comparative analysis of banks robbed in the HDA and banks not robbed in the HDA is necessary.

Inside vs. Inside

While location type has thus far proven to be an important variable in assessing a bank's vulnerability, it cannot be analyzed here. All grocery store banks in the HDA were robbed (and quite regularly) during the time period – which itself is a statement about the strength of this variable.

However, the same cannot be said for vulnerability based on the distance-to-freeway. Thus far, this variable had correlated (relatively) high and been statistically significant. However, when comparing the thirteen banks inside the HDA that were robbed (mean distance of 0.628 miles) to the four banks that were not robbed (mean distance of 0.903 miles), the differences were not statistically significant ($t(15)=1.124$) at $p>.05$. This variable does not explain why these four banks in the HDA were not robbed.

The parking lot egress variable could potentially isolate banks with clearly different parking lot structures, and lend insight into why particular banks were not robbed. However, this was not the case. The thirteen banks inside the HDA that were robbed had a mean 3.154 parking lot egresses. The four banks inside the area that were not robbed had a mean of 2.5. This difference was not statistically significant ($t(15)=.857$) at $p>.05$. Similar to earlier findings, egress is not able to explain the lack of robberies at these four locations.

Parcel size, up to this point an ineffective vulnerability variable, remained consistent. The mean parcel size of banks robbed in the area was 135,959 feet. The mean size of banks not robbed in the area was 164,391 feet. This difference was found to be not statistically significant ($t(15)=0.30$) at $p>.05$. Once again, it does not appear to relate to bank robbery activity.

Similar to parcel size, the surrounding area density has not provided much insight. The trend continued in this analysis: the mean density of the thirteen robbed banks in the HDA was 700.54 addresses, and the mean density of the four banks not robbed in the area was 668.5 addresses. The difference was not statistically significant ($t(15)=0.190$) at $p>.05$.

Mean nearest neighbor has given valuable perspective in the previous tests. However, it does not appear to explain the robbed versus not-robbed differences among banks in the HDA. The mean nearest neighbor of banks robbed in the HDA was 836.68 feet; the mean of banks not robbed was 1491.60 feet. Despite the latter being almost twice as far as the former, the difference was not statistically significant ($t(15)=1.175$) at $p>.05$.

Lastly, the building-to-street variable demonstrated moderate correlations citywide, and insignificant differences when analyzing the HDA – mixed results. In this case, the mean building-to-street distance for the thirteen robbed banks was 0.039 miles. The mean for the four banks not robbed was 0.035 miles. This difference was not statistically significant ($t(15)=0.274$) at $p>.05$.

Figure 25 summarizes these results.

Figure 25

Comparison of Banks Robbed vs. Banks Not Robbed (all in High Density Area)

Variable	t test score*	Result
Distance-to-freeway	1.124	Not statistically significant
Parking Lot Egress	0.857	Not statistically significant
Parcel Size (area)	0.3	Not statistically significant
Surrounding Area Density	0.19	Not statistically significant
Nearest Neighbor	1.175	Not statistically significant
Building-to-street Distance	0.274	Not statistically significant

(* two-tailed t tests for independent means)

These findings would suggest that among all analyzed variables there are no significant differences between banks robbed and banks not robbed in the HDA. The largest differences, distance-to-freeway and nearest neighbor (which were found to be significant in the earlier tests comparing banks inside the HDA and banks outside) suggests that robbed banks are (again) closer to the freeway and closer to each other. Yet these differences are not significant. This warrants a more in-depth analysis.

HDA Banks: Robbed

For a better appreciation of the banks that were robbed in the High Density Area, correlations were run on each vulnerability variable and the frequency of robberies at each of the thirteen robbed banks.

Location type has consistently been a strong vulnerability factor. In this instance, a moderately strong positive correlation (r^2=.482) was found between location type and robbery frequency of the thirteen robbed HDA banks. Grocery stores make up four of the thirteen robbed banks in this area (31%), yet account for 24 of 59 bank robberies (41%). Each grocery store in the area averages 6 bank robberies, while stand-alone banks in the area average 3.89 robberies (grocery stores outside the HDA average 1 bank robbery).

Distance-to-freeway as a vulnerability variable is interesting. There is a moderately strong positive correlation between robbery frequency and distance-to-freeway of the thirteen robbed banks in the HDA (r^2=.557). This is somewhat contradictory to previous analyses. This correlation shows that as the distance-to-freeway *increases*, the frequency of robberies also increases. Previous analysis demonstrated that distance-to-freeway has consistently been the variable that has shown relationships with increased robberies and *decreased* distance. However, it appears there may be a threshold among banks already located in a High Density Area that have been statistically proven to be closer to the freeway. The possibility exists of being *too* close to the freeway.

It is not only possible, but statistically significant. By comparing means of distance-to-freeway of the top five robbed banks in the HDA to the bottom eight banks using a one-tailed t test, the differences are found to be statistically significant ($t(11)=2.45$) at $p>.05$. Thus, it appears that the banks most often robbed are not those that are *the* closest to the freeway, but rather are *generally* close to the freeway. Banks can be *too* close to the freeway.

Examination of parking lot egress also proves insightful. A strong positive correlation ($r^2=.593$) suggests that as the number of parking lot egresses increase, the frequency of being robbed also increases. Similar (but stronger) to the citywide egress correlation, this score shows that while egress may not be a factor in determining whether a bank will get robbed, it does prove useful in analyzing how *often* it gets robbed.

Parcel size demonstrates similar results. A moderately strong positive correlation ($r^2=.459$) was found between parcel size and robbery frequency. This is the first time this variable has shown any comparative or significant value in this study. This result is consistent with location type; most grocery store banks are large parcels. Considering the percentage of robberies in the HDA that occur in grocery store banks (41%), this result should be somewhat expected.

Similar to parcel size, surrounding area density has not been very productive. However, a moderately strong negative correlation ($r^2=-.501$) illustrates that as the surrounding density of a robbed bank in the HDA decreases, robbery frequency increases. This result suggests that more isolated banks have experienced greater robbery activity. This is somewhat contradictory to the theory that greater density allows a greater ability to blend, thus increasing the robbery potential at banks in denser areas. However, it is very consistent with the Density Paradox Theory. In Tempe, a lack of potential witnesses (guardians) may outweigh the standard chaos of a densely frequented area.

Nearest neighbor proves to be different when comparing only robbed banks in the HDA. A moderate positive relationship (r^2=.388) exists between nearest bank neighbor and robbery frequency. Robbery frequencies increase as banks are closer together. This is different than density, as nearest neighbor is only comparing the proximity of banks to each other. Therefore, combining the results, clusters of banks in isolated areas could experience more robberies.

Lastly, building-to-street distance was not significant in previous tests but did correlate on a citywide level. When comparing robbed banks in the HDA, the results were similar: a moderately strong relationship (r^2=.526) between building-to-street distance and robbery frequency. This finding is consistent with the location type and parcel size variables; most grocery store banks are on large parcels and have spacious parking lots, increasing their building-to-street distance.

Figure 26 summarizes these results.

Figure 26

Correlation of Variable w/Robbery Frequency	r^2 value
Location Type (Grocery vs. Stand-alone)	0.482
Distance-to-freeway	0.557
Parking Lot Egress	0.593
Parcel Size (area)	0.459
Surrounding Area Density	-0.501
Nearest Neighbor	0.388
Building-to-street Distance	0.526
Average Correlation score (absolute value)	0.501

Thus, it appears that the combination of these variables may contribute to the high amounts of robberies at these locations. However, these correlations are not perfect, as four banks were not robbed at all. Further, while none of these four banks were grocery stores, they do collectively rank

- Fifth in distance to freeway (one of the four banks)
- Fourth and fifth in least surrounding density (two of the four banks)
- First and sixth in parcel size (two of the four banks)
- Third in nearest neighbor (one of the four banks)
- Fifth and sixth in largest building to street distance (two of the four banks)

The correlations may help interpret repeat incidents at a location, but do not entirely account for the banks not robbed. Further analysis is required.

HDA Banks: Not Robbed

To understand why four of the banks in the HDA were not robbed in this time period, the statistics must be revisited with a qualitative approach, with particular attention to the unique factors among these locations.

To begin, most banks (even inside grocery stores) are small physical structures. While grocery stores can be quite wide, they are typically not tall. Usually in Arizona and especially Tempe, they are one story buildings. Two banks not robbed in the HDA are two stories high, and a third is a 10+ story, multi-building office complex. Simply put: *these three banks do not look like banks*. Research has shown that a majority of banks have uniform layouts and security measures (Weisel 2007). A lack of uniformity appears to relate to a robber's comfort level. The three banks described above possess this lack of uniformity, and therefore a lack of robbery activity. Each is at least two stories tall and shares the building with several other businesses/offices. Multi-story banks do not fit the typology of a typical "bank." At first sight, they appear to be offices, not banks. It is no surprise that these three have not been robbed; it appears these aesthetic qualities outweigh geographic variables. In other words, it does not matter that these banks are in the HDA because they do not have the same qualities as other HDA banks. Naturally, they were not robbed.

(Interestingly, the fourth bank not robbed does not fit this office/business complex exterior layout. However, the earliest police call for service at this location is February 2006, indicating that it has now been open for the majority of the time period studied. This gives this bank roughly one year for the "opportunity" to be robbed in this study. Previous research has shown that as time advances, banks increase their chance for robbery (Weisel 2007).)

The distance-to-freeway variable has interesting implications. The difference in distance-to-freeway between banks robbed in the HDA and banks not robbed was not found to be statistically significant. However, the banks not robbed represent two of the four farthest banks from the freeway (including the farthest, which is more than five times as far from the freeway as the closest bank in the HDA). Previous tests between the banks in the HDA and those not in the HDA revealed their distance-to-freeway as a significant factor. Furthermore, one of the banks not robbed in the HDA was the fifth *closest* bank to a freeway. As other previous analysis demonstrated, it is possible to be too close to the freeway. This may, in part, explain the absence of robberies at these locations.

The four banks not robbed in the HDA each represent the two lowest scores for parking lot egresses (2 and 3). Interestingly, some banks in the HDA with 2 and 3 egresses experienced as much as six robberies. However, every bank in the HDA with 2 or 3 egresses that *was* robbed was also connected via parking lots to a strip mall or office complex. This gives these banks an enhanced parking lot size, with naturally more egresses and greater access to roads. Of the four banks not robbed, two are isolated and have *no* connections to adjacent parking lots, and a third has very limited parking lot connections. Therefore, these banks are limited by their own parking lots.

Figure 27 demonstrates this difference in parking lot connectivity. Both banks were scored as having the same number of egresses; however their adjacent property may alter the offender's perception.

Figure 27


Bank with attached Parking Lot (six robberies)


Bank without attached Parking Lot (zero robberies)

As for parcel size, a bank with the largest parcel area was not robbed, and a bank with the third smallest area was not robbed (the other two banks not robbed rank sixth and eleventh largest). Most analysis in this study found little (and often no) relationship between parcel size and robbery activity. It is far too simplistic (and incorrect) to say that only small banks or large banks are targeted, especially given the skew of the parcel area data (skew=2.56, n=40). Rather, this variable does not appear to be a good indicator of bank robbery activity in Tempe.

With regard to surrounding area density, the mean for banks robbed in the area is 700 and the mean for banks not robbed is 669. However, the data for banks not robbed is skewed. Of all seventeen banks in the area, the third densest bank is one which experienced no robberies. Only one of the top five *robbery* locations in the HDA ranked among the top five *densest* locations. On the other hand, two banks not robbed ranked as the fourth and fifth least dense banks in the area. The top five robbery locations represent two of the three least dense banks. This demonstrates that surrounding area density among banks not robbed is not a simple rule; it proves to be an inaccurate measure of robbery activity.

Nearest neighbor is an interesting calculation. Three of the four banks not robbed in the High Density Area account for three of the bottom five nearest neighbor distances. However, it appears possible (and likely) that these four banks are not robbed because they each have a nearest neighbor that is consistently robbed. Three of the banks not robbed have a nearest neighbor that has been robbed *at least six times* (and two of these three are nearest to a bank robbed eight times). The fourth bank has two neighbors of virtually the same distance which total five robberies. The pattern is clear: these banks are continually avoided, not necessarily by their own vulnerability but based on the *higher* vulnerability of their neighbors. It is logical that they are not chosen as they are located in an area (the HDA) which appears to have “better” targets.

This analysis of nearest neighbors is able to transcend individual offenders. The variables that make a target appealing to one offender are the same which make it appealing to other, like-minded ones. Research has shown that certain typologies of offenders prefer certain bank characteristics (Weisel 2007). This serves as an essential piece to the explanation of these four banks.

Furthermore, building-to-street distances were varied among the banks not robbed. The bank with the closest building-to-street distance was not robbed. Two of the bottom six banks in the HDA for this variable were not robbed. It is very possible that being extremely close and extremely far from the street has an effect. Similar to the distance to freeway calculations, a “closeness” threshold may exist.

What can be deduced from this analysis is that banks not robbed in the HDA are not uniform – they have vastly different parcel areas, densities, proximities to the freeway and building to street distances. These variables, which for the most part were not proven to be indicative of robbery when applied to entire sample (with the exception of distance to freeway), are not the essential measures. It is the characteristics they do share – parking lot egress, lack of typical building structure and (most importantly) frequently victimized nearest neighbors – that appear most indicative for their lack of robbery activity. While this study has explained the commonalities among the most frequent victims (location type, distance to freeway, nearest neighbor), it is just as important to recognize these characteristics among the non-victimized. The exterior layout/design of the banks not robbed appears to be an important indicator. This is something that *can* be controlled by a bank. However, the nearest neighbor measurements appear to be a strong indicator of a lack of robbery activity. This was shared among all banks not robbed in the HDA. Interestingly, it also may be the most difficult for a bank to control.

Figure 28 summarizes the results of all tests on the original hypotheses.

Figure 28

#	Hypothesis	Support/Explanation
1	Banks with optimal escape routes will be robbed more often than banks without.	**Yes:** In all Tempe banks, parking lot egress correlated moderately strong with robbery frequency. Comparing banks in the HDA to those outside, distance-to-freeway was significantly different. Grocery store banks consistently proved to be significantly different and a more common target.
2	Robbed banks will be surrounded by banks that are not robbed.	**No:** Original density maps of the Tempe banks demonstrated roughly 1/3 of all banks accounted for more than 2/3 of bank robberies. **Yes:** All banks not robbed in the HDA each had a nearest neighbor with an exceptionally high robbery frequency.
3	Banks which lack uniformity will experience less robbery activity.	**Yes:** All robbed banks in the HDA had moderate/strong correlations with each variable. The 4 banks in the HDA that were not robbed exhibited noticeable factors of difference, especially building design, lack of parking lot connectivity & extreme building-to-street distances.

Conclusions

Policy Recommendations

Law Enforcement

One of the primary goals of this study is to successfully affect police response to bank robbery. By understanding how and why a bank is chosen as a target, ideally this study will lead to the quicker apprehension of offenders. Obviously, this effect would have to be measured over time. However, it is the hope that this project not only encourages further research, but also establishes a relevant connection to standard operating procedures. For example, if a particular bank is continually robbed, and one of its strongest vulnerability variables is its parking lot egress, police response can be geared toward cutting off this egress, or following specific travel paths. This would be a real application of the study. It is a *proactive* response in a typically *reactive* situation.

Furthermore, this study has the potential to increase the effectiveness of bank security plans. By understanding the geographic features that appear to be good predictors of robbery (and repeated victimization), there can be a coordination of individual response plans for specific banks. This can be done retroactively for the forty current Tempe banks, as well as a standard measure for any new bank construction. At a minimum, group response plans for typologies of banks should be created. For example, banks found in the HDA that are stand-alone, possess three or less parking lot egresses, and are close to the freeway, warrant a specific response. The goal is to move away from one uniform police response simply because it is a common crime. Instead, this attention to detail when responding to a location needs to be considered. This does not necessarily have to be the responsibility of the patrol officer, but possibly a support services function (dispatcher, crime analyst).

This study should be used in the identification of serial bank robbers. Beside the obvious factors (i.e. surveillance images, composite sketches, modus operandi), an investigative “profile” could be constructed for an offender. This profile would be solely based on target selection, and would not include inferences about the individual’s personality or characteristics. It would be a comparison of the vulnerability variables of the targeted banks to comprehend what factors are consistent for that offender. The model could be applied to other locations and analyzed for potential future targets. This would aid investigators in forecasting future robberies from that suspect. Used in conjunction with additional spatial and temporal analysis, this study could increase the quality of surveillance conducted on specific offenders.

Banks

This study should be used to make banks aware if they are “high” risk. Obviously banks know how often they are robbed, but they may not know their comparative rank among their financial counterparts in the city. Understanding not only where their location ranks but *why* it does could help keep employees alert. However, this needs to be taken cautiously, as it has the potential to incite fear in bank employees. The goal is to spread useful information in a productive manner to maximize its use. Educating employees about the realities of a location does this. There must be a delicate balance between crime prevention and causing an environment of fear.

Another implication is the possibility of altering current locations. This could involve re-routing traffic flow within a parking lot, or disabling access to adjacent lots (both of which would appear to have positive effects based on this study). Unfortunately, this is unlikely to occur, largely because of cost and feasibility. However, if money were irrelevant, the main alterations that do not involve complete reconstruction are only the ones suggested above. Other characteristics (location type, parcel size) are rather permanent. Further, any drastic changes would have to be weighed against customer comfort and convenience. In a market-driven society these are real cost-benefit considerations that a business will have to weigh.

Along the same lines, the removal of banks from grocery stores would likely have a strong effect on robbery locations. No longer building banks inside grocery stores would terminate a very popular target type. Not only is this not likely to occur (for many of the same reasons mentioned previously about for-profit businesses), but it also raises the issue of displacement. Bank robberies are likely to still occur, and location preferences of offenders would shift based on the available targets. Removing a type of target will not necessarily eliminate that crime.

The reality is that from a corporate standpoint not much can be done to an existing location. However, future developers should factor these considerations into the planning process. Obviously, most business decisions are made with a focus on profit, customer comfort and access, but the reality is that a new bank should take the potential for being robbed into account. On the other hand, these policy implications are great for police. Given constant demands on a small work force, efficiency is essential.

Increasing staffing levels may appear to be the fix, but working intelligently and more effectively could be more successful.

Suggestions for Further Research

The intent of this study was to contribute to the growing body of research on bank robbery and geographic/spatial analysis. While this study provides a thorough review of banks and bank robbery data for a five year time period in the City of Tempe, there is always opportunity for further research. From a local perspective, these same vulnerability variables should be analyzed against a larger data set, encompassing more years of bank robbery activity. One downside to this approach (and one of the reasons that a five year range was chosen) is that going too far back may lose contemporary relevance. Just as this study excluded three bank robberies because the banks no longer existed, a more historical approach will likely experience this at a greater rate. Benefits can still be gained, but the applicability to specific banks that are *currently* in operation may be lost.

Beyond the City of Tempe, these variables should be applied to other cities in Maricopa County. This has the potential to show larger patterns and correlations. What was demonstrated in Tempe may not apply to all cities in the area. Obviously, the data collection and analysis would be more rigorous, but using this study as a model could help.

Furthermore, the variables introduced in this study should be tested against other geographic areas. A comparison of rural, suburban (which would accurately characterize Tempe) and urban areas may reveal noteworthy similarities and differences. Potentially, models for these different city types could be developed. Therefore, once a city was appropriately categorized, bank characteristics typical for similar cities could be quickly determined. This could result in widespread use of this and similar studies.

What is important to remember is that this study, to an extent, served as a trial and error of vulnerability variables. From the results, one can learn what was found to be significant and what was not. These share equal importance. Determining which variables were not significant lends as much insight to the issue as the variables that were significant. Further, variables not significant in this study may prove otherwise when applied to different geographic areas or larger data sets.

These broader comparisons will undoubtedly involve understanding the underlying geography and street networks of each city analyzed. While comparing Tempe to New York City may not initially appear appropriate, some interesting comparisons could be made. For example, a variable of significance in Tempe (nearest neighbor) may prove to be not significant in New York City, and vice versa (i.e. surrounding area density).

From a GIS standpoint, this study was limited by the accuracy of geocoding, aerial photography and computer measurements for data analysis. In future research, actual physical measurements could be obtained and site visits could be conducted at each location. This would be a *very* time consuming process, and may not significantly increase accuracy, but the possibility exists.

One of the strongest suggestions for further research is to interview convicted robbers. These interviews should be structured towards understanding the geographic considerations (if any) the offender employed when planning and executing the robbery. Questions could include reference to the following:

- Pre-incident planning
    - Target selection
    - Escape plan
    - Expectations
- Post-incident actions
    - Getaway
    - Execution of any pre-incident plans
- Appealing and unappealing bank variables
    - Most and least noticeable features which attracted offender to target(s)
- Knowledge of the target's geography
    - Awareness of the vulnerability variables

These answers have the potential to confirm or refute the findings of this study. It is the hope that this study has laid some of the groundwork for further research in this arena. Additional work in spatial analysis of crime will strengthen criminological theory and increase the effectiveness of practical decisions in law enforcement.

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