The Spatial Relationship Between Crime and Public Transportation: A Geospatial Analysis of Salt Lake City's Trax System

Joel W. Warren
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/etd

Part of the Landscape Architecture Commons

Recommended Citation

This Thesis is brought to you for free and open access by the Graduate Studies at DigitalCommons@USU. It has been accepted for inclusion in All Graduate Theses and Dissertations by an authorized administrator of DigitalCommons@USU. For more information, please contact digitalcommons@usu.edu.
THE SPATIAL RELATIONSHIP BETWEEN CRIME AND PUBLIC TRANSPORTATION:
A GEOSPATIAL ANALYSIS OF SALT LAKE CITY'S TRAX SYSTEM

by

Joel W. Warren

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF LANDSCAPE ARCHITECTURE

Approved:

Sean E. Michael, PhD
Major Professor

Shujuan Li, PhD
Committee Member

Scott C. Bates, PhD
Committee Member

Mark R. McLellan, PhD
Vice President for Research and Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2014
ABSTRACT

The Spatial Relationship Between Crime and Public Transportation:
A Geospatial Analysis of Salt Lake City's TRAX System

by

Joel W. Warren, Master of Landscape Architecture
Utah State University, 2014

Major Professor: Dr. Sean E. Michael
Department: Landscape Architecture and Environmental Planning

Crime patterns exist. Some urban areas, or hot spots, have a disproportionate level of crime density than others. Researchers have argued that criminal events require the intersection of a motivated criminal with a suitable target in space and time. Studies have shown that criminals generally choose targets from among places they encounter on daily transportation routes. This suggests that changes in a city's transportation infrastructure will be correlated with shifts in the location of hot spots. Crimes may cluster around transportation nodes after new stops are opened. Research thus far, however, has been unable to demonstrate the pattern hot spots follow after major transportation changes. The answer to this question is important because it would allow for a more effective response to societal changes following transit development.

(157 pages)
PUBLIC ABSTRACT

The Spatial Relationship Between Crime and Public Transportation: A Geospatial Analysis of Salt Lake City's TRAX System

Joel W. Warren

It is well-known that, when it comes to crime, some neighborhoods are safer than others. Researchers who make maps of crime have observed that some areas of cities have more crime than others. These areas of high crime are often called hot spots. Crime pattern theory explained why some neighborhoods have more crime than others by looking at criminal events as a meeting between a motivated criminal and a target. Social scientists, geographers, and city planners have shown that criminals generally choose targets from places they see every day, for example on their ride to work or the grocery store. This means that when the daily routine of a criminal changes, the location of that person's criminal behavior could change too. When trends in the daily routine of a whole city change, the location of crimes in that city could change because criminals, in general, will choose targets from different places in the city. In fact, some researchers have suggested that crimes will become clustered around transportation nodes, such as street car stations, after new lines are opened. But so far only a few studies have tried to demonstrate the pattern hot spots follow in the years following major transportation changes. The answer to this question is important to urban designers and police because it would allow them to respond to changes in the location of hot spots when new public transportation projects occur.
ACKNOWLEDGMENTS

I would like to thank my committee members, Drs. Sean Michael, Shujuan Li, and Scott Bates, for their support. I also wish to give special thanks to my wife Megan for her patience.

Joel W. Warren
# CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>iii</td>
</tr>
<tr>
<td>PUBLIC ABSTRACT</td>
<td></td>
<td>iv</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td></td>
<td>v</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>ix</td>
</tr>
<tr>
<td>I.</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II.</td>
<td>LITERATURE REVIEW</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Patterns of Crime</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Hot Spots</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Crime Pattern Theory</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Target Selection</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Changes in Hot Spot Location</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Need to Understand Relationship of Patterns to Public Transportation</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Hypothesis</td>
<td>18</td>
</tr>
<tr>
<td>IV.</td>
<td>METHODOLOGY</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Source of Methodological Approach</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Data Source</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Data Exploration</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Hot Spot Existence</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Hot Spot Location</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>Relationship to Transportation Nodes</td>
<td>35</td>
</tr>
<tr>
<td>V.</td>
<td>RESULTS</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Hot Spot Existence</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Hot Spot Location</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Relationship to Transportation Nodes</td>
<td>44</td>
</tr>
<tr>
<td>VI.</td>
<td>DISCUSSION</td>
<td>53</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prior Studies Summary</td>
<td>16</td>
</tr>
<tr>
<td>2. TRAX Stations by Date</td>
<td>28</td>
</tr>
<tr>
<td>3. Average Nearest Neighbor Test Results</td>
<td>41</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Dynamic search area</td>
<td>8</td>
</tr>
<tr>
<td>2.</td>
<td>Example of geocoded crime incidents</td>
<td>26</td>
</tr>
<tr>
<td>3.</td>
<td>Example of size graduated markers exploration</td>
<td>27</td>
</tr>
<tr>
<td>4.</td>
<td>Example of kernel density results</td>
<td>30</td>
</tr>
<tr>
<td>5.</td>
<td>Getis-Ord Gi* test example</td>
<td>33</td>
</tr>
<tr>
<td>6.</td>
<td>Final hot spot location for burglary 2000</td>
<td>35</td>
</tr>
<tr>
<td>7.</td>
<td>Service area overlap example</td>
<td>38</td>
</tr>
<tr>
<td>8.</td>
<td>Average number hot spots per year</td>
<td>43</td>
</tr>
<tr>
<td>9.</td>
<td>Average hot spot size per year</td>
<td>44</td>
</tr>
<tr>
<td>10.</td>
<td>Aggravated assault mean center test results</td>
<td>45</td>
</tr>
<tr>
<td>11.</td>
<td>Rape mean center test results</td>
<td>46</td>
</tr>
<tr>
<td>12.</td>
<td>Larceny mean center test results</td>
<td>46</td>
</tr>
<tr>
<td>13.</td>
<td>Arson mean center test results</td>
<td>47</td>
</tr>
<tr>
<td>14.</td>
<td>Burglary mean center test results</td>
<td>48</td>
</tr>
<tr>
<td>15.</td>
<td>Homicide mean center test results</td>
<td>48</td>
</tr>
<tr>
<td>16.</td>
<td>Robbery mean center test results</td>
<td>49</td>
</tr>
<tr>
<td>17.</td>
<td>Motor vehicle theft mean center test results</td>
<td>50</td>
</tr>
<tr>
<td>18.</td>
<td>Average distance from crime incidents to nearest TRAX nodes</td>
<td>51</td>
</tr>
<tr>
<td>19.</td>
<td>Service area overlap</td>
<td>52</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

For centuries, researchers have attempted to discover the root cause of crime. But it was not until the early 1900s that criminologists and social scientists began studying not why crime exists, but where. Each theory that sought to explain crime was the product of its social and political context (Lilly, Cullen, & Ball, 2011). Crime itself is an ever-changing and extremely complex phenomenon. This means that while each theory throughout the history of criminology has shed some light onto the question of why crime exists, no single theory has been able to adequately explain crime.

The classical school of criminology, which drew heavily from the Greco/Roman tradition, claimed that criminals by nature act in a self-interested way. Modern rational choice theory can trace its roots back to the classical school. This theory claimed that criminals seek to manage effort, risk, and reward (Cornish & Clark, 1986). With the rise of social Darwinism in the mid-1800s came early theories of biological positivism. These theories claimed that crime exists due to the genetic makeup of individuals (Lilly et al., 2011). Clues to an individual's genetic predisposition to crime, according to this theory, were manifested in a person's physiology. Perhaps the most famous adherent to early biological positivism was Cesare Lombroso who sought to identify “atavistic” tenancies among prison inmates by measurements of their physical characteristics (Lilly et al., 2011; Lombroso, 1876). The “school” of biological positivism held sway among criminologists until mass immigration, the Great Depression, and the World Wars of the early 1900s began to change people's world view. Widespread societal changes led to the
development of mainstream criminology, often referred to as the Chicago School (Lilly et al., 2011). The primary characteristic of Chicago School theorists was that they began to reject individually-based explanations of crime and to look outward toward societal explanations. It was during this time period that spatial theories of crime emerged.

In order to help explain rapid changes that were occurring in American cities due to mass immigration, Ernest Burgess developed the concentric zone theory. This theory divided a typical city into various rings or zones beginning with a central core (Burgess, 1925; Lilly et al., 2011). Commercial entities were located in the central core in order to take advantage of transportation resources. On the other hand, Burgess observed that expensive residential neighborhoods tended to be located on the outside ring of city because those with higher income were able to afford living far from the discomfort and crowding of the city center.

But what did Burgess’s concentric zone theory have to do with crime? Even early studies of urban crime were explicit about the spatial nature of crime (Reckless, 1933). The concept that some urban areas, or hot spots, have a disproportionate level of crime is still relevant (Gorr & Kurland, 2012; Weisburd, Bushway, Lum, & Yang, 2004). But it was Burgess’s model that led early Chicago School theorists to discover that neighborhood organization was instrumental in the location of crime (Gibbons, 1979; Lilly et al., 2011; Pfohl, 1985). Shaw and McKay (1972) used Burgess’s model to explain how the nature of a person's neighborhood, rather than the nature of the individual, could explain criminal behavior. They argued that in Burgess’s zone of transition the lack of institutional soundness among schools and churches, coupled with poverty, high turnover in housing, and a complex mixture of ethnic and racial identities
led to a phenomenon they termed “social disorganization.” It was this chaotic social environment, the by-product of a rapidly changing urban form, which, in many people's minds, was responsible for crime.

Later, Burgess’s model was replaced by more complex models of urban development. But the idea that the urban form could have an influence on criminal behavior has remained a fundamental tenant of criminology. The social upheaval of the late 1960s and the 1970s led to such theories as labeling theory, conflict theory, Marxist, feminist, and white-collar theories (Lilly et al., 2011). These theories in many ways represented a departure from spatially-oriented criminological theories. For example, conflict theory concerned itself mostly with the power structure of society and how corporate environments contribute to business-related crime.

The conservative era that began in the 1980s and continues to this day, however, constitutes a resurgence of interest in the spatial aspects of crime. These theories include, broadly, rational choice, broken windows, routine activities, and environmental criminology. Such theories differ markedly from the Chicago School because they place the onus of crime back on the individual, rather than on society at large (Lilly et al., 2011). But while modern conservative theories assume that individuals, not society, are responsible for the existence of crime, they also claim that individual behavior is influenced by one's environment. For example, Wilson and Kelling's (1982) “broken windows theory” was based on the concept that social disorganization led to crime through environmental cues. In other words, “disorderly people” who caused minor crimes such as vandalism, vagrancy, and loitering gave signals to other would-be criminals that a particular neighborhood lacked the social structure required to deter
criminal events. In this sense, as with other modern conservative theories, the urban environment acted as a stage, or a backcloth, on which criminal events took place (rather than as a root cause).

Routine activities theory took the examination of criminal environments to a new level by drawing its focus from rational choice theory. Rational choice theory stated that criminals seek to manage effort, risk, and reward in order to accomplish their self-interested, immediate gratification (Cornish & Clark, 1986; Lilly et al., 2011). Cohen and Felson's (1979) routine activities theory argued that particular environments were more conducive to criminal behavior based on one's ability to manage effort, risk, and reward within that environment (Lilly et al., 2011). As such, criminal behavior tended to occur within a person's daily routine. Furthermore, it was the absence of guardians, such as a family at home or a security guard that allowed a criminal to reduce risk and effort in exchange for a perceived reward. While routine activities theory still sought to explain the root cause of crime, relying heavily on rational choice theory, subsequent research sought to explain why crime happens in certain locations.

Crime pattern theory sought not to explain why crime exists, rather to explain patterns of crime. In other words, crime pattern theory was not focused on the why of criminology, but the where. Crime pattern theory explained spatial patterns of crime by defining a criminal event as the opportune cross product between a motivated criminal and a suitable target in space and time (Brantingham & Brantingham, 1993; Paulsen & Robinson, 2009). This theory was in many ways a combination of previous theories, including rational choice, routine activities, and environmental criminology theories. The theory's focus on process rather than causation also led it to incorporate the concept of
paths, nodes and edges (Paulsen & Robinson, 2009). This trio of concepts was first introduced by Kevin Lynch (1960) in his central work *The Image of the City*. Lynch suggested that people understood their environment through their interaction with paths, such as sidewalks, nodes, such as intersections or destinations, and edges, such as walls or city boundaries—in addition to districts and landmarks (Lynch, 1960). The Brantinghams took this concept a step further by suggesting that the way criminals interacted with paths, nodes, and edges influenced the city-wide pattern in which crimes were carried out. Currently, the primary criticism against crime pattern theory is that it is largely untested (Paulsen & Robinson, 2009). This is, in part, due to the difficulty of verifying mental maps. But mapping software, such as ArcGIS, allows researchers to test other key parts of the theory (Paulsen & Robinson, 2009). It is partly for this reason, to fill a gap in the literature on the subject, that this thesis was chosen.

The connection between Lynch’s research and the field of criminology is indicative of a wider trend of landscape architects becoming involved in criminological research. In fact, the spatial nature of crime offers a superb opportunity for the study of crime by landscape architects. The holistic approach landscape architects take toward social problems lends itself well to the complexity of crime and security (Vale, 2005). Successful implementation of this approach in projects with strong emphasis on criminal behavior and security include the Washington Monument, Pennsylvania Avenue, the World Trade Center redesign, various military installations, and other high-profile or at-risk sites (Blumenauer, 2002; Courtenay, 2002; Forgey, 2002; Hammatt, 2002; Mather, 2002; May, 2002; Sipes, 2002; Speckhardt & Dowell, 2002).
The approach landscape architects take toward design allows them to balance the prevention of criminal behavior with other critical factors, such as public perception. For example, while concrete barriers around at-risk sites provide protection from violent attacks by vehicles, they also create a sense of fear among pedestrians (Blumenauer, 2002; Courtenay, 2002; Forgey, 2002; Hammatt, 2002; Mather, 2002; May, 2002; Sipes, 2002; Speckhardt & Dowell, 2002). Landscape architects successfully replaced concrete barriers with calming, yet just-as-effective planters, stone work, and other design elements in the Washington, D.C. area among others (Blumenauer, 2002; Courtenay, 2002; Forgey, 2002; Hammatt, 2002; Mather, 2002; May, 2002; Sipes, 2002; Speckhardt & Dowell, 2002). Even minor details such as plant choice, a critical area of knowledge common to most, if not all, landscape architects, can play an important role in security design (Brigham, 2002).

Landscape architects are trained to anticipate human behavior. The classic example of the anticipation of human behavior through design is William Whyte's observation of the environmental influences on human behavior in public plazas (Whyte, 1980). Whyte found that while behavior may have seemed unpredictable, when one considered the environment in which behavior takes place, certain society-wide conclusions could be made. For example, the observation that people preferred to sit in the shade during the hottest parts of the day allowed one to predict with reasonable certainty the location at which most people would sit in any given plaza (Whyte, 1980). When one considers that criminal behavior is merely a specific type of human behavior, or site use, it is easy to see how training among landscape architects lends itself well to the study of criminology. The success of former American Society of Landscape
Architects (ASLA) president Leonard Hopper in reducing crime in New York City's public housing through behavior-oriented design is yet another indication that the relationship between landscape architecture and criminology will continue to grow (Hopper & Droge, 2005; Vale, 2005). Hopper and his associates were successful in replacing illegitimate behavior, such as violence or the sale of drugs, with community-building behavior based on their analysis of the urban environment (Bloom, 2009). Again, it is the focus on human behavior in response to environmental cues that allows such projects to be successful.

Most of the projects discussed thus far have focused on site-level planning and design. The same concept, however, applies to neighborhood or even city-wide projects. The Brantinghams' (1981) study, *Notes on the Geometry of Crime*, was based on city-level, aggregate behavior. The study was based, in part, on prior research which indicated that criminals generally chose suitable targets from among places they encountered on daily transportation routes (Brantingham & Brantingham, 1981). They argued that if a criminal's mental map was subject to those areas which the criminal encountered on a daily basis, and if targets were chosen from a criminal's mental map, then changes to the criminal's daily routine would result in changes in the location of criminal activity. This suggested that changes in a city's transportation infrastructure would be associated with shifts in the location of hot spots. (Brantingham & Brantingham, 1981; Paulsen & Robinson, 2009). Diagrams from this study show how areas of high daily activity could also become high crime areas.
The concept of hot spots, or areas with high concentrations of crime, is a well-accepted aspect of crime analysis. Mapping hot spots is a common task for crime analysts (Gorr & Kurland, 2012). In fact, hot spot mapping has been a part of criminal research even since the early days of modern criminology. Modern studies have confirmed what early research suggests about crime: that criminal events tend to cluster in certain parts of a city (Weisburd et al., 2004). Hot spot mapping is important to police because hot spots change over time and because they tend to indicate areas where police intervention is most important (Gorr & Kurland, 2012). Hot spots are not to be confused with the related, yet separate concept of revictimization. Revictimization is when
individuals are victimized by criminals more than once while hot spots describe areas of high crime (Paulsen & Robinson, 2009).

The existence of hot spots is considered an empirical reality (Paulsen & Robinson, 2009). Studies which have established the empirical reality of hot spots are numerous. But one notable example is Sherman, Gartin, and Burger's (1989) study of 323,979 calls to police. Hot spots have been shown to exist for virtually every type of crime (Brantingham & Brantingham, 1999). Researchers have studied homicide, gang violence, liquor-related crime, drug crimes, burglary, and more.

While the existence of hot spots is not generally debated, explanations for their cause and descriptions of the way in which hot spots change over time is still an important area of research (Paulsen & Robinson, 2009). Any number of societal anomalies may influence the location of hot spots. Sherman (1998) was one of the first modern researchers to propose why certain neighborhoods have higher than expected levels of crime. He cited community composition, social structure, oppositional culture (due to financial strain), criminogenic commodities, and physical disorder as possible reasons a neighborhood could be considered more dangerous than others (Sherman, 1998). But the extent to which neighborhood factors, including the physical environment, are responsible for hot spot location remains undetermined (Paulsen & Robinson, 2009). Technological advancement in crime mapping software, however, may allow researchers to better understand these societal processes.

It was not until recently that bus stops and public transportation became a focus of research into hot spot location (Loukaitou-Sideris, 1999). Similarly, it was not the intention of the Brantingham's Notes on the Geometry of Crime to debate the existence of
hot spots. Rather the intent was to propose ways in which hot spots may change over

time, when they suggested that changes in societal transportation patterns would result in

changes in the location of hot spots.

The proposition that hot spot location has some relationship to transportation

nodes, despite its implications, has not been widely tested. Research thus far has been

unable to demonstrate the pattern hot spots follow during major changes in transportation

infrastructure. In other words, researchers know that hot spots of crime exist and have

suggested that hot spots change over time in response to societal changes. The way in

which hot spots change has yet to be determined. The answer to this question is

important to urban designers and police because it may allow more accurate response to

city-wide crime in the wake of transportation development.

While the cause of crime has been discussed for centuries, the actual dynamics of

the way crime changes in space over time has been left relatively unexplored. The

purpose of this study, therefore, is to describe whether and how hot spots move during a

time period where major changes in transportation infrastructure have occurred.

Specifically, this study proposes to a) determine the location of hot spots each year by

crime type, b) determine whether or not the location of hot spots is statistically due to

chance (i.e., validate the hot spot location), and c) describe any patterns hot spots follow

over time as they relate to transportation nodes.
CHAPTER II
LITERATURE REVIEW

Patterns of Crime

Early research into the nature of crime has shown that crime is not spatially ubiquitous. Some areas of a city have more crime than others because crime is spatial in nature. In fact, without the element of place, a crime cannot occur (Paulsen & Robinson, 2009). Like any other social phenomenon, crime tends to cluster in areas that are more conducive to its existence.

Hot Spots

This means that some urban areas generate a disproportionate level of crime (Weisburd et al., 2004). Such areas could be considered criminogenic because they exhibit conditions which lead to criminal behavior (Naess, 1964). Many studies have been conducted which sought to identify the most dangerous parts of cities (Block & Block, 1995; Block & Christakos, 1995; Eck & Weisburd, 1995; Green, 1995; Sherman et al., 1989; Sherman & Rogan, 1995). Areas typically exhibiting higher than normal clustering of crime have included bars, entertainment districts, and bus stops (Cochran, Bromley, & Branch, 2000; Roncek & Maier, 1991; Thomas & Wolfer, 2003). The existence of hot spots and their location within neighborhoods is a well-established phenomenon. But the study of city-wide patterns is a more recent development.
Crime Pattern Theory

Crime pattern theory, one of many spatial theories of crime, was developed to explain not why crime occurs, but why it occurs in certain places. Patricia and Paul Brantingham (1993) theorized that “each criminal event is an opportune cross-product of law, offender motivation, and target characteristics.” Certain characteristics made some targets more attractive than others, and to appear more suitable to the offender. One could argue that if a criminal event requires the cross-product of law, offender motivation, and a suitable target, the absence of a suitable target will preclude a crime event.

Theoretically, this means that if opportunities or suitable targets shift spatially, crime should follow. This primary limitation of this theory, however, is that it is largely untested (Ratcliff, 2006; Tita & Griffiths, 2005). On the other hand, advancements in crime mapping software have improved the ability to test this theory.

But what makes some targets suitable while others are not? While many factors may contribute to the decision to commit a crime, a motivated offender’s ideal target is one that provides minimal risk, with maximum gain (Shannon, 1988). For example, in the case of burglary, those sites that provide minimal risk to offenders are the ones located within their own area of experience. The more a burglar knows about a site, the greater the burglar's opportunity to reduce risk. Furthermore, the areas close to one’s home are the places one is most familiar with (Carter & Hill, 1979). If a burglar knows when a certain home is vacant, the burglar can assume the house will be unoccupied during a certain time, thus reducing the risk of being caught.
Target Selection

Criminals tend to choose targets from within their own mental map, or an internal, personal image of their own neighborhood (Eck & Weisburd, 1995; Garling, 1986; Genereux, 1983). While it is impossible to measure a person's mental map directly, studies have shown that mental maps are limited to those areas a person experiences often (Brantingham & Brantingham, 1993). Reason dictates that if an individual has little access to transportation, that person's primary area of experience will be smaller, resulting in a restricted mental map. It follows that if a criminal lives in an area where access to transportation is limited, that person's choice of suitable targets will come from within a constricted area. On the other hand, if a criminal has access to transportation, the criminal will be active over a broader geographic area.

The idea that hot spots will change location following major changes in transportation infrastructure can be traced back to Burgess’s early work on the growth of a city (Burgess, 1925). Burgess suggested that areas with high mobility, activity, and changes in movement patterns were associated with higher levels of crime. The Brantinghams (1981) theorized that changes in transportation patterns would result in changes in the spatial pattern of crime because people's mental maps would change along with their daily routes. While the implications of this theory are substantial, the ways in which patterns of crime may change shortly after the implementation of a new transit system have not been established (Paulsen & Robinson, 2009).

Changes in Hot Spot Location

Prior studies that examined the movement of crime in general tended to focus on
single types of crime, especially homicide (Cohen & Tita, 1999; Cork, 1999; Fishcher, Anderson, Hickman, & Heatlie, 2002; Mencken & Barnett, 1999; Messner et al., 1999; Morenoff & Sampson, 1997; Rice & Smith, 2002; Rosenfeld, Bray, & Egley, 1999; Smith, Frazee, & Davison, 2000). Overall, such studies lacked a cohesive framework and methodology. But as an early effort they indicated that crime did move over space and time. Such studies tended to focus on diffusion in general rather than on clustering around specific nodes.

The Brantinghams' study, *Notes on the Geometry of Crime*, was not an empirical study; rather it sought to pull from earlier works on the location and movement of crime in order to derive a central theory that described a phenomenon upon which those works agreed (Brantingham & Brantingham, 1981). The study made several proscriptive statements toward a central theory. Among these was the concept that spatial patterns of crime were dependent upon the distribution of offenders, the distribution of potential targets, the awareness space of offenders, the perceived quality of the target, and interchange of information between criminals (Brantingham & Brantingham, 1981).

Furthermore, the Brantinghams' (1981) study suggested that “development of major transportation arteries [led] to a concentration of criminal events close to highways, particularly near major intersections.” On the other hand, major nodes could exist on other forms of transportation, such as streetcar stops, and the convergence of awareness spaces at these nodes should result in clusters of crime (Brantingham & Brantingham, 1981). The fundamental concept the study described is that if a community generally relied on one form of transportation, when another form was introduced, the pattern of crime clusters shifted toward the nodes of the newly-introduced infrastructure.
Paulsen and Robinson (2009) also cited the relationship between transportation nodes and patterns of crime as an area of potential future research. Little or no doubt exists about whether or not hot spots move over time. But the way in which clusters move in relation to transportation nodes has not been adequately described by prior research.

Need to Understand Relationship of Patterns to Public Transportation

An extensive search has uncovered several prior studies which examined the effect the opening of transit lines had on patterns of crime clusters. While these studies are related in the sense that they all examined the relationship between crime and public transportation, they varied widely in scope and approach. In general, such studies attempted to answer the question: did new public transit systems in certain neighborhoods increase crime in that neighborhood?

Of the eight primary studies in this group, only one found a decrease in crime (Billings, Leland, & Swindel, 2011). Out of those that found an increase, one study reported an increase in inner-city crime while crime in surrounding suburbs decreased (Ihlanfeldt, 2003). Another study found an immediate increase in crime around nodes followed by a decrease (Poister, 1996). Block and Block (2000) found that crime increased in areas 1 to 1.5 blocks from new stations. Other studies found an increase in crime, but attributed the increase to other factors. Plano (1993) cited lack of data at the census block level as a reason no attribution could be assigned. Another study found that having a small sample size resulted in no relationship (Liggett, Loukaitou-Sideris, & Iseki, 2002). A subsequent study by the same team of researchers showed that crime did
not move in correlation with transportation nodes (Liggett, Loukaitou-Sideris, & Iseki, 2003). An eighth study found that crime tends to cluster around areas of high activity, including transportation nodes (Uittenbogaard, 2013). The discrepancies among the outcome of these studies could be due to variations in the methodological approach, sources of data, differences in scope, variation between cities, or a number of other factors.

### Table 1

<table>
<thead>
<tr>
<th>Study</th>
<th>Type</th>
<th>Years</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plano, 1993</td>
<td>Trends within service areas</td>
<td>6</td>
<td>Cannot attribute increase to rail</td>
</tr>
<tr>
<td>Poister, 1996</td>
<td>Piecewise regression</td>
<td>4.5</td>
<td>Increase at opening followed by decrease</td>
</tr>
<tr>
<td>Block &amp; Block, 2000</td>
<td>Spatial analysis of robbery only</td>
<td>1</td>
<td>Increased 1–1.5 blocks from stations</td>
</tr>
<tr>
<td>Liggett et al., 2002</td>
<td>Qualitative &amp; quantitative</td>
<td>1</td>
<td>Sample size too small to rule out other factors</td>
</tr>
<tr>
<td>Ihlanfeldt, 2003</td>
<td>Economic model</td>
<td>4</td>
<td>Increase in city, decrease in suburbs</td>
</tr>
<tr>
<td>Liggett et al., 2003</td>
<td>Spatial analysis, regression</td>
<td>10</td>
<td>Crime not transported to suburbs</td>
</tr>
<tr>
<td>Billings et al., 2011</td>
<td>Quasi-experimental</td>
<td>10</td>
<td>Decrease</td>
</tr>
<tr>
<td>Uittenbogaard, 2013</td>
<td>Spatial analysis, regression</td>
<td>4</td>
<td>Crime clusters around nodes</td>
</tr>
</tbody>
</table>


Although previous studies varied in data, scope, location, and outcome, some generalities about their approach can be drawn. All studies in this group agreed that it was only through the close examination of more transit lines that the relationship between
nodes and crime patterns could be appropriately defined. Almost all mentioned that future studies should focus on change over time, and must therefore require a large temporal data set. Another area of consensus was the focus on nodes, and the area within walking distance of those nodes. The primary shortcoming in all studies of this kind was that they failed to describe the way in which patterns of crime changed during the time period.

The contribution this thesis seeks to make to the existing body of literature is to a) examine a city where this type of study has not been done before, b) to provide an adequate description of the way in which crime patterns (the location of clusters of crime) change in that city, and c) to describe additional, incremental methodological steps which go beyond the approach taken by previous studies.

This furtherance of this particular vein of research may also prove to be a valuable communication tool between transportation planners, urban designers, and law enforcement. Urban designers often claim to influence the health, safety, and welfare of a place (Kaplan, Kaplan, & Ryan 1998; Lynch, 1984). But inasmuch as public planning projects such as transit lines can influence people's behavior for the better, such projects would be improved if all types of behavior, including crime, in the area were fully understood. If the body of research to which this study belongs could provoke a future discussion between planners and law enforcement, much progress could be made toward planning for safety. It is for that reason, in part, that the methodology for this thesis is based on the practical application of hot spot policing.
Hypothesis

Broadly, this study could be considered a work of correlational research because it seeks to describe the patterns that exist between two aspects of the social environment: crime and public transportation (Groat & Wang, 2002). This study is a relationship study, as opposed to a causal-comparative study, because it does not seek to ascribe causal power to any variable (Groat & Wang, 2002). On the contrary, the purpose of this study is to map and describe patterns based on observations and exploration of an existing data set; not to determine why crime happens in certain locations, but to measure where it has happened over time. In this sense, the study is also archival in nature because it seeks to put an existing data set to use (Groat & Wang, 2002).

The null hypothesis for this study is that crime does not cluster around transportation nodes after the implementation of public transit. But the answer to this question requires several intermediate steps.
CHAPTER III
METHODOLOGY

Source of Methodological Approach

While prior studies have disagreed on the appropriate methodological approach for this type of research, the practice of crime mapping has provided an appropriate way of answering the fundamental question of this thesis. The methodology used to answer that question was recommended due to its ability to overcome the shortcomings encountered in prior studies (Billings et al., 2011; Block & Block, 2000; Ihlanfeldt, 2003; Liggett et al., 2002, 2003; Plano, 1993; Poister, 1996). It was also recommended by Paulsen and Robinson's (2009) book Crime Mapping and Spatial Aspects of Crime, and ESRI's recent publication GIS Tutorial for Crime Analysis (Gorr & Kurland, 2012). The pattern of tests outlined in these sources is both well-accepted and widely-used among crime analysts (Gorr & Kurland, 2012). The approach is practice-focused, yet based on the general theoretical foundation for crime mapping (Gorr & Kurland, 2012). The GIS Tutorial for Crime Analysis coincides with and reinforces the concepts found by Paulsen and Robinson. As a central textbook on crime mapping, Paulsen and Robinson's (2009) book covered both theoretical and practical applications.

According to Paulsen and Robinson, there are both advantages and disadvantages to the approach outlined below. One advantage of dual kernel density mapping is that it allows researchers to measure changes in crime patterns over time. This is an explicit requirement past studies have made for future studies of this type (Paulsen & Robinson, 2009). Kernel density provides the true shape of the hot spot and a constant density
(Paulsen & Robinson, 2009). Although kernel density is somewhat subjective (there is no clear definition of what a hot spot is throughout the field of criminology) it is also statistically better at determining hot spots because it is more objective than other approaches (Levine, 2006). Other disadvantages or sources of error are mentioned at each step outlined below.

One advantage which must be mentioned about this study's methodological approach centers on the question of point versus aggregate data. Point data are popular in crime analysis because they are straightforward, they work well for determining spatial patterns, they allow for large scale analysis, and they are not dependent on jurisdictional boundaries (Paulsen & Robinson, 2009). On the other hand, aggregate data (or data that has been summed up for a specific geographic unit, such as a block) can compare rates of crime and have more practical significance because they can be applied to police beats (Paulsen & Robinson, 2009).

There are a few drawbacks for both point and aggregate data which it is important to make note of. Despite their ease of use, it is difficult to compare point data to other data which are aggregated (Paulsen & Robinson, 2009). Also, geocoding (or creating points out of addresses from a table) is a potential source of error due to poor data entry or incidents that occur at locations without a specific address (Paulsen & Robinson, 2009). Issues with aggregate data include its inability to describe cross-boundary phenomena (Paulsen & Robinson, 2009). Another problem is the ecological fallacy, which states that aggregate data cannot inform personal or individual behavior (Rossomo, 2000). This means that to assume crime will occur at an individual level based on city-wide patterns would be fallacious.
In light of the advantages and drawbacks of each data type, it follows that an ideal methodological approach would use both. If the point data and aggregate data methods for the same area agree, then a stronger argument for the validity of the outcome can be made. This aspect is evident in the original outline for the method this thesis follows (Gorr & Kurland, 2012).

It is worth mentioning here that some scholars have disagreed with hot spot policing in general and they have claimed that it is a tautological process (Lilly et al., 2011). The concern is that if a certain area is labeled as a hot spot, police will spend more time there. If police spend most of their time in a certain area, they will also conduct most of their arrests there. Those arrests are recorded and analyzed, thus reinforcing the high crime rate in certain areas. One could argue, however, that if crime exists there in the first place, law enforcement has an obligation to address the problem.

Data Source

Data for this project were generated at the lowest level by officer reports at the time incidents occurred. Those reports were sent to a crime analyst for classification (C. Allred, personal communication, January 26, 2012). The data were retrieved for use in this study from the Salt Lake City Police department via a Government Records Access and Management Act request (SLCPD, 2013). GRAMA reports for groups of data are usually made by the media while individual crimes can be accessed by individual citizens within reason. An initial request was made for burglary events, which was fulfilled. But as the scope of the study grew a request was made, and fulfilled, for all criminal events from 1994 to 2012 within the city boundaries. In fact, the scope of data sent would have
been even greater except that no records before 1994 were digitized. However, the raw data set spans 18 years, 4 years prior to opening of the TRAX lines to 13 years after opening. While the original data set includes data from 1994 to 2012, the exploratory phase of analysis showed that the 1994 data entries were extremely low. This could be due to the fact that data were just beginning to be computerized in Salt Lake in 1994, so some data may be missing or erroneous from that year. The temporal scope of the study was therefore restricted to the period between 1995 and 2012 to accommodate this discrepancy.

All prior studies in the literature had a more limited temporal span than this thesis, yet all agreed that a larger temporal span was required (Billings et al., 2011; Block & Block, 2000; Ihlanfeldt, 2003; Liggett et al., 2002, 2003; Plano, 1993; Poister, 1996). The largest temporal span in prior research was 5 years prior to opening and 5 years post-opening of a transit line. Prior studies of this kind also commented on the difficulty of obtaining data, and the data set obtained for this study is well in excess of that used in prior studies.

The data include all crime types (recorded at the city level, according to federal, state and local ordinances) over the 17-year span. The data include incident start date, incident start time, address (street name only), and a brief description/classification of the crime. The geographic scope of the data is the city limits of Salt Lake City.

**Data Exploration**

While the amount of data received for this study is exceptional, several additional steps were required to prepare the data for analysis. In total, the original data set contains
441,715 violations. Many of these were ruled out of the final data set due to classification. Those lines that were missing data, such as crime type or address, were also ruled out. Lines missing data, however, account for only a small portion of the total data set.

The scope of crimes in this study includes the top 8 classifications of the Unified Crime Reports system: criminal homicide, forcible rape, robbery, aggravated assault, burglary, larceny (except motor vehicle), motor vehicle theft, and arson. These classifications are considered the most serious crimes, and are arranged in a hierarchy (FBI, 2004).

Using UCR classification is a precedent set by previous studies, and seems to be a general practice in the field of criminology. UCR classification is also critical to the ability of this study to be applied to other situations. Local jurisdictions often differ in the way they classify crimes, but the UCR reports were designed to be a cross-jurisdictional format (FBI, 2004). The original data set for this study was more specific than the URC reports, having been collected at the local level. The first step in data analysis, therefore, was to reclassify the highly specific local categories into the broader UCR categories. For example, under the UCR category 'Larceny', the original local data lists: larceny of bike parts, larceny from a motor vehicle, larceny from a building (not to be confused with burglary), larceny from coin machine, larceny from government property, larceny from malls, larceny from yards, larceny no force purse snatching, larceny parts auto, and larceny shoplifting. The fact that the data goes from more specific to more general categories is one important source of informational integrity.
But classification is one possible source of error because it is impossible to know and record the exact circumstances for every incident. Furthermore, there is the issue of multiple crimes per incident. For example, how does one classify an event where an individual used a stolen vehicle to commit a drive-by shooting? Fortunately, the UCR process has a way of dealing with multiple crimes committed during a single incident (FBI, 2004). These discrepancies are usually dealt with at the local level, so it must be assumed that the crimes listed in the data are accurate to what actually occurred. It is important to recognize, however, that errors in reporting have been commonly cited as typical weaknesses in studies of this kind (Billings et al., 2011; Block & Block, 2000; Ihlanfeldt, 2003; Liggett et al., 2002, 2003; Plano, 1993; Poister, 1996).

Another commonly cited source of error for this type of study is unreported crimes. Crimes that often go unreported, such as rape, may actually exist in much higher numbers than the data show (Coleman & Moynihan, 1996; Paulsen & Robinson, 2009; Western, 2006).

Studies of crime at the city level are often unable to account for details relating to peculiarities among certain types of crime. For example, burglaries occur in very particular ways due to their nature, and cannot always be compared to robberies, which involve face-to-face interaction between the victim and perpetrator by definition (FBI, 2004). In an effort to be more sensitive to differences between crime types, the data in this study were separated into eight types rather than the traditional two (property and personal crime). The data in each category were also separated by year. Previous studies generally focused on two time periods only (before and after opening of public transit). But such studies also recommended that future studies focus on change over time rather
than just two time periods (Billings et al., 2011; Block & Block, 2000; Ihlanfeldt, 2003; Liggett et al., 2002, 2003; Plano, 1993; Poister, 1996). The ability to investigate crime year-by-year gives a more accurate picture of changes which have occurred over time.

The final step in classification of data was to geocode the incidents. Geocoding is the process by which ArcGIS mapping software turns text address information from a table into points on a map. The software uses an address locator to determine where in the city each event occurred (ESRI, 2012). Geocoding naturally results in mismatches and non-matched addresses. While non-matches are one possible source of error in the study, address locators are extremely accurate. This is in part due to the use of new online locator packages which allow sharing and composite locators (ESRI, 2012). For example, out of the 239 homicides geocoded in the study, only two were unmatched. The 10.0 US Streets Geocode Service was used because the data extent is restricted to Salt Lake City. Using the most geographically specific service also reduces mismatches.

The purpose of exploratory statistics is to describe the main features of the data (Moore, 2007). The exploratory phase should inform the development of a hypothesis (Paulsen & Robinson, 2009). But not all statistical tests require exploratory statistics, and the tests used in the study do not list any as prerequisites (ESRI, 2012). It is for this reason that the exploratory phase of this study was limited to the use of graduated point markers. It was determined, however, that the study must account for changes in base levels of crime (see Appendix A: “Base Levels of Crime”). This was measured as numbers of crime incidents per year per crime type.
As part of the exploratory phase, the data points were displayed using size-graduated point markers (Gorr & Kurland, 2012). The purpose of this step is to conduct a visual inspection of whether or not clustering exists. This step displays areas where more than one crime of a certain type occurred at the same address. This suggests that the next step, a statistical test for clustering (the average nearest neighbor test), will successfully reject the null hypothesis.
Figure 3. Example of size graduated markers exploration. This figure shows size- graduated markers for burglaries in 2000. Potential hot spots are displayed as groups of larger circles.

It was discovered during the exploratory phase that this study must account for the fact that not all TRAX lines were opened at the same time. While previous studies focused on before and after time periods based on the grand opening of a transportation system, light rail lines rarely open all at once. In the case of TRAX, lines were opened every few years from 1999 to 2012 and are in fact still being built and opened to the present day. This factor constituted another reason for doing a year-by-year analysis.
Table 2

TRAX Stations by Date

<table>
<thead>
<tr>
<th>Station</th>
<th>Address</th>
<th>Date Open</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballpark</td>
<td>180 W 1300 S</td>
<td>December 4, 1999</td>
</tr>
<tr>
<td>City Center</td>
<td>80 S Main</td>
<td>December 4, 1999</td>
</tr>
<tr>
<td>Gallivan Plaza</td>
<td>300 S Main</td>
<td>December 4, 1999</td>
</tr>
<tr>
<td>Temple Square</td>
<td>110 W South Temple</td>
<td>December 4, 1999</td>
</tr>
<tr>
<td>Delta Center</td>
<td>320 W South Temple</td>
<td>December 4, 1999</td>
</tr>
<tr>
<td>Courthouse</td>
<td>500 S Main</td>
<td>December 4, 1999</td>
</tr>
<tr>
<td>Library</td>
<td>225 E 400 S</td>
<td>December 15, 2001</td>
</tr>
<tr>
<td>Trolley</td>
<td>625 E 400 S</td>
<td>December 15, 2001</td>
</tr>
<tr>
<td>900 East</td>
<td>875 E 400 S</td>
<td>December 15, 2001</td>
</tr>
<tr>
<td>Stadium</td>
<td>1349 E 500 S</td>
<td>December 15, 2001</td>
</tr>
<tr>
<td>University South Campus</td>
<td>1790 S Campus Dr</td>
<td>September 29, 2003</td>
</tr>
<tr>
<td>University Medical Center</td>
<td>10 N Medical Dr</td>
<td>September 29, 2003</td>
</tr>
<tr>
<td>Fort Douglas</td>
<td>200 S Wasatch Dr</td>
<td>September 29, 2003</td>
</tr>
<tr>
<td>900 South</td>
<td>850 S 200 W</td>
<td>May 19, 2005</td>
</tr>
<tr>
<td>Old Greektown</td>
<td>200 South 400 West</td>
<td>April 27, 2008</td>
</tr>
<tr>
<td>Salt Lake Central</td>
<td>250 South 600 West</td>
<td>April 27, 2008</td>
</tr>
<tr>
<td>Planetarium</td>
<td>200 South 400 West</td>
<td>April 27, 2008</td>
</tr>
</tbody>
</table>

Hot Spot Existence

The purpose of the average nearest neighbor test is to determine statistically whether or not the data are spatially clustered. The test was conducted for each crime classification for each year. The null hypothesis for this test is that points are randomly distributed or that no statistically significant clustering exists (Gorr & Kurland, 2012). The calculation is based on the average distance from each point to its nearest neighboring point (Ebdon, 1985; ESRI, 2012; Mitchell, 2005).

The acceptance of the null hypothesis (that no clustering exists) for a certain data set precludes the following methodological steps for that crime type during that particular
year. The z-score from this test provides an indication of how many standard deviations an original observation is from the mean (by direction, negative for observations smaller than the mean) (Moore, 2007). For the purposes of this study, z-scores lower than -3 indicate spatial clustering exists.

The average nearest neighbor test is area-sensitive, so a standard area of 3,098,991,575 square feet (the area of the Salt Lake City boundary) will be used for all tests. While minor changes to the city boundaries have occurred over time, they are not significant enough to warrant using a different area calculation for each year. Manhattan Distance, as opposed to Euclidean Distance, was used because Salt Lake City streets and TRAX lines are oriented to a North/South East/West grid system. Manhattan Distance assumes only North/South and East/West travel while Euclidean is a straight-line distance (Ebdon, 1985; ESRI, 2012; Mitchell, 2005). This is also the calculation recommended by ESRI for this type of analysis (Gorr & Kurland, 2012). Rejection of the average nearest neighbor null hypothesis means that some process is responsible for the location of crimes in Salt Lake City, but the location of clusters of crime is still unknown at this point in the process.

**Hot Spot Location**

The purpose of this step is to determine the location of hot spots by year for all 8 crime types. Kernel density works with raster data, where each cell on a sheet indicates the mean level of crime per unit area (Gorr & Kurland, 2012; Silverman, 1986). Kernel density works by drawing a “bell” over the point (or “kernel”) with the highest level of crime (Gorr & Kurland, 2012; Silverman, 1986). This means that crimes close to a
cluster will contribute to the sum of crimes while those far away from the tip of the bell will contribute less. The search radius of the bell is determined through calibration (admittedly, a somewhat arbitrary process) in which the user visually inspects areas of density using various search radii. In fact, there is no standard way of defining numerically at what threshold a certain cluster of crime can be considered a hot spot (Gorr & Kurland, 2012; Paulsen & Robinson, 2009).

Figure 4. Example of kernel density results. This map shows kernel density for burglary in 2000.

The most reasonable hot spot boundary is determined by trial and error, with large radii showing too much smoothing and small radii too many hot spots to analyze. In all types of crime except arson and homicide, a search radius of 2000 (with area units set to
square feet) was found to be the most suitable. For arson and homicide, a search radius of 5000 (also with area units set to square feet) was used because there were less data.

It should be noted that increasing the search radius does not change the values of the output (the calculated density values) because with a larger search radius, more points will fall into a larger area. The effect is a smoother output rather than a different calculated value (ESRI, 2012; Silverman, 1986). While the same search radius was used for each crime type per year (for consistency among the type), arson and homicide required a different search radius for hot spot definition due to variance among the characteristics of each crime type.

The first step in the kernel density test is to draw rings around areas which indicate visual high concentration of crimes. Using size-graduated point markers from the exploratory phase, the person conducting the study simply draws a circle around those areas which show a large number of points in a small area. This is akin to the traditional, pre-computerized method of hot spot mapping in which an officer would place push pins in a wall-mounted map, then draw a circle around areas of high concentration (Gorr & Kurland, 2012; Paulsen & Robinson, 2009). The purpose is not to find all hot spots by eye, but simply to form a good enough sample with which to calibrate the kernel density test (Gorr & Kurland, 2012).

The original data set is made up of points. Each point indicates the address of an incident for a certain crime type by date. These points are the input for the kernel density test. A raster cell size of 50 was used in order to reduce computer processing time. Like the average nearest neighbor test, no minimum number of points is required.
Visual inspection of the kernel density test can provide strong evidence that the hot spots shift over time, but a second test is required to confirm that the hot spot locations are due to some phenomenon, not simply due to chance. The purpose of the Getis-Ord Gi* (pronounced “g-i-star”) test is to identify which clusters are not due to chance. It is a way of weeding out false-positives from the previous steps. For example, one area may look like a hot spot to the eye, but could actually be a chance circumstance and not related to any underlying social pattern.

The nature of the Getis-Ord Gi* test requires that data be aggregated. The test works by comparing incidents with the centroid of a particular area. Census blocks were used as the area because police beats and associated community problems are often exhibited at the block level (Gorr & Kurland, 2012). Previous studies also confirmed that the block should be the primary area of analysis when studying crime (Billings et al., 2011; Block & Block, 2000; Ihlanfeldt, 2003; Liggett et al., 2002, 2003; Plano, 1993; Poister, 1996). The test considers an area a hot spot if it as well as neighboring areas both have high counts, or high numbers of incidents (Gorr & Kurland, 2012; Mitchell, 2005; Getis & Ord, 1992; Ord & Getis, 1995).
The first step in the test is to create centroids for each block in the city. Census 2000 block designations were used because they fall roughly in the center of the study's time period (more so than the 2010 designations). While census block designations change by year, it is assumed that the result will be roughly the same because the Getis-Ord Gi* test compares the sum for a feature and its neighbors to the sum of all features (ESRI, 2012; Getis & Ord, 1992; Mitchell, 2005; Ord & Getis, 1995). Any crime within a 20-foot-offset from a street center line is considered part of the block (Gorr & Kurland, 2012). Once centroids are created for the census blocks, a block ID is assigned to each
crime incident. Federal Information Processing Standards (FIPS) were used because they provide codes which are unique to each census block. FIPS codes for census blocks are a concatenation of the state FIPS code, census tract code and tabulation block number (United States Census Bureau, 2011). After being joined by FIPS code (using the spatial join tool ArcGIS), summary statistics are done on the new layer to determine the number of crimes per block. This data is then exported as a table and joined with the block centroids. Null values are changed to zeros by exporting the block centroids layer to a new feature layer. The field calculator is then used to change the null values to zeroes.

Once the data is set up, the test can be conducted. The purpose is to match hot spots according to the search radius determined in the previous steps (Gorr & Kurland, 2012). This means that where a search radius of 2000 square feet was used in the kernel density test, the same radius is used in the Getis-Ord Gi* test. The false positive designation (areas classified as hot spots which are in fact only due to chance) is set at a standard level of 0.05 (Gorr & Kurland, 2012; Moore, 2007). The visual output of the test in ESRI software displays areas with a z-value higher than 1.29 as orange and previous hot spots containing lower z-values are deleted by hand.
Figure 6. Final hot spot location for burglary 2000. This image shows an example hot spot location by year and crime type. Recall that this process was repeated for all 8 crime types per year in the study period.

**Relationship to Transportation Nodes**

At this point in the literature, the methodology, in general, moves directly into discussion. Since the location of hot spots has been confirmed, the practitioner would then submit the information to officers who would then decide which action to take. The goal thus far has been to determine where hot spots are located, and in practice, law enforcement would simply visually inspect the relationship between hot spots and other factors, such as poverty, broken windows, etc. (Gorr & Kurland, 2012).

In order to conform to the purpose of this study, however, and in order to further the field of research, additional methodological steps were taken. Since there is no
precedent in the literature for subsequent steps, the best method for proceeding with the study was agreed upon after discussion with thesis committee members. The following steps also seem to be the simplest way of answering the question at hand: did the hot spots of crime in this study tend to cluster around transportation nodes over time? Furthermore, these next steps help ensure that any change indicated by the data after the implementation of TRAX did not in fact exist prior to its opening.

An additional step taken which is not in the methodological framework outlined by the literature is to further describe the nature of hot spots by examining their various attributes over time. Specifically, in order to further describe the way in which crime moves over time it was decided that the spatial area and number of hot spots be compared over time and between crime types. This allows the study to discuss not only the movement of hot spots but how hot spots change over time.

It was determined that the next step should be to measure the average distance from all crime points by year and type to transportation nodes. This will answer the question: did hot spots move toward transportation nodes or away from them over the time period? To further answer that question, the average distance from individual crime points were measured and compared. The average distance measurement was created using by doing a spatial join in ArcGIS. The spatial join allows one to measure the distance between each crime incident and the nearest TRAX node. Each point is given the attributes of the point closest to it from the other layer (the TRAX nodes layer). The TRAX node layer which was joined to each data set (by year and crime type) varied according to which TRAX stations were in existence at the time. The result is that each crime point is assigned a distance field which represents the distance from that point to
the nearest streetcar station. The average of those distance fields for each year and crime type was taken. The result is an overall indication of whether or not crime points in general moved toward TRAX stations or not during any given year for any given crime type.

An additional measure was to examine the behavior of the epicenter of hot spots over time. The use of the mean center measurement is used for this type of analysis in other studies (ESRI, 2012; Mitchell, 2005). Mean center measurements are useful for comparing the spatial behavior of large data sets because they provide an indication of the set as a whole. The mean center is the central point of all data features, or all hot spots. The mean center for each year and type was calculated, and compared to the mean center of existing TRAX stations.

An important limitation of the mean center measurement is that it is sensitive to extreme values (ESRI, 2012; Mitchell, 2005). For example, a single point located miles to the west of a certain set of points may cause the mean center to appear farther west than it otherwise would have. This means that where extreme values are present, the mean center of a set of points may be unreliable. Despite this limitation, however, the mean center tool is useful for tracking the movement of large data sets over time.
Figure 7. Service area overlap example. This example shows the level of overlap between burglary hot spots in the year 2000 with service areas from existing TRAX stations. The red area was calculated as a percentage of the dark blue (total hot spot) area.

Additionally, it was recommended that a 1/4 mile buffer be drawn around transportation nodes in order to determine whether or not hot spots overlap these areas more or less over time. This strategy conforms to one aspect of previous studies which examined crimes within walking distance from transportation nodes (Billings et al., 2011; Block & Block, 2000; Ihlanfeldt, 2003; Liggett et al., 2002, 2003; Plano, 1993; Poister, 1996). The process is to create the buffer in ArcGIS, then to measure the total area of all hot spots for that year and crime type. The total area of hot spots which overlaps the service area buffer is determined by clipping two polygons. The remaining area (the area
of overlap between hot spots and service area) is then measured and compared to the total hot spot area for that year and crime type. The percent area overlap, therefore, represents the area of hot spot polygons which overlaps the service areas of TRAX nodes as a percentage of the total area of hot spots for that year and crime type.
CHAPTER IV

RESULTS

Hot Spot Existence

This study found that hot spots existed for all crime types and for nearly all time periods. The only crime types that were not clustered during specific time periods were arson and homicide. No homicide hot spots existed during the years 1996, 1997, 2000, 2001, 2002, 2005, 2006, 2009, 2011, or 2012, and no arson hot spots existed during the years 1999 or 2008.

Those years during which no clustering existed for arson or homicide events were, out of necessity, left out of subsequent analytical steps. But among those years during which hot spots existed, several important observations can be made. Clustering for all types of crime, with the exception of arson, peaked during the years prior to the opening of the first TRAX lines. Peak years for clustering were 1996 for aggravated assault, 2000 for arson, 1996 for burglary, 1995 for homicide, 1998 for larceny, 1995 for motor vehicle theft, 1996 for rape, and 1998 robbery.

A second important trend in the average nearest neighbor test results is the propensity of z-scores to remain relatively stable after peak years. A comparison of the z-scores on a year-to-year basis following years of peak clustering shows that the level of clustering for all crime types changes very little after the first TRAX lines were opened. In other words, hot spots did not become, in general, appreciably more or less clustered over time.
Table 3

<table>
<thead>
<tr>
<th>Year</th>
<th><strong>A.</strong></th>
<th>Arson</th>
<th>Burglary</th>
<th>Homicide</th>
<th>Larceny</th>
<th>***MVT</th>
<th>Rape</th>
<th>Robbery</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>-21.81</td>
<td>-2.58</td>
<td>-40.47</td>
<td>-4.02</td>
<td>-155.27</td>
<td>-91.31</td>
<td>-9.52</td>
<td>-23.45</td>
</tr>
<tr>
<td>1996</td>
<td>-27.12</td>
<td>-4.70</td>
<td>-52.78</td>
<td>*-1.14</td>
<td>-165.82</td>
<td>-62.71</td>
<td>-14.65</td>
<td>-25.21</td>
</tr>
<tr>
<td>1997</td>
<td>-16.05</td>
<td>-3.44</td>
<td>-31.27</td>
<td>*0.30</td>
<td>-99.75</td>
<td>-35.79</td>
<td>-8.07</td>
<td>-16.24</td>
</tr>
<tr>
<td>1999</td>
<td>-20.62</td>
<td>*-0.66</td>
<td>-44.08</td>
<td>-2.02</td>
<td>-154.68</td>
<td>-48.88</td>
<td>-11.10</td>
<td>-23.90</td>
</tr>
<tr>
<td>2000</td>
<td>-21.26</td>
<td>-4.88</td>
<td>-46.48</td>
<td>-2.00</td>
<td>-146.45</td>
<td>-45.68</td>
<td>-12.51</td>
<td>-25.85</td>
</tr>
<tr>
<td>2001</td>
<td>-22.06</td>
<td>-3.53</td>
<td>-45.77</td>
<td>*-1.41</td>
<td>-152.98</td>
<td>-45.68</td>
<td>-11.81</td>
<td>-25.36</td>
</tr>
<tr>
<td>2002</td>
<td>-22.49</td>
<td>-3.54</td>
<td>-49.27</td>
<td>*-0.74</td>
<td>-160.02</td>
<td>-53.36</td>
<td>-9.24</td>
<td>-26.42</td>
</tr>
<tr>
<td>2005</td>
<td>-22.95</td>
<td>-2.23</td>
<td>-43.20</td>
<td>*-1.18</td>
<td>-146.26</td>
<td>-52.26</td>
<td>-12.46</td>
<td>-23.55</td>
</tr>
<tr>
<td>2006</td>
<td>-24.05</td>
<td>-3.12</td>
<td>-45.70</td>
<td>*-1.95</td>
<td>-139.36</td>
<td>-51.76</td>
<td>-12.68</td>
<td>-25.87</td>
</tr>
<tr>
<td>2008</td>
<td>-23.73</td>
<td>*-1.98</td>
<td>-44.08</td>
<td>-2.48</td>
<td>-149.05</td>
<td>-47.44</td>
<td>-9.43</td>
<td>-23.49</td>
</tr>
<tr>
<td>2009</td>
<td>-23.52</td>
<td>-4.00</td>
<td>-43.36</td>
<td>*0.11</td>
<td>-135.74</td>
<td>-40.49</td>
<td>-10.99</td>
<td>-22.01</td>
</tr>
<tr>
<td>2010</td>
<td>-23.62</td>
<td>-2.50</td>
<td>-41.17</td>
<td>-3.54</td>
<td>-129.82</td>
<td>-42.32</td>
<td>-12.13</td>
<td>-22.15</td>
</tr>
<tr>
<td>2011</td>
<td>-25.91</td>
<td>-4.30</td>
<td>-32.35</td>
<td>*-1.79</td>
<td>-129.96</td>
<td>-41.47</td>
<td>-12.96</td>
<td>-18.56</td>
</tr>
<tr>
<td>2012</td>
<td>-20.85</td>
<td>-3.08</td>
<td>-30.86</td>
<td>*1.33</td>
<td>-117.49</td>
<td>-37.37</td>
<td>-10.05</td>
<td>-25.42</td>
</tr>
</tbody>
</table>

* Values below -2 indicate no clustering exists for crime type during that year
** Aggravated Assault
*** Motor Vehicle Theft

Hot Spot Location

While important observations can be made about the average nearest neighbor (ANN) test results for this study, the primary purpose of the ANN test was to ensure that hot spots existed as a precursor to the kernel density tests. The kernel density tests for each crime type during each year confirmed the location of hot spots which were drawn by eye. Furthermore, the Getis Ord Gi* tests confirmed the location of hot spots drawn during the kernel density tests, with several. Those few hot spots that were shown to be
false-positives by the Getis Ord Gi* tests were invariably small and isolated. Most Getis Ord Gi* tests did not reject any hot spots. This study must conclude, therefore, that the final hot spots drawn in the analysis are not due to chance, but are in fact the result of some societal process.

A visual examination of hot spot polygons shows that most hot spots for all types of crime prior to the initial opening of TRAX tend to be located near the intersection of I-80 and I-15 (see Appendix B: “Final Hot Spot Locations”). Motor vehicle theft and aggravated assault seem to be the most centrally located while arson, burglary, larceny, rape, and robbery hot spots tend to be located just to the east of the I-80/I-15 intersection. The overall location of arson and homicide prior to the opening of TRAX is difficult to determine because the movement of hot spots for those types of crime seems to be more sporadic.

Not only the location but the fundamental characteristics of each hot spot exhibited change over time. Several important observations can be made about the number of hot spots by crime type for each year. Overall, there seems to be no indication of a common peak year for number of hot spots. The number of hot spots for each crime type seems to generally reside around two to four hot spots per year per crime type. Some types of crime exhibited higher overall numbers of hot spots per year, and it is interesting to note that this seems to be unrelated to the total number of crimes per year for that crime type. For example, motor vehicle theft has higher numbers of hot spots per year than larceny, but larceny is by far the most prevalent crime by number of incidents per year. This trend presents itself notwithstanding of the location or existence of TRAX stations.
Figure 8. Average number hot spots per year. This graph shows the average number hot spots by crime type per year.

Another important characteristic of hot spots themselves is size. Most years have average hot spot sizes from 0.72 to 2.15 square miles. While most crime types except have peak average hot spot size near the initial opening of TRAX, larceny and rape peak at 2007 and 2005, respectively. Arson and burglary have two noticeable spikes in average hot spot size. Larceny also has two primary spikes in hot spot size, but seems to remain fairly stable over time. Aggravated assault, motor vehicle theft, and rape have single spikes in size, and homicide and robbery have multiple. The only crime with peak hot spot size prior to the opening of the first set of TRAX lines is motor vehicle theft.
A comparison between the mean centers of each crime type by year and the mean center of existing TRAX stations for that year shows that hot spots did in general move over time. The mean center for TRAX stations itself, however, also moved. In general, as new stations were added to the system, the TRAX mean center moved from east to west. Only between the fourth and fifth phases did the TRAX mean center move from west to east.

Aggravated assault hot spots were generally located around the intersection of I-15 and I-80, but during the years that constitute the middle-range for this study, the mean centers of aggravated assault hot spots shifted to the south-east. Then, during the later

Figure 9. Average hot spot size per year.

**Relationship to Transportation Nodes**


years of the study, aggravated assault hot spots seem to have shifted back toward the original location near the I-15/I-80 intersection. Rape follows a similar pattern, except that hot spots of rape during the later years did not reach all the way back to the original 1995 area. The pattern of larceny is somewhat similar in the sense that the mean centers shift to the southwest, then back. But especially when compared to rape, larceny events seem to hover around the freeway intersection throughout the duration of the study. The east-west movement of these three types (aggravated assault, rape, and larceny) seems to follow the same general pattern of TRAX mean centers themselves. But the pattern of these three types of crime also has a north-south characteristic.

Figure 10. Aggravated assault mean center test results.
Figure 11. Rape mean center test results.

Figure 12. Larceny mean center test results.
The only type of crime whose mean center seems to move generally away from the mean center of TRAX stations throughout the time period is arson. Despite this general trend away from TRAX, it is important to note that some mean centers for late hot spots are still located on the east side of I-15 near TRAX.

![Figure 13. Arson mean center test results.](image)

Those hot spots whose mean centers seem to move toward TRAX over the course of the study include burglary and homicide. Burglary begins the study period closer to the phase 1 TRAX mean center than the other types of crime (and on the east side of the I-15/I-80 intersection), but moves closer over the time period. Homicide begins to the far-west of the I-15/I-80 intersection, and then migrates toward the TRAX mean center throughout the time period.
Figure 14. Burglary mean center test results.

Figure 15. Homicide mean center test results.
Robbery is unique among the crime types for this study. Its mean center begins the study period near the phase 1 TRAX mean center. During the middle-years of the study, robbery mean centers move to the north-east (opposite the pattern of aggravated assault, rape, and larceny) only to move back toward the TRAX mean center during the later years. In fact, several middle-year mean centers cross the I-15/I-80 intersection onto the north-east side of the intersection only to return to the south-west side (toward the TRAX mean center) in later years.

Figure 16. Robbery mean center test results.
Motor vehicle theft is also unique in that its epicenters remain in the area south of the mean center for TRAX stations. These mean centers move in somewhat of a pendulum motion, beginning to the south-west of the TRAX mean center, moving to the south-east of the TRAX mean center, and finally ending in the south-central area of the TRAX mean center.

![Figure 17. Motor vehicle theft mean center test results.](image)

The average distance measurements for all types of crime tend to be between 1.1 and 1.7 miles. In fact, the average distance at which crimes occurred from the nearest streetcar node to the incident location was generally stable over time. The only crime type to have an average distance from nearest nodes greater than 1.8 miles is arson. Rather than decreasing steadily over time, the average distance measurements in general
tend to decrease rapidly from the year 2000 to 2002, then level out, with only minor fluctuations from the period between 2002 and 2012. The only crimes to return to a pre-2002 level are homicide and arson.

Figure 18. Average distance from crime incidents to nearest TRAX nodes. Abbreviations: AGAS, Aggravated assault; MVT, Motor vehicle theft; Rob, Robbery.

The final test, percent area overlap, shows several interesting patterns. Percent overlap between aggravated assault hot spots and walking-distance-areas for TRAX stations increase slightly from the opening of the first set of stations to 2003, where there is a decrease through 2006, followed by a slight increase. On the other hand, percent overlap for arson tends to decrease overall, with the exception of large increase from 2000 to 20001. Percent overlap for burglary fluctuates, but is generally between 30 and 40%, while percent overlap for homicide generally decreases. Percent overlap for aggravated assault, homicide, larceny, robbery, and motor vehicle theft seem to peak at
2003, and then generally decrease, although percent overlap for robbery increases from 2007 to 2011. Peaks of percent overlap for rape and burglary occur in 2002. These peaks occur only slightly earlier than other types of crime. The earliest peak is for arson in 2001.

*Figure 19.* Service area overlap. Percent overlap was calculated by dividing the area that overlaps with streetcar service areas with the total area covered by hot spots for that crime type in that year.
CHAPTER V
DISCUSSION

This study could not conclude that crimes tend to cluster around streetcar nodes over time. The data does not support the hypothesis that a spatial correlation exists between hot spots and TRAX nodes. This is likely due to other factors that may influence the movement of crime patterns, such as land use, population, or police intervention. Future studies must account for these factors. Additional concepts for future research were also discovered.

Hot Spot Existence

Although the ANN test indicated that some types of crime during certain years are not clustered (see Table 2: Average Nearest Neighbor Test Results), this observation does not refute the previously established concept that crime tends to cluster. The lack of clustering among arson and homicide events is almost certainly due to scarcity. For example, during the year 1999, the arson set of crimes received a $z$-score of only -0.662207, while the larceny data set for the same year received a $z$-score of -154.683565. During the same year, there were 13,144 incidents of larceny compared to only 71 arson incidents. This pattern applies to other years during which arson and homicide received low $z$-scores while crimes with higher numbers of events received higher $z$-scores.

It is important to remember that the average nearest neighbor tool works by measuring the distance between an incident and the next nearest incident. It is only when the average of all such distances among a data set is less than the average for a
hypothetical, random distribution that a crime type for a particular year can be considered clustered (Ebdon, 1985). The hypothetical random distribution is based on the same number of features covering the same total area as the input data set (in this case, the total area of the city). So, one can safely assume that given an adequate number of incidents those types of crime would result in hot spots. In fact, the same test conducted for those years during which arson and homicide were more prevalent supports the idea that all crimes tend to cluster.

**Hot Spot Characteristics**

The general consistency among the number of hot spots per crime type over time coincides with the evidence that crime levels in the city are not changing dramatically. The Brantinghams (1981) suggested that while hot spots of crime change location over time, the overall rate of crime must not necessarily change. This issue is especially important for future research because the creation of more complex studies of urban crime must unavoidably include rates of crime. The consistency of hot spot numbers may also be due to the nature of hot spot mapping itself. But it seems to be more a product of general crime trends in the city. Most levels of crime (measured as total numbers of incidents per year per crime type) remained relatively stable over the study period, with the exception of the first few years of the study period. The general trend among the data is to decrease dramatically from 1996 to 1997, then to level off and decrease gradually over the remaining years (see Appendix A: “Base Levels of Crime”). Base levels of crime in the city indicate that crime is generally decreasing. This
observation adds to the conclusion that there is no relationship between crime patterns and transportation nodes.

An examination of the peak average hot spot sizes for crime types over the study period for this thesis also conforms to certain aspects of prior research. Recall that out of the few studies of this kind done previously, two studies reported a slight increase in levels of crime after the opening of public transit stations while one reported an immediate increase followed by a decrease (see Table 1: Prior Studies Summary). The fact that most peak hot spot sizes occur during or after the opening of the first TRAX lines suggests that hot spots may actually expand in size following the opening of street car nodes. Earlier studies reported an increase in size followed by return to normal sizes in areas served by transportation nodes. If hot spots increase in size in the years following an opening, crime in neighborhoods which heretofore have seen low levels of crime will change. The temporary nature of this change is also reflected in the return to previous hot spot sizes toward the end of the study period. Whether or not this is the case in the Salt Lake City would require further research because the change may also be the result of land use, population changes, police intervention, or other factors.

**Relationship to Transportation Nodes**

This study cannot conclude that there is a relationship between hot spots of crime and transportation nodes. Although hot spots were shown to have changed position over time, there is no evidence that hot spots tended to cluster around or migrate toward TRAX nodes. This suggests that there is no relationship between hot spots and transportation nodes.
If there were a relationship between streetcar nodes and hot spots, one would expect the mean centers of those hot spots to show an observable pattern of movement toward the mean centers of TRAX nodes over time. One would also expect the area of hot spots to gradually encroach on areas served by streetcar nodes. On the contrary, while the data exhibited several interesting patterns between types of crime, no overall pattern in relation to transportation nodes could be determined. The lack of relationship between streetcar nodes and crime is especially evident in the average nearest distance test. Rather than increasing over time, the data for this study showed that the distance between crime incidents and streetcar nodes generally decreased over time, or remained relatively stable after streetcars were introduced. This means that, in general, crimes did not cluster around streetcar stops in this study.

There are many possible explanations for this lack of relationship, but one of the most plausible seems to be the influence of population. It is a well-established fact that high population areas have higher levels of crime (Paulsen & Robinson, 2009). Public transportation nodes are located in areas of high density in order to serve a higher number of people and increase ridership. Ridership on TRAX has generally increased since its opening (APTA, 2013). It is difficult to separate these two factors when it comes to patterns of crime because they are so closely related spatially.

A similar concern in this study was the existence of bus stops. One could argue that although hot spots appear to be clustering around new light rail stops, they may actually be clustering around new or old bus stops. An investigation into the spatial pattern of bus stops in the area over the time period shows that bus stops are more or less located evenly throughout the study area. It is for this reason, as well as the fact that bus
routes are invariably on public roads in Salt Lake City (i.e., there exists no bus rapid transit, or other dedicated bus-only routes in the city) that this factor was considered a non-issue for this study. It may, however, be an interesting topic for future studies in areas where bus stops are more concentrated or for the specific opening of a new bus stop.

Another issue is that of land use. Public transportation is only one of many types of land use that may relate to patterns of crime. Prior studies have found that there is a relationship between other types of land use and crime. For example, areas around bars have been shown to have higher levels of crime (Paulsen & Robinson, 2009). This study could not determine that streetcar nodes are associated with crime. But the relationship between nodes and other types of land use may be a useful topic for future research. If certain types of businesses tend to locate near streetcar nodes, and whether those businesses are criminogenic or not, may be important information for planners and police. Similar studies have been conducted on the location of gas stations (Paulsen & Robinson, 2009).

Police intervention is a topic that seems to have been given little attention in prior studies on the relationship between crime and public transportation. Some criminologists have argued that hot spot policing itself is a tautological process (Lilly et al., 2011). In other words, the very act of planning to send more police officers to a certain area will actually increase statistical levels of crime in that area because police will make more arrests. On the other hand, police intervention could reduce crime in hot spots, causing those hot spots to change location or causing certain neighborhoods to no longer be considered hot spots. It is difficult to determine the effect of police intervention for the
same reason it is difficult to determine the relationship between crime and streetcar nodes; there are simply too many other factors which could be important. Yet, the cost in time, money, and effort in focusing on all factors at once may be too high. It is for that reason that studies of this kind must continue to be conducted. It is only when unknown factors which may contribute to the spatial patterning of crime continue to be eliminated that research can begin to focus on those topics which are most critical.

**Future Studies**

This study makes several recommendations for future research. In addition to the factors listed above, such as land use, police intervention, and population, future research should also continue to account for changes over time. Prior studies agree that large temporal data sets are an advantage for this type of study. This thesis used a larger data set than prior studies, yet an even longer temporal span would be important for future research. Some patterns that seem to exist during one time frame may actually be part of larger patterns and recurring patterns may seem to be only isolated events if a time frame is too short. Additionally, relationships that seem nonexistent may actually be observable on a different temporal scale. Such extensive data is difficult to obtain, and may require the digitization of historical paper records. For example, this study's data did not go beyond 1995 because that is the limit at which digital data could be obtained. But a researcher with greater means and access could use pre-computerized data to further define relationships between hot spots and societal factors such as transportation.

Another limitation that must be addressed by future studies is the lack of a standard methodology for hot spot mapping. This study used as a basis for its
methodology the generally accepted way hot spot mapping is carried out by practitioners today (Gorr & Kurland, 2012). But even generally accepted approaches may have flaws. If future researchers took the opportunity to validate hot spot policing as a theoretically sound practice, credibility would be added to hot spot research. In other words, one topic for future research could be the advantages limitations of hot spot mapping itself.

Finally, this study recommends that more studies in more cities be conducted. The literature disagrees on the relationship public transportation has with crime patterns. But as public transportation continues to be increasingly important in crowded urban spaces, the importance of understanding the complex societal interactions which may coincide with those changes will also grow. As mapping technology becomes more accessible and larger data sets become more available, the complex nature of public transportation and crime may be better understood.

Speculation

**Types of crime.** This study could not conclude that a relationship exists between streetcar nodes and hot spots of crime in Salt Lake City, but several interesting observations were made about specific types of crime. The differences among patterns between types of crime leads one to speculate that future studies may benefit from either focusing on single types of crime or from separating crime data into very specific categories. Speculation on patterns of specific types of crime, and why those patterns exist lead to several interesting ideas.

For instance, the mean center test found that aggravated assault, rape, and larceny may follow a similar pattern. But aggravated assault and rape are personal
crimes while larceny is strictly a property crime. This distinction could be an important one. While larceny mean centers follow a similar pattern to those of aggravated assault and rape, they do not move as far toward the mean center for TRAX stations as aggravated assault and rape mean centers. If larceny differs from other types of crime by moving toward then away from TRAX nodes, then why, as a subset of property crime as opposed to rape and aggravated assault (the two types of personal crime which follow a similar pattern) is the extent to which larceny moves toward TRAX stations less? This question may or may not prove to be a valuable topic for future research.

One could also ask: what is it about burglary and homicide that could account for similarities between their spatial patterns? Burglary, perhaps more than any other type of crime, is site-dependent because it is the site itself which is the target (Paulsen & Robinson, 2009). Burglary targets are either homes or businesses while targets of homicide are, of course, people (FBI, 2004). While the actual targets between these two types of crime are different, closer examination of the propensities of each reveals that the environmental backcloth on which both occur may actually be similar. Studies have shown that most homicides occur either very close to or within a victim's home (Groff & McEwen, 2006; Messner & Tardiff, 2006). While much of the burglary data for this study may include buildings other than homes, future studies may be able to conclude that a large portion of those burglaries constitute homes, such as apartments (Bernasco & Nieuwbeerta, 2005). It follows that if homicide and burglary tend to occur against a similar environmental backcloth, and if that backcloth changes location, the location of the crime itself will, at the city-wide-level, change. While this type of discussion is highly speculative, it may nevertheless be useful in generating ideas for future studies.
**Types of crime that may move away from stations over time.** Distinction between the types of crime which do not seem to move toward TRAX stations is also an interesting exercise. This study found that robbery differed from all other types of crime in that its hot spots begin the study period near the TRAX mean center, then move away from, then back toward the TRAX mean center even though the TRAX mean center itself moved over time. This observation, while inconclusive in and of itself, nevertheless leads one to wonder what could make robbery different from other types of crime. For instance, robbery is defined as the taking of a victim's property while the victim is present (FBI, 2004). It could be the element of force against a present victim which separates robbery from other types of theft, such as burglary or larceny, in which the victim is not necessarily present (FBI, 2004). In fact, it is often difficult to distinguish between assault and robbery because, in order to be classified as robbery, the violence inflicted on the victim must have been committed in furtherance of the robbery itself.

But what could that distinction have to do with the spatial pattern of robbery? It could be that, of all the eight crimes in this study, robbery is arguably the only one that is both a property and personal crime. The person is involved because they have violence, or the threat thereof, inflicted upon them. The person’s property is involved because that is the perpetrator's target. Any given robbery involves at least one individual victim and at least one item of property. While most crimes occur as single events, property crimes where a victim is present can quickly develop into personal crimes, thus causing a “multiple-offense” situation (FBI, 2004). For example, if a person committing an armed robbery fires a gun at a shop owner, killing him, the UCR hierarchy rule dictates that the crime is reported as homicide, not as armed robbery (FBI, 2004). Interestingly, arson,
justifiable homicide, and motor vehicle theft are exempt from the hierarchy rule (FBI, 2004). In other words, if any arson is committed in conjunction with other Part 1 crimes, both types are reported separately. It is for that reason that Unified Crime Reports are organized in a hierarchical scale. Also, the hierarchy rule does not influence the way perpetrators are charged; only the way crimes are reported. While this study assumes that all perpetrators of robbery attempt to manage effort, risk, and reward, there may be some differences in the way street robberies versus convenience store robberies are carried out (D’Alessio & Stolzenberg, 1990; Deakin, Smithson, Spencer, & Medina-Ariza, 2007). Future studies which examine specific environments in which robberies occur, and how they may be different from other types of crime, could be an important addition to the existing body of literature.

The unique pattern of motor vehicle theft (MVT) also leads one to speculate, especially when one considers that motor vehicle theft is simply a specific type of larceny. The only reason MVT is in a separate category is its high level of occurrence (FBI, 2004). But, as is the case with the other types of crime in this study, the specific environments in which MVT offenses are carried out differ from other types of crime. Consider that larceny includes such crimes as shoplifting, purse snatching, pickpocketing, theft of bicycles, and theft from coin-operated machines, among others (FBI, 2004). Shoplifting must occur at a commercial establishment, but shopping centers may be conducive to theft for other reasons. Future research may benefit from the examination of what those reasons could be.

Motor vehicle theft may occur in very different places from larceny based on the way MVT is carried out. Saville and Murdie (1988) found that most MVT occurred in
industrial areas, high-density residential areas, and at the international airport. They went on to say that joyriding, rather than monetary gain, was the primary motivation for MVT (Saville & Murdie, 1988). If MVT incidents tend to occur in industrial areas, then the implementation of public transit nodes, which are generally located in high-pedestrian-activity areas, will not be associated with a dramatic shift in the location of MVT incidents. On the other hand, transit nodes do tend to service high-density-residential areas, and those areas have been previously cited as potential targets for MVT hot spots. It is for that reason, among others, that this topic requires further investigation.

**High density housing.** A further conjecture that may or may not prove to be important relates to the development of TRAX nodes in conjunction with high-density housing. Several TRAX nodes were created specifically to serve areas of high-density housing (Oliver, Clayton, & Drake, 2013). For example, the Utah Transit Authority is planning to continue the development of the stop at 600 West and 300 South, with access to Gateway and City Creek shopping centers, as inter-modal transit hubs (Norris, Baxter, & Clayton, 2013). The relationship between housing and the TRAX stop at 900 South has been a topic of public discussion (Henetz, 2005). One could argue that the spatial pattern of hot spots for these two types of crime may be more related to housing itself rather than TRAX nodes. Describing the spatial aspects of crime specific to transit-oriented-development is yet another important area for future research.

**Design elements of nodes.** One important topic for further research is the influence specific aspects of the streetcar system itself have on crime. In order to accommodate increasing ridership over time, transit authorities must make progressive
changes to the transit system, and TRAX is no exception. Studies on the importance of environmental attributes of public transportation when it comes to safety are growing (Loukaitou-Sideris, 1999). But because environmental attributes of stations are very site-specific, a large number of studies are still required in order to focus on which attributes are most important to safety.

The discussion of specific environmental aspects of transit nodes which may or may not contribute to crime is reminiscent of CPTED (Crime Prevention Through Environmental Design). The purpose of CPTED is to identify physical characteristics of the environment that provide opportunities for crime to occur (Brantingham & Faust, 1976). While CPTED has a mixed history of success, subsequent theories and the concept that specific site details such as lighting can make areas safer may be an effective way to approach safety in public transportation networks (Paulsen & Robinson, 2009). Smith and Clark (2000) have suggested that good design of transit stations could reduce crime at certain stations. While evidence exists that good design can reduce crime at specific sites, there seems to be little or no research into the effect such interventions have at the city-wide scale.

One speculative example is the use of kiosks on platforms. It was not until a large influx of riders in 2005 that TRAX considered the implementation of kiosks on platforms where passengers can buy tickets (Taylor, 2006). While no study could be found linking safety to the use of kiosks, the use of kiosks on train platforms may be similar to other environmental aspects of station use which are criminogenic. For example, kiosk use and ATM use may be similar for several reasons. Both may involve the user standing with their back facing outward while they are focused on the kiosk or
ATM itself. Both involve the transfer of money. Studies have shown that ATMs can be criminogenic during certain times of the day (Guerette & Clarke, 2003). If ATMs are criminogenic and if behavior around kiosks is similar to ATM behavior, it may be worthwhile to examine the influence kiosk use on train platforms has on safety.

**Other theoretical connections.** Finally, the relationship between criminology and landscape architecture seems to be a rich source for future research. It was discussed earlier how the spatial aspects of criminological theories offer excellent opportunities for landscape architectural research. This is also true for new and developing criminological theories. One influential trend in criminological research is the study of life course theories. Life course theories are significant because they have explained the age crime curve, or the observation that crimes tended to occur during offenders’ teenage years (Lilly et al., 2011). To date, no other theory has been able to adequately explain this phenomenon. Furthermore, life course theories are considered integrated theories because they seek to apply and evaluate knowledge from various fields under a single framework (Lilly et al., 2011). Integration is especially important when complex societal issues such as crime and public transportation are being examined. The drawback of integration, however, is that it may lead to inconsistent theorizing, where many relevant variables are left out (Lilly et al., 2011). It is also often difficult to reconcile differences between fundamental theoretical world-views as well as methodological approaches (Groat & Wang, 2002). But landscape architects are also familiar with the benefits and restrictions of integration because landscape architecture is a multidisciplinary field.
For example, Sampson and Laub's (1993) social bond theory (a life course theory) was based on the concept of social capital, or the benefit derived from interpersonal relationships. Sampson and Laub's work was focused primarily on the family, but they have admitted that other important sources of social capital, and their relationship to crime, have yet to be studied adequately. On the other hand, a fairly consistent vein of research in the field of landscape architecture and urban planning is the emotional attachment of people to place. Researchers have defined attachment to place as “the feeling of possessiveness an occupant has toward a particular territory because of its associations with self-image or social identity.” (Bower, 1980; Deuchar, 2009; Hopkins, 2010; Neal, 2011). While this concept is somewhat different than the concept of parental attachment, the underlying idea – that emotional attachment can influence either positive or negative behavior – is the same. One wonders how attachment to place is influenced by public transportation and, in turn, how that level of attachment influences other aspects of society such as social capital and crime. Future studies may find that collaboration between fields of research is the most effective way of investigating such complex societal issues.
REFERENCES


APPENDICES
Appendix A. Base Levels of Crime
Rape Base Levels

Number Crimes

Year

1995 1997 1999 2001 2003 2005 2007 2009 2011

Robbery Base Levels

Number Crimes

Year

1995 1997 1999 2001 2003 2005 2007 2009 2011
Appendix B. Final Hot Spot Locations
Aggravated Assault 1995

TRAX Stations
- Existing Stations
- Future Stations
Aggravated Assault Hot Spots

Aggravated Assault 1996

TRAX Stations
- Existing Stations
- Future Stations
Aggravated Assault Hot Spots
Aggravated Assault 2003

TRAX Stations
● Existing Stations
○ Future Stations
Aggravated Assault Hot Spots

Aggravated Assault 2004

TRAX Stations
● Existing Stations
○ Future Stations
Aggravated Assault Hot Spots

Homicide 2003

Homicide 2004

TRAX Stations
- Existing Stations
- Future Stations

Homicide Hot Spots