Mapping Hotspots of Crime and Traffic Violation in Fitchburg, MA

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Abstract

This mapping project is an independent study of the critical component of the DDACTS (Data Driven Approaches to Crime and Traffic Safety) program at the Fitchburg Police Department (FPD). It focused on mapping and identifying "hotspots" in crime patterns and traffic accidents in Fitchburg, Massachusetts using a GIS (Geographic Information System). Crime and traffic violation data ranging from January 2008 to June 2012 were organized, geocoded, and overlaid to produce a series of hotspot maps. The spatial patterns revealed could be used for visual and spatial references to the police officers at FPD and could assist them deploying law enforcement and other resources effectively and efficiently.

Introduction

The City of Fitchburg, Massachusetts is located in the north central part of the state and is approximately 50 miles to the northwest of Boston. Historically the city was a mill and manufacturing hub in New England. Today, it is a primarily working-class city with 40,318 residents. The ethnic composition of the population is 78.2% White, 5.1% Black, 3.6% Asian, and 13.1% other ethnicities. Hispanics make up 21.6% of the population [1]. The median household income in Fitchburg was $45,481 in 2010, which was lower than the state median of $64,081, and the national median of $50,221. Fitchburg had 17,117 housing units in 2010 and 11.4% of them were vacant [1]. Criminal activity is prevalent in areas with low income and vacant buildings [2]. The city has an average violent crime rate of 7.81 per 1,000 persons and a property crime rate of 26.61 per 1,000 persons [3]. Fitchburg has a total of 192 miles of public roads leading to the rate of 5.42 traffic violations per mile [4]. Overall, the city has had higher

crime rates and traffic violations compared to other areas in the state in the past few decades. The economic recession since 2008 has put additional risks on the city and, thus, negatively impacted the safety and economic growth of the area.

The Fitchburg Police Department (FPD) consists of 73 sworn officers and 5 non-sworn personnel. The FPD implemented the "Data Driven Approaches to Crime and Traffic Safety" (DDACTS) procedure in the city starting from February 2011. According to the *DDACTS Operational Guidelines* [5] by the Bureau of Justice Assistance, National Institute of Justice, and National Highway Traffic Safety Administration, DDACTS "integrates location-based crime and traffic crash data to establish effective and efficient methods for deploying law enforcement and other resources". In traditional policing procedures, officers are assigned to inflexible, specific patrol areas. In contrast, during a DDACTS procedure, officers are deployed based on "hotspots" – the locations where crimes and traffic violations occur the most [6]. As locations of crimes and traffic violations move, so do the hotspots. A police department's knowledge of hotspots has to be current and accurate for the successful implementation of the DDACTS program. In the FPD, there were three officers who practiced DDACTS. They were provided with hotspot maps of crime and traffic violations every six to eight weeks. They patrolled the city in designated areas guided by the hotspots maps.

The goal of this independent mapping project was to assist the FPD in producing hotspot maps and analyzing the spatial patterns of crimes and traffic violations in Fitchburg using GIS (Geographic Information System) technology based on the data provided by the FPD. The project was sponsored by the Regional Economic Development Institute (REDI) at Fitchburg State University.

Methodology

Data Collection

Crime and traffic violation data ranging from January 2008 to June 2012 were extracted from the FPD's Record Management System, where officers' reports of crime and traffic incident were stored. The data were then "cleaned" to remove crimes that fell into the shoplifting category. Shoplifting within stores do not share the same characteristics as other crimes because they don't move, but stay in stores' locations. Thus, street patrols have no effect on deterring them. The cleaned data were reorganized on a quarterly basis from the 1st quarter of 2008 through the 2nd quarter of 2012.

Geocoding

Geocoding is the process of developing geometric/geographic representation for locations (often expressed as latitude and longitude) from other geographic data, such as street addresses. It transformed the tabular crime and traffic violation data into maps, which set the foundation for hotspot map generation. A series of quarterly locational maps of crime and traffic violation for the study period were generated. See Figures 1 and 2 for samples.

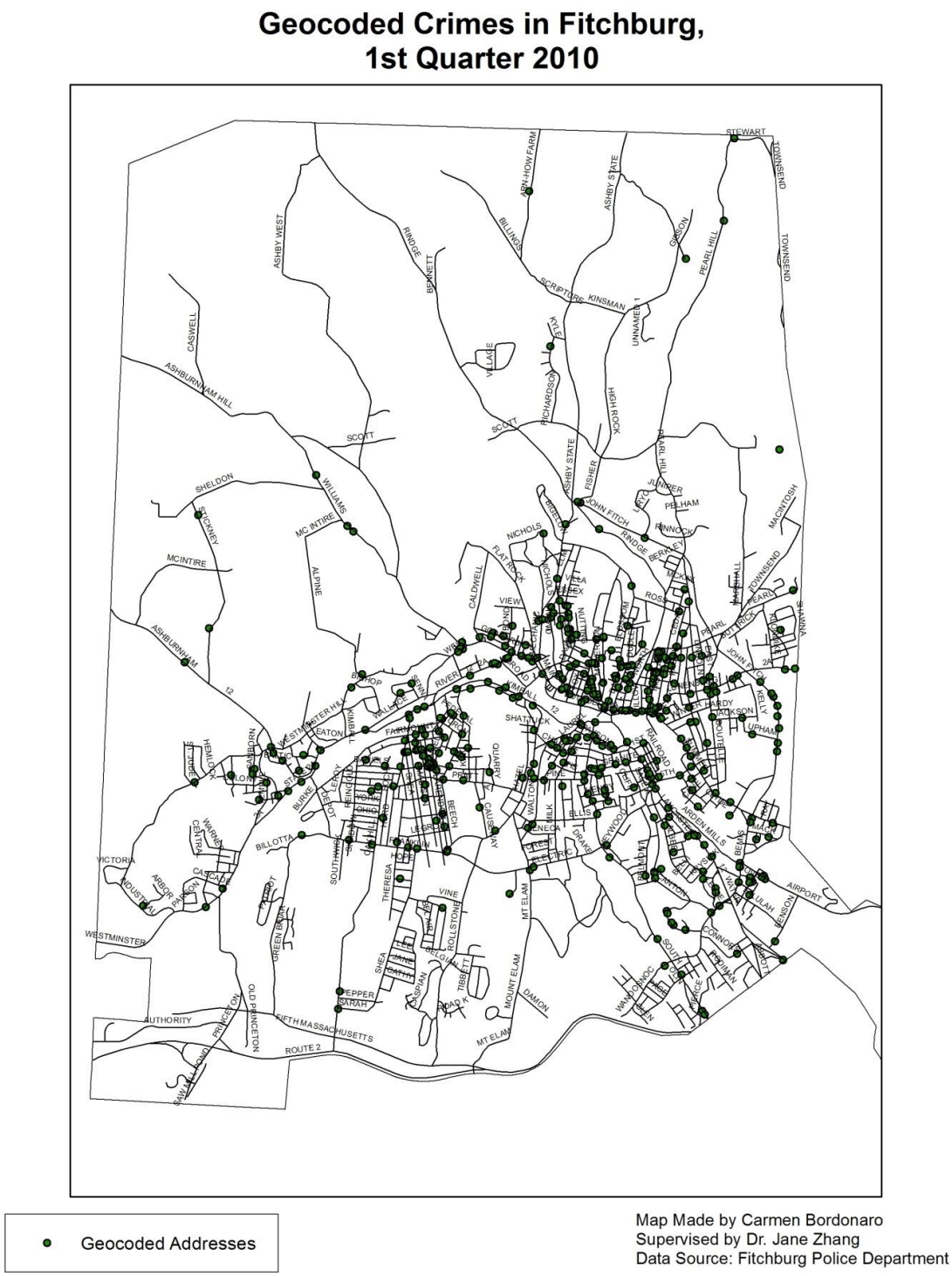


Figure 1: Sample Map of Geocoded Locations of Crimes

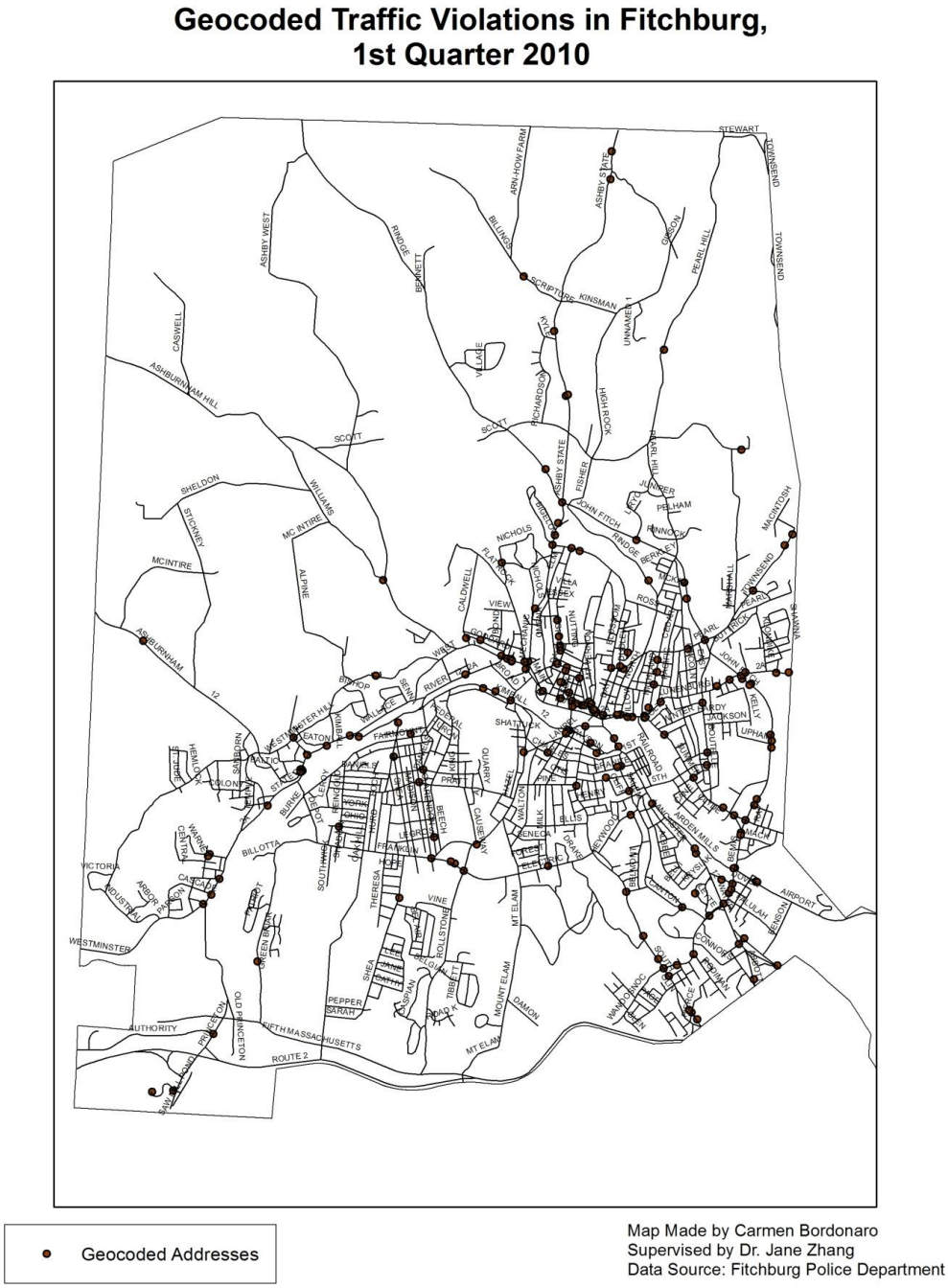


Figure 2: Sample Map of Geocoded Locations of Traffic Violations

Hotspots Mapping

The crime and traffic violation maps were processed to generate hotspot maps through a spatial analysis procedure called Kernel Density analysis, which calculates the density of points

around each output raster cell. This procedure counts the number of points and assigns magnitude values represented by a colored surface to the output map, which display the spatial patterns of hotspots. Figures 3 and 4 are samples of the crime and traffic violation hotspot maps.

A standardized color scheme representing a range of magnitude values was applied to every map, as shown in Figures 3 and 4, where white represents “very low”, green “low”, yellow “medium”, orange “high”, and red “very high”. The results of the classification were that each color represented the same meanings (magnitude values) of crimes or traffic violation for the entire dataset. The standardization made it possible to compare hotspot patterns quarter to quarter (map to map) for the entire study period. Notice the magnitude values were not the numbers of crimes or traffic violation incidents; they were, instead, merely indicators of dot density magnitudes.

Table 1 shows the magnitude values of crime and traffic violation classes and their corresponding colors and color labels. For example, white represented “very low” in crime maps where the magnitude values fall into the class of 0-200; it also meant a “very low” value in traffic violation maps where the class ranged from 0 -125.

Crime Values	Color	Displayed Values	Traffic Violation Values
0 - 200	White	Very Low	0 – 125
201 - 400	Green	Low	126 – 250
401 - 600	Yellow	Medium	251 – 375
601 - 800	Orange	High	376 – 500
801 or above	Red	Very High	501 or above

Table 1: Classification Values of Quarterly Hotspots Maps

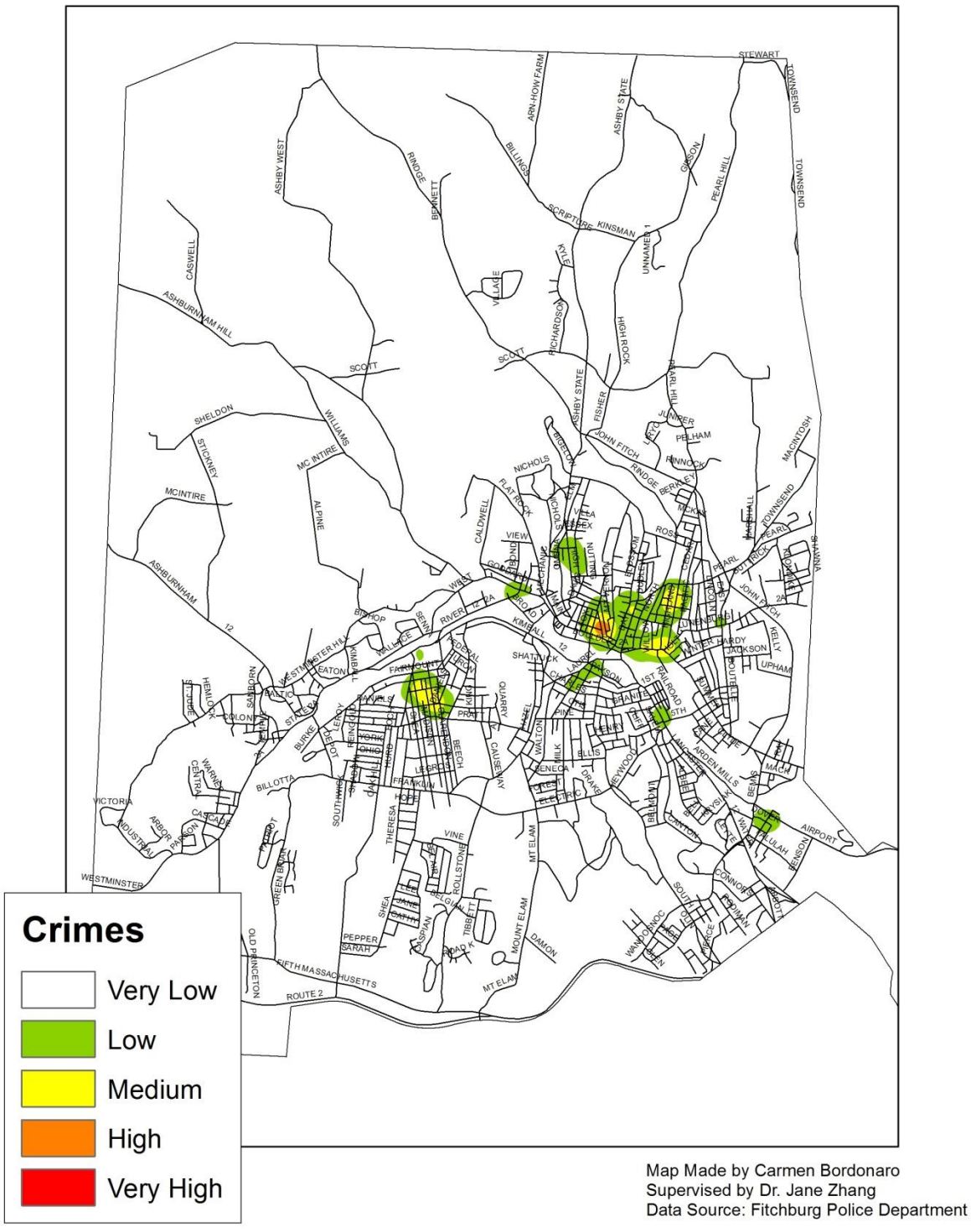


Figure 3: Sample Crime Hotspot Map

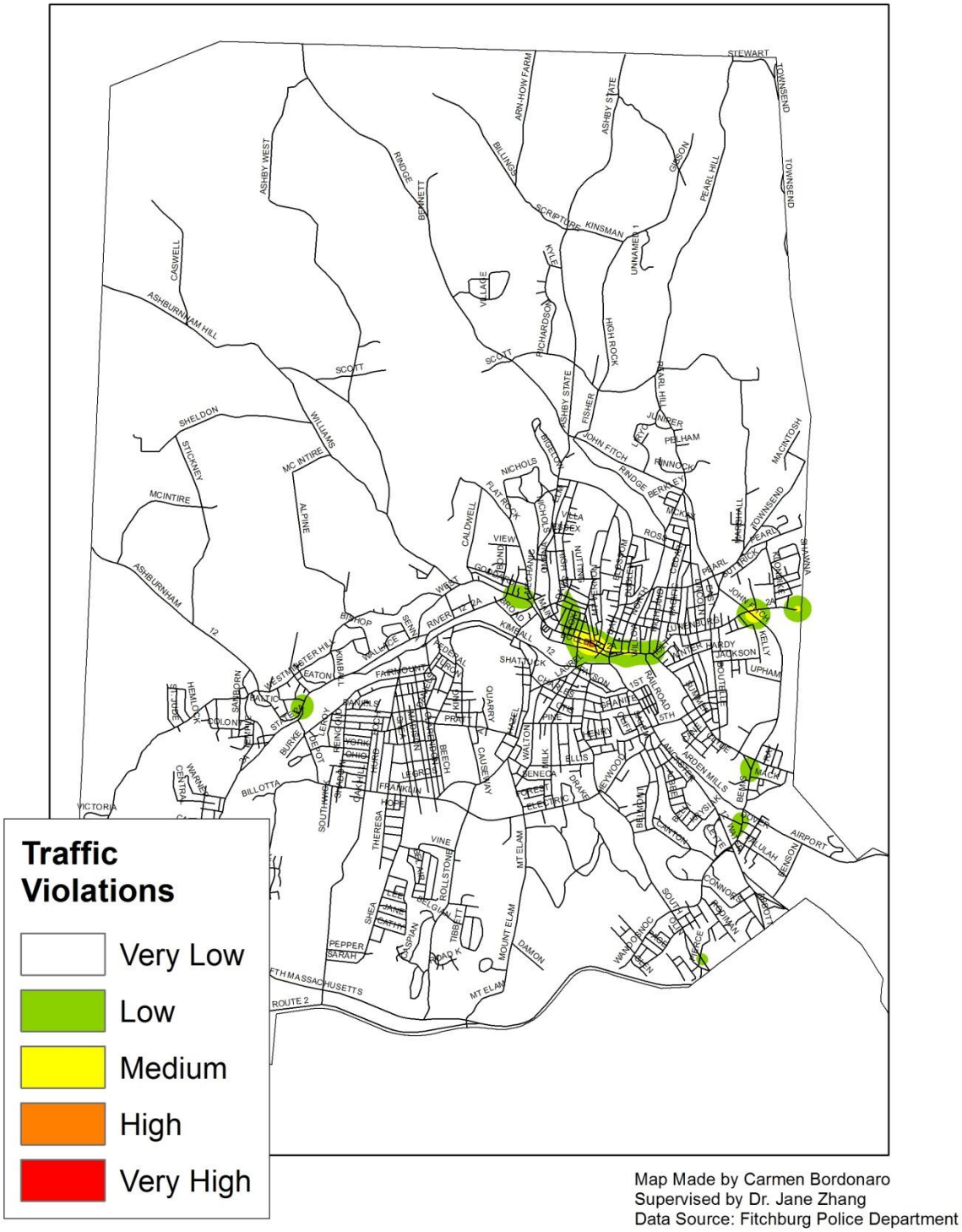


Figure 4: Sample Traffic Violation Hotspot Map

Map Overlay

The quarterly maps of each year were used as inputs to generate five composite hotspot maps of Fitchburg for the years 2008-2012. See Figures 5 and 6 for samples.

Although the same color schemes of white to red were applied to the annual composite maps, the magnitude values for each color, however, are significantly greater due to the overlay effect. See Table 2 for the specific class values in the annual composite maps of Figures 5 and 6.

Crime Values	Color	Displayed Values	Traffic Violation Values
0 - 100	White	Very Low	0 – 100
101 - 500	Green	Low	101 – 300
501 - 1,000	Yellow	Medium	301 – 500
1,001 - 1,500	Orange	High	501 - 1,000
1,501 & above	Red	Very High	1,001 & above

Table 2: Classification Values of the Annual Composite Overlay Maps (Figures 5 and 6)

The last map overlay procedure used the five annual composite maps (year 2008, 2009, 2010, 2011, and 2012) as inputs and produced the general overlay maps of crime and traffic violation hotspot maps as shown in Figures 7 and 8. The class values of the general overlay maps are listed in Table 3.

Crime Values	Color	Displayed Values	Traffic Violation Values
0 - 500	White	Very Low	0 – 300
501 - 1,500	Green	Low	301 - 1,000
1,501 - 3,000	Yellow	Medium	1,001 - 2,000
3,001 - 6,000	Orange	High	2,001 - 3,000
6,001 & above	Red	Very High	3,001 & above

Table 3: Classification Values of the General Overlay Maps (Figures 7 and 8)

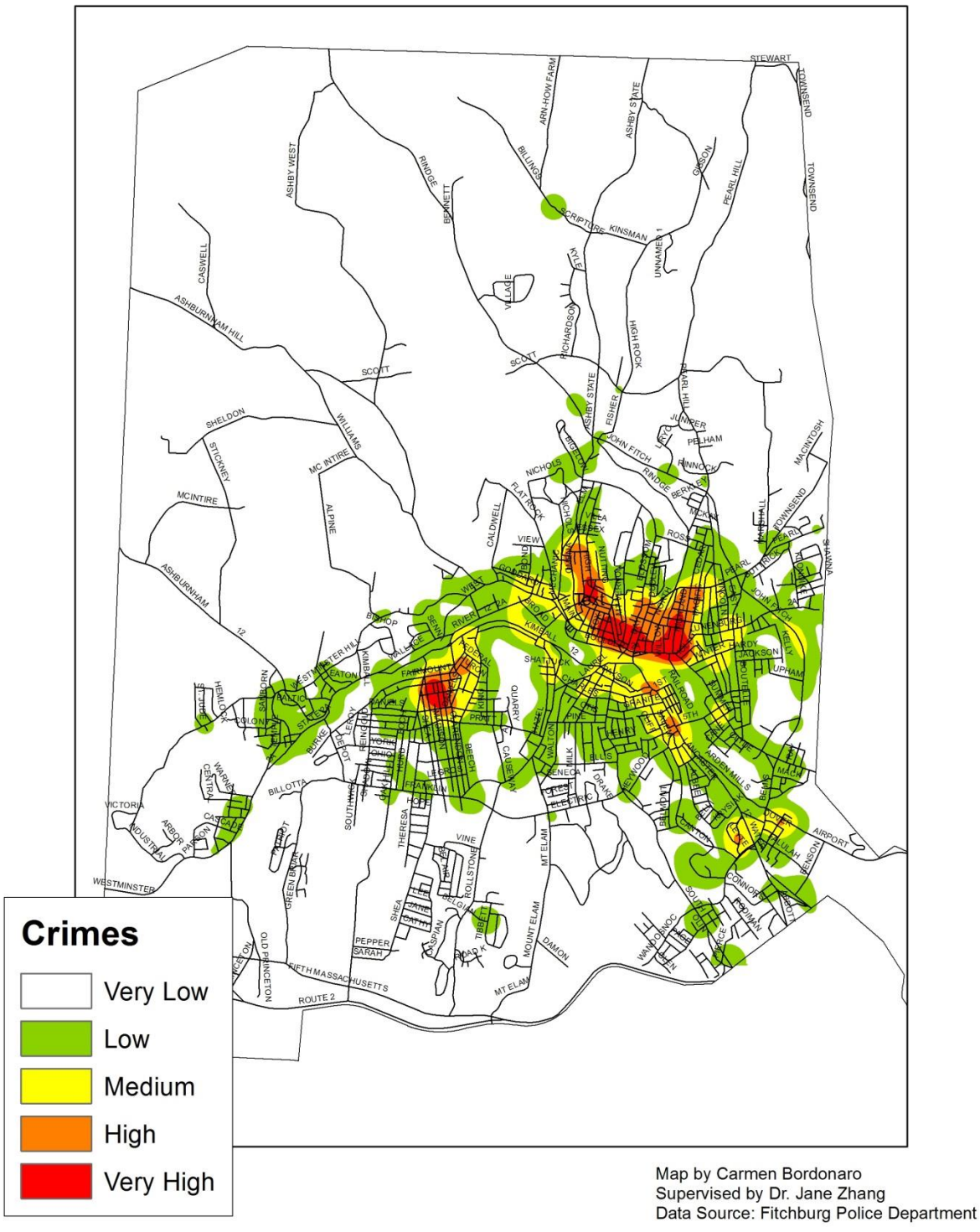


Figure 5: Sample Annual Composite Crime Hotspot Map

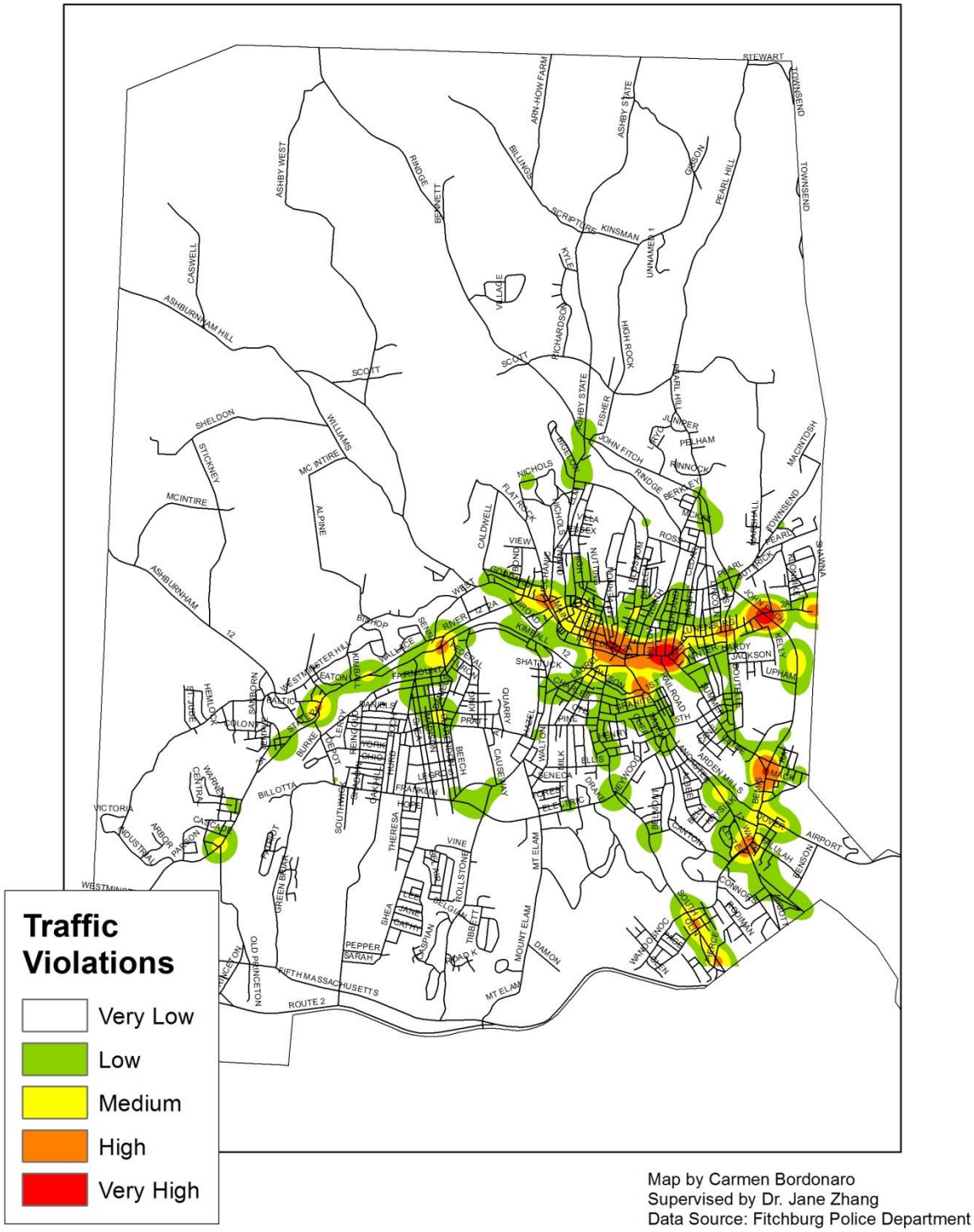


Figure 6: Sample Annual Composite Traffic Violation Hotspot Map

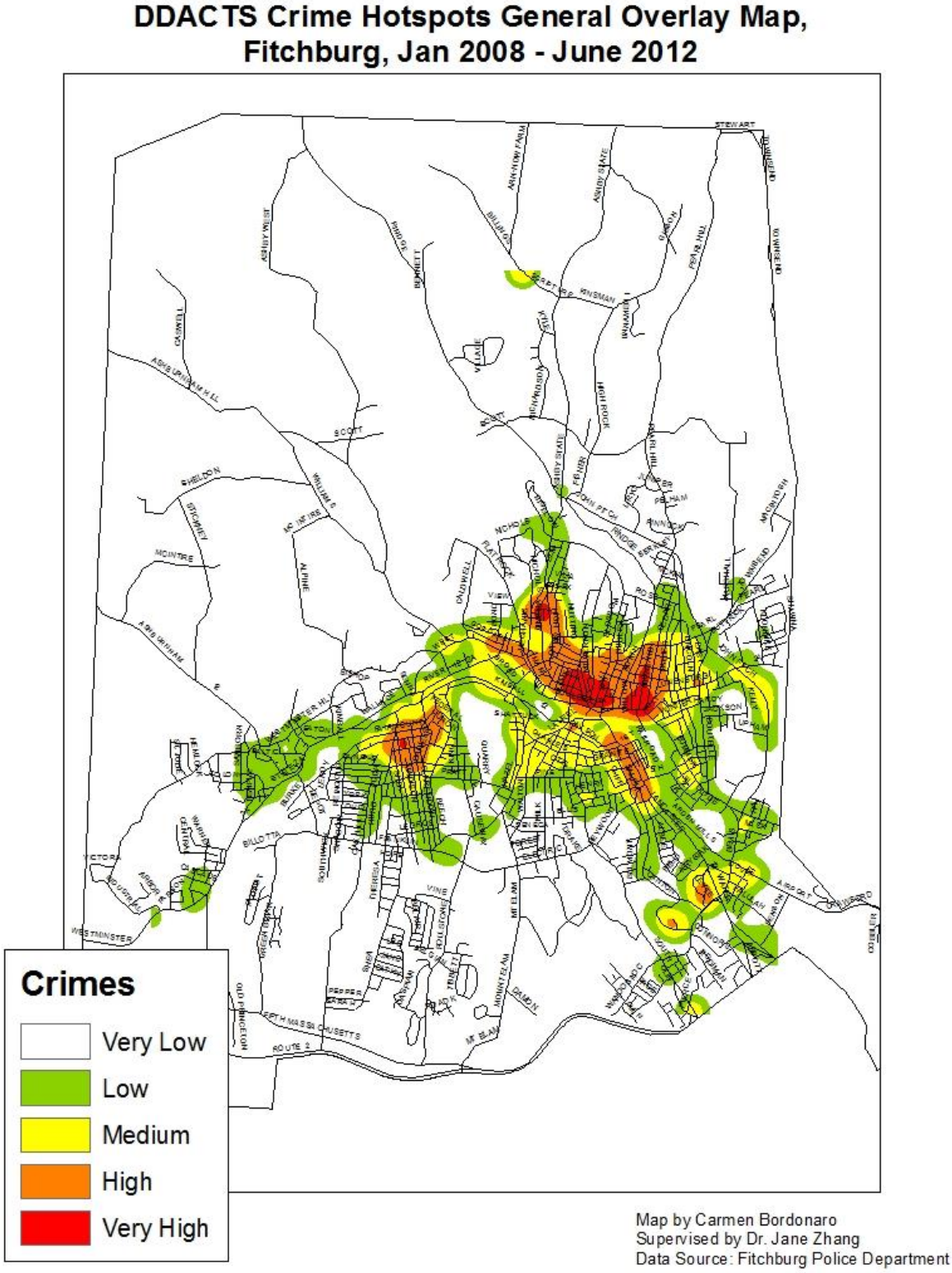


Figure 7: Crime Hotspots General Overlay Map

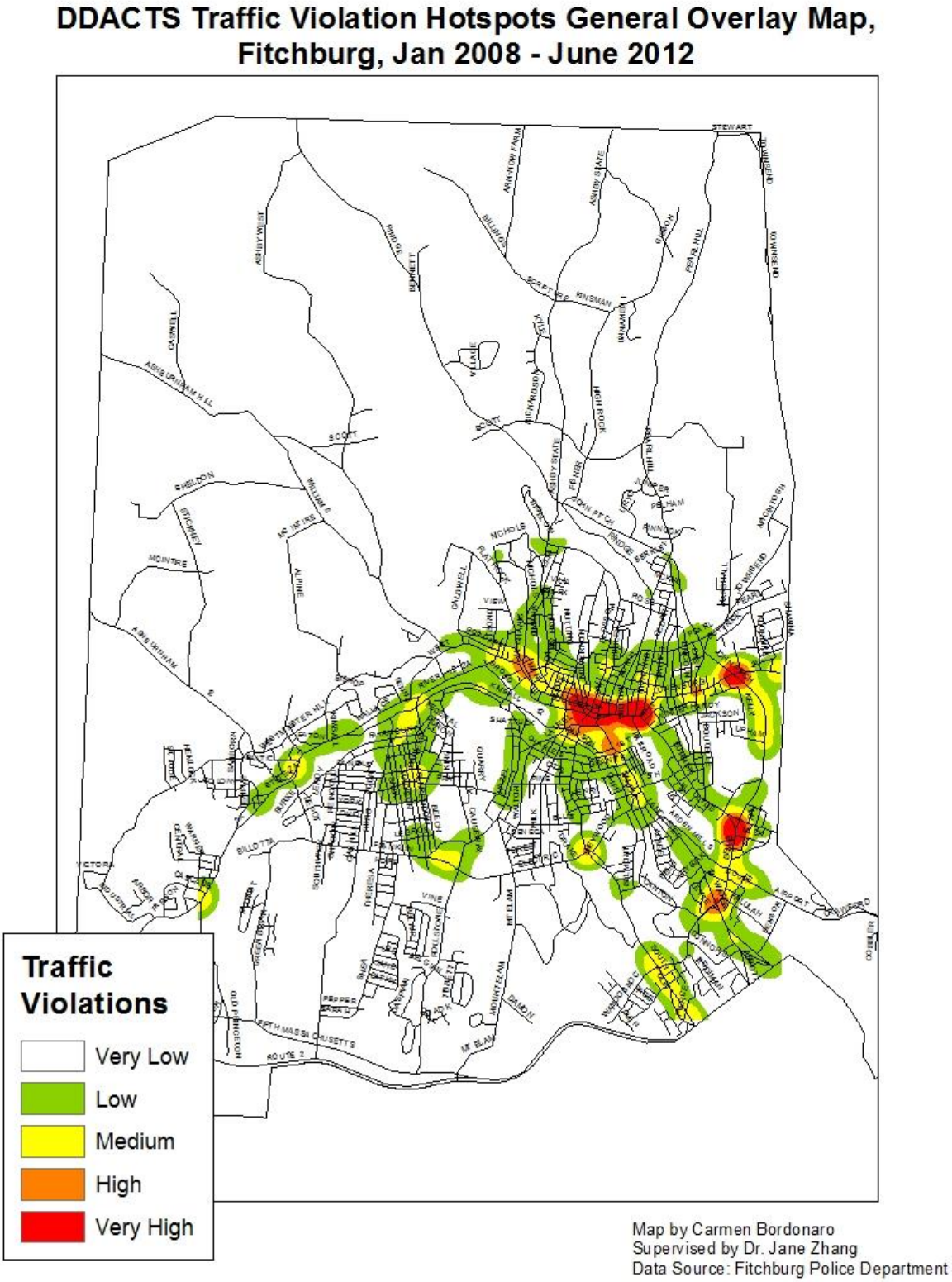


Figure 8: Traffic Violation Hotspots General Overlay Map

Total Weighted Crime

Crimes vary in frequency and severity. Although the frequency of crime locations was captured in hotspot maps, the severity of crimes was not taken into account. Therefore, a compound index of crimes was produced. Table 4 shows the types of crimes which occurred during the study period. Each type was assigned a weight to reflect the crime severity on a scale ranging from 0 – 1. These weights were inputted into the attribute tables of each hotspot map. Table 5 shows a sample of an attribute table (1st Quarter 2010), where the types of crime are listed in column two and their weights in column three.

A total weighted crime index was calculated in ArcGIS for each crime hotspot map. It should be noted that the total weighted crime is not the total number of crimes that took place; rather, it refers to the overall severity of the crimes for a certain time period.

Crime Type	Weight
Weapon Law	0.25
Drug Violation	0.3
Vandalism	0.35
All Other Larceny	0.4
Theft of Motor Vehicle Acc.	0.45
Theft From a Motor Vehicle	0.5
Theft From a Coin Machine	0.55
Theft From a Building	0.6
Purse Snatching	0.65
Pocket Picking	0.7
Burglary/ Breaking & Entering	0.75
Simple Assault	0.8
Aggravated Assault	0.85
Robbery	0.9

Table 4: Crime Severity Index: Weights of Crimes

Table

1stQuarterCrime2012NoSL

IBRCodes_I	IBRDescrip	Weight	Address	ZONE	INCIDENTTI	ARREST
520	Weapon Law Violations	0.25	50 MARSHALL ST	C3	0004	
520	Weapon Law Violations	0.25	32 GAGE ST	C3	0051	
520	Weapon Law Violations	0.25	132 SNOW ST	C3	0818	
520	Weapon Law Violations	0.25	52 GERARD DR	C5		0254
520	Weapon Law Violations	0.25	WATER ST	C1	1256	
520	Weapon Law Violations	0.25	27 WESTMINSTER ST	C4	0223	
520	Weapon Law Violations	0.25	1022 MAIN ST	C2		2043
520	Weapon Law Violations	0.25	105 BLOSSOM ST	C3	2350	
35A	Drug / Narcotic Violations	0.3	200 COLUMBUS ST	C4		1755
35A	Drug / Narcotic Violations	0.3	29B WESTMINSTER ST	C4		2003
35A	Drug / Narcotic Violations	0.3	173 MECHANIC ST	C3		0929
35A	Drug / Narcotic Violations	0.3	BOULDER DR	C3	2342	
35A	Drug / Narcotic Violations	0.3	MAIN ST	C3		1934
35A	Drug / Narcotic Violations	0.3	545 ELECTRIC AVE	C4	1713	
35A	Drug / Narcotic Violations	0.3	20 ELM ST	C3		0853
35A	Drug / Narcotic Violations	0.3	MYRTLE AVE	C5		0006
35A	Drug / Narcotic Violations	0.3	BOUTELLE ST	C5		0055
35A	Drug / Narcotic Violations	0.3	139 MECHANIC ST	C3	1111	
35A	Drug / Narcotic Violations	0.3	20 ELM ST	C3		0822
35A	Drug / Narcotic Violations	0.3	10 WORCESTER ST	C1		0847
35A	Drug / Narcotic Violations	0.3	310 MAIN ST	C3		0005
35A	Drug / Narcotic Violations	0.3	137 CLARENDON ST	C4		1813
35A	Drug / Narcotic Violations	0.3	245 OAK HILL RD	C4		0135
35A	Drug / Narcotic Violations	0.3	324 LUNENBURG ST	C5		2111
35A	Drug / Narcotic Violations	0.3	105 BLOSSOM ST	C3		0024
35A	Drug / Narcotic Violations	0.3	15 MAIN ST	C5		2009

Table 5: Sample Attribute Table Displaying Crime Types and Their Weights

Results

Hotspot Maps

The quarterly maps revealed that the hotspots were not stationary; rather, they moved. However, the hot spots shared many common locations as illustrated in the general composite maps (Figures 7 and 8). In Figure 7, there were four major crime hotspots on the Blossom, Myrtle, Elm, and Orchard Streets. Stemming from these hotbeds of crime, the streets surrounding these areas tended gradually to decrease in crime density every couple of blocks into the next level. Figure 8 displayed that there were three main traffic violation hotspots on Main, Mack, and Lunenburg Streets.

Total Weighted Crime

Figure 9 illustrates the temporal pattern of total weighted crimes for the time period of January 2008 to June 2012. The wavy pattern displays that the beginning and the end of each year appear to have the lowest values (with 4th quarter 2009 being an exception), and the 2nd or 3rd quarters tend to generate peaks in the year. Overall, 2009 had the lowest crime rate and 2011 had the highest. Table 6 summarizes crime statistics in annual and quarterly averages.

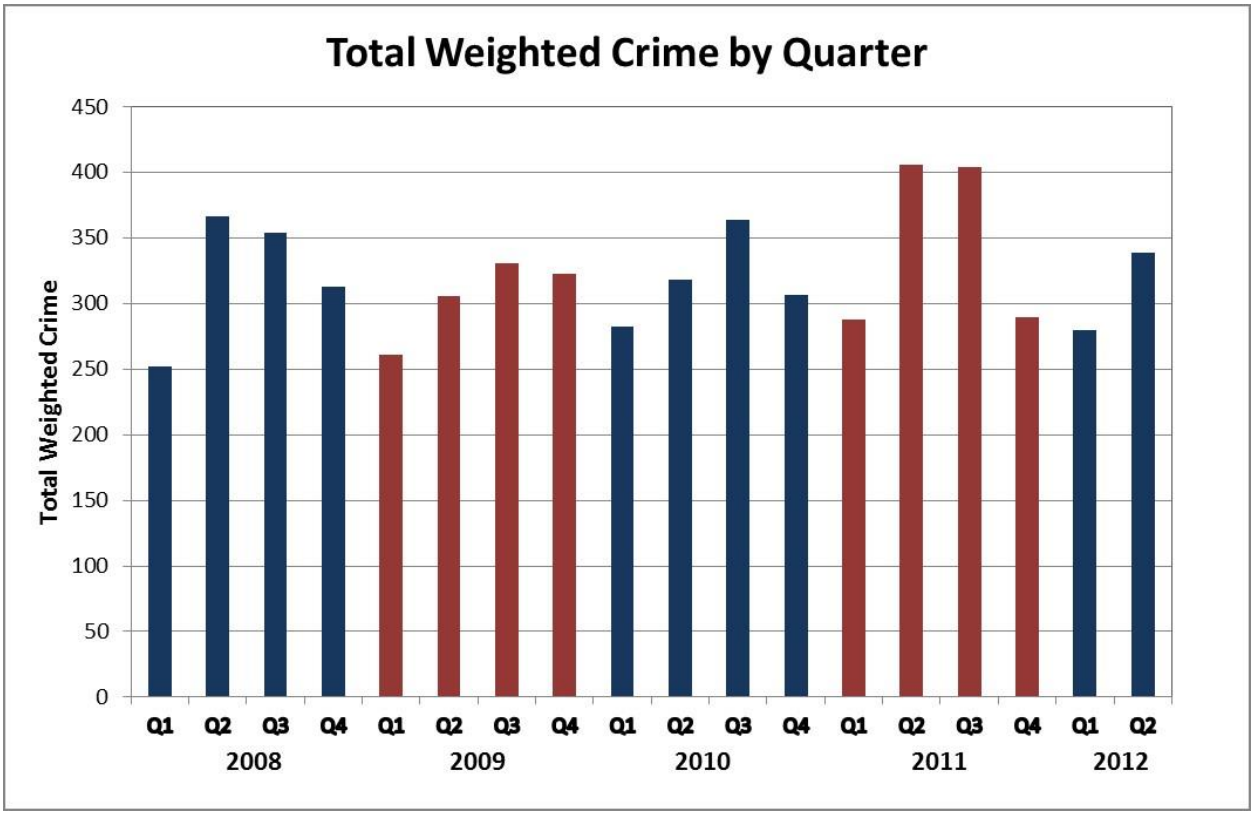


Figure 9: Total Weighted Crime by Quarter

Total Weighted Crime					
Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average
2008	251.6	366.2	353.6	312.7	321.0
2009	260.5	305.6	330.7	322.9	304.9
2010	287.2	318.3	363.2	306.2	318.7
2011	287.3	405.3	403.4	289.3	346.3
2012	279.4	338.6	No Data	No Data	309.0
Average	273.2	346.8	362.7	307.7	

Table 6: Statistical Summary of the Quarterly Total Weighted Crimes

Traffic Violations

Figure 11 illustrates the temporal trend of traffic violations in the study period. The pattern appeared to show a reversed trend to the crime outline shown in Figure 9. It tends to peak in cold months (1st and 4th quarters) and decrease significantly in warm months (2nd and 3rd quarters). The similarity between the two patterns, however, is that traffic violations also have a low year in 2009 and a high year in 2011. The quarterly and yearly statistics (table 7) also exhibit this pattern.

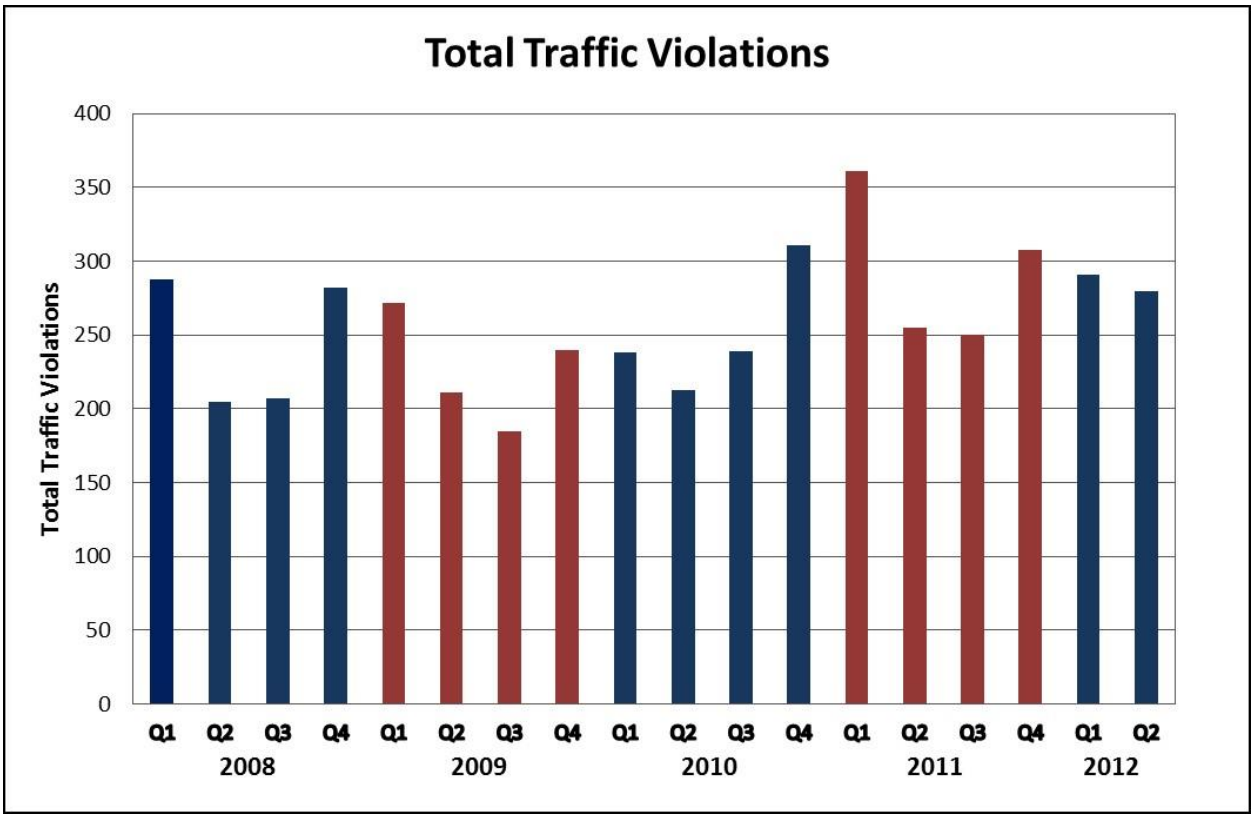


Figure 10: Total Traffic Violations

Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Average
2008	288	205	207	282	246
2009	272	211	185	240	227
2010	238	213	239	311	250
2011	361	255	250	308	294
2012	291	280	No Data	No Data	286
Average	290	232.8	220.3	285.2	

Table 7: Statistical Summary of the Quarterly Traffic Violations

Summary and Conclusions

In this study, crime and traffic violation patterns during the time period of January 2008 to June 2012 were examined spatially and temporally. Two comprehensive reference maps, Figures 11 and 12, were produced as points of reference for naming the spatial distribution of crime or traffic violation hotspots, respectively. It was found that the largest hotspots of crime occurred within the central/downtown part of the city. This area consisted of the streets within two blocks of the Fitchburg State University campus, including Davis, Myrtle, Highland, and Boulder streets.

The spatial distribution of traffic violation hotspots shared many similarities with the crime hotspots, such as quite comparable central clusters located at the Main, Boulder, and Highland streets area. At the same time, traffic violations had two unique hotspots located on the John Fitch Highway and Bemis Street. A closer look at these hotspots revealed that four way intersections, traffic lights, and roads with three or more lanes contributed to forming the hotspots.

There was moderate correlation between crime and traffic violation hotspots. Spatially, crime and traffic violation hotspots overlapped significantly at the central cluster in the downtown area. There were hotspots, however, that belonged to either crime or traffic violations with no overlap in between, such as the crime hotspots at Omena Place and Orchard streets, or the traffic violation hotspots at John Fitch Highway and Bemis street. Temporally, crime and traffic violations had opposite trends, where crimes peaked in warmer months and traffic violations in colder months.

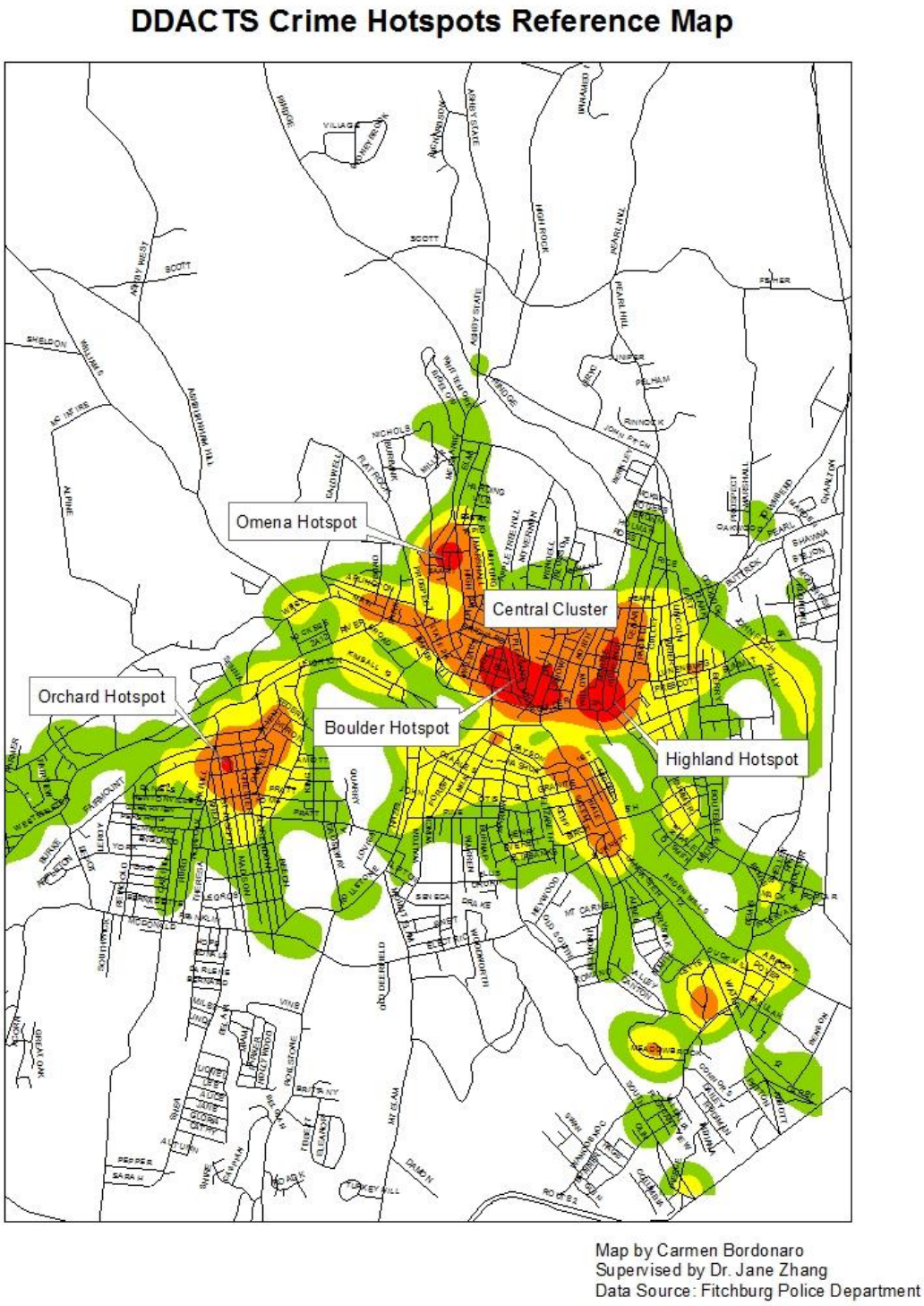
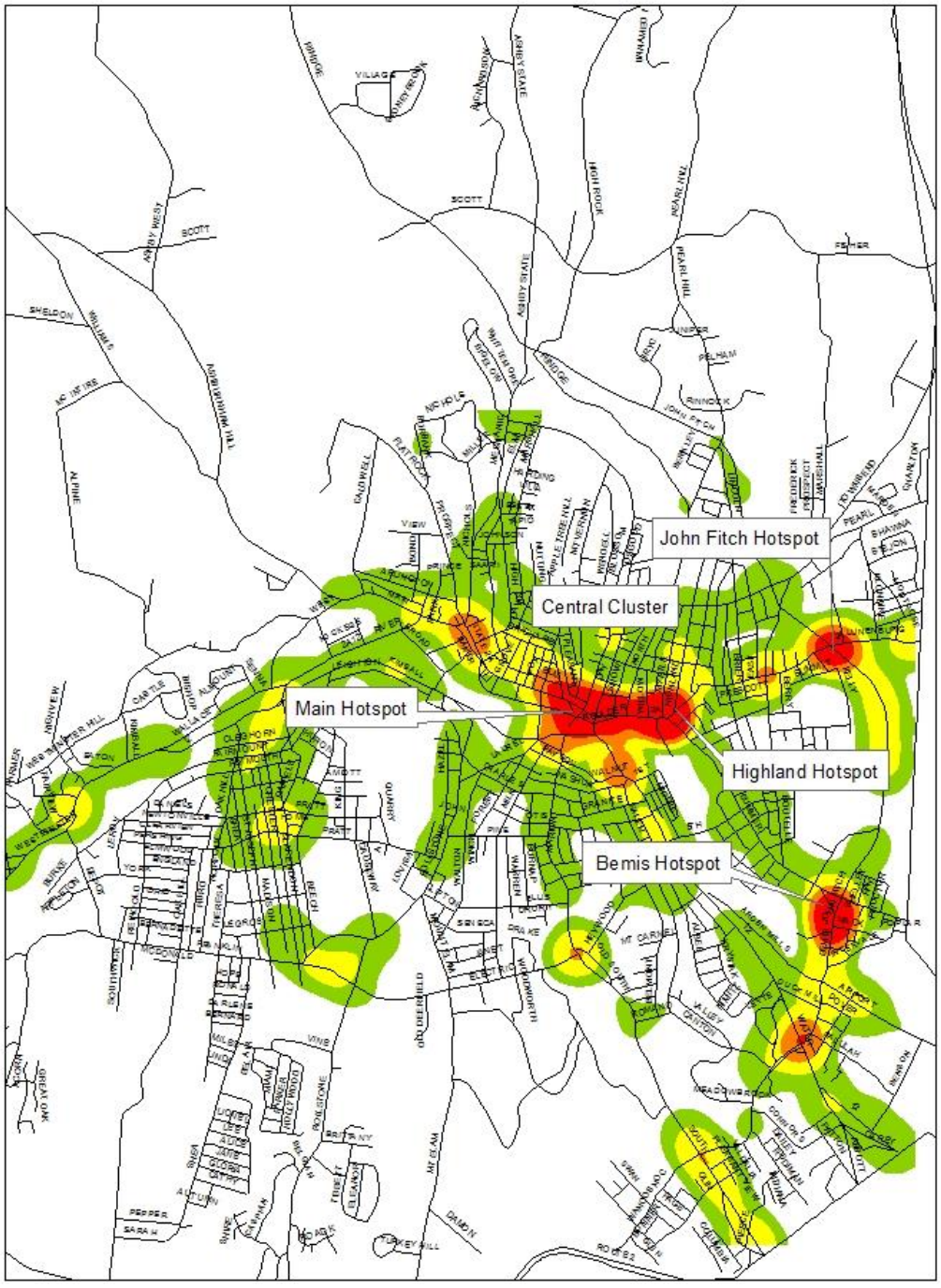


Figure 11: DDACTS Hotspots Crime Reference Map

DDACTS Traffic Violation Hotspots Reference Map



Map by Carmen Bordonaro
Supervised by Dr. Jane Zhang
Data Source: Fitchburg Police Department

Figure 12: DDACTS Hotspots Traffic Violation Reference Map

Discussion

There were several limitations in the project. First was the quality of the raw data and its impact on the geocoding process. The original crime and traffic violation data contained spelling errors and omissions of street numbers, which created unmatchable addresses during the geocoding process. In the first quarter of 2010, for example, approximately 400 crimes occurred, and, yet, only 350 of them matched successfully during geocoding, creating a data omission for the later mapping and analysis processes.

Second, the categorization of crime types in the original dataset introduced unwanted crimes into the mapping and analysis processes. Domestic violence, an indoor non-moving crime type that was not covered by DDACTS patrol, was not categorized specifically from the general assault crime type, and, thus, was unable to be separated from the original dataset. Therefore, additional crimes would have been added into the later mapping and analysis processes. In contrast, shoplifting crimes, which were clearly categorized in the original dataset, were successfully removed from the dataset at the early stage of the project.

The third limitation, which could lead to a potential future project, resided in the understanding of the dynamic relationship between DDACTS patrol to the volumes of crime and traffic violation. The Fitchburg Police Department started practicing DDACTS patrol in 2011. It was also the year when both crime and traffic violation volumes peaked, compared to other years in the study period. It might appear that DDACTS did not prevent or reduce crime or traffic violations. Another plausible explanation, however, could be that high efficiency patrol practice, such as DDACTS, may have resulted in police officers locating themselves to high frequency/potential crime or traffic violation areas effectively. Thus, more reporting and arrests would ultimately show an increase in the records. As argued by Zimiring [7], an increase of this nature may not be a negative outcome. It may, on the contrary, be a positive indication of the effectiveness of policing.

Meanwhile, it must be pointed out that the FPD halted DDACTS patrol each year during summer months due to staff shortages, which may have contributed to the pattern of crime and traffic violation distribution and frequency.

Lastly, a closer examination of the impact of the changing population levels in the university campus and adjacent areas on the volume of crime and traffic violation would benefit relevant projects in the future. The Fitchburg State University campus and the adjacent student rental housing areas experience fluctuating populations between school semesters vs. summer breaks. A careful separation of student-involved vs. resident-committed crime or traffic violation could improve the understanding of these incidents' spatial and temporal patterns.

Acknowledgements

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