

**AN ANALYSIS OF CYCLING INFRASTRUCTURE  
AND CYCLING ACTIVITY IN THE  
CITY OF SALEM, MASSACHUSETTS**

**Honors Thesis**

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An Analysis of Cycling Infrastructure and Cycling Activity

In the City of Salem, Massachusetts

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**ABSTRACT**

Over the last decade, the City of Salem, Massachusetts has made significant investments in infrastructure to support cycling in the City, such as the construction of new bike lanes and cycle paths. To what extent do these investments meet the actual activities and needs of cyclists? What routes do cyclists commonly use? To better understand cyclists' usage of roads in the City of Salem, this research will analyze user-populated information from Strava, a mobile application that records a user's coordinates as they cycle through Salem. Geographic Information Systems (GIS) will be used to analyze and create maps that highlight the aggregate habits of cyclists in Salem and compare those to cycling infrastructure, and public safety. This information can be used to help guide cycling growth and investment in the City of Salem. The research and analysis is valuable for demonstrating the true impact and usage of cyclists on roads in Salem.

*Keywords:* Geographic Information Systems (GIS), Strava, Cyclists, Salem, Massachusetts, Heatmap, Modes, Transportation, Accidents, Infrastructure, Mobile application, Bicycle infrastructure, Bicycle lanes

INTRODUCTION

Salem, Massachusetts is located on the North Shore of the Boston metro region on the coast of the Atlantic Ocean (Figure 1). The City of Salem is 18.1 square miles. Its downtown is located close to the ocean and suburban sprawl ranges outwards. As of the 2010 census the

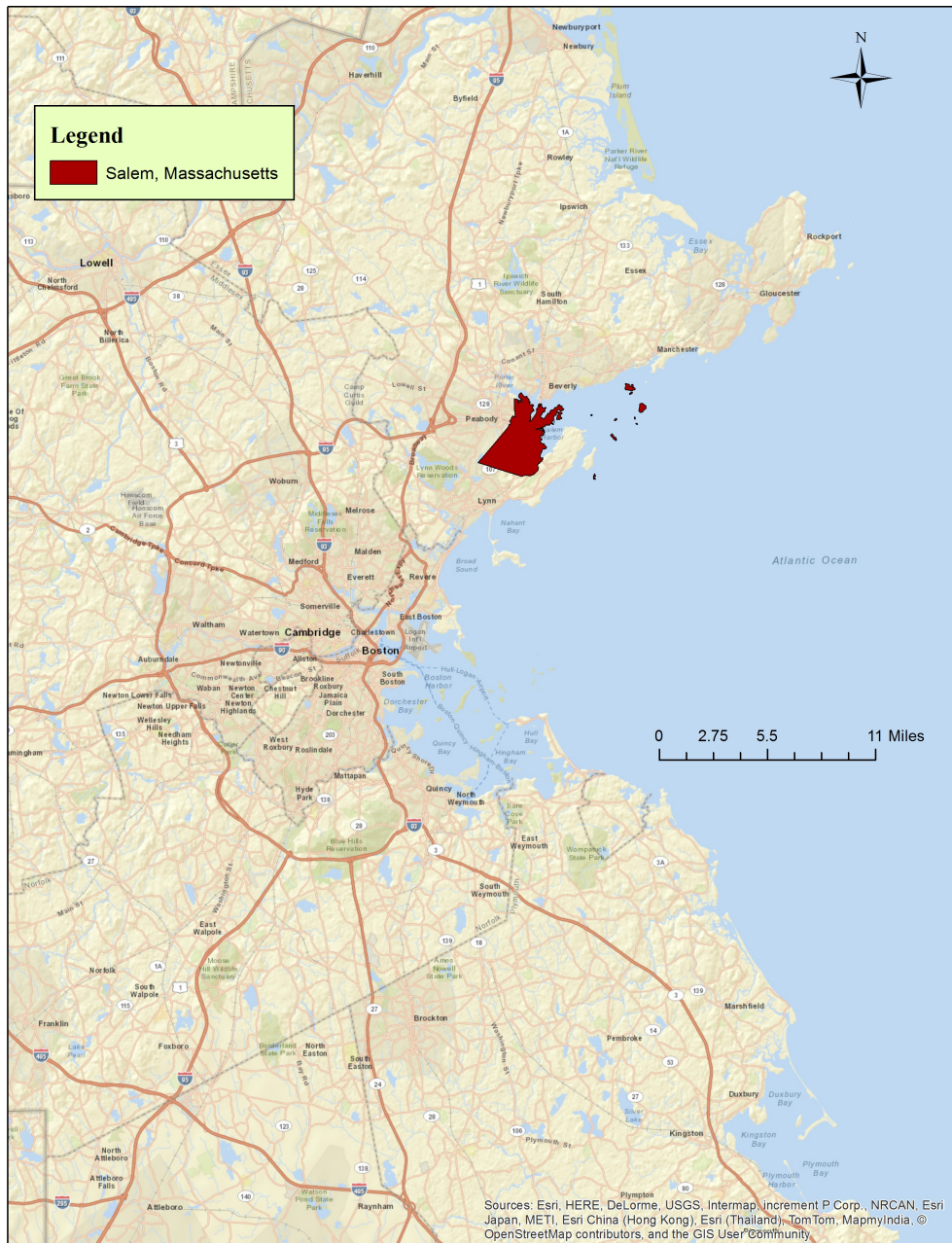


Figure 1 Overview of Salem, Massachusetts

population was 41,340 and by 2012 has grown to 42,219 residents. Five other municipalities

border Salem: the City of Peabody, the City of Lynn, the City of Beverly, the Town of Swampscott, and the Town of Marblehead. Each municipality interacts with Salem, and the roadways connecting these communities are access points for cyclists entering Salem. Salem Mayor Kim Driscoll has been proactive within the city to promote cycling and help implement the bicycle-sharing program Salem Spins, which is a free service for residents and tourists alike. Salem Spins offers hubs at Salem State University, the Hawthorne Hotel in Downtown Salem and the Salem wharf, where Boston Harbor Cruises offers a ferry from Salem into downtown Boston. The city of Salem is a vibrant hub of action, drawing acclaim for the quality of restaurants within town and the eccentric tourism of the Salem Witch Trials in 1692. Salem sees a lot of residential and tourist use of its roadways, and more recently, cyclists' use of roads and bicycle paths. In June 2006, the city created the Bike Path Committee to help promote the existing bicycle paths and to sketch ideas for new paths to connect major paths through downtown areas. The Committee works closely with the City Planning and Community Development Department, and each has played an essential role in "promoting a more bike-friendly environment throughout the City" (Fay, Spofford and Thorndike, 2010).

Although there is a lack of detailed data on cycling behavior in the United States, some see cycling on the rise, including John Pucher, a contributing author of *Bicycling Renaissance In North America? An Update And Re-Appraisal Of Cycling Trends And Policies*. Pucher argues that cycling across the nation has grown and gained widespread interest, almost a renaissance of sorts. The growth in cycling has been tied to specific areas such as cities and university campuses and their surrounding areas. Salem is following the trend described by Pucher. It is a growing city with more cyclists on the roads. Salem is experiencing an increased population of cyclists due to the university and the North Shore region, both of which attract a broad range of

cyclists, recreational and commuters that ride through Salem. In 2012, the City of Salem and the Bike Path Committee “submitted an application for recognition as a “Bicycle Friendly Community” with the League of American Bicyclists... and was awarded an Honorable Mention for its efforts to date building and promoting bike infrastructure and education” (Taormina, 2012). Pucher points out that the “boom in cycling” has been concentrated in cities that have introduced various programs to aggressively promote cycling.

Cities such as Salem, which are investing in the future and adding bicycle infrastructure, are faced with decisions of how to invest. Most choices are between painted bicycle lanes, cycle tracks along roadways, or bicycle paths that are not in conjunction with current roads (Broach, Dill, and Gliebe, 2012). Decisions about where and how to invest in cycling infrastructure are hindered due to a lack of empirical studies of cyclists’ behavior, such as that collected with GPS. For the City of Salem to create cycling infrastructure with the greatest impact, it will be constructive for Salem to obtain a sample of data on the precise habits of cyclists to understand where investments are needed. This empirical data will provide a wealth of information for Salem to develop an evidence-based and well-planned cycling infrastructure for the city. Furthermore Salem will be able to better understand bicyclists’ preferences, which will also help future cycling investments. This analysis utilizes data on cycling activity in Salem, as well as accident data and cycling infrastructure to assess the City of Salem’s current cycling infrastructure and needs.

There is limited research assessing cycling and how cyclists interact with cycling infrastructure. According to Broach, Dill, and Gliebe (2012), much of the research that has been conducted in North America groups cyclists and pedestrians into one category of “non-motorized trips.” This leads to a real lack of understanding about where and why cyclists are going because

cyclists' tendencies differ from pedestrians', especially in the range of a trip. Another issue that these authors mention is how regional transportation planners and engineers modeling travel demand in the U.S. assume that cyclists choose the "minimum-distance path between origins and destinations using a fixed travel speed." The problem is that this approach lacks data to support this assumption and, in addition, does not take into account road conditions such as the gradient of the road, traffic volumes that may change throughout the day, and whether or not an alternate bicycle path is nearby.

There are multiple community benefits to be derived from this analysis. Salem's Bike Path Committee is continuously seeking ways to expand the existing bicycle infrastructure of on- and off-road bike lanes and paths throughout Salem. The city is seeking ways to aid their programs of reducing "traffic congestion and improving air quality, advocating for bike safety, and encouraging cycling both as a form of alternative transportation and as a form of exercise and better health" (Taormina, 2012). Improved understanding of cycling behavior and needs and potentials for better investment choices will enable the City of Salem to continue with its progress as a green community, an important part of which is focused on providing better infrastructure for cyclists. The goal for this project is to help and encourage Salem to increase bicycling for transportation where it is needed most. This project will fill the current data gap on cycling behavior and needs and help Salem promote cycling in a more effective, evidence-based way.

This study identifies and describes the cycling activity and infrastructure in the City of Salem using commercial GPS data of cycling behavior, and GIS-based measures of accidents and infrastructure. There are four key questions that this analysis seeks to answer through data analysis: What is the relationship between motor vehicle traffic volume and cycling activity and

accidents in Salem? Where is the cycling infrastructure in Salem and how well does it align with the most frequently used cycling routes? Is there a relationship between bicycle accidents and the lack or presence of cycling infrastructure? Is there a relationship between bicycle accidents and cycling activity?

## **METHODS**

To facilitate this analysis, data was gathered from the City of Salem's Department of Planning and Community Development. Data collected include GIS layers of Salem's street network, bicycle lanes, paths and sharrows and bicycle parking locations.

The accident data for the city of Salem was obtained from the Salem Police department. The data table provided contained all bicycle related accidents that occurred between January 1, 2013 and December 31, 2013. This information was tabulated and geo-located by address or intersection to create GIS layers.

To obtain the crucial data of cycling activity that shows exactly where cyclists have ridden with GPS accuracy, data was solicited from Strava. Strava is a cycling company that is designed to log, store and analyze all cycling data of its users. This commercial logging of GPS data is done through iPhones, Androids and Garmin GPS units. Strava developed this platform to host users' information so that users can analyze their own exercise and see how they compare to other users in the same area. Strava donated a sample of its data stripped of user identification to conduct this activity analysis. Strava's data allows for a full picture of Salem's cycling patterns from time of day to monthly trends.

Once all data was collected, it was catalogued and cleaned for input into a GIS. Cleaning consisted of converting data into a common format and coordinate systems, NAD 1983 State

Plane for Massachusetts's mainland. This allowed for a consistent method to identify and correct any errors or inconsistencies within the data.

The data provided by Strava is extensive and constitutes the main area of analysis. The data given consists of an Open Street Map (OSM) network in a shapefile format, and tables of data broken up by year, on-season cycling period and by month, from January 2013 to December 2013. This breakdown of the data allowed for ways to identify the most commonly used roads in Salem, to see the volume of riders who rode during the commuting hours between 7-10 a.m. and 4-7 p.m. and what percentage of the rides took place on or near cycling infrastructure.

In order to find a spatial relationship between the accident data and the cycling activity, a spatial join of the data was done. This allows the attributes of both datasets to be combined into a new table that ties the two datasets together based on their relative spatial locations. To create a visual reference, a map was generated that displays the accidents based on density. A density analysis takes the known quantities of a phenomenon, cycling accidents, and spreads them across Salem based on the addresses provided. The density surface shows where points of the accidents concentrate together and then predict a distribution of the accidents in Salem based on the original point. In addition to a visual map, a scatterplot graph was mapped to see if a correlation between the accidents and activity existed.

To analyze the accidents as compared to the cycling activity, a measure of the average distance from infrastructure to an accident was taken. This allowed statistics to be generated of how far and what percentage of bicycle related accidents took place on or off of cycling infrastructure. In order to compare the accidents to the infrastructure another map was generated using a raster heat map for accidents joined with Salem's cycling infrastructure.

## RESULTS

The City of Salem has a vibrant cycling community. In 2013 alone there were 226,817 logged rides using Strava, averaging 621 rides a day. Part of Salem’s cycling infrastructure begins at the Salem/Marblehead town line with a bicycle lane running down Lafayette Street that ends just before reaching Salem’s downtown area. From there, painted sharrows begin that help guide cyclists towards the historic Salem Common. With intermittent coverage of cycling

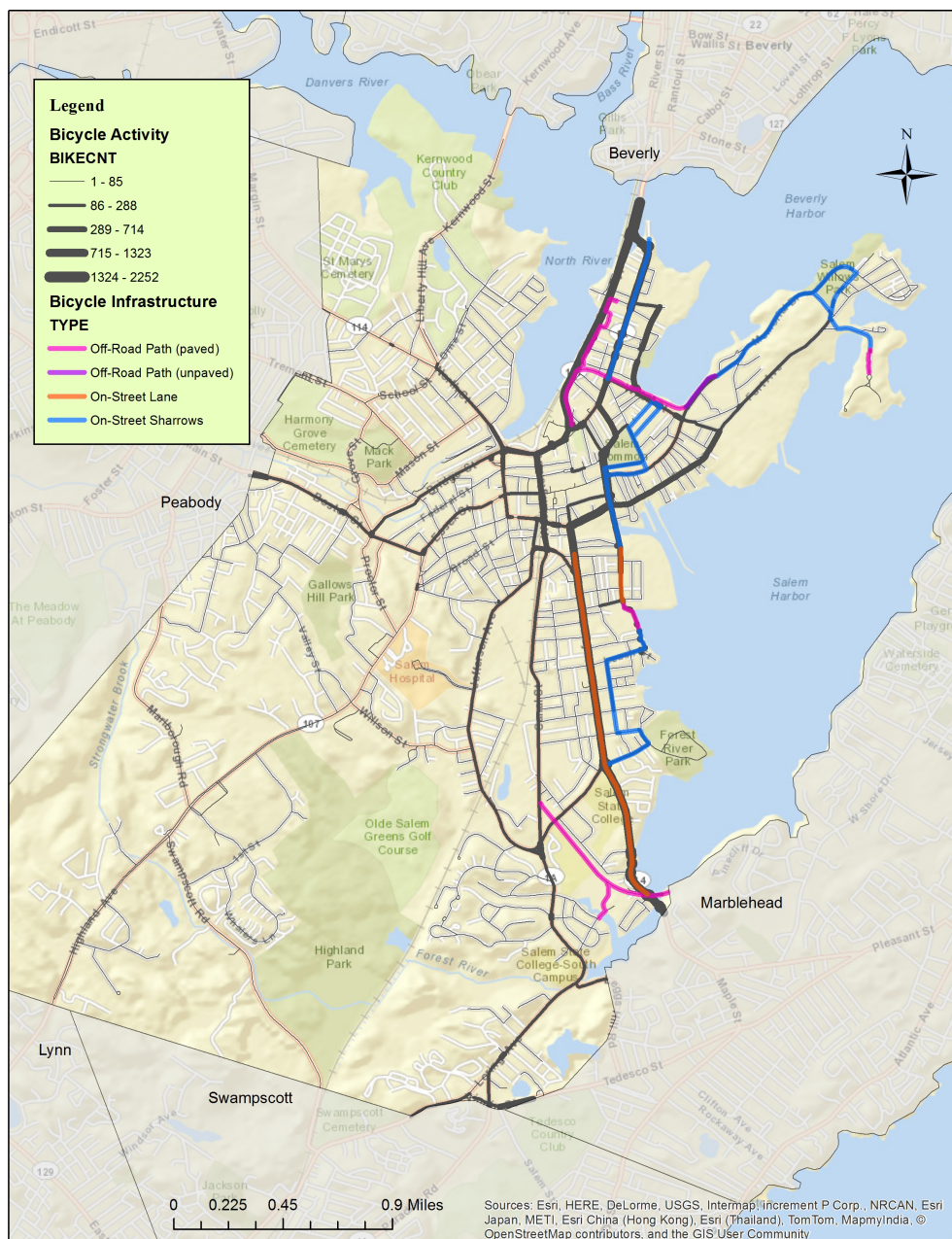


Figure 2 Cycling Activity & Cycling Infrastructure

infrastructure throughout Salem, a cyclist is able to pass from the Salem Common to Bridge Street and out to the Salem/Beverly town line. This route described seems to be the most common trend of cycling in Salem that feeds cyclists through Salem from Marblehead and Beverly. This can be seen in Figure 2. Figure 2 shows the borders of Salem, which are defined by the greyed areas of the map. Pink, purple, orange and blue lines designate where Salem has various types of cycling infrastructure. The black/grey line depicts a graduated symbol where the greater amount of activity the thicker the line. Much of Salem's infrastructure is helping feed high a number of cyclists from Marblehead to Beverly. It is also encouraging to see that the area with high activity on Lafayette Street has infrastructure to help guide a cyclist's passage from downtown towards Marblehead or vice versa. Lafayette Street is the busiest road for cycling in all of Salem, with 51,894 bicycles rides in 2013, accounting for 25% of all riding in Salem. Bridge Street is ranked the second busiest road and saw 39,802 cyclists in 2013, accounting for 19% of all riding. Both of the top two ranked roads for cycling usage in Salem have cycling infrastructure, Lafayette Street has a newly painted bicycle lane as of 2013 and Bridge Street has sharrows that indicate shared use between cyclists and motor vehicles.

What is especially curious in my findings is that where cycling infrastructure is placed plays an important role in whether or not it will be used. This is seen in Figure 3, where the Ayube Memorial Bicycle Path, the pink off-road cycling path that is paved runs parallel in sections to the Bridge Street Extension. The bicycle path is not experiencing the same volume of cycling activity despite having cycling infrastructure, whereas the Bridge Street Extension does not have cycling infrastructure, but has much greater cycling activity. Similar to Figure 2, the pink, purple, orange and blue lines designate various types of cycling infrastructure. The black/grey is a graduated symbol, where the greater the amount of activity the thicker the line.

The cycling infrastructure within Salem is composed of bicycle lanes, off-road-paved paths and sharrows that determine areas of shared road use with automobiles without a designated bicycle lane. As expected infrastructure has areas of high and low use.

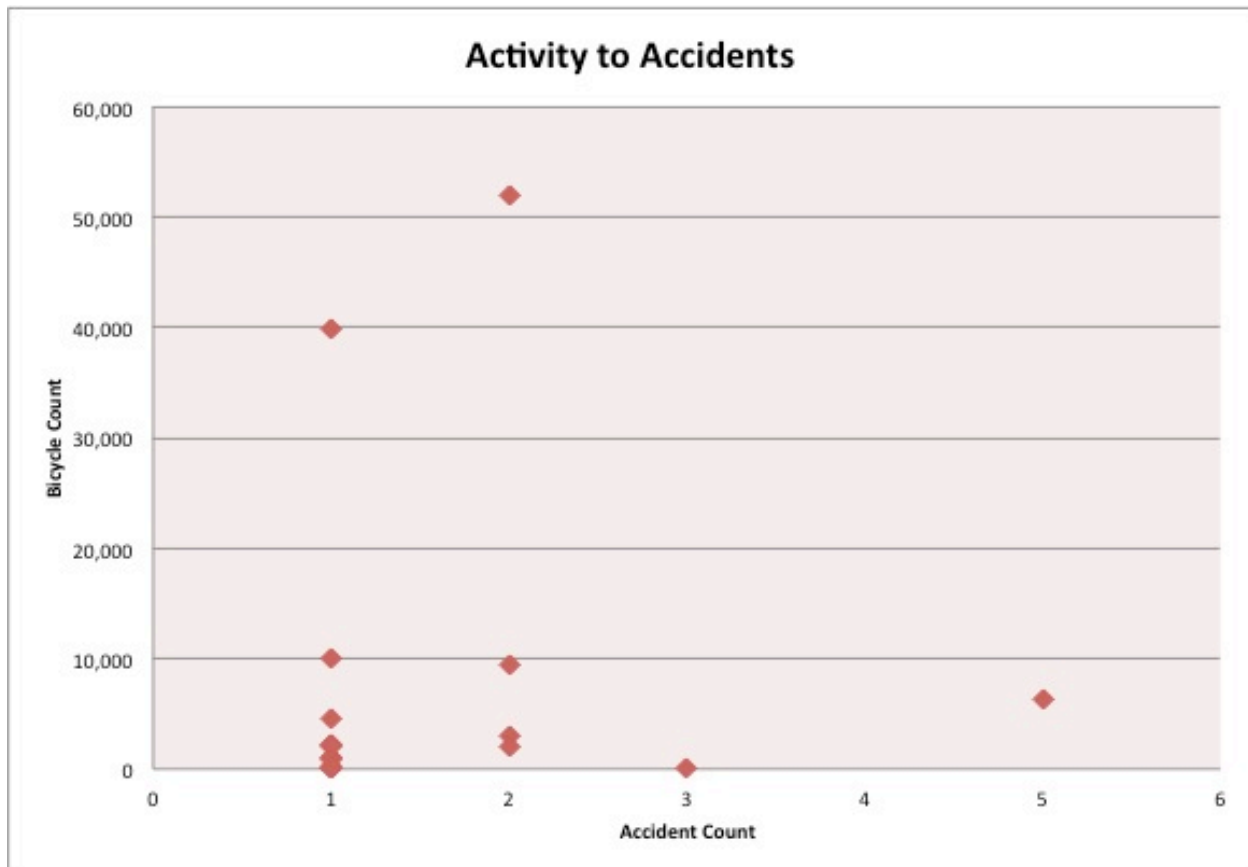


Figure 3 Cycling Activity & Cycling Infrastructure Zoom

When examining the relationship of cycling activity to accidents it was surprising to find that there was no clear relationship. I had hypothesized that a positive relationship would exist,

such that areas of high cycling activity would coincide with areas that have a high number of accidents. Figure 4 shows accidents on the x-axis and a sum of bicycle counts on the y-axis.

The graph leads one to believe the bicycle related accidents are occurring at random. With the hypothesis negated and no clear relationship apparent between cycling activity and accidents, I focused on the relationship between cycling activity and bicycle related accidents in the downtown area and what was causing the clustering of accidents in Figure 5. What becomes



**Figure 4 Total Bicycle Count to Bicycle Accidents**

apparent is the bulls' eye of accidents in Salem's downtown. Once more, the black/grey line is a graduated symbol, where the greater the amount of activity the thicker the line, and the accidents depicted on the density map show the clustering of accidents. There is also minor clustering of accidents to the North of Salem's downtown. This bull's eye pattern is worrisome for cyclists

because this area experiences moderate cycling usage in Salem and is where many businesses and the farmers market are located.

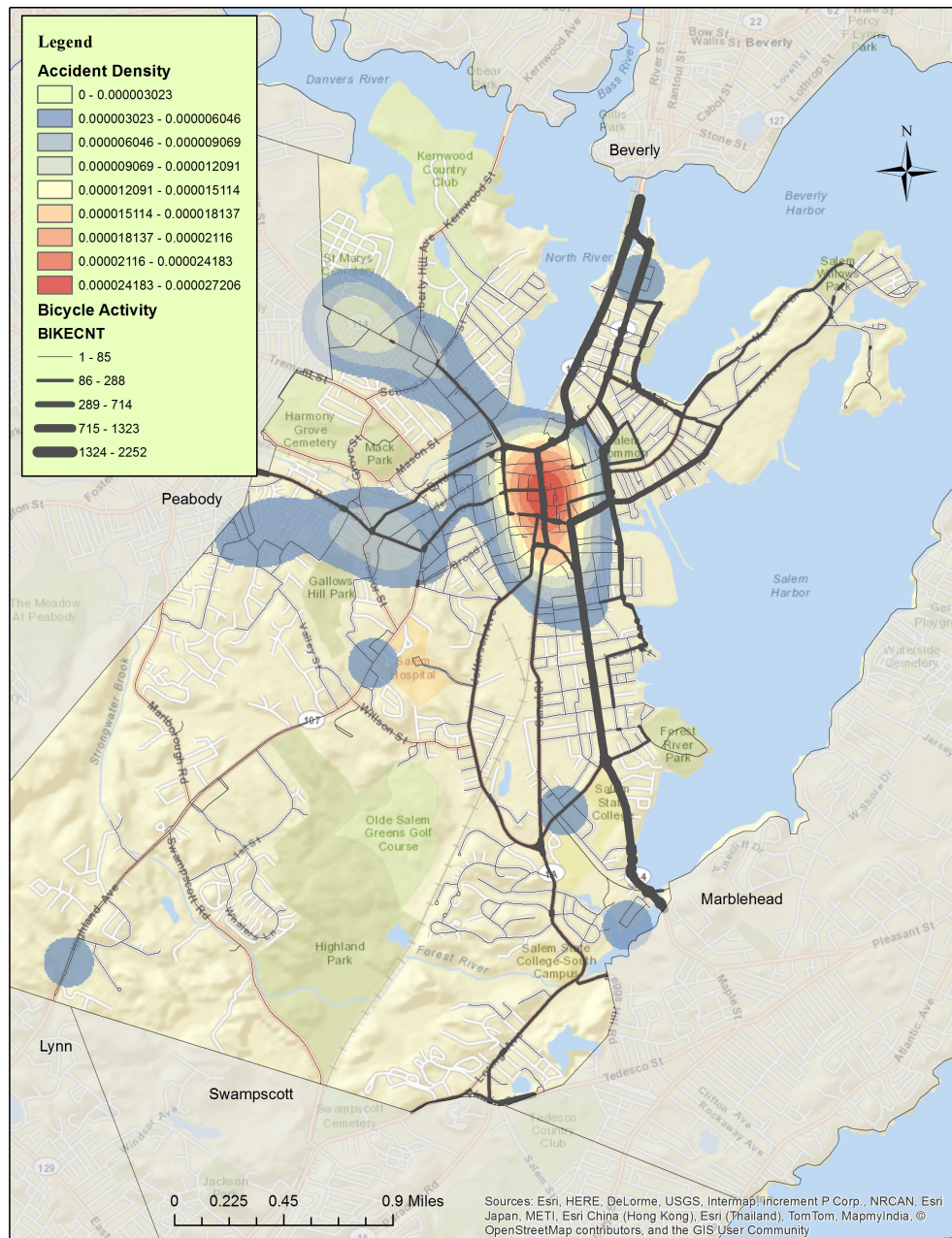


Figure 5 Cycling Activity Bicycle Related Accidents

The arterial areas of high activity towards the Beverly/Salem town line and the Marblehead/Salem town line show high cycling activity and there are a low number of accidents

occurring near these areas, which supports the findings from Figure 4 that there is no correlation between areas of high cycling activity and a high number of bicycle related accidents.

In order to further examine the clustering of accidents in Salem’s downtown areas Figure 6 is a zoomed in look of the area with specific accident locations shown as green dots.

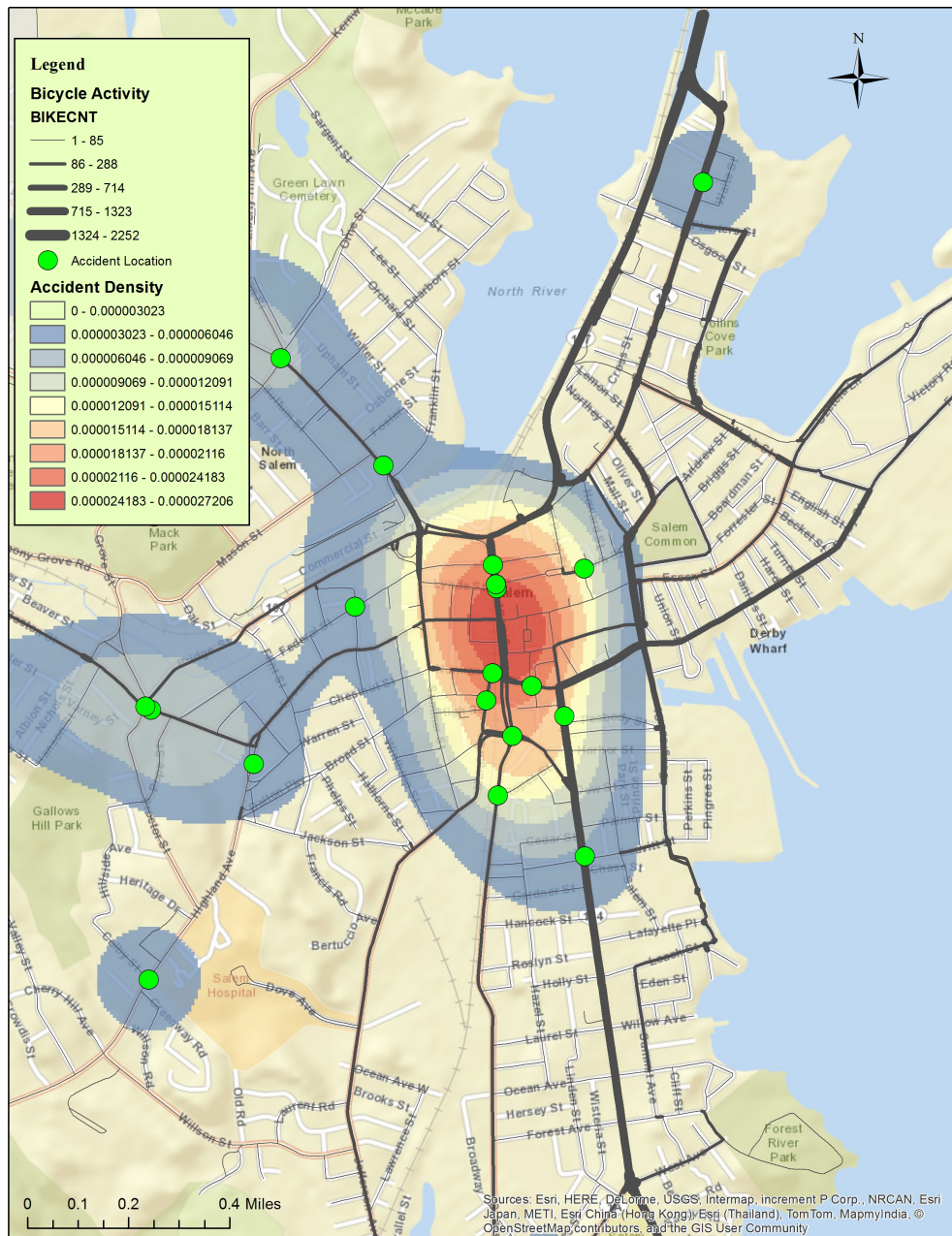


Figure 6 Cycling Activity & Bicycle Related Accidents (Downtown zoom)

Many of these accidents occurred on Washington Street and New Derby Street. These areas are often congested with motor vehicles making frequent turns. The accident data shows that downtown Salem is the most dangerous area for a cyclist to ride in the city.

The most convincing way to link why the accidents are occurring in the downtown is due to the relationship between cycling activity and cycling infrastructure. In Figure 7 it is apparent that there is a cluster of bicycle related-accidents where there is no cycling infrastructure. In fact, the vast majority of bicycle-related accidents occur off of, or far away from, cycling infrastructure.

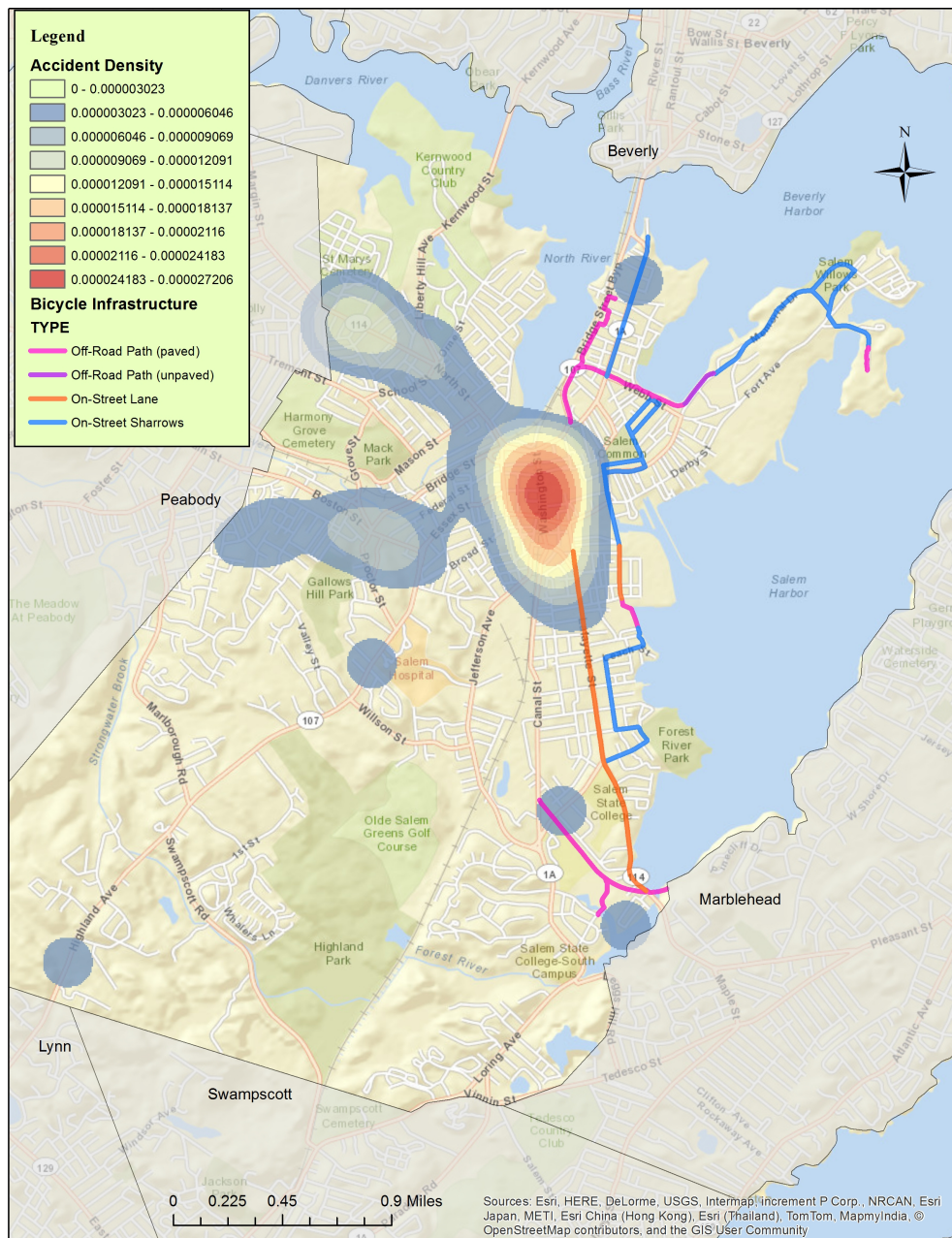


Figure 7 Cycling Infrastructure & Bicycle Related Accidents

Based on the measured average distance from infrastructure to an accident, and the percentage of bicycle related accidents that took place on or off of cycling infrastructure, it was found that 93.3% of all accidents in 2013 occurred off of cycling infrastructure. Even more curious is that 50% of bicycle-related accidents occur more than 1,000 feet away from cycling infrastructure. With most accidents occurring off of cycling infrastructure, it makes sense that only 36% of rides took place on cycling infrastructure. However, that is an encouraging amount of use when only 6% of all roads in Salem contain cycling infrastructure.

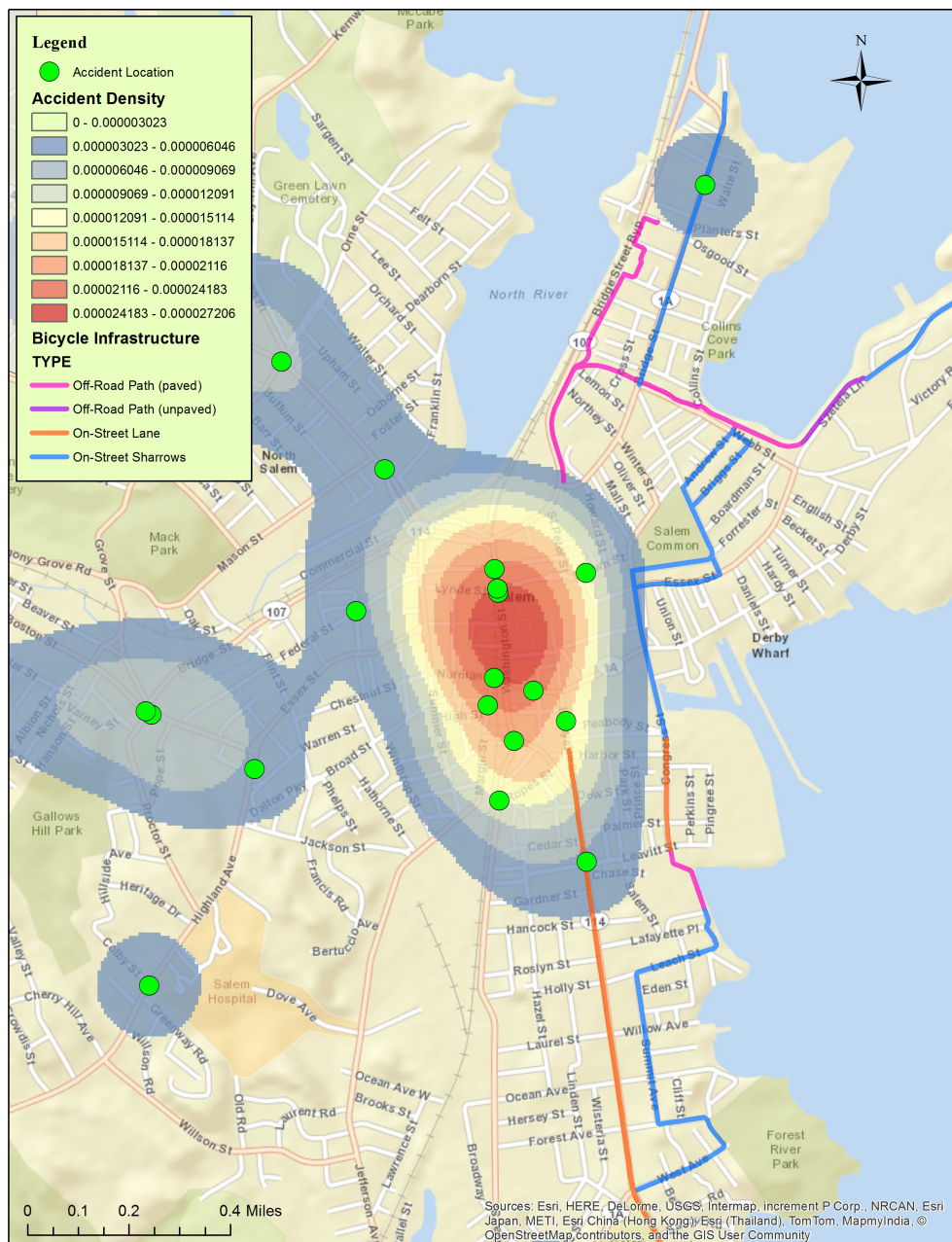


Figure 8 Cycling Infrastructure & Bicycle-Related Accidents (Downtown zoom)

Again this point is reiterated in Figure 8. A comparison of cycling infrastructure in the pink, purple, orange and blue lines and a density map of the bicycle related accidents in addition to the physical locations of accidents or intersections where they occurred in the downtown area. In this approach, it can be seen that only one of all accidents that occurred in the bull's eye clustering took place on infrastructure.

In order to determine some of the most commonly used roads by cyclists in Salem a top ten ranked-roads table was generated (Table 1). These top ten ranked roads account for 70% of all the riding in Salem. The top ten ranked roads help identify areas of high cycling usage in Salem, with Lafayette Street alone accounting for 25% of all rides that took place in Salem. Out

<b>Main Artery Count</b>			
<b>Rank</b>	<b>Street Name</b>	<b>Total Bike Rides</b>	<b>Percent</b>
1	Lafayette Street	51894	25%
2	Bridge Street	39802	19%
3	Loring Avenue	10054	5%
4	Washington Street	9477	4%
5	Salem Bypass Road	9083	4%
6	Derby Street	7844	4%
7	North Street	6290	3%
8	Washington Square	5365	3%
9	Essex Street	4531	2%
10	Jefferson Avenue	3712	2%
<b>Totals</b>		<b>148052</b>	<b>70%</b>

Table 1 Top Ten Ranked Roads

of the total 226,817 rides in Salem for 2013, 82,035 or 36% of all rides in Salem took place on cycling infrastructure.

Infrastructure Rides			All Rides	
Peak AM (7-10)	44.50%	36,513	42%	94,699
Peak PM (4-7)	21.40%	17,584	22%	50,031
<b>Total</b>		<b>54,097</b>		<b>226,817</b>

Table 2 Peak Commuting Bicycle Rides

Timing of when cycling occurs is important because cyclists' use of the road is shared and peak cycling times can overlap with peak motor vehicle use making it dangerous for both parties. Between the two high commuting periods of 7-10 a.m. and 4-7 p.m. 64% of all riding took place in Salem.

## CONCLUSION

The City of Salem, Massachusetts has made significant investments in infrastructure to support cycling. Salem has added new on street bicycle lanes and off road paved bicycle paths. This analysis described Salem's active cycling use throughout the city from the data provided by Strava, Salem's Police Department and the Planning and Community Development Department. From this data, maps and tables were generated that highlighted the aggregated habits of cyclists in Salem. In addition this analysis examined cyclists use of the bicycle infrastructure, and the relationship of bicycle accidents to cycling activity and bicycle infrastructure. This analysis can be used to help guide cycling growth and investment in the City of Salem.

It is important to note that Salem's downtown area currently experiences a moderate level of activity, but there is no infrastructure that helps guide these cyclists through downtown either with a protected bicycle lane or sharrows (Figure 1). This lack of infrastructure in downtown

does not stop cyclists from using the space, but the City of Salem could look to expand their coverage for cyclists especially to promote frequent stops and purchasing of goods in the downtown area.

As seen in Figure 2 and Figure 3, having areas of bicycle infrastructure near areas of high bicycle activity does not guarantee usage. In order to avoid spending money on cycling infrastructure that is not garnering ridership, it is recommended that further activity studies be conducted to determine areas that best serve the needs of cyclists. The phenomenon that the Ayube Bicycle Path is underused despite being a safer route could be explained by the fact that it is not the shortest route from Salem's train station to Beverly. In fact, once a cyclist reaches the end of the Ayube path riding from the train station towards Beverly, a cyclist must stop to cross traffic when turning left onto Bridge Street, making the route not only more time consuming but also more complex.

The lack of infrastructure in the downtown district of Salem is concerning particularly because of the clustering of accidents seen in Figure 7. The addition of infrastructure in the downtown area could help alleviate the bicycle related accidents due to the correlation found between the effectiveness of cycling infrastructure in relation to bicycle accidents.

The addition of cycling infrastructure in the downtown areas is beneficial for cyclists and local businesses owners alike. The addition of cycling infrastructure in the downtown would promote healthy activity, improve the connectivity of the Salem Spins bicycle-sharing program, and spur economic activity in the downtown area.

Salem has a vibrant cycling community, but two-thirds of riding does not take place on cycling infrastructure. If this were to change and the City of Salem were to invest in cycling infrastructure even further than the city has, particularly in the downtown area, there would be a

reduction in the bull's eye clustering of accidents in the downtown. This is because this research has shown that bicycle related accidents seem to cluster in areas lacking cycling infrastructure.

Salem's cycling infrastructure network is advanced in comparison to the five surrounding towns and cities, however when focusing on Salem's network for cycling infrastructure there is a noticeable trend to create a funneled network that allows for infrastructure to easily pass from Marblehead through Salem and into Beverly or vice versa. It would be beneficial for the city to expand on infrastructure in the downtown area. It is clear Salem has a vision to create a network of bicycle lanes, paths and sharrows that allows for the untrained cyclist to navigate the roads in a safe and manageable way with interacting with other traffic.

Cycling in Salem can be divided into two categories, that of a recreational cyclists and commuters. An experienced recreational cyclist may have a pattern of simply finding the shortest route through Salem and studies found that "experienced cyclists prefer lanes over separate paths" to access the neighboring towns of Beverly and Marblehead (Broach, Dill, and Gliebe, 2012). Commuter cyclists have a variable pattern compared to a recreational cyclist. A commuter benefits greatly from cycling infrastructure, often needing designated space to form a lane between moving traffic and parked cars. According to Broach, Dill, and Gliebe (2012), "less-experienced cyclists have a higher preference for more separated facilities and avoiding high traffic volumes or speeds". The trend of a commuter cyclist often orients around a downtown area, where access to farmers markets, businesses and the commuter rail station are important. Thus, bike lanes are the ideal solution to reduce the clustering of accidents, as well as encouraging safe and enjoyable riding. Finally this research and its products highlight Strava's contribution and unique data analysis potentials for cycling research and policy for other cities across the country, who wish to analyze if their cycling infrastructure is being used by cyclists.

## ACKNOWLEDGEMENTS

A summary of process and findings, along with the online visualizations, were presented at the Association of American Geographers (AAG) annual meeting in Tampa, Florida on April 8 to April 12, 2014; for City officials of Salem; and to the Strava SDAP board.

This research and its products highlight Strava's contribution and unique data analysis potentials for cycling research and policy. This research will be used to satisfy a senior thesis requirement for the commonwealth honors undergraduate program. Strava's contribution will be publicly acknowledged in the report of this project. This project was presented at the Association of American Geographers (AAG) annual meeting in Tampa, Florida, a professional conference, which brings together thousands of researchers and government officials from across the country and around the world. Finally, the summary report and online map will be presented to the City of Salem for its consideration. I would also like the opportunity to present my research and online maps to the STRAVA SDAP board to demonstrate this data's applicability in municipal research and cycling advocacy.

I would also like to thank Dr. Marcos Luna for his guidance and countless hours of meetings in pursuance of this final product. This project would not have been possible if it were not for his expertise in this field.

## RESEARCH FUNDING

Salem State University provided support to present this work at the AAG conference in Tampa, Florida. The Department of Geography is provided \$300 and the conference registration fee. In addition, I have received a \$500 research and travel grant from the Commonwealth Honors Program at Salem State University in order to fund my travel expenses to Tampa, Florida.

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