Culver Road and East Main Street Intersection

Traffic Analysis Report

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Introduction

There has been intense study in the area of traffic management since the mid-1990s. The ability to quantify and discern underlying patterns by use of a simple loop detector is a useful tool in understanding the complex nature of transportation systems. We were tasked with identifying unique trends in the data and to provide sound recommendations to improve traffic conditions for the intersection of Culver Road and East Main Street in Rochester, New York. The data, obtained from a loop detector approximately 200 feet away from intersection in the southbound lane, has nearly eight months of data stretching from October of 2013 to June of 2014. The loop detector transmits data in five minute intervals, and calculates pertinent metrics such as estimated hourly volume, number of cars approaching a red light, delay, and others.

The intersection, pictured in **??**, is part of an important byway between Bay Street and East Main Street. Zoning data provided by the city of Rochester shows us that the area surrounding this portion of Culver Road is mainly residential. However, there are designated commercial zones at both the intersections of Bay and East Main, and additional commercial lots in between both of these locations [**?**]. These are mainly smaller business and not large scale commercial plazas similar to those in Henrietta or elsewhere in the city of Rochester. It is important to consider this information in conjunction with the results of our analyses when providing meaningful suggestions.

We also consider the Traffic Volume Map that is provided by the County of Monroe and the City of Rochester. Culver Road normally experiences a large amount of traffic that is comparable to East Main [**?**]. Furthermore, it appears as though the traffic continues down Culver and that there is no noticeable amount of traffic turning onto East Main that would contribute to any possible congestion.

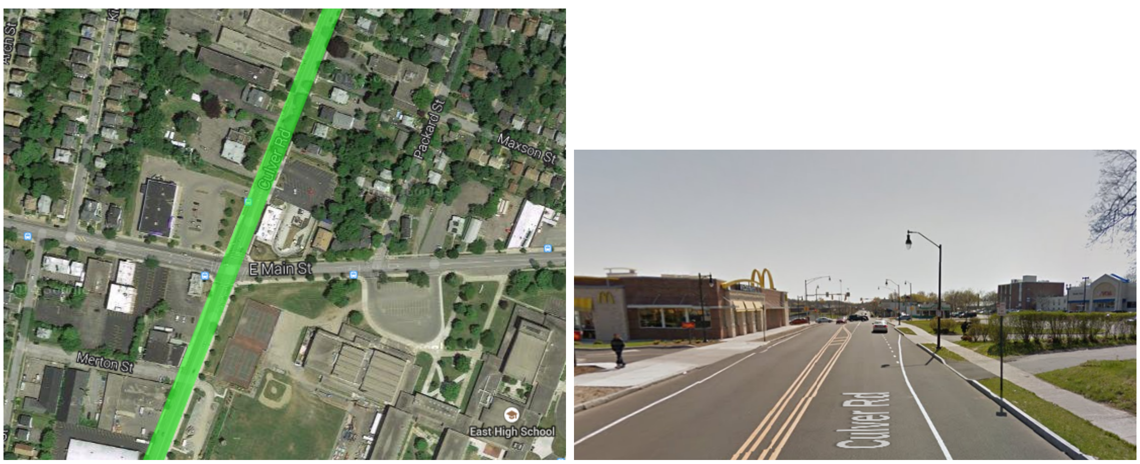

Figure 1: Pictured Left: satellite image of the intersection of Culver and East Main. Culver Road is highlighted in a light green. To the bottom right is East High School of the Rochester School District. Pictured Right: A streetview of Culver Road as it approaches East Main. Several businesses are located on both sides of the street. Location is approximate to where the loop detector is installed. Both images courtesy of Google Maps.

Data Analysis

To assess the traffic conditions at the Culver Road and East Main Street intersection, we determined the current state of the intersection in terms of federal DOT guidelines for this class of intersection, as well as analyses to examine trends and patterns in the traffic recorded and to predict occurances of traffic congestion based on time of day, day of the week, and the weather conditions present.

Traffic Analysis

There are a few common characteristics to examine when determining the traffic flow for a particular intersection. Namely, it is important to determine the amount of delay experience by drivers as they enter the intersection, the density of the vehicles as they pass through the intersection, and the velocity at which traffic flows through the intersection. With these three variables, it is possible to determine the effects of traffic congestions on the flow of traffic through the intersection.

The amount of time that vehicles wait at an intersection is refered to as the Level of Service (LOS). Ranked in letter grades from A to F, the LOS is an identifier for the overal health of the intersection. Ideally, an intersecton should be classified as being either A, B, or C, denoting free flow, reasonably free flow, and stable flow, respectively. The 2010 Highway Capacity Manual classifications for LOS can be seen in Table **??**, in which grade A intersections have less then 10 seconds of vehicle control delay, whereas grade F intersections have more than 80 of vehicle control delay.

Table 1: Level of Service classifications published in the 2010 Highway Capacity Manual.

LOS	**Vehicle Control Delay (Sec.)**
A	≤ 10
B	$10 - 20$
C	$20 - 35$
D	$35 - 55$
E	$55 - 80$
F	≥ 80

Using these classifications, we examined the average vehicle control delay for each five minute observation period. As shown in Figure **??**, the majority of observations have a Grade F Level of Service (58.38%). Each of the other levels of service occured in between 7.45% and 8.63% of observations. This suggests that the Culver Road and East Main Street intersections is experienceing traffic congestion, in which each vehicle move in lock step with the vehicle in front of it [**?**].

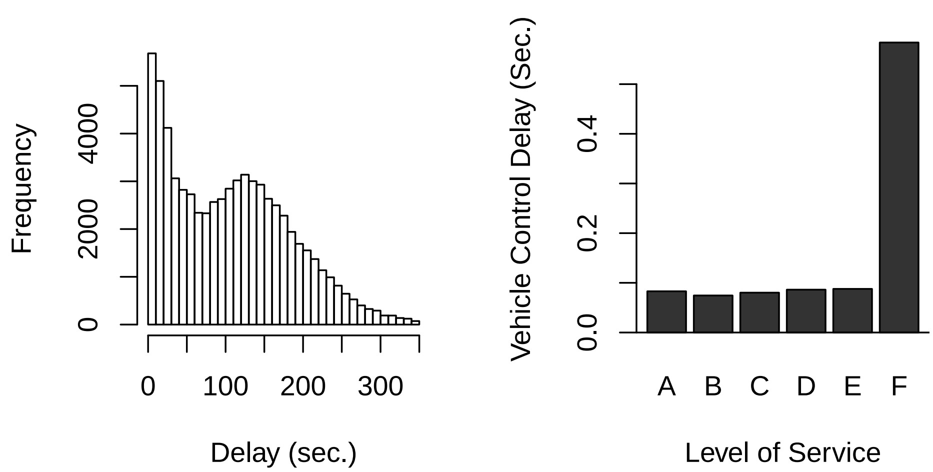

Figure 2: The Culver Road/East Main Street intersection has a poor Level of Service. The histogram on the left shows the distribution of the average vehicle control delay for each observation. The distribution is bimodal with peaks at zero seconds and 140 seconds. The median delay was 103 seconds with a IQR of 123 seconds. The bar plot on the right shows the distribution of each LOS grade for each observation in our data set. Observations were given a letter grade based on the average vehicle control delay for each 5 minute interval. The majority of all observations had a delay of greater than 80 seconds, suggesting that the intersection is predominantly grade F.

We also examined the relationship between the traffic density and traffic volume, also known as flux. Whe plotted, the relationship between the traffic density and the traffic volume creates the fundamental diagram of traffic flow [?], as shown in Figure ??. Using linear regression techniques, we were able to estimate the free flow velocity to be 19.5 miles per hour and the traffic wave velocity to be 2.43 miles per hour against the direction of traffic. We also determiend thecritical traffic density to be 42.8 vehicles per mile. As the vehicle denisty passes the critical density, the traffic flow becomes more unstable leading to traffic waves and congestion. To maximize the traffic flow, the vehicle density must remain below the critical density.

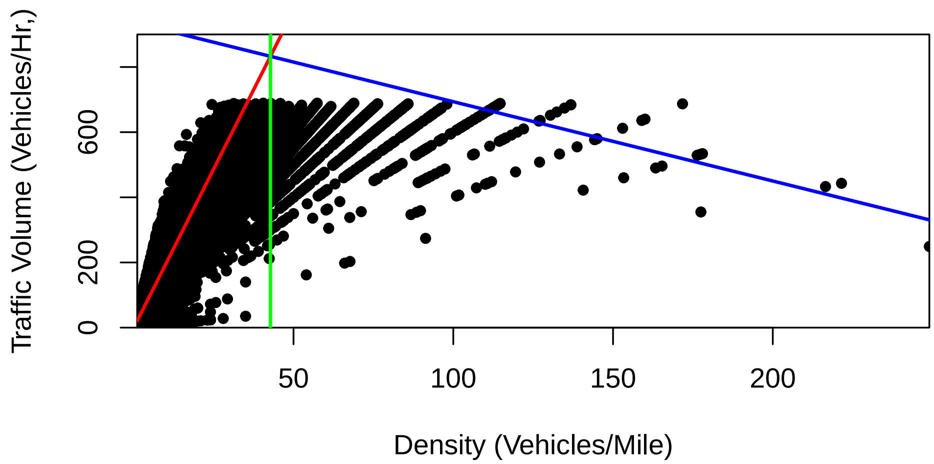

Figure 3: Fundamental diagram of traffic flow provides free flow and traffic wave velocities. Traffic density was calculated by dividing the traffic volume by the traffic speed. Using linear regression, we found the free flow velocity (19.5 mph) as depicted in red, the traffic wave velocity (2.43 mph) as depicted in blue, and the critical density (42.8 vehicles per mile) as depicted in green.

Trend Analysis

To examine the general trend in the metrics we were provided, we performed linear and multivariate regression. These techniques allows us to approximate the traffic volume and delay. Figure ?? shows the median delay for each week and the median traffic volume for each week with the linear regression for each data set. Our data suggest that the median amount of time that vehicles wait at the intersection may be increasing by 0.24 seconds per week. Our data also suggest that the median number of vehicles utilizing the intersection may be increasing by approximately 11 vehicles per week. Although the correlation coefficients are rather low, we are confident that the traffic congestions will worsen as more vehicles utilize the intersection.

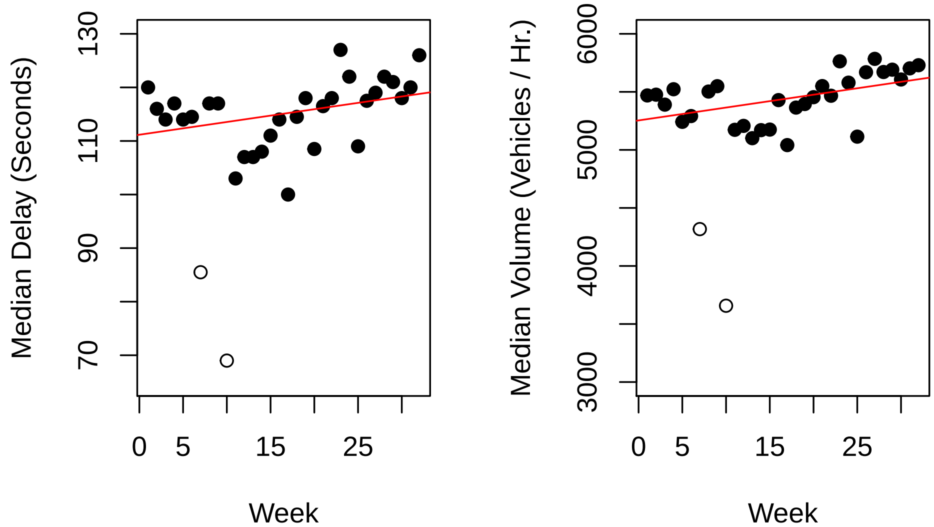

Figure 4: The median traffic delay and median weekly traffic volume are increasing over time. A linear regression of the median traffic delay for each week suggests that the traffic delay may be increasing 0.24 seconds per week ($R^2 = 0.13$). Similarly, a linear regression of the median number of vehicles to pass through the intersection per week suggests that the number of vehicles utilizing the intersection may be increasing at a rate of 11.08 vehicles per week ($R^2 = 0.24$).

Pattern Analyses

A secondary way of understanding the traffic passing though the Culver Road and East Main Street intersection is to assess the prevailing patterns of traffic. Two methods of analyzing traffic patrerns are clustering and correlation analysis. Clustering algorithims give us an opportunity to treat each day's traffic like a single data point. By comparing the distance between each day's traffic, we can group similar traffic patterns together. Correlation analyses, on the other hand, examine how similar each individual pairing of days is by comparing each traffic observation together. These two different techniques provide different ways of finding patterns: clustering allows us to find similar large-scale similarities between days, whereas correlations gives a more granular measure of similarity between a day and the expected traffic.

Using a CLARA clustering algorithim, we clustered the daily traffic volume for each day of data using 10-minute intervals. We found that there are three primary types of traffic: weekday traffic, Saturday traffic, and Sunday traffic. Each of these types in named after the days in which they are most likely to occur. Figure **??**A, shows a cluster plot of the three clusters of traffic measured along their principle components. The circles represent traffic classified as Sunday traffic, the triangles are weekday traffic, and the pluses are Satuday traffic. It should be noted that the most variable traffic yupe is the Sunday classification, suggesting that there may be incidences of highly irregular traffic that are more similar to Sundays than any other day of the week. A notable example of this is Thanksgiving Thursday on November 28, 2013. Thanksgiving experiences durastically lower traffic than both the typical Sunday and the typical Thursday, but the low traffic volume is more similar to a Sunday so it was clustered accordingly, as shown in Figure **??**B.

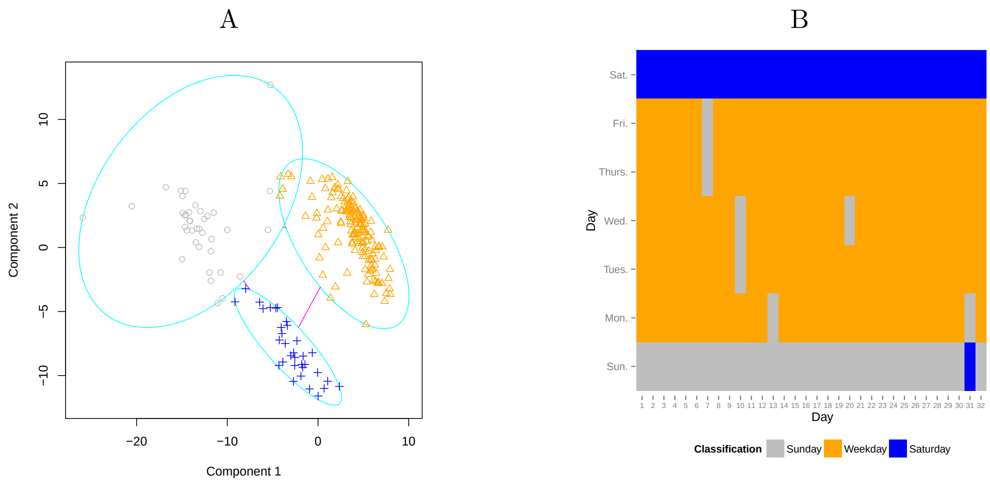

Figure 5: CLARA clustering suggests three primary traffic types.

For our correlation analyses we compared each day's traffic volume to the median traffic for that day of the week. For example, we examined the correlation between the traffic volume for Thanksgiving to the median traffic volume at each 5-minute interval for all Thusdays. A plot of each day's correlation, as shown in Figure ??, outlines the variablity in each day's traffic patterns. It should be noted that the days of abnormally low correlation relate to weekdays clustered as Sunday traffic in Figure ??B. In this figure high correlation suggests that the day's traffic is very similar to the expected traffic for that day of the week, whereas a low correlation is indicative of an abnormality in traffic volume. One interesting case of abnormal traffic is the seventh Thursday of the data set, which corresponds to Thanksgiving. The 2013 Thanksgiving traffic was abnormally low for a Thursday. Similarly, the 10th and 20th Wednesdays of the data set exhibit similar patterns of minimal traffic. Interestingly, weekdays have a higher median correlation (0.946) and a lower variance in correlation (0.003) than the weekends. This suggests that weekdays have a relatively stable or predictable traffic pattern with a few dramatic exceptions.

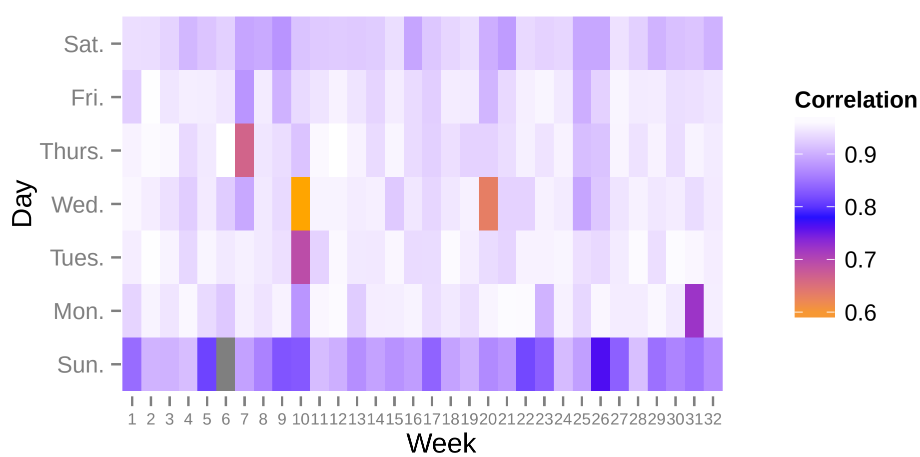

Figure 6: Correlation analysis shows holidays, data collection errors, and small-scale traffic patterns. In this color scale, white indicates high correlation, purple indicates moderate correlation, and orange indicates low correlation. Some days of interest include the seventh Thursday, which corresponds with Thanksgiving, the 10th Tuesday and Wednesday, and the 20th Wednesday.

Bayesian Analysis

In order to determine how the probability of congestion relates to the time of day we adapted Bayes' Theorum for use with the data provided. Because the traffic on the weekend is not as intense as the traffic during the weekdays, the decision was made to evaluate each day independently of one another so as not to induce any sort of bias into the results. Congestion was determined simply by using the critical density of the intersection, identified as 42.8 Vehicles per Mile. Any situation where the density is equal to or greater than this measure is determined to be 'congested.' Any situation below this measure is simply 'not congested.'

This is then sorted for each time step, and a proportion is generated about how many times (on a specific day of the week) that particular time is considered congested. For example, this means that if 2 out of the 10 observations at 2:10am on Wednesdays is considered to be congested, equal or exceeding the critical density, the proportion is calculated to be 0.2. This is then multiplied by the probability of congestion at any time amongst all the observations, and is then divided by the probability of randomly selecting that time from the dataset.

Figure **??** provides a way of seeing the probability of congestion occuring given the day of the week and the time of day. As expected the probability of congestion increases dramatically between 4 and 6 PM, which correspond with the traditional rush hour period. Interestingly, there is a non-trivial probability of traffic congestion occuring between 2 and 6 AM. This may correspond with people who work during the evening. Additionally, there is a slight spike at 7 AM, which may correspond with school traffic or people leaving for jobs with 7:20 or 8 AM starting times.

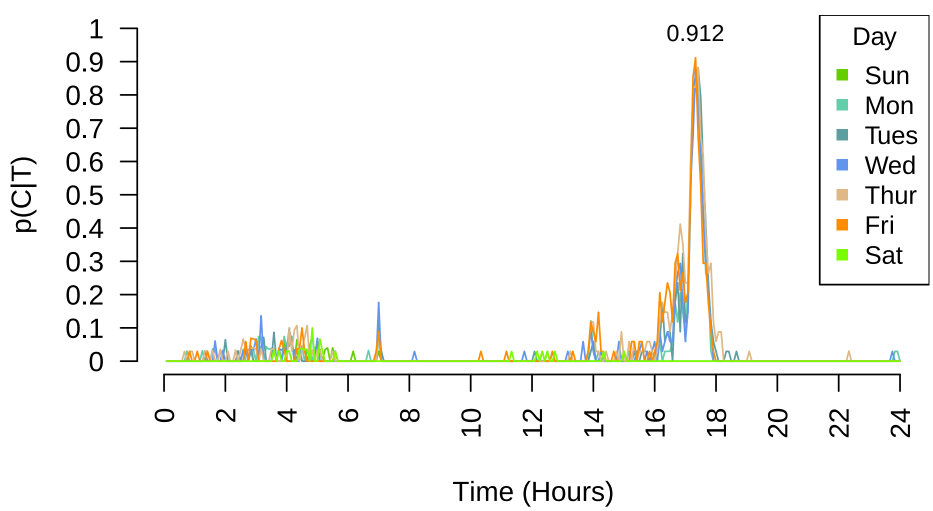

Figure 7: Probability of observing congestion based on specific times throughout the day (represented as p(C|T)). All days are represented as separate lines. A maximum probability of 91.2% is shown on the graph and occurs at 5:15pm on Friday. Most weekdays have the highest probability of congestion between 5:00pm and 5:25pm, or during evening rush hour.

Table presents times that have he highest probability of observing traffic congestion. For the purposes of this table Saturday and Sunday were omitted from the table due to the fact that their relative probabilities were approximately zero. A point of interest is that congested periods start earlier on Fridays, suggesting that people may be leaving work early on Fridays.

Table 2: Selected results from Bayesian analysis of traffic data.

Time	Mon	Tues	Wed	Thur	Fri
17:05	0.500	0.471	0.529	0.588	0.500
17:10	0.765	0.824	0.677	0.824	0.853
17:15	0.824	0.853	0.882	0.824	0.912
17:20	0.853	0.882	0.765	0.882	0.677
17:25	0.588	0.794	0.647	0.677	0.529

Weather Analysis

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[1] City of Rochester, *Property Information Application*. http://maps.cityofrochester.gov/propinfo/.

[2] City of Rochester, *Traffic Volume Map*. 2014. http://www2.monroecounty.gov/files/dot/pdfs/City-adt-map-through-2014.pdf.

[3] Transportation Research Board of the National Academies, *Highway Capacity Manual 2010*. 5th edition, 2010.