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Innovative Analysis for Reducing Data Using a Tracking Methodology

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Innovative analysis for reducing data using a tracking methodology

by

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Dedication

First I would like to dedicate this thesis to my family, specifically my parents and grandparents. Without their inspiration and support, writing this thesis would not have been possible.

I would also like to dedicate this thesis to my fiancée, Emily. Without her support and understanding, I would never have been capable of finishing this thesis. Her endurance for my multiple late-nights working and trips were much appreciated.

Table of Contents

List of Tables

List of Figures

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Finally, I would like to thanks my family for all of their support through all of my studies.

Abstract

Every year the National Highway Traffic Safety Administration (NHTSA) publishes its finding of crash statistics and, in the latest data from 2010, speeding was a factor in 31% of the traffic fatalities in 2010(NHTSA Speeding, 2010). As a surrogate for speed safety, reductions in speeds statistics are used to determine whether treatments are effective at improving safety. The issue with this type of analysis is that the treatments are directed toward a specific user and by using all vehicles data, some vehicles not affected by the treatment are included in the analysis.

To mitigate these vehicles, tracking may be used to reduce the data collected to only the affected vehicles. This provides more accurate and precise data when evaluating the effectiveness of the treatment. Limited research has been completed for tracking, because of this it is unknown whether reducing the data will provide any statistical difference as well as indicators for when tracking should be used. The objective of this thesis is to determine difference using a standard method and tracking method as well as provide indicators of when tracking should be used. In addition, a speed reduction method will be analyzed as well to determine a separate safety surrogate measure.

Using two current research projects for the analysis, traffic calming and curve safety, the standard method and tracking method were compared. The results showed that the standard method both under- and over-estimated the effectiveness of the treatments depending on the site location. After reviewing the data the access points around the treatment provided an indicator for when the speed statistics were statistically different using the tracking method. This was expected because of turning movements created by such points that affect the vehicles speeds. Upstream speeds were the other indicator found that

had an effect on the data. In this situation it affected the speed reduction statistics that were calculated with tracking vehicles. These statistics provided a detailed view of where vehicles speeds were being reduced that would not be capable with the standard method. Overall, the objectives of the thesis were met by showing that tracking vehicles does have an effect on speed statistics. Indicators were found but further research must be completed to determine other possible indicators as well as other possible ways to reduce data.

Chapter 1 Introduction

1.1 Motivation

Safety has been a major concern within the transportation field so much that the United Nations has declared this decade to be the "Decade for Action for Road Safety". Current research being completed involving safety must face short deadlines which is not conducive for a crash analysis. With the direct measurement not being suitable for short durations, speed has been used as a surrogate for safety. The greater speeds are reduced the safer the road is determined to be. This correlates with the National Highway Traffic Safety Administration (NHTSA) latest crash statistics showing that in 2010 speeding was a factor in 31% of the traffic fatalities in 2010(NHTSA Speeding, 2010). The types of treatments that are being researched using this analysis are typically directed at a specific type of driver that will be impacted the most and their results should reflect this effect. That is not always the case and tracking only affected vehicles may be a more precise measurement of the safety effectiveness.

The safety of all users of the roadway depends on three parts: the road, the vehicle and the driver. Engineers have influence on the vehicle and the road, but drivers make their own choices which are not always the safest decision. Although engineers cannot make the drivers decisions, they do try to implement different safety treatments to convey to the driver to make safer decisions. Many drivers knowingly decide to speed because they feel that the roadway conditions are conducive to that choice. When roadway conditions change and this is not communicated to the driver, they are unaware that they need to slow down. In situations like these engineers can use some of the same techniques to slow drivers down. Since speed is used as an indicator for safety the treatments can easily be tested to see if drivers speeding choices have changed by comparing speed statistics before and after the implementation. When studying these treatments the speed statistics are analyzed before and after if any decrease can be seen which show the treatment was successful at lowering the drivers speed choice. This may be used in determining whether a treatment is beneficial but the actual effectiveness may not be accurate.

Many of these treatments tested are directed at a specific type of driver so shouldn't the data collected reflect these drivers choices? Typically, when data has been collected for a treatment the data collection device is placed after the treatment then after the data is reduced speed statistics are calculated using all of the data. This includes every vehicle that passed that point whether the driver was affected by the treatment or not. Vehicle speeds are included in the analysis that may potentially alter the results. A supplement to this type of analysis would be to eliminate the vehicles that are not affected by the treatment and only analyze the vehicles that are affected giving a more precise and accurate measurement. Tracking provides a way to follow vehicles while they are approaching the treatment being studied and verify they are being affected by the treatment. For instance, drivers traveling under the speed threshold before they reach a dynamic speed feedback sign would not receive any feedback. In traditional speed studies, drivers who were already complying would have been counted in the mean speed even though they were not affected by the treatment.

Tracking vehicles before and after the treatment may be a more effective way of analyzing the data because the exact vehicles the treatments directed towards are the only ones included in the data. This method eliminates vehicles that are turning on and off the road that have significant impacts on the speed data, most likely lowering the mean speed.

When multiple exit and entry points are located along the road section tracking collects data without any of those influences providing the best data reflecting the effectiveness.

This will open a variety of sites that were not included in studies before based on the impacts other roadway features may have in the data collection. Some researchers avoid collecting data near intersection and major driveways because of turning vehicles (Hallmark, 2007). Locations with multiple driveways usually are eliminated from the site selection because of these influence turning vehicles can have on the data as well as other road intersections and business where significant turning traffic exists. Tracking eliminates these outside factors and allows for only the drivers going through the treatment to be analyzed. Less than ideal locations could be used more without the negative evaluating impacts associated with using all of the data.

Since limited research has been performed on a tracking analysis, the effectiveness of the tracking method must be determined compared to the standard analysis being completed. This will be achieved by using current research projects data, traffic calming and curve safety, to determine any changes in the speed statistics with tracking. The traffic calming study used various treatments in rural communities to slow drivers down as they are entering the community Most of these sites in this study had multiple driveways or roads around the treatment which makes them perfect candidates for tracking. The curve speed study used TAPCO signs to alert drivers on state and county highways that a curve was approaching and that the driver needed to reduce their speed when traversing the curve. Some of the curves had T-intersections located within the curve while other had no access points which allows for a good analysis in determining the effectiveness of the tracking. The curve study also allowed for tracking to be used in a non-transition zone and a supplement to the traffic calming. Based on the findings when comparing the tracking method to the standard method, indicators will be developed for when the tracking method should be used instead of the standard method.

1.2 Thesis Objectives

Limited research has been performed on a tracking data analysis so the primary objective of this study is to evaluate the differences in the standard method of analyzing speed statistics and a tracking method. The methods will be used on multiple different sites that are trying to reduce the speed of drivers. The following objectives will be achieved through this research.

- Calculate speed statistics using a standard method and a tracking method then determine if there are any differences from tracking vehicles. The difference will be analyzed in terms of standard speed statistics that are used for similar safety research projects.
- Using the tracking data, a speed reduction statistic will be calculated to determine how much vehicles are slowing down when they approach the treatments. This statistic will be presented as a third methodology to be used since it cannot be calculated using the standard method. The benefits will be discussed for analyzing effectiveness of treatments in more detail.
- The benefits of the tracking method will be summarized as well as the limitations of tracking vehicles. The tracking method may not be suitable in all situations so indicators will also be developed to determine which sites would benefit from tracking.

1.3 Thesis Organization

This thesis is organized into seven chapters.

Chapter 2: *Background* reviews the limited research has been completed using tracking to reduce data and determine safety benefits. This chapter also provides a standard speed statistics that are using when determining the safety benefits of a treatment. In addition, other competing methods for collecting and determining speed statistics will also be discussed.

Chapter 3: *Sites and Treatments* presents the two current research projects are being used to compare the standard and tracking method. The research involves traffic calming and curve safety with treatments directed as slowing vehicles down for safety. The treatments are discussed as well as the types of vehicles they are directed towards.

Chapter 4: *Data* provides details of how the data was collected and how strategically placing the data collection points achieves the focus vehicles of the respective studies.

Chapter 5: *Methodology* discusses the three methodologies that are applied to the data. The three methodologies consist of the standard method, a tracking method, and a speed reduction method. Additionally this chapter will discuss the analysis and statistics that will be used for comparison of the standard and tracking method.

Chapter 6: *Results and Discussion* analyzes all of the sites from the traffic calming and curve safety using all three methodologies. Comparisons are made between the standard and tracking method using the procedures addressed in the methodology.

Finally, Chapter 7: *Conclusion* summarizes the results for all the sites and provides indicators of when tracking would be most beneficial. The limitations of the tracking method are discussed as well as future research that should be conducted to improve the tracking methodology.

A framework of the thesis progression can be seen in Figure 1-1 with where each section is being analyzed at.

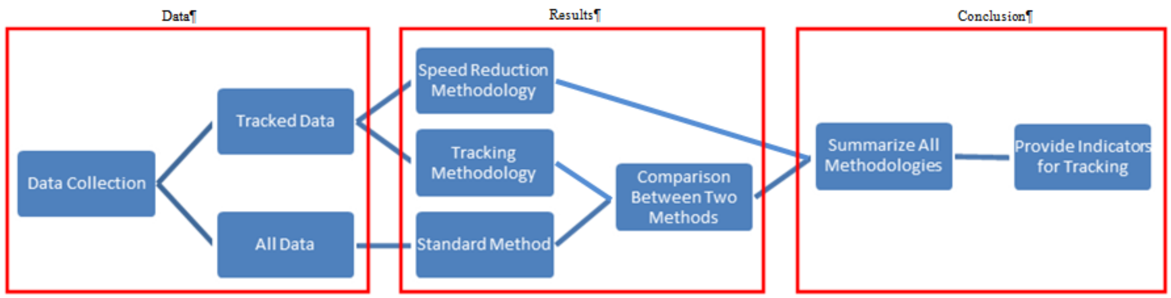

Figure 1-1 Framework for Analysis

Chapter 2 Background

2.1 Overview of Tracking

Limited research has been performed in evaluating tracking vehicles versus the standard method of analyzing speed reduction. Only one paper by Ivette Cruzado and Eric Donnell (2009) was found that used tracking to reduce data down to only affected vehicles. Cruzado and Donnell (2009) used tracking in “Evaluating Effectiveness of Dynamic Speed Display Signs in Transition Zone of Two-Lane, Rural Highway in Pennsylvania”. This aligns very well with the traffic calming study as both are on rural highways and located in transition zones. Vehicles were tracked so that only free-flow passenger vehicles would be analyzed eliminating vehicles that were influenced by a turning movement. To track the vehicles in their report the vehicle speed, vehicle length, and time headway were compared at each data collection location.

The standard method was used by determining the mean speed, 85th percentile speed and percentage of vehicles exceeding the posted speed first in their analysis but was not used in determining the effectiveness. Instead a true effect (TE) was calculated by tracking vehicles then determining the speed reduction of each vehicle before and after implementation. The true effect was calculated as shown below:

$$\text{True Effect} = \Delta V_{1\text{-}2,\ \text{during}} - \Delta V_{1\text{-}2,\ \text{before}}$$

The tracked data is used to determine the statistics $\Delta V_{1\text{-}2,\ \text{during}}$ which is the mean speed reduction between sensors 1 and 2 during the study and $\Delta V_{1\text{-}2,\ \text{before}}$ which is the mean speed reduction between sensors 1 and 2 before implementation. Cruzado and Donnell (2009) briefly discuss that depending on the upstream data collection the data may be over- or under-estimated.

A two-sample t-test was used to determine if changes in speed reductions were statistically significant. This was used to make sure that the speed reduction after implementation was statistically effective in changing the speed reduction from before.

No analysis in the report was used on all of the data to determine whether turning movements would have had an effect on the data. Only the mean speed changes of the tracked vehicles were compared to the true effect.

2.2 Standard Method Literature

Before tracking can be compared, a baseline of what the standard method for analyzing effectiveness of safety treatments must be developed. To determine this, literatures from other studies using speed statistics as indicators for safety were reviewed. Similar situations involving treatments slowing vehicles were used in these studies such as speed indicator devices (Walter and Knowles, 2008), other traffic calming measures (Hallmark, 2007 and Ewing, 1999), and pavement markings (Hunter, 2010 and Katz, 2004).

The most common statistic that was used in the reports was the mean speed and 85th percentile speeds. These statistics provide an adequate analysis of speeds both before and after the implementation of the safety treatment. Reductions in the speeds are expected to improve road safety in that area which is why the speeds reductions are used as a surrogate safety measure to estimate effectiveness (Hunter, 2010). When comparing the before and after data a t-test was used to determine whether the change in mean speed was statistically significant. Because of the inclusion of these statistics with all researchers and the importance these statistics were determined to be the baseline for the standard method.

In addition to the most common statistics, there were other statistics that were found in various different reports. Some of the statistics include speed variance and percent of vehicles going over a speed. The speed variance is used as another surrogate because it is shown that high speed variance are associated with high crash risk (Hunter, 2010). When you have a wide variety of speeds there is confusion of how fast a vehicle is moving based on what the driver believes the vehicle should be going. This causes unsafe decisions to be made based on this perception. The speed variance was included in the study as well for determining statistical significance of the change in mean speed but when comparing the tracking method and standard method there is not expected to be any changes because of the similar data sets. The percentage of vehicles going over a designated speed was used in multiple reports as well. The designated speeds were not always the same based on the treatment being implemented. In some situations the percentage of speeds were analyzed relative to the speed limit (Hallmark, 2007 and Jeihani, 2012) while other were set speeds set by the police chiefs perception of where speeds are enforced (Walter and Knowles, 2008). This statistic does provide the compliance of vehicles in relation to the designated speed to determine if the treatment has any impacts. This statistic was also included in the study to determine whether vehicles are complying with the designated speed.

All of the statistics discussed have been in relation to the data point directly after the treatment for comparisons of the speed reduction. Consideration also must be made to changes in conditions in the different data collection periods. To account for this, data collection points upstream would be used when the circumstances were capable. This allowed for the speeds approaching the treatment to be considered when evaluating effectiveness. With an upstream data collection points, if an increase in speeds upstream are seen while speeds are similar at the treatment it could be concluded that the treatment was effective at reducing speeds since vehicles were approaching at a higher rate of speed. In other cases where no upstream speed changes are seen then the upstream data collection point would be considered a control statistic.

The most common data collection types for researcher were in-roadway pavement sensors to determine speeds and volumes. Pneumatic road tubes were the most heavily used because of their low cost and the accuracy of the data. Compared to other data collection methods, pneumatic road tubes are the only method that can be transferable and collect all vehicles speed regardless of weather, time, or vehicle type. Because of this pneumatic road tubes were suitable in this research.

Other methods that could be used are magnetic sensors for in-roadway measurement and video image processors, and microwave radar for over-roadway sensors (The Vehicle Detector Clearinghouse, 2007). The magnetic sensors pick up a magnetic anomaly when the vehicle passes and count this as a vehicle and can determine the speeds. The sensors are easily installed but typically have a small detection zone possibly missing vehicles that pass. Once the data has been collected it will be stored in bins but if possible to collect individual vehicles data the tracking method could be applied to magnetic sensors. Over-roadway sensors also have limitations leading to them not being used. Whether it is video detection or radar, over-roadway sensors do not pick up all vehicles. If an obstruction in the video or inclement weather is present the sensors may not detect a vehicles has passed. These inaccuracies lead to the over-roadway sensors not being used. With improvements in technology video detection and radar could also be used to track vehicles then determine which are affected by the treatment. With other data collection processes out in use the tracking methodology could be applied to all with only slight changes in the reduction process.

Chapter 3 Sites and Treatments

3.1 Traffic Calming Sites

For this study five sites were selected for different implementations of low cost traffic calming. These sites were selected on a set of criteria to precisely evaluate the effectiveness of the traffic calming. Table 3-1 shows all of the study locations and the number of treatments at each location, which in total gives ten locations to evaluate a tracking method of analysis. Most of the rural communities are built along major routes which cause a high volume of vehicles that are only passing through the town. In Iowa most drivers are traveling long distance at high rates of speed between cities and when they enter a town must reduce their speed to as low as 25 mph. This speed reduction is only for a short distance so most driver either ignore the speed reduction or do not even realize they are entering a community. This creates an unsafe community and a need for outside factors to slow the drivers down. The traffic calming in these communities focuses on reducing the speeds of those drivers that are not slowing down as they are entering the community.

Table 3-1 Traffic Calming Sites

Community	Number of Treatments	Treatment
St Charles	4	TuffCurb and Blinkersign
Jesup	2	Speed Limit Pavement Marking
Quasqueton	2	Transverse Pavement Markings
Hazelton	1	Transverse Pavement Markings
Ossian	1	Speed Limit Pavement Marking

Since the focus of the traffic calming is on drivers that are entering the town after traveling a long distance then tracking is ideal so that the reduced data only reflects the effects of those drivers. Tracking allows for all of the data collected to be narrowed down to only those vehicles. How this is achieved is by strategically placing the data collection points so that only the vehicles hitting all data collection points are included in the study. For these communities a data collection point was placed a half mile outside of town and then directly after the treatment at the entrance to town. The data location upstream ensures that the driver is coming into town along the major route and if the vehicle also is detected at the treatment location then it can be determined that it is entering town.

3.2 Curve Safety Sites

To supplement the analysis of tracking in speed transition, curve projects were also used to study the impacts of a tracking method of analysis. The tracking of curves are very different than the traffic calming and provided additional situations where tracking may be beneficial. The curves were also located on rural two-lane highways but were not located in a speed transition or in a town like the traffic calming. Speeding was a problem in all of the curves and was a major factor in crashes that occurred in the past. To reduce the speed of drivers as well as notify the driver a curve is approaching, flashing sequential light up chevrons manufactured by TAPCO were installed. The signage consisted of a curve warning sign that flashed as vehicles approached and sequentially lighting up chevrons through the curves with the number varying between sites. A photo of the treatment can be seen in Figure 3-1. The focus of the treatment is again on vehicles that are traveling long distances and are approaching the curve at a high rate of speed.

Figure 3-1 TAPCO Curve Warning and Chevron Signs

The tracking in this situation will analyze the vehicles speed through the curve at different points. For the curves, only vehicles that go through the entire curve were analyzed. Again, data collection points were strategically placed upstream, at the point of curvature and center of curvature to capture the intended vehicles. Vehicles that went through all three data collection points were determined to be affected by the treatment and evaluated using the tracking method. Some of the curves did have entry and exit points before and after the curve or even within the curve so these vehicles were eliminated from the data because they were not the focus of the treatment and may impact the results.

Chapter 4 Data

4.1 Data Collection

The data for this study focused on the speed before and after implementation of the traffic calming treatment and TAPCO signs. To obtain this data, pneumatic road tubes were installed within a month before installation of the treatment and then again one month after installation. This provided an adequate analysis of the effects the safety treatment would have on the surrogate speed measurements. Jamar pneumatic road tubes were used to collect the data by spacing the road tubes eight feet apart across both lanes of traffic. The data was later reduced so that only the impacted lane of traffic was used with the following data collected: volume, speed, gap and classification of the vehicle. Each data collection period for the traffic calming was 48 hours with the exception of the north site in Quasqueton which was only collected for 24 hours because the road tubes were cut at that time. The curve study had a data collection period of 24 hours. The length of data collection was set by each study but both gave sufficient amounts of data to be analyzed with both the standard and tracking methods. Both studies have a base of 24 hours which allows for all traffic patterns to be incorporated. By collecting all 24 hours of data this removes impacts related to speed choices based on the time of day. The collection periods occurred between Monday-Friday while avoiding holidays to avoid any unusual traffic patterns. This ensured that consistent data was collected for both time periods for an accurate comparison.

4.1.1 Traffic Calming

The traffic calming treatments used were all placed at the final speed transition entering the town to slow the drivers down to speeds that would be carried through town. When entering most of the communities, the transition zone has various transition speeds to slow the drivers down gradually over a long area. An example of this would be for a town located along a 55 mph highway to have a 35 mph zone that then transitions to a 25 mph zone which would be the final speed transition and the speed that will be used through town until exiting the city. In some cases, where the final transition was too far into town, the next transition was used so that vehicles would be traveling at a slower speed when they entered the community and final transition. This was done so that the traffic calming was being used to alert drivers as they are entering the town and with the speed transition already within the town it would have the same impacts.

With all of the treatments, the data collection point was located directly after the treatment in order to determine the impacts the treatment had on the vehicles speed. This verifies that the speed reduction would be accounted to the traffic calming implementation and no other outside influences on the speed in both data collection periods. An upstream data collection location was also used to determine the speeds of vehicles entering the community. This typically has been used to justify the assumption that without the treatment, speeds would be the same as the before condition. If the upstream data varies too much from the before data than some other outside factor may influence the speed at the treatment. This location was placed a half mile upstream from the treatment data collection location which allowed for adequate space so that the vehicle would not be affected from the speed transition or treatment but also not so far out that vehicles would not be accurately tracked. With the tracking method the upstream data collection is actually utilized as more than just a check for an assumption. The upstream data allows for the speed reduction to be determined to find out how much vehicles are actually slowing down as they enter the community. A layout of the typical data collection can be seen in Figure 4-1.

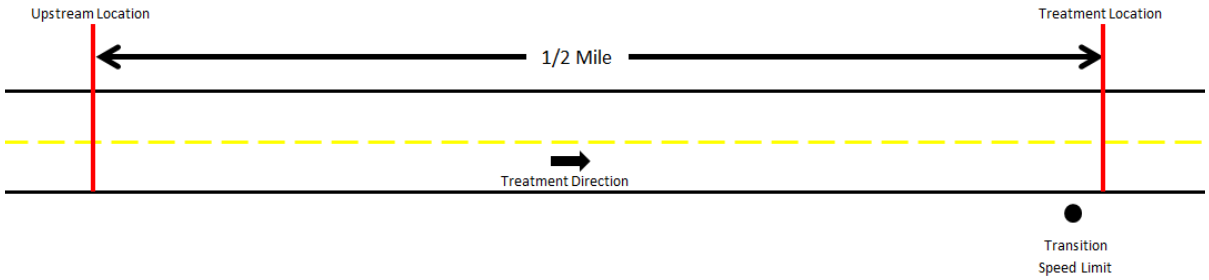

Figure 4-1 Traffic Calming Data Collection

4.1.2 Curve Safety

The curve data collection was obtained in a similar manner as the traffic calming locations but with three data collection locations through the curve. The upstream data collection was 750' before the curve warning sign which was chosen so that the radar would not pick up the vehicle yet and they would not being slowing down due to the curve. The radar on the warning sign picks up vehicles around 500' so with the first point past that then the vehicles would not have any influence of the curve warning sign or chevrons activating. At this point the driver would also not being slowing down yet before entering the curve or if there is any slowing down it would be similar in both data collection periods. Once the vehicle reaches the curve it will go through two more data collection points, at the beginning of the curve called the point of curvature and in the center of the curve. Tracking vehicles through all three points allows for only vehicles entering the curve to be analyzed and any vehicles turning on and off the road disregarded. The layout of the data collection can be seen in Figure 4-2.

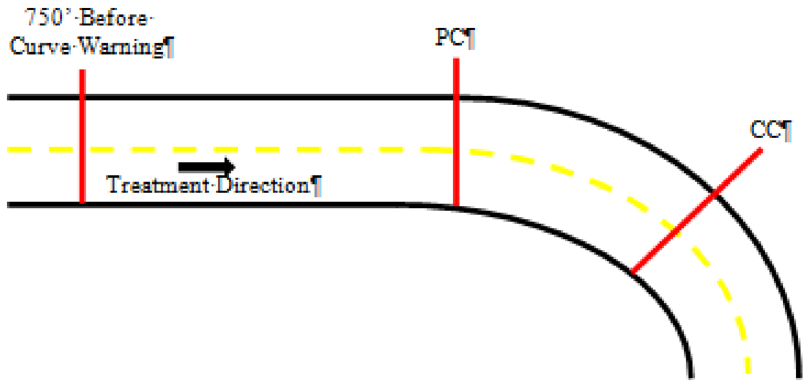

Figure 4-2 Curve Safety Data Collection

4.1.3 Tracking Precision

To be able to track the vehicles, precision was needed so when reducing the data vehicles are able to accurately be tracked. To achieve this all of the pneumatic counters needed to be synced to the same time. With these data counters drift is a concern which is the slowing and speeding of the internal clocks. To account for this a stopwatch was also started at the synchronization of the counters and when picked up both times were recorded. When reducing the data, if any counters drifted more than 10 seconds away from the actual time then this would be accounted for by adding the time linearly over the duration of the data collection period. This allowed for the time lossed or gained by the end of the count to be accounted for. Distances were also measured between data collection points to determine ranges of times it should take a vehicle to travel that distance. This was used in the tracking method as one of the criteria for vehicle to be accurately tracked.

4.2 Data Reduction

The data collected was used to analyze the speed changes from before and after implementation to determine the effectiveness of the treatment. The standard method consisted of using all of the data collected while the tracking method reduced the data to only effected vehicles. To achieve this reduced data steps must be taken to track the vehicles to determine which vehicles are affected. To track the vehicles, the data for that vehicle must be recorded at all of the data points. Because the data collection points are strategically placed to capture only the affected vehicles than any vehicle that is recorded at all data points will be included in the reduced tracking data set.

To track the vehicles, three measurements from the pneumatic tubes were analyzed: the time between counters, the gap between the vehicles and the classification of the vehicle. The process to track vehicles is very labor intensive and requires data points to be manually removed if they cannot be accurately tracked. All three of the variables were analyzed simultaneously and if one measurement was not accurate than points would be removed for vehicles that were not tracked to meet the desired requirements.

The time between the counters measured the time it took for a vehicle to be counted at the upstream location till it was counted at the treatment location. This was achieved by subtracting the time stamp of the treatment data point by the upstream data point. The purpose of this statistic was to verify that it was feasible for the vehicle to travel the distance that was measured in the amount of time calculated. A range was used for each site because not all vehicles speed reductions are the same so the time varied between vehicles. Any vehicle not in the range would be removed allowing the other vehicles to be tracked then.

The second measurement used was the gap between vehicles. This was calculated by taking the time stamp of the vehicle and subtracting the time stamp of the vehicle before. The time gap between vehicles at the upstream location should be the same as the time gap between vehicles at the treatment location. If the gaps were not within a 2-3 seconds of each other than the vehicle was not the same at both locations and one of the vehicles would be removed based on surrounding data points.

The final measurement considered was the FHWA vehicle classification. The Jamar pneumatic tube counter is able to determine the classification based on the number of axles and the distance between axles. This was used in the analysis and both the upstream and treatment locations should have the same classification in order to be tracked. When tracking, not all the vehicles did have the same classification which could be accounted for by error with the counter. In these cases the classification was further analyzed by determining if the classes for each were similar and verifying the other two measurements were acceptable. Appendix A shows an example of how the process of removing vehicles was performed.

In most cases the tracking method was able to accurately track 90% of all the data that is collected at each data collection location. What this statistic means is that of all the data collected the reduced tracking data set will include almost 90% of the data at all data collection points. This statistic is different for each site depending on the influences that are present and will be presented along with the speed statistics for each site. The increase in access points allows more drivers to get on and off the route making them untrackable and not desired for this study which is the percentage of data that has been removed.

Chapter 5 Methodology

The methodology for this analysis will be to use the two separate data sets to determine the same speed statistics. The standard method will use all of the data collected by the traffic counter whereas the tracking method will used the reduced data set that was achieved in Chapter 4. To analyze the differences between the methods a procedure will be used to determine any significant changes. This procedure will be documented in this chapter.

In addition to the two methods described above, another method of analysis will be completed using a separate speed statistic that cannot be found using the standard method. By tracking the vehicles a speed reduction can be found and the method of calculating this and determining its impacts will be documented in this chapter as well.

5.1 Standard Method

The standard method in this study refers to the way that data has been reported in most safety research papers. This method focuses only on the data collection where the treatment is located and uses all of the vehicle counts that are collected during the study duration. No reductions to the data will be made and the following speed statistics will be found for the data set. Speed statistics at the treatment location are evaluated based whether reductions are seen from before to after implementation as the surrogate for safety. The standard statistics found from the background in Chapter 2 that were used are shown below:

- Mean speed
- Standard Deviation
- 85^{th} percentile speed

- Percentage of vehicles over speed limit/advisory speed
    - Percentage of vehicles going 5, 10, 15, and 20 mph over
    - Speed limit was used for traffic calming
    - Curve advisory speed was used for the curve safety

From the data collection the spot speeds were found directly after the treatment and by averaging the mean speed is calculated. The mean speed can be found both before and after implementation. Mean speed was calculated using:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

where:

$\bar{x}$=arithmetic average or mean speed of observed values

x_i=*i*th individual speed statistic

N=sample size

In addition to the mean speed the standard deviation will also be found. This statistics allows for the variance to be determined and shows the variation present in the sample. The standard deviation was calculated using:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

where:

σ=standard deviation

$\bar{x}$=arithmetic average or mean speed of observed values

x_i=ith individual speed statistic

N=sample size

The 85th percentile speed is the speed where 85 percent of the vehicles are traveling at or below that speed and 15 percent of the vehicles are traveling greater than that speed. This can be determined by ordering the data from smallest to largest then placing an integer value from one to the total sample size. By determining what integer is 85 percent of the sample size the 85th percentile speed can be located.

The percentage of vehicles going over a designated speed gives a comparison of speed compliance before and after implementation. For this study the vehicles going 5, 10, 15, and 20 mph over the speed limit or curve advisory speed will be calculated. To calculate these values the ordered data from the 85th percentile speeds can be used to determine how many vehicles were going over the designated speed. This value can be divided by the total sample size to give a percentage of vehicles going over that speed. This will be completed for both the data collection periods and comparisons can be made in the reduction of vehicles going over that speed.

All of the statistics presented will be calculated for the data before the implementation of the treatment as well as the one month after implementation data. With both statistics the change can be found by taking the one month after statistic subtracted by the before statistic. These statistics will be analyzed to determine whether reductions in speeds can be seen. A negative value is desired showing that the speed were lower in the after data collection period. The following equation shows the change in mean speed:

$$\Delta mean\ speed = \bar{x}_{after} - \bar{x}_{before}$$

where

$\Delta mean\ speed$=change in mean speed from before to after implementation

$\bar{x}_{after}$=change in mean speed using after data

$\bar{x}_{before}$=change in mean speed using before data

To determine whether the change in mean speed is statistically significant a t-test must be performed. For a t-test both samples need to be normally distributed. To verify the normal distribution a normal probability plot was created for both data collection periods. The data was ordered from smallest to largest then the z-score was determined for each individual speed value. The z-score can be calculated using the following equation:

$$z = \frac{(x_i - \bar{x})}{\sigma}$$

where

z=z-score

x_i=ith individual value of statistic

$\bar{x}$=arithmetic average or mean of the sample

σ=standard deviation

The z-score and ordered speeds can be plotted and to be normally distributed must be in a straight line with the intersection of the z-score at zero being the mean speed of the sample. This was completed for both data collection periods and a sample plot can be seen in Appendix B. All data collected in this study were found to normally distributed.

With the normal distributed data the t-test could be completed assuming unequal variances. The hypothesis for this study is that the mean speeds are equal. At a 90% confidence level the hypothesis and if statistically significant than the mean speeds were not equal. To determine the t-statistic the following equation was used:

$$t = \frac{(\bar{x}_{before} - \bar{x}_{after})}{\sqrt{\frac{\sigma_{before}^2}{n_{before}} + \frac{\sigma_{after}^2}{n_{after}}}}$$

where

$\bar{x}_{before}$=mean speed before implementation

$\bar{x}_{after}$=mean speed 1 month after implementation

σ_{before}=standard deviation before implementation

σ_{after}=standard deviation 1 month after implementation

n_{before}=sample size of before data

n_{after}=sample size of 1 month after data

With this method the purpose of the upstream data collection typically is to ensure that there is consistency with the vehicles entering town in both the before and after periods. If an outside factor is causing the vehicles to drive slower upstream then that will affect the speed reduction at the treatment. One situation in this study occurred where the data collected upstream was lowered by 10 mph because of construction. This data was then thrown out and recollected. If this was not used inaccurate speed reductions would have been found due to the lower speed vehicles were entering town at.

Overall this method is effective for analysis but the problem is that not all of the data that was collected may reflect the effectiveness of the treatment. When determining the effectiveness of a treatment only the vehicles affected should be included and there is no way for this method to achieve that. This method also cannot account for changes in travel pattern that depending on the traffic movement could vary the speed statistics. A road close to the data collection could have an increased traffic flow which would sway the results and the researcher would never be able to account for this. Another problem with this method is the underutilization of the upstream data. The data upstream could be used more in the analysis but in the standard method is only an assumption check that speeds are similar entering town in both collection periods.

5.2 Tracking Method

The tracking method uses both the upstream and treatment or other data collection points to track individual vehicles through the treatment. All of the data that is included in the standard method is used to begin with then reduced down to only those vehicles affected by the treatment based on tracking which is shown in Chapter 4. Most of the locations in this study have multiple access points while approaching the treatment which creates turning movements on and off of the route. The traffic calming study focuses on vehicles that are entering the community and more specifically vehicles that have been driving at a higher rate of speed for a considerable distance then must slow down when entering the community. The curve study also focused on drivers going long distances on major routes then approaching the curves without realizing their speed needed to be reduced to traverse the curve. Tracking vehicles eliminates drivers that pull onto the road between the upstream location and treatment location and also the vehicles that pull off the road before even entering the treatment area. These vehicles are either slowing down already to turn or are speeding up which in both situations have lower speeds and have not been influenced by the treatments that were installed. In both cases these vehicles that are traveling at a lower speed than what the typical driver entering town would be which lowers the speed statistics collected in the standard method.

For this analysis the tracked vehicles statistics will be compared to the standard method. To do this the same statistics will be calculated as the standard method. This time instead of using all of the data only the tracked vehicles data will be used. The mean speed, standard deviation, 85^{th} percentile speed, and percentage of vehicles over a speed will all be found the same way using the tracked sample size instead. The reduced data must also be tested for a normal distribution which will be completed in the same method. All sites were found to have a normal distribution for both the before and after data; a sample normal probability plot for the tracked data can be seen in Appendix B. With the normal distributions the t-test were conducted at a 90% confidence interval for the change in mean speed in the same manner as the standard method. All equations can be seen in Chapter 5.1.

With the tracking method the data set is reduced compared to the standard method so the percentage of data retained will also be presented. The before and after data both had different percentages of data retained, which in most cases were identical, so an average percentage of vehicles tracked will be presented. To determine this statistic the sample size of the tracking method will be divided by the sample size of the standard method, or all the data, to determine a percentage of vehicles tracked. The percentage will show how many vehicles were tracked compared to the standard method. In most cases the percentages were greater than 90%. An example will show what this statistics purpose is. If the percent of vehicles tracked equals 85% this means that 85% of the vehicles were tracked and deemed to be affected by the treatment. The other 15% of the vehicles data was removed because the vehicles were not affected by the treatment and potentially could impact the speed statistics. In this case 85% of the original data set was retained for tracking method of analysis. Each data collection point will have its own individual percentage of vehicles tracked.

5.3 Comparison of Standard and Tracking Method

A comparison of the standard method and tracking method will be completed for each site to determine whether reducing the data set by tracking has any impacts on the effectiveness. The vehicles being removed from the data are expected to have an impact on the mean speed so a t-test will be used to determine whether significant changes in the mean speeds are seen. This will be completed for both the before and after data comparing the all of the data to the reduced tracked data. The hypothesis for this test is that the mean speeds are equal in both data sets. The significance will be tested at a 90% confidence level. If determined to be statistically significant then the tracking method will be proven to be effective by removing the vehicles that are altering the speed statistics. The data sets were already proven to be normally distributed so the following equation was used to determine the t-statistic:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

where

$\bar{x}_1$=mean speed using the standard method (before/after)

$\bar{x}_2$=mean speed using the tracking method (before/after)

σ_1=standard deviation using the standard method (before/after)

σ_2=standard deviation using the tracking method (before/after)

n_1=sample size of standard method data set

n_2=sample size of tracking method data set

If the mean speeds are determined to be statistically significant than the differences between the changes in mean speeds can then be analyzed. The change in mean speed has typically been the surrogate measure for speed safety, therefore any changes in this statistic with the tracking method will show that the standard method, or using all of the data, over- or under-estimates the effectiveness of the treatment in improving safety. Since the tracking data is the vehicles affected by the treatment this change in mean speed is deemed a more accurate representation of the effectiveness. If the standard method is over-or under-estimating the effectiveness then it shows that those vehicles eliminated from the data set are impacting the speed statistics. A reason must be associated with these eliminated vehicles so site characteristics will be analyzed for indicators of why the standard method did not estimate the effectiveness correctly.

The other speed statistics will also be analyzed for the differences in the changes of each statistic. Trends will be analyzed for differences with the tracking method for the other statistics.

5.4 Speed Reduction Method

Tracking vehicles through the data collection points allows for the speed of each vehicle to be known at all points. With the vehicle tracked and its speeds known at different points a speed reduction statistic can be calculated and provides another statistic to be analyzed. This speed statistic would be another surrogate measure for safety similar to the change in mean speed documented in the standard and tracking method. Using this statistic creates another method of analysis that will be called the speed reduction method. This statistic is not capable of being found with the standard method; this can only be used with tracked vehicles.

The speed reduction for each point will be found by subtracting the upstream data from the downstream data. The mean speed reduction can then be found both before and after the implementation. The equation is the same as the mean speed and can be seen below:

$$Mean\ speed\ reducation = \frac{1}{N}\sum_{i=1}^{N} speed\ reduction_i$$

where

N=sample size of tracked vehicle (before/after)

$speed\ reduction_i$=ith individual speed reduction statistic (before/after)

With the speed reductions, a similar statistic that was used by Cruzado and Donnell (2009) can be determined called the true effect. The true effect can be found by obtaining the differences of the mean speed reduction before and after implementation. This statistic will determine whether vehicles are reducing their speed more while they approach the treatment. The following equation is used to calculate the true effect:

$$\text{True Effect} = \Delta V_{After} - \Delta V_{Before}$$

where

True Effect=difference in mean speed reduction

ΔV_{After}=mean speed reduction one month after treatment

ΔV_{Before}=mean speed reduction before treatment

The true effect is comparable to the change in mean speed as they both account for reductions in speed at the treatment. The only difference the true effect has is that it considers the condition of the upstream speed in the analysis. If vehicles are going slower coming into town then the true effect accounts for this with a lower speed reduction. What this accomplishes is normalizing the data without additional control statistics like the change in mean speeds needs with the upstream change in mean speeds.

When analyzing the change is mean speed a negative value shows that a treatment is effective in reducing the speed of the driver. When using the true effect the treatment is effective when a positive value is found. This is because the true effect is the change in the speed reduction from before to after and a higher speed reduction after, which is desired, results in a positive value.

To determine whether the true effect is significant a paired t-test was used at a 95% confidence level. The t-test requires a normal distribution so a normal probability plot was created for the speed reduction statistics. The same process is applied to the speed reduction statistics as the speeds in the standard method and a sample normal probability plot of the speed reduction can be seen in Appendix B. The normal probability plot was created for both the before and after data at all sites with them all appearing normally distributed. The hypothesis for the t-test was whether the speed reduction of the before and after data were equal. A 90% confidence level was used similar to the other t-test. If the true effect was statistically significant then it shows that there was a change in speed reduction because of the treatment. The following equation was used to find the t-statistic:

$$t = \frac{(\Delta V_{before} - \Delta V_{after})}{\sqrt{\frac{\sigma_{before}^2}{n_{before}} + \frac{\sigma_{after}^2}{n_{after}}}}$$

where

ΔV_{before}= mean speed reduction one month after treatment
ΔV_{after}= mean speed reduction before treatment
σ_{before}=standard deviation of speed reduction before implementation
σ_{after}=standard deviation of speed reduction 1 month after implementation
n_{before}=sample size of speed reduction before tracked data
n_{after}=sample size of speed reduction 1 month after tracked data

Chapter 6 Results and Discussion

Each site in this study had very different situations which will be noted in the results to help explain difference between the two methods of analysis. The methodology presented in Chapter 5 will be followed to evaluate the effectiveness of the treatment at each location. The traffic calming sites will first be analyzed to determine the effectiveness of the tracking in a speed transition zones where some previous research has been documented. This analysis will then be repeated for the curve safety to determine if the tracking can have similar effects with higher speeds and not located in a transition zone. The sites will be evaluated both with the standard method and tracking method followed by comparison of the differences. The speed reduction method with the true effect will then also be compared to see if changes in effectiveness can be seen with this statistic. All of the mean speed changes and true effects were statistically significant at a 90% confidence level unless noted.

6.1 Traffic Calming Sites

6.1.1 St Charles

The City of St Charles is a rural community in Iowa that is 10 miles south of Des Moines and is bisected by State Highway 251/County Road G50 going east-west and County Road R35 going north-south. The city had a documented speeding problem at all four entrances to town so traffic calming was installed as a measure to slow the drivers down while coming into town. The east entrance to town had a TAPCO Blinkersign installed while the other three entrances had TuffCurb installed along the center of the roadway. Pictures of the installed treatment can be seen in Figure 6-1.

Figure 6-1 St Charles North/East Traffic Calming

6.1.1.1 North Entrance

Standard Method

For the north entrance to St Charles, TuffCurb was installed in the center of County Road R35 for approximately 150'. Of all the entrance in St Charles, the north entrance had the lowest AADT of 550. Table 6-1 shows the speed data that was collected using the standard method of analysis. A 2.2 mph mean speed reduction was found which showed that the TuffCurb was effective at reducing the speeds of vehicles as they entered town. Along with the mean speed reduction there were also major reductions in all percentages of the drivers going over the speed limit. What this shows is that there are fewer drivers that are going over the speed limit and the higher speed vehicles are being affected by the treatment. The 85^{th} percentile speed also went down 3.0 mph due to the treatment. For the control, the upstream location showed no change in the mean speed which validates the assumption that there did not appear to be any outside influence on the speeds between the before to after data collection.

Tracking Method

The tracking method was then applied to determine the same speed reduction statistics, which can be seen in Table 6-2. With the tracking method, the data is reduced with, in this case, 86% of the data at the upstream tracked while 81% of the treatment data were tracked. These percentages show that after tracking the vehicles 14% of the data upstream and 19% at the treatment were not tracked, meaning these vehicles either turned on or off of the road between the counters locations. Using the tracking data only, a 2.7 mph reduction in the mean speed was determined which, like the standard method, shows that the treatment was effective at reducing the vehicles speeds. The percentages of vehicles going over the speed limit again saw major reductions and the 85th percentile speed was reduced by 3.0 mph, overall showing that the TuffCurb was effective at reducing speeds of the that vehicles entered town. There was only a 0.2 mph reduction in mean speed upstream so similar conditions were present in both collection periods.

Comparison of Standard and Tracking Method

Both methods of analysis showed that the treatment installed was effective at reducing vehicles mean speeds while entering St Charles. When comparing the different methods the first thing to be noticed is that the mean speed for the tracking data is around 2 mph higher than in the standard method. The statistical t-test showed that the mean speeds both before and after were statistically significant showing that the vehicles that were removed were impacting the statistics calculated in the standard method. The vehicles not included in the tracking data have much lower mean speeds then the vehicles that are entering the town swaying the statistics to be lower. This was expected which is why the treatment was installed to slow the vehicles that were entering town and tracking documented this.

Mean speeds are lower due to a road located just before the treatment location entering town where vehicles could be turning on and off of County Road R35. Turning movements such as these solidify the reasoning to use the tracking method. The vehicles that are turning are not a focus of the study which the tracking method eliminates in the analysis. The difference was a 0.5 mph underestimate of the mean speed change in the standard method. The percentages of vehicles that are going over the speed limit are also higher since the lower speed vehicles from the turning movements are the data points being removed. The changes in percentages are similar though with both methodologies. Like the mean speeds, the 85th percentile speeds were higher but no differences were seen in the change in 85th percentile speed.

Speed Reduction Method

The extra statistic that can be provided from tracking vehicles gave similar safety effectiveness results as the change in mean speeds. The true effect shown in Table 6-2 was 2.5 mph. The 2.5 mph increase in speed reduction after installation of the treatment shows vehicles were slowing down more while entering town. With limited change in upstream speeds, the true effect gave similar effectiveness that was documented with the change in mean speed.

Table 6-1 St Charles North Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	50.2	50.2	0.0
85th Percentile	58	58	0
Standard Deviation	8.3	8.0	
Count	610	557	-53
At Treatment			
Mean Speed	29.3	27.1	-2.2
85th Percentile	37	34	-3
Standard Deviation	7.3	6.4	
% Vehicles 5+ Over Limit	49%	35%	-29%
% Vehicles 10+ Over Limit	24%	13%	-46%
% Vehicles 15+ Over Limit	7%	2%	-71%
% Vehicles 20+ Over Limit	1%	0%	-100%
Count	648	593	-55

Table 6-2 St Charles North Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	50.8	50.6	-0.2
85th Percentile	58	58	0
Standard Deviation	6.9	7.2	
Count	524	490	-34
At Treatment			
Mean Speed	31.1	28.4	-2.7
85th Percentile	38	35	-3
Standard Deviation	6.3	5.9	
% Vehicles 5+ Over Limit	58%	41%	-29%
% Vehicles 10+ Over Limit	30%	16%	-47%
% Vehicles 15+ Over Limit	8%	3%	-65%
% Vehicles 20+ Over Limit	1%	0%	-100%
Count	524	490	-34

			True Effect
Speed Reduction	19.7	22.2	2.5

6.1.1.2 South Entrance

Standard Method

The south entrance to St Charles is mainly a residential housing area and had some of the highest speeds in the initial data for St Charles. Since this entrance was in a residential area, many driveways were present so only 130’ of the TuffCurb was installed in the center of the roadway. The AADT of this entrance was 1300. The speed data using the standard method again showed that the curbing was effective in reducing the speeds of drivers entering town which can be seen in Table 6-3. There was a 1.9 mph reduction in the mean speed and a 1 mph reduction in the 85th percentile speed. The percentage of vehicles going over the speed limit saw a minimum of a 20% reduction for each speeding category. The upstream data was consistent between the before to after data collection with only a 0.1 mph reduction in speed.

Tracking Method

With the tracking method 92% of the vehicles were tracked upstream while only 81% were tracked at the treatment. The large difference in percentage of vehicles tracked indicated that there would be changes in the speed statistics shown in Table 6-4. These statistics though showed that the treatment was effective at reducing the speeds of vehicles entering town like the standard method. The mean speeds of the vehicles were reduced by 1.5 mph and the 85th percentile speed was reduced by 1 mph. The percentage of vehicles going over the speed limit also showed significant decreases with at least 20% in each speeding category again. The upstream data in the tracking method showed that the speeds of vehicles entering town were actually higher in the after period by 0.6 mph. With this higher speed it could be said the safety impacts were greater since vehicles were entering town faster. The true effect method using this data will account for this.

Comparison of Standard and Tracking Method

Being in a more residential area created enough access points at this location but a road directly before the traffic calming treatment was also present similar to the north entrance. Comparing the data again shows that the tracking data mean speeds were around 1 mph higher than the standard method which could also be seen in the 85th percentile speeds as well as higher percentage of vehicles going over the speed limit. The t-test between the standard and tracking method showed there were statistically significant changes in means speeds both before and after installation of the treatment. The reduced data set speeds were statistically different from all of the data showing the impacts of the vehicles not affected by the treatment. This again is likely due to the vehicles turning on and off of County Rd R35 and producing lower speeds at the treatment data collection point. In this case though, the tracking data showed that the standard method overestimates the effectiveness of the treatment by 0.4 mph. The changes in 85th percentile and percentage of vehicles over the speed limit were similar with both methods but the individual data was higher in the tracking method again.

Speed Reduction Method

This site showed the first impacts the true effect has when analyzing speed reduction. In this case vehicles were entering town faster shown with a higher upstream speed. The true effect captured this with a 2.1 mph increase in the speed reduction shown in Table 6-4. As a safety measure, the true effect showed greater safety benefits than the change in mean speeds of both methods showed.

Table 6-3 St Charles Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.0	52.9	-0.1
85th Percentile	60	60	0
Standard Deviation	7.7	8.4	
Count	1181	1121	-60
At Treatment			
Mean Speed	29.2	27.3	-1.9
85th Percentile	36	35	-1
Standard Deviation	6.8	6.9	
% Vehicles 5+ Over Limit	47%	36%	-23%
% Vehicles 10+ Over Limit	21%	15%	-29%
% Vehicles 15+ Over Limit	7%	5%	-29%
% Vehicles 20+ Over Limit	2%	1%	-50%
Count	1322	1301	-21

Table 6-4 St Charles South Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.3	53.9	0.6
85th Percentile	60	60	0
Standard Deviation	7.4	6.9	
Count	1114	1016	-98
At Treatment			
Mean Speed	30.3	28.8	-1.5
85th Percentile	37	36	-1
Standard Deviation	6.5	6.3	
% Vehicles 5+ Over Limit	53%	43%	-20%
% Vehicles 10+ Over Limit	24%	18%	-24%
% Vehicles 15+ Over Limit	8%	6%	-28%
% Vehicles 20+ Over Limit	2%	1%	-50%
Count	1114	1016	-98

			True Effect
Speed Reduction	23.0	25.1	2.1

6.1.1.3 West Entrance

Standard Method

The entrance on the west side of St Charles saw a higher amount of traffic that is traveling between towns because the county seat of Madison County is located in that direction causing a higher number of trips being in that direction. The AADT for State Highway 251 is 1400. To slow the drivers down from this direction, two sets of curbing were installed in 100' sections before and after a driveway. The second section of TuffCurb was installed where curb and gutter began; with St Charles being a farming community many farmers could not make it through so that section was removed after two weeks. The 1 month after data was reflecting only the implementation of the first 100' section of TuffCurb.

As seen in Table 6-5, the speed study at this location using the standard method showed that vehicles mean speeds actually increased by 0.4 mph. The 85^{th} percentile speeds showed no change and there was no significant change in the percent of vehicles going over the speed limit. The upstream speeds decreased in the after period by 1.6 mph. This could show that there was some influence upstream that had drivers entering the community at a lower speed but overall the data shows that the curbing at this location was not effective at reducing the speeds of vehicles entering St Charles. The lower upstream speeds further show that there were no impacts from the treatment. The treatment would be deemed not effective at reducing the speeds of vehicles entering the community.

Tracking Method

The tracking method was capable of tracking 91% of the upstream vehicles and 87% of the treatment vehicles. The data from the tracking method can be seen in Table 6-6 but the data shows similar results as the standard method. There was again an increase of 0.4

mph in the mean speed and no change in the 85th percentile speeds. No significant differences were seen in the percentage of vehicles speeding which shows that the treatment was not effective at reducing speeds.

Comparison of Standard and Tracking Method

The data for both methods were identical which is due to less access points located along the entrance to town. There were occasional driveways between the data collection points but no major roads like the previous sites in St Charles that could generate higher volumes of vehicles that could alter and lower the speeds. The mean speeds did change slightly between the two methods for both the before and after. Using the t-test the differences were statistically significant. The driveways only had small changes in the speed statistics but were statistically significant. This did not alter the change in mean speeds but demonstrates how tracking was more accurate and beneficial.

Speed Reduction Method

With lower speeds upstream it could have possibly been difficult to explain whether the speed reduction coming into town were due to the treatment. The lower speeds could be accounted to some other outside factor that was not accounted for. In this case the speeds at the treatment were increased which resulted in the true effect shown in Table 6-6 being higher. The true effect showed that speed reduction decreased by 1.9 mph in the after period. Vehicles were not slowing down as much and show that the treatment was not effective at slowing vehicles down to improve safety. What the true effect did account for was the lower speed entering town which would not have been caught with the other methods.

Table 6-5 St Charles West Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.3	51.7	-1.6
85th Percentile	60	59	-1
Standard Deviation	7.3	7.6	
Count	1309	1186	-123
At Treatment			
Mean Speed	27.6	28.0	0.4
85th Percentile	33	33	0
Standard Deviation	5.2	5.3	
% Vehicles 5+ Over Limit	34%	36%	6%
% Vehicles 10+ Over Limit	9%	10%	11%
% Vehicles 15+ Over Limit	2%	2%	0%
% Vehicles 20+ Over Limit	0%	0%	0%
Count	1418	1285	-133

Table 6-6 St Charles West Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.6	52.1	-1.5
85th Percentile	60	59	-1
Standard Deviation	7.0	7.0	
Count	1229	1134	-95
At Treatment			
Mean Speed	28.0	28.4	0.4
85th Percentile	33	33	0
Standard Deviation	4.9	5.1	
% Vehicles 5+ Over Limit	37%	39%	3%
% Vehicles 10+ Over Limit	9%	10%	8%
% Vehicles 15+ Over Limit	2%	2%	0%
% Vehicles 20+ Over Limit	0%	0%	0%
Count	1229	1134	-95

			True Effect
Speed Reduction	25.6	23.7	-1.9

6.1.1.4 East Entrance

Standard Method

The east entrance was the most heavily traveled entrance in St Charles with an AADT of 2200. The increased traffic along State Highway 251 is because this route connects St Charles to Interstate 35. A TAPCO Blinkersign was installed at this entrance and the data using the standard method of analysis can be seen in Table 6-7. The data shows that the sign was not very effective at slowing the drivers down as they were entering town. There was only a 0.4 mph reduction in the mean speed along with no change in the 85th percentile. The percentage of vehicles going over the speed limit showed similar results with little to no change. The upstream data also had no change from before to 1 month after so overall this treatment seemed to have little effect on vehicle speeds while entering the town.

Tracking Method

The tracking data observed in Table 6-8 showed differing results for the BlinkerSign. The tracking method was able to track 93% of the upstream and 87% of the treatment data. The mean speed was decreased by 0.6 mph in the after period and there was a 1 mph decrease in the 85th percentile speed. The percentage of vehicles going 5 and 10 mph over the speed limit decreased by ten percent while there was no change to the higher speeding categories. The upstream data showed that speed were consistent with only a 0.1 mph decrease in speed in the 1 month after period. Although the figures are not high there are more signs of reduction in speed seen with the Blinkersign.

Comparison of Standard and Tracking Method

The location of the Blinkersign was in a position that had a significant amount of vehicles turning on and off of State Highway 251 because of a bank entrance and a gravel road before the treatment. The turning movements at this location caused some increases in all of the speed data. The increases in mean speeds between the two methods were statistically significant for the before and after data. The increases in mean speeds were less than 1 mph higher but resulted in the standard method slightly underestimating the effectiveness of the treatment. The standard method also did not show any change in the 85^{th} percentile speeds which the tracking method did show. While only minor impacts were seen, the turning traffic did have some effects on the results.

Speed Reduction Method

With little change in the upstream data the true effect showed similar effectiveness as the change in mean speeds. There was a 0.5 mph increase in speed reduction after the treatment was installed showing that treatment was effective at reducing vehicles speeds entering town.

Table 6-7 St Charles Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.7	53.8	0.1
85th Percentile	60	59	-1
Standard Deviation	6.7	5.8	
Count	2313	2087	-226
At Treatment			
Mean Speed	29.0	28.6	-0.4
85th Percentile	35	35	0
Standard Deviation	6.0	6.0	
% Vehicles 5+ Over Limit	46%	42%	-9%
% Vehicles 10+ Over Limit	18%	16%	-11%
% Vehicles 15+ Over Limit	4%	5%	25%
% Vehicles 20+ Over Limit	1%	1%	0%
Count	2479	2209	-270

Table 6-8 St Charles East Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.0	53.9	-0.1
85th Percentile	60	59	-1
Standard Deviation	6.2	5.7	
Count	2147	1954	-193
At Treatment			
Mean Speed	29.8	29.2	-0.6
85th Percentile	36	35	-1
Standard Deviation	5.6	5.8	
% Vehicles 5+ Over Limit	51%	46%	-10%
% Vehicles 10+ Over Limit	20%	18%	-12%
% Vehicles 15+ Over Limit	5%	5%	0%
% Vehicles 20+ Over Limit	1%	1%	0%
Count	2147	1954	-193

			True Effect
Speed Reduction	24.2	24.7	0.5

6.1.2 Jesup

Ten miles east of Waterloo, Iowa is the City of Jesup with a population of 2,517. State Highway 939 passes through the south side of Jesup and is where most of the businesses are located. With so many businesses in this area it creates potential conflicts from vehicles entering and exiting the attraction's which is why it is important to slow the drivers down. The traffic calming measure for these sites are a high friction pavement marking that displays "35" in one red box and "MPH" in another. Pictures of both treatments can be seen in Figure 6-2. The pavement marking will be used to alert the driver that they are entering the community and that the speed limit is being reduced. With the speed limit on the pavement in large red boxes more attention is drawn towards the pavement notifying the driving to adjust their speed. This pavement marking draws more attention than what the speed limit sign would do along.

Figure 6-2 Jesup East/West Traffic Calming

6.1.2.1 West Entrance

Standard Method

The west entrance to town has no access on or off of State Highway 939 before the treatment and is in an open fielded area. The open area and wide shoulders gives the driver the perception they can drive faster because the conditions are optimal. The pavement markings are a focal point when entering the town and easily draw the necessary attention from the drivers to reduce their speed. The speed statistics in Table 6-9 shows the results of the standard method. There was a 1.5 mph reduction in the mean speed along with a 2 mph reduction in the 85th percentile speed. All of the percentage of vehicles going over the speed limit also decreased which overall showed that the pavement marking did effectively slow the drivers as they were entering Jesup. The speeds upstream were fairly consistent from before to after with only a 0.4 mph reduction in mean speed showing no doubt the treatments were effective at reducing speeds.

Tracking Method

With the tracking method there was a 1.3 mph reduction in the mean speed and a 2 mph reduction in the 85th percentile speed. The percentage of vehicles going over the speed limit was also significantly decreased in the lower three speeding categories. All of this data can be seen in Table 6-10. The tracking of vehicles at this site was very effective with 95% of the vehicles upstream and 91% of the vehicles at the treatment be tracked.

Comparison of Standard and Tracking Method

This location was in a fairly open area with no access while entering town. Because there was no access the standard method and tracking method were almost identical showing the pavement markings were effective at reducing the speeds of vehicles entering Jesup. There were slight differences in the mean speeds between the methods but with the t-test the differences were shown not to be statistically significant. This was expected because of the lack of access points for vehicles to turn on and off the roadway. The statistics from both methods are identical with only slight differences in the change in mean speeds and the percentage of vehicles going over the speed limit.

Speed Reduction Method

The benefit of the tracking the vehicles at this site was in accounting for the reduction in speed upstream by the true effect. The true effect for this site was 0.8 mph showing the effectiveness of the treatment was not as high as the changes seen in the mean speeds. The true effect was lower than both of the changes in mean speeds. Since vehicles are driving slower when they are entering town then they do not have to reduce their speed as much which was accounted for in the true effect. With the positive value though the true effect does show that the pavement markings are effective at reducing the speed of vehicles entering Jesup as a safety surrogate.

Table 6-9 Jesup West Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.6	54.2	-0.4
85th Percentile	60	60	0
Standard Deviation	5.7	5.5	
Count	3864	3978	114
At Treatment			
Mean Speed	38.5	37.0	-1.5
85th Percentile	43	41	-2
Standard Deviation	4.7	4.6	
% Vehicles 5+ Over Limit	37%	26%	-30%
% Vehicles 10+ Over Limit	10%	6%	-40%
% Vehicles 15+ Over Limit	2%	1%	-50%
% Vehicles 20+ Over Limit	0%	0%	0%
Count	4037	4149	112

Table 6-10 Jesup West Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.9	54.4	-0.5
85th Percentile	60	60	0
Standard Deviation	5.5	5.3	
Count	3619	3787	168
At Treatment			
Mean Speed	38.4	37.1	-1.3
85th Percentile	43	41	-2
Standard Deviation	4.6	4.5	
% Vehicles 5+ Over Limit	36%	26%	-29%
% Vehicles 10+ Over Limit	9%	6%	-38%
% Vehicles 15+ Over Limit	2%	1%	-48%
% Vehicles 20+ Over Limit	0%	0%	0%
Count	3619	3787	168
			True Effect
Speed Reduction	16.5	17.3	0.8

6.1.2.2 East Entrance
Standard Method

The east entrance to Jesup is more developed than the west side and is primarily where more of the businesses are located. This creates more vehicles entering and exiting the roadway which in turn creates more conflicts. The final speed transition was located directly in front of a farm implement store which had two entrances located both before and after the treatment location. Vehicles turning in and out of the business were expected to have impacts on the speed statistics. The standard method showed a 1.3 mph mean speed reduction and a 2 mph reduction in the 85th percentile speed, both of which can be seen in Table 6-11. There were also decreases in the percentage of vehicles going over the speed limit which helped to show that the pavement marking were again effective at reducing the speeds of vehicles entering the community. The upstream speeds were 0.5 mph higher in the after data collection period.

Tracking Method

Table 6-12 showed a higher mean speed reduction of 1.8 mph from using the tracking method. There were reductions in the 85th percentile speeds of 2 mph along with decreases in the percentage of vehicles going over the speed limit. This site in Jesup also saw high tracking rates with 95% of the upstream being tracked as well as 92% of the treatment vehicles. The tracking method showed that the pavement marking were effective at slowing the drivers down as they were entering Jesup from the East. The upstream speeds were also higher in the after period by 0.5 mph using the tracking method.

Comparison of Standard and Tracking Method

It was suspected that the business in the area would affect the speed statistics and this can be seen in the data with the standard method having mean speeds 1 mph lower than the tracking method. This reduction in mean speeds was statistically significant with the t-test. The vehicles turning in and out of the business significantly decreased the speeds and actually affected the change in mean speed because the tracking method was 0.5 mph higher. This location again shows that the standard method underestimates the effectiveness in the treatment with the mean speed. Other statistics saw no changes between the methods.

Speed Reduction Method

The true effects were higher than the changes in mean speeds of both methods because of the higher speeds entering the community. The true effect shown in Table 6-12 was 2.3 mph. Vehicles were slowing down more after the implementation of the treatment which showed the treatment was a success using the true effect as a safety surrogate measure.

Table 6-11 Jesup East Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.6	55.1	0.5
85th Percentile	60	60	0
Standard Deviation	6.7	6.5	
Count	2853	2766	-87
At Treatment			
Mean Speed	35.3	34.0	-1.3
85th Percentile	41	39	-2
Standard Deviation	6.9	5.9	
% Vehicles 5+ Over Limit	23%	13%	-44%
% Vehicles 10+ Over Limit	5%	3%	-40%
% Vehicles 15+ Over Limit	1%	0%	-100%
% Vehicles 20+ Over Limit	0%	0%	0%
Count	3004	2842	-162

Table 6-12 Jesup East Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.9	55.4	0.5
85th Percentile	60	60	0
Standard Deviation	6.2	6.1	
Count	2712	2645	-67
At Treatment			
Mean Speed	36.6	34.8	-1.8
85th Percentile	41	39	-2
Standard Deviation	5.2	4.7	
% Vehicles 5+ Over Limit	25%	14%	-45%
% Vehicles 10+ Over Limit	6%	3%	-50%
% Vehicles 15+ Over Limit	1%	0%	-100%
% Vehicles 20+ Over Limit	0%	0%	-0%
Count	2712	2645	-67

			True Effect
Speed Reduction	18.3	20.6	2.3

6.1.3 Ossian

In the Northeast corner of Iowa is the City of Ossian with a population of 884. Ossian is located in Winneshiek County and has County Road W42 entering the town from the north where a speeding problem occurs. The traffic calming for this location used the same high friction pavement markings that were used in Jesup but for a 25 mph transition zone rather than a 35 mph transition. Slowing drivers in this area was important because of the many kids in the area and the concern parents had already with the speeds entering town. As can be seen in Figure 6-3, the pavement marking is a large reminder that the speed is 25 mph and that speeds need to be reduced. Also seen in the picture is the slow children sign below the 25 mph speed limit which shows this has been an ongoing issue and concern in the area.

Figure 6-3 Ossian North Tracking Treatment

6.1.3.1 North Entrance
Standard Method

The speeding problem documented was effectively decreased by the traffic calming implemented. The mean speeds were reduced by 2.3 mph and the 85th percentile speeds were also decreased by 2 mph. The percentages of drivers going over the speed limit were reduced in all speeding categories and showed that pavement marking were effective at reducing speeds. These speed statistics are documented in Table 6-13 along with upstream data which showed that there was 0.6 mph increase in speed.

Tracking Method

The tracking of vehicles was high at this location with 97% of the upstream data tracked and 89% of the treatment data tracked. The data for the tracking method can be seen in Table 6-14 which showed that there was a 2.4 mph reduction in the mean speed. The 85th percentile speeds were reduced by 2 mph and there were decreases in all of the percentage of vehicles going over the speed limit. The treatment was effective at reducing the speeds of the vehicles that were entering the town. Upstream speeds were higher by 0.5 mph so a speed reduction at the treatment could be seen.

Comparison of Standard and Tracking Method

This entrance to Ossian was located around cropland so there were no access points other than two residential driveways that were located before the treatment. Slight increases were seen in the mean speeds both before and after between the methods. The differences in mean speeds were statistically significant for the before and after data. No increases in the 85th percentile speeds were documented but slight increases in the percentage of vehicles speeding were seen in the lower speeding categories. The volumes of vehicles using these driveways were not high enough to alter the data drastically making the changes of speed statistics similar in both methods. The mean speed change was only 0.1 mph higher with the tracking method.

Speed Reduction Method

Table 6-14 shows the true effect to be 2.9 mph. This documented that the vehicles coming into town were slowing down 2.9 mph more once the treatment was installed. As a safety surrogate measure this shows that the treatment was effective at improving the safety of the area. The true effect was again valuable like at the west entrance to Jesup because it showed that the vehicles entering town were actually slowing down more than what the change in mean speed documented. The speeds of vehicles entering town were higher in the 1 month after data collection requiring that drivers to slow their vehicles more which the true effect records.

Table 6-13 Ossian North Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	56.6	57.2	0.6
85th Percentile	63	62	-1
Standard Deviation	6.6	5.9	
Count	921	1000	79
At Treatment			
Mean Speed	30.2	27.9	-2.3
85th Percentile	36	34	-2
Standard Deviation	6.3	6.2	
% Vehicles 5+ Over Limit	54%	38%	-30%
% Vehicles 10+ Over Limit	22%	14%	-36%
% Vehicles 15+ Over Limit	7%	3%	-57%
% Vehicles 20+ Over Limit	1%	1%	0%
Count	1009	1086	77

Table 6-14 Ossian North Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	56.8	57.3	0.5
85th Percentile	63	62	-1
Standard Deviation	6.4	5.7	
Count	895	970	75
At Treatment			
Mean Speed	30.9	28.5	-2.4
85th Percentile	36	34	-2
Standard Deviation	5.6	5.7	
% Vehicles 5+ Over Limit	57%	40%	-30%
% Vehicles 10+ Over Limit	23%	15%	-37%
% Vehicles 15+ Over Limit	7%	3%	-52%
% Vehicles 20+ Over Limit	1%	1%	0%
Count	895	970	75

			True Effect
Speed Reduction	25.9	28.8	2.9

6.1.4 Quasqueton

The City of Quasqueton is a small town with 553 residents located 15 miles east of Waterloo, Iowa with County Road W35 going north-south through town. For the Quasqueton sites, transverse pavement marking were used on both the north and south entrances of town. The pavement markings were placed at the 35 mph transition on the north entrance and at the 25 mph transition on the south entrance. On the north side of town the final transition zone was deemed too far into town for the treatment so the next transition zone was selected. Pictures of both entrances can be seen in Figure 6-4. The transverse pavement markings have two affects in this situation: draw attention that a community will be entered and give the driver the sense of feeling they are increasing their speed. Both affects should slow the driver down as they are entering the community.

Figure 6-4 Quasqueton North/South Traffic Calming

6.1.4.1 North Entrance

Standard Method

At the north entrance to Quasqueton the transverse pavement markings were placed at the 35mph speed transition. When the one month after data was collected the tube was cut after 24 hours so only 24 hours of data was available for this site compared to the 48 hours at the other traffic calming sites. The speed data in Table 6-15 shows that there was increases in speeds from the before to after data location of 1.4 mph. Similar increases were seen in the 85th percentile speed and the percentage of vehicles going over the speed limit. Overall the statistics measured showed that the transverse pavement marking were not effective at this location. The upstream data did show that speeds increased by 0.6 mph coming into town but this increase in speed entering town could not account for the increase at the treatment.

Tracking Method

The tracking method showed similar results as the standard method. In Table 6-16 the mean speed increased in the after period by 1.1 mph and the 85th percentile speed increased by 1 mph. The percentage of vehicles going over the speed limit also increased in the 1 month after data collection period. The upstream speed also increased with the tracking method there was not enough of an increase to show any effectiveness. The data does show the treatment was ineffective but the tracking method successfully tracked 97% of the vehicles at both data collection locations. There were no access points between the upstream and treatment data locations so it was expected that a high percentage of vehicles would be tracked.

Comparison of Standard and Tracking Method

Because there were no access points, the speed statistics in both methods are identical. When comparing the mean speeds between the two methods the before mean speed were statistically different while the after speeds were not. The mean speeds being statistically different before means that the three percent of the removed data had some impact on the mean speeds. There was a farm located next to the roadway so some turning vehicles may have come of this area in the before condition that were not present in the after period. The statistics between the two methods are similar with only slight changes between the methods. The tracking method did show that the speed increase was not as severe with a lower mean speed increase and only a 1 mph increase in the 85th percentile speed.

Speed Reduction Method

In this type of situation the true effect could have had a major impact in the results. The changes in mean speeds were fairly low so with an increase in speed upstream the true effect could have potentially showed an effectiveness at this treatment. The speeds in this case did not increase as much upstream and resulted in a decrease in the true effect of 0.7 mph. The true effect can be seen in Table 6-16 showing that the speed reduction after implementation being lower than before. The treatment in this case would be ineffective at reducing the speed of drivers entering Quasqueton.

Table 6-15 Quasqueton North Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	57.9	58.5	0.6
85th Percentile	62	62	0
Standard Deviation	5.8	4.4	
Count	1757	949	-808
At Treatment			
Mean Speed	41.6	43.0	1.4
85th Percentile	48	50	2
Standard Deviation	7.7	7.5	
% Vehicles 5+ Over Limit	68%	74%	9%
% Vehicles 10+ Over Limit	37%	46%	24%
% Vehicles 15+ Over Limit	11%	15%	36%
% Vehicles 20+ Over Limit	2%	4%	100%
Count	1768	946	-822

Table 6-16 Quasqueton North Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	58.1	58.5	0.4
85th Percentile	62	62	0
Standard Deviation	5.2	4.4	
Count	1699	933	-766
At Treatment			
Mean Speed	42.0	43.1	1.1
85th Percentile	49	50	1
Standard Deviation	7.2	7.3	
% Vehicles 5+ Over Limit	69%	75%	8%
% Vehicles 10+ Over Limit	37%	47%	26%
% Vehicles 15+ Over Limit	11%	15%	38%
% Vehicles 20+ Over Limit	2%	4%	100%
Count	1699	933	-766

			True Effect
Speed Reduction	16.1	15.4	-0.7

6.1.4.2 South Entrance
Standard Method

The south entrance traffic calming treatment was located at the 25 mph speed transition and proved to be effective at slowing drivers down. Tracking was suspected to have an effect at this site because a city road was located within the area where the transverse pavement marking were placed. All of the speed statistics shown in Table 6-17 from the standard method decreased from before to 1 month after. The mean speed was reduced 1.2 mph after the treatment was installed along with a 1 mph reduction in the 85th percentile speed. There were only slight reductions in the percentages of vehicles going over the speed limit. The upstream data showed higher speeds entering town after the treatments installation of 0.9 mph. This will not affect the results and shows the treatment may be even more effective than what is shown with the mean speed reduction.

Tracking Method

The tracking percentages at this entrance of Quasqueton were lower than most of the other sites. Only 80% of the vehicles were tracked at the treatment location while 93% of the vehicles were tracked upstream. There was a change in the mean speed of 0.7 mph showing that the treatment was effective at reducing the speeds of vehicles entering town. Table 6-18 also showed that the 85th percentile speed lowered by 1 mph while there were even lower percentages of vehicles going over the speed limit. The tracking method showed that the pavement marking were effective at slowing the vehicles down entering town. Similar to the standard method, the upstream speeds were higher coming into town after the installation which could show that the treatment was more effective at reducing vehicles speeds.

Comparison of Standard and Tracking Method

With an access point within the transverse pavement markings the two methods showed different results. This was documented with the t-test showing that the differences of the mean speeds between the two methods were statistically significant. The mean speeds in the tracking method were around 2 mph higher which accounts for the slower moving vehicles turning on and off of the road located before the treatment. The difference in the mean speeds both before and after implementation effected the change in mean speeds as well. The standard method is shown overestimating the effectiveness by 0.5 mph. There are differences among the other speed statistics but the changes are similar between the methods. Although the differences do not change the effectiveness it does show vehicles were not slowing down as much as depicted with the standard method.

Speed Reduction Method

The true effect was beneficial at this site because the higher upstream speeds were accounted for in the safety measurement. The change in mean speeds do not account for vehicles entering the town at a higher rate of speed where the true effect accounted for this resulting in vehicles reducing their speeds 1.3 mph more after implementation. These were higher than the changes in mean speed for both methods because it shows that vehicles actually needing to slow down more to reach the lower mean speed. The treatment was deemed effective at making vehicles slow down more entering town.

Table 6-17 Quasqueton South Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.7	55.6	0.9
85th Percentile	60	60	0
Standard Deviation	6.6	5.6	
Count	1687	1613	-74
At Treatment			
Mean Speed	34.7	33.5	-1.2
85th Percentile	41	40	-1
Standard Deviation	6.7	6.8	
% Vehicles 5+ Over Limit	80%	73%	-9%
% Vehicles 10+ Over Limit	57%	50%	-12%
% Vehicles 15+ Over Limit	24%	20%	-17%
% Vehicles 20+ Over Limit	4%	3%	-25%
Count	1907	1920	13

Table 6-18 Quasqueton South Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	55.1	55.7	0.6
85th Percentile	60	60	0
Standard Deviation	5.4	4.8	
Count	1572	1504	-68
At Treatment			
Mean Speed	36.4	35.7	-0.7
85th Percentile	42	41	-1
Standard Deviation	5.3	5.1	
% Vehicles 5+ Over Limit	92%	88%	-4%
% Vehicles 10+ Over Limit	66%	61%	-8%
% Vehicles 15+ Over Limit	28%	23%	-16%
% Vehicles 20+ Over Limit	5%	3%	-42%
Count	1572	1504	-68

			True Effect
Speed Reduction	18.7	20.0	1.3

6.1.5 Hazelton

The City of Hazelton is another site located in Northeast Iowa. The entrance studied in Hazelton was along County Road C57 on the east side of town. Transvers pavement marking were again used and located at the 25 mph speed zone transition. A picture of the transverse pavement marking can be seen in Figure 6-5. Only driveways were located between the upstream data collection point and the treatment location.

Figure 6-5 Hazelton East Traffic Calming

6.1.5.1 East Entrance

Standard Method

The east entrance to Hazelton is a lower volume road having an AADT of 850 but did see significant impacts on the speed with the implementation of the traffic calming treatment. The mean speed was reduced by 1.6 mph and there was a 1 mph reduction in the 85th percentile speeds. There were only minimal changes in the percentage of vehicles going less than 10 mph over the speed limit but greater changes were seen in the vehicles going 10 mph or more over the speed limit. This location saw a decrease in the mean speed upstream of 0.8 mph which may account for some of the speed reduction that was seen at the treatment location. All of the data can be seen in Table 6-19. Even with the higher upstream speed the standard method shows that the treatment effectively reduced the speeds of vehicles entering the town.

Tracking Method

With the tracking method 99% of the vehicles upstream were tracked while only 89% of the vehicles at the treatment location were tracked. Tracking provided similar results as the standard method with a 1.4 mph reduction in the mean speed and a 1 mph reduction in the 85th percentile speed. There were also more impacts on the vehicles going 10 mph or more over the speed limit and only smaller changes in the percentage of vehicles going less than 10 mph. The mean speed of the vehicles entering town were 0.7 mph higher in the before period meaning vehicles were entering town slightly slower in the after period. The statistics do show that the transverse pavement marking were effective at reducing the speed of vehicles as they entered town. The data can be seen in Table 6-20.

Comparison of Standard and Tracking Method

With no major access points between the data collection points, only small changes were expected. The differences in the mean speed before and after between the two methods were statistically significant using the t-test. The small changes are likely due to the vehicles exiting their driveway and entering town. Driveways do not create high volumes which are why there were only small changes. The other speed statistics were identical for both methods which can also be seen in the changes of all of the statistics.

Speed Reduction Method

Like the true effect has done for higher speeds entering town, the true effect can also show the affects when vehicles are driving slower in the after period. Vehicles entering the town slower are more difficult to account for because it is hard to determine whether the speed reductions documented are due to the treatment being installed or are due to the drivers going slower during that period. To bypass this, the true effect accounts for the changes in speeds entering town by showing how much vehicles are reducing their speed entering town. If the speed reduction coming into town is larger in the after period than it is proven that there was still some speed reduction pertaining to the treatment. Table 6-20 shows that the true effect for this site was 0.7 mph making the treatment effective at reducing the speeds of vehicles entering town and improving the safety.

Table 6-19 Hazelton East Entrance Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	55.8	55.0	-0.8
85th Percentile	61	60	-1
Standard Deviation	7.2	6.7	
Count	832	672	-160
At Treatment			
Mean Speed	36.2	34.6	-1.6
85th Percentile	43	42	-1
Standard Deviation	6.9	7	
% Vehicles 5+ Over Limit	84%	77%	-8%
% Vehicles 10+ Over Limit	59%	52%	-12%
% Vehicles 15+ Over Limit	32%	24%	-25%
% Vehicles 20+ Over Limit	10%	6%	-40%
Count	906	748	-158

Table 6-20 Hazelton East Entrance Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	55.9	55.2	-0.7
85th Percentile	61	61	0
Standard Deviation	6.8	6.2	
Count	822	663	-159
At Treatment			
Mean Speed	36.6	35.2	-1.4
85th Percentile	43	42	-1
Standard Deviation	6.8	6.6	
% Vehicles 5+ Over Limit	86%	80%	-7%
% Vehicles 10+ Over Limit	62%	54%	-13%
% Vehicles 15+ Over Limit	34%	26%	-24%
% Vehicles 20+ Over Limit	11%	7%	-37%
Count	822	663	-159

			True Effect
Speed Reduction	19.3	20.0	0.7

6.2 Curve Safety Sites

The curve sites also used tracking but in a higher speed situation with lower speed changes. The same methodology will be applied to the curve safety sites as the traffic calming sites. With the curve sites comparisons will be made for the point of curvature and the center of curve. The tracking will be used in determining the effectiveness of the TAPCO signs by determining the speed reductions while entering the curve at the point of curvature and also while the vehicles are in the curve at the center of the curve. Tracking will be highlighted with a study such as this by tracking speeds from upstream into the entrance of the curve and then to the center of curve such that the speed changes can be depicted throughout. Unlike the traffic calming though, little change was seen in the average speeds. The impact tracking has for the curves were the details the speed reduction statistics were capable of providing.

6.2.1 Missouri Curves

6.2.1.1 Highway 221 Curve

Standard Method

The curve along Highway 221 in Missouri had an advisory speed of 40 mph so the flashing chevron signs at this location aimed at trying to slow the drivers down to this speed when entering and then throughout the curve. In Table 6-22 the before and after speed statistics can be seen at all three data collection locations using the standard method. The mean speed had a 1.5 mph reduction at the point of curvature and an increase of 0.3 mph at the center of the curve. The statistics also show there was a 1 mph decrease in the 85th percentile speed and decreases in all of the percentages of vehicles going over the advisory speed at the point of curvature. However at the center of the curve there were no changes in the 85th percentile speed and little changes to increases in the percentage of vehicles going over the advisory speed. The speed upstream showed that there was an increase in vehicle speeds approaching the curve of 0.6 mph. From this data, the signs alerted the drivers sooner that a curve was approaching which resulted in the lower entrance speeds into the curve but after entering the curve the speed was consistent in both situations. The treatment would therefore be effective at reducing speeds when entering the curve but have no impact throughout the curve. There may be additional safety benefits because of the higher speeds entering the curve.

Tracking Method

With the tracking method the data was reduced to only the vehicle going through all three data collection locations which resulted in 97% of the vehicles being tracked at all locations. In Table 6-23 the mean speed changes were exactly the same as the standard method with a reduction in 1.5 mph at the point of curvature and an increase of 0.3 mph at the center of curve. The 85th percentile speeds as well as the percentage of vehicles going over the advisory were identical in both methods. The upstream speeds were similar to the standard method as well with an increase in the speed. Since there was no major changes in the data the same conclusion of effectiveness is seen here.

Comparison of Standard and Tracking Method

The results for the tracking method and standard method are identical. There were no access points approaching the curve so it was expected that the data would be the same. No t-test was needed in this case between the methods because there was no difference in the mean speeds. The changes in mean speeds were also exactly the same because of this. This curve had no outside features that would cause vehicles to turn on and off the road.

Speed Reduction Method

The true effect had different results with the speed reduction from the upstream to point of curvature increasing by 2.0 mph and the speed reduction from the upstream to center of curve increasing by 0.2 mph. In addition to that, the speed reduction actually decreased between the point of curvature to the center of curve by 1.8 mph. These statistics, seen in Table 6-21, are capable of providing a more detailed view at how the drivers are behaving. It can be seen that the vehicles were approaching the curve at a higher rate of speed and had to slow down more in the 1 month after data collection. The treatment was effective though at reducing the speed of vehicles entering the curve but did not impact the driver through the curve. The treatment slowed vehicles down enough while entering the curve that they were at the desired speed through the curve and did not have to slow down as much which can be seen with the negative true effect from the point of curvature to the center of curve.

Table 6-21 Highway 221 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	0.6	2.6	2.0
Speed Reduction Upstream to CC	4.0	4.2	0.2
Speed Reduction PC to CC	3.4	1.6	-1.8

Both methods come to the same conclusion but with the true effect a more detailed view of the situation can be seen. The vehicles are actually slowing down more due to the higher speed the vehicles were approaching the curve at but once they were in the curve they only slightly reduced their speed compared to the before period. By incorporating the upstream data a more detailed view can be seen as well as larger impacts from the higher speeds approaching the curve.

Table 6-22 Highway 221 Curve Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	52.2	52.8	0.6
85th Percentile	57	58	1
Standard Deviation	4.8	4.9	
Count	2568	2531	-37
Point of Curvature			
Mean Speed	51.7	50.2	-1.5
85th Percentile	56	55	-1
Standard Deviation	4.7	4.8	
% Vehicles 5+ Over Advisory	94%	88%	-6%
% Vehicles 10+ Over Advisory	70%	58%	-17%
% Vehicles 15+ Over Advisory	25%	17%	-32%
% Vehicles 20+ Over Advisory	4%	2%	-50%
Count	2566	2523	-43
Center of Curvature			
Mean Speed	48.3	48.6	0.3
85th Percentile	53	53	0
Standard Deviation	4.4	4.6	
% Vehicles 5+ Over Advisory	82%	82%	0%
% Vehicles 10+ Over Advisory	38%	42%	9%
% Vehicles 15+ Over Advisory	7%	9%	15%
% Vehicles 20+ Over Advisory	1%	1%	0%
Count	2559	2522	-37

Table 6-23 Highway 221 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	52.3	52.8	0.5
85th Percentile	57	58	1
Standard Deviation	4.7	4.9	
Count	2501	2459	-42
Point of Curvature			
Mean Speed	51.7	50.2	-1.5
85th Percentile	56	55	-1
Standard Deviation	4.7	4.8	
% Vehicles 5+ Over Advisory	94%	88%	-6%
% Vehicles 10+ Over Advisory	70%	58%	-17%
% Vehicles 15+ Over Advisory	25%	17%	-32%
% Vehicles 20+ Over Advisory	4%	2%	-50%
Count	2501	2459	-42
Center of Curvature			
Mean Speed	48.3	48.6	0.3
85th Percentile	53	53	0
Standard Deviation	4.4	4.6	
% Vehicles 5+ Over Advisory	82%	82%	0%
% Vehicles 10+ Over Advisory	38%	42%	9%
% Vehicles 15+ Over Advisory	7%	9%	15%
% Vehicles 20+ Over Advisory	1%	1%	0%
Count	2501	2459	-42

6.2.2 Wisconsin Curves

6.2.2.1 Highway 213 Curve

Standard Method

In Wisconsin, the first curve analyzed was along Highway 213. The advisory speed for this curve was 50 mph so only small changes in the speeds were anticipated. In Table 6-25 you can see the speed statistics that were calculated with the standard method. The mean speed decreased at the point of curvature by 0.7 mph. At the center of curve the mean speed decreased by 1.0 mph. With speeds decreasing at both locations along the curve it shows that the signs helped drivers detect the curve early and slowed them down while going through the curve. The 85th percentile speeds did not change at the point of curvature but were reduced by 1 mph at the center of curve. The percentage of vehicles that were going 15 mph or less did see some reductions at both locations as well. The upstream data in this case did show that vehicles were traveling 1 mph faster in the after data collection showing the vehicles may be slowing down more than shown with the mean speed change. Overall it can be said that the treatment was effective at slowing vehicles down while entering and through the curve.

Tracking Method

This location was again successful at tracking vehicles with 97% tracked upstream, 98% tracked at the point of curvature and 92% tracked at the center of curve. Table 6-26 shows that the mean speed change at the point of curvature and center of curve were 0.7 mph with the tracking method. There was no change in the 85th percentile speed and slight reductions in the percentage of vehicles going over the advisory speed, again only seen in the vehicles going less than 15 mph over the advisory speed. With similar changes in statistics the tracking method also showed that the treatment was effective at reducing speeds of vehicles entering and throughout the curve. The upstream mean speeds increased with the tracking method as well.

Comparison of Standard and Tracking Method

When comparing the data of the upstream and point of curvature the data is almost exactly the same with only the percentage of vehicles going 5 mph over the advisory speed being much higher in the tracking method. At the point of curvature the difference in the mean speeds were not statistically significant for the before or after data. The biggest difference is located between the center of curvature data. Between the point of curvature and center of curve there was a road that made a T-intersection with the curve. This road saw significant turning movements on and off of the roadway which lead to impacts on the center of curve. The mean speeds were 2 mph lower in the standard method which was statistically significant for both data collection periods. The road located within the curve did have an impact on the standard methods data. With the center of curves data being the only affected, what this showed is that there is a high volume of traffic that was turning off of the T-intersection roadway and onto the curve. Since this data was only counted by the center of curve data collection point, it was removed from the tracking method. This resulted in the standard method overestimating the speed reduction by 0.3 mph at the center of curve.

Speed Reduction Method

Upstream the speeds were 1 mph higher in the 1 month after data collection leading to the true effect to be higher with vehicles reducing their speed 1.7 mph more after the treatment was installed. The speed reductions between the point of curvature and center of curve were the same in both the before and after period meaning the only effects on speed choice were seen when entering the curve. While going through the curve no speed reduction changes were seen. The true effect statistics can be seen in Table 6-24.

Table 6-24 Highway 213 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	3.4	5.1	1.7
Speed Reduction Upstream to CC	4.2	5.9	1.7
Speed Reduction PC to CC	0.8	0.8	0.0

The true effect data incorporated the upstream speed data which the standard method cannot do. Using this as a surrogate safety measure, increased safety benefits can be seen comparative to the change in mean speeds. What the standard method also cannot show in this case is that once within the curve vehicles had the same speed reduction between the point of curvature and center of curve. This shows that vehicles were entering the curve at a lower speed but still felt they needed to reduce their speed through the curve similar to the before condition. Knowing this, there may still be improvements for vehicles to lower their speeds more when entering the curve.

Table 6-25 Highway 213 Curve Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	58.8	59.8	1.0
85th Percentile	63	64	1
Standard Deviation	5	4.8	
Count	1159	1121	-38
Point of Curvature			
Mean Speed	55.3	54.6	-0.7
85th Percentile	61	61	0
Standard Deviation	7	6.6	
% Vehicles 5+ Over Advisory	63%	57%	-10%
% Vehicles 10+ Over Advisory	28%	21%	-25%
% Vehicles 15+ Over Advisory	3%	3%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	1156	1119	-37
Center of Curvature			
Mean Speed	53.2	52.2	-1.0
85th Percentile	61	60	-1
Standard Deviation	9.7	9.8	
% Vehicles 5+ Over Advisory	59%	52%	-12%
% Vehicles 10+ Over Advisory	25%	20%	-20%
% Vehicles 15+ Over Advisory	2%	3%	50%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	1220	1970	750

Table 6-26 Highway 213 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	58.9	59.9	1.0
85th Percentile	63	64	1
Standard Deviation	4.8	4.8	
Count	1134	1098	-36
Point of Curvature			
Mean Speed	55.5	54.8	-0.7
85th Percentile	61	61	0
Standard Deviation	6.5	6.2	
% Vehicles 5+ Over Advisory	85%	58%	-32%
% Vehicles 10+ Over Advisory	29%	22%	-25%
% Vehicles 15+ Over Advisory	3%	3%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	1134	1098	-36
Center of Curvature			
Mean Speed	54.7	54.0	-0.7
85th Percentile	61	61	0
Standard Deviation	7.7	7.5	
% Vehicles 5+ Over Advisory	63%	57%	-10%
% Vehicles 10+ Over Advisory	27%	22%	-19%
% Vehicles 15+ Over Advisory	3%	3%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	1134	1098	-36

6.2.2.2 Highway 20 Curve

Standard Method

Highway 20 in Wisconsin has a curve advisory speed of 30 mph so significant decreases in speed were expected in this curve. Because of the implementation of the treatment there was a 1.8 mph reduction in the mean speed at both the point of curvature and center of curve using the standard method. Table 6-28 shows these results along with a 2 mph reduction in the 85th percentile speed at both locations. Significant decreases were also seen in the percentage of vehicles going over the advisory as well. The upstream location did have a mean speed that was 1.5 mph higher in the 1 month after data collection which shows speed reduction may be greater than what the change in mean speed shows. Overall the data shows that the TAPCO signs were effective at reducing the speed entering and throughout the curve.

Tracking Method

With the tracking method, 87% of the upstream data was tracked along with 79% at the point of curvature and 91% at the center of curve. The statistics using that tracking method can be seen in Table 6-29. With the vehicles that were tracked, it shows that the mean speed was reduced by 2.0 mph at the point of curvature and 1.7 mph at the center of curve. This proved that the signs were also effective at reducing speeds entering and throughout the curve with the tracking method. There were also reduction in the 85th percentile speeds of 3 mph at the point of curvature and 2 mph at the center of curve. Reductions in percentage of vehicles going over the advisory speed were also seen in the tracking method at all speeding categories. With a higher upstream speed of 1.6 mph it can be expected that the effectiveness of the treatment may be greater.

Comparison of Standard and Tracking Method

This curve had two roads that could potentially impact the speed statistics using the different methods of analysis. The first road was located directly before the curve while the other road was another T-intersection between the point of curvature and center of curve. Analyzing only the percentage of vehicles tracked it is expected that a majority of the turning vehicles were turning onto the T-intersection missing the center of curve data collection point. In addition it appeared other vehicles were turning off of the road before the curve and only being counted at the point of curvature and center of curve. In both cases the vehicles were determined not to be affected by the treatment and not included in the tracking method.

The results of these turning movements are the tracking method having mean speeds 2 mph higher than the standard method at the point of curvature and slightly higher mean speeds at the center of curve. The differences in mean speeds between the two methods were compared with the t-test. The differences were statistically significant at the point of curvature and the center of curve. This shows that the turning movements did affect the standard method speed statistics. This does not change the effectiveness found with the treatment but with this information, this make the curve a great candidate for the tracking method. The tracking method showed a slightly larger reduction in mean speed at the point of curvature meaning an underestimate by the standard method. The center of curve was 0.1 mph lower in the tracking method only slightly overestimating.

Speed Reduction Method

The upstream speed using tracking was 1.6 mph higher in the after period which, with the true effect, showed even larger effect in the change in speed reduction. The speed reduction at the point of curvature was 3.6 mph higher after installation and 3.3 mph greater at the center of curve. The speed reduction between the point of curvature and center of curve was slightly lower meaning that vehicles were not as affected through the curve due to the treatment. The true effects can be seen below in Table 6-27.

Table 6-27 Highway 20 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	12.0	15.6	3.6
Speed Reduction Upstream to CC	16.2	19.5	3.3
Speed Reduction PC to CC	4.3	4.0	-0.3

The true effect for this location was considerably higher than the mean speed reductions in both methods. This was due to the higher speed approaching the curve and can show that the TAPCO signs were actually more effective as a safety surrogate measure than what the change in mean speed states. The true effects can show that the speed were reduced approaching the curve but were not decreased through the curve. This may be due to the desired speed being achieved while entering the curve and not needing to reduce their speed through the curve. This is again something that could not be obtained using only the standard method.

Table 6-28 Highway 20 Curve Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.7	55.2	1.5
85th Percentile	61	61	0
Standard Deviation	9.1	6.1	
Count	1585	1408	-177
Point of Curvature			
Mean Speed	39.6	37.8	-1.8
85th Percentile	47	45	-2
Standard Deviation	7.6	7.1	
% Vehicles 5+ Over Advisory	77%	70%	-9%
% Vehicles 10+ Over Advisory	58%	47%	-19%
% Vehicles 15+ Over Advisory	27%	16%	-41%
% Vehicles 20+ Over Advisory	7%	3%	-57%
Count	1692	1556	-136
Center of Curvature			
Mean Speed	37.4	35.6	-1.8
85th Percentile	42	40	-2
Standard Deviation	4.8	4.6	
% Vehicles 5+ Over Advisory	77%	63%	-18%
% Vehicles 10+ Over Advisory	33%	18%	-46%
% Vehicles 15+ Over Advisory	6%	2%	-67%
% Vehicles 20+ Over Advisory	1%	0%	-100%
Count	1456	1350	-106

Table 6-29 Highway 20 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.1	55.7	1.6
85th Percentile	61	61	0
Standard Deviation	8.9	5.6	
Count	1318	1251	-67
Point of Curvature			
Mean Speed	42.1	40.1	-2.0
85th Percentile	48	45	-3
Standard Deviation	5.7	5.4	
% Vehicles 5+ Over Advisory	92%	86%	-7%
% Vehicles 10+ Over Advisory	70%	57%	-19%
% Vehicles 15+ Over Advisory	33%	20%	-39%
% Vehicles 20+ Over Advisory	9%	3%	-62%
Count	1318	1251	-67
Center of Curvature			
Mean Speed	37.8	36.1	-1.7
85th Percentile	42	40	-2
Standard Deviation	4.4	4.1	
% Vehicles 5+ Over Advisory	81%	67%	-17%
% Vehicles 10+ Over Advisory	34%	19%	-44%
% Vehicles 15+ Over Advisory	6%	2%	-67%
% Vehicles 20+ Over Advisory	1%	0%	-100%
Count	1318	1251	-67

6.2.2.3 Highway 67 Curve

Standard Method

Also in Wisconsin was Highway 67 which had an advisory speed of 25 mph. The mean speeds were reduced at both the point of curvature and center of curve by 1.6 mph and 1.8 mph respectively using the standard method. Table 6-31 also shows that the upstream speeds were reduced by 1.1 mph as well affecting the change in mean speed impacts. With vehicles approaching the curve at lower speeds it is unknown whether the speed reduction was due to the treatment or vehicles driving at a lower speed. Another result seen from the treatment was reducing the 85^{th} percentile speeds and percentage of vehicles going over the advisory speed. The effects were lower at the point of curvature by 1 mph but at the center of curve there was a 2 mph reduction in the 85^{th} percentile speed. The point of curvature also saw significant decreases in the percentage of vehicles going over the advisory speed especially in the higher speeding categories. With this analysis the treatment would be effective at reducing speeds of vehicles both entering and throughout the curve but the speed reduction would be in question with the lower upstream speeds.

Tracking Method

The curve at this location along Highway 67 had very high tracking rates with 96% of vehicles tracked at each data collection location. There were no access points within the collection points which allowed for the high and consistent success rate. Because of this the data mirrored the standard method with a 1.6 mph reduction in the mean speed at the point of curvature and a 1.8 mph reduction at the center of curve which can be seen in Table 6-32. All other statistics were also the same with the tracking method and the same conclusion could be made.

Comparison of Standard and Tracking Method

This location had no access points when entering the curve and because of this a high rate of vehicles were tracked. This resulted in all speed statistics being identical with both methods. Because of this the mean speeds in both methods are exactly the same as well as the mean speed reductions. Typically, with the other sites that had no access, the results would be the same and tracking would not be necessary for analysis.

Speed Reduction Method

The true effects were significantly lower at this location with only a 0.5 mph reduction at the point of curvature and a 0.7 mph change at the center of curve. The true effects can be seen in Table 6-30. Even with the lower upstream speeds vehicles were slightly reducing when approaching the curve. Larger speed reductions were expected because of the low advisory speed but most of the speed reduction occurs within the curve. The true effect through the curve, point of curvature to center of curve, was 0.2 mph showing vehicles reducing their speed more after the implementation. It appears from the true effects at this site that the lower speeds approaching the curve may have had an impact on the results which was not shown in the standard method.

Table 6-30 Highway 67 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	3.9	4.4	0.5
Speed Reduction Upstream to CC	10.3	11.0	0.7
Speed Reduction PC to CC	6.4	6.6	0.2

In this case though the lower upstream speed makes the true effect at the point of curvature statistically insignificant and raises the concern that the speed reduction seen at the point of curvature is only a result of vehicles approaching the curve slower. The true effect data demonstrates that there may be some speed reduction due to the treatment but most of the effects come from the lower upstream speed.

Table 6-31 Highway 67 Curve Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	50.0	48.9	-1.1
85th Percentile	59	59	0
Standard Deviation	11.8	12.4	
Count	1727	1998	271
Point of Curvature			
Mean Speed	46.1	44.5	-1.6
85th Percentile	52	51	-1
Standard Deviation	5.9	6	
% Vehicles 5+ Over Advisory	99%	99%	0%
% Vehicles 10+ Over Advisory	97%	94%	-3%
% Vehicles 15+ Over Advisory	87%	80%	-8%
% Vehicles 20+ Over Advisory	65%	51%	-22%
Count	1726	1992	266
Center of Curvature			
Mean Speed	39.7	37.9	-1.8
85th Percentile	45	43	-2
Standard Deviation	5.0	5.0	
% Vehicles 5+ Over Advisory	97%	95%	-2%
% Vehicles 10+ Over Advisory	86%	76%	-12%
% Vehicles 15+ Over Advisory	53%	38%	-28%
% Vehicles 20+ Over Advisory	15%	8%	-47%
Count	1713	1979	266

Table 6-32 Highway 67 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	50.0	48.9	-1.1
85th Percentile	59	59	0
Standard Deviation	11.7	12.4	
Count	1668	1931	263
Point of Curvature			
Mean Speed	46.1	44.5	-1.6
85th Percentile	52	51	-1
Standard Deviation	5.8	6	
% Vehicles 5+ Over Advisory	99%	99%	0%
% Vehicles 10+ Over Advisory	97%	94%	-3%
% Vehicles 15+ Over Advisory	88%	80%	-9%
% Vehicles 20+ Over Advisory	65%	52%	-20%
Count	1668	1931	263
Center of Curvature			
Mean Speed	39.7	37.9	-1.8
85th Percentile	45	43	-2
Standard Deviation	5.0	5.0	
% Vehicles 5+ Over Advisory	97%	95%	-2%
% Vehicles 10+ Over Advisory	87%	76%	-12%
% Vehicles 15+ Over Advisory	53%	38%	-28%
% Vehicles 20+ Over Advisory	15%	8%	-47%
Count	1668	1931	263

6.2.3 Washington Curves

6.2.3.1 SR 7 Curve

Standard Method

Along SR 7 in Washington, TAPCO signs were installed along a curve to slow drivers down to the advisory speed of 20 mph. Table 6-34 shows that the signs were very effective at reducing the speed of the drivers entering the curve with the standard method. The mean speed was reduced by 2.8 mph at the point of curvature and 1.4 mph at the center of curve. The 85th percentile was also reduced by 2 mph and 1 mph at the point of curvature and center of curve respectively. The percentages of vehicles over the advisory speed were reduced significantly at all ranges at the point of curvature but only in the lower speeding categories at the center of curve. One downfall from this data is that the upstream data was 2 mph lower in the after data which causes concern for an outside influence on the speed reduction. From the data the treatments appear effective at reducing the data at the point of curvature but with the decreased speeds upstream the effects at the center of curve are inconclusive.

Tracking Method

95% of the vehicles were tracked at the upstream and center of curve while 94% were tracked at the point of curvature. The tracked vehicles statistics show in Table 6-35 that the mean speed was reduced by 2.8 mph at the point of curvature and 1.2 mph at the center of curve. Similar effects were seen with the percentage of vehicles over the advisory speed as the standard method. The 85th percentile speeds were reduced 3 mph at the point of curvature and 1 mph at the center of curve. From the data it appears the vehicles are reducing their speed approaching the curve from the treatment but the same cannot be said for at the center of the curve. The data is inconclusive since the upstream speeds were lower than the before data collection.

Comparison of Standard and Tracking Method

This location had a road directly before the curve which accounts for the lower percentage of vehicles tracked at the point of curvature since vehicles were likely turning onto SR 7. This road did not affect the mean speeds as they were identical in both methods. The t-test showed that the differences were not statistically significant between the methods. The changes in mean speeds were also similar with only the center of curve having a 0.2 mph lower change. The issue with the standard method in this case is the inability to conclusively say whether the speed reductions were related to the treatment or vehicles were just approaching the curve at a slower speed.

Speed Reduction Method

The true effect at this location was again lower than the change in mean speeds due to the lower upstream speed. From upstream to the point of curvature the speed reduction increase by 1.0 mph but to the center of curve the speed reduction actually decreased by 0.6 mph and from the point of curvature to center of curve it decreased by 1.6 mph. These statistics are shown in Table 6-33. The lower true effects are due to the reduction in the mean speed upstream of 1.8 mph in the 1 month after data. With this tracking data the same conclusion cannot be concluded to as the standard method. The true effects show that the vehicles are decreasing their speed more when approaching the curve but are not decreasing their speed throughout the curve. With a lower speed entering the curve the vehicles may be at their desired or comfortable speed already which results in lower speed reductions within the curve. The vehicles must slow down more through the curve in the before condition rather than being at the correct speed upon entering the curve with the treatment. The treatment would be deemed successful at reducing the speed of vehicles entering the curve.

Table 6-33 SR 7 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	9.3	10.3	1.0
Speed Reduction Upstream to CC	15.4	14.8	-0.6
Speed Reduction PC to CC	6.1	4.5	-1.6

The true effects are where the most impact was seen at this location. With the true effects it could be determined that vehicles were reducing their speed when entering the curve and because of this did not have to reduce their speed anymore through the curve. Without the tracking method it would be determined that the treatment was effective at reducing the speeds of vehicles at both the point of curvature and center of curve which is true may not be due to effects of the treatment through the curve. The desired entering speed is achieved before the curve and the driver does not have the reduce speed through the curve.

Table 6-34 SR 7 Curve Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	42.5	40.5	-2.0
85th Percentile	48	48	0
Standard Deviation	6.9	8	
Count	759	761	2
Point of Curvature			
Mean Speed	33.1	30.3	-2.8
85th Percentile	37	35	-2
Standard Deviation	4.7	4.6	
% Vehicles 5+ Over Advisory	96%	89%	-7%
% Vehicles 10+ Over Advisory	80%	56%	-30%
% Vehicles 15+ Over Advisory	37%	18%	-51%
% Vehicles 20+ Over Advisory	9%	2%	-78%
Count	763	766	3
Center of Curvature			
Mean Speed	27.2	25.8	-1.4
85th Percentile	30	29	-1
Standard Deviation	2.9	3.3	
% Vehicles 5+ Over Advisory	84%	68%	-19%
% Vehicles 10+ Over Advisory	20%	11%	-45%
% Vehicles 15+ Over Advisory	1%	1%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	750	770	20

Table 6-35 SR 7 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	42.6	40.8	-1.8
85th Percentile	48	48	0
Standard Deviation	6.8	7.7	
Count	716	733	17
Point of Curvature			
Mean Speed	33.3	30.5	-2.8
85th Percentile	38	35	-3
Standard Deviation	4.6	4.4	
% Vehicles 5+ Over Advisory	97%	91%	-7%
% Vehicles 10+ Over Advisory	82%	58%	-29%
% Vehicles 15+ Over Advisory	38%	19%	-51%
% Vehicles 20+ Over Advisory	9%	2%	-79%
Count	716	733	17
Center of Curvature			
Mean Speed	27.2	26.0	-1.2
85th Percentile	30	29	-1
Standard Deviation	2.8	3.1	
% Vehicles 5+ Over Advisory	85%	71%	-17%
% Vehicles 10+ Over Advisory	21%	12%	-43%
% Vehicles 15+ Over Advisory	1%	1%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	716	733	17

6.2.3.2 SR 9 Curve

Standard Method

Also in Washington was SR 9 which had a curve advisory speed of 40 mph. The treatment at this location was effective at reducing the mean speed with reductions of 1.4 mph and 0.9 mph at the point of curvature and center of curve respectively. Not as many vehicles at this location were going over the advisory speed so only slight changes were seen in the lower advisory speed categories. A 1 mph reduction of the 85th percentile speed was seen at both data collection points as well. An increase in the upstream mean speed was also seen in Table 6-37 of 1.8 mph. With the statistics from the standard method the treatment would be deemed successful at reducing the speeds of vehicles entering the curve and going through the curve.

Tracking Method

96% of the vehicles at this location were successfully tracked at all three data collection points with the tracking method. The mean speed changes in Table 6-38 showed that there was a 1.4 mph reduction at the point of curvature and 1.0 mph reduction at the center of curve. 1 mph reductions were again seen with the 85th percentile speeds as well as slight reductions in the percentage of vehicles going over the advisory speed. The upstream speeds were also higher with the tracking method by 1.7 mph in the after period.

Comparison of Standard and Tracking Method

This location did not have any access points when entering the curve which resulted in the mean speeds being similar in both methods and a high tracking rate. The t-test showed no statistically significant differences between the methods for either data collection period.

The mean speed change was 0.1 mph higher at the center of curve with the tracking method but the same at the point of curvature. All other statistics were the same using both methods which are the reason the same conclusion can be made with both methods.

Speed Reduction Method

Because of the higher upstream speed of 1.7 mph the true effect was also higher with a 3.1 mph increase in speed reduction to the point of curvature and a 2.7 increase to the center of curve. True effects are shown in Table 6-36. There was a decrease in the speed reduction from the point of curvature to the center of curve showing that the treatment did not have an effect of vehicles through the curve but this could be due to the lower speed entering the curve. The treatment was effective at slowing vehicles down as they approached the curve.

Table 6-36 SR 9 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	6.0	9.1	3.1
Speed Reduction Upstream to CC	6.8	9.5	2.7
Speed Reduction PC to CC	0.8	0.4	-0.4

The true effects are much higher than the mean speed changes which accounts for the higher upstream speeds and show that the treatment does not have an effect on the driver going through the curve due to the lower speed entering the curve.

Table 6-37 SR 9 Curve Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	46.9	48.7	1.8
85th Percentile	51	53	2
Standard Deviation	5.3	5.1	
Count	2730	3087	357
Point of Curvature			
Mean Speed	41.0	39.6	-1.4
85th Percentile	46	45	-1
Standard Deviation	5	5	
% Vehicles 5+ Over Advisory	23%	16%	-30%
% Vehicles 10+ Over Advisory	4%	2%	-50%
% Vehicles 15+ Over Advisory	1%	0%	-100%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	2702	3062	360
Center of Curvature			
Mean Speed	40.2	39.3	-0.9
85th Percentile	45	44	-1
Standard Deviation	5.0	5.0	
% Vehicles 5+ Over Advisory	19%	14%	-26%
% Vehicles 10+ Over Advisory	3%	2%	-33%
% Vehicles 15+ Over Advisory	0%	0%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	2688	3081	393

Table 6-38 SR 9 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	47.1	48.8	1.7
85th Percentile	51	53	2
Standard Deviation	5.0	5.0	
Count	2598	2949	351
Point of Curvature			
Mean Speed	41.1	39.7	-1.4
85th Percentile	46	45	-1
Standard Deviation	4.9	4.9	
% Vehicles 5+ Over Advisory	23%	16%	-32%
% Vehicles 10+ Over Advisory	4%	2%	-41%
% Vehicles 15+ Over Advisory	1%	0%	-18%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	2598	2949	351
Center of Curvature			
Mean Speed	40.3	39.3	-1.0
85th Percentile	45	44	-1
Standard Deviation	5.0	4.9	
% Vehicles 5+ Over Advisory	19%	14%	-25%
% Vehicles 10+ Over Advisory	3%	2%	-31%
% Vehicles 15+ Over Advisory	0%	0%	0%
% Vehicles 20+ Over Advisory	0%	0%	0%
Count	2598	2949	351

6.2.3.3 SR 203 Curve

Standard Method

The final curve in Washington was along SR 203 and the curve selected had an advisory speed of 40 mph. Table 6-40 shows that the treatment only effectively slowed the vehicles that were entering the curve using the standard method. The change in speed reduction was 2 mph at the point of curvature but at the center of curve was only 0.1 mph lower. Similar results were seen with the 85th percentile as there was a 2 mph reduction at the point of curvature but no change at the center of curve. The percentages of vehicles going over the advisory speed were more affected in the higher speeds rather than the lower speeds. There was no change in the percentage of vehicles going over the advisory speed at the center of curve. There was also only a small amount of change in the upstream data speeds with only an increase of 0.4 mph. The treatment effectively reduced vehicles speeds only when entering the curve.

Tracking Method

The tracking method was able to align 94% of the vehicles at all of the data collection points through the curve. The tracking method statistics shown in Table 6-41 replicate the statistics from the standard method. There was a 2.0 mph reduction in mean speed at the point of curvature along with a 2 mph reduction in 85th percentile speed. The percentages of vehicles going over the speed limit were the same as the standard method at both data collection locations. The tracking data for the center of curve was also similar to the standard method with only a 0.2 mph reduction in mean speed and no change in the 85th percentile speeds. The upstream speed was also low with the tracked method with only a 0.3 increase in the mean speed. The same conclusion can be made as the standard method.

Comparison of Standard and Tracking Method

No access points were located when entering the curve so it was expected that not many changes were to occur in the mean speeds using the different methods. The differences in the mean speeds were only statistically significant between the two methods for the before data at the center of curve. With approximately 6% of the data removed from those points, some of the data may have affected the mean speeds calculated. No other changes were noticed between the two methods. In this situation the effectiveness was determined to be the same with vehicles slowing down when entering the curve but not having any effect through the curve. The standard method was able to show in this case what could be seen in the tracking method.

Speed Reduction Method

The true effect showed slightly higher effects due to the upstream increase in speed. The upstream to point of curvature saw a 2.3 mph increase in speed reduction while to the center of curve there was only a 0.5 mph increase. The point of curvature to center of curve saw a decrease in speed reduction of 1.8 mph. Upon looking at this data closer it can be seen that after implementation the vehicles slow down to enter the curve then maintain their speed throughout. The true effect though in the tracking method is capable of giving a more thorough look at how drivers are behaving in their speed choices.

Table 6-39 SR 203 Curve Speed Reduction Data

			True Effect
Speed Reduction Upstream to PC	0.5	2.8	2.3
Speed Reduction Upstream to CC	2.3	2.8	0.5
Speed Reduction PC to CC	1.8	0.0	-1.8

Table 6-40 SR 203 Standard Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	53.8	54.2	0.4
85th Percentile	59	59	0
Standard Deviation	6.1	6.1	
Count	4950	5231	281
Point of Curvature			
Mean Speed	53.5	51.5	-2.0
85th Percentile	58	56	-2
Standard Deviation	5	4.5	
% Vehicles 5+ Over Advisory	96%	94%	-2%
% Vehicles 10+ Over Advisory	83%	71%	-15%
% Vehicles 15+ Over Advisory	43%	23%	-47%
% Vehicles 20+ Over Advisory	8%	3%	-63%
Count	4901	5190	289
Center of Curvature			
Mean Speed	51.6	51.5	-0.1
85th Percentile	56	56	0
Standard Deviation	4.6	4.6	
% Vehicles 5+ Over Advisory	94%	94%	0%
% Vehicles 10+ Over Advisory	72%	70%	-3%
% Vehicles 15+ Over Advisory	25%	24%	-4%
% Vehicles 20+ Over Advisory	3%	3%	0%
Count	4921	5148	227

Table 6-41 SR 203 Curve Tracking Data

	Before	After	Change/ Percent Change
Upstream			
Mean Speed	54.1	54.4	0.3
85th Percentile	59	59	0
Standard Deviation	5.5	5.7	
Count	4637	4902	265
Point of Curvature			
Mean Speed	53.6	51.6	-2.0
85th Percentile	58	56	-2
Standard Deviation	4.7	4.5	
% Vehicles 5+ Over Advisory	96%	94%	-2%
% Vehicles 10+ Over Advisory	84%	71%	-15%
% Vehicles 15+ Over Advisory	44%	24%	-46%
% Vehicles 20+ Over Advisory	8%	3%	-63%
Count	4637	4902	265
Center of Curvature			
Mean Speed	51.8	51.6	-0.2
85th Percentile	56	56	0
Standard Deviation	4.5	4.6	
% Vehicles 5+ Over Advisory	94%	94%	0%
% Vehicles 10+ Over Advisory	73%	70%	-3%
% Vehicles 15+ Over Advisory	26%	24%	-6%
% Vehicles 20+ Over Advisory	3%	3%	0%
Count	4637	4902	265

Chapter 7 Results and Discussion

7.1 Key Findings

After reviewing all of the sites, it can be seen that there is an effect on the speed statistics from tracking vehicles. Different roadway features can be used to determine whether impacts will be found with the tracking method as well as the indicators from the standard method. The two most influential variables in determining whether tracking has any effects are the access points and the upstream speed. Note that in the conclusion the mean speed changes are positive to show a decrease in mean speed for comparison with the true effects.

The traffic calming locations were part of the initial study to determine the effects of the tracking method in a speed transition zone. In that study four out of the ten sites were found to have access points when entering town that produced a significant flow of traffic. It is no surprise that these four sites had the highest values in the change in mean speed of all the sites as well; this can be seen in Table 7-1. The speed changes were not only increases, which were expected. Two sites had 0.5 mph increases in mean speed change and two sites had decreases in mean speed change at 0.4 mph and 0.5 mph. This shows that the standard method may over- or under-estimate the true mean speed change. What all of these sites had in common was a large generator of traffic flow turning on to or off of the roadway. In the other sites locations that had smaller flows, such as driveways, saw small changes in the statistics and the sites with no access points saw almost no changes. When there was little change the same can be seen that the changes were neither consistently over- nor under-estimates. The sites with only residential driveways saw only small changes in mean speed because the flows coming from these access points are much smaller than the roads or other traffic generators such as businesses. Figure 7-1 also shows the variability of all three surrogate safety measure statistics.

The true effect for the traffic calming sites showed that seven out of the ten sites underestimated the actual speed reductions due to the treatment. The true effect accounts for vehicle speeds as they are entering town and gives a more accurate representation of how vehicles react when traversing the treatment without the assumption that the vehicles are entering town at the exact speed as the before condition. This assumption is almost never exactly true and with no other outside influences between the data collection points, gives a more representative value showing the speed reduction due to the treatment. Because most of the upstream speeds were similar in the before and 1 month after data collection, there is not much change between the true effect and mean speed change in the standard method.

What can be gathered from this information is that if an access point is located near the treatment than the tracking method should be implemented to produce more accurate data in the changes in mean speed. Tracking is able to reduce the data to only affected vehicles and give a more precise value of the mean speeds and mean speed changes. The sites that had access points also saw increases and decreases in the mean speed for both data collection periods. With this information it shows that the standard method is inaccurate with the presence of outside roadway features. Every site selected is not always an ideal location, so by implementing the tracking method for sites that may have other influences a more precise statistic is found. The upstream speeds were not a large indicator with the traffic calming sites since speeds were fairly consistent but there are some differences in the true effect from the mean speed change which can be seen in Table 7-1 and Figure 7-1as well. The true effect in this case with only two data collection points is a good supplement to the mean speed change to account for variance between the collection periods.

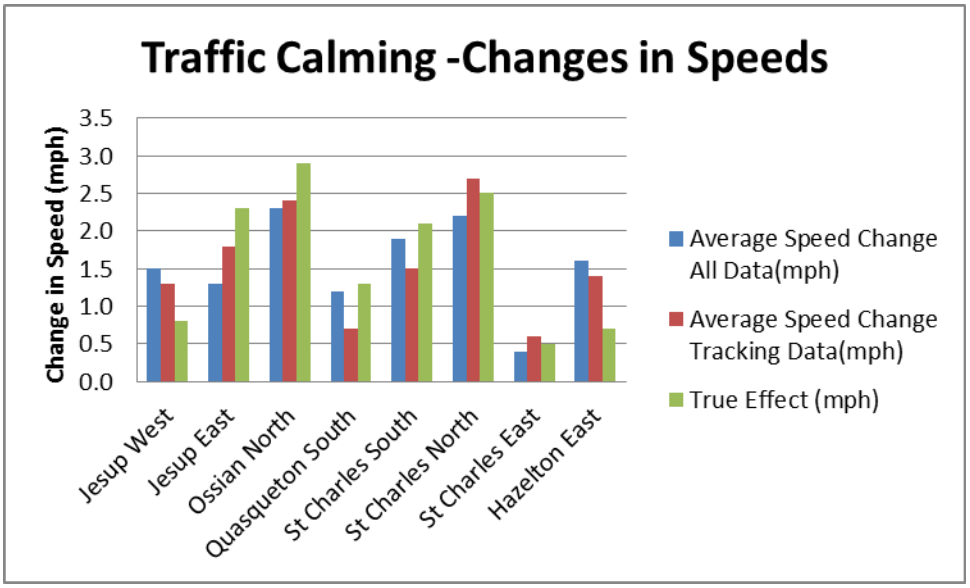

Figure 7-1 Traffic Calming Changes in Speeds

Table 7-1 Traffic Calming Speed Changes

			Standard Method		Tracking Method	
	Access Points	True Effect (mph)	Mean Speed Change(mph)	Percent Change from TE	Mean Speed Change (mph)	Percent Change from Standard
Jesup West	Nothing	0.8	1.5	-47%	1.3	-13%
Jesup East	Business Driveways	2.3	1.3	77%	1.8	38%
Ossian North	Driveways	2.9	2.3	26%	2.4	4%
Quasqueton South	Road Before	1.3	1.2	8%	0.7	-42%
Quasqueton North	Nothing	-0.7	-1.4	50%	-1.1	-21%
St Charles South	Road Before	2.1	1.9	11%	1.5	-21%
St Charles North	Road Before	2.5	2.2	14%	2.7	23%
St Charles East	Driveway	0.5	0.4	25%	0.6	50%
St Charles West	Bank Entrance/Road	-1.9	-0.4	-375%	-0.4	0%
Hazelton East	Nothing	0.7	1.6	-56%	1.4	-13%

Mean Speed Changes were converted to positive for reduction in speed to compare with True Effect

In addition to the traffic calming data, curve data was used to see if tracking had an effect in locations without a transition zone and multiple data collection points. The curves had three data location points for vehicles to be tracked through which allowed for a more detailed comparison between the two methods. With the curves that were selected, four had no access points through the curve while two curves had roads located within the curve and the final curve had a road before the curve. Like the traffic calming sites, the curves with no access points saw similar results in both methods and the curve with a road located directly before also saw similar results because a high volume of traffic may not be generated from this road. The two curves with roads located within them are where changes were seen. Depending on whether vehicles were turning on or off, the point of curvature and center of curve mean speeds were changed using the tracking method. At one site, the center of curve mean speeds were 2 mph lower while at the other site the point of curvature mean speeds were 3 mph higher. These changes in mean speeds did slightly alter the change in mean speed at both locations by up to 0.3 mph where the other locations saw little to no change.

After all of the analysis the greatest indicator of what was actually occurring at the site was the true effects. Using more than two data collection points allows for the interaction between the data points to be seen using the true effect. The tracking method allows for the true effect to be calculated and show how vehicles were slowing down approaching the curve, to the center of the curve and throughout the curve. With only the mean speed changes in the standard method, it can only be inferred that the vehicles are slowing down both as they enter the curve and throughout the curve. True effect values were found from upstream to the point of curvature, upstream to the center of curve, and from the point of curvature to the center of curve. Comparing these values from before to after shows where vehicles are actually changing their speeds. Most sites showed that there were considerable speed reductions from upstream to the point of curvature. This showed that the treatment was slowing the vehicles down while they were approaching the curve. The true effect between the point of curvature and center of curve could then be used to see how vehicles were slowing down through the curve. This gives a comparison actually within the curve rather than the mean speeds before and after. Some sites showed that the speed reductions were the same in the before and after condition meaning that the treatment was slowing the vehicles down only while approaching the curve. Other sites had lower speed reduction in the 1 month after data collection or no speed reduction. What this meant was that vehicles had slowed down enough approaching the curve that they did not have to slow down as much through the curve and the treatment was effective at making the driver choose a better speed to traverse the curve at. The true effect allows for a more detailed account of what is occurring through the curve and the actual effects the treatment is having on the vehicle at different stages through the curve.

Other than the benefits above with the true effect, the true effect again accounted for the upstream speed. These sites had much larger differences in the upstream speed than the traffic calming sites. As can be seen in Table 7-2 and Table 7-3, the true effects showed that the mean speed changes both under- and over-estimated the effects of the treatment again. These values give a more accurate comparison of the effects of the treatment than the mean speed changes because with a higher or lower upstream speed the treatment may have a greater or lesser impact on the speeds. In the case of one curve at the center of curve, the true effect actually showed that the vehicles were not reducing their speed as much as the before condition where the mean speed changes showed that there were lower speeds. In another case the upstream speeds were lower and the true effect showed that there was almost no speed reduction where the standard method showed decreases in the mean speed.

Overall with the curves, the upstream speeds and access points are a major indicator for when tracking should be used for changes in the results. It would be recommended for sites with more than two data collection points to use a tracking method because of the benefits associated with the true effects. These statistics provided much insight into the behaviors of drivers and allowed for the speeds approaching the curve to be accounted for. This variable is an outstanding addition to the tracking method that cannot be precisely found using the standard method.

Table 7-2 Curve Speed Changes-Point of Curvature

		All Data		Tracking Data	
	True Effect (mph) (UP-PC)	Mean Speed Change (mph)	Percent Change from TE	Mean Speed Change (mph)	Percent Change from TE
Wisconsin Hwy 67	0.5	1.6	-69%	1.6	-69%
Wisconsin Hwy 20	3.6	1.8	100%	2.0	80%
Wisconsin Hwy 213	1.7	0.7	143%	0.7	143%
Missouri Hwy 221	2.0	1.5	33%	1.5	33%
Washington SR7	1.0	2.8	-64%	2.8	-64%
Washington SR9	3.1	1.4	121%	1.4	121%
Washington SR203	2.3	2.0	15%	2.0	15%

Mean Speed Changes were converted to positive for reduction in speed to compare with True Effect

Table 7-3 Curve Speed Changes-Center of Curve

		All Data		Tracking Data	
	True Effect (mph) (UP-CC)	Mean Speed Change (mph)	Percent Change from TE	Mean Speed Change (mph)	Percent Change from TE
Wisconsin Hwy 67	0.7	1.8	-61%	1.8	-61%
Wisconsin Hwy 20	3.3	1.8	83%	1.7	94%
Wisconsin Hwy 213	1.7	1.0	70%	0.7	143%
Missouri Hwy 221	0.2	-0.3	167%	-0.3	167%
Washington SR7	-0.6	1.4	-143%	1.2	-150%
Washington SR9	2.7	0.9	200%	1.0	170%
Washington SR203	0.5	0.1	400%	0.2	150%

Mean Speed Changes were converted to positive for reduction in speed to compare with True Effect

What can be gathered from both of these analyses is that there are two factors leading to the tracking method being selected over the standard method: the access points and the upstream speed. With an access point located before the treatment it is shown that the vehicles turning on or off the route impact the mean speeds and the changes in mean speeds. Using the tracking method eliminated those vehicles from the analysis and generated more accurate statistics for comparison. The upstream speed is another indicator for the tracking method to be used because of the true effect statistic. The true effect takes the mean speed reductions between the data points and takes into account the upstream speed where the standard method does not. The tracking method is a better utilization of the data collected and incorporating many variables rather than a selected few.

The tracking method give more accurate speed statistics by removing vehicles that are not affected by the treatment but the true effect has been shown to be a great indicator for the effects of the treatment. Using this statistic in conjunction with the mean speed changes can show that the actual effect may be more or less because of outside conditions that were present in each situation. The true effect is not a statistics that can be used alone but is a great supplement to the mean speed change. In cases with more than two data collection points the true effect is a valuable statistic to show interactions between the data points as well as vehicle behavior due to the treatments which could be seen with the curve sites.

7.2 Study Limitations

The first limitation with this study is the number of sites that were analyzed as well as the variety of sites. With only a small sample, conclusive decisions were not plausible. An accurate statement could not be made about whether tracking over-or under-estimated in certain conditions because on a few locations had those conditions. This study focused on using data that was available from current research projects for application uses. With this preliminary studies results more sites should be selected for testing.

In addition to the sites the application of the tracking method was only used in speed reduction situation on two-lane highway. While it is believed that tracking could be transferred to other uses involving speeds or classification, further research must be conducted.

7.3 Future Research

This study has shown that tracking vehicles is a great way to reduce the data collected to only the affected vehicles and gives a more accurate representation of the effects due to the treatment. More research needs to be completed to determine if there are other locations where tracking can be beneficial as well as other situations. The next step in this research would be to collect the 1 year after data for all of the analyzed sites and compare those results to what was collected in this report. This would allow for more comparison between the sites and to determine if some of the assumptions made in the speed reductions are accurate.

Another step in the analysis process would be to eliminate vehicles down even further. The first way this would be accomplished is by removing the vehicles that are following too closely to the vehicle in front of them at the treatment. If a vehicle is following too close to the vehicle in front of them then their speed choice is determined by that vehicle rather than their own choice. Since the focus is only on the affected vehicles, vehicles following too closely would not be in the free flow condition and not be accurately representing the effects of the treatment. This would most likely increase the mean speeds or speed reduction because the vehicle would be deciding to travel at a higher speed. This can be accomplished by determining what time gap is acceptable and removing any vehicles that had a time gap less than that at the treatment data collection location.

Vehicles turning on and off of the roadway not only occur before the treatment but may be located after the treatment as well. An access point after the treatment data collection point was not accounted for in this study but could easily be done by adding another downstream data location point. This data collection point would have two benefits. The first is to remove vehicles that are turning directly after the treatment. Vehicles making this movement are more likely to be reducing their speed through the treatment and lowering the mean speed. The second benefit is that another true effect can be determined so that the speed after the treatment can be analyzed. This will show whether the treatment is sustaining at reducing the vehicles speeds or whether drivers are choosing to increase their speed again after the treatment.

The tracking method can be a reliable method of showing more accurate speed statistics. More research still needs to be completed to determine when the method should be used as well as other ways to improve the method to only affected vehicles. This research has shown two indicators of when to use the tracking method but other may still be present with further research.

Appendix A Sample Tracking

Removal of Data Point

Upstream				Treatment				Tracking		
Time	Class	Speed(MPH)	Gap(Sec)	Time	Class	Speed(MPH)	Gap(Sec)	Time Between	Gap Difference	Classification
2:44:11 PM	8	56	0:01:20	2:44:48 PM	8	37	0:01:20	0:00:37	0:00:00	Same
2:44:14 PM	3	56	0:00:03	2:44:51 PM	3	30	0:00:03	0:00:37	0:00:00	Same
2:44:19 PM	2	49	0:00:05	2:44:57 PM	2	34	0:00:06	0:00:38	0:00:01	Same
2:44:21 PM	5	50	0:00:02	2:44:59 PM	5	35	0:00:02	0:00:38	0:00:00	Same
2:47:37 PM	2	34	0:03:16	2:45:25 PM	1	19	0:00:26	Error	0:02:50	NO
2:48:32 PM	6	56	0:00:55	2:48:15 PM	2	49	0:02:50	Error	0:01:55	NO
				2:49:10 PM	6	37	0:00:55			

Remove Data Point

Data Point Removed: Accurate Tracking

Upstream				Treatment				Tracking		
Time	Class	Speed(MPH)	Gap(Sec)	Time	Class	Speed(MPH)	Gap(Sec)	Time Between	Gap Difference	Classification
2:44:11 PM	8	56	0:01:20	2:44:48 PM	8	37	0:01:20	0:00:37	0:00:00	Same
2:44:14 PM	3	56	0:00:03	2:44:51 PM	3	30	0:00:03	0:00:37	0:00:00	Same
2:44:19 PM	2	49	0:00:05	2:44:57 PM	2	34	0:00:06	0:00:38	0:00:01	Same
2:44:21 PM	5	50	0:00:02	2:44:59 PM	5	35	0:00:02	0:00:38	0:00:00	Same
2:47:37 PM	2	34	0:03:16	2:48:15 PM	2	49	0:03:16	0:00:38	0:00:00	Same
2:48:32 PM	6	56	0:00:55	2:49:10 PM	6	37	0:00:55	0:00:38	0:00:00	Same

Appendix B Normal Probability Plots

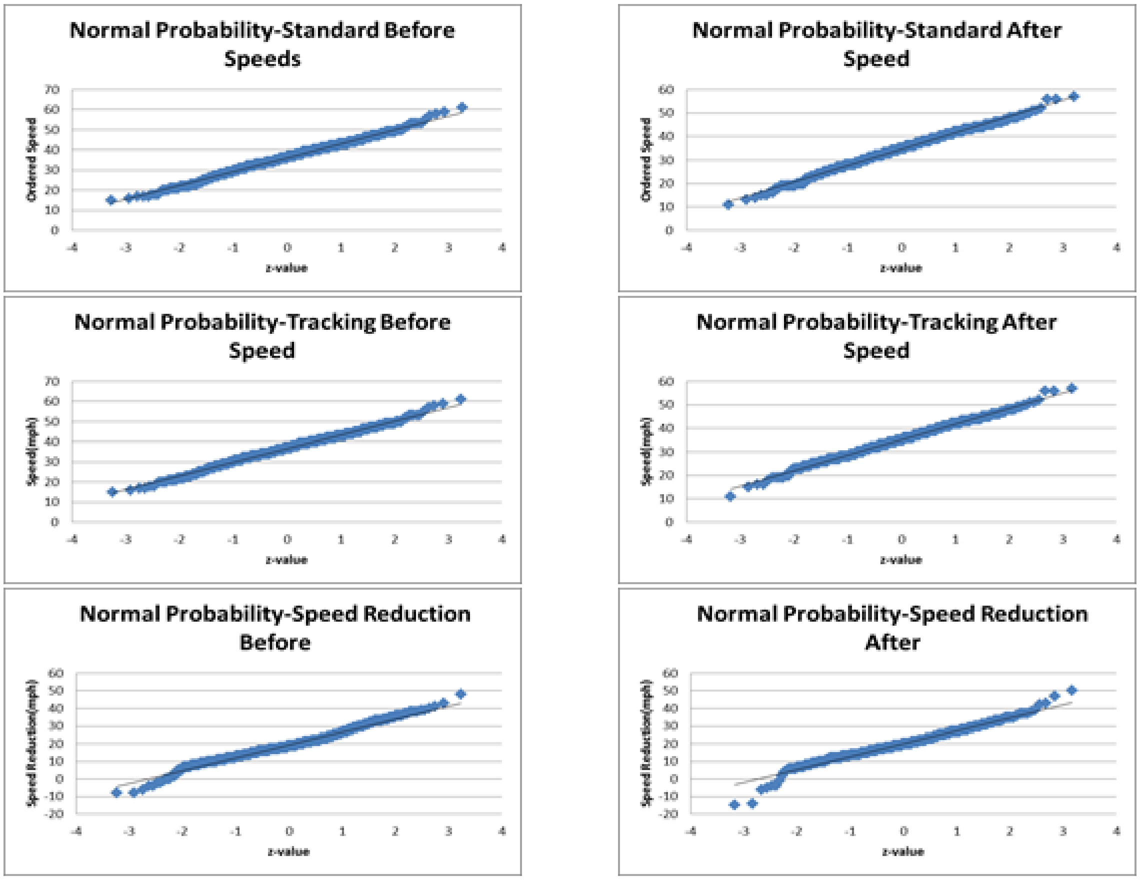

Figure B-1 Normal Probability Plots-Hazelton East

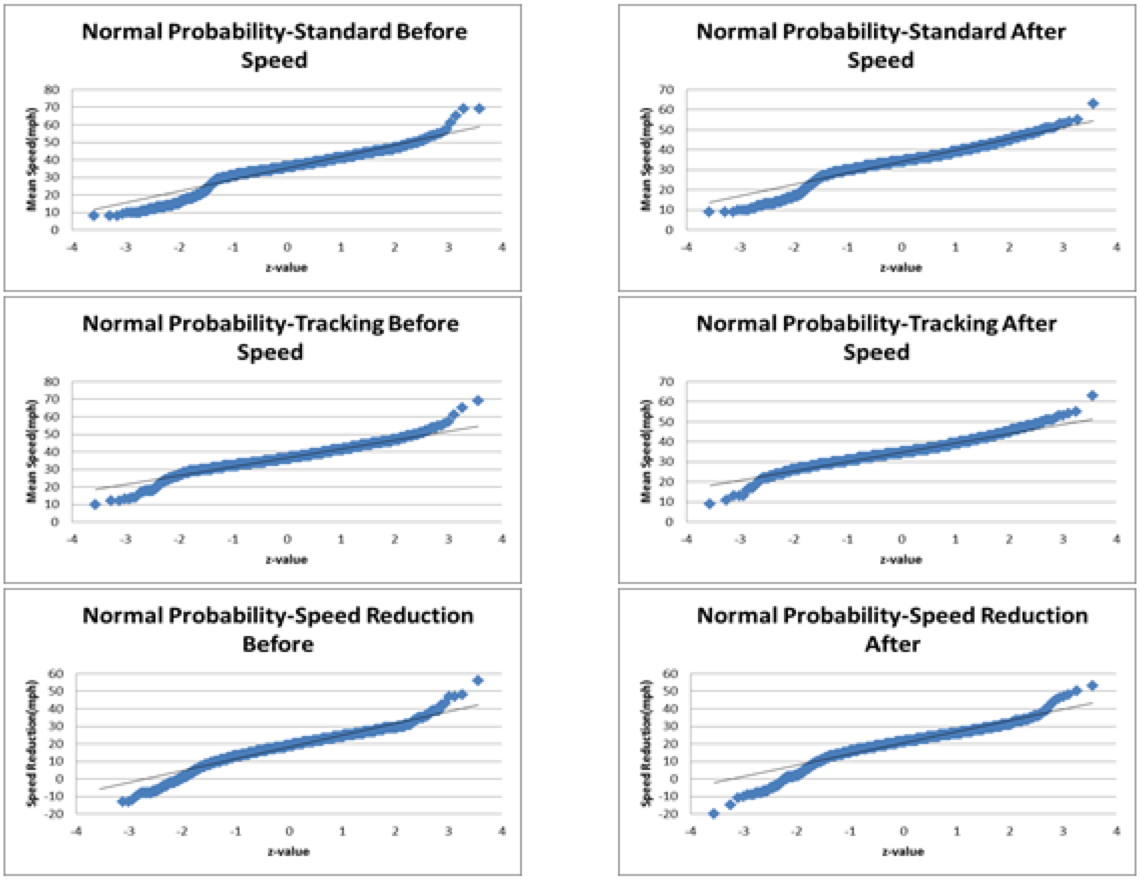

Figure B-2 Normal Probability Plots-Jesup East

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