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Evaluation of rural intersection treatments in Iowa

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by

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NOMENCLATURE

DOT	Department of Transportation
AADT	Annual Average Daily Traffic
EPDO	Equivalent Property Damage Only
SHRP2	Second Strategic Highway Safety Program
NDS	Naturalistic Driving Study
TAPCO	Traffic and Parking Control Products
INTRANS	Institute for Transportation
IDS	Intersection Decision System
MPH	Miles per hour

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ABSTRACT

In Iowa, intersection crashes account for 30 percent of severe crashes, with 40 percent of those crashes occurring in rural areas. Rural intersection crashes can be very severe due to the high approach speeds present. Moreover, crashes at rural intersections are frequently a result of failure to yield. As a result, agencies attempt to find countermeasures which encourage drivers to stop and yield appropriately. The objective of this research was to evaluate the effectiveness of stop sign mounted beacons on improving safety. Since it is difficult to conduct a crash analysis in the short-term, measures of effectiveness focused on unsafe driver behaviors and evaluated how treatments affected those behaviors.

CHAPTER 1. INTRODUCTION

1.1 Background

Motor vehicle crash fatality rates are higher in rural areas when compared to urban areas. According to the 2001 National Highway Traffic Safety Administration (NHTSA) traffic safety statistics, 61% of all traffic fatalities occurred in rural areas even though rural areas account for only 40% of the vehicle miles traveled and 21% of the population. Although motor vehicle injury fatality rates have declined over the last 20 years, rural rates continue to exceed urban rates [1].

Researchers have all concluded that there are several reasons for this phenomenon. The increase in motor vehicle injury fatality rates in rural areas is significant compared to urban areas due to the following:

- Rural crashes may be more severe when compared to urban crashes because of the difference in speed limit and road conditions. Rural areas such as Iowa have a speed limit of 70 mph on freeways when compared to a freeway in Des Moines of 55 mph. This difference in speed may result in less reaction time resulting in more crashes in rural areas.
- Drivers in rural areas may drive more miles than in urban areas as cities may be further apart. This increase in miles can allow the average driver to become more fatigued and increase their chances of being involved in a crash.
- Emergency response to crashes tend to be longer in rural areas and this may affect the outcome of injured person who was involved in a crash.

1.2 Scope of Problem

In Iowa, intersection crashes account for 30% of severe crashes, with 40 % of those crashes occurring in rural areas (Iowa DOT, 2013). More than 20 % of fatalities nationwide occur at intersections and more than 80 % of rural intersection fatalities are at unsignalized intersections. For this project the researcher evaluated the effectiveness of the use of flashing beacons at rural intersection to reduce crashes.

1.3 Objectives

One of the main contributing factors for rural intersection crashes is failure to yield. Agencies, such as the Department of Transportation, attempt to find different countermeasures to encourage drivers to stop and yield appropriately. Countermeasures that are usually used to reduce crashes are considered as treatments and the effectiveness of these treatments have yielded mixed results.

The objective of this research was to select rural intersection treatments in Iowa and evaluate their impact on improving safety. High crash intersections with similar roadway conditions were selected and then evaluated based on driver behavior. Dynamic (radar) activated stop signs with flashing beacons were installed and a before and after analysis was done to evaluate effectiveness. This would be lower cost device that agencies can invest in if the treatment is evaluated and shown to be effective in reducing crashes at rural intersections.

CHAPTER 2. LITERATURE REVIEW

2.1 Rural Intersection Crashes

Rural intersections pose a crash risk for drivers turning or crossing the intersection from the minor road. Errors made during gap detection, perception and acceptance are the main factors that influence crashes at this type of intersection [2]. Although rural intersection crashes are fewer in number than urban intersection crashes, they more often result in fatalities because of the high speeds involved on rural highways and expressways.

2.2 Lower cost treatments

To reduce the crash risk at intersections, cost effective treatments are evaluated to be used as countermeasures. Intersection Decision Systems (IDS) is a cost-effective treatment that can be used to assist drivers in responding to safe gaps at rural intersections. This study investigates young (20-40 years) and old (55-75 years) drivers' gap acceptance performance in stimulated day and night driving conditions in a stop sign condition and four intersection IDS [2]. Signs that provided detailed gap information (i.e., time-to-arrival values, warning levels of gap) as well as advisory information about unsafe conditions resulted in the best performance among old and young drivers in comparison to other signs. Overall, the findings of this study indicate that an IDS system is useful for encouraging safer gap acceptance decisions at rural stop- controlled intersections.

During the last 25 years, several studies have reported the use of rumble strips and paint stripes to induce drivers to slow down or to exhibit otherwise appropriate behavior at intersections and other critical locations [3]. After conducting a before and after analysis, Zaidel et al proved that paint stripes had a minor influence on driver behavior, whereas rumble strips lowered speeds by an average of 40 percent. This study showed that drivers speed were lowered but there was no evidence to show that drivers yielded appropriately at rural intersections. More information on a driver's behavior should be included in this study to effectively evaluate rumble strips.

Another low-cost treatment was the use of a stop sign at rural intersections. This study determined whether stop-sign control was useful in regulating traffic at low volume rural intersections [4]. This was demonstrated by the percentage of observed motorist violation and compliance rate. The dependent variables of violation and compliance rate, conflicts, and accidents were compared in a factorial experimental design with the independent variables of major-roadway volume, minor-roadway sight distance, rural or urban traffic condition, and type of intersection geometry [4]. The results concluded that the violation rate decreases with increasing major-roadway volume. In addition, when sight is restricted the violation rate was significantly higher [4]. Overall, stop signs were effective and the addition of other countermeasures to stop signs can increase the effectiveness at rural intersections.

2.3 Flashing Beacons

Another set of treatments which have been applied at rural intersections were overhead or stop sign mounted beacons. Several Studies have evaluated these treatments. The effectiveness of the overhead flashers in reducing traffic accidents was earmarked as the primary objective of the analysis [5]. A before and after analysis was conducted and accident exposure during the two periods was compared based on exposure rates, severity indexes, and equivalent property damage only accidents and rates. The results revealed that the relationship between the installation of a flashing beacon and reduction in equivalent property damage only (EPDO) crash rate was found to be statistically significant at the 1 percent confidence level [5]. A major flaw in this research was that they utilized property damage crashes rather than more severe crash types which are typically the target of rural intersection treatments.

Another study evaluated the effectiveness of stop sign beacons by using factors such as vehicular speeds, stop-sign violations, service delay, gap acceptance, and accidents [6]. It was found that intersection control beacons generally reduced vehicular speeds in the major directions, particularly at intersections with inadequate sight distance. In addition, the intersection control beacons had, in general, little or no effect on accepted or rejected gaps and on service delays. This proves that beacons were effective in reducing speeds and do not create additional problems at rural intersection.

The Second Strategic Highway Safety Program (SHRP 2) conducted a large-scale naturalistic driving study (NDS) using instrumented vehicles which provides a significant amount of on-road driving data for a range of drivers. This study utilized the NDS data to observe driver stopping behavior at rural intersections using video and vehicle kinematics data [7]. In this study, a model of driver braking behavior was developed using a small dataset of vehicle activity traces for several rural stop-controlled intersections. The model was developed using the point at which a driver reacts to the upcoming intersection by initiating braking as its dependent variable with driver's age, type and direction of turning movement, as well as countermeasure presence as independent variables. After analysis was done using a linear mixed effect model, countermeasures which are intended to alert drivers to the presence of the intersection such as overhead flashing beacons and on pavement signing increase the distance at which the driver begins braking [7]. Although this research was preliminary, it suggests that these countermeasures were effective in drawing a driver's attention to the intersections causing them to react earlier.

CHAPTER 3. SITE SELECTION

3.1 Site Selection Methodology

This study focused on minor street stop-controlled intersections with 2-lane minor streets and 2-lane and 4-lane divided highways. A set of intersection was identified using a database of Iowa intersections which was previously developed by the Iowa DOT in conjunction with the Institute for Transportation (INTRANS). Potential intersections were identified and crash data from 2010 to 2014 (5 years) was used to extract the total number of crashes for each intersection. Subsequently, potential intersections were sorted by number of crashes and any intersection with 9 or more crashes was flagged. This resulted in a list of 60 potential locations. Characteristics present in the intersection database were extracted for each intersection including:

- Signing by approach
- Presence and type of medians
- Number of approaches
- Presence and type of lighting
- Roadway surface type
- Channelization.

The researchers then used aerial imagery and Google road view to extract other characteristics which were not available in the intersection database such as:

- Advance stop line rumble strips
- Overhead beacons
- Stop sign beacons
- Advance signing

- Type of pavement markings
- Roadway surface type
- Presence of lighting

The initial list of potential intersections was then further reviewed and prioritized based on:

- Presence of other countermeasures (ideally the fewer existing countermeasures the better)
- Number of crashes or crash rate
- Intersection configuration (unusual configurations may not be used if they are significantly atypical)
- Volume (it may difficult to collect data at locations with low traffic volumes)
- Location (all other things being equal, closer locations facilitate data collection)

Locations with stop sign beacons or overhead flashing beacons were removed from further consideration since they already have a prominent countermeasure which may confound further analysis. In addition, locations that have a traffic signal or were in an urban area were removed. Locations that had adverse geometry (i.e. significant skew) or a railroad crossing near the intersection were also removed.

Site visits were made prior to final selection of sites to collect any relevant variables not available through other means. This also ensured that the proposed treatment could be installed. The total number of sites remaining after considerations mentioned above was six sites as shown in Table 3-1. Project funds used for the installation of stop sign beacons were received from the Iowa Department of Transportation.

Table 3-1 Interactions Receiving Stop Sign Beacon

Configuration	County	Coordinates	Installation Date
2-lane/2-lane	Buena Vista	42.662, -95.152	9/24/2017
2-lane/2-lane	Benton	41.963, -92.085	10/21/2017
2-lane/2-lane	Johnson	41.831, -91.498	10/21/2017
2-lane/2-lane	Clay	43.1262, -95.1125	10/6/2017

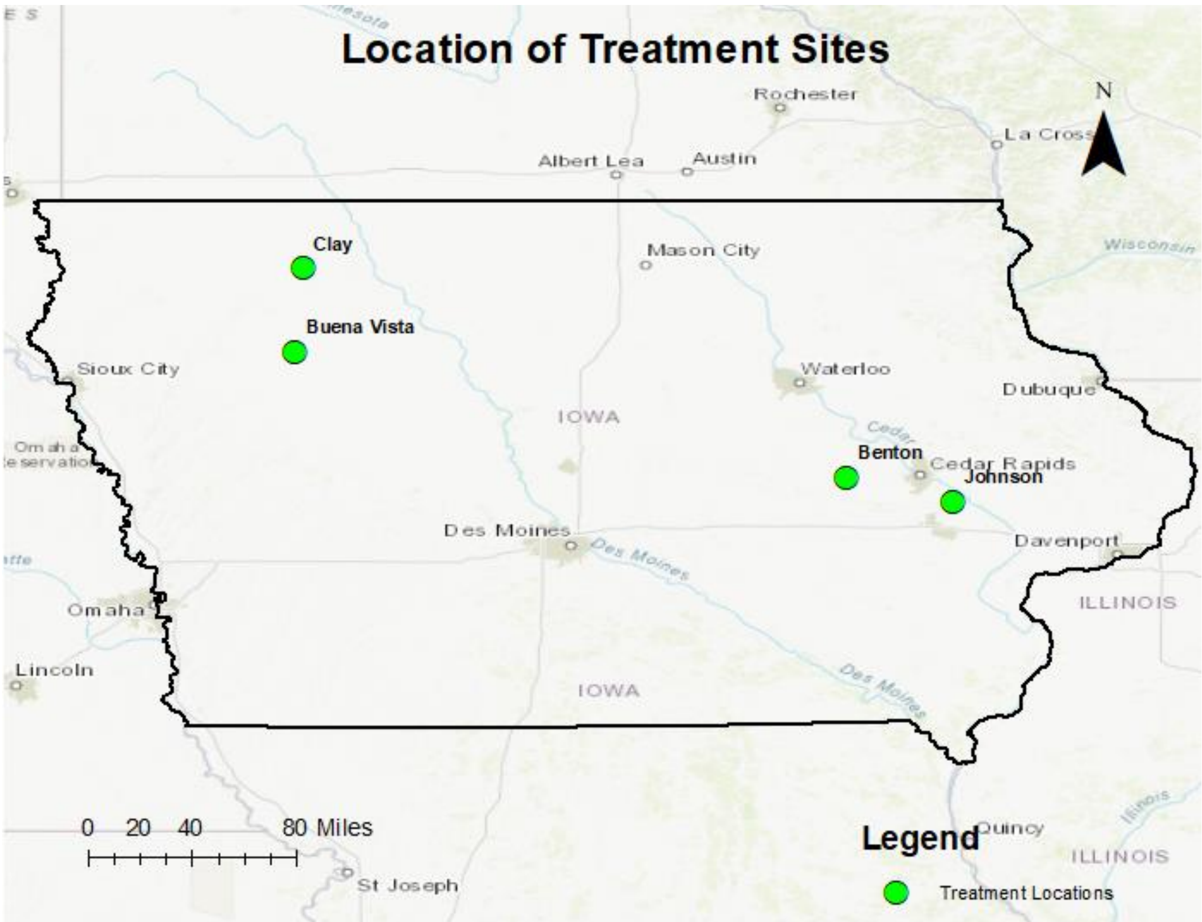

Figure 3-1 Illustrates Treatment location dispersed across Iowa

The Location of each intersection is shown on a map in Figure 3-1 and the characteristics of each intersection is shown in Table 3-2. These characteristic will help to interpret the results of the treatment.

Table 3-2: Intersection Characteristics

County	Speed Limit		Volume (AADT)		Lane Configuration		Vehicle type	
	Major road	Minor road	Major road	Minor road	Major road	Minor Road	Passenger	Trucks
Benton	55	55	6100	1760	2 Lane	2 Lane	80.08%	19.92%
Johnson	55	55	5200	560	2 Lane	2 Lane	92.02%	7.96%
Clay	55	55	4190	2520	2 Lane	2 Lane	92.74%	7.28%
Buena Vista East	55	55	2400	1620	2 Lane	2 Lane	78.36%	21.64%
Buena Vista West	55	55	3270	2400	2 Lane	2 Lane	78.36%	21.64%

3.2 Location of Rural Intersections

3.2.1 Buena Vista County

This treatment location was the east and west approach of 590th street and 130th avenue in Buena Vista County. The installation date was on September 24th, 2017. The coordinates for this location is 42.662, -95.152 and this is shown in figure 3-2 below.

Figure 3-2: Intersection location in Buena Vista County

Figure 3-3: Beacon illuminated at the west approach of 590th street and 130th avenue in Buena Vista County

3.2.2 Benton County

Only the south approach of Lincoln Hwy and 21st Avenue in Benton County was treated. The installation date is on October 21st, 2017 and the coordinates for this treatment location is 41.963, -92.085. Figure 3-4 illustrates the location of this treatment.

Figure 3-4: Intersection location in Benton County

Figure 3-5: Beacon illuminated at the south approach of Intersection Lincoln Hwy and 21st Avenue in Benton County.

3.2.3 Johnson County

Another treatment site was in Johnson County at the south approach of Hwy 1 and 140th Street. The installation date was on October 21st, 2017. The coordinates for 41.831, -91.498 is shown below in figure 3-6.

Figure 3-6: Intersection location in Johnson County

Figure 3-7: Beacon illuminated at the south approach of Hwy 1 and 140th Street.

3.2.4 Clay County

This treatment location is the east approach of 360th street and 240th Avenue in Clay County. The Installation date was on October 06th 2017. The Coordinates of this treatment is 43.1262, -95.1125 and shown below in figure 3-8.

Figure 3-8: Intersection location in Clay County

Figure 3-9: Beacon installed at the east approach of 360th street and 240th Avenue in Clay County

3.3 Speed Activated Stop Sign Beacons

The stop signs mounted beacons used for this project were purchased from TAPCO. This specific flashing beacon (figure 3.10) was selected because the configuration included a radar, so that the system would only activate when an approaching vehicle's speed was over a pre-determined threshold.

Figure 3-10: Flashing beacon installed at one of the treatment sites

This configuration was selected to contrast actuated versus continuous beacon operation at rural intersections. The objective was to target vehicles which were not likely to stop rather than targeting all vehicles, similar to a dynamic speed feedback sign. Since installation was a rather involved process, the team worked in conjunction with the Iowa DOT district technicians. The team coordinated with the district sign crew to meet team at the site location. Some locations were more challenging than others due to the condition of existing sign control at each intersection.

Typically, the sign crew would remove the existing telephone pole and replace it with a longer pole to accommodate the beacon, sensor box, operational box and solar panel. All items were installed on the same post position facing the lane of approaching traffic.

After installation the beacon was configured to flash when vehicles were approaching the intersection at 40 mph or greater. The radar can detect speed approximately 400-500 feet before stop sign. When a vehicles speed was greater than 40 mph as it approaches the intersection, the flashing beacon would activate to signal the driver that there is a stop sign ahead. When activated, the beacon flashes at a standard flashing rate of 9 seconds allowing the driver enough time to register and respond to the intersection ahead.

Figure 3-11: Flashing beacons at rural intersection source: Stein and Neuman 2007

CHAPTER 4. DATA COLLECTION AND REDUCTION

The effectiveness of the flashing beacons was evaluated by comparing several driver behaviors before and after installation. Ideally, a crash analysis would be conducted but this requires several years of data after installation which is beyond the scope of this project due to time frame. As a result, only driver behavior could be evaluated in the short term. Since the stop sign beacon only activates for vehicles who are traveling over a speed threshold, the countermeasure was expected to have a noticeable impact on speed, stopping point, and other characteristics.

4.1 Data Collection

Data were collected using video cameras mounted on trailers. These trailers have been used on other projects at the Institute for Transportation (INTRANS) and are reliable in collecting data. A trailer array was set up at each approach where beacons were installed and shown in Figure 4-1. This ensures coverage of some portion of the upstream approach as well as the intersection as illustrated in Figure 4-2.

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Figure 4-1: Video Data Collection Array

Video data were collected for 7 days at each site between 1 to 3 months before installation. The trailers upload the data regularly and can be assessed by the team from a website. This ensures the data were regularly stored on devices other than the field-based trailers. Data were also collected approximately 1 to 3 months after installation.

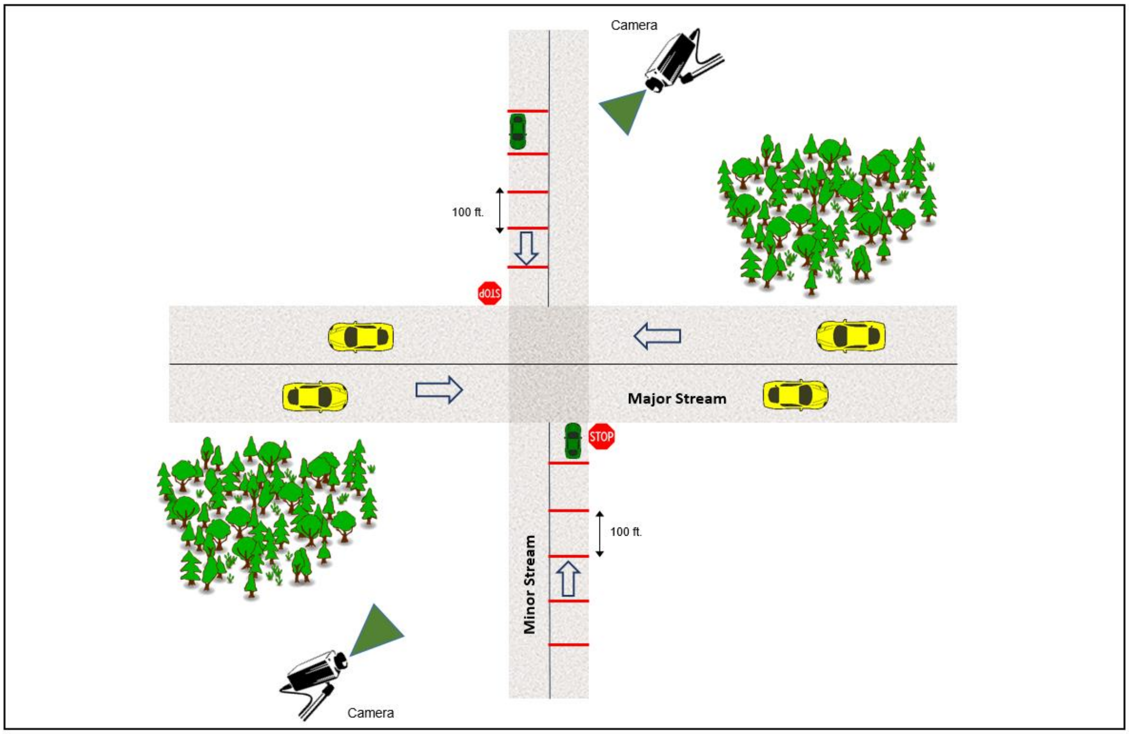

Figure 4-2 Illustrates the Video Data Collection Setup

4.2 Data Reduction

After data were collected for each intersection, a sampling of minor approach events, which consists of one driver negotiating the intersection from the minor approach where the treatment will be installed, were manually reduced. Table 4-1 shows the variables that were reduced for each event. Data were not coded during the nighttime or inclement weather due to visibility.

Table 4-1: Variables Extracted from Video

Data Reduced	Summary
First Time Vehicle appears in video	The time a car appears in the video frame
Brake activation Time	The time brake is applied before arriving at the intersection
Brake Activation Distance	Lines were placed on the road at 100 meter increments.
Number in Queue	Indicates if there is a queue formed at the intersection as a vehicle slows down and if so how much cars.
Following	Shows if the vehicle being coded is following another vehicle.
Number of time Braking	How much times does a driver brake in the 500 meter area leading up to the intersection
Vehicle stopped at opposing minor road	Indicates if a vehicle is stopped at an opposing minor road.
Vehicle Visible	How many vehicles are seen moving perpendicular to the intersection as a car approaches the stop sign
Turning Movement	Indicates the turning movement of the car approaching the intersection.
Type of Stop	Choices are a complete stop, slow rolling, fast rolling and Nonstop.
Stop Location	Before the stop bar, after the stop bar or right at the stop bar are the options coded.
Conflict	A description of any conflict that is observed while coding the vehicles.
Beacon status and time	Is the beacon activated based on the approaching speed and also the time this beacon is illuminated

After completing two intersections (Benton County North and Clay county north), the team realized that the process was more resource intensive than expected. As a result, it was decided to code a sample of events rather than coding all events. The sampling plan consisted of coding every fourth vehicle. This represented a random sample of available vehicles.

The process of coding is described below for each variable. Variables were manually reduced by data reductionist. They were all trained, and their work reviewed periodically to ensure coding was consistent from one coder to another.

4.2.1 Type of Vehicle

The type of vehicle was recorded using the following designations:

- Motorcycles
- Passenger cars.
- Minivan/ SUV

- Pickups: single unit vehicles with an open back with two axles and four tires
- Buses
- Farm vehicles: any vehicles that cannot be classified into any other category and are used on a farm
- Single unit trucks: vehicles on a single frame, including trucks, camping and recreational vehicles, motor homes, etc., with two axles and dual rear wheels
- Multi-Unit trucks: vehicles with five or fewer axles consisting of two or more units.

4.2.2 First Appearance

A time stamp was recorded for the first time a vehicle appears in the video (see Figure 4-3). The time stamp was recorded in hour and minute and was noted as soon as the front of a vehicle was visible in the video. This was reduced so that the vehicle could be easily found later if needed.

Figure 4-3 : First appearance of vehicle in video

4.2.3 Brake Activation Time

The time when a driver first applied the brake to decelerate a vehicle was noted as "brake activation time". This was determined by activation of brake lights for the vehicle. When the coders did not note any braking, "brake activation time" was coded as N/A.

Figure 4-4: An Example of Brake activation

4.2.4 Brake Activation Distance

The approximate distance from the intersection approach stop bar where a vehicle began braking was noted as "brake activation distance." This was noted by estimating the vehicle location based on the 100-foot markings and assuming the vehicle stopped at the stop bar. As a result, the brake activation distance indicates the distance at which the vehicle start to brake in order to stop at the intersection. If a vehicle was approximately midway between to 2nd and 3rd set of markings, the distance would be reported as 250 feet. Since the distance was estimated, it can be assumed that the distance was accurate to approximately 50 feet. If the vehicle did not apply brakes within the video frame, braking distance was reported as N/A. However, for this study majority of drivers applied their brake. Brake activation point, and brake activation distance were only noted when a vehicle visibly applied the brakes. Vehicles may have begun slowing down prior to that point but this could not be determined and as a result could not be accounted for. In addition, if a car entered the video frame braking, the brake activation time was recorded as 500 ft. Since it was difficult to measure distances in the videos, the team painted white lines at 100 ft increments upstream of the intersection before video recording began as shown in Figure 4-5.

Figure 4-5: White lines marked in the field to show every 100 ft.

The lines were then located in the video frame and re-marked (see Figure 4-6) so that they were clearly visible to data reductions. Every intersection was slightly different, so this had to be done for each approach.

Figure 4-6: Marks placed in video frame to ensure distance are visible to data reductionists

4.2.5 Number in Queue

The 'Number in Queue' indicated the position of the subject vehicle in queue as they approached and stopped at the intersection. Number in queue was the number of vehicles ahead of the subject vehicle. If no vehicles were ahead of the subject vehicle, number in queue was noted as "0". Figure 4-7 below illustrate an example of this variable.

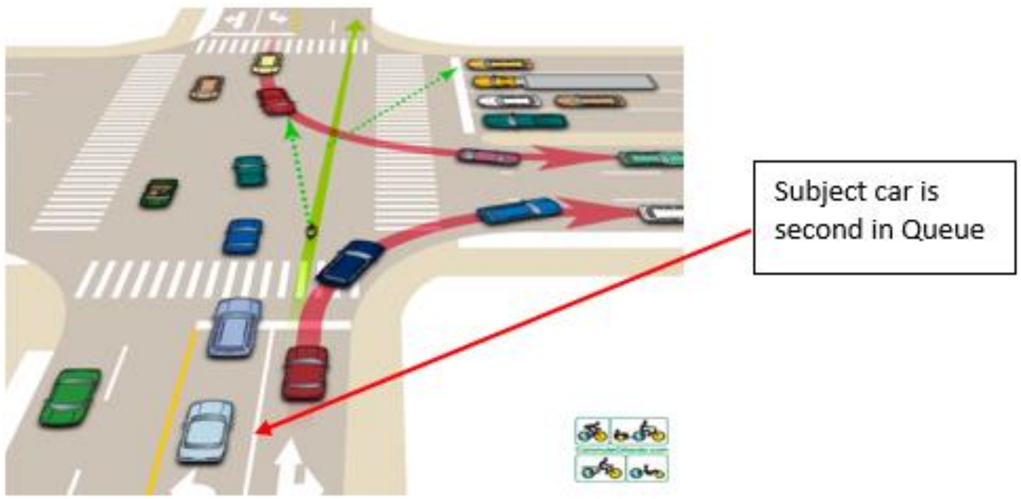

Figure 4-7: Number in queue (Image source: Keri Cafferey, Cycling Savvy)

4.2.6 Following

Whether the subject vehicle was following another vehicle was also recorded since braking for the following car may be influenced by the lead car. Following was a subjective measure. Data reductionists coded the subject vehicle as "following" if they were approximately 2 feet (or seconds) behind another vehicle.

4.2.7 Beacon Status

The status of the flashing beacon was noted for vehicles only in the after period since the beacons were not present in the before period. Beacon status was noted as "active" or "not active." When activated, it was assumed the subject (or surrounding vehicles) were traveling over 40 mph at the trigger point 500 feet upstream. If the beacon was active at any point while the subject vehicle was present within the video frame, status was marked as “active.” If beacon was activated at some point after the vehicle entered the frame, status was marked as also active. If the beacon terminated while the vehicle was within the video frame but before the vehicle reached the stop bar position, the status was noted as N/A.

Figure 4-8: Beacon shown as active as the subject car approaches the intersection in Dallas County

4.2.8 Number of Times Braking

The “number of times braking” variable indicates how many times a driver applied the brake before they come to a complete stop at the intersection. Also, if a driver did not come to a complete stop at the stop bar, the number of times braking was still recorded. In some cases, drivers brake 2 or 3 times before they reach the stop bar. Although it was not clear whether this is a positive behavior, it may indicate drivers are paying attention well before they reach the stop bar as compared to a driver who brakes immediately before.

4.2.9 Stopped at Opposing Minor Road

This variable indicates whether a vehicle was present at the stop bar of the opposing minor road approach. There was a sense that when an opposing vehicle was present, drivers may be more likely to come to a full stop since they are more likely to perceive the potential for a conflict. This variable was a dummy variable with “0” indicating no vehicles at the on-coming approach and “1” indicating a vehicle was present. The subject vehicle was coded as soon as the vehicle becomes visible in the video frame, so that the influence of the car at the opposing minor can be noted on the braking of the subject car.

Figure 4-9:Image showing a car stopped at an opposing minor road (Source: Stein and Neuman 2007)

4.2.10 Turning Movement

Turning movement was the direction of intended travel for the subject vehicle (i.e. left, though, right).

4.2.11 Number of Vehicle Visible

This variable indicated the number of vehicles on the major road which would have been visible to the subject vehicle. It was expected that the subject driver decision to brake and stop would be affected by the presence of on-coming vehicles on the major approach. The number of vehicles on the major approach were counted from the time the subject vehicle was 500 feet upstream of the intersection stop bar until they reached the stop bar.

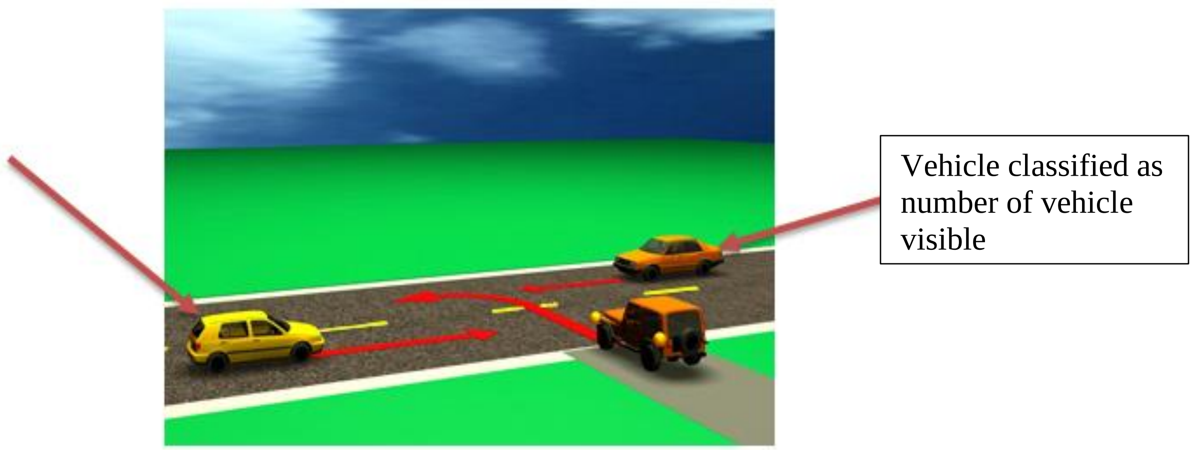

Figure 4-10: Image illustrates vehicles moving perpendicular to a car stopped at an intersection (Source: Driversed.com)

4.2.12 Type of Stop

The type of stop was how well a vehicle complied with the stop control. Type of stop was coded using the following criteria.

- Complete stop: vehicle comes to a complete stop at the stop bar (velocity = 0 for at least and identifiable fraction of a second)
- Slow rolling: Clear braking as vehicle slows down but at no point does the vehicle make a complete stop.
- Fast Rolling: Vehicle was moving at a fast pace as it approaches the stop sign, but brake light was visible to indicate that the brake was applied but at no point does the vehicle make a complete stop. In addition, no brake light visible would result in a non-stop.
- Non-Stop: This was when a vehicle does not stop at the stop sign. In this case, there was no noticeable effort to slow and was determined in most cases by not seeing any brake light.

4.2.13 Stop Location

This variable indicates where the vehicle stopped at the intersection based on the location of the front tip of the vehicle. All intersections had a clear visible painted stop bar and the following designations were used:

- Before: subject vehicle stopped well before the stop bar, Subject vehicle should be at least a foot from stop bar for it to be classified as "before".
- At: subject vehicle stopped exactly at the stop bar but did not cross the stop bar line.
- After: subject vehicle stopped after crossing the stop bar.

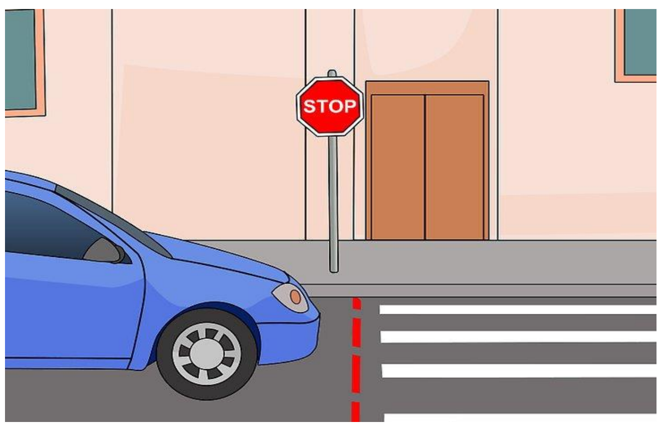

Figure 4-11: Vehicle stopped at the stop bar (Source: Wikihow)

4.2.14 Conflict

A conflict was defined as a near-crashes or evasive maneuvers at the intersection involving at least one minor street vehicle. Conflicts included actions such as significant slowing, brake application, or lane changes of major stream vehicles due to the movement of minor stream vehicles. A near-crash was as an event where vehicles nearly collided or made significant evasive maneuvers to avoid a collision. No crashes were observed.

Unlike other metrics where a subset of vehicles was sampled, all video data were reviewed to identify conflicts. As a result, all evasive maneuvers that occurred during the daytime data collection period were recorded. Figure 4-12 shows examples of evasive maneuvers.

Figure 4-12 Example of conflict (Image source: Hallmark, et al 2017)

4.2.15 Weather

No data was recorded at night or in conditions of snow or rain to ensure that weather was not a factor which may affects driver behavior.

CHAPTER 5. ANALYSIS

5.1 Statistical Methodology

The researcher evaluated the final data and the sample size for all counties analyzed in this paper is shown in Table 5-1.

Table 5-1: Total Sample Size for each County

Location	Before One Month Treatments	After One Month Treatment
Benton North	881	1056
Buena Vista East	200	201
Buena Vista West	200	200
Clay North	2076	1215
Johnson West	200	200

To analyze driver behavior, the brake activation distance, vehicle type and number of times braking will be compared in the before data and the after data. The following tables illustrate the data summaries of the variables mentioned above for the various counties as well as a key for the corresponding vehicles mentioned. A summary of the data for each intersection is provided in Table 5-2.

Table 5-2: Legend for Vehicle type

Vehicle Type	Corresponding Number
Motorcycle	1
Passenger Car	2
Minivan/SUV	3
Pickup	4
Buses	5
Single-Unit	6
Multi-Unit	7
Farm Vehicles	8
Add "T' for trailer	

Table 5-3: Benton County North Data Summary

Variables	W/o Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	100	500	500	457.15	70.348
Number of times braking	1	4	1	1.11	0.423
Variables	With Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	100	550	500	459.38	75.95
Number of times braking	1	4	1	1.38	0.59

Table 5-4: Buena Vista East Data Summary

Variables	W/o Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	100	500	500	402.50	118.612
Number of times braking	1	5	1	1.27	0.614
Variables	With Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	150	500	500	439.30	81.79
Number of times braking	1	5	1	1.42	0.67

Table 5-5: Buena Vista West Data Summary

Variables	W/o Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	100	500	500	451.25	85.064
Number of times braking	1	3	1	1.31	0.533
Variables	With Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	300	500	500	478.47	46.61
Number of times braking	1	4	1	1.37	0.64

Table 5-6: Clay County North Data Summary

Variables	W/o Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	100	550	500	472.7119	82.89857
Number of times braking	1	7	1	1.368015	0.701236
Variables	With Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	150	500	500	494.2798	30.39852
Number of times braking	1	3	1	1.158848	0.395803

Table 5-7: Johnson County West Data Summary

Variables	W/o Treatment				
	Min	Max	Mode	Mean	Std Dev
Brake activation distance (1st braking event)	100	550	500	472.7119	82.89857
Number of times braking	1	7	1	1.368015	0.701236
Variables	**With Treatment**				
	Min	**Max**	**Mode**	**Mean**	**Std Dev**
Brake activation distance (1st braking event)	150	500	500	494.2798	30.39852
Number of times braking	1	3	1	1.158848	0.395803

Minivans/SUV accounted for majority of the vehicles that were included in this study, while Farm vehicles and Motor cycles were the least (See table 5-8).

Table 5-8: Vehicle type at each treatment location

Vehicle type	Benton County		Buena Vista East		Buena Vista West		Clay County		Johnson County	
	Before	After	Before	After	Before	After	Before	After	Before	After
Motorcycle	0%	1%	4%	0%	3%	0%	2%	10%	4%	1%
Passenger Cars	37%	26%	39%	24%	27%	30%	31%	16%	29%	26%
Minivan/SUV	28%	27%	29%	43%	35%	46%	33%	18%	36%	36%
Pickups	23%	21%	19%	31%	20%	23%	25%	18%	12%	28%
Buses	2%	10%	1%	0%	8%	0%	0%	12%	7%	1%
Single-unit Trucks	10%	14%	4%	2%	6%	3%	6%	14%	7%	4%
Multi-unit Trucks	0%	1%	2%	1%	2%	0%	3%	12%	6%	5%
Farm Vehicle	0%	0%	3%	0%	0%	0%	0%	0%	0%	1%

5.2 Logistic Regression Model

A Logistic Regression Model was used to evaluate the relationship between the type of vehicle and the stopping behavior at intersection. This seemed like the appropriate model to conduct because the model develops a predictive analysis which can be used to describe the data and explain the relationship between one dependent binary variable and one more nominal, ordinal, and interval or radio-level independent variables.

Logistic regression is a very useful statistical method for analyzing a dataset in which there are one or more independent variables that determine an outcome. The outcome is measured with a dichotomous variable (in which there are only two possible outcomes). The goal of logistic regression is to find the best fitting model to describe the relationship between the dichotomous characteristic of interest and a set of independent variables. Logistic regression generates the coefficients (and its standard errors and significance levels) of a formula to predict a logit transformation of the probability of presence of the characteristic of interest:

$$logit(p) = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_kX_k$$

Where p is the probability of presence of the characteristic of interest. The logit transformation is defined as the logged odds:

$$odds = \frac{p}{1-p} = \frac{probability\ of\ presence\ of\ characteristic}{probability\ of\ absence\ of\ characteristic}$$

And

$$logit(p) = \ln\left(\frac{p}{1-p}\right)$$

Rather than choosing parameters that minimize the sum of squared errors (like in ordinary regression), estimation in logistic regression chooses parameters that maximize the likelihood of observing the sample values.

CHAPTER 6. RESULTS AND DISCUSSION

6.1 Data Summary

As shown in Figure 6-1 more drivers applied their brake at 300 ft. or more when the flashing beacon was installed. This can be accounted for by drivers becoming more cautious as they approach the intersection due to the presence of the flashing beacon. At 400 ft. more drivers applied their brake in the before study than the after study and this can serve as a comfortable distance for drivers to first apply their brake as they approach the intersection.

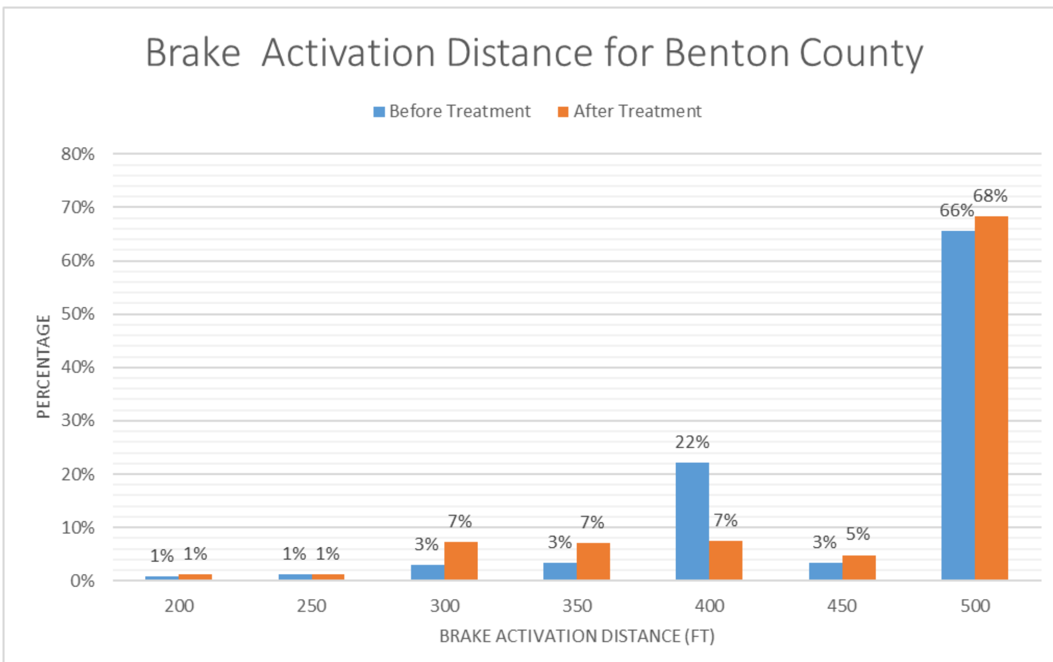

Figure 6-1: Brake Activation Distance for Benton County

Most drivers applied their brake once in the before treatment when compared to after the flashing beacon was installed. This can be explained by drivers applying their brake twice due to the presence of a flashing beacon (figure 6-2) in Benton County.

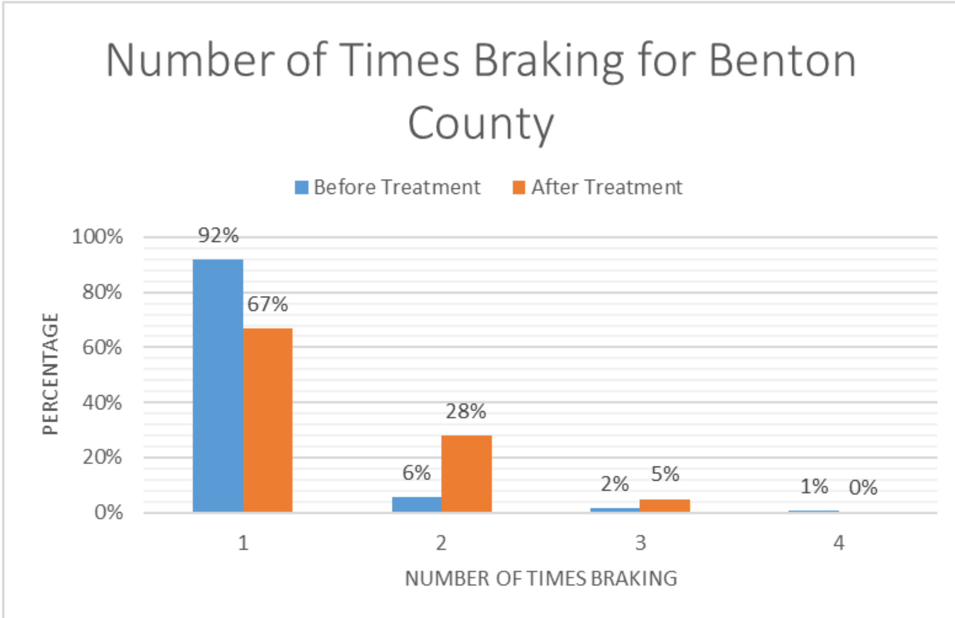

Figure 6-2: Number of times a vehicle applied the brake for Benton County

Overall there was a slight increase in the distance a vehicle stopped in Buena Vista East County when the flashing beacon was installed. In addition, Figure 6-3 shows that driver behavior changed from some drivers first applying the brake at 100 ft. in the before treatment to drivers starting to brake at 200 ft. in the after data.

The braking distance for each vehicle type before and after treatment is shown in figure 6-3 and Figure 6-4 to better interpret the results mentioned above.

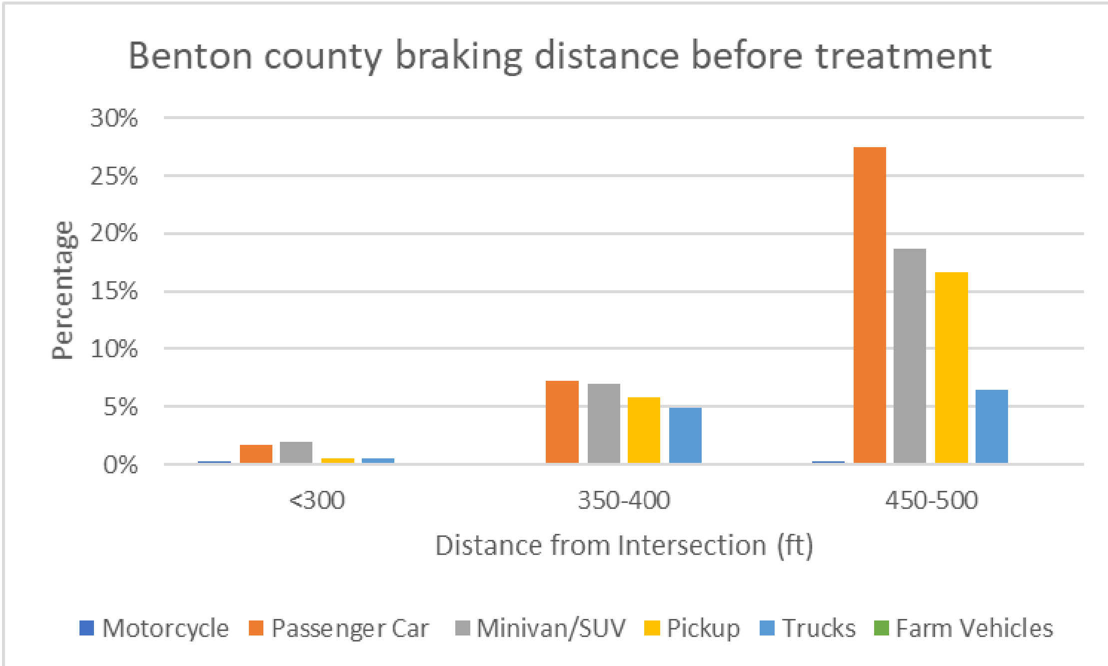

Figure 6-3: Braking distance for Benton county before treatment was installed

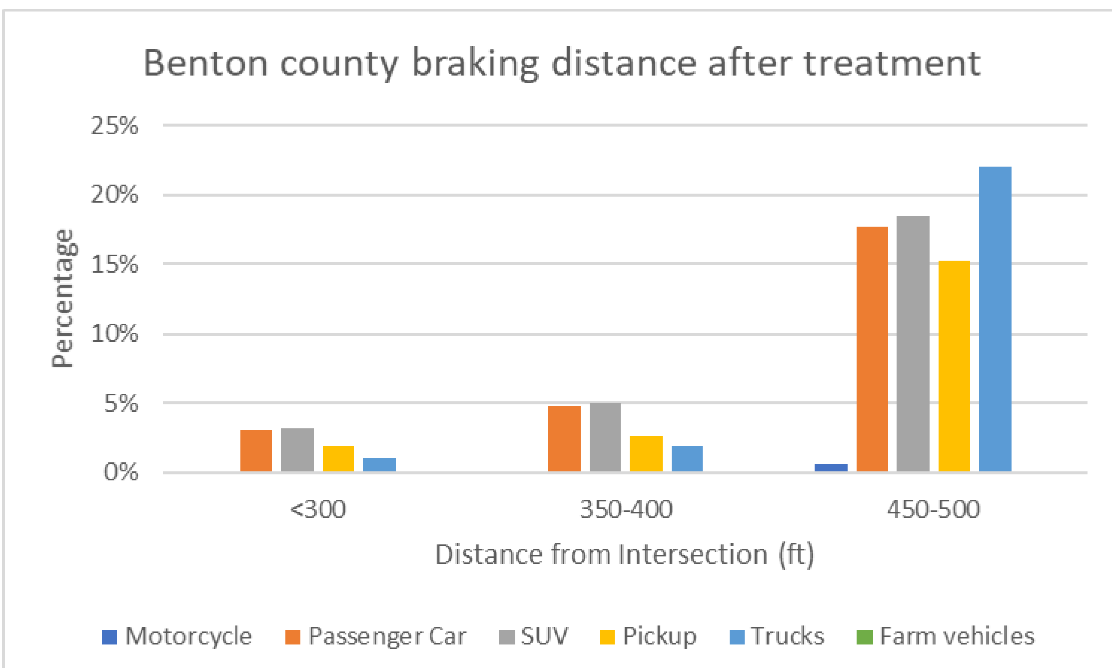

Figure 6-4: Braking distance for Benton county after treatment was installed

The number of times braking was also broken down by vehicle type as shown in figure 6-5 and figure 6-6.

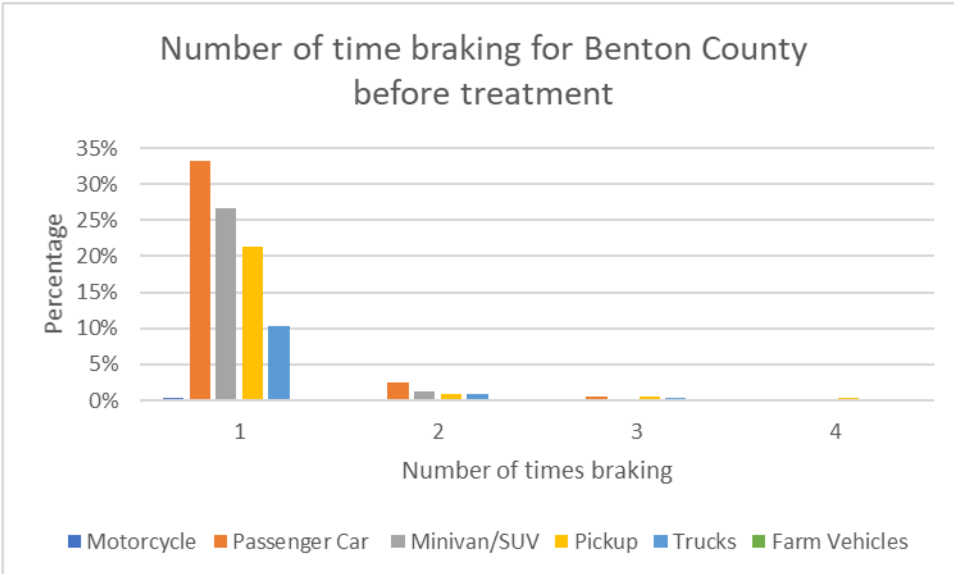

Figure 6-5: Number of times braking for each vehicle type in Benton county before treatment was applied

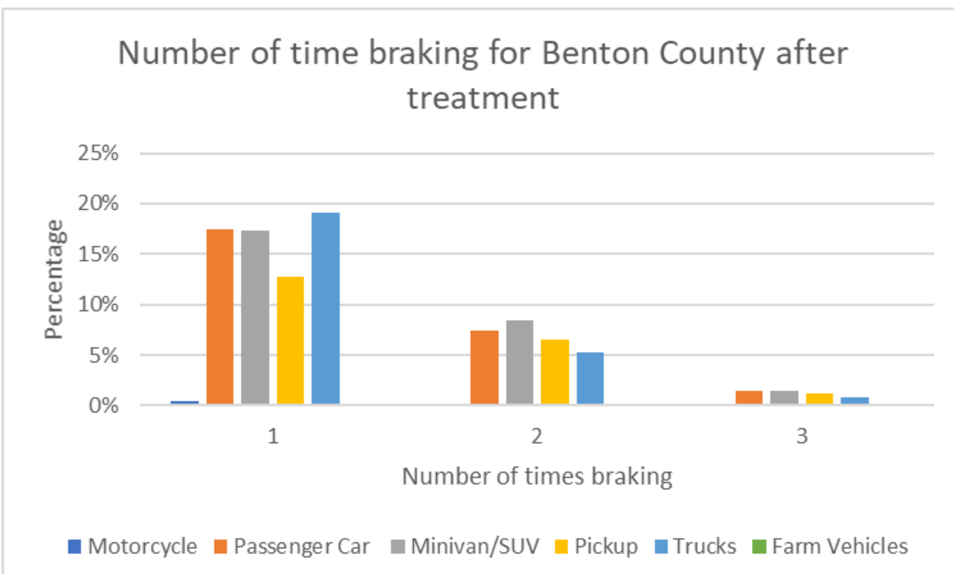

Figure 6-6: Number of times braking for each vehicle type in Benton county after treatment was applied

As observed in other treatment locations, Buena Vista East showed more drivers braking more than once in the after treatment when compared to before flashing beacons were installed. (Figure 6-7)

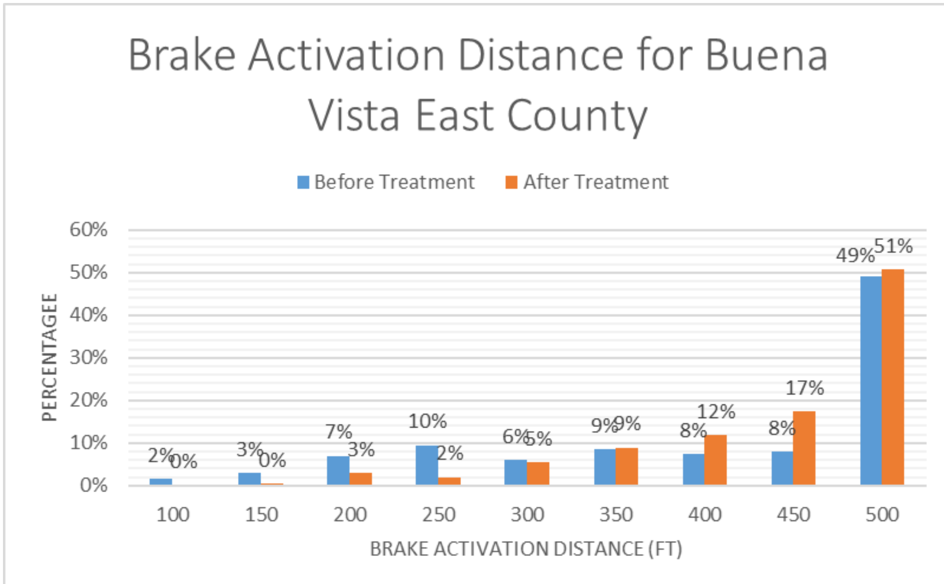

Figure 6-7: Brake Activation distance for Buena Vista East County

Buena Vista West County showed more drivers braking at 450 ft. and 500 ft. in the after treatment when compared to the before treatment (figure 6-8). 400 ft. showed the greatest increase from 4 % for the before treatment to 13 % in the after treatment.

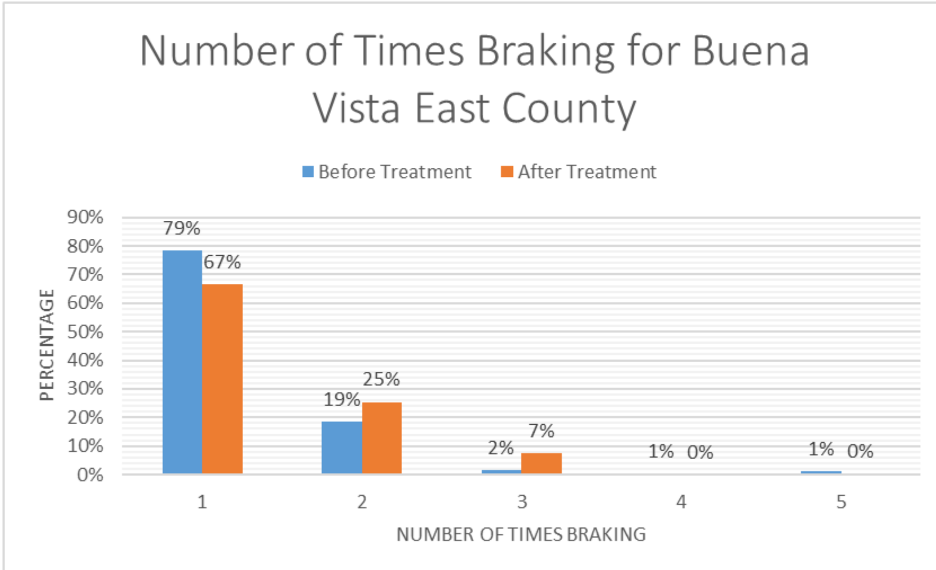

Figure 6-8: Number of times braking for Buena Vista East County

The braking Distance for Buena Vista East County was broken down for each vehicle type and displayed in figure 6-9 and 6-10.

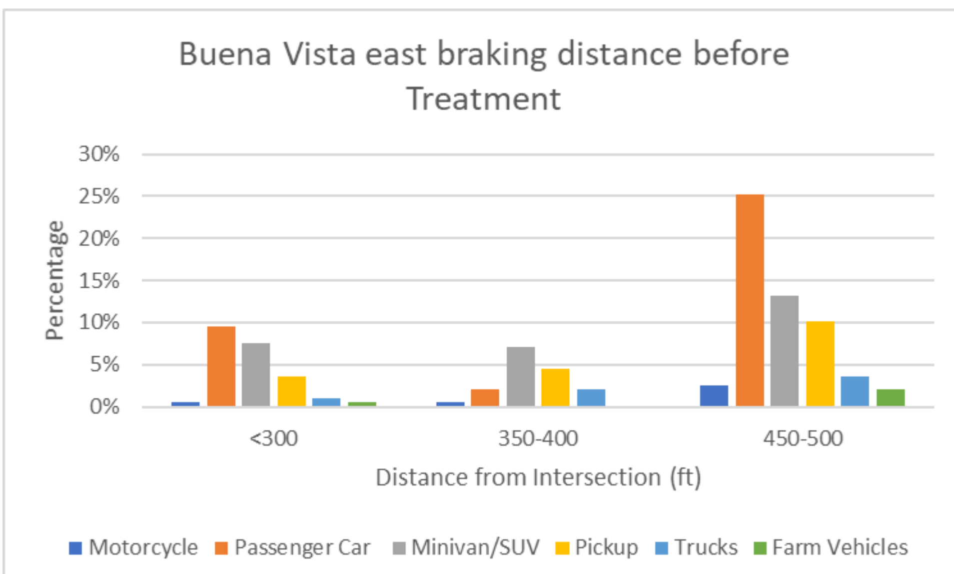

Figure 6-9: Braking distance before treatment was applied to Buena Vista east county

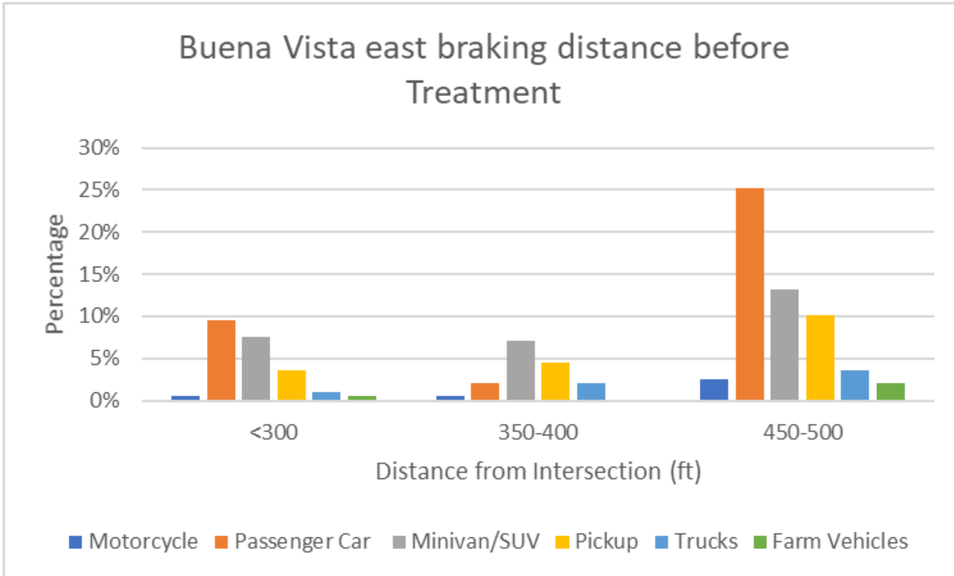

Figure 6-10: Braking distance after treatment was applied to Buena Vista east county

The number of times braking was also broken down for each vehicle type and displayed in figure 6-11 and 6-12.

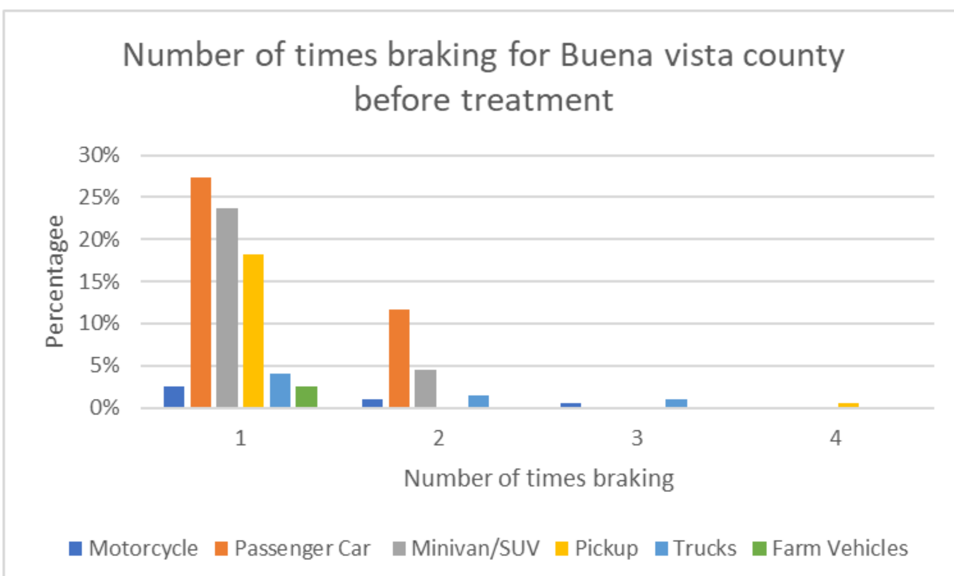

Figure 6-11: Number of times braking for each vehicle type before treatment was applied to Buena Vista east county.

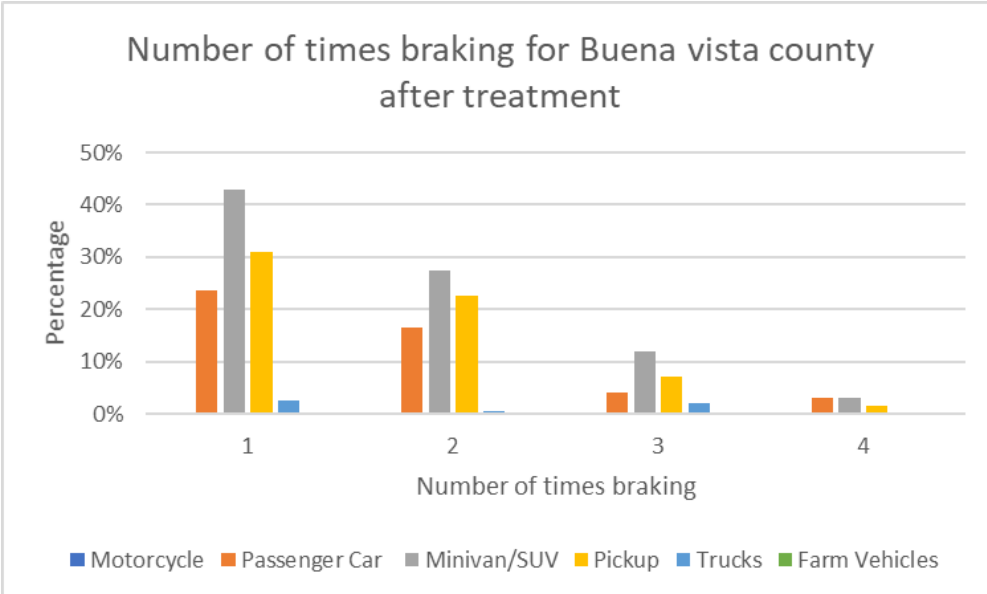

Figure 6-12: Number of times braking for each vehicle type after treatment was applied to Buena Vista east county

Buena Vista West drivers showed a three percent decrease in drivers applying their brake two times or more in the after treatment while there was a three percent increase in applying the brake three times (figure 6-13). The presence of the flashing beacon was a factor as more drivers tend to brake three times as they approach the intersection (figure 6-14).

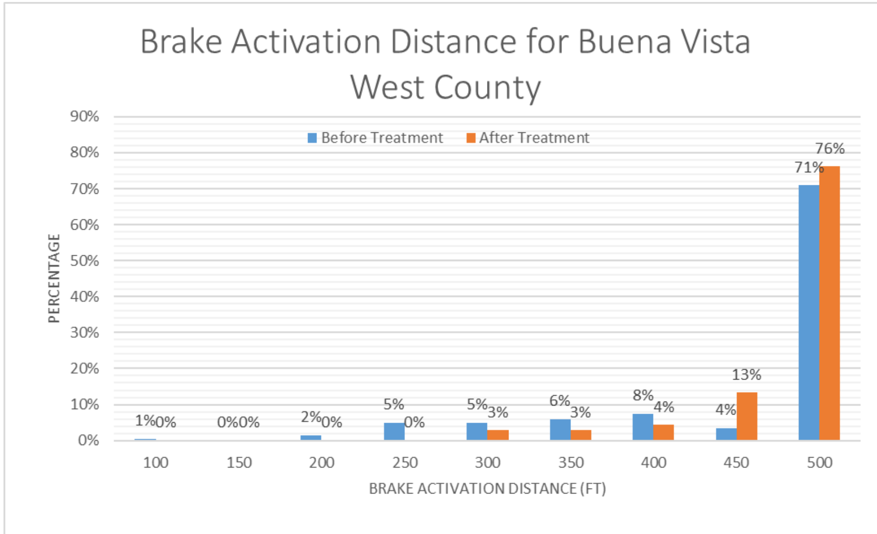

Figure 6-13: Brake Activation distance for Buena Vista West County

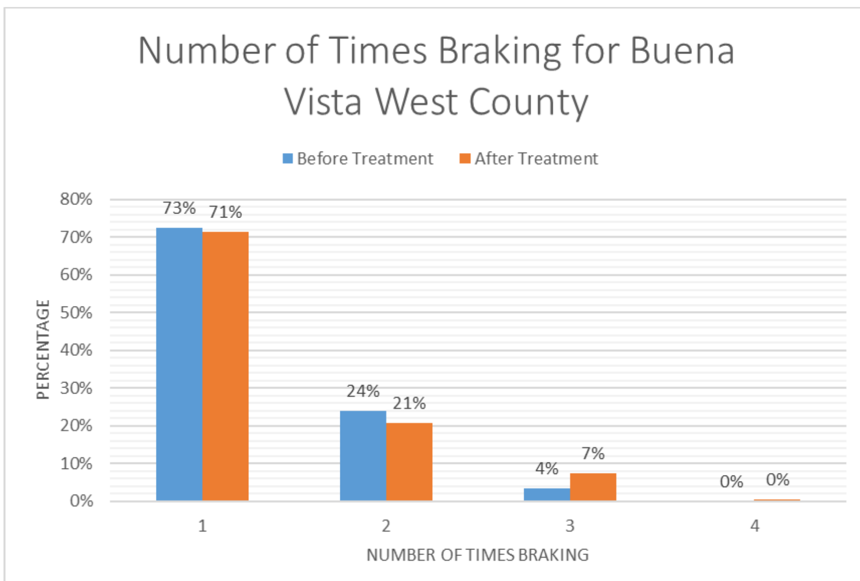

Figure 6-14: Number of times braking for Buena Vista West County

The braking Distance for Buena Vista West County was broken down for each vehicle type and displayed in figure 6-15 and 6-16.

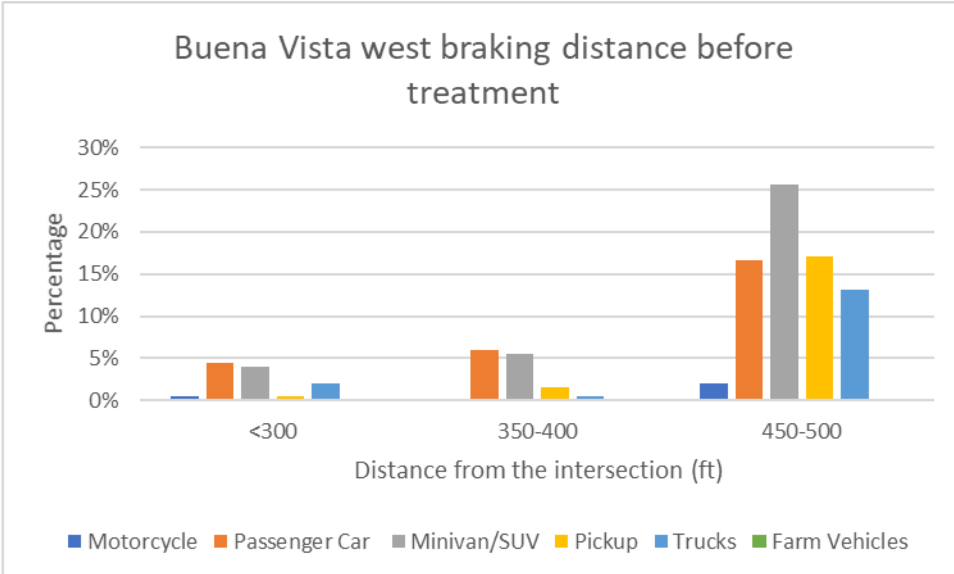

Figure 6-15: Braking distance for each vehicle type for Buena Vista west before treatment was installed

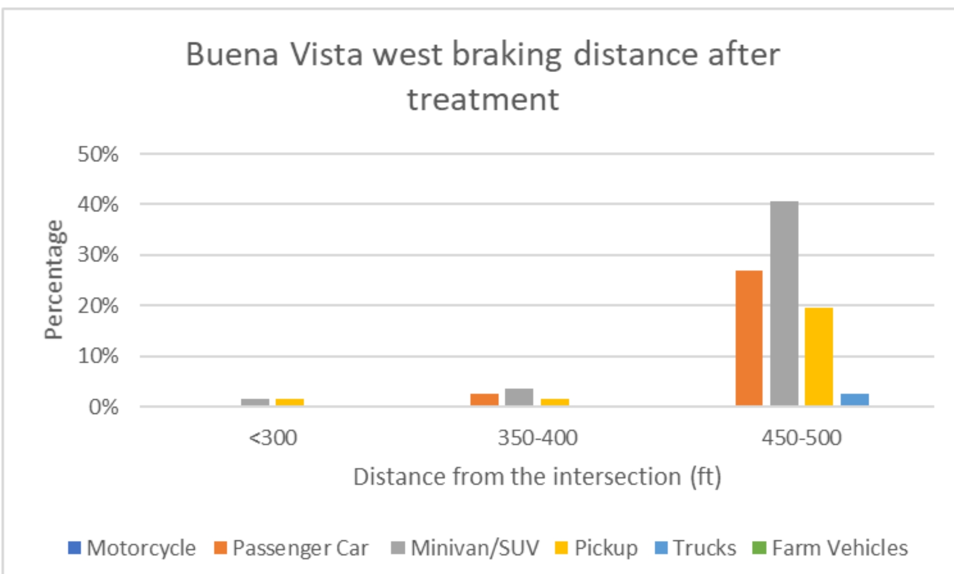

Figure 6-16: Braking distance for each vehicle type for Buena Vista west after treatment was installed

The number of times braking per vehicle type is also shown in figure 6-17 and figure 6-18.

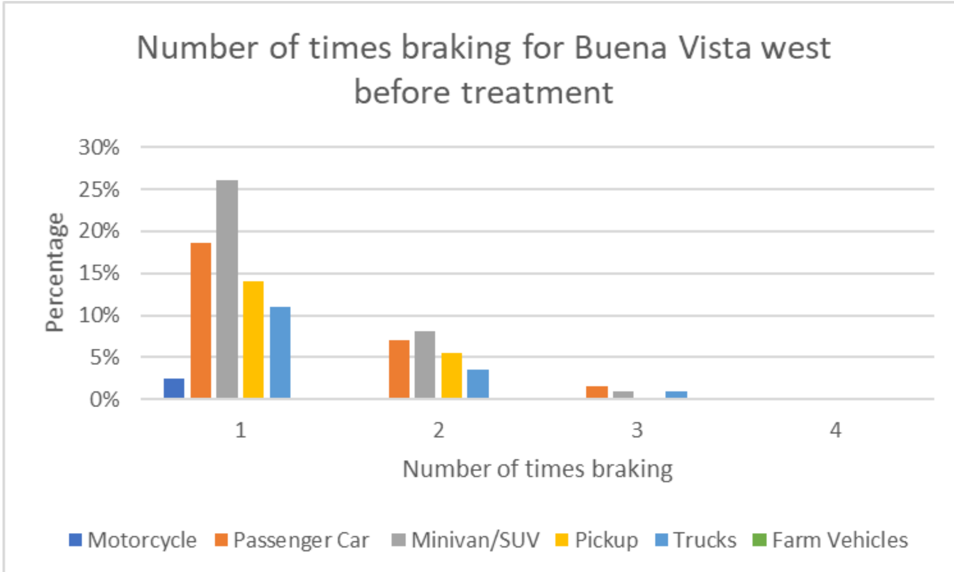

Figure 6-17: Number of times braking for each vehicle type for Buena Vista West before treatment

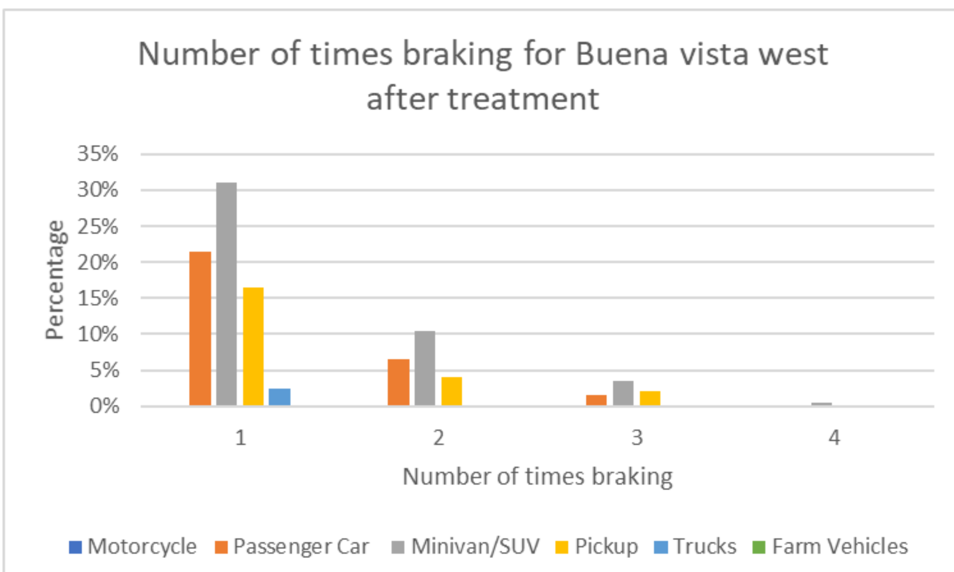

Figure 6-18: Number of times braking for each vehicle type for Buena Vista West after treatment

Clay County showed a 44% increase in the stopping distance in the after treatment. This shows that drivers applied their brake at 500 ft. after the flashing beacon was installed (Figure 6-19).

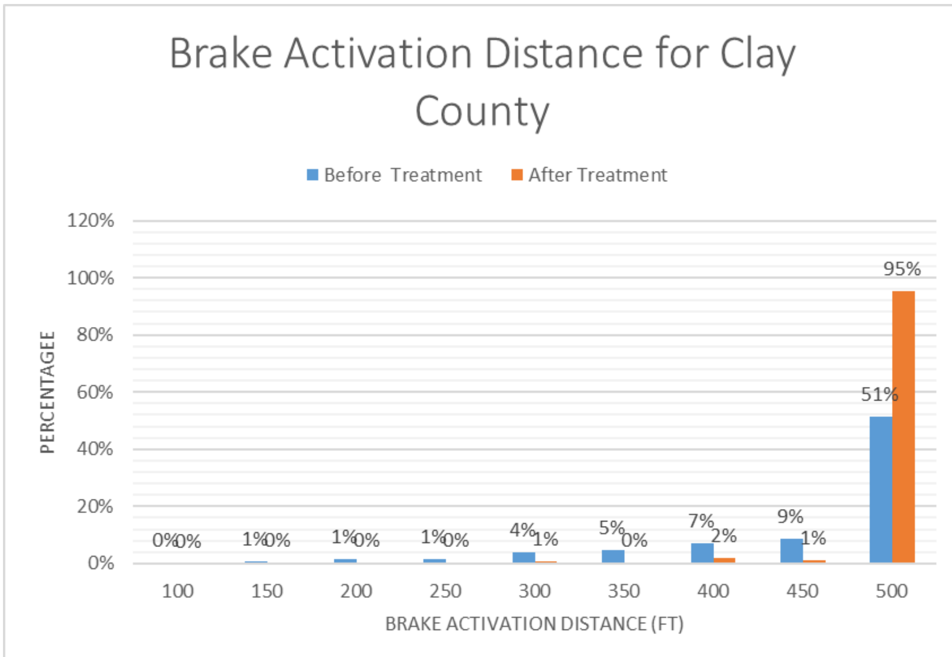

Figure 6-19: Brake Activation Distance for Clay County

For Clay County more drivers braked once (85%) in the after period when compared to the before treatment (74%) as shown in figure 6-20.

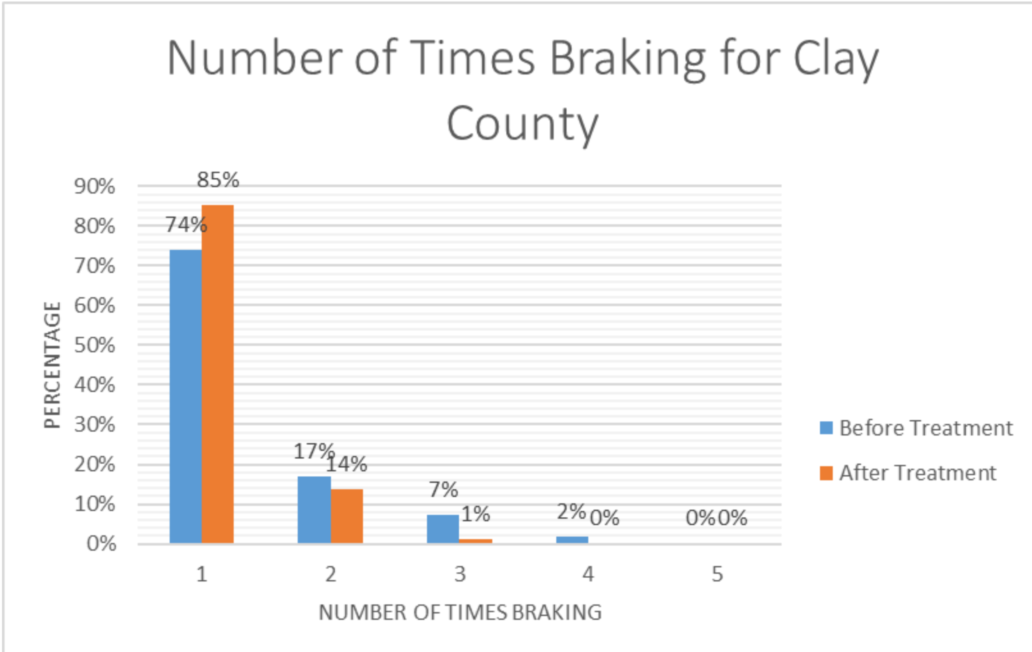

Figure 6-20: Number of times braking for Clay County

The braking distance for Clay County was broken down for each vehicle type and displayed in figure 6-21 and 6-22.

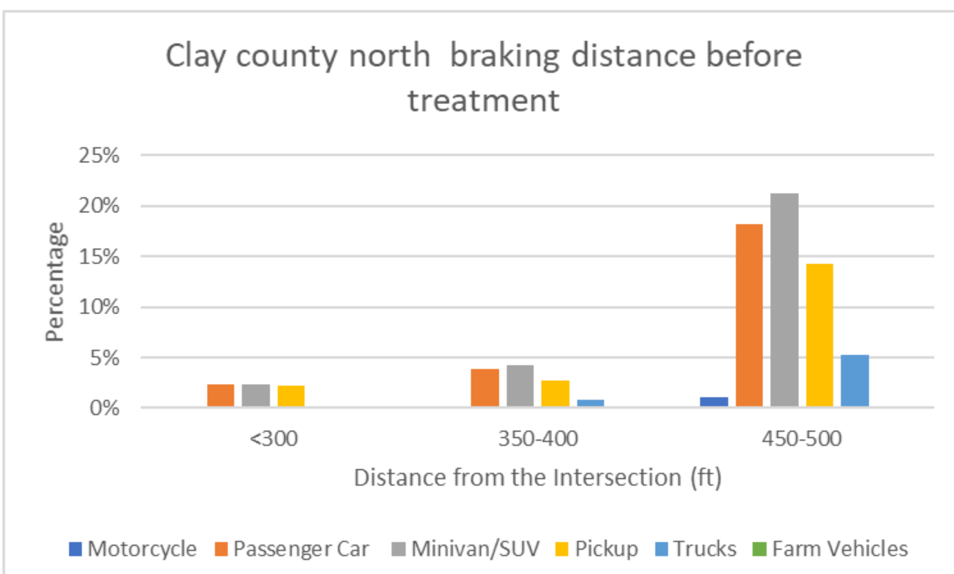

Figure 6-21: The braking distance for Clay county showing each vehicle type before treatment was applied

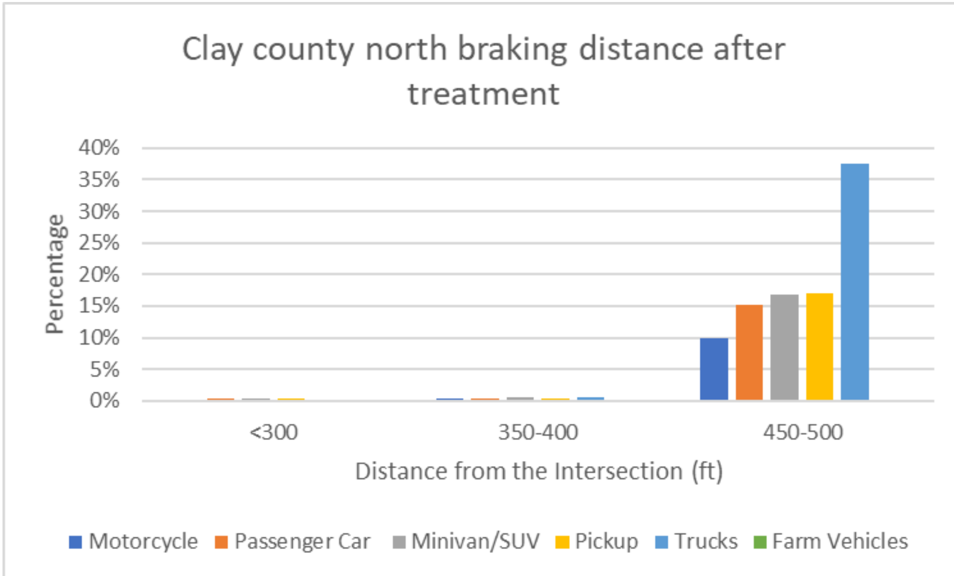

Figure 6-22: The braking distance for Clay county showing each vehicle type before treatment was applied

The number of times braking per vehicle type is also shown in figure 6-23 and figure 6-24.

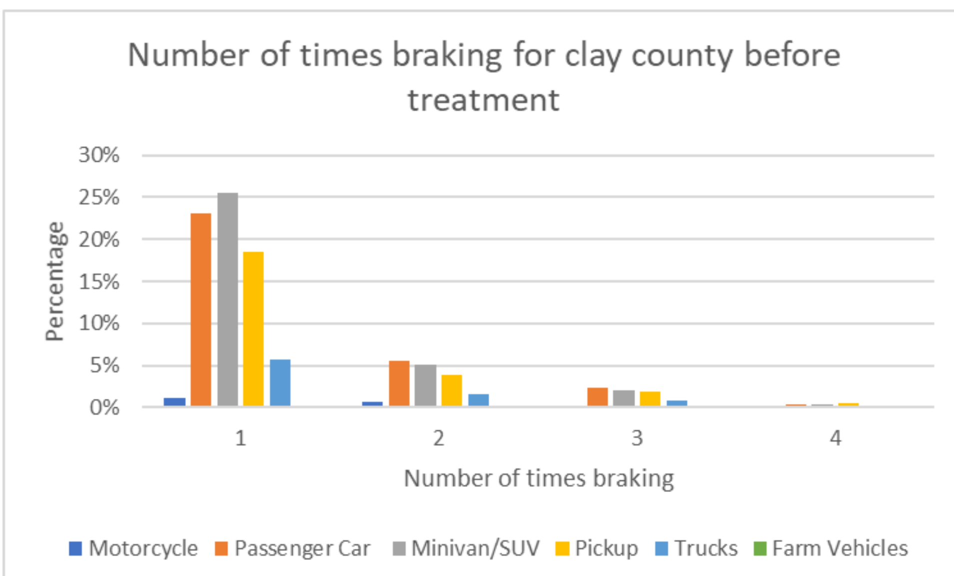

Figure 6-23: Number of times braking for each vehicle type before treatment was applied to clay county

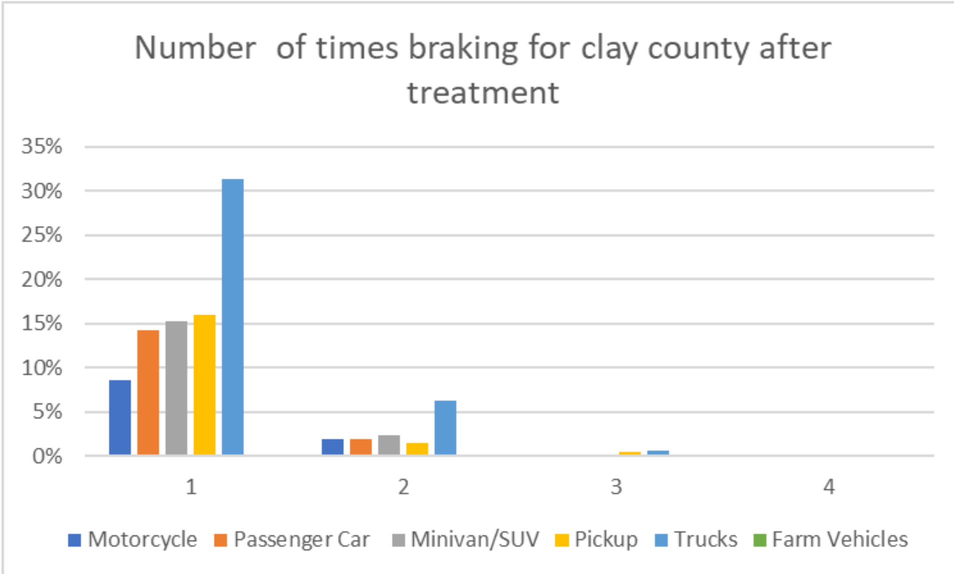

Figure 6-24: Number of times braking for each vehicle type before treatment was applied to clay county

Johnson County had less drivers braking at 500 ft. in the after treatment (Figure 6-25). This was different from most of the other treatment locations which showed an increase in the after treatment.

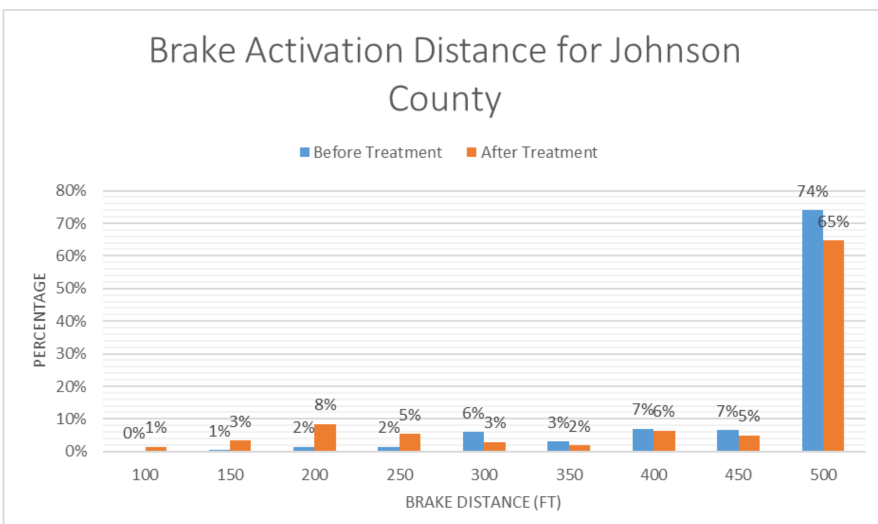

Figure 6-25: Brake Activation Distance for Johnson County

Johnson County was also different from other treatment locations as more drivers (86%) applied their brake once in the after treatment when compare to before flashing beacons were installed (70%). Usually it would be expected that drivers would brake more than once when they observe a flashing beacon (figure 6-26).

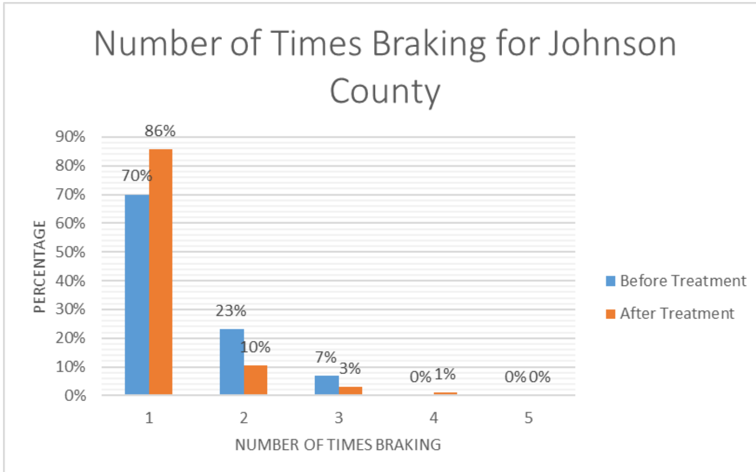

Figure 6-26: Number of times braking for Johnson County

The braking distance for Johnson County was broken down for each vehicle type and displayed in figure 6-27 and 6-28.

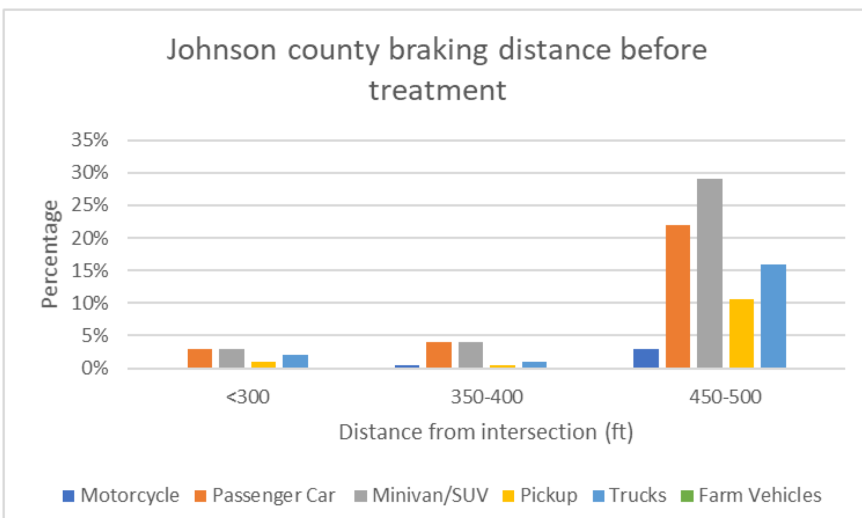

Figure 6-27: Braking distance for each vehicle type in Johnson county before treatment was applied

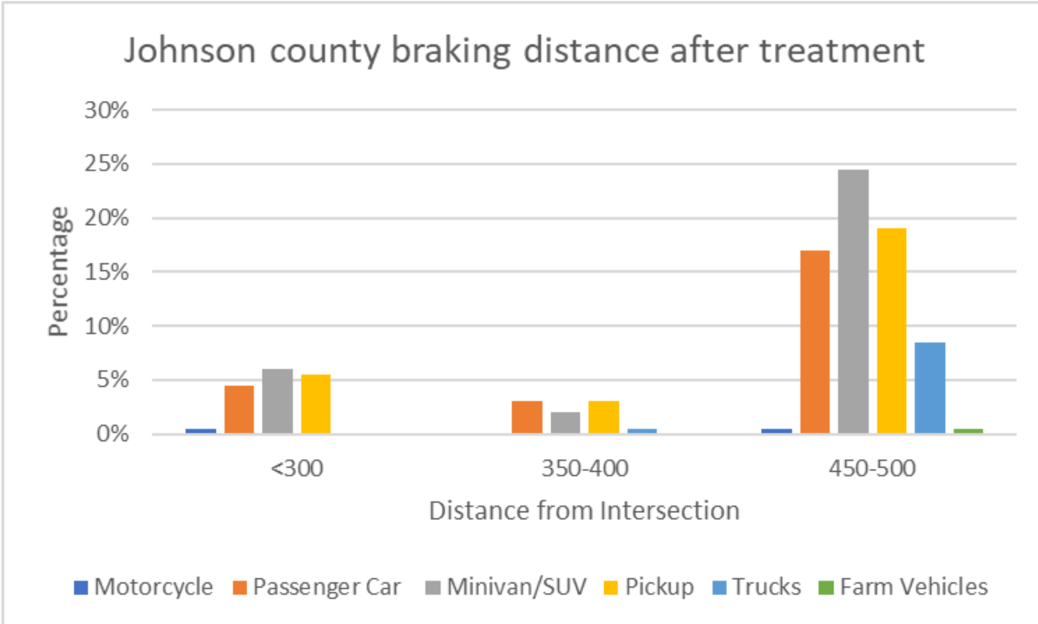

Figure 6-28: Braking distance for each vehicle type in Johnson county after treatment was applied

The number of times braking per vehicle type is also shown in figure 6-29 and figure 6-30.

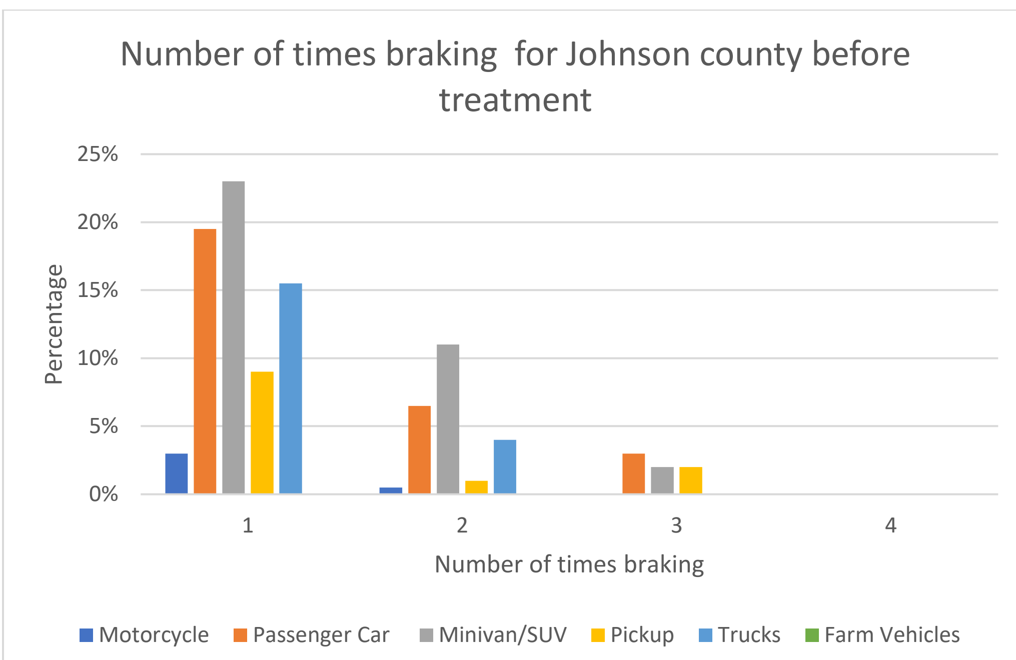

Figure 6-29: Number of times braking for Johnson county before treatment was applied

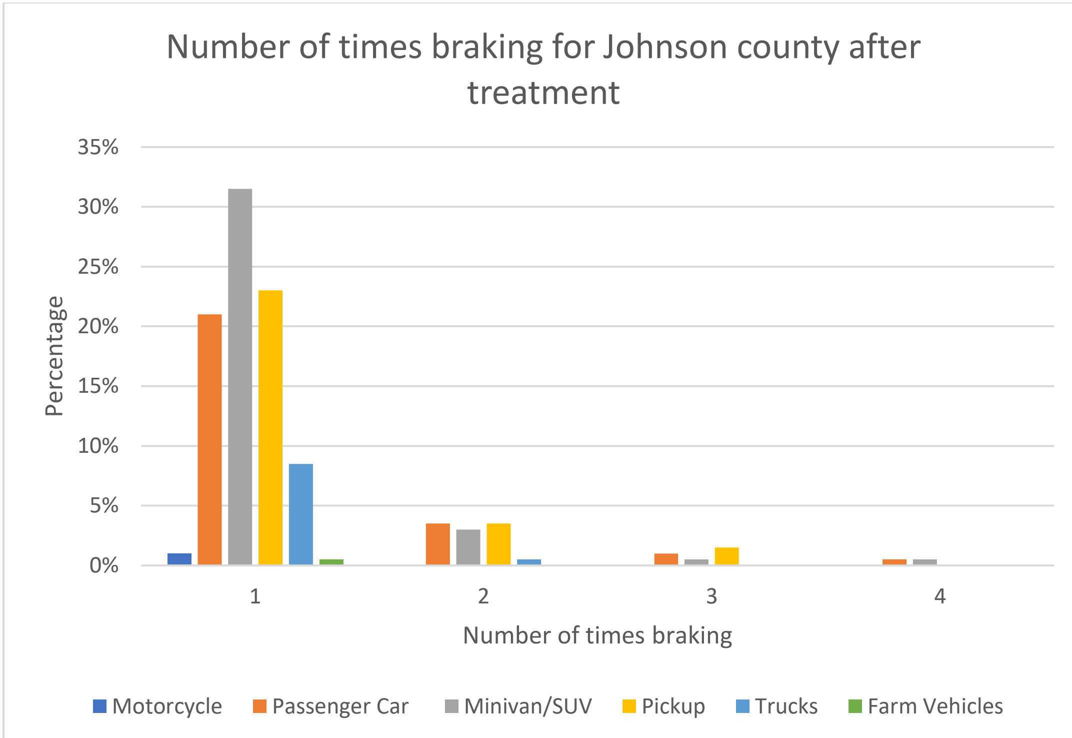

Figure 6-30: Number of times braking for Johnson county after treatment was applied

6.2 Logistic Regression Model Results

To run this model the vehicle classes were modified into different classes to simplify the analysis (Table 6-2). Overall this model showed that vehicle class 3 (pickup), vehicle class 4 (trucks) and vehicle class 5 (farm vehicles) were significant in braking further away from the stop bar when compared to all other vehicles. The model revealed that 450 ft. to 500 ft. was significant for all drivers in the after treatment and this was good as it shows that drivers are braking further from the stop bar after flashing beacons were installed. Table 6-1 shows the results of the Logistic Regression Model.

Table 6-1: Results from Logistic Regression Model

County		Before			After		
	Term	Estimate	Std Error	p Value	Estimate	Std Error	p value
Benton	Intercept	-1.713102	0.25292	<.0001	-1.39554	0.5497507	**0.0111**
	1st Braking Distance [300]	0.26413532	0.4643795	0.5695	-0.67428	0.2487515	**0.0067**
	1st Braking Distance [350]	0.39316273	0.4267937	0.3569	-0.55428	0.2447475	**0.0235**
	1st Braking Distance [400]	0.08333681	0.2527496	0.7416	0.382755	0.2084544	0.0663
	1st Braking Distance [450]	0.18857791	0.4612745	0.6827	0.842551	0.2434941	**0.0005**
	Vehicle Class 3	-0.0655871	0.1479078	0.6575	0.074737	0.0750148	0.3191
	Vehicle Class 4	-0.2891174	0.1821085	0.1124			
	Vehicle Class 1				0.628358	0.5366531	0.2416
Buena Vista West	Intercept	-1.1222991	0.4471214	0.0121	-0.93448	0.2554348	**0.0003**
	1st Braking Distance [250]	-0.0606811	0.6961142	0.9305			
	1st Braking Distance [300]	-0.0088382	0.6986747	0.9899			
	1st braking Distance [350]	-1.2616911	0.8674344	0.1458			
	1st Braking Distance [400]	0.88515648	0.5518426	0.1087			
	1st Braking Distance [450]				-0.12659	0.2367095	0.5928
	Vehicle Class 3	-0.1246323	0.1883396	0.5081	0.027237	0.1951431	0.889
	Vehicle Class 4	-0.1669179	0.296441	0.5734			
Buena Vista East	Intercept	-2.1365477	0.6598702	**0.0012**	0.139936	0.6006474	0.8158
	1st Braking Distance [200]	-0.445698	0.7197038	0.5357			
	1st Braking Distance [300]	-0.7216132	0.9027067	0.4241			
	1st braking Distance [400]	-1.3076741	0.9450339	0.1664			
	1st Braking Distance [450]	1.87301987	0.5943309	**0.0016**	-0.531	0.2356222	**0.0242**
	Vehicle Class 3	1.32720369	0.5362156	**0.0133**	0.158738	0.2032013	0.4347
	Vehicle Class 4	-0.6833274	0.3685431	0.0637	-1.06277	0.5887512	0.0711
Clay	Intercept	0.20957213	0.3580961	0.5584	-1.81973	0.4343225	<.0001
	1st Braking Distance [150]	-1.0940314	0.652888	0.0938			
	1st Braking Distance [300]	0.11465375	0.2425998	0.6365			
	1st Braking Distance [350]	0.18510301	0.2226138	0.4057			
	1st Braking Distance [400]	0.59667224	0.1888926	**0.0016**	0.177229	0.5395217	0.7425
	1st Braking Distance [450]	0.637054	0.1784278	**0.0004**	-0.52605	0.721414	0.4659
	1st Braking Distance [500]	-0.8622816	0.1439253	**<.0001**			
	Vehicle Class 4	-0.2455764	0.0908233	**0.0069**	-0.12435	0.1071422	0.2458
	Vehicle Class 1	-0.2612677	0.1722112	0.1292	-0.21037	0.1377349	0.1267
	Vehicle Class 5	-0.6610582	0.276719	**0.0169**			
	Vehicle Class 3				-0.09413	0.1053343	0.3715
Johnson	Intercept	-1.1031971	0.506871	**0.0295**	-0.72887	0.3581578	**0.0418**
	1st Braking Distance [350]	-0.997902	0.7620714	0.1904			
	1st Braking Distance [450]	1.28655569	0.540762	**0.0174**	0.927081	0.3456938	**0.0073**
	Vehicle Class 4	0.35650789	0.2857582	0.2122			
	Vehicle Class 3	0.19268005	0.2365568	0.4153	-0.32668	0.2451272	0.1826

Table 6-2: Vehicle Class Description.

Vehicle Class	Description
Class 1	Motorcycle
Class 2	Passenger Cars and Minivan
Class 3	Pickup
Class 4	Trucks
Class 5	Farm vehicles

CHAPTER 7. CONCLUSION AND LIMITATION

7.1 Conclusion

Flashing beacons installed on stop signs affect the braking distance of drivers. The brake activation distance was different with the after treatment when compared to the before treatment. Drivers in the after treatment tend to brake further away from the stop bar when compared to before a flashing beacon was installed. The intersection in Benton County showed more drivers braking in the before treatment at 400 ft. than after the treatment was applied. Further analysis then showed that trucks and pickups were responsible for braking at 400 ft. before treatment was applied. Trucks and pickups are usually taller when compared to other vehicle types so the sight distance is usually better and this could be a possible reason why these vehicle types brake nearer to the stop bar in Benton County.

Flashing beacons also affected the number of times drivers applied their brake as the approach the rural intersection. Overall drivers applied their brake more than once after flashing beacons were installed. A plausible reason for this result was because drivers were more alert as they saw the flashing beacon and eventually brake more than once to ensure that they were decelerating appropriately as they approached intersections.

Only two treatment intersection illustrated that drivers braked once in the after treatment when compared to before data. Further analysis was done to indicate why these treatments were different. For The Intersection in Clay County more trucks braked only once (25 %) when flashing beacon was activated and a possible reason for this is that trucks take longer to come to a complete stop and it would not make sense to start braking and release the brake, resulting in applying the brake more than once. The second treatment location in Johnson County showed that minivan, pickups and trucks braked once but still braked at 450

– 500 ft. away from the Intersection when the flashing beacon was activated. This shows that even thou some drivers brake once they apply their brake further away from the intersection. This will allow them to reduce their speed and yield to traffic on the major stream and then maneuver the intersection when it is safe to proceed.

With the use of the Logistic Regression Model, pickups, trucks and farm vehicles were significant in braking further away from the stop bar when compared to other vehicles. As mentioned previously pickups and trucks are larger and tend to take longer to come to a complete stop. In addition, even thou there were few farm vehicles present in this study, majority of them braked further away from the intersection. The model also revealed that between 400 ft. and 500 ft. was comfortable for drivers to brake as they approach a rural Intersection in Iowa.

In conclusion, the results of this study can be used as a reference for the installment of flashing beacons on stop signs to act as a precaution for drivers who may not brake appropriately at intersections and to minimize the approach speed of drivers as this is the main reason why crashes at rural intersections are so sever. Hopefully, this counter measure can assist in reducing crashes at intersections by reducing the speed of drivers. Future work would involve evaluating if flashing beacons can significantly decrease crash rate at rural intersections and evaluate if the number of times braking impacts how safe a driver will maneuver an intersection.

7.2 Limitation

The Researcher encountered a few limitations that affected the data obtained. After all data was collected and the video footage was being reduced, some of the video was obscured and could not be analyzed. Furthermore, some variables that were reduced are subjective based on the data reductionist and this could affect the results. Overall eight persons reduced the data and the variability of each coder should be taken into account when interpreting the results.

There were a few limitations to the data analyzed such as appropriate sigh distance at each intersection and a longer time period to measure crash rate and driver behavior, as this analysis was only done, one month before and after the installation of flashing beacons.

In addition, some cameras were dislocated from the original position selected due to uncontrollable circumstances. Figure 7-1 is an example of a dislocated camera that affected the data reduction process.

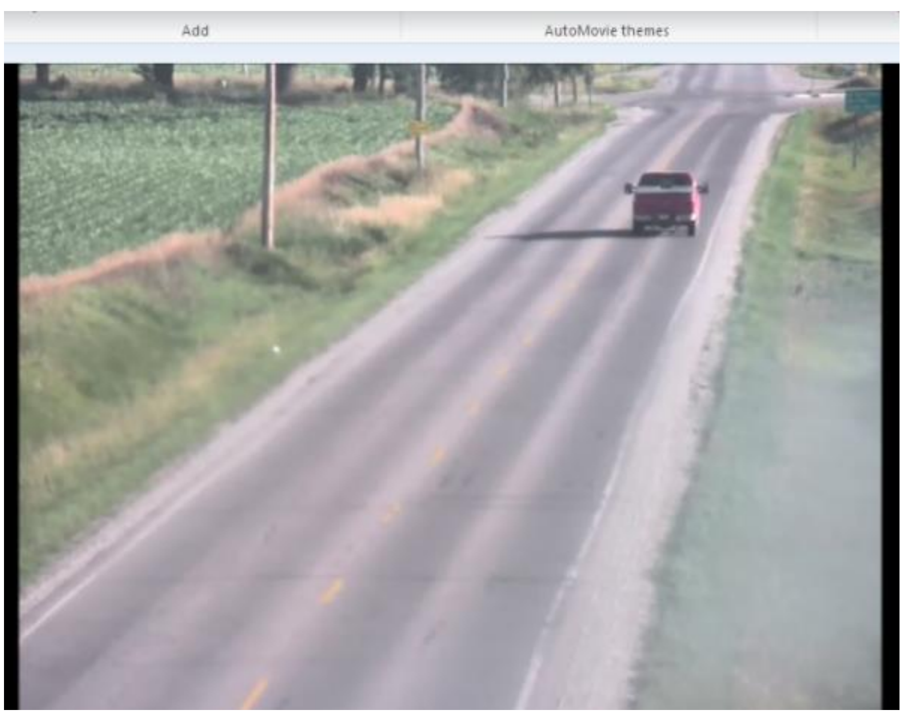

Figure 7-1: Dislocated camera for Benton county North not showing Flashing Beacon Stop sign

Other limitations include accurately recording what location a car stopped in relation to the stop bar as it approached the intersection. The researcher and data reductionists had to estimate if a car stopped before or after the stop bar and this is the reason why this variable was not included in the final analysis. In addition, cameras could not capture video in the night (Figure 7-2). It would be recommended to install a better camera to record at night so night-time data can be accessible.

Figure 7-2: View of cameras in the night

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