Evaluation of Driveway Assistance Devices in Signalized Work Zones

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16. Abstract

An evaluation was conducted along State Route 60, in Muskingum County, Ohio as associated with ODOT's construction contract 210208, (PID 101004) to examine the performance differences between traditional temporary traffic signals and Driver Assistance Devices (DADs) at driveways in a work zone. The project consisted of a field and microsimulation analysis to quantify operational and safety of both work zone driveway devices, a benefit-to-cost analysis and a user survey. The overall results of the research study (field and microsimulation analysis) indicate that the DADs provide higher levels of driver compliance, improved operational performance and reduced the potential for crashes through work zones over the traditional temporary traffic signal devices. The roadway users understood the operation of the DADs and construction personnel preferred the DADs over the temporary traffic control signal devices for construction operations and safety reasons. The benefit-to-cost ratio supports the utilization of the DADs over the temporary traffic signal devices.

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Problem Statement

Construction work zones on US highways are hazardous both for motorists and for workers. Statistics from the National Safety Council indicate that in 2019, 842 people were killed, and 39,100 people were injured in work zone crashes (NSC, 2019). Regardless, work zones are necessary for road improvement projects and are cause for changing traffic patterns, reduced speed limits, congestion and an influx of construction and maintenance workers as well as equipment on the roadway. Work zones along major thoroughfares separate traffic flow through the use of rigid barriers; however, along two-lane, two-way roadways, typically temporary traffic signal devices are utilized to allow for alternating traffic flow utilizing part-width construction methods for the roadway, particularly common along suburban and rural two-lane roadways.

When a part-width work zone requires one-way travel along a two-way corridor, driveways and low volume intersecting roads within the work zone create additional challenges. Temporary traffic signals are a proven technology that allows for 24-hour, one-way operations on two-way roads; however temporary traffic signals have limitations. In order to allow motorists to enter the mainline one-way traffic stream from a driveway in the middle of a work zone, temporary traffic signals stop mainline traffic to allow vehicles at driveways or intersecting roads to proceed and therefore must wait for the vehicle(s) to clear the one-way work zone before returning flow back to the mainline. This can cause a substantial delay for all drivers. Additional driveways require their own phasing, further increasing delay for mainline traffic if multiple calls are received at the same time.

Thus, Driveway Assistance Devices (DADs) have been developed to safely control driveway traffic within single-lane operation work zones with two-way traffic but these DADs have not received approval for inclusion in the FHWA's Manual on Uniform Traffic Control Devices (MUTCD). DADs have the potential to improve operations by allowing motorists at driveways (and potentially for low volume intersecting roads) to join an existing queue of vehicles (traveling in the same desired direction on the mainline) rather than calling for an additional phase at the temporary traffic signal specifically for driveway movements. This could significantly improve the efficiency of one-way work zones, reducing user delay, increasing safety, and improving construction efficiency (if one-way work zones can be expanded). Over the last decade, the concept of DADs has evolved with a variety of configurations being proposed and preliminary testing (Texas, Michigan, New Jersey) performed. However, there still exists a need to further evaluate DADs to provide detailed guidance that can assist with decision making.

In order to determine the feasibility for future use of DADs, the devices will be evaluated for their effectiveness in terms of traffic operation, motorist safety and worker risk in one-way, two-lane work zones with the presence of driveways within the work zone. If the DADs are proven to be a safe, efficient, and effective temporary traffic control device, inclusion in the MUTCD would allow for widespread use which could have a significant impact on user delay, safety, and construction costs.

Research Background

An evaluation was conducted along State Route 60, in Muskingum County, Ohio as associated with ODOT's construction contract 210208, (PID 101004) to examine the performance differences between traditional temporary traffic signal devices and DADs at driveways in a work zone. State Route 60, a two-lane two-way roadway, as shown in Figure 1, is classified as a Rural Minor Arterial with a posted speed limit of 55 miles per hour in the vicinity of the project, and currently has an average daily traffic volume of 3,800 vehicles per day with 13-percent heavy vehicles. The construction project was approximately 8 miles in length and involved full depth pavement replacement, widening, bridge rehabilitation, and box culvert replacement. The work zone configurations included the closure of one of two of the travel lanes for approximately 1000-feet in length while construction was occurring on the other lane. During construction, access to the driveways was maintained by either a temporary traffic signal or the DAD. Traffic was controlled at both ends of the work zones with a temporary traffic signal. The specific study area included four work zones, three utilizing DADs at driveway locations and one utilizing temporary traffic signal devices at driveway locations. All of the work zones utilized temporary traffic signal devices at the end of each work zone. The four project locations along State Route 60 are presented in Figure 1 with Work Zones #1 and 2 on the south end of the State Route 60 project and Work Zones #3 and #4 on the north end of the project. Details regarding the driveway locations, types and traffic control device utilized are provided in Table 1.

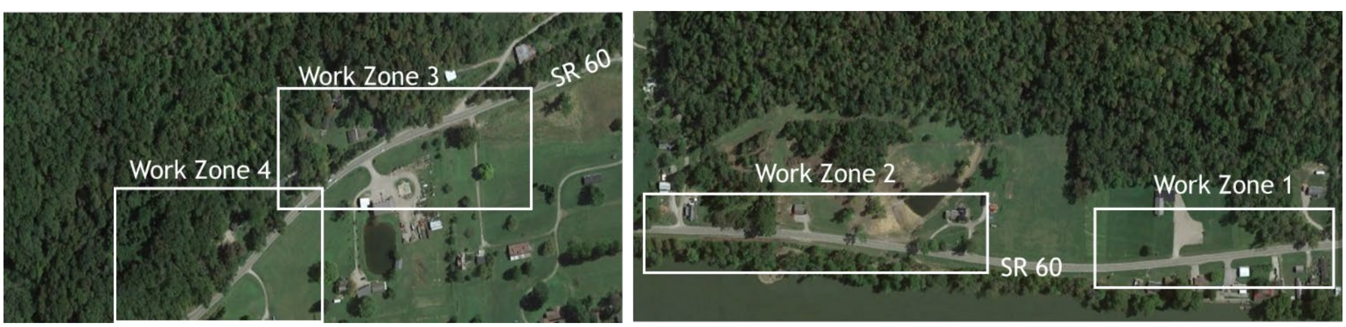

Figure 1. State Route 60 Project Area

Table 1. Work Zone Driveway Information

Work Zone Number	Driveway Number	Project Station Number	Width and Type of Driveway	Driveway Control Device	Type of Facility
1	78	188+66.5	33' Gravel	DAD Device	Single Family Home
1	79	190+13	33' Gravel	DAD Device	Single Family Home
1	80	190+88	28' Gravel	DAD Device	Church
1	81	192+19	14' Grass	DAD Device	Single Family Home
2	82	200+00	20' Gravel	DAD Device	Single Family Home
2	83	202+00	14' Gravel	DAD Device	Single Family Home
2	84	207+11.5	20' Gravel	DAD Device	Single Family Home
2	85	212+58	24' Paved	Temporary Traffic Signal	Shaver Road
3	112	335+17	20' Gravel	Temporary Traffic Signal	Rio Villa Drive
3	113	335+57.4	54' Gravel	Temporary Traffic Signal	Single Family Home
3	114	338+78	16' Gravel	Temporary Traffic Signal	Multi-Family Drive (2 Houses)
3	115	339+79	37' Gravel	Temporary Traffic Signal	Construction Business
3 and 4	116	342+80.5	15' Gravel	DAD Device/Temporary Traffic Signal	Single Family Home
4	117	346+28.5	18' Gravel	DAD Device	Single Family Home
4	118	348+58	15' Gravel	DAD Device	Single Family Home
4	119	358+39	16' Gravel	DAD Device	Single Family Home

The overall goal of this research project was to evaluate performance of the DADs in comparison to the traditional temporary traffic signal devices and, based on the findings, provide recommendations to ODOT on their safety, effectiveness, and cost-efficiency for adoption in signalized work zones. This goal was achieved utilizing the following elements of the project:

1) Determined if the devices (temporary traffic signal and DAD) are properly maintaining driveway traffic in a work zone.
2) Determined if the devices (temporary traffic signal and DAD) are substantially negatively interfering with traffic operations along the mainline roadway.
3) Determined the safety impacts of the devices (temporary traffic signal and DAD) in a work zone for mainline and driveway traffic.
4) Determined the factors for utilization of DADs in various work zones, including traffic volumes and signal timing.
5) Analyzed the costs affiliated with the utilization of DADs in work zones in comparison to traditional work zones.

Research Approach

To accomplish the overall goal of the research of evaluating the performance of the DAD devices in comparison to the traditional temporary traffic signals, several tasks were completed as follows:

1) Field studies were conducted to collect volume, queuing, compliance, safety and speed of vehicles within the work zone, both along the mainline as well as at the driveways.
2) Surveys questionnaires were administered to determine public and worker perception of the traffic control devices.
3) Microsimulation-based analyses were conducted to compare operational performance of the temporary traffic signals and the DADs. A sensitivity analysis was also conducted utilizing microsimulation to determine appropriate deployment metrics for the DADs.
4) A benefit-to-cost analysis was conducted to determine the efficacy of utilizing the DADs in future partial width construction utilizing one-lane, one-way traffic.

Field Studies

In order to collect volume, queuing, compliance, safety and speed of vehicles within the work zone, both along the mainline as well as at the driveways, video data was collected using Miovision Scout Cameras located at the start and end of each work zone as well as at each driveway within the work zone. The placements of the cameras were in a manner such that, at each driveway or intersecting road within the work zone, cameras were able to capture compliance and queue length with the ability to capture the mainline traffic data. The cameras were also located at the end of the work zones in order to capture the end of any vehicular queues that formed. The placement of the cameras was such that they were clear of the contractor's equipment and operations while being placed at an elevation above the roadway surface but not interfering with overhead utility wires and within the right-of-way of State Route 60. To assure proper functioning of the cameras, the video operation and camera angle was checked remotely as well as in-person. Since some of the driveways appear to have seasonal or recreational sensitive traffic such as camping, the research team believes that extended weekday and weekend data collection would be beneficial to capture the highest traffic volumes possible. Work Zones #1 and #3 were under construction simultaneously and the data was continuously collected from June 28, 2022 through July 7, 2022 for 24 hours every day. Work Zones #2 and #4 were under construction simultaneously and the data was continuously collected from October 12, 2022 through October 19, 2022 for 24 hours every day.

The data collected at the driveway locations included the following information:

- Camera information (i.e., driveway location and name)
- Data collection timeframe (i.e., day and time)
- Direction of travel (i.e., mainline and driveway)
- Platoon description of the mainline vehicles (i.e., platoon or random arrivals)

- Number of mainline vehicles not a platoon (i.e., including straggler vehicles)
- Time of the front of middle platoon vehicle and end of vehicle passing a specified location
- Time of arrival and departure of a driveway vehicle
- Driveway queue length
- Notes on any conflict of the driveway motorists with the mainline vehicular traffic
- Turn compliance (i.e., whether the driver complied with the device)
- Turn relation to the mainline adjacent vehicle (i.e., within 150-feet or less)
- Turn direction (i.e., with or against the mainline traffic flow)

Data was also collected at the end of the work zones and included the following information:

- Camera information (i.e., driveway location and name)
- Data collection timeframe (i.e., day and time)
- Direction of mainline travel
- End of the work zone queue length at the start of the green signal indication

Additional information can be realized for the driver behavior at each of the devices based upon the data collected to further understand the implications of the device compliance in terms of safety. Motorists can be classified as being compliant with the signal thereby proceeding in a safe manner (Compliant, Safe). Motorists that turn against the flow of traffic are considered proceeding in an unsafe manner (Unsafe). Those that turn in the direction of the mainline traffic flow and closer than 150-feet of an adjacent vehicle but not in compliance with the signal are generally turning after the mainline platoon passes the driveway, yet doing so too close to a mainline vehicle (Non-Compliant, Unsafe). On the other hand, those that turn in the direction of mainline traffic flow against the signal but make the turn greater than 150-feet from a passing vehicle do so in a safe condition (Non-Compliant, Safe). Those motorists that turn against the flow of traffic have the potential to be involved in a head-on collision within the work zone area (Unsafe). The motorists that turn in the direction of mainline traffic but closer than 150-feet may be involved in a rear-end crash or a sideswipe crash with the closest vehicle in the main line traffic stream (Non-Complaint, Unsafe). Understanding driver actions can assist in the assessment of safety impacts along the work zone.

As there were not any crashes associated with the work zones, specifically the driveway devices utilized for driveway traffic control, a conflict analysis was conducted using the FHWA's Surrogate Safety Assessment Model (SSAM) software in order to quantitatively reflect the safety performance in the work zones for either traffic control device. The SSAM software was developed in order to predict crashes along a roadway due to the random nature of crashes occurring and potentially not present during a study period. By analyzing vehicle trajectories, SSAM assists in the determination of potential conflicts along roadway segments indicating that two road users would likely collide without evasive action taken. This provides an advantage of utilizing a simulation program to identify potential conflicts along road segments as once an evasive action is taken by a driver and no conflict occurs, the event is not recorded or identified. Therefore, SSAM provides data that would otherwise be unavailable for analysis. The SSAM analysis was performed following the microsimulation analysis and is described in the microsimulation section of this report.

Surveys

The research team administered a driver intercept survey to vehicles that will encounter the DADs within the pilot work-zones. The primary aim of this survey was to gain an understanding of driver's perceptions of the DADs. The survey was administered electronically through a weblink and provided to households along State Route 60 regardless of whether or not their driveway utilized the DADs. The specific configuration of the DADs provided in the survey is shown in Figure 2.

Figure 2. DAD Device for Household Survey

Household residents were specifically quizzed about two signal conditions on the device; *what movement can be made in a dual red arrow situation* and *what movement can be made with a flashing right turn arrow*. A summary of the responses is provided in Table 2.

Table 2. Household Survey Responses

Question	Correct Response	Incorrect Response
Under a red arrow condition, can you turn onto the main road? (Yes, No, Unsure)	75%	25% (12.5% unsure)
Under a red arrow condition, what direction can you turn? (Right, Left, Right and Left, Neither, Unsure)	62.5%	37.5%
Under a flashing right turn arrow, can you turn onto the main road? (Yes, No, Unsure)	100%	0%
Under a flashing right turn arrow, what direction can you turn? (Right, Left, Right and Left, Neither, Unsure)	62.5%	37.5% (Right and Left)
Under a flashing right turn arrow, what direction can't you turn? (Right, Left, Right and Left, Neither, Unsure)	62.5%	37.5% (25% unsure)
Under a flashing right turn arrow, what direction is the main road traffic heading? (Left, Right, Unsure)	75%	25% (12.5% unsure)

Based upon the household surveys, an overwhelming number of respondents (>60%) understood the movements that were allowed under the DADs signal configuration.

Surveys were also administered to individuals involved in the construction of the State Route 60 project. The purpose of this survey was to determine how people involved in highway construction project perceived the relationship between temporary traffic control devices, highway safety in work zones, and construction productivity when comparing the DAD devices to temporary traffic signal devices. The respondents included 30.77% ODOT employees, 23.08% consultants, and 46.16% construction personnel. The responses from the survey are summarized as follows:

- 100% of the respondents prefer the DADs over the traditional temporary traffic signal devices.
- 84.62% of the respondents felt safer in the work zone with the DADs than those with temporary traffic signals and the remaining felt both work zones were equally safe.
- 76.92% of the respondents experienced excessive delays when waiting in work zones controlled with temporary traffic signal devices.
- 84.62% of the respondents felt that construction work is delayed due to the time construction vehicles have to wait in queues before entering work zones.
- 57.14% of the respondents felt that the DADs increased work zone safety as it clearly indicated the direction of traffic flow and/or improved traffic efficiency as cycle lengths and queues are minimized.
- 92.31% of the respondents felt that the driveways controlled with DADs provided an improved rate of construction productivity.

It should be noted that while the vast majority of the survey respondents felt the DADs provided improved traffic flow, reduced delays, travel times and queue lengths; however, these were personal statements. Data was collected that was able to quantitatively evaluate these statements in the field and simulation studies portion of this project in order to obtain an unbiased result.

Microsimulation Analysis

In order to further investigate the operational and safety impacts of DADs a microsimulation-based analysis was completed using the VISSIM 7.0 software and the SSAM software. A sensitivity analysis was also conducted to explore the impact of multiple traffic parameters on operational and safety performance of the work zone segments. The simulation results will complement the evaluation results based upon the field data collected and described above.

The simulation roadway network was developed utilizing aerial photography and defining all the roadway features (lane width, number of lanes, driveway locations, etc.) in accordance with the actual site conditions. The length and exact locations of the work zones (Work Zones #1 and #3 shown in Figure 1 were utilized for the simulation study) were specified per the construction plans provided by ODOT. Four different scenarios were created for Work Zones #1 and #3 utilizing temporary traffic control devices and DADs in each work zone. For example, this will allow for direct comparison of Work Zone #1 with driveways controlled with temporary traffic control devices and with driveways controlled by DADs.

Assumptions were incorporated for the mainline traffic including volume inputs set at 206 vehicles per hour northbound and 136 vehicles per hour southbound during peak hour, which was calculated from AADT K, and D factors obtained from ODOT TMMS dataset. The vehicle classification consisted of 82-percent passenger vehicles, 13-percent of truck traffic and 5-percent of bus traffic. It was also assumed that there would be 4 vehicles per hour on each driveway, which is substantially higher than what is represented in the field, with half of the vehicles turning left and the remaining turning right. This assumption was based upon the highest traffic volume observed during the peak period for the church driveway (DR 80) in work zone #1 with the DADs and the business driveway (DR 115) in work zone #3 with the temporary traffic signal devices. The vehicles exiting the driveways were set as 100-percent passenger vehicles.

For each of the four operational scenarios analyzed with VISSIM, the simulation time was one hour, with a 15-minute warmup period which allows vehicles to load onto the simulation network prior to the commencement of the data collection. To allow for statistical comparison, 30 simulation runs (for each scenario) were completed; and during each simulation run, operational and safety performance data were collected for an hourly average and a peak 15-minute average.

The Surrogate Safety Assessment Model (SSAM) was utilized to evaluate the safety performance of the work zone segments utilizing temporary traffic control devices and the DADs. Using vehicle trajectory files (i.e., output from VISSIM), SSAM utilizes time-to-collision and minimum post-encroachment time in order to assess whether a conflict between two vehicles occurred given the geometrics an operational data of the roadway segment. All conflicts with time-to-collision times less than 1.5 seconds and post-encroachment times less than 5 seconds were identified through the SSAM simulation.

The operational and safety performance data that were collected are provided in Table 3.

Table 3. Simulation Operational and Safety Performance Measures

Analysis Type	Performance Measure	Position
Operational	Control Delay	Mainline & Driveways
	Travel Time	Mainline Only
	Queue Length	Mainline & Driveways
Safety	Time-to-collision	For each identified conflict
	Post-encroachment Time	

Comparisons were conducted to assess the differences in the field data observations and the microsimulation findings for the represented scenarios.

The sensitivity analysis explored the performance of the DADs under various design parameter settings. The intention was to explore how the DADs would perform for mainline roadways and driveways with substantially higher traffic volumes; therefore, the parameters that were modified for a variety of simulations included the driveway traffic volumes, mainline traffic volumes and signal timings as shown in Table 4. The theoretical maximum allowances for each direction of travel along the mainline was 1900 vehicles per hour per lane and for the driveway was 100 vehicles per hour.

Table 4. Simulation Sensitivity Analysis

Simulation Scenario Mainline Growth/ Driveway Growth	Mainline Traffic Volume	Driveway Volume
Baseline	350 vehicles per hour	4 vehicles per hour
Double/Quad Traffic	700 vehicles per hour	16 vehicles per hour
Quad/10x Traffic	1400 vehicles per hour	40 vehicles per hour
10x/25x Traffic	3500 vehicles per hour	100 vehicles per hour

Benefit-to-Cost Analysis

A benefit-to-cost analysis was conducted to evaluate the benefits and costs of the utilization of the DADs for driveways within one-lane, two-way operational work zones in comparison with the benefits and costs of the utilization of temporary traffic control devices for similar work zones. The rationale for the analysis was to maximize the utilization of governmental funding of transportation projects for public use and a benefit-to-cost analysis is one method for documenting the decision-making process. The benefit-to-cost analysis utilized the data from the field evaluation as well as the microsimulation evaluation and its accompanying sensitivity analysis. Several types of costs have been utilized in the analysis and are provided in Table 5.

Table 5. Benefit-to-Cost Analysis Categories

Governmental Agency Costs	Road User Costs	Nonroad User Costs
Engineering Design and Planning	Travel Time	Noise
Work Zone Traffic Control Devices	Delay	
Maintenance of Work Zone Traffic Control Devices	Crashes	

For the purpose of this analysis, it was assumed that the engineering design and planning costs would be similar for work zones designed with either temporary traffic signal devices or DADs as both require coordination among the various traffic signals at the end of the work zone as well as at each driveway within the work zone. While the costs may be initially higher for DADs at the onset due to the lack of experience for designers, over time the costs should stabilize and be similar to that of temporary traffic signal devices. In the same vein as the engineering design and planning costs, contractor productivity was considered. The productivity rates for the State Route 60 project, production days for the DAD driveway-controlled work zones were compared to the temporary traffic signal device work zones. The production days for either type of work zone were equivalent to each other, with the DAD driveway controlled work zone completing a phase one day earlier. Therefore, contractor productivity was not considered in the benefit to cost analysis as a conservative approach.

The work zone plan assumed for the analysis included a two-lane, two-way roadway that would be constructed by part-width indicating that one lane would be closed along the roadway for the duration of the project. It was also assumed that the lane closure in the work zone would be one-mile in length. The construction closure was assumed to begin in March and reopen by the end of November to traffic yielding a nine-month construction period per year. As many construction projects are multi-year, the analysis utilized a one-year period to establish the benefit-to-cost ratio. For multi-year projects, the benefits-to-costs would be reflective of the annual cost.

Due to the single lane closure throughout the duration of the project, temporary traffic signal devices would be utilized at the work zone ends to control the one-way traffic through the work zone. Therefore, the cost of the mainline traffic signals was not included in the benefit-to-cost analysis as they would be included in either scenario utilized. The work zone traffic control that was evaluated was solely the initial cost of the DADs and the temporary traffic signal devices utilized to control driveways throughout the one-lane closure. The cost for a temporary traffic signal device was set at $5600 per month while a DADs cost was set at $1800 per month. In terms of maintenance, each of the devices would require generators in addition to the solar panels in order to assure operation over a 24-hour period. The number of generators required differs based upon the type of the DAD utilized. The solar panel of a DAD device could be located at the bottom of the trailer which leads to a loss of power to the device after being in operation for 6 weeks; however, placing the solar panel on top of the traffic indications allows the device to maintain the charge. Therefore, the benefit-to-cost analysis was conducted for the DADs with the cost for an additional generator per DAD at a cost of $500 every six weeks throughout the duration of the project. This also yields a minimum of six additional maintenance services for each DAD with the solar panel located near the bottom of the trailer on the construction site annually which has been set at a cost of $250 per maintenance service.

The road user costs affiliated with the operation of the vehicle were subdivided into two categories; passenger vehicle and heavy vehicle. The types of vehicles observed along State Route 60 were used as the basis for the determination of the operating parameters of the vehicle types. The average salary for Blue Ash, Ohio was found to be approximately $56,000 per year which amounts to an hourly wage of $26.92 per hour. This hourly wage rate was set as the passenger vehicle value of time where as a rate twice that was set for the heavy vehicles. The number of vehicles was based upon the current annual average daily traffic volumes along State Route 60 and broken down by northbound and southbound directions of travel. It was assumed that 82-percent of the vehicles were passenger vehicles and 13-percent were heavy vehicles. Due to the presence of a work zone, an additional five-percent of heavy vehicles were included in the traffic percentages for a total of 18-perent heavy vehicle types.

In terms of crashes, the National Safety Council publishes the cost of motor-vehicle crashes based upon wage and productivity losses, medical and administrative expenses, the actual damage to the motor vehicle and the employers' costs. As such, the average economic cost (NSC, 2020) of a fatal crash is $1.75 million, the cost of an injury type A is $101,000, the cost of an injury type B is $29,000, the cost of an injury type C is $23,900, and a property damage only crash cost is $4700. Based upon the percentages of conflict identified from the field study and the time-to-collision parameters collected from the microsimulation analysis, assumptions of the type of crash have been made to apply a crash cost to the traffic control device scenarios. The two considerations were the non-compliant, unsafe and the unsafe conditions which could result in either a rear-end/sideswipe crash or a head-on collision, respectively. It was assumed that rear-end or sideswipe crashes with a time-to-collision greater than three-seconds would result in a property damage only crash and for a time-to-collision less than three-seconds would result in an injury type C crash. For the circumstances of the head-on collision, the type of crash was related to the travel speed of the platoon along the lane closure. If the speed was greater than 45 miles per hour, a fatal crash was assumed to occur. For speeds between 45 and 35 miles per hour, an injury type B crash was assumed to occur. It was assumed any lower speeds would likely result in an injury type C for a head-on collision.

While there are non-road user costs affiliated with the project due to noise of both the physical construction and the generators for the traffic control devices, the cost affiliated with such was deemed to be similar for either the temporary traffic signal device or the DAD utilization. Therefore, non-road user costs were not utilized in the analysis.

Research Findings and Conclusions

Statistical Analyses

The operational and safety measures of effectiveness were analyzed with parametric and non-parametric statistical analyses to identify any differences between work zones with DADs and those with traditional temporary traffic signal devices controlling driveways through work zones. The statistical analyses indicated whether the operational and safety measures within the studied work zones were attributable to the presence of the DADs or simply chance. The statistical analyses were conducted on the following elements of the project:

- Field Study
    - Work zones with driveways controlled with temporary traffic signal device versus work zones with driveways controlled with DADs
        - Comparison of driveway delay, queue length (driveway and mainline roadway), level of compliance at driveways, mainline vehicular speed within the work zone
- Field Study and Microsimulation
    - Field study temporary traffic signal device data versus microsimulation temporary traffic signal device results and field study DAD data versus microsimulation DAD results
        - Comparison of driveway delay, and queue length (driveway and mainline roadway)
- Microsimulation
    - Simulated work zones with driveways controlled with temporary traffic signal device versus simulated work zones with driveways controlled with DADs
        - Comparison of delay (driveway and mainline), queue length (driveway and mainline roadway), travel time through the work zone, and number of queue stops with VISSIM
        - Comparison of time-to-collision, post-encroachment time and conflict types (all types, crossing and rear-end) with Surrogate Safety Assessment Model (SSAM)

Field Study Analyses

Based upon the collected field data, the percentage of driver's complying with the devices, the time waiting at the device, and the driveway queue were calculated for both work zones utilizing the temporary traffic signal devices and the DADs at driveways for traffic control. In addition, data was collected along the mainline roadway, State Route 60, at each end of the work zones utilizing both the temporary traffic signal devices and the DADs at the driveways. The data collected at the driveways as well as along State Route 60 for the mainline traffic is presented in Table 6.

Table 6. Driver Compliance and Operational Data Results

Performance Measure		DAD Devices	Temporary Traffic Signal Devices
Compliance	Complied with Device Signal	80.00%	22.27%
	Did Not Comply with Device Signal	20.00%	77.73%
Driveway Waiting Time	Delay in Seconds (Minutes)	48 (0.80)	88.8 (1.48)
Driveway Queue Length	Number of Vehicles	1.14	1.08
Mainline Travel Speed (within the work zone)	Miles per Hour	15.08	20.88
Mainline Queue Length	Number of Vehicles	4.84	7.10

Table 7 provides further details regarding the compliance and safe maneuvers of motorists for both the temporary traffic signal devices and the DAD devices. The first two columns indicate the overall compliance throughout the work zones. The second two columns indicate the compliance specifically at driveways located at the end of the work zone (EWZ) where motorists were able to monitor the mainline traffic signal phase. Additional details of the data collected with the field study are provided in Appendix C.

Table 7. Driver Safety Data Results

Safety Measure		DAD Devices	Temporary Traffic Signal Devices	Nearest EWZ Driveway DAD Devices	Nearest EWZ Driveway Temporary Traffic Signal Devices
Compliant		80.00%	22.27%	82.6%	52%
Non-Compliant	Safe	2.58%	30.81%	0%	19%
	Unsafe	5.16%	27.96%	2.2%	4.8%
Unsafe		12.26%	18.96%	15%	24%

Overall, the DADs for driveway control performed better than the traditional temporary traffic signals devices. The following specific conclusions regarding DADs can be drawn from the field study along State Route 60:

- DADs yielded statistically shorter delays at driveways and shorter queue lengths along the mainline roadway at the end of the work zone.
- DADs yielded statistically slower vehicular speeds through the work zone.
- DADs yielded statistically higher levels of driver compliance.
- The placement of DADs in the work zone does not impact driver compliance.

A detailed discussion of the field study results are provided in Appendix E.

Field Study and Microsimulation Analyses

As the collection of field data related to operational characteristics along roadway networks is not only time consuming but also costly, simulation emerged as an alternative method which allows for experimental control, efficiency, low cost and ease of data collection. However, the validity of the simulation as a research tool is an important issue to consider. It was found that the microsimulation model, while not perfectly correlated to the field conditions, yielded approximately 3.5 times greater operational delays and queues than the field study, yet was loaded with 4 times as many vehicles at the driveways in order to yield quantifiable results. Therefore, the microsimulation results can be considered a valid representation of the field conditions. A detailed discussion of the field study and microsimulation comparison is provided in Appendix E.

Microsimulation Analyses

There were various microsimulation analyses that were conducted including the comparison of results from the temporary traffic signal device to the DADs for the driveway operational parameters, as well as the mainline operational parameters for work zone #1 and work zone #3. All of the data collection was analyzed to test the null hypothesis that there were no significant differences between the operational performance in work zones with driveways controlled by temporary traffic signal devices or DAD devices. To evaluate the safety performance of the work-zone segments with DADs and temporary traffic signal devices, a conflict analysis was conducted using the Surrogate Safety Assessment Model (SSAM) software utilizing time-to-collision, post-encroachment time and conflict types (crossing and rear-end maneuvers). Overall, the following conclusions can be drawn from the microsimulation analysis in regards to the work zones simulated along State Route 60:

- DADs for driveway control statistically yield shorter delays and queue lengths at driveways.
- DADs for driveway control statistically yield shorter travel times through the work zones studied.
- DADs for driveway control statistically yield shorter queue delays and lengths along the mainline roadway at the end of the work zone.
- Temporary traffic signal devices for driveway control statistically yield fewer number of queue stops along the mainline roadway through the work zone.
- Geometric alignment of the roadway, such as roadways with curves having driveways on the inside and the outside of the curve, may lead to increases in time-to-collision, post-encroachment time and conflicts. Work zone #1 was based along a straight alignment of State Route 60 and had fewer time-to-collision and post-encroachment times, and fewer conflicts than work zone #3 which was along a curved portion of State Route 60.

A detailed discussion of the microsimulation analysis is provided in Appendix E.

Sensitivity Analysis

In order to explore the safety and operation performances of DADs under different traffic parameter settings of the work zone network, a sensitivity analysis was performed for work zone #1 due to its straight roadway segment and consistent performance in the simulation analysis. Overall, the following conclusions can be drawn from the sensitivity analysis in regards to the work zone #1 simulated along State Route 60:

- DADs for driveway control maintain driveway delays of on average less than 50 seconds per vehicle with 30 to 50 vehicles per hour utilizing the driveway.
- DADs for driveway control have stable time-to-collision and post-encroachment time values with 50 or fewer vehicles per hour utilizing the driveways.
- Additional mainline traffic volumes up to 5000 vehicles per day yields a maximum of 14 vehicles queuing along the mainline roadway at the end of the work zone.
- Longer all-red signal timings do not substantially increase queue delays at driveways.

A detailed discussion of the sensitivity analysis is provided in Appendix E.

Benefit-to-Cost Summary

Due to the small sample size of the field data evaluation, the microsimulation operational parameters were utilized in the benefit-to-cost analysis. The benefit-to-cost analysis included the calculation of several types of road user costs including the cost of driveway delay per day, travel speed cost per day, queue delay cost per day and conflict costs per day in addition to the maintenance and initial costs for the devices. The construction season was assumed to be nine-months in length or 275 days. A summary of the costs are provided in Table 8 with additional details in Appendix D.

Table 8. Costs Summary

Type of Calculation	Temporary Traffic Signal Device	DAD Device
Traffic Control Costs	$50,400	$16,200
Additional Maintenance Costs	$0	$3000
Additional Generator Costs	$0	$1500
Driveway Delay Cost per Year	$21,912.88	$11,844.80
Travel Speed Cost per Year	$787,596.90	$155,308.80
Queue Delay Cost per Year	$740,505	$126,894.40
Conflict Cost per Year	$418,632,500	$282,768,750
Total Road User Costs Per Year	$420,182,515	$283,662,798
Total Road User Costs without Conflict Cost	$1,550,015	$894,048

As crash costs typically can sway a benefit-to-cost analysis, the benefit-to-cost ratio was determined without the conflict costs. The overall benefit-to-cost ratio only considering the device and maintenance cost was 7.6:1 whereas with the road user cost (less the conflict costs) the ratio was 153.37:1. Including the conflict costs would increase the benefit-to-cost ratio to over 250:1. Therefore, the benefits of using the DADs greatly outweigh those of the temporary traffic signal devices for driveway control.

The road user cost that has the greatest impact on the benefit-to-cost ratio is the queue delay cost for the mainline vehicular traffic, which include the construction vehicles. The queue delay cost per day for the temporary traffic control devices for driveway control is nearly six-times more than the cost for the DADs. The benefit of the operational flow of traffic along the mainline while utilizing the DADs is critical and constitutes the greatest benefit for the utilization of the DADs.

Research Gaps

Due to the low volume, the number of driveways and the type of driveways along rural roadways, the sample size collected during the 18 continuous days of data observation did not produce a substantial portfolio for the DADs. However, this research project is among many that have arrived at similar conclusion regarding the efficacy of the DADs and the entirety of the research portfolio on DADs should be considered when decisions are made regarding their utilization.

The safety analysis (based on surrogate measures) indicated that geometric alignment may increase conflicts and thereby reduce safety within the work zone. Therefore, geometric alignments with extensive roadway curvature should be further evaluated.

Recommendations for Implementation

The results of the research study indicate that the DADs provide the following benefits over the temporary traffic signal devices for driveway control:

- Reduced driveway delays
- Reduced mainline queue lengths (and delays) at the end of the work zone
- Improved driver compliance, especially for driveways located near the end of the work zone

Implementation

Based upon the results of the safety and microsimulation analysis, it is recommended that the DADs will perform satisfactorily when utilized as follows:

- At driveway locations with less than 30 to 50 vehicle per hour to keep levels of service at driveways below 50 seconds of delay.

- Mainline volumes of 5000 vehicles per day in each direction will yield a 14-vehicle queue length at the end of the work zone.
- The signal phasing should be designed to provide optimal travel flow for the mainline traffic and minimize the time allowable for the driveways as the delay at the driveways is not impacted by signal phasing.
- Geometrically straight work zone sections of roadway will have better safety outcomes than those with roadway curvature.

In order to determine the maximum length of a work zone, the highway capacity software should be utilized to model a signal at each end of the work zone to maximize the green phase while minimizing the queue length along the mainline as this is the most critical operational performance measure as well as road user cost element.

Due to the additional costs affiliated with the DADs with solar panels located at the bottom of the trailer, the DAD devices with the solar panels mounted above the signal heads should be utilized.

Various homeowners noted concerns with the noise of the generators located at the temporary traffic signals as well as the DADs; therefore, it would be helpful if advanced notification were provided to homeowners regarding the potential noise, the necessity for the devices and the duration in which to expect the situation to last. Given the nature of construction, updates to the homeowners may be helpful throughout the project in order to notify them in advance that the project is either on or not on schedule.

Expected Benefits and Costs

The most costly element, in terms of road user costs, are the queue delay cost along the mainline roadway affiliated with the end of work zone queues as well as the cost of crashes. Without the safety costs, the benefit-to-cost ratio for the DAD devices is over 153:1. There is substantial benefit and minimal costs associated with the utilization of the devices. To continue to minimize the benefits, the DAD devices with the solar panels located above the signal heads should be utilized.

Potential Safety and Operational Risks

As with any device utilized within a work zone, the risks are proportional to driver compliance particularly as traffic volumes increase along the roadway network. With both of the temporary traffic signal devices and the DADs, there were motorists that proceeded to travel against the flow of traffic, albeit typically near the end of the work zone where they could visually see vehicles stopped prior to the work zone. However, the compliance with the DADs is much higher than the compliance affiliated with the temporary traffic control devices. Therefore, any safety risk that will exist with the DAD devices would be substantially higher with the temporary traffic control devices. As such, the DADs provide a much safer work zone traffic control measure for driveway control than what has been utilized in the past and the benefits far outweigh the safety and operational risks.

Future Performance Evaluation

As the microsimulation analysis identified increased traffic conflicts along a roadway with a curvature in the geometric alignment, future evaluation should be considered for roadways with excessive degrees of curvature present within the work zone to assure the safety conflicts do not translate into vehicular crashes. While driveway volumes were analyzed with microsimulation and found to work with the DADs, commercial driveways with more than 30 to 50 vehicles per hour should be further evaluated prior to their installation.

Appendices

Appendix A Literature Review

The concept of DADs was developed approximately a decade ago to improve the practicality of roadway maintenance along two-lane, two-way roadways over an extended construction period where the use of flaggers (either automated or manual and with or without pilot vehicles) and temporary traffic signals at each driveway along the work zone was impractical and cost-prohibitive.

In 2009, the Texas Department of Transportation (TxDOT) began developing device concepts to control traffic from access points within a two-way, one-lane construction zone (8). The first device developed was a 'Modified Stop Sign Device' which led to questions of legality, interpretation, and entrapment of wrong-way vehicles within the lane closure. This led to the development of a 'Hybrid Device', shown in Figure A-1, which was a combination of a portable temporary traffic signal and an automated flagger assistance device (8). The device utilizes a steady red indication in the middle and two flashing/steady yellow arrow indications on either side of the steady red. The steady yellow arrow indication was utilized to serve as a change interval between the flashing yellow arrow and the steady red indication. The device would be placed at driveways within the work zone and would be synchronized with the portable temporary control signals at either end of the work zone. There were initial concerns with the hybrid device including motorist confusion regarding the yield nature of the yellow arrow as well as the additional regulatory signs which may also create confusion and information overload for drivers.

Figure A-1. TxDOT Hybrid Device (8)

In consultation with the Federal Highway Administration (FHWA), TxDOT and the Texas Transportation Institute (TTI) modified the 'Hybrid Device' ('Modified Hybrid Device') utilizing a “doghouse” style signal moving the arrow indications below the steady red indication and side-by-side (8). The device would operate in the same manner as the hybrid device and would only utilize the ‘No Turn on Red’ (NTOR) regulatory sign. While considering the modified hybrid device, researchers also reviewed the potential for dual arrow signal indications, combinations of red, yellow arrow and green arrow indications, and illuminated blank-out signs displaying movement prohibition signs. The modified hybrid device and the illuminated blank-out sign option, shown in Figure A-2, were further studied in the field to determine their effectiveness in terms of operation and safety. The other options described above were not moved forward to field evaluation due to cost.

Figure A-2. Blank-Out Sign Device (8)

Prior to the field evaluation of the modified hybrid device and the illuminated blank-out sign device by TxDOT and TTI, the New Jersey Department of Transportation (NJDOT) had an urgent need for roadway construction along Route 35 where the storm surge from Hurricane Sandy (in 2012) destroyed portions of Route 35 in several locations. Route 35 was the main access for residential homes which led to difficulty controlling traffic along the one-lane work zone during construction (10). As there were 31 residential driveways along this stretch of Route 35, flaggers at each driveway were cost-prohibitive and providing right-of-way for individual driveways caused substantial queues resulting from the increased cycle lengths at the portable temporary traffic signals at the ends of the work zone. Horizon Signal Technologies worked with NJDOT on the prototype signal, DADs, that would allow for simultaneous control of multiple driveways along the work zone without increasing cycle lengths and their resulting queues. The DAD utilized included a steady red indication and two flashing red arrow indications on either side. The DAD utilized along Route 35 in New Jersey is shown in Figure A-3 (10). It should be noted that the DAD is the configuration that ODOT will utilize during this research project. NJDOT utilized a DAD at each driveway and all the DADs flashed arrows in the same direction of travel simultaneously. The DADs were utilized for 13 months during construction of Route 35, managed heavy volumes of traffic and nearly eliminated all wrong-way incidents throughout the reconstruction (11). The Route 35 project was key to the research efforts of the DADs due to its emergency use.

Figure A-3. Horizon Signal Technologies DAD

The following summer after Hurricane Sandy in 2013, TxDOT and TTI began conducting field studies on the modified hybrid device and the blank-out sign device, shown in Figures 1 and 2, respectively (8). A non-controlled field study was conducted with one day of data collected for each device type and a controlled field study was conducted using 16 participants as passengers. The controlled field study found that 100-percent of the drivers reacted correctly to the blank-out sign device and 43-percent of drivers were stopped from making a wrong turn when the modified hybrid device was in use. The controlled field study also included a survey of the participants and indicated that all drivers, regardless of device utilized, understood they needed to yield to the mainline traffic and could not turn when a steady red signal was present. While there was confusion regarding the phasing of the modified hybrid device, both the motorists and researchers believed that with education and experience the motorists would understand the device. During the non-controlled study, 39 motorists were observed interacting with the modified hybrid device (8). Three drivers turned the wrong way onto the mainline and two drivers turned during the steady red indication, this accounted to 13-percent non-compliant drivers. Only 13 motorists were observed interacting with the blank-out sign device and three or 23-percent were found to be in non-compliance with the device of which two of those turned during the steady red indication and joined the back of the mainline platoon (8). The TxDOT/TTI study provided promising results for both of the devices utilized in the field experiment; however, the sample size was extremely low in both situations and likely not statistically significant.

TxDOT/TTI also conducted motorist surveys to examine motorist understanding of the experimental devices utilized in the field studies. 320 participants, 18 and older, were utilized in the study that were recruited at driver license offices in the State of Texas (8). The participants viewed a video sequence of one of the DAD devices as the signal indications transitioned through phases and then answered questions related to what their driving response would be in the situation. The researchers found that both the Modified Hybrid Device and the blank-out device were understood by 85-percent or more of the participants; however, participants were unsure if they had to come to a complete stop before turning for the Modified Hybrid Device particularly without the 'No Turn on Red' regulatory sign (8).

In the summer of 2015, the Michigan Department of Transportation (MDOT) undertook a case-study type evaluation of the Horizon Signal Technologies DAD along five different projects through 2018 (9). The device utilized for the study was slightly modified from that utilized by NJDOT by using a 'Proceed on Flashing Red Arrow After Stop' sign instead of the 'Yield in Direction of Flashing Red Arrow After Stop' utilized by the NJDOT. Figure A-4 depicts the DAD studied in Michigan.

Figure A-4. MDOT DAD Device (9)

Over the five project study sites, MDOT observed 3,026 motorist interactions with the DAD devices (337 along M-44, 703 along M-68, 20 along US-23, 1890 along M-66 and 76 along US-31) (12). MDOT found that for all the sites, 82.8-percent of the motorists obeyed the DAD device correctly, remained stopped on red and only proceeded under the flashing arrow, and another 15.7-percent proceeded incorrectly but in a safe manner, motorists stopped on the solid red indication and proceeded to turn in the direction of travel at the end of the mainline platoon (12). This provides an overall safe behavior pattern of 98.5-percent of all interactions with the DADs (12). Some of the issues raised during the MDOT study included visibility of the portable temporary traffic signals while a motorist was located at a driveway controlled by the DAD, traffic signal timing adjustments based upon traffic volumes along the mainline as well as the driveway to provide gaps for driveway traffic, and driveway geometric alignment for queuing. The MDOT study also recommended evaluating the limitations of the DAD at locations with higher volumes, such as commercial driveways and residential roadways.

As part of the FHWA 2016 Work Zone and Guardrail Safety Grant Program, Michigan State University (MSU) conducted a national survey of drivers over the age of 18 and received 1,015 responses evenly split among genders and with a median age between 35 and 44 (9). The objective of the survey was to determine drivers understanding of various aspects of the DADs sign message, display arrangement and arrow color, and the necessity of the 'No Turn On Red' sign. Using a Qualtrics platform, survey respondents were presented with different scenarios and configurations of the DAD system. Driver respondents decided correctly 35-percent more frequently with the presence of the 'No Turn On Red' sign on the DAD system (9). The respondents also responded favorably to sign messages stating 'Turn Only in Direction of Arrow', 'WAIT Turn Only in Direction of Arrow', and 'WAIT For Arrow Before Turning'. The two signs with 'Yield' in the message were not as well understood by the survey respondents, although the yield concept is commonly utilized for low-volume intersections, roundabouts and freeway entrance ramps across the nation. When combined with the 'No Turn On Red' regulatory sign, both the 'Turn Only in Direction of Arrow' and 'WAIT Turn Only in Direction of Arrow' were understood better. In terms of the display arrangement, both the 'doghouse' and horizontal arrangement were understood nearly equally and better than a 4-signal head configuration, which is one configuration currently being studied in Nebraska. When asking respondents about actions to take when faced with a flashing yellow or flashing red arrow, the presence of the flashing red arrow led respondents to stop and turn when traffic was clear a significantly higher proportion of the time. MSU is also conducting a field study in collaboration with MDOT to evaluate the same configurations of DADs as studied with their national survey (9). The field study confirmed the results of the national survey with the 'WAIT' signs resulting in 72-percent higher legal and safe turning movements (9). Additional analysis needs to be conducted on the illegal and unsafe movements to fully understand the implications and rationale why the movement occurred. It was hypothesized that the illegal maneuvers occurred when the drivers could not see the mainline traffic which led to confusion on what to do and ultimately impatience led to poor behaviors. The MSU study also indicated future research is needed in the areas of signal timing with coordination and clearance intervals, the placement of the DADs in respect to the temporary traffic signals for the mainline, and four-way intersections.

Almost half of the states in the nation, as seen if Figure A-5, either have FHWA experimental projects underway, have non-FHWA projects or interest expressed in the use of DADs for two-lane, two-way construction projects in order to maintain traffic through the work zone in a safe and efficient manner (9).

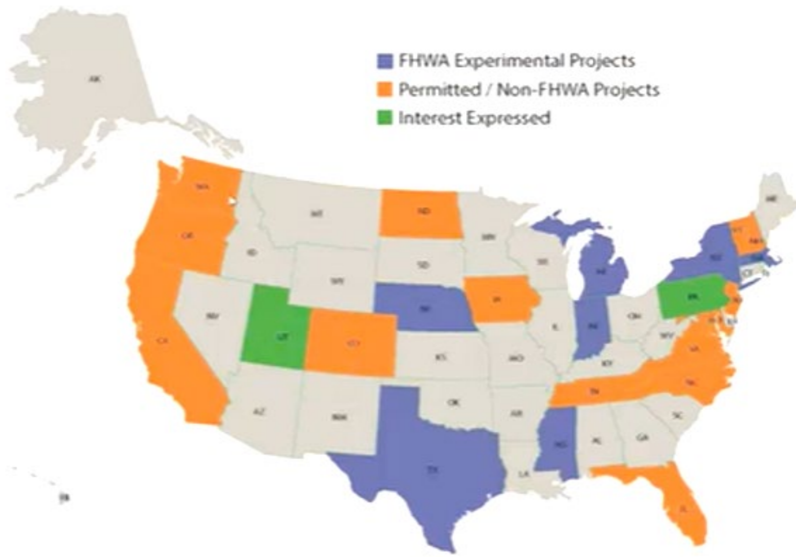

Figure A-5. National Interest in DAD Devices (9)

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Appendix B Survey Instruments

Driver Survey

Demographics

Gender

- ◯ Male
- ◯ Female
- ◯ Prefer not to answer

How old are you?

- ◯ Under 18
- ◯ 18-24 years old
- ◯ 25-34 years old
- ◯ 35-44 years old
- ◯ 45-54 years old
- ◯ 55-64 years old
- ◯ 65+ years old

What is the highest level of education you have completed?

- ◯ Some High School
- ◯ High School
- ◯ Some College
- ◯ Associate's Degree
- ◯ Bachelor's Degree
- ◯ Master's Degree
- ◯ Ph.D. or higher
- ◯ Trade School
- ◯ Prefer not to say

In this section, shown is the Driveway Assisted Device is showing a red indication.

Can you turn onto the main road?

- ◯ Yes
- ◯ No
- ◯ Unsure

Which direction can you turn?

- ◯ Right
- ◯ Left
- ◯ Right and Left
- ◯ Unsure
- ◯ Neither

Which direction can't you turn?

- ◯ Right
- ◯ Left
- ◯ Right and Left
- ◯ Unsure
- ◯ Neither

In this section, shown is the Driveway Assisted Device is showing an arrow indication.

Can you turn onto the main road?

- ◯ Yes
- ◯ No
- ◯ Unsure

Which direction can you turn?

- ◯ Right
- ◯ Left
- ◯ Right and Left
- ◯ Unsure
- ◯ Neither

Which direction can't you turn?

- ◯ Right
- ◯ Left
- ◯ Right and Left
- ◯ Unsure
- ◯ Neither

Which direction can't you turn?

- ◯ Right
- ◯ Left
- ◯ Right and Left
- ◯ Unsure
- ◯ Neither

Which direction do you think vehicles on the main road are going?

- ◯ Left
- ◯ Right
- ◯ Unsure

Do you need to yield to vehicles on the main road?

- ◯ Yes
- ◯ No
- ◯ Unsure

Do you have to come to a complete stop before turning?

- ◯ Yes
- ◯ No
- ◯ Unsure

Do you have any comments or concerns about the Driveway Assisted Device you viewed?

User Survey

How do you describe yourself?

- Male
- Female
- Non-binary / third gender
- Prefer to self-describe
- Prefer not to say

How old are you?

- under 20 years old
- 20 – 30 years old
- 30–45 years old
- +45 years old
- Prefer not to answer

What is the highest level of education you have completed?

- Some high school or less
- High school diploma or GED
- Some college, but no degree
- Associates or technical degree
- Bachelor's degree
- Graduate or professional degree (MA, MS, MBA, PhD, JD, MD, DDS etc.)
- Prefer not to say

What is your role in the project?

- Construction personnel
- Contractor member
- Consultant member
- ODOT member

Do you think highway safety in construction work zones is related to construction productivity?

- Yes
- Maybe
- No

Please rate the factors that you think might affect or influence road construction productivity. (Using a scale of 0= Not at all important to 5= extremely important)

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Work conditions (Job size and complexity, site accessibility, equipment use, safety risks, and work zone setup)	○	○	○	○	○
Labor characteristics (Age, skill, experience, leadership, and motivation of the workforce)	○	○	○	○	○
External events (weather events, lack of material and equipment, inspection delays, indirect labor, and work stoppages)	○	○	○	○	○

Do you think the correct deployment of temporary traffic control devices could help to prevent safety risks in road construction?

- Yes
- Maybe
- No

Do you believe that the total cycle lengths, as well as the phases (green, yellow and red intervals) of the traffic control devices within the work zone, can be optimized?

- Yes
- Maybe
- No

Driveway Assistant Device (DAD)

Traditional Assistant Device

Which of the following temporary traffic control devices do you prefer in work zone with Driveways?

- Driveway Assistant Devices
- Traditional Control Devices

How do you feel when driving and/or walking through the work zone where Driveway Assistant Devices are deployed?

- Safer than driving/walking through the work zone with Traditional Devices
- Less safe than driving/walking through the work zone with Traditional Devices
- Safe in both work zones
- Unsafe in both work zones

Have you ever experienced an excessive delay waiting in the queues trying to enter to the work zone?

- Yes, in work zones where traditional devices were deployed
- Yes, in work zones where Driveway Assistant Devices were deployed
- Yes, in both work zones
- No, I have never experience a delay in any of the work zones

Do you think construction works get delayed due to the excessive time construction vehicles have to wait in the queues before entering the work zone?

- Yes
- Maybe
- No

Which of the following statements do you consider best describes the advantages of using Driveway Assistant Devices (DADs) in work zones? (allow to select more than one option)

- Increases work zone safety: it clearly indicates the direction of traffic flow.
- Improves traffic efficiency: cycle lengths and queues are kept at a minimum
- Unlimited quantities wirelessly connect an unlimited number of DADs
- Sequential Operation, flashing arrows are activated and deactivated sequentially
- All the above
- None of the above

Do you think that by lengthening the work zones in highway projects, construction productivity could increase? If yes, explain why.

- Definitely
- Maybe
- No

Have you seen any improvement in construction productivity in the zone where DADs were placed?

- Yes
- No

Do you think construction activities in the zone with Driveway Assistant devices were completed faster than in the zone with traditional devices?

- Yes
- No

Appendix C Field Study Results

DAD Devices Summary																
Camera Base	Camera Name	Day	Time	Direction of Travel	Turn Direction	Mainline Direction of Travel	Time of Arrival at Driveway Location	Time of Departure at Driveway Location	Time Waiting	Queue Length in Driveway	Any conflict with mainline Vehicles	Turn Compliance; Compliant	Turned within 150' of adjacent Vehicle	Turned Against the flow of traffic; UnSafe	Non-Compliant; Safe	Non-Compliant; Unsafe
DR 78	SCU 8AB	6/28/2022	7:04:33	WB	NB	NB	7:04:33	7:07:52	0:03:19	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/28/2022	11:27:26	WB	NB	NB	11:27:26	11:28:08	0:00:42	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/29/2022	7:05:53	WB	NB	NB	7:05:53	7:06:16	0:00:23	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/29/2022	9:22:31	WB	NB	NB	9:22:31	9:22:50	0:00:19	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/29/2022	19:40:50	WB	NB	NB	19:40:50	19:43:35	0:02:45	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	6:50:07	WB	SB	SB	6:50:07	6:50:16	0:00:09	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	7:07:26	WB	NB	NB	7:07:26	7:07:50	0:00:24	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	7:39:20	WB	SB	SB	7:39:20	7:39:29	0:00:09	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	8:47:27	WB	NB	NB	8:47:27	8:47:53	0:00:26	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	9:04:32	WB	NB	NB	9:04:32	9:04:54	0:00:22	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	9:41:36	WB	SB	NB	9:41:36	9:41:42	0:00:06	1	NO	NO	YES	YES	NO	NO
DR 78	SCU 8AB	6/30/2022	11:39:51	WB	NB	NB	11:39:51	11:41:23	0:01:32	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	6/30/2022	16:15:04	WB	NB	NB	16:15:04	16:15:27	0:00:23	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/1/2022	7:07:14	WB	NB	NB	7:07:14	7:09:24	0:02:10	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/1/2022	7:45:00	WB	SB	SB	7:45:00	7:45:18	0:00:18	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/1/2022	8:47:38	WB	NB	NB	8:47:38	8:49:40	0:02:02	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/1/2022	11:24:00	WB	NB	NB	11:24:00	11:26:25	0:02:25	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/1/2022	15:52:22	WB	NB	NB	15:52:22	15:53:19	0:00:57	1	YES	NO	YES	NO	NO	YES
DR 78	SCU 8AB	7/2/2022	10:20:59	WB	NB	NB	10:20:59	10:21:22	0:00:23	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/2/2022	14:45:09	WB	NB	NB	14:45:09	14:48:06	0:02:57	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/2/2022	20:36:40	WB	NB	NB	20:36:40	20:38:20	0:01:40	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	11:00:01	WB	SB	SB	11:00:01	11:00:13	0:00:12	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	11:20:10	WB	NB	NB	11:20:10	11:22:40	0:02:30	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	14:52:06	WB	NB	NB	14:52:06	14:53:02	0:00:56	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	17:11:47	WB	NB	NB	17:11:47	17:13:03	0:01:16	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	22:50:09	WB	NB	NB	22:50:09	22:50:17	0:00:08	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	22:53:30	WB	NB	NB	22:53:30	22:53:36	0:00:06	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/3/2022	23:15:09	WB	NB	NB	23:15:09	23:16:47	0:01:38	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/4/2022	10:07:27	WB	NB	NB	10:07:27	10:07:45	0:00:18	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/4/2022	10:49:35	WB	NB	NB	10:49:35	10:51:13	0:01:38	1	NO	YES	YES	NO	NO	NO
DR 78	SCU 8AB	7/4/2022	19:32:36	WB	NB	NB	19:32:36	19:34:59	0:02:23	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/28/2022	5:56:38	WB	SB	SB	5:56:38	5:56:42	0:00:04	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/28/2022	14:20:00	WB	SB	SB	14:20:00	14:20:04	0:00:04	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/28/2022	16:58:22	WB	NB	NB	16:58:30	16:58:30	0:00:00	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/29/2022	5:28:55	WB	NB	NB	5:28:55	5:29:40	0:00:45	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/29/2022	10:36:00	WB	NB	NB	10:36:00	10:36:15	0:00:15	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/29/2022	16:09:50	WB	NB	NB	16:10:00	16:10:00	0:00:00	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	6/30/2022	21:01:32	WB	NB	NB	21:01:32	21:02:10	0:00:38	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	7/1/2022	11:16:30	WB	NB	NB	11:16:30	11:16:48	0:00:18	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	7/1/2022	13:32:50	WB	SB	NB	13:32:50	13:33:34	0:00:44	1	YES	NO	YES	YES	NO	NO
DR 79	SCU 50G	7/1/2022	13:56:10	WB	NB	NB	13:56:10	13:56:30	0:00:20	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	7/1/2022	15:44:55	WB	NB	SB	15:44:55	15:45:45	0:00:50	1	NO	NO	YES	YES	NO	NO
DR 79	SCU 50G	7/2/2022	9:33:00	WB	SB	SB	9:33:00	9:33:05	0:00:05	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	7/2/2022	11:54:25	WB	NB	NB	11:54:25	11:54:40	0:00:15	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	7/2/2022	17:21:00	WB	SB	NB	17:21:00	17:21:52	0:00:52	1	NO	NO	YES	YES	NO	NO
DR 79	SCU 50G	7/2/2022	17:35:46	WB	NB	SB	17:35:46	17:37:18	0:01:32	1	NO	NO	YES	YES	NO	NO
DR 79	SCU 50G	7/2/2022	20:58:01	WB	NB	NB	20:58:01	20:58:11	0:00:10	1	NO	YES	YES	NO	NO	NO
DR 79	SCU 50G	7/3/2022	9:39:11	WB	NB	SB	9:39:11	9:39:17	0:00:06	1	NO	NO	YES	YES	NO	NO
DR 79	SCU 50G	7/3/2022	11:18:28	WB	SB	NB	11:18:28	11:19:38	0:01:10	1	NO	NO	YES	YES	NO	NO
DR 79	SCU 50G	7/3/2022	14:12:40	WB	SB	SB	14:12:40	14:12:45	0:00:05	1	NO	YES	YES	NO	NO	NO
DR 81	SCU 15B	6/28/2022	7:58:31	WB	SB	SB	7:58:31	7:59:20	0:00:49	1	NO	NO	YES	NO	NO	YES
DR 81	SCU 15B	6/29/2022	8:02:38	WB	NB	NB	8:02:38	8:03:33	0:00:55	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	6/29/2022	8:05:00	WB	NB	SB	8:05:00	8:06:51	0:01:51	2	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	6/29/2022	8:07:00	WB	NB	SB	8:07:00	8:07:00	0:00:00	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	6/30/2022	8:12:19	WB	NB	SB	8:12:19	8:13:34	0:01:15	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/1/2022	8:16:40	WB	NB	NB	8:16:40	8:17:05	0:00:25	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/1/2022	8:18:23	WB	NB	SB	8:18:23	8:20:13	0:01:50	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/1/2022	11:48:38	WB	NB	NB	11:48:38	11:49:22	0:00:44	5	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/1/2022	11:49:35	WB	NB	NB	11:49:35	11:49:56	0:00:21	2	NO	NO	YES	NO	NO	YES
DR 81	SCU 15B	7/2/2022	11:50:11	WB	SB	SB	11:50:11	11:51:02	0:00:51	2	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/2/2022	11:51:34	WB	SB	SB	11:51:34	11:54:07	0:02:33	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/3/2022	11:52:53	WB	NB	NB	11:52:53	11:52:56	0:00:03	2	NO	NO	YES	NO	NO	YES
DR 81	SCU 15B	7/3/2022	11:52:56	WB	NB	NB	11:52:56	11:53:04	0:00:08	1	NO	NO	YES	NO	NO	YES
DR 81	SCU 15B	6/28/2022	11:54:20	WB	SB	SB	11:54:20	11:54:21	0:00:01	2	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	6/28/2022	11:54:26	WB	NB	SB	11:54:26	11:55:59	0:01:33	6	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	6/29/2022	11:56:31	WB	NB	SB	11:56:31	11:59:19	0:02:48	2	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/2/2022	11:47:19	WB	SB	SB	11:47:19	11:57:20	0:10:01	1	NO	NO	NO	NO	YES	NO
DR 81	SCU 15B	7/2/2022	11:59:25	WB	SB	NB	11:59:25	12:00:52	0:01:27	2	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/2/2022	7:55:08	WB	NB	SB	7:55:08	7:57:47	0:02:39	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/3/2022	8:00:12	WB	NB	SB	8:00:12	8:01:01	0:00:49	1	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/3/2022	8:03:11	WB	NB	SB	8:03:11	8:04:25	0:01:14	2	NO	YES	NO	NO	NO	NO
DR 81	SCU 15B	7/3/2022	8:04:36	WB	SB	NB	8:04:36	8:04:51	0:00:15	1	NO	NO	YES	YES	NO	NO
DR 81	SCU 15B	7/3/2022	8:05:08	WB	NB	SB	8:05:08	8:07:45	0:02:37	3	NO	YES	NO	NO	NO	NO
DR 80	SCU 15B	7/3/2022	1:35:15	EB	SB	NB	1:35:15	1:38:05	0:02:50	1	NO	YES	NO	NO	NO	NO
DR 83	SCU9BA	10/12/2022	8:44:34	EB	NB	NB	8:44:34	8:44:45	0:00:11	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/13/2022	9:27:15	EB	SB	NB	9:27:13	9:27:15	0:00:02	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/13/2022	9:28:13	EB	NB	NB	9:28:13	9:28:16	0:00:03	1	NO	YES	YES	NO	NO	NO

DAD Devices Summary

Camera Base	Camera Name	Day	Time	Direction of Travel	Turn Direction	Mainline Direction of Travel	Time of Arrival at Driveway Location	Time of Departure at Driveway Location	Time Waiting	Queue Length in Driveway	Any conflict with mainline Vehicles	Turn Compliance; Compliant	Turned within 150' of adjacent Vehicle	Turned Against the flow of traffic; UnSafe	Non-Compliant; Safe	Non-Compliant; Unsafe
DR 84	SCU9BA	10/13/2022	12:41:13	EB	NB	NB	12:41:13	12:41:19	0:00:06	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/13/2022	19:15:08	EB	SB	SB	19:15:08	19:16:18	0:01:10	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/14/2022	10:36:35	EB	NB	NB	10:36:35	10:36:41	0:00:06	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/14/2022	15:17:20	EB	NB	NB	15:17:20	15:17:23	0:00:03	1	NO	YES	YES	NO	NO	NO
DR 84	SCU9BA	10/14/2022	19:25:16	EB	SB	SB	19:25:16	19:25:20	0:00:04	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/15/2022	12:12:49	EB	SB	SB	12:12:39	12:12:49	0:00:10	3	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/15/2022	16:49:54	EB	NB	NB	16:49:54	16:50:02	0:00:08	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/15/2022	18:06:20	EB	NB	NB	18:06:20	18:06:25	0:00:05	1	NO	YES	YES	NO	NO	NO
DR 84	SCU9BA	10/15/2022	19:19:10	EB	SB	SB	19:19:10	19:19:16	0:00:06	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/16/2022	8:43:15	EB	SB	SB	8:43:15	8:43:21	0:00:06	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/16/2022	12:36:50	EB	NB	NB	12:36:50	12:37:22	0:00:32	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/16/2022	14:44:45	EB	NB	NB	14:44:45	14:45:00	0:00:15	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/16/2022	18:19:00	EB	NB	NB	18:19:00	18:20:38	0:01:38	2	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/17/2022	5:14:28	EB	NB	NB	5:14:28	5:15:58	0:01:30	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/17/2022	15:26:20	EB	SB	SB	15:26:20	15:26:35	0:00:15	1	YES	NO	YES	YES	NO	NO
DR 83	SCU9BA	10/18/2022	5:50:36	EB	NB	NB	5:50:36	5:53:52	0:03:16	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/18/2022	7:09:22	EB	NB	NB	7:09:22	7:10:22	0:01:00	1	NO	YES	YES	NO	NO	NO
DR 83	SCU9BA	10/18/2022	14:59:03	EB	SB	SB	14:59:03	14:59:15	0:00:12	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/12/2022	17:55:11	WB	NB	SB	17:55:11	17:56:25	0:01:14	1	NO	NO	YES	YES	NO	NO
DR84	SCU75E	10/13/2022	11:25:54	WB	NB	NB	11:25:54	11:26:00	0:00:06	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/13/2022	20:26:10	WB	NB	NB	20:26:10	20:27:34	0:01:24	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/14/2022	3:21:16	WB	NB	NB	3:21:16	3:21:26	0:00:10	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/14/2022	16:02:37	WB	NB	SB	16:02:37	16:02:40	0:00:03	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/14/2022	18:15:48	WB	SB	SB	18:15:48	18:15:52	0:00:04	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/15/2022	16:42:24	WB	NB	SB	16:42:24	16:42:38	0:00:14	1	NO	NO	YES	YES	NO	NO
DR84	SCU75E	10/16/2022	11:49:31	WB	NB	NB	11:49:31	11:49:45	0:00:14	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/16/2022	12:36:08	WB	NB	SB	12:36:08	12:36:35	0:00:27	1	NO	NO	YES	YES	NO	NO
DR84	SCU75E	10/16/2022	13:50:50	WB	NB	NB	13:50:50	13:51:18	0:00:28	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/16/2022	13:54:46	WB	NB	SB	13:54:46	13:54:56	0:00:10	1	NO	NO	YES	YES	NO	NO
DR84	SCU75E	10/16/2022	19:43:00	WB	NB	SB	19:43:00	19:35:09	0:07:51	1	NO	NO	YES	YES	NO	NO
DR84	SCU75E	10/17/2022	11:32:29	WB	NB	NB	11:32:29	11:32:49	0:00:20	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/17/2022	18:05:48	WB	SB	SB	18:05:48	18:06:44	0:00:56	1	NO	YES	YES	NO	NO	NO
DR84	SCU75E	10/18/2022	18:54:00	WB	NB	SB	18:54:00	18:54:05	0:00:05	1	NO	NO	YES	YES	NO	NO
DR 119	SCU 5NQ	10/12/2022	12:58:15	EB	SB	NB	12:58:15	12:58:34	0:00:19	1	NO	NO	YES	YES	NO	NO
DR 119	SCU 5NQ	10/12/2022	17:28:56	EB	SB	NB	17:28:56	17:29:05	0:00:09	1	NO	NO	YES	YES	NO	NO
DR 119	SCU 5NQ	10/13/2022	7:31:38	EB	SB	SB	7:31:38	7:32:06	0:00:28	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/14/2022	9:40:31	EB	SB	SB	9:40:31	9:40:51	0:00:20	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/14/2022	16:42:48	EB	SB	SB	16:42:48	16:43:26	0:00:38	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/15/2022	11:30:12	EB	SB	SB	11:30:12	11:30:49	0:00:37	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/15/2022	16:37:19	EB	SB	SB	16:37:19	16:37:45	0:00:26	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/16/2022	8:55:38	EB	NB	NB	8:55:38	8:58:38	0:03:00	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/16/2022	15:57:23	EB	SB	SB	15:57:23	15:57:35	0:00:12	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/17/2022	12:32:50	EB	SB	NB	12:32:50	12:32:09	0:00:41	1	NO	NO	YES	YES	NO	NO
DR 119	SCU 5NQ	10/17/2022	13:27:36	EB	SB	SB	13:27:36	13:27:51	0:00:15	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/18/2022	10:30:44	EB	SB	SB	10:30:44	10:31:01	0:00:17	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/18/2022	15:06:34	EB	NB	NB	15:06:34	15:09:40	0:03:06	1	NO	YES	YES	NO	NO	NO
DR 119	SCU 5NQ	10/18/2022	15:50:00	EB	SB	SB	15:50:00	15:52:13	0:02:13	1	NO	YES	YES	NO	NO	NO
DDR 117	SCU 864	10/12/2022	12:44:28	WB	SB	NB	12:44:28	12:44:33	0:00:05	1	NO	NO	NO	NO	YES	NO
DDR 117	SCU 864	10/13/2022	17:24:35	WB	SB	NB	17:24:35	17:24:40	0:00:05	1	NO	NO	NO	NO	YES	NO
DDR 117	SCU 864	10/14/2022	14:06:53	WB	SB	NB	14:06:53	14:06:56	0:00:03	1	NO	NO	YES	NO	NO	YES
DDR 117	SCU 864	10/15/2022	17:55:57	WB	SB	SB	17:55:57	17:56:01	0:00:04	1	NO	NO	YES	NO	NO	YES
DDR 117	SCU 864	10/15/2022	17:31:43	WB	NB	NB	17:31:43	17:31:53	0:00:10	1	NO	NO	YES	NO	NO	YES
DDR 117	SCU 864	10/16/2022	12:05:02	WB	NB	NB	12:05:02	12:05:19	0:00:17	1	NO	YES	YES	NO	NO	NO
DDR 117	SCU 864	10/18/2022	11:04:09	WB	SB	NB	11:04:09	11:04:13	0:00:04	1	NO	YES	NO	NO	NO	NO
DDR 117	SCU 864	10/18/2022	13:26:53	WB	SB	NB	13:26:53	13:27:08	0:00:15	1	NO	YES	NO	NO	NO	NO
DDR 117	SCU 864	10/18/2022	17:49:13	WB	SB	NB	17:49:13	17:49:18	0:00:05	1	NO	YES	NO	NO	NO	NO
DDR 118	SCU5OG	10/12/2022	10:17:15	EB	SB	SB	10:17:20	10:17:58	0:00:38	1	NO	NO	NO	NO	YES	NO
DDR 118	SCU5OG	10/14/2022	8:27:52	EB	NB	SB	10:17:23	10:18:12	0:00:49	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/14/2022	9:31:52	EB	NB	NB	9:31:53	9:31:59	0:00:06	1	NO	NO	YES	YES	NO	NO
DDR 118	SCU5OG	10/14/2022	14:09:23	EB	SB	NB	14:09:25	14:09:48	0:00:23	1	NO	YES	NO	NO	NO	NO
DDR 118	SCU5OG	10/14/2022	16:39:06	EB	SB	NB	16:39:15	16:39:47	0:00:32	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/14/2022	17:30:19	EB	NB	NB	17:30:20	17:30:26	0:00:06	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/15/2022	13:22:05	EB	NB	SB	13:22:05	13:22:36	0:00:31	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/15/2022	14:53:42	EB	SB	NB	14:53:51	14:53:55	0:00:04	1	NO	YES	NO	NO	NO	NO
DDR 118	SCU5OG	10/15/2022	14:58:57	EB	SB	NB	14:58:57	14:58:57	0:00:00	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/17/2022	12:27:18	EB	NB	NB	12:27:18	12:27:25	0:00:07	1	NO	YES	NO	NO	NO	NO
DDR 118	SCU5OG	10/17/2022	18:10:28	EB	SB	SB	18:10:30	18:10:44	0:00:14	1	NO	YES	NO	NO	NO	NO
DDR 118	SCU5OG	10/17/2022	17:41:53	EB	SB	SB	17:41:56	17:41:53	0:00:03	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/18/2022	12:09:18	EB	SB	SB	12:09:18	12:09:32	0:00:14	1	NO	YES	NO	NO	NO	NO
DDR 118	SCU5OG	10/18/2022	12:29:11	EB	SB	SB	12:29:11	12:29:30	0:00:19	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/18/2022	14:19:45	EB	SB	SB	14:19:45	14:19:45	0:00:00	1	NO	YES	YES	NO	NO	NO
DDR 118	SCU5OG	10/18/2022	17:10:55	EB	SB	SB	17:10:58	17:11:42	0:00:44	1	NO	YES	YES	NO	NO	NO
DR 116	SCU5NX	6/28/2022	6:00:43	WB	NB	NB	6:00:43	6:00:56	0:00:13	1	NO	YES	NO	NO	NO	NO
DR 116	SCU5NX	6/29/2022	16:10:19	WB	SB	SB	16:10:19	16:10:31	0:00:12	1	NO	YES	NO	NO	NO	NO
DR 116	SCU5NX	7/1/2022	13:01:45	WB	SB	SB	13:01:45	13:01:51	0:00:06	1	NO	YES	NO	NO	NO	NO
DR 116	SCU5NX	7/5/2022	10:46:49	WB	NB	SB	10:46:49	10:46:52	0:00:03	1	NO	YES	NO	NO	NO	NO
DR 116	SCU5NX	7/7/2022	12:44:58	WB	SB	SB	12:44:58	12:45:09	0:00:11	1	NO	YES	NO	NO	NO	NO
DR 116	SCU5NX	7/7/2022	20:52:35	WB	NB	NB	20:52:35	20:52:41	0:00:06	1	NO	YES	NO	NO	NO	NO

Traditional Signal Devices Summary															
Camera Base	Camera Name	Day	Time	Direction of Travel	Turn Direction	Mainline Direction of Travel	Time of Arrival at Driveway Location	Time of Departure at Driveway Location	Time Waiting	Queue Length in Driveway	Any conflict with mainline Vehicles	Turn Compliance; Compliant	Turned within 150' of adjacent Vehicle	Turned Against the flow of traffic; UnSafe	Non-Compliant ; Safe	Non-Compliant; Unsafe
DR 115	SCU 75E	6/28/2022	7:00:18	WB	NB	SB	7:00:18	7:00:51	0:00:33	2	NO	NO	YES	YES	NO	NO
DR 115	SCU 75E	6/28/2022	9:34:58	WB	NB	SB	9:34:58	9:35:51	0:00:53	1	NO	NO	YES	YES	NO	NO
DR 115	SCU 75E	6/28/2022	20:31:33	WB	NB	NB	20:31:33	20:31:58	0:00:25	1	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/29/2022	8:53:42	WB	NB	SB	8:53:42	8:54:07	0:00:25	1	NO	NO	YES	YES	NO	NO
DR 115	SCU 75E	6/29/2022	11:04:10	WB	SB	SB	11:04:10	11:05:57	0:01:47	1	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/29/2022	12:12:48	WB	SB	SB	12:12:48	12:13:56	0:01:08	1	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/29/2022	12:32:23	WB	NB	NB	12:32:23	12:32:58	0:00:35	1	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/29/2022	12:42:29	WB	NB	NB	12:42:29	12:42:52	0:00:23	1	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	6/29/2022	13:01:58	WB	NB	NB	13:01:58	13:02:09	0:00:11	1	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	6/29/2022	17:52:16	WB	NB	NB	17:52:16	17:52:28	0:00:12	1	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/30/2022	7:06:41	WB	NB	NB	7:06:41	7:06:53	0:00:12	3	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/30/2022	19:01:15	WB	NB	NB	19:01:15	19:01:26	0:00:11	1	NO	YES	YES	NO	NO	NO
DR 115	SCU 75E	6/30/2022	19:16:58	WB	NB	NB	19:16:58	19:17:04	0:00:06	1	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	6/30/2022	19:31:37	WB	NB	NB	19:31:37	19:32:02	0:00:25	2	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	7/1/2022	7:53:37	WB	SB	SB	7:53:37	7:53:51	0:00:14	1	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	7/1/2022	8:40:08	WB	SB	SB	8:40:08	8:40:43	0:00:35	1	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	7/1/2022	9:01:47	WB	SB	SB	9:01:47	9:02:06	0:00:19	1	NO	NO	YES	NO	NO	YES
DR 115	SCU 75E	7/1/2022	9:15:02	WB	NB	SB	9:15:02	9:16:17	0:01:15	1	NO	NO	YES	YES	NO	NO
DR 115	SCU 75E	7/2/2022	13:22:10	WB	NB	SB	13:22:10	13:22:21	0:00:11	1	NO	NO	YES	YES	NO	NO
DR 115	SCU 75E	7/3/2022	17:00:47	WB	NB	SB	17:00:47	17:01:02	0:00:15	1	NO	NO	YES	YES	NO	NO
DR 113	SCU 5M6	6/28/2022	7:09:51	EB	NB	NB	7:09:51	7:10:27	0:00:36	2	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	6/28/2022	7:10:27	EB	NB	NB	7:10:27	7:10:39	0:00:12	2	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	6/28/2022	16:32:09	EB	NB	NB	16:32:09	16:33:51	0:01:42	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	6/29/2022	6:44:45	EB	NB	SB	6:44:45	6:47:14	0:02:29	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	6/29/2022	7:06:01	EB	NB	SB	7:06:01	7:15:38	0:09:37	1	YES	NO	NO	YES	NO	NO
DR 113	SCU 5M6	6/29/2022	7:06:32	EB	NB	NB	7:06:32	7:06:55	0:00:23	2	YES	NO	NO	NO	YES	NO
DR 113	SCU 5M6	6/29/2022	11:20:26	EB	SB	SB	11:20:26	11:26:36	0:06:10	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	6/29/2022	11:34:01	EB	SB	SB	11:34:01	11:34:44	0:00:43	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	6/29/2022	12:30:00	EB	SB	SB	12:30:00	13:00:34	0:30:34	1	NO	YES	YES	NO	NO	NO
DR 113	SCU 5M6	6/29/2022	17:44:03	EB	NB	SB	17:44:03	17:47:07	0:03:04	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	6/29/2022	18:23:07	EB	NB	NB	18:23:07	18:23:13	0:00:06	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	6/30/2022	6:19:28	EB	NB	NB	6:19:28	6:19:33	0:00:05	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	6/30/2022	7:05:47	EB	NB	NB	7:05:47	7:06:19	0:00:32	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	6/30/2022	14:06:32	EB	NB	NB	14:06:32	14:07:11	0:00:39	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	6/30/2022	21:28:30	EB	NB	NB	21:28:30	21:28:50	0:00:20	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	7/1/2022	6:58:58	EB	NB	NB	6:58:58	6:58:34	0:00:24	1	NO	YES	NO	NO	NO	NO
DR 113	SCU 5M6	7/1/2022	9:54:00	EB	NB	NB	9:54:00	9:54:35	0:00:35	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	7/1/2022	17:39:57	EB	NB	NB	17:39:57	17:40:58	0:01:01	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	7/2/2022	8:43:50	EB	NB	NB	8:43:50	8:45:35	0:01:45	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	7/2/2022	17:09:58	EB	SB	SB	17:09:58	17:11:01	0:01:03	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	7/2/2022	18:16:59	EB	NB	SB	18:16:59	18:17:55	0:00:56	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/3/2022	7:47:24	EB	NB	SB	7:47:24	7:48:35	0:01:11	1	NO	NO	YES	YES	NO	NO
DR 113	SCU 5M6	7/3/2022	17:06:22	EB	NB	SB	17:06:22	17:07:36	0:01:14	1	NO	NO	YES	YES	NO	NO
DR 113	SCU 5M6	7/4/2022	8:11:17	EB	NB	SB	8:11:17	8:12:47	0:01:30	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/5/2022	7:42:29	EB	NB	SB	7:42:29	7:43:19	0:00:50	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/5/2022	9:00:09	EB	NB	NB	9:00:09	9:01:15	0:01:06	1	NO	YES	NO	NO	NO	NO
DR 113	SCU 5M6	7/5/2022	18:19:10	EB	NB	SB	18:19:10	18:20:31	0:01:21	1	NO	NO	YES	YES	NO	NO
DR 113	SCU 5M6	7/6/2022	7:06:22	EB	NB	NB	7:06:22	7:06:33	0:00:11	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	7/6/2022	16:26:48	EB	NB	SB	16:26:48	16:27:10	0:00:22	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	7/7/2022	6:38:09	EB	SB	SB	6:38:09	6:38:33	0:00:24	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	7:06:05	EB	SB	SB	7:06:05	7:30:01	0:23:56	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	7/7/2022	8:06:39	EB	NB	SB	8:06:39	8:09:04	0:02:25	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	11:31:25	EB	NB	SB	11:31:25	11:32:57	0:01:32	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	11:53:44	EB	SB	NB	11:53:44	11:54:30	0:00:46	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	14:23:40	EB	NB	SB	14:23:40	14:26:12	0:02:32	1	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	16:35:55	EB	NB	NB	16:35:55	16:36:02	0:00:07	1	NO	NO	NO	NO	YES	NO
DR 113	SCU 5M6	7/7/2022	16:36:30	EB	NB	NB	16:36:30	16:46:30	0:10:00	1	NO	NO	YES	NO	NO	YES
DR 113	SCU 5M6	7/7/2022	17:38:44	EB	NB	SB	17:38:44	17:39:14	0:00:30	2	NO	NO	NO	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	17:39:14	EB	NB	SB	17:39:14	17:39:19	0:00:05	2	NO	NO	YES	YES	NO	NO
DR 113	SCU 5M6	7/7/2022	17:36:56	EB	NB	SB	17:36:56	17:49:11	0:12:15	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	6/28/2022	6:17:46 AM	WB	NB	SB	6:17:46	6:18:09 AM	0:00:23	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/28/2022	9:59:03 AM	WB	SB	NB	9:59:03	9:59:20 AM	0:00:17	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/28/2022	1:31:07 PM	WB	NB	SB	13:31:07	1:31:15 PM	0:00:08	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/28/2022	4:55:00 PM	WB	NB	NB	16:55:00	4:55:53 PM	0:00:53	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	6/28/2022	8:05:50 PM	WB	NB	NB	20:05:50	8:05:58 PM	0:00:08	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	6/28/2022	9:26:51 PM	WB	NB	NB	21:26:51	9:29:43 PM	0:02:52	1	NO	YES	YES	NO	NO	NO
DR 114	SCU 864	6/28/2022	10:08:49 PM	WB	NB	NB	22:08:49	10:08:54 PM	0:00:05	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/28/2022	11:10:12 PM	WB	NB	NB	23:10:12	11:11:08 PM	0:00:56	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	6/29/2022	7:18:33 AM	WB	NB	SB	7:18:33	7:21:10 AM	0:02:37	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/29/2022	11:20:56 AM	WB	NB	SB	11:20:56	11:23:43 AM	0:02:47	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/29/2022	11:40:55 AM	WB	NB	SB	11:40:55	11:41:12 AM	0:00:17	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/29/2022	12:46:12 PM	WB	SB	SB	12:46:12	12:46:59 PM	0:00:47	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/29/2022	1:07:28 PM	WB	NB	NB	13:07:28	1:11:23 PM	0:03:55	1	NO	NO	YES	YES	NO	NO
DR 114	SCU 864	6/29/2022	2:19:56 PM	WB	NB	NB	14:19:56	14:22:57	0:03:01	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	6/29/2022	3:57:24 PM	WB	NB	NB	15:57:24	15:58:02	0:00:38	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	6/29/2022	5:36:09 PM	WB	NB	SB	17:36:09	17:40:09	0:04:00	2	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/29/2022	5:40:12 PM	WB	NB	NB	17:40:12	17:45:14	0:05:02	2	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/29/2022	5:58:13 PM	WB	NB	NB	17:58:13	17:58:20	0:00:07	1	NO	NO	NO	NO	YES	NO

Traditional Signal Devices Summary															
Camera Base	Camera Name	Day	Time	Direction of Travel	Turn Direction	Mainline Direction of Travel	Time of Arrival at Driveway Location	Time of Departure at Driveway Location	Time Waiting	Queue Length in Driveway	Any conflict with mainline Vehicles	Turn Compliance; Compliant	Turned within 150' of adjacent Vehicle	Turned Against the flow of traffic; UnSafe	Non-Compliant ; Safe	Non-Compliant; Unsafe
DR 114	SCU 864	6/30/2022	9:32:11 AM	WB	NB	NB	9:32:11	9:33:17	0:01:06	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/30/2022	9:40:49 AM	WB	SB	NB	9:40:49	9:40:58	0:00:09	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	6/30/2022	12:26:33 PM	WB	NB	NB	12:26:33	12:27:32	0:00:59	1	NO	YES	NO	NO	NO	NO
DR 114	SCU 864	6/30/2022	1:11:50 PM	WB	NB	SB	13:11:50	13:19:19	0:07:29	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	6/30/2022	4:31:04 PM	WB	NB	NB	16:31:04	16:31:24	0:00:20	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/30/2022	4:59:07 PM	WB	NB	NB	16:59:07	17:00:00	0:00:53	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	6/30/2022	7:58:53 PM	WB	NB	NB	19:58:53	19:59:54	0:01:01	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/1/2022	9:34:15 AM	WB	SB	SB	9:34:15	9:45:32	0:11:17	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/1/2022	3:14:14 PM	WB	NB	NB	15:14:14	15:18:15	0:04:01	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/1/2022	3:34:23 PM	WB	NB	SB	15:34:23	15:35:04	0:00:41	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	7/1/2022	4:58:12 PM	WB	NB	NB	16:58:12	16:59:14	0:01:02	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/1/2022	5:24:57 PM	WB	NB	NB	17:24:57	17:26:35	0:01:38	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/1/2022	6:18:07 PM	WB	NB	NB	18:18:07	18:18:35	0:00:28	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/2/2022	8:59:37 AM	WB	NB	NB	8:59:37	8:59:42	0:00:05	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/2/2022	1:53:06 PM	WB	NB	NB	13:53:06	13:54:46	0:01:40	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	7/2/2022	2:01:27 PM	WB	NB	NB	14:01:27	14:04:04	0:02:37	1	NO	YES	NO	NO	NO	NO
DR 114	SCU 864	7/2/2022	2:55:26 PM	WB	NB	NB	14:55:26	14:56:30	0:01:04	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/2/2022	3:54:24 PM	WB	NB	NB	15:54:24	15:55:39	0:01:15	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/2/2022	7:38:02 PM	WB	NB	NB	19:38:02	19:38:45	0:00:43	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/2/2022	8:44:44 PM	WB	NB	SB	20:44:44	20:44:49	0:00:05	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	7/3/2022	12:55:24 PM	WB	NB	SB	12:55:24	12:56:20	0:00:56	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	7/3/2022	1:08:56 PM	WB	NB	NB	13:08:56	13:09:41	0:00:45	1	NO	YES	NO	NO	NO	NO
DR 114	SCU 864	7/3/2022	3:29:00 PM	WB	NB	NB	15:29:00	15:32:56	0:03:56	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/4/2022	1:10:31 PM	WB	NB	SB	13:10:31	13:15:19	0:04:48	1	YES	NO	NO	YES	NO	NO
DR 114	SCU 864	7/4/2022	2:25:02 PM	WB	NB	NB	14:25:02	14:28:04	0:03:02	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/4/2022	2:39:00 PM	WB	NB	NB	14:39:00	14:39:11	0:00:11	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/4/2022	3:05:52 PM	WB	NB	NB	15:05:52	15:06:16	0:00:24	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/4/2022	3:14:13 PM	WB	NB	NB	15:14:13	15:14:59	0:00:46	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/4/2022	3:22:39 PM	WB	NB	SB	15:22:39	15:26:13	0:03:34	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	7/4/2022	3:31:14 PM	WB	NB	NB	15:31:14	15:31:24	0:00:10	1	NO	NO	YES	NO	NO	YES
DR 114	SCU 864	7/4/2022	4:05:40 PM	WB	NB	NB	16:05:40	16:08:41	0:03:01	1	NO	NO	NO	NO	YES	NO
DR 114	SCU 864	7/4/2022	4:21:01 PM	WB	NB	SB	16:21:01	16:23:10	0:02:09	1	NO	NO	NO	YES	NO	NO
DR 114	SCU 864	7/4/2022	7:10:32 PM	WB	NB	NB	19:10:32	19:14:33	0:04:01	1	NO	NO	NO	NO	YES	NO
DR 112	SCU 76P	6/28/2022	6:41:43	EB	NB	NB	6:41:43	6:42:03	0:00:20	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	6/28/2022	9:32:01	EB	NB	NB	9:32:01	9:32:12	0:00:11	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	6/29/2022	7:41:07	EB	NB	NB	7:41:07	7:42:18	0:01:11	1	NO	NO	YES	NO	NO	YES
DR 112	SCU 76P	6/29/2022	9:48:47	EB	NB	NB	9:48:47	9:49:29	0:00:42	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	6/29/2022	18:42:58	EB	NB	NB	18:42:58	18:43:05	0:00:07	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	6/30/2022	7:51:04	EB	NB	NB	7:51:04	7:54:28	0:03:24	1	NO	NO	YES	NO	NO	YES
DR 112	SCU 76P	7/1/2022	9:53:09	EB	NB	NB	9:53:09	9:53:23	0:00:14	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	7/1/2022	16:23:11	EB	NB	NB	16:23:11	16:23:16	0:00:05	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	7/1/2022	17:54:56	EB	NB	NB	17:54:56	17:55:01	0:00:05	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	7/2/2022	15:29:07	EB	NB	NB	15:29:07	15:39:30	0:10:23	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	7/3/2022	9:51:44	EB	NB	NB	9:51:44	9:51:58	0:00:14	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	7/3/2022	12:41:55	EB	NB	NB	12:41:55	12:42:01	0:00:06	1	NO	NO	YES	NO	NO	YES
DR 112	SCU 76P	7/3/2022	15:56:41	EB	NB	NB	15:56:41	15:56:47	0:00:06	1	NO	YES	YES	NO	NO	NO
DR 112	SCU 76P	7/3/2022	17:35:51	EB	NB	NB	17:35:51	17:36:55	0:01:04	1	NO	YES	YES	NO	NO	NO
DR 116	SCU 5NX	6/29/2022	18:00:43	WB	Right	NB	18:00:43	18:00:56	0:00:13	1	NO	NO	NO	NO	YES	NO
DR 116	SCU 5NX	6/30/2022	10:46:49	WB	Left	SB	10:46:49	10:47:53	0:01:04	1	NO	NO	NO	NO	YES	NO
DR 116	SCU 5NX	7/1/2022	14:16:33	WB	Right	NB	2:16:33	2:26:33	0:10:00	1	NO	NO	NO	NO	YES	NO
DR 116	SCU 5NX	7/1/2022	14:45:09	WB	Right	NB	14:45:09	14:48:49	0:03:40	1	NO	NO	YES	NO	NO	YES
DR 116	SCU 5NX	6/29/2022	16:10:19	WB	left	SB	16:10:19	16:10:31	0:00:12	1	NO	NO	YES	NO	NO	YES
DR 116	SCU 5NX	6/30/2022	13::36:15	WB	Right	NB	13:36:18	13:37:21	0:01:03	1	NO	NO	NO	NO	YES	NO
DR 116	SCU 5NX	6/29/2022	14:02:31	SB	LEFT	EB	14:02:31	14:02:39	0:00:08	1	YES	NO	YES	YES	NO	NO
DR 85	SCU5M6	10/12/2022	5:45:07	WB	NB	NB	5:45:07	5:45:14	0:00:07	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	5:48:49	WB	NB	SB	5:48:49	5:48:57	0:00:08	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	6:16:33	WB	NB	SB	6:16:33	6:16:46	0:00:13	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	6:25:17	WB	NB	SB	6:25:17	6:25:24	0:00:07	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	6:32:35	WB	NB	NB	6:32:35	6:32:56	0:00:21	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	6:57:19	WB	NB	NB	6:57:19	6:57:34	0:00:15	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	7:09:23	WB	NB	SB	7:09:23	7:09:45	0:00:22	2	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/12/2022	7:24:32	WB	NB	NB	7:24:32	7:24:54	0:00:22	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	7:35:12	WB	SB	NB	7:35:12	7:36:28	0:01:16	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	7:49:07	WB	NB	NB	7:49:07	7:49:20	0:00:13	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	8:20:02	WB	NB	NB	8:20:02	8:20:53	0:00:51	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/12/2022	8:31:10	WB	SB/NB	NB	8:31:10	8:33:37	0:02:27	2	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/12/2022	9:47:24	WB	NB	SB	9:47:24	9:47:36	0:00:12	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	10:05:19	WB	SB	SB	10:05:19	10:05:27	0:00:08	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	10:29:55	WB	NB	NB	10:29:55	10:30:02	0:00:07	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	10:32:23	WB	NB	SB	10:32:23	10:32:38	0:00:15	2	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/12/2022	11:24:18	WB	NB	NB	11:24:18	11:26:12	0:01:54	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	11:29:11	WB	NB	SB	11:29:11	11:31:26	0:02:15	2	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/12/2022	12:35:58	WB	NB	NB	12:35:58	12:36:06	0:00:08	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	12:55:33	WB	NB	SB	12:55:33	12:55:42	0:00:09	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	13:31:00	WB	NB	NB	13:31:00	13:31:08	0:00:08	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/12/2022	14:38:33	WB	NB	NB	14:38:33	14:38:41	0:00:08	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	14:45:02	WB	SB	SB	14:45:02	14:56:56	0:11:54	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/12/2022	14:55:26	WB	SB/NB	NB	14:55:26	14:57:40	0:02:14	2	NO	YES	NO	NO	NO	NO

Traditional Signal Devices Summary																
Camera Base	Camera Name	Day	Time	Direction of Travel	Turn Direction	Mainline Direction of Travel	Time of Arrival at Driveway Location	Time of Departure at Driveway Location	Time Waiting	Queue Length in Driveway	Any conflict with mainline Vehicles	Turn Compliance; Compliant	Turned within 150' of adjacent Vehicle	Turned Against the flow of traffic; UnSafe	Non-Compliant ; Safe	Non-Compliant; Unsafe
DR 85	SCU5M6	10/12/2022	16:01:22	WB	NB	SB	16:01:22	16:01:27	0:00:05	1	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/13/2022	7:07:04	WB	SB	NB	7:07:04	7:07:32	0:00:28	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	7:16:54	WB	NB	NB	7:16:54	7:17:01	0:00:07	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	7:21:22	WB	SB	NB	7:21:22	7:23:53	0:02:31	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	7:26:50	WB	NB	NB	7:26:50	7:26:59	0:00:09	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/13/2022	7:53:03	WB	NB	SB	7:53:03	7:53:14	0:00:11	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/13/2022	8:08:24	WB	NB	NB	8:08:24	8:08:32	0:00:08	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/13/2022	8:15:15	WB	SB	NB	8:15:15	8:15:55	0:00:40	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/13/2022	8:22:42	WB	NB	NB	8:22:42	8:22:53	0:00:11	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/13/2022	8:35:40	WB	NB	SB	8:35:40	8:35:58	0:00:18	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	8:44:44	WB	SB	NB	8:44:44	8:44:51	0:00:07	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	9:12:01	WB	NB	SB	9:12:01	9:12:10	0:00:09	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	16:11:54	WB	SB	SB	16:11:54	16:12:01	0:00:07	1	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/13/2022	16:42:20	WB	NB	SB	16:42:20	16:42:36	0:00:16	1	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/13/2022	17:11:20	WB	SB	NB	17:11:20	17:11:46	0:00:26	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	17:26:48	WB	NB	SB	17:26:48	17:26:55	0:00:07	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/13/2022	18:10:58	WB	NB	SB	18:10:58	18:11:06	0:00:08	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	7:22:36	WB	NB	SB	7:22:36	7:22:41	0:00:05	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	8:00:39	WB	NB	NB	8:00:39	8:01:06	0:00:27	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	8:09:31	WB	NB	SB	8:09:31	8:09:40	0:00:09	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	8:14:06	WB	NB	SB	8:14:06	8:14:13	0:00:07	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/14/2022	8:28:54	WB	NB	SB	8:28:54	8:29:03	0:00:09	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	8:34:59	WB	NB	SB	8:34:59	8:35:20	0:00:21	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	8:52:06	WB	SB	NB	8:52:06	8:53:03	0:00:57	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	8:58:21	WB	NB	SB	8:58:21	8:58:29	0:00:08	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	9:21:59	WB	NB	NB	9:21:59	9:22:12	0:00:13	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/14/2022	9:22:50	WB	NB	SB	9:22:50	9:23:02	0:00:12	1	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/14/2022	9:35:24	WB	NB	NB	9:35:24	9:35:33	0:00:09	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/14/2022	9:45:39	WB	NB	SB	9:45:39	9:45:45	0:00:06	1	NO	YES	NO	NO	NO	NO
DR 85	SCU5M6	10/14/2022	9:52:06	WB	NB	SB	9:52:06	9:52:26	0:00:20	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	15:25:37	WB	NB	SB	15:25:37	15:25:44	0:00:07	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	15:47:12	WB	NB	NB	15:47:12	15:47:19	0:00:07	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	16:09:33	WB	SB	SB	16:09:33	16:09:40	0:00:07	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	17:04:11	WB	NB	SB	17:04:11	17:04:16	0:00:05	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/14/2022	17:20:00	WB	NB	SB	17:20:00	17:20:27	0:00:27	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	17:24:15	WB	NB	SB	17:24:15	17:25:13	0:00:58	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/14/2022	17:27:14	WB	NB	SB	17:27:14	17:27:22	0:00:08	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/14/2022	18:24:20	WB	NB	SB	18:24:20	18:24:54	0:00:34	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	7:05:58	WB	NB	NB	7:05:58	7:06:48	0:00:50	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	7:23:05	WB	NB	SB	7:23:05	7:23:11	0:00:06	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	7:40:24	WB	NB	NB	7:40:24	7:40:47	0:00:23	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	8:16:35	WB	NB	NB	8:16:35	8:16:41	0:00:06	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	8:20:40	WB	SB	SB	8:20:40	8:20:46	0:00:06	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/15/2022	8:29:20	WB	NB	NB	8:29:20	8:29:28	0:00:08	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/15/2022	8:38:23	WB	NB	NB	8:38:23	8:38:34	0:00:11	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/15/2022	8:45:24	WB	NB	NB	8:45:24	8:45:32	0:00:08	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/15/2022	9:16:23	WB	NB	NB	9:16:23	9:16:45	0:00:22	1	NO	YES	YES	NO	NO	NO
DR 85	SCU5M6	10/15/2022	9:28:41	WB	NB	SB	9:28:41	9:28:53	0:00:12	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	9:34:23	WB	NB	NB	9:34:23	9:34:34	0:00:11	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	9:48:58	WB	SB	NB	9:48:58	9:50:26	0:01:28	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	9:50:38	WB	NB	SB	9:50:38	9:50:47	0:00:09	1	NO	NO	NO	NO	YES	NO
DR 85	SCU5M6	10/15/2022	16:32:03	WB	NB	NB	16:32:03	16:32:14	0:00:11	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/15/2022	17:07:02	WB	SB	SB	17:07:02	17:09:22	0:02:20	2	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/15/2022	17:56:12	WB	NB	SB	17:56:12	17:56:39	0:00:27	1	NO	NO	YES	NO	NO	YES
DR 85	SCU5M6	10/15/2022	18:53:31	WB	SB	SB	18:53:31	18:54:59	0:01:28	1	NO	NO	YES	NO	NO	YES

DAD Devices Summary											
Day	Time	Direction of Travel	Number of Vehicles in Queue	Type of Queue Beginning	Number of Vehicles not in Platoon	Stragler Vehicles at End of Queue	Signal Non-Compliance Type	Reference Driveway Width in Feet	Time of Front of Middle Vehicle in Queue Passes	Time of End of Middle Vehicle in Queue Passes	Queue Speed in mph
6/28/2022	7:04:33	NB	5	Platoon	0	0	Jumper	33	7:07:59	7:08:01	11.25
6/28/2022	11:27:26	NB	7	Platoon	2	1	Runner	33	11:27:07	11:27:09	11.25
6/29/2022	7:05:53	NB	5	Random Arrivals	4	1	Jumper	33	7:06:09	7:06:11	11.25
6/29/2022	9:22:31	NB	4	Random Arrivals	4	0	Jumper	33	9:22:53	9:22:55	11.25
6/29/2022	19:40:50	NB	2	Platoon	0	0	Jumper	33	19:43:40	19:43:42	11.25
6/30/2022	6:50:07	SB	3	Random Arrivals	2	1	Jumper	33	6:49:49	6:49:51	11.25
6/30/2022	7:07:26	NB	6	Platoon	0	0	Jumper	33	7:07:55	7:07:56	22.50
6/30/2022	7:39:20	SB	2	Random Arrivals	1	1	Jumper	33	7:39:46	7:39:47	22.50
6/30/2022	8:47:27	NB	7	Platoon	2	2	Jumper	33	8:48:42	8:48:44	11.25
6/30/2022	9:04:32	NB	4	Random Arrivals	2	0	Runner	33	9:04:38	9:04:39	22.50
6/30/2022	9:41:36	NB	2	Random Arrivals	2	0	Runner	33	9:41:25	9:41:27	11.25
6/30/2022	11:39:51	NB	4	Platoon	0	0	Jumper	33	11:41:32	11:41:34	11.25
6/30/2022	16:15:04	NB	6	Platoon	1	0	Runner	33	16:15:16	16:15:17	22.50
7/1/2022	7:07:14	NB	2	Platoon	0	0	Jumper	33	7:09:39	7:09:40	22.50
7/1/2022	7:45:00	SB	2	Platoon	0	0	Runner	33	7:44:59	7:45:01	11.25
7/1/2022	8:47:38	NB	2	Platoon	0	0	Jumper	33	8:49:35	8:49:36	22.50
7/1/2022	11:24:00	NB	3	Random Arrivals	3	0	Jumper	33	11:26:31	11:26:33	11.25
7/1/2022	15:52:22	NB	4	Platoon	0	0	Jumper	33	15:53:28	15:53:29	22.50
7/2/2022	10:20:59	NB	8	Platoon	0	0	Runner	33	10:21:11	10:21:22	2.05
7/2/2022	14:45:09	NB	3	Platoon	0	0	Jumper	33	14:48:10	14:48:11	22.50
7/2/2022	20:36:40	NB	5	Platoon	0	0	Jumper	33	20:38:31	20:38:32	22.50
7/3/2022	11:00:01	SB	5	Random Arrivals	4	0	Jumper	33	11:01:27	11:01:28	22.50
7/3/2022	11:20:10	NB	2	Random Arrivals	0	0	Jumper	33	11:22:56	11:22:57	22.50
7/3/2022	14:52:06	NB	2	Random Arrivals	0	0	Jumper	33	14:52:59	14:53:00	22.50
7/3/2022	17:11:47	NB	1	Random Arrivals	0	0	Jumper	33	17:13:14	17:13:15	22.50
7/3/2022	22:50:09	NB	1	Random Arrivals	0	0	Runner	33	22:50:13	22:50:14	22.50
7/3/2022	22:53:30	NB	1	Random Arrivals	0	0	Runner	33	22:53:33	22:53:34	22.50
7/3/2022	23:15:09	NB	4	Platoon	1	1	Jumper	33	23:16:56	23:16:57	22.50
7/4/2022	10:07:27	NB	5	Platoon	0	0	Jumper	33	10:07:42	10:07:43	22.50
7/4/2022	10:49:35	NB	8	Platoon	0	0	Runner	33	10:51:09	10:51:10	22.50
7/4/2022	19:32:36	NB	6	Platoon	2	0	Runner	33	19:34:58	19:34:59	22.50
6/28/2022	5:56:38	SB	1	Random Arrivals	0	0	runner	33	5:56:31	5:56:33	11.25
6/28/2022	14:20:00	SB	3	Platoon	0	0	jumper	33	14:20:29	14:20:30	22.50
6/28/2022	16:58:30	NB	2	Random Arrivals	2	0	jumper	33	16:58:40	16:58:41	22.50
6/29/2022	5:28:55	NB	1	Random Arrivals	0	0	runner	33	5:29:32	5:29:33	22.50
6/29/2022	10:36:00	NB	2	Random Arrivals	2	0	jumper	33	10:36:32	10:36:33	22.50
6/29/2022	16:09:50	NB	2	Random Arrivals	2	0	jumper	33	16:10:16	16:10:17	22.50
7/1/2022	11:16:30	NB	3	Platoon	0	1	runner	33	11:16:33	11:16:34	22.50
7/1/2022	13:32:50	NB	1	Random Arrivals	0	0	runner	33	13:33:22	13:33:23	22.50
7/1/2022	13:56:10	NB	4	Platoon	0	1	jumper	33	13:56:53	13:56:54	22.50
7/1/2022	15:44:55	SB	10	Platoon	1	1	runner	33	15:45:26	15:45:27	22.50
7/2/2022	9:32:58	SB	2	Platoon	0	0	jumper	33	9:33:01	9:33:02	22.50
7/2/2022	11:54:25	NB	4	Platoon	0	0	runner	33	11:54:37	11:54:38	22.50
7/2/2022	17:21:00	NB	3	Platoon	0	0	runner	33	17:21:46	17:21:48	11.25
7/2/2022	17:35:46	SB	4	Platoon	1	0	runner	33	17:36:48	17:36:49	22.50
7/2/2022	20:58:01	NB	5	Platoon	2	0	jumper	33	20:58:34	20:58:35	22.50
7/3/2022	9:39:11	SB	6	Platoon	0	0	jumper	33	9:41:17	9:41:18	22.50
7/3/2022	11:18:28	NB	1	Random Arrivals	0	0	runner	33	11:19:31	11:19:33	11.25
7/3/2022	14:12:40	SB	4	Platoon	0	0	jumper	33	14:13:11	14:13:12	22.50
10/14/2022	14:06:53	SB	6	Platoon	0	0	runner	18	14:06:30	14:06:31	12.27
10/15/2022	17:55:57	SB	1	Random Arrivals	0	0	jumper	18	17:56:10	17:56:11	12.27
10/15/2022	17:31:43	NB	2	Platoon	2	0	runner	18	17:31:48	17:31:49	12.27
10/16/2022	12:05:02	NB	4	Platoon	0	0	jumper	18	12:05:06	12:05:08	6.14
10/14/2022	8:27:52	NB	8	Platoon	0	0	runner	18	8:27:45	8:27:46	12.27
10/14/2022	16:39:06	SB	11	Platoon	0	2	jumper	18	16:39:26	16:39:27	12.27
10/14/2022	17:30:19	NB	3	Platoon	0	2	jumper	18	13:22:22	13:22:23	12.27
10/15/2022	14:58:57	SB	5	Platoon	0	0	jumper	18	14:59:00	14:59:01	12.27
10/17/2022	17:41:53	SB	6	Platoon	1	0	jumper	18	17:42:05	17:42:06	12.27
10/18/2022	12:29:11	SB	4	Platoon	0	1	jumper	18	12:29:15	12:29:16	12.27
10/18/2022	14:19:45	SB	3	Platoon	1	0	runner	18	14:19:40	14:19:41	12.27
10/18/2022	17:10:55	SB	4	Platoon	1	1	jumper	18	17:10:58	17:10:59	12.27
10/12/2022	8:44:34	NB	12	Platoon	2	0	jumper	14	8:44:52	8:44:53	9.55
10/13/2022	9:28:13	NB	6	Random Arrivals	1	0	jumper	14	9:28:18	9:28:19	9.55
10/13/2022	12:41:13	NB	5	Random Arrivals	0	0	runner	14	12:41:12	12:41:13	9.55
10/13/2022	19:15:08	SB	13	Platoon	2	0	jumper	14	19:15:42	19:15:43	9.55
10/14/2022	10:36:35	NB	9	Platoon	1	0	jumper	14	10:36:43	10:36:44	9.55
10/14/2022	15:17:20	NB	10	Platoon	1	1	jumper	14	15:17:36	15:17:37	9.55
10/14/2022	19:25:16	SB	10	Platoon	2	1	jumper	14	19:25:45	19:25:46	9.55
10/15/2022	12:12:39	SB	4	Random Arrivals	0	0	jumper	14	12:12:57	12:12:58	9.55
10/15/2022	16:49:54	NB	7	Platoon	1	0	jumper	14	16:50:21	16:50:22	9.55
10/15/2022	18:06:20	NB	3	Random Arrivals	1	0	jumper	14	18:06:51	18:06:52	9.55
10/15/2022	19:19:10	SB	6	Platoon	0	1	jumper	14	19:19:45	19:19:48	3.18
10/16/2022	8:43:15	SB	5	Platoon	0	0	runner	14	8:42:43	8:42:44	9.55
10/16/2022	12:36:50	NB	4	Random Arrivals	0	0	jumper	14	12:37:51	12:37:52	9.55
10/16/2022	14:44:45	NB	12	Platoon	0	1	jumper	14	14:45:32	14:45:33	9.55
10/16/2022	18:19:00	NB	5	Random Arrivals	0	0	runner	14	18:18:31	18:18:32	9.55
10/17/2022	5:14:28	NB	7	Platoon	0	0	runner	14	5:15:31	5:15:32	9.55
10/18/2022	5:50:36	NB	9	Platoon	1	0	jumper	14	5:53:58	5:53:59	9.55
10/18/2022	7:09:22	NB	10	Platoon	0	0	runner	14	7:10:02	7:10:03	9.55
10/18/2022	14:59:03	SB	7	Platoon	1	0	jumper	14	14:59:25	14:59:26	9.55
10/18/2022	15:21:18	SB	3	Random Arrivals	0	0	jumper	16	15:21:18	15:21:19	10.91
10/12/2022	11:49:32	NB	4	Random Arrivals	0	0	jumper	16	11:49:34	11:49:35	10.91
10/12/2022	11:32:29	NB	8	Platoon	0	0	jumper	16	11:32:33	11:32:34	10.91
10/12/2022	12:58:15	NB	3	Platoon	0	0	runner	16	12:58:15	12:58:16	10.91
10/13/2022	7:31:38	SB	12	Platoon	11	1	runner	16	7:31:58	7:32:00	5.45
10/14/2022	9:40:31	SB	1	Random Arrivals	0	0	runner	16	9:40:47	9:40:48	10.91
10/18/2022	15:06:34	NB	10	Platoon	1	2	runner	16	15:09:20	15:09:21	10.91

Traditional Signal Devices Summary

Day	Time	Direction of Travel	Number of Vehicles in Queue	Type of Queue Beginning	Number of Vehicles not in Platoon	Stragler Vehicles at End of Queue	Signal Non-Compliance Type	Reference Driveway Measurement in Feet	Time of Front of Middle Vehicle in Queue Passes	Time of End of Middle Vehicle in Queue Passes	Queue Speed in mph
6/28/2022	7:00:18	SB	1	Random Arrivals	0	0	Runner	37	7:00:28	7:00:36	3.15
6/28/2022	9:34:58	SB	5	Platoon	0	0	Runner	37	9:35:27	9:35:29	12.61
6/28/2022	20:31:33	NB	1	Random Arrivals	0	0	Runner	37	20:31:06	20:31:07	25.23
6/29/2022	8:53:42	SB	5	Platoon	2	0	Runner	37	8:53:48	8:53:50	12.61
6/29/2022	11:04:10	SB	5	Platoon	0	0	Jumper	37	11:05:36	11:05:38	12.61
6/29/2022	12:12:48	SB	1	Random Arrivals	0	0	Runner	37	12:10:49	12:10:51	12.61
6/29/2022	12:32:23	NB	5	Platoon	3	0	Runner	37	12:30:52	12:30:54	12.61
6/29/2022	12:42:29	NB	6	Platoon	2	0	Runner	37	12:42:30	12:42:31	25.23
6/29/2022	13:01:58	NB	7	Random Arrivals	0	0	Runner	37	13:01:31	13:01:32	25.23
6/29/2022	17:52:16	NB	3	Random Arrivals	0	0	Runner	37	17:52:16	17:52:17	25.23
6/30/2022	7:06:41	NB	10	Platoon	4	0	Runner	37	7:06:08	7:06:09	25.23
6/30/2022	19:01:15	NB	2	Random Arrivals	0	0	Runner	37	19:00:55	19:00:56	25.23
6/30/2022	19:16:58	NB	7	Platoon	2	0	Runner	37	19:15:49	19:15:50	25.23
6/30/2022	19:31:37	NB	5	Platoon	1	0	Runner	37	19:31:02	19:31:04	12.61
7/1/2022	7:53:37	SB	7	Platoon	0	0	jumper	37	7:55:10	7:55:11	25.23
7/1/2022	8:40:08	SB	5	Random Arrivals	0	0	Runner	37	8:42:18	8:42:20	12.61
7/1/2022	9:01:47	SB	6	Random Arrivals	0	0	Runner	37	9:00:36	9:00:37	25.23
7/1/2022	9:15:02	SB	8	Platoon	3	0	Runner	37	9:15:50	9:15:51	25.23
7/2/2022	13:22:10	SB	3	Platoon	0	0	jumper	37	13:21:57	13:21:58	25.23
7/3/2022	17:00:47	SB	5	Platoon	1	0	Runner	37	17:00:27	17:00:28	25.23
6/28/2022	7:09:51	NB	7	Platoon	0	0	Runner	54	7:10:06	7:10:07 AM	36.82
6/28/2022	7:10:27	NB	7	Platoon	0	0	Runner	54	7:10:06	7:10:07 AM	36.82
6/28/2022	16:32:09	NB	6	Platoon	0	0	Runner	54	16:33:42	16:33:43	36.82
6/29/2022	7:06:01	SB	8	Platoon	0	0	Runner	54	7:14:36	7:14:37 AM	36.82
6/29/2022	7:06:32	NB	9	Platoon	0	0	Runner	54	7:06:46	7:06:47 AM	36.82
6/29/2022	11:34:01	SB	1	Random Arrivals	0	0	Runner	54	11:34:42	11:34:43 AM	36.82
6/29/2022	12:30:00	SB	6	Platoon	0	0	Runner	54	13:00:22	1:00:23 PM	36.82
6/29/2022	17:44:03	SB	18	Platoon	0	2	Jumper	54	17:45:45	5:45:46 PM	36.82
6/30/2022	7:05:47	NB	9	Platoon	0	0	Runner	54	7:06:06	7:06:07 AM	36.82
6/30/2022	6:58:58	NB	3	Platoon	0	0	Runner	54	6:57:10	6:57:11 AM	36.82
7/1/2022	9:54:00	NB	9	Platoon	0	0	Jumper	54	9:54:25	9:54:26 AM	36.82
7/1/2022	17:39:57	NB	4	Platoon	0	0	Runner	54	17:40:51	5:40:52 PM	36.82
7/1/2022	8:43:50	NB	3	Platoon	1	0	Runner	54	8:45:28	8:45:29 AM	36.82
7/2/2022	18:16:59	SB	7	Platoon	1	1	Runner	54	18:17:36	6:17:41 PM	7.36
7/2/2022	7:47:24	SB	3	Random Arrivals	0	0	Runner	54	7:48:30	7:48:31 AM	36.82
7/3/2022	17:06:22	SB	6	Platoon	3	0	Runner	54	17:07:29	5:07:30 PM	36.82
7/3/2022	8:11:17	SB	1	Random Arrivals	0	0	Runner	54	8:12:31	8:12:32 AM	36.82
7/4/2022	7:42:29	SB	1	Random Arrivals	0	0	Jumper	54	7:43:01	7:43:02 AM	36.82
7/5/2022	9:00:09	NB	2	Platoon	0	0	Runner	54	9:00:53	9:00:54 AM	36.82
7/5/2022	18:19:10	SB	3	Platoon	0	0	Runner	54	18:20:16	6:20:17 PM	36.82
7/5/2022	7:06:22	NB	3	Platoon	0	0	Runner	54	7:06:20	7:06:21 AM	36.82
7/5/2022	16:26:48	SB	6	Platoon	2	0	Runner	54	16:26:56	4:26:57 PM	36.82
7/5/2022	6:38:09	SB	1	Random Arrivals	0	0	Jumper	54	6:38:12	6:38:13 AM	36.82
7/6/2022	8:06:39	SB	5	Platoon	2	0	Jumper	54	8:08:42	8:08:43 AM	36.82
7/6/2022	11:31:25	SB	4	Platoon	0	0	Jumper	54	11:32:50	11:32:51 AM	36.82
7/6/2022	11:53:44	NB	4	Platoon	0	0	Runner	54	11:54:10	11:54:11 AM	36.82
7/6/2022	14:23:40	SB	3	Platoon	0	0	Runner	54	14:24:56	14:24:58	18.41
7/6/2022	16:36:30	NB	5	Platoon	0	0	Runner	54	16:36:16	16:36:20	9.20
7/6/2022	17:38:44	SB	5	Platoon	1	0	Runner	54	17:39:04	5:39:05 PM	36.82
7/6/2022	17:39:14	SB	5	Platoon	1	0	Runner	54	17:39:04	5:39:05 PM	36.82
7/6/2022	17:36:56	SB	3	Platoon	0	0	Runner	54	17:49:03	5:49:04 PM	36.82
10/15/2022	8:45:24	NB	8	Platoon	3	1	Runner	24	6:01:22	6:01:23	16.36
10/15/2022	9:16:23	SB	10	Platoon	0	0	Runner	24	16:10:09	16:10:10	16.36
10/15/2022	9:28:41	SB	6	Platoon	0	0	Jumper	24	13:01:35	13:01:36	16.36
10/15/2022	9:34:23	SB	5	Platoon	1	0	Jumper	24	10:45:43	10:45:44	16.36
10/15/2022	9:48:58	SB	5	Platoon	0	2	Runner	24	12:44:57	12:44:58	16.36
10/15/2022	9:50:38	NB	3	Platoon	0	0	Runner	24	20:53:35	20:53:36	16.36
10/12/2022	5:45:07	NB	5	Platoon	1	0	Runner	24	5:46:01	5:46:02	16.36
10/12/2022	5:48:49	SB	3	Platoon	0	0	Runner	24	5:48:33	5:48:34	16.36
10/12/2022	6:16:33	SB	4	Platoon	0	0	Jumper	24	6:16:28	6:16:29	16.36
10/12/2022	6:25:17	SB	5	Platoon	1	0	Runner	24	6:25:57	6:25:58	16.36
10/12/2022	6:32:35	NB	10	Platoon	0	0	Runner	24	6:32:31	6:32:32	16.36
10/12/2022	6:57:19	NB	4	Platoon	0	1	Runner	24	6:57:12	6:57:13	16.36

Traditional Signal Devices Summary												
Day	Time	Direction of Travel	Number of Vehicles in Queue	Type of Queue Beginning	Number of Vehicles not in Platoon	Stragler Vehicles at End of Queue	Signal Non-Compliance Type	Reference Driveway Measurement in Feet	Time of Front of Middle Vehicle in Queue Passes	Time of End of Middle Vehicle in Queue Passes	Queue Speed in mph
10/12/2022	7:09:23	SB	4	Platoon	0	0	Jumper	24	7:11:06	7:11:07	16.36
10/12/2022	7:24:32	NB	7	Platoon	0	0	Jumper	24	7:24:41	7:24:42	16.36
10/12/2022	7:35:12	NB	13	Platoon	1	0	Runner	24	7:35:52	7:35:53	16.36
10/12/2022	7:49:07	NB	13	Platoon	2	0	Runner	24	7:50:34	7:50:35	16.36
10/12/2022	8:20:02	NB	13	Platoon	2	0	Runner	24	8:19:56	8:19:57	16.36
10/12/2022	8:31:10	NB	9	Random Arrivals	4	1	Jumper	24	8:32:28	8:32:29	16.36
10/12/2022	9:47:24	SB	5	Platoon	2	0	Jumper	24	9:46:28	9:46:29	16.36
10/12/2022	10:05:19	SB	3	Platoon	0	0	Jumper	24	10:06:51	10:06:52	16.36
10/12/2022	10:29:55	NB	7	Platoon	0	0	Jumper	24	10:29:43	10:29:44	16.36
10/12/2022	10:32:23	SB	4	Platoon	0	0	Runner	24	10:32:15	10:32:16	16.36
10/12/2022	11:24:18	NB	9	Platoon	0	0	Runner	24	11:25:40	11:25:41	16.36
10/12/2022	11:29:11	SB	10	Platoon	2	0	Runner	24	11:33:02	11:33:03	16.36
10/12/2022	12:35:58	NB	6	Platoon	1	0	Runner	24	12:36:31	12:36:32	16.36
10/12/2022	12:55:33	SB	4	Platoon	0	0	Runner	24	12:55:54	12:55:55	16.36
10/12/2022	14:38:33	NB	7	Platoon	0	0	Runner	24	14:39:14	14:39:15	16.36
10/12/2022	14:45:02	SB	14	Platoon	0	0	Jumper	24	14:46:22	14:46:23	16.36
10/12/2022	14:55:26	NB	3	Platoon	0	0	Jumper	24	14:56:28	14:56:29	16.36
10/12/2022	16:01:22	SB	18	Platoon	3	2	Jumper	24	16:03:00	16:03:01	16.36
10/13/2022	7:07:04	NB	11	Platoon	0	1	Runner	24	7:07:09	7:07:10	16.36
10/13/2022	7:16:54	NB	10	Platoon	1	0	Runner	24	7:18:21	7:18:42	0.78
10/13/2022	7:21:22	NB	14	Platoon	0	0	Runner	24	7:22:58	7:22:59	16.36
10/13/2022	7:26:50	NB	10	Platoon	1	0	Jumper	24	7:27:43	7:27:44	16.36
10/13/2022	7:53:03	SB	6	Platoon	2	1	Jumper	24	7:54:47	7:54:48	16.36
10/13/2022	8:08:24	NB	6	Random Arrivals	3	0	Runner	24	8:10:14	8:10:15	16.36
10/13/2022	8:15:15	NB	15	Platoon	2	0	Runner	24	8:14:52	8:14:53	16.36
10/13/2022	8:22:42	NB	12	Platoon	1	0	Runner	24	8:23:24	8:23:25	16.36
10/13/2022	8:35:40	SB	7	Platoon	1	0	Runner	24	8:36:51	8:36:52	16.36
10/13/2022	8:44:44	NB	11	Platoon	1	0	Runner	24	8:46:48	8:46:49	16.36
10/13/2022	9:12:01	SB	4	Platoon	0	0	Runner	24	9:13:58	9:13:59	16.36
10/13/2022	16:11:54	SB	10	Platoon	0	0	Jumper	24	16:13:35	16:13:36	16.36
10/13/2022	16:42:20	SB	14	Platoon	1	0	Runner	24	16:44:01	16:44:02	16.36
10/13/2022	17:11:20	NB	12	Platoon	0	0	Runner	24	17:11:15	17:11:16	16.36
10/13/2022	17:26:48	SB	13	Platoon	1	0	Runner	24	17:28:46	17:28:47	16.36
10/13/2022	18:10:58	SB	15	Platoon	2	0	Jumper	24	18:12:29	18:12:30	16.36
10/14/2022	7:22:36	SB	7	Platoon	0	0	Runner	24	7:24:04	7:24:05	16.36
10/14/2022	8:00:39	NB	9	Platoon	0	0	Runner	24	8:00:44	8:00:45	16.36
10/14/2022	8:09:31	SB	6	Platoon	0	0	Runner	24	8:11:18	8:11:19	16.36
10/14/2022	8:14:06	SB	5	Platoon	0	0	Jumper	24	8:15:53	8:15:54	16.36
10/14/2022	8:28:54	SB	9	Platoon	0	1	Runner	24	8:30:38	8:30:39	16.36
10/14/2022	8:34:59	SB	2	Platoon	0	0	Runner	24	8:42:05	8:42:06	16.36
10/14/2022	8:52:06	NB	3	Platoon	0	0	Runner	24	8:52:10	8:52:11	16.36
10/14/2022	8:58:21	SB	5	Platoon	0	0	Jumper	24	8:59:12	8:59:13	16.36
10/14/2022	9:21:59	NB	9	Random Arrivals	4	1	Runner	24	9:21:49	9:21:50	16.36
10/14/2022	9:22:50	SB	6	Platoon	0	0	Runner	24	9:24:37	9:24:38	16.36
10/14/2022	9:35:24	NB	5	Platoon	0	0	Jumper	24	9:36:41	9:36:42	16.36
10/14/2022	9:45:39	SB	5	Random Arrivals	4	0	Jumper	24	9:47:23	9:47:24	16.36
10/14/2022	9:52:06	SB	13	Platoon	2	0	Jumper	24	9:51:54	9:51:55	16.36
10/14/2022	15:25:37	SB	12	Platoon	0	0	Jumper	24	15:27:11	15:27:12	16.36
10/14/2022	15:47:12	NB	13	Platoon	1	0	Runner	24	15:46:56	15:46:57	16.36
10/14/2022	16:09:33	SB	17	Platoon	0	0	Runner	24	16:11:08	16:11:09	16.36
10/14/2022	17:04:11	SB	19	Platoon	4	0	Runner	24	17:05:54	17:05:55	16.36
10/14/2022	17:20:00	SB	20	Platoon	2	0	Runner	24	17:19:39	17:19:40	16.36
10/14/2022	17:24:15	SB	19	Platoon	1	0	Runner	24	17:24:27	17:24:28	16.36
10/14/2022	17:27:14	SB	17	Platoon	1	0	Runner	24	17:29:03	17:29:04	16.36
10/14/2022	18:24:20	SB	14	Platoon	1	0	Jumper	24	18:26:18	18:26:19	16.36
10/15/2022	7:05:58	NB	6	Platoon	2	0	Runner	24	7:06:27	7:06:28	16.36
10/15/2022	7:23:05	SB	3	Platoon	0	1	Runner	24	7:24:57	7:24:58	16.36
10/15/2022	7:40:24	NB	5	Platoon	0	0	Runner	24	7:40:30	7:40:31	16.36
10/15/2022	8:16:35	NB	6	Platoon	0	0	Runner	24	8:18:15	8:18:16	16.36
10/15/2022	8:20:40	SB	1	Random Arrivals	0	0	Runner	24	8:22:08	8:22:09	16.36
10/15/2022	8:29:20	NB	7	Platoon	1	0	Jumper	24	8:30:53	8:30:54	16.36
10/15/2022	8:38:23	NB	3	Platoon	0	0	Jumper	24	8:38:50	8:38:51	16.36
10/15/2022	8:45:24	NB	15	Platoon	0	0	Runner	24	8:46:48	8:46:49	16.36
10/15/2022	9:16:23	NB	5	Platoon	1	0	Runner	24	9:18:03	9:18:04	16.36
10/15/2022	9:28:41	SB	10	Platoon	0	0	Runner	24	9:28:39	9:28:40	16.36
10/15/2022	9:34:23	NB	5	Platoon	2	0	Jumper	24	9:35:16	9:35:17	16.36
10/15/2022	9:48:58	NB	3	Platoon	0	1	Runner	24	9:49:52	9:49:53	16.36
10/15/2022	9:50:38	SB	4	Platoon	0	0	Runner	24	9:52:25	9:52:26	16.36
10/15/2022	16:32:03	NB	9	Platoon	0	0	Jumper	24	16:32:44	16:32:45	16.36
10/15/2022	17:07:02	NB	7	Platoon	0	0	Runner	24	17:09:05	17:09:06	16.36
10/15/2022	17:56:12	SB	8	Platoon	0	0	Runner	24	17:56:15	17:56:16	16.36
10/15/2022	18:53:31	SB	6	Platoon	0	0	Runner	24	18:54:41	18:54:42	16.36

Appendix D Benefit-to-Cost Calculations

Given the assumptions stated in the main body of the report, the following calculations for the benefit-to-cost ratio are summarized as follows:

Input Parameters	Temporary Traffic Signal Device	DAD Device	
Driveway Delay (minutes)	1.48	0.8	Peak Hour
Mainline Work Zone Travel Speed	30.845	30.315	Yields Type C Crash
NB Queue Delay (minutes)	4.57	0.91	Peak Hour
SB Queue Delay (minutes)	5.56	0.77	Peak Hour
NB Queue Length (Feet)	256.345	78.965	Peak Hour
SB Queue Length (feet)	292.785	45.1	Peak Hour
NB Queue Stops	49.9	97.685	Peak Hour
SB Queue Stops	65.6	65.115	Peak Hour

Volume Data	Temporary Traffic Signal Device	DAD Device
AADT	3803	3803
NB AADT	1919	1919
SB AADT	1884	1884
NB Passenger Vehicles (82%)	1574	1574
SB Passenger Vehicles (82%)	1545	1545
NB Trucks (18%) Including 5% Construction Vehicles	345	345
SB Trucks (18%) Including 5% Construction Vehicles	339	339
Peak Hour NB Passenger Vehicles	169	169
Peak Hour SB Passenger Vehicles	112	112
Peak Hour NB Trucks	37	37
Peak Hour SB Trucks	24	24

Value of Time	Temporary Traffic Signal Device	DAD Device
Passenger Vehicle Value of Time ($/hr)	26.92	26.92
Truck Value of Time ($/hr)	53.84	53.84
Passenger Vehicle Running Cost ($/mi)	0.16	0.16
Truck Running Cost ($/mi)	0.65	0.65

Conflict Data	Temporary Traffic Signal Device	DAD Device	Type	Cost
Number of Crossing Conflicts	57.5	38.5	Yields Type C Crash	$23,900
Number of Rear End Conflicts	31.5	23	Yields PDO Crash	$4,700

Roadway Data	Temporary Traffic Signal Device	DAD Device
Number of Driveways Total	10	10
Number of Vehicles per Driveway per Peak Hour	4	4
Roadway Length (feet)	5280	5280
Speed Reduction Area (feet)		
Work Area Length (feet)	1000	1000
NB Queue (feet)	256.35	78.97
SB Queue (feet)	292.79	45.10
Downstream Acceleration (feet)	500	500
Entire Work Zone Influence Area (feet)	2049.13	1624.065
Remaining Road at Speed (feet)	3230.87	3655.935
Speed Limit	55	55
Work Zone Speed	30.845	30.315

	Temporary Traffic Signal Device	DAD Device
Cost of Driveway Delay per day (equivalent to 3-Peak Hours)	**79.68**	**43.07**

Travel Speed Cost	Temporary Traffic Signal Device	DAD Device
Single PC Mainline Travel Speed Cost	0.30	0.34
Single Truck Mainline Travel Speed Cost	0.60	0.68
Single PC Work Zone Travel Speed Cost	0.34	0.27
Single Truck Work Zone Travel Speed Cost	0.68	0.55
Total Single PC Travel Speed Cost	0.64	0.61
Total Single Truck Travel Speed Cost	1.28	1.22
PC Travel Speed Cost per Day	1990.23	1908.64
Truck Travel Speed Cost per Day	873.76	837.94
Travel Speed Cost per Day	**$2,863.99**	**$2,746.58**

Queue Delay Cost	Temporary Traffic Signal Device	DAD Device
NB Mainline Passenger Vehicle Queue Delay Cost per Peak Hour	346.45	68.74
NB Mainline Truck Queue Delay Cost per Peak Hour	151.70	30.10
SB Mainline Passenger Vehicle Queue Delay Cost per Peak Hour	279.60	38.48
SB Mainline Truck Queue Delay Cost per Peak Hour	119.83	16.49
Queue Delay Cost per Peak Hour	$897.58	$153.81
Queue Delay Cost per Day (equivalent to 3-Peak Hours)	**$2,692.75**	**$461.43**

Conflict Costs	Temporary Traffic Signal Device	DAD Device
Crossing Conflict Cost per Day	$1,374,250	$920,150
Rear End Conflict Cost per Day	$148,050	$108,100
Conflict Costs per Day	**$1,522,300**	**$1,028,250**

Cost Summary	Temporary Traffic Signal Device	DAD Device
Total Road User Costs per Day	**$1,527,936**	**$1,031,501**
Total Road User Costs per Day without Conflict Cost	**$5,636**	**$3,251**
Construction Days (March - November)	275	275
Total Road User Cost	**$420,182,515**	**$283,662,798**
Total Road User Cost without Conflict Cost	**$1,550,015**	**$894,048**
Total Road User Cost Savings without Conflict Cost		**$655,967**
Traffic Control Cost Savings without Conflict Cost - Benefits		**$34,200**
Total Costs		**$4,500**
B:C Ratio Control Cost Only		**7.6**
B:C Ratio Overall		**153.37**

Appendix E Statistical Analysis Results

Statistical Test Selection

Based upon the data collected during the field study and the microsimulation analysis, parametric and non-parametric tests were selected for the analysis. Parametric tests, the Student's t-test, were utilized to determine differences in means between data that was quantitative; such as queue, delay, speed, number of conflicts, time-to-collision or post-encroachment time. Non-parametric tests, the chi-square test, were required for the analysis of categorical data, such as compliance of driveway devices due to the violation of the quantitative data assumption for parametric tests. A description of the statistical tests utilized are provided herein.

Student's t-test for the Comparison of Means

The Student's t-test was used to determine if differences in the quantitative data were statistically significant. A two-tailed Student's t-test was conducted with a null hypothesis stating there was no difference between two means for work zone with the temporary traffic signal devices and those with the DAD devices at driveways. The alternative hypothesis stated that one of the mean speeds was higher or lower than the other or that one treatment was better or worse than the other. The two-tailed test was used for this research as the effect on any of the mean quantitative data in regards to the type of driveway control device was not known. If the calculated t-value was found to be greater than the critical t-value obtained in available statistical tables, the difference in means was determined to be statistically significant. The calculated t-value was found with the following equation for $[N_B + N_A - 2]$ degrees of freedom assuming the collection of unequal sample sizes:

$$t_{\text{calc}} = \frac{\left(\overline{X}_B - \overline{X}_A\right)}{\sqrt{\sigma^2\left(\frac{1}{N_B}+\frac{1}{N_A}\right)}}$$

Where:

$\overline{X}_B$ = sample mean for the work zones with temporary traffic control devices
$\overline{X}_A$ = sample mean for the work zones with DAD devices
N_B = number of work zones with temporary traffic control devices
N_A = number of work zones with DAD devices
σ = common standard deviation

If the variances for any of the quantitative variables were not equal, the Welch's modification to the Student's t-test was utilized to test the differences in the means of the two groups. The Welch's method has shorter confidence intervals and more power than the Student's t-test when the variances were found to be substantially different. The Welch's test statistic is as follows:

$$W = \frac{(\overline{X}_B - \overline{X}_A)}{\sqrt{\left(\frac{\hat{\sigma}_B^2}{N_B} + \frac{\hat{\sigma}_A^2}{N_A}\right)}}$$

$$k' = \frac{\left(\frac{\hat{\sigma}_B^2}{N_B} + \frac{\hat{\sigma}_A^2}{N_A}\right)^2}{\frac{\left(\frac{\hat{\sigma}_B^2}{N_B}\right)^2}{N_B - 1} + \frac{\left(\frac{\hat{\sigma}_A^2}{N_A}\right)^2}{N_A - 1}}$$

Where:

$\overline{X}_B$ = sample mean for the work zones with temporary traffic control devices
$\overline{X}_A$ = sample mean for the work zones with DAD devices
N_B = number of work zones with temporary traffic control devices
N_A = number of work zones with DAD devices
$\hat{\sigma}_B$ = standard deviation of work zones with temporary traffic control devices
$\hat{\sigma}_A$ = standard deviation of work zones with DAD devices
k' = degrees of freedom

Correlation coefficients can also be used to describe the effect size of a relationship and indicate an objective measurement of the significance of the relationship. The effect size can be determined through the following equation:

$$r = \sqrt{\frac{t^2}{t^2 + df}}$$

Where:

t^2 = t-calculated
df = degrees of freedom
r = effect size correlational coefficient

The relationship between effect size and the correlation coefficient is shown in Table E-1.

Table E-1. Correlation Coefficients and Effect Size Relationship

Correlation Coefficient	Effect Size
±0.10	Small Effect; Low level of practical significance
±0.30	Medium Effect; Moderate level of practical significance
±0.50	Large Effect; High level of practical significance

Chi-Square Test for the Comparison of Categorical Data

In order to determine if the distributions between compliant, non-compliant but safe, non-compliant and unsafe and unsafe, comparisons were made between the work zones with the temporary traffic signal devices and those with the DAD devices at driveways. When comparing an observed frequency distribution or percentage with the corresponding values of an expected distribution, the intent was to test whether the discrepancies between the observed and expected frequencies or percentages could be attributed to chance. If the discrepancies were attributed to chance, then the differences between the two percentages would be deemed insignificant. The statistical equation used to determine if driver compliancy distribution in the sample population were significantly different between the two driveway control devices was the test for goodness-of-fit, or the chi-square test. The chi-square goodness-of-fit test was used to examine the null hypothesis that the driver compliancy was similar in both types of work zones regardless of the control device utilized at the driveways. The following equation was used to test the chi-square or goodness of fit.

$$\chi^2 = \sum_{i=1}^{k} \frac{(o_i - e_i)}{e_i}$$

Where:

o_i = value of the observed frequency of driver compliancy with the temporary traffic signal devices
e_i = value of the expected frequency of driver compliancy with the DAD signal devices
k = number of categories, four

The result of this calculation yields the calculated chi-square value which was compared with the critical chi-square value obtained from available statistical tables. If the calculated chi-square value was greater than the critical chi-square value then the differences in the driver compliancy were significant and the null hypothesis was rejected. The chi-square test has underlying assumptions including discrete or categorical data of non-overlapping categories and nominal data. The chi-square test can be a very powerful test for large samples; however, becomes quite weak when dealing with small samples where a single category has an expected frequency less than five.

Sample Size

The required sample size to detect statistical significance at a level of confidence of 95 percent or alpha equal to 0.05 and a power of 80 percent or beta equal to 0.20 can be determined to provide a minimum target for data collection efforts in order to provide a statistically valid representative sample. Upon the completion of data collection efforts, the detectable difference can be assessed in a similar fashion. The following formula was utilized to determine the detectable difference in mean values for the various comparisons:

$$n = \frac{\left(Z_\beta - Z_{\alpha/2}\right)^2 \times \sigma^2}{\varepsilon^2}$$

Where:

Z_β= critical value corresponding to a given value of β in the upper tail of the standard normal distribution
Z_α= critical value corresponding to a given value of $\alpha/2$ in the lower and upper tail of the standard normal distribution
σ = standard deviation of the difference
ε = detectable difference in the means

n = sample size

The detectable difference in means is then utilized to further understand the results of the statistical analysis. For example, a statistically detectable difference of one mile per hour should not be considered to the same extent as a statistically detectable difference of five miles per hour based upon the ability of the driver to detect such a difference with repeatability.

Field Study Analyses

Based upon the collected field data, the percentage of driver's complying with the devices, the time waiting at the device, and the driveway queue was calculated for both work zones utilizing the temporary traffic signal devices and the DAD devices at driveways for traffic control. In addition, data was collected along the mainline roadway, State Route 60, at each end of the work zones utilizing both the temporary traffic signal devices and the DAD devices at the driveways.

A detailed summary of the data collected at the driveways and along State Route 60 for the mainline traffic is presented in Table E-2 along with the results of the statistical analyses.

Table E-2. Quantitative Field Study Results

Performance Measure	Driveway Control Type	Sample Size (N)	Mean	Standard Deviation	t-calc	Degrees of Freedom (df)	Significance (p)	Effect Size (r)
Driveway Waiting Time (minutes)	Trad. Signal	211	1.48	3.32	2.684	285.203	0.008 Statistically Significant	0.16
	DAD	155	0.80	1.26				
Driveway Queue Length (vehicles)	Trad. Signal	211	1.08	0.29	-1.182	207.363	0.239	N/A
	DAD	155	1.14	0.60				
Mainline Travel Speed (within the work zone - mph)	Trad. Signal	135	20.88	8.88	5.732	218.553	<0.001 Statistically Significant	0.36
	DAD	87	15.08	6.20				
Mainline Queue Length (vehicles)	Trad. Signal	135	7.10	4.36	4.565	218.823	<0.001 Statistically Significant	0.30
	DAD	87	4.84	3.02				

Based upon the statistical analyses for the field data, the null hypothesis stating that there were no differences between the operational performance in the work zones with driveways controlled by temporary traffic signal devices or DAD devices was rejected for the driveway waiting time or delay, the mainline travel speed and the mainline queue length. Therefore, there were statistically significant differences between the driveway control methods of the temporary traffic signal devices and the DAD devices. The null hypothesis associated with the driveway queue lengths was accepted indicating there was no statistically significant difference between two driveway control options.

The effect size, or the measure of practical significance, varies from small to medium effect sizes depending on the quantitative parameter evaluated. In terms of driveway waiting time or delay there is a small effect size indicating the practical significance may be low; however, for the mainline queue length and the mainline travel speed, the effect size indicates a medium practical significance. To fully understand the impacts of the statistical analysis given the sample size, the detectable difference observed for the statistically significant tests should be reviewed.

In order to determine the detectable difference given the sample size collected in the field, the following formula was considered in the estimation of the sample size:

$$n = \frac{\left(Z_{\beta} - Z_{\alpha/2}\right)^2 \times \sigma^2}{\varepsilon^2}$$

Where:

Z_{β}= critical value corresponding to a given value of β in the upper tail of the standard normal distribution

$Z_{\alpha/2}$= critical value corresponding to a given value of $\alpha/2$ in the lower and upper tail of the standard normal distribution

σ = standard deviation of the difference

ε = detectable difference in the means

n = sample size

The above equation not only utilizes the level of confidence or alpha level which corresponds to Type I error, it also accounts for the power of the test, 1- β, in order to control the Type II error rate which if not controlled could potentially yield an irrelevant test result.

Utilizing the equation, the detectable differences were calculated based upon the sample sizes realized in the field and are shown with the conclusions for each quantitative parameter in Table E-3.

As indicated in the table, the DAD devices provided statistically and measurable differences in driveway waiting time or delay, the mainline queue length at the end of the work zones and speed limit within the work zone along the mainline. The driveway queue length was not statistically different mainly due to the low number of vehicles utilize the driveway at any given time. Typically, only one vehicle was present along the driveway during an observational period for either control devices.

Table E-3. Field Study Conclusions

Performance Measure	Driveway Control Type	Sample Size (N)	Mean	Standard Deviation	Detectable Difference	Conclusions
Driveway Waiting Time (minutes)	Trad. Signal	211	1.48	3.32	0.312	DAD Driveways Provide Statistically Shorter Delays
	DAD	155	0.80	1.26		
Driveway Queue Length (vehicles)	Trad. Signal	211	1.08	0.29	0.10	No Difference Between Traditional Temporary Signals and DAD Devices
	DAD	155	1.14	0.60		
Mainline Travel Speed (within the work zone - mph)	Trad. Signal	135	20.88	8.88	2.54	DAD Driveways Provide Statistically Slower Speeds
	DAD	87	15.08	6.20		
Mainline Queue Length (vehicles)	Trad. Signal	135	7.10	4.36	1.22	DAD Driveways Provide Statistically End of Work Zone Queue Lengths
	DAD	87	4.84	3.02		

The second type of analysis for the field study involved conducting a chi-square test to determine whether the percentage of compliant drivers were statistically similar regardless of the type of driveway control device utilize. The chi-square test determines an expected frequency distribution for the DAD devices given the observed frequency distribution for the temporary traffic signal device driver behaviors and compares the expected frequency distribution for the DAD devices with the observed data. Table E-4 provides a summary of the individual observations for each compliancy category by driveway control device as well as the statistical results of the test.

Table E-4. Driver Behavior at Driveways

Safety Measure		Temporary Traffic Signal Devices	DAD Devices Observed	Total	DAD Devices Expected	χ^2	Degrees of Freedom (df)	Significance (p)
Compliant		47	124	171	35	129.12	3	<0.001 Statistically Significant
Non-Compliant	Safe	65	8	73	48			
	Unsafe	59	4	63	43			
Unsafe		40	19	59	29			
Total		211	155	366	155			

While there are less than five observations in one category of the DAD devices, the calculated expected values did not produce a result of less than five observations in one category. Therefore, the chi-square test provided valid results without weakening the power of the test. As seen in the table above, there is a statistically significant difference between the driver compliancy behaviors observed with the temporary traffic signal devices and the DAD devices. Based upon the chi-square test, the

DAD devices provided a statistically significant better result for driver compliancy with the devices than the temporary traffic signal devices.

Field Study and Microsimulation Analyses

As the collection of field data related to operational characteristics along roadway networks is not only time consuming but also costly, simulation emerged as an alternative method which allows for experimental control, efficiency, low cost and east of data collection. However, the validity of the simulation as a research tool is an important issue to consider. As such the validity of the microsimulation was conducted using the student's t-test comparing work zone data collected in the field and comparing that with similar results from the microsimulation runs. A detailed summary of the data for the microsimulation validation analysis is presented in Table E-5 along with the results of the statistical analyses.

Table E-5. Microsimulation Validation Summary

Performance Measure and Control Type	Location	Sample Size (N)	Mean	Standard Deviation	t-calc	Degrees of Freedom (df)	Significance (p)
Driveway Waiting Time (minutes) – Trad. Signal	Field	211	1.48	3.32	-2.099	155.273	0.037 Statistically Significant
	VISSIM	150	4.83	19.33			
Driveway Waiting Time (minutes) - DAD	Field	155	0.80	1.26	-1.941	120.624	0.055
	VISSIM	120	3.19	13.40			
Driveway Queue Length (vehicles) – Trad. Signal	Field	211	1.08	0.29	-9.302	149.681	<0.001 Statistically Significant
	VISSIM	150	4.97	5.11			
Driveway Queue Length (vehicles) - DAD	Field	155	1.14	0.60	-5.759	172.134	<0.001 Statistically Significant
	VISSIM	87	4.84	3.02			
Mainline Queue Length (vehicles) – Trad. Signal	Field	135	7.10	4.36	-13.442	193	<0.001 Statistically Significant
	VISSIM	60	16.03	4.09			
Mainline Queue Length (vehicles) - DAD	Field	87	4.84	3.02	-27.224	141.384	<0.001 Statistically Significant
	VISSIM	60	15.60	1.76			

As the statistical results indicated above, the microsimulation analysis has not been found to be perfectly correlated to the field study as the majority of the statistical analysis indicate differences in the two scenarios for both the temporary traffic signal device and the DAD device. However in all cases, the microsimulation produced results that were approximately 3.5 times longer than those realized in the field. This is a direct result of the microsimulation assumption that there would be 4 vehicles per hour on each driveway where as in the field condition generally only one vehicle was observed to exit the driveway within an hour period with the exception of the church (DR 80) and the business (DR 115) driveways. Therefore, while the validation of the microsimulation model can be assumed to be similar to the field conditions albeit with higher traffic volumes present.

Microsimulation Analyses

There were various microsimulation analyses that were conducted including the results from the temporary traffic signal device to the DAD device for the driveway operational parameters, as well as the mainline operational parameters for work zone 1 and work zone 3. All of the data collection was analyzed to determine test the null hypothesis that there were no differences between the operational performance in work zones with driveways controlled by temporary traffic signal devices or DAD devices. The Student's t-test was utilized to test the null hypothesis for the driveway and mainline operational parameter analysis. A detailed summary of the data collected at the simulated driveways conditions is presented in Table E-6 along with the results of the statistical analysis.

Table E-6. Quantitative Microsimulation Driveway Study Results

Performance Measure	Driveway Control Type	Sample Size (N)	Mean	Standard Deviation	t-calc	Degrees of Freedom (df)	Significance (p)	Effect Size (r)
All Work Zones Driveway Waiting Time (seconds)	Trad. Signal	270	23.61	47.48	7.421	288.819	<0.001 Statistically Significant	0.40
	DAD	270	1.77	9.12				
All Work Zones Driveway Queue Length (feet)	Trad. Signal	270	0.52	0.83	6.961	368.490	<0.001 Statistically Significant	0.34
	DAD	270	0.14	0.36				

Based upon the statistical analysis for the driveway simulation data, the null hypothesis was rejected indicating there was a statistically significant difference between the driveway controlled temporary traffic signal devices and the DAD devices in terms of driveway operational parameters. Specifically, the DAD devices have statistically shorter wait times with shorter queue lengths at the driveways for vehicles intending to join the mainline traffic flow.

Work zone 1 and work zone 3 were replicated in the microsimulation analysis separately due to slightly different geometric conditions in the field. Work zone 1 was located along a straight segment of State Route 60 without limited sight distance whereas work zone 3 was located along a slight curve in the roadway with driveways located on both the interior and exterior of the curve. The quantitative data collected for the microsimulation of work zone 1 is presented in Table E-7 along with the results of the statistical analysis.

Table E-7. Quantitative Microsimulation Work Zone 1 Study Results

Performance Measure	Control Type	Sample Size (N)	Mean	Standard Deviation	t-calc	Degrees of Freedom (df)	Significance (p)	Effect Size (r)
Travel Time NB (seconds)	Trad. Signal	30	31.16	0.46	-5.714	58	<0.001 Statistically Significant	0.60
	DAD	30	30.59	0.30				
Travel Time SB (seconds)	Trad. Signal	30	30.53	0.47	-4.550	58	<0.001 Statistically Significant	0.513
	DAD	30	30.04	0.36				
Queue Delay NB (seconds)	Trad. Signal	30	330.79	11.19	-111.02	46.927	<0.001 Statistically Significant	1.00
	DAD	30	67.553	6.59				
Queue Delay SB (seconds)	Trad. Signal	30	253.50	17.01	-60.920	34.065	<0.001 Statistically Significant	1.00
	DAD	30	56.18	5.05				
Queue Length NB (feet)	Trad. Signal	30	300.30	3.25	-54.441	30.852	<0.001 Statistically Significant	0.99
	DAD	30	116.70	18.18				
Queue Length SB (feet)	Trad. Signal	30	238.34	14.55	-59.023	40.917	<0.001 Statistically Significant	0.99
	DAD	30	65.51	6.75				
Queue Stops NB	Trad. Signal	30	25.70	0.837	29.959	48.454	<0.001 Statistically Significant	0.97
	DAD	30	46.10	3.241				
Queue Stops SB	Trad. Signal	30	19.00	0.983	26.326	44.609	<0.001 Statistically Significant	0.97
	DAD	30	28.93	1.818				

Based upon the statistical analysis for work zone 1 simulation data, the null hypothesis was rejected for all of the operational parameters indicating there was a statistically significant difference between the driveway controlled temporary traffic signal devices and the DAD devices in terms of operational parameters. Specifically, the DAD devices have statistically shorter travel times with shorter queue lengths and queue delays for the mainline traffic. On the other hand, the temporary traffic signal devices had statistically fewer number of queue stops for the mainline traffic.

The quantitative data collected for the microsimulation of work zone 3 is presented in Table E-8 along with the results of the statistical analysis.

Table E-8. Quantitative Microsimulation Work Zone 3 Study Results

Performance Measure	Control Type	Sample Size (N)	Mean	Standard Deviation	t-calc	Degrees of Freedom (df)	Significance (p)	Effect Size (r)
Travel Time NB (seconds)	Trad. Signal	30	29.14	0.277	-5.741	58	<0.001 Statistically Significant	0.602
	DAD	30	28.74	0.261				
Travel Time SB (seconds)	Trad. Signal	30	29.55	0.436	-7.984	51.204	<0.001 Statistically Significant	0.745
	DAD	30	28.78	0.298				
Queue Delay NB (seconds)	Trad. Signal	30	217.55	9.486	-111.24	31.356	<0.001 Statistically Significant	0.999
	DAD	30	21.00	1.914				
Queue Delay SB (seconds)	Trad. Signal	30	414.20	38.00	-55.759	29.282	<0.001 Statistically Significant	0.995
	DAD	30	26.39	2.651				
Queue Length NB (feet)	Trad. Signal	30	212.39	3.44	-143.82	48.542	<0.001 Statistically Significant	0.999
	DAD	30	41.23	5.53				
Queue Length SB (feet)	Trad. Signal	30	347.23	26.49	-66.15	29.941	<0.001 Statistically Significant	0.997
	DAD	30	24.69	3.37				
Queue Stops NB	Trad. Signal	30	74.10	2.40	27.874	30.568	<0.001 Statistically Significant	0.981
	DAD	30	149.27	14.57				
Queue Stops SB	Trad. Signal	30	112.20	6.25	1.807	31.701	0.08	N/A
	DAD	30	101.33	8.38				

Based upon the statistical analysis for work zone 3 simulation data, the null hypothesis was rejected for nearly all of the operational parameters, except for the southbound number of queue stops, indicating there was a statistically significant difference between the driveway controlled temporary traffic signal devices and the DAD devices in terms of operational parameters. Specifically, the DAD devices have statistically shorter travel times with shorter queue lengths and queue delays for the mainline traffic. On the other hand, the temporary traffic signal devices had statistically fewer number of queue stops for the northbound mainline traffic while there was not a statistical significant difference in the southbound mainline direction of travel.

Given the microsimulation analysis results for both work zone 1 and work zone 3, the geometric differences in State Route 60 did not impact the results of the operational analysis as the analysis for work zone 1 and work zone 3 as their results were similar in nature to each other.

To evaluate the safety performance of the work-zone segments with DAD devices and temporary traffic signal devices, a conflict analysis was conducted using the Surrogate Safety Assessment Model (SSAM) software utilizing time-to-collision, post-encroachment time and conflict types (crossing and rear-end maneuvers). The time-to-collision (TTC) data from all of the conflict points throughout the 30 simulation runs for each scenario utilizing the temporary traffic signal devices and the DAD devices for driveway control. Comparisons were made in terms of TTC distribution, TTC cumulative distribution, TTC time and descriptive statistics. The TTC distributions are provided in Figure E-1 for work zone 1 and Figure E-2 for work zone 3.

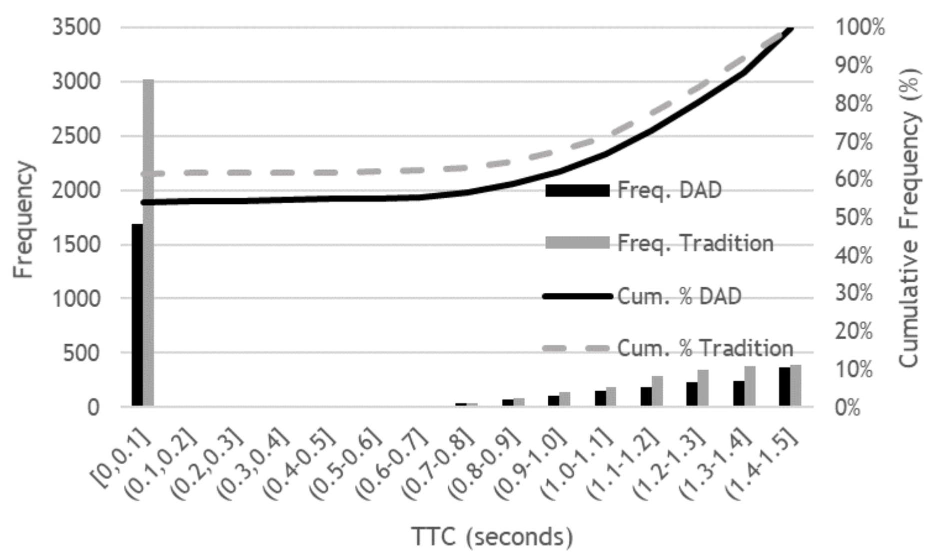


Figure E-1. Time-To-Collision Distributions Work Zone 1

The TTC distribution results for work zone 1 indicate a higher proportion of shorter time-to-collision times which represent potentially higher crash rates for the traditional temporary traffic control devices controlling the driveways.   The TTC bin of [0,0.1] indicates a high probability of a crash likely to occur which is where the majority of the distribution occurs for both types of devices.

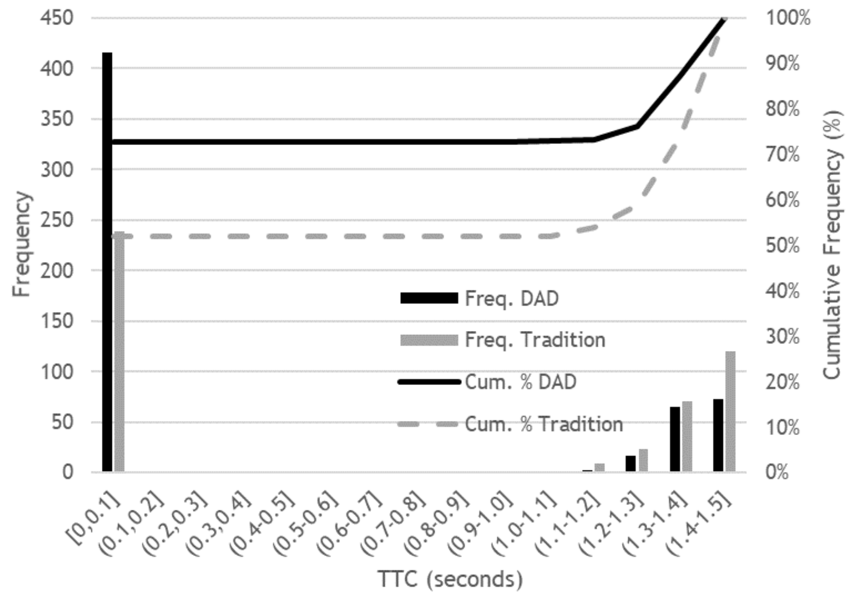


Figure E-2. Time-To-Collision Distributions Work Zone 3

The TTC distribution results for work zone 3 indicate a higher proportion of shorter time-to-collision times which represent potentially higher crash rates for the DAD devices located at the driveway locations. This is the opposite of the results from work zone 1 indicating that the either a geometric or operational difference between the two work zones. It should be noted that work zone 3 introduced roadway curvature which likely contributes to drivers at the driveways experiencing difficulty with seeing on-coming traffic in order to make a safe turning movement after the perceived mainline traffic queue has passed the driveway. Table E-9 presents the mean and standard deviations for the TTC results from the microsimulation.

Table E-9. Time-to-Collision Microsimulation Results

Work Zone	Control Type	Time-to-Collision (seconds)	
		Mean	Standard Deviation
Work Zone 1	Temporary Traffic Signal	0.49	0.63
	DAD	0.58	0.65
Work Zone 3	Temporary Traffic Signal	0.69	0.72
	DAD	0.39	0.64

The post-encroachment data (PET) from all of the conflict points throughout the 30 simulation runs for each scenario utilizing the temporary traffic signal devices and the DAD devices for driveway control. Comparisons were made in terms of PET distribution, PET cumulative distribution, post-encroachment time (PET) and distributions, and descriptive statistics. The PET distributions are provided in Figure E-3 for work zone 1 and Figure E-4 for work zone 3.

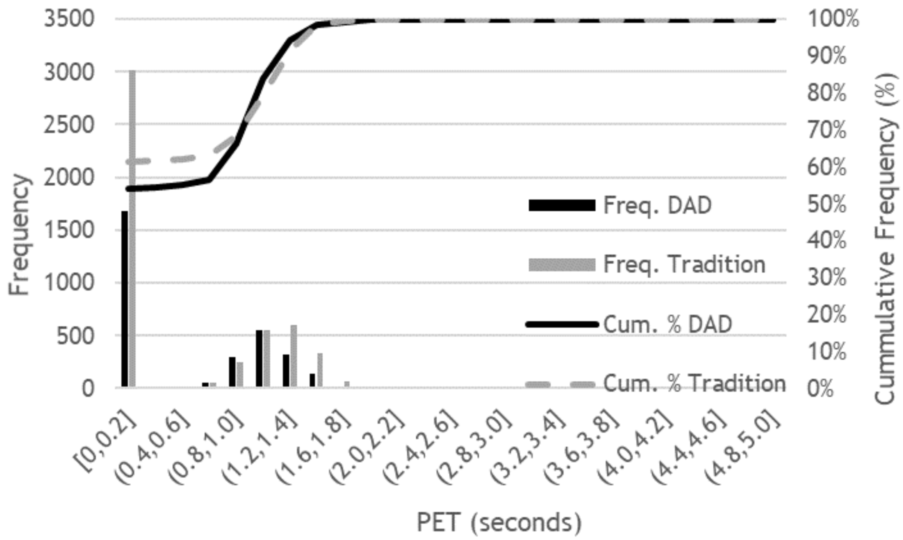


Figure E-3. PET Distributions Work Zone 1

The PET distribution results for work zone 1 indicate a higher proportion of shorter post-encroachment times which represent potentially higher crash rates for the traditional temporary traffic control devices controlling the driveways. The PET bin of [0,0.2] indicates a high probability of a crash likely to occur which is where the majority of the distribution occurs for both types of devices.

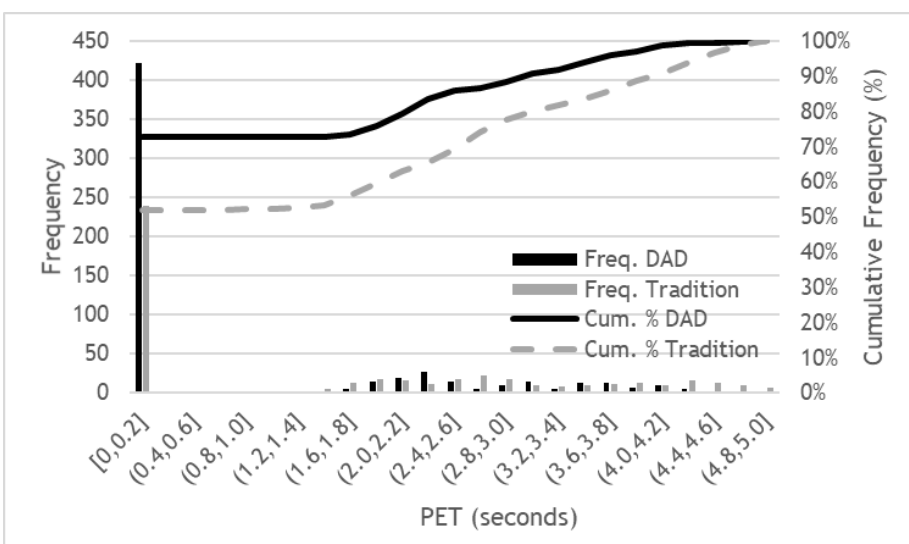


Figure E-4. PET Distributions Work Zone 3

The PET distribution results for work zone 3 indicate a higher proportion of shorter time-to-collision times which represent potentially higher crash rates for the DAD devices located at the driveway locations. Similarly to the TTC, this is the opposite of the results from work zone 1 indicating that the roadway curvature likely contributes to drivers at the driveways experiencing difficulty with seeing on-coming traffic in order to make a safe turning movement after the perceived mainline traffic queue has passed the driveway. Table E-10 presents the mean and standard deviations for the PET results from the microsimulation.

Table E-10. Post-Encroachment Time Microsimulation Results

Work Zone	Control Type	Post-Encroachment (seconds)	
		Mean	Standard Deviation
Work Zone 1	Temporary Traffic Signal	0.49	0.63
	DAD	0.55	0.62
Work Zone 3	Temporary Traffic Signal	1.51	1.71
	DAD	0.80	1.36

A conflict analysis was also conducted utilizing the SSAM software for work zone 1 and work zone 3 separately. A conflict indicates that a collision is likely to occur without evasive action taken by one of the drivers. The crossing conflict occurs where the collision angle is greater than 85-degrees indicating a turning movement that crosses the flow of traffic, such as in this circumstance NB mainline traffic has the right-of-way and a driver exiting the driveway turns in SB direction. The rear-end conflict occurs when a driver enters the flow of traffic in the same direction of travel. The conflict summary is presented in Table E-11 along with the statistical analysis results.

Table E-11. Quantitative Microsimulation Conflict Analysis Results

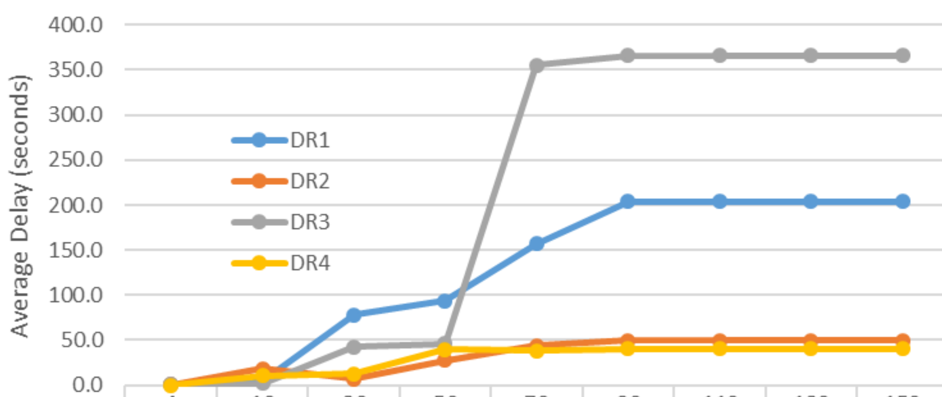
Work Zone and Conflict Type	Driveway Control Type	Mean	Standard Deviation	t-calc	Degrees of Freedom (df)	Significance (p)	Effect Size (r)
Work Zone 1 Crossing Conflicts	Trad. Signal	107	39.02	-5.312	58	<0.001 Statistically Significant	0.57
	DAD	63	23.88				
Work Zone 1 Rear-End Conflicts	Trad. Signal	56	8.28	-6.637	58	<0.001 Statistically Significant	0.66
	DAD	41	9.50				
Work Zone 3 Crossing Conflicts	Trad. Signal	8	11.71	2.433	58	0.018 Statistically Significant	0.30
	DAD	14	7.60				
Work Zone 3 Rear-End Conflicts	Trad. Signal	7	2.84	-3.307	58	0.002 Statistically Significant	0.40
	DAD	5	2.46				

Based upon the statistical analysis for conflict data, the null hypothesis was rejected for all of the analyses, indicating there was a statistically significant difference between the driveway controlled temporary traffic signal devices and the DAD devices in terms of number of conflicts for both crossing and rear-end maneuvers. The results for work zone 1 and work zone 3 are contradictory with the DAD devices in work zone 1 having fewer crossing and rear-end conflicts but higher conflicts in work zone 3. As such, the safety analysis does not provide a consistent indication that the DAD devices for driveway control are safer than the temporary traffic signal devices.

Sensitivity Analyses

In order to explore the safety and operation performances of DAD devices under different traffic parameter settings of the work zone network, a sensitivity analysis was performed for work zone 1 due to straight roadway segment and consistent performance in the simulation analysis. The parameters of mainline vehicle volume, driveway vehicle volume, the all-red time length were modified to understand the impact on the traffic operational parameters of average travel time, average delay, average queue length, number of queue stops, TTC and PET.

With an increase in the driveway volumes from 4 vehicles per hour to 150 vehicles per hour, the average delay for the driveways also increased and is presented in Figure E-5 and the average queue length is presented in Figure E-6.

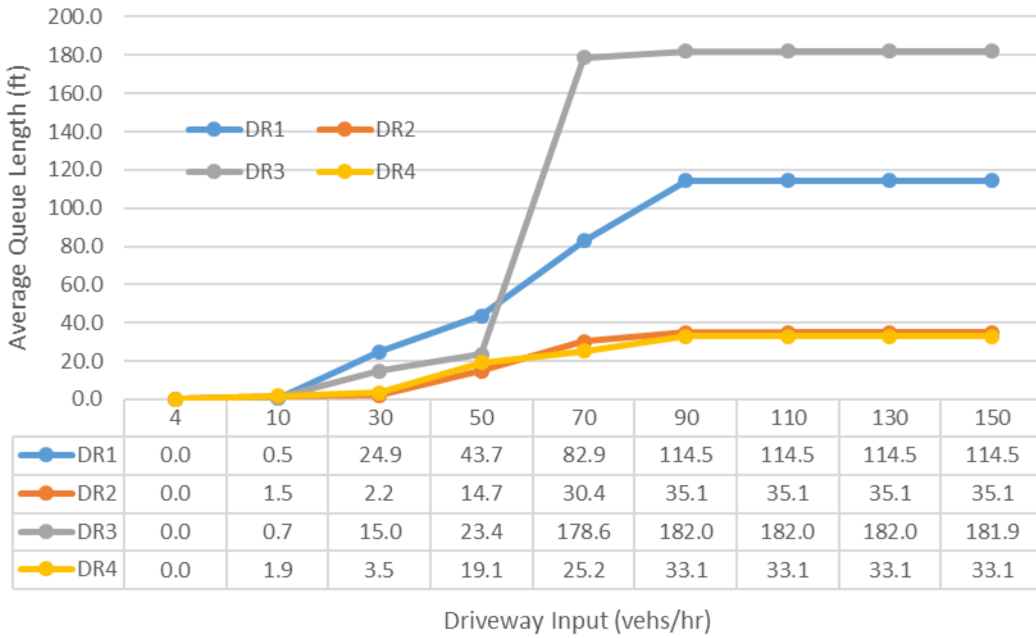


	4	10	30	50	70	90	110	130	150
DR1	0.5	4.9	78.4	93.9	157.1	203.7	203.7	203.7	203.7
DR2	0.7	18.6	6.8	27.4	44.0	49.5	49.5	49.5	49.5
DR3	0.3	2.3	42.4	46.4	355.4	365.9	366.1	366.2	366.2
DR4	0.0	10.2	12.5	39.5	38.4	40.7	40.7	40.7	40.7

Driveway Input (vehs/hr)

Figure E-5. Driveway Volume and Delay Sensitivity

As shown in the figure above, the average delay increases with driveway vehicular volumes, as expected. However, the delays begin to increase substantially after a vehicular volume of 10 vehicles per hour and again at 50 vehicles per hour. For an unsignalized intersection, any delay over 50 seconds can be considered a level of service F per the Highway Capacity Manual. Therefore, the DAD devices seem to perform well for less than 50 vehicles per hour at a driveway.



	4	10	30	50	70	90	110	130	150
DR1	0.0	0.5	24.9	43.7	82.9	114.5	114.5	114.5	114.5
DR2	0.0	1.5	2.2	14.7	30.4	35.1	35.1	35.1	35.1
DR3	0.0	0.7	15.0	23.4	178.6	182.0	182.0	182.0	181.9
DR4	0.0	1.9	3.5	19.1	25.2	33.1	33.1	33.1	33.1

Figure E-6. Driveway Volume and Queue Sensitivity

As shown in the figure above, the average queue also increases with driveway vehicular volumes, as expected. However, the delays begin to increase substantially after a vehicular volume of 50 vehicles per hour with most driveways maintaining approximately two vehicles in a queue at 50 vehicles per hour but increasing to four (driveway 1) and nine (driveway 3). Therefore, the DAD devices seem to perform well under a 50 vehicles per hour at a driveway condition.

The safety performance of work zone 1 with the SSAM software given changes to driveway volumes was examined and is presented in Figure E-7 for TTC and PET and in Figure E-8 for number of conflicts anticipated.

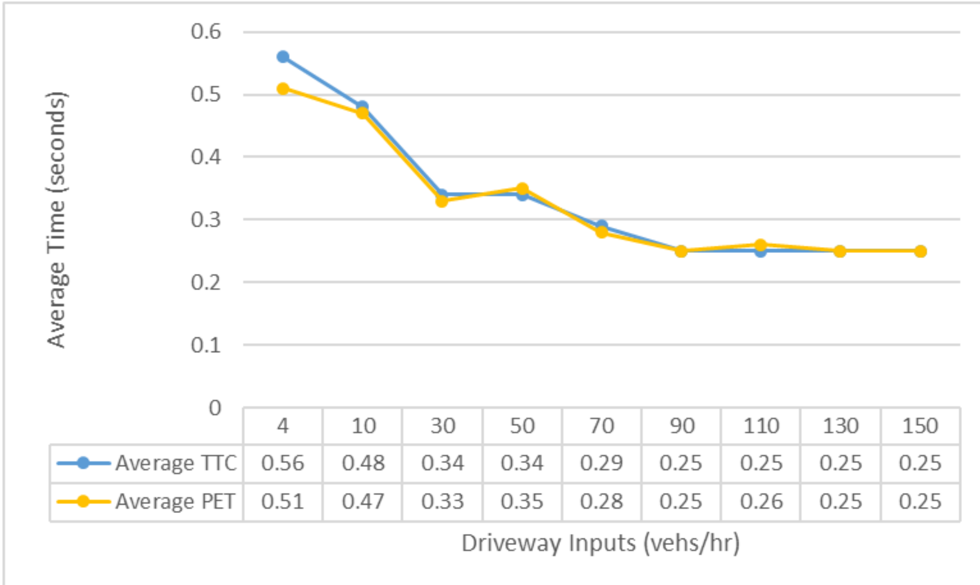


Figure E-6. Driveway Volume and TTC and PET Analysis

As shown in the figure above, the TTC and PET decrease with an increase with driveway vehicular volumes, as expected. However, the TTC and PET stabilize between 30 and 50 vehicles per hour before beginning to further decline with additional vehicles at each driveway. Therefore, the DAD devices seem to provide a stable TTC and PET until a 50 vehicles per hour at a driveway condition.

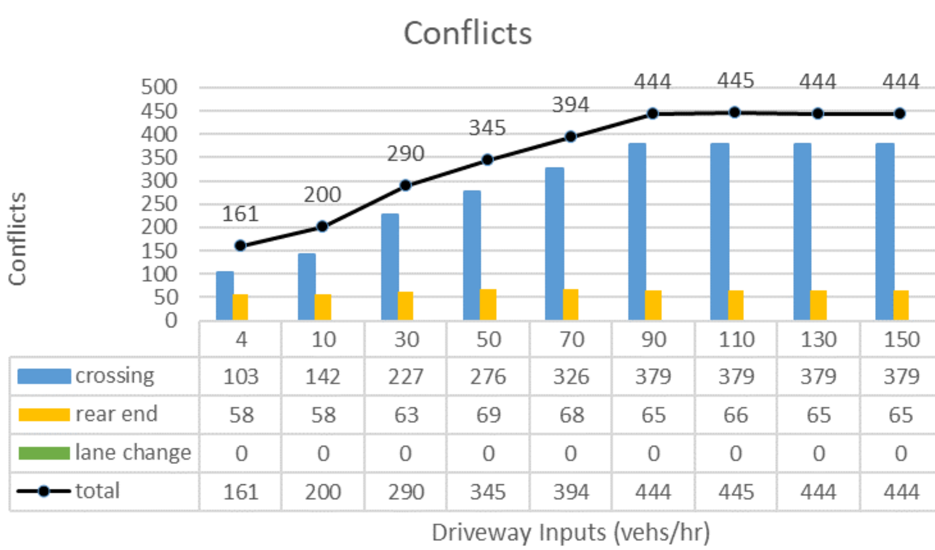


Figure E-8. Driveway Volume and Conflict Analysis

As shown in the figure above, the conflicts also increase with driveway vehicular volumes, as expected. Obviously, the higher the levels of conflict that exist along a roadway network, the higher the probability of a crash occurring. It should be noted that although the simulation previous identified several conflicts occurring along work zone 1, there were not any actual traffic collisions likely due to drivers being able to make evasive actions.

The secondary analysis included maintaining the driveway traffic volumes at four vehicles per hour but increasing the mainline traffic by an increment of ten-percent of the initial values to a maximum increase of 100-percent. While the traffic volumes were increased, delay and queue length were evaluated. Figures E-9 and E-10 present the delay changes for northbound and southbound traffic volume increases, respectively.

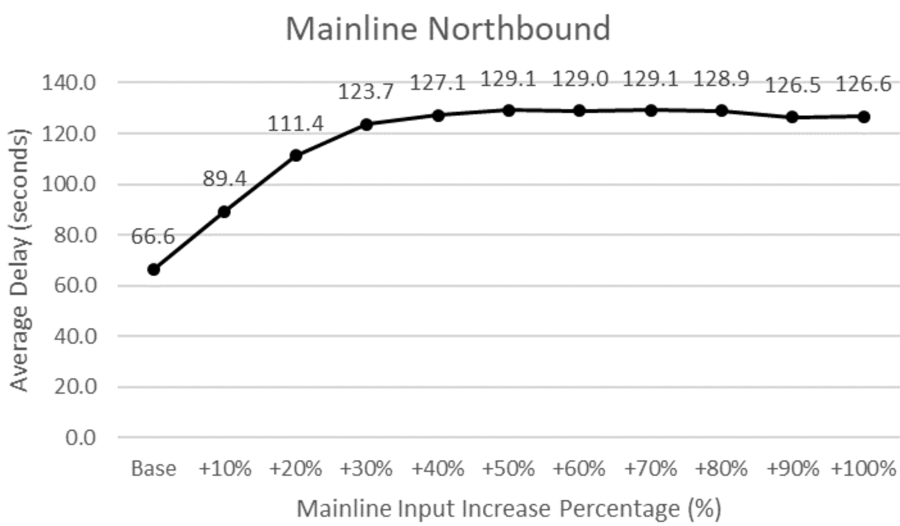


Figure E-9. Northbound Mainline Volume and Average Delay

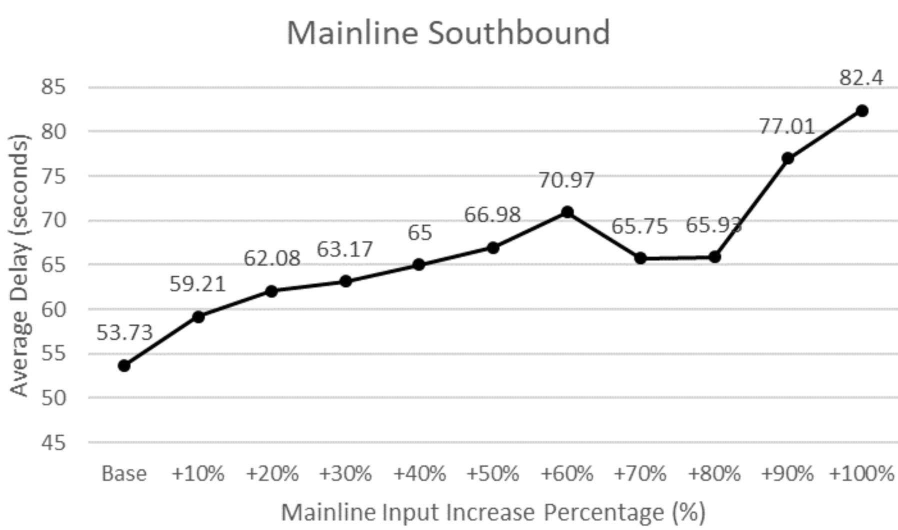


Figure E-10. Southbound Mainline Volume and Average Delay

As seen in the figures above, the average delay begins to stabilize with approximately 30-percent additional traffic which would equate to approximately an AADT of 5000 vehicles. It should be noted that this delay was determined without changes to the signal timing of the DADs and the temporary traffic signals at the end of the work zone.

Figures E-11 and E-12 present the queue length changes for northbound and southbound traffic volume increases, respectively.

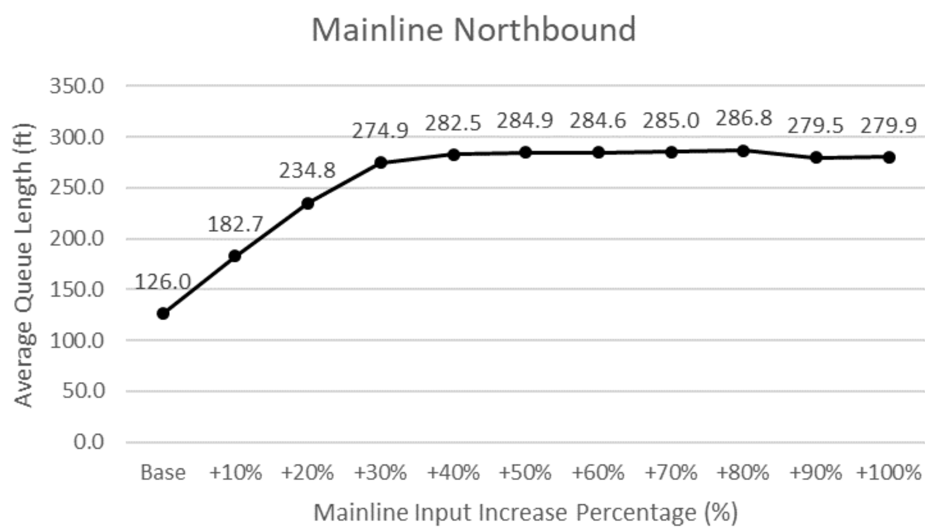


Figure E-11. Northbound Mainline Volume and Queue Length

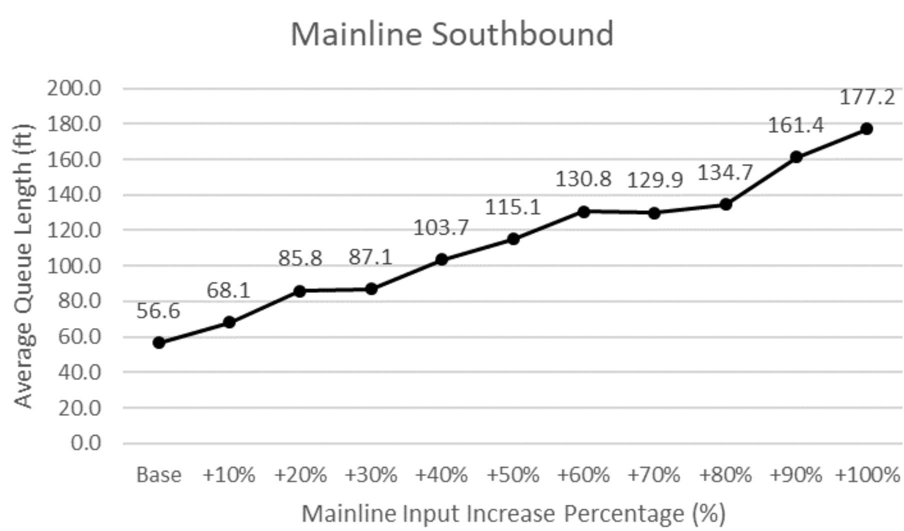


Figure E-12. Southbound Mainline Volume and Queue Length

As seen in the figures above, the northbound average queue begins to stabilize with approximately 30-percent additional traffic which would equate to approximately an AADT of 5000 vehicles. This would also be equivalent of 14 vehicles waiting at the temporary traffic signal along the mainline. The southbound direction of travel does not stabilize even with twice the amount of traffic along the roadway.

Lastly, the signal timings for the mainline traffic signals were modified from 70-seconds of red time to a minimum of 23 seconds which is the minimum time needed for the last vehicle crossing the stop line at one end of the work zone to pass through the entire work zone. It is obvious that with shorted red times along the mainline, the delay and queue length along the mainline would decrease. Therefore, the changes in average delay for the driveways was evaluated and presented in Table E-12.

Table E-12. Driveway Delay by Red Signal Display

All-Red Time	Driveway and Delay (minutes)			
	DR1	DR2	DR3	DR4
70	0.5	0.7	0.3	0
60	0.6	1.3	0.1	0
50	0.6	1.3	0.3	0
40	0.8	1.3	0.3	0
30	0.8	0.0	0.2	0
25	0.4	0.6	0.3	0
23	0.7	0.0	0.1	0

As seen in the table above, with four vehicles per hour at the driveway, the delay at any of the driveways remains minimal. Therefore, the signal timing at the temporary traffic signals at the beginning of the work zone is more critical to minimize mainline traffic delay and queue lengths than that of the driveways.