Ohio Department of Transportation
District 12

CUY-43-11.13 Safety Study

(Lee Road at Miles Avenue & South Miles Road)

HSP Rank - Urban Intersection #32 (2014), #25 (2015)

MOTT MACDONALD

VAR STW - Safety Studies No. 2015-2
Task #8
Mott MacDonald Project No. 346464

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MOTT MACDONALD ISSUE AND REVISION RECORD:

REV	DATE	ORIGINATOR	CHECKED	REVIEWED	DESCRIPTION
A	3/31/2016	SJB	SJT	CWP	FIRST ISSUE
B	10/31/2016	SJB		CWP	FINAL

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Executive Summary

Purpose

The purpose of this study is to identify crash trends, determine site-specific countermeasures, and set up reasonable time periods to implement the proposed countermeasures for the SR 43/Lee Road and Lee Road/South Miles Road intersections in the City of Cleveland, Cuyahoga County, Ohio. This location is being studied because the intersection ranked #32 on ODOT's 2014 Highway Safety Program Priority List for Urban Intersections based on the frequency and severity of crashes.

Background

SR 43 (Miles Avenue) and South Miles Road are located less than 500 feet from each other along Lee Road with signals at each intersection. The signals are coordinated. An at-grade railroad crossing is located between the two intersections. SR 43 and Lee Road are classified as urban principal arterials. Lee Road is the major roadway with an ADT of approximately 16,000 vehicles per day.

A new signal was installed at the SR 43/Lee Road intersection in 2014 providing upgrades to signal visibility, detection, and timing. At that time, no changes were made at the South Miles Road intersection except signal timing tweaks.

Crash Results and Possible Causes

Mott MacDonald verified 68 crashes at the study intersections between 2012 and 2014. Three major crash trends are as follows:

1. Nine crashes occurred on southbound Lee Road at South Miles Road, including rear end, sideswipe, and left turn crashes. All crashes were directly related to the southbound shared through/left lane.
2. Nine crashes occurred at the driveway on Lee Road for the gas station on the northwest corner of SR 43 and Lee Road. All nine were angle crashes with the at-fault vehicle exiting the drive. The cause appears to be the width of the drive (90 feet) and the proximity to the intersection.
3. Twenty rear end crashes occurred on Lee Road and appear to be largely congestion related.

Recommended Countermeasures

Mott MacDonald recommends the following short-term countermeasures:

- Upgrade pedestrian and vehicle detection at the South Miles Road intersection, retime both intersections including optimizing the coordination parameters, and evaluate the need for railroad traffic signal preemption.

Mott MacDonald recommends the following medium-term countermeasures:

- Improve the transition and surface of the at-grade railroad crossing
- Narrow the driveway to the gas station on the northwest corner of SR 43/Lee Road

Mott MacDonald recommends the following long-term countermeasures:

- Widen Lee Road south of SR 43 to add an exclusive southbound left turn lane at the South Miles Road intersection which would necessitate new mast arms, signals with backplates, pedestrian signals, and vehicle detection at the South Miles Road intersection.

Existing Conditions

The study area is SR 43 (Miles Avenue) at Lee Road (CR 8), Lee Road at South Miles Road, the segment in between, and 500 feet along each intersection approach. Both SR 43 and Lee Road are classified as urban principal arterials while South Miles Road is a major urban collector. SR 43 is an east-west route that provides access to I-480 N and I-271 to the east and SR 14 (Broadway Avenue) to the west. Lee Road is a north-south route that provides access to I-480 to the south and Shaker Heights and East Cleveland to the north. SR 43 and Lee Road are National Highway System (NHS) routes.

The study area by Network Linear Feature Identifier (NLFID) is as follows.

Route	Local Name	NFLID	Logpoint	Location
SR 43	Miles Avenue	SCUYSR00043**C	11.13	Lee Road
CR 8	Lee Road	CCUYCR00008**C	1.81 - 1.93	S. Miles Road to SR 43

The speed limit is 35 MPH on all legs except the north leg of Lee Road and South Miles Road which are 25 MPH. Based on traffic counts in September of 2015, the annual average daily traffic (AADT) is approximately 9,000 vehicles per day on SR 43, 16,000 vehicles per day on Lee Road, and 5,000 vehicles per day on South Miles Road. Lee Road is composed of concrete pavement. SR 43 and South Miles Road are both asphalt roadways however the approaches to Lee Road are concrete. Sidewalks are present on both sides of all roadways in the study area and vary from integral walk to offset walk with grass tree lawns. In general, pavement and walk is in fair condition. Pavement markings are in good condition throughout and per the City of Cleveland, will be restriped as part of routine city operations in the coming months.

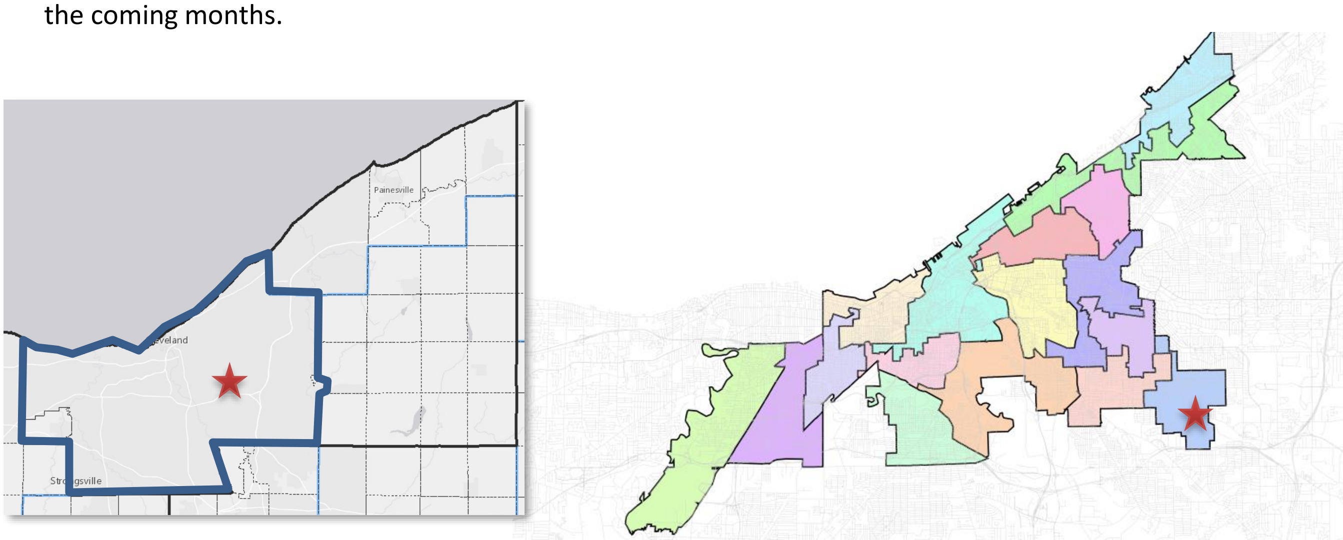


Figure 1 - Study Location, District 12, Cuyahoga County (left), City of Cleveland (right)

There is evidence of truck off-tracking at the SR 43/Lee Road intersection, particularly at the southwest and southeast corners, in the form of visible tire marks across the curb ramps and walk as well as scraped wood utility poles.

Figure 3 – At-Grade Railroad Crossing

Both intersections operate under semi-actuated, coordinated traffic signal control with Lee Road mainline under minimum recall. At the SR 43/Lee Road intersection, left turn lanes are present for each approach with powerhead loop detectors and protected/permissive left turn phasing. In addition to the left turn lanes, each approach has a through lane and a shared through/right lane. Backplates and LED signal indications are present throughout. Pedestrian crosswalks and countdown LED signals are present for each approach. Pushbuttons are present for all crossings. All curb ramps appear to be ADA compliant. LED street lighting is present on both roadways and at the intersection.

Figure 2 - SR 43/Lee Controller

At the Lee Road/South Miles Road intersection, South Miles Road tees into Lee Road on the east side and a church driveway acts as a fourth approach on the west side of the intersection. South Miles Road is vehicle actuated via loops and the driveway utilizes a microwave detector to call vehicles. The southbound approach of Lee Road is made up of a shared through/left lane and a shared through/right lane. This approach has a leading green phase with a protected left. Backplates are not present. Signal indications appear to all be LED. Crosswalks and pedestrian signals are present on the north and east legs. The north-south crossing is on recall while the east-west crossing is pushbutton activated. All curb ramps appear to be ADA compliant. LED street lighting is present on both roadways and at the intersection.

The SR 43 and South Miles Road signals are coordinated along Lee Road. The signal to signal coordination appears to be via hardwire aerial interconnect cable. The signals operate with a zero second offset referencing the end of yellow on the Lee Road north-south phase at both intersections.

Figure 4 - Discontinuous Walk

The City of Cleveland noted that the controller and UPS at the SR 43/Lee Road intersection was hit by a vehicle and damaged in January of 2016. The controller was replaced at that time but the UPS was not replaced. Figure 2 shows the foundation and footprint for the controller and UPS cabinets installed in 2014 as well as the current cabinet installed in 2016.

A single track at-grade railroad crossing is present between the two intersections. Per the Ohio Rail Development Commission (ORDC) and the Public Utilities Commission of Ohio (PUCO) online databases, the operating railroad is the Cleveland Commercial Railroad Company and the crossing owner is Norfolk Southern. Per the City of Cleveland, there is no railroad preemption or communication between the railroad signals and vehicular signals at this location. The material in between the tracks is in poor condition and the transition from pavement to tracks is not smooth. In addition, the sidewalks on both sides of Lee Road are discontinuous at the crossing.

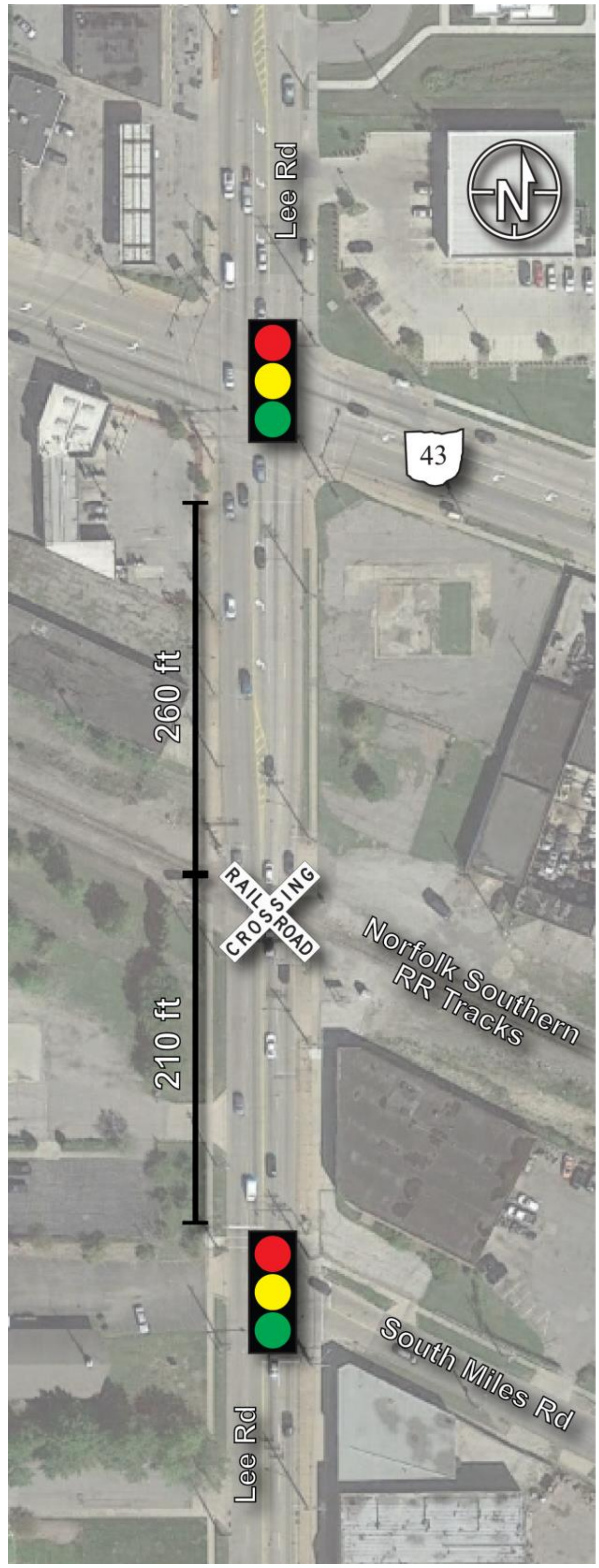
The area is commercial and industrial along both SR 43 and Lee Road and heavily residential off of these two major routes. The southeast corner of the SR 43/Lee Road intersection is vacant while the other three corners are occupied. The northwest quadrant contains a large curb cut access point on Lee Road extending across the gas station at the corner and the multi-use commercial building just north.

The Greater Cleveland Regional Transit Authority (RTA) runs bus #19 along Miles Avenue and #40 along Lee Road within the project area with stops approximately every 30 minutes during peak periods.

SR 43, Lee Road (SR 43 to South Miles Road), and South Miles Road are on the City of Cleveland's Bikeway Implementation Plan.

Mott MacDonald conducted a field review on March 23, 2016, with Andy Cross from the City of Cleveland. The weather was 50 degrees, clear, and dry. The observation was performed on what was deemed to be a typical day based on weather, a non-holiday week, and no known events that would have altered traffic conditions. Other observations were made between January and March namely to observe signal timing and progression.

Figure 5 - Signal and Railroad Crossing Spacing



Crash Data

The intersection was identified on ODOT's 2014 Highway Safety Program Safety Priority List as #32 for urban intersections and on the same list in 2015 as #25.

ODOT provided Mott MacDonald crash summaries in CAMTool format. Crashes were queried in ODOT's GCAT system by spatial location at the intersection and adjoining segment for years 2012 through 2014 (the three most recent years available at the time of the study). The query resulted in 76 total crashes.

Mott MacDonald downloaded OH-1 reports from the Ohio Department of Public Safety's website and reviewed crashes to verify location and type. Mott MacDonald removed crashes that were located outside of the study area. A total of eight crashes were removed from the analysis resulting in 68 total crashes. A number of crashes were revised in the CAMTool based on location, NLFID, logpoint or type of crash. These updates were submitted to ODOT following hand log revision procedures. A summary of the verified crashes is presented below.

Figure 6 - Crash Summary

CRASH SEVERITY	Number	%
Injury Crash	**24**	35.3%
Property Damage Crash	**44**	64.7%
Grand Total	**68**	**100.0%**

TRAFFIC CRASH YEAR	Number	%
2012	**18**	26.5%
2013	**25**	36.8%
2014	**25**	36.8%
Grand Total	**68**	**100.0%**

TYPE OF CRASH	Number	%
Rear End	**31**	45.6%
Sideswipe - Passing	**13**	19.1%
Angle	**12**	17.6%
Left Turn	**5**	7.4%
Fixed Object	**3**	4.4%
Sideswipe - Meeting	**2**	2.9%
Pedestrian	**2**	2.9%
Grand Total	**68**	**100.0%**

- Of the injury crashes, one was classified as incapacitating, one as severe, and five as minor.
- No fatal crashes were reported.
- Over 70% of the crashes occurred either under no adverse weather condition, with dry roads, or in daylight.
- Twelve crashes (18%) involved a hit/skip.
- Forty one crashes occurred at the SR 43/Lee Road intersection, 25 crashes occurred at the Lee Road/South Miles Road intersection, and two segment crashes occurred between the two.
- No crashes involved a train.
- Two crashes involved a tractor/semi-trailer, one of which scraped a pole turning right from northbound Lee Road to SR 43.

Of the two pedestrian crashes, one occurred when a wheelchair user was crossing South Miles Road south to north in the crosswalk and was struck by a vehicle attempting to turn right on red from South Miles Road to northbound Lee Road. The other occurred when a driver on SR 43 attempted to turn right on red from the westbound approach and struck a pedestrian in the crosswalk crossing east to west across Lee Road. In both cases, the operator of the vehicle was at fault for failing to yield to the pedestrian.

As an update to this report, Mott MacDonald downloaded and reviewed 2015 crashes and found 36 crashes within the study area with nearly identical trends as the 2012 through 2014 data in terms of location, type, and severity. A brief summary is below.

- One-third of 2015 crashes involved an injury.
- A majority of the crashes (15) were rear-end crashes (42%), followed by sideswipe-passing and angle crashes, with eight crashes each.
- Nearly 60% of all 2015 crashes occurred between the hours of 3PM and 7PM.
- 30% of all crashes involved a hit/skip.
- One crash involved a pedestrian, struck while crossing on the “do not walk” phase across the west approach of Miles Avenue from south to north.

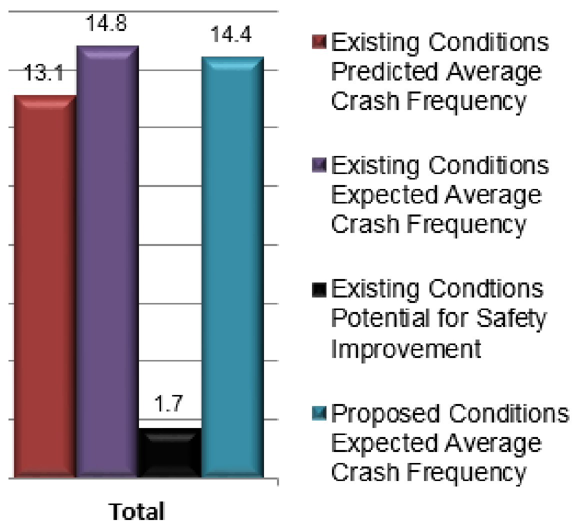
Crash Analysis

The most frequently occurring crashes were those associated with the Lee Road southbound left turn movement at South Miles Road. A total of nine crashes (three left turn, three rear end, and three sideswipe-passing) were associated with this left turn movement from the shared through/left turn lane. Five of the nine crashes involved an injury.

Figure 7 - SB Vehicle on Lee Road Waiting to Turn Left onto South Miles Road

The other major crash trend was angle crashes at the gas station drive on Lee Road at the northwest corner of the SR 43/Lee Road intersection. Nine angle crashes occurred when the at fault vehicle attempted to exit the gas station and was struck by a southbound vehicle on Lee Road. All nine crashes were property damage only crashes and all occurred between the hours of 12 PM and 7 PM.

Figure 8 - HSM Potential for Safety Improvement



Rear end crashes were the most frequently occurring crash type but the location of rear end crashes were spread out. Twenty rear end crashes occurred on Lee Road and were largely related to congestion stemming from the two signalized intersections.

A notable trend in 2015 crashes was that crashes peaked during the hours with heaviest volumes (PM peak).

Mott MacDonald performed a safety analysis for the two study intersections using Highway Safety Manual (HSM) methodology in ODOT's Economic Crash Analysis Tool (ECAT). Based on site characteristics and crash history, the intersections are expected to have approximately 15 crashes per year combined. This is slightly higher than similar sites within the state. Based on the HSM methodology, the potential for safety improvement is two crashes per year.

Figure 9 – SR 43/Lee Road Collision Diagram

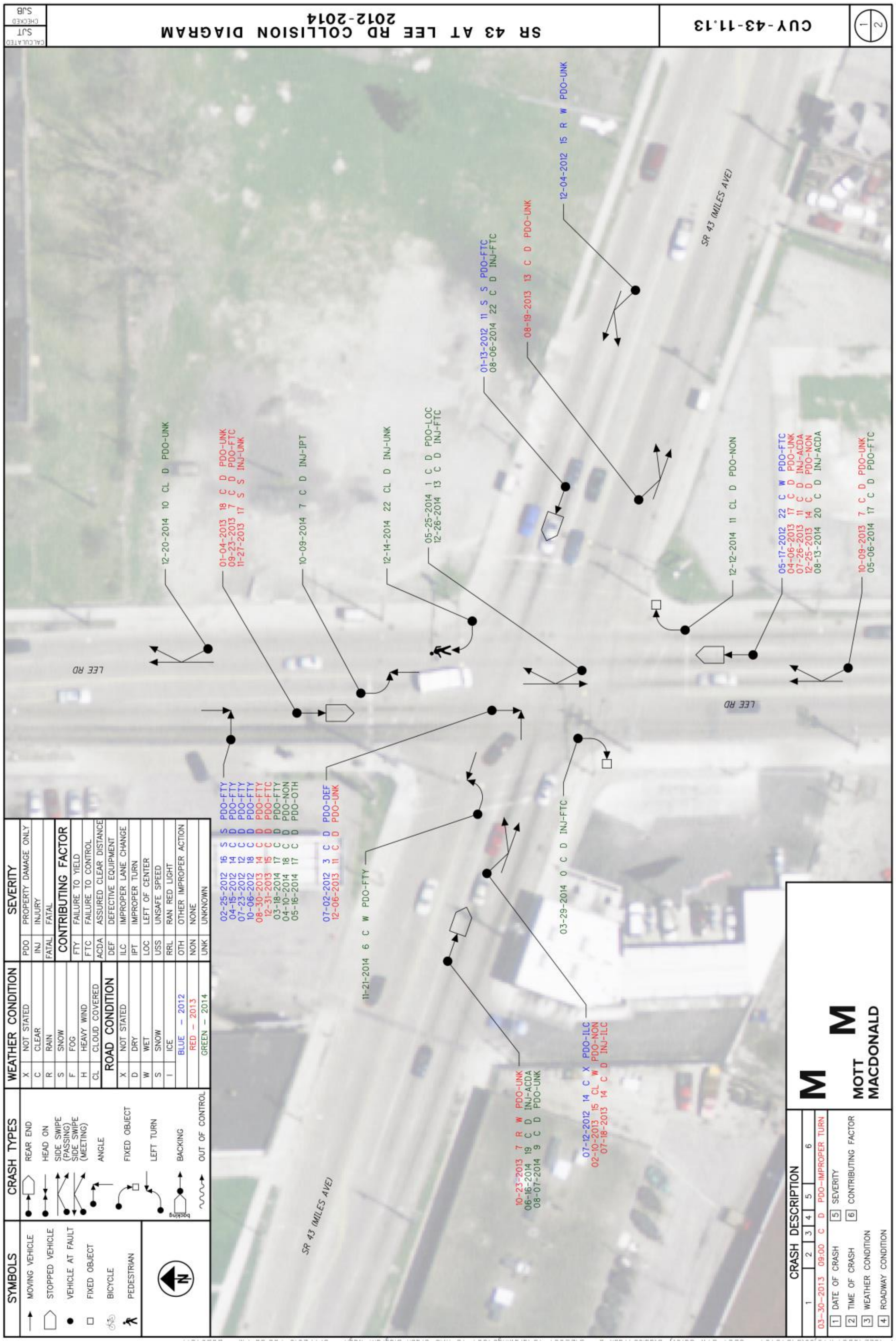
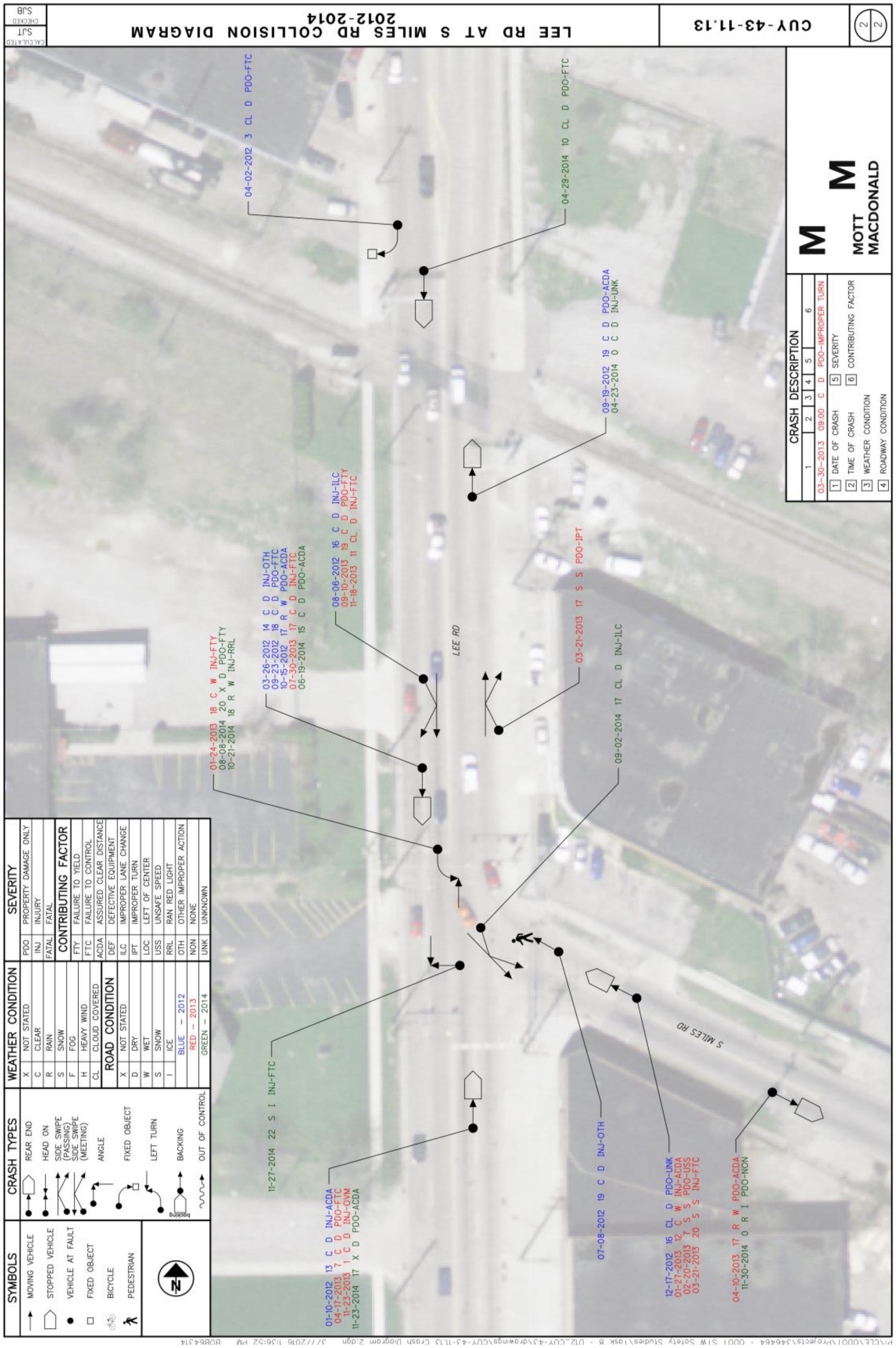


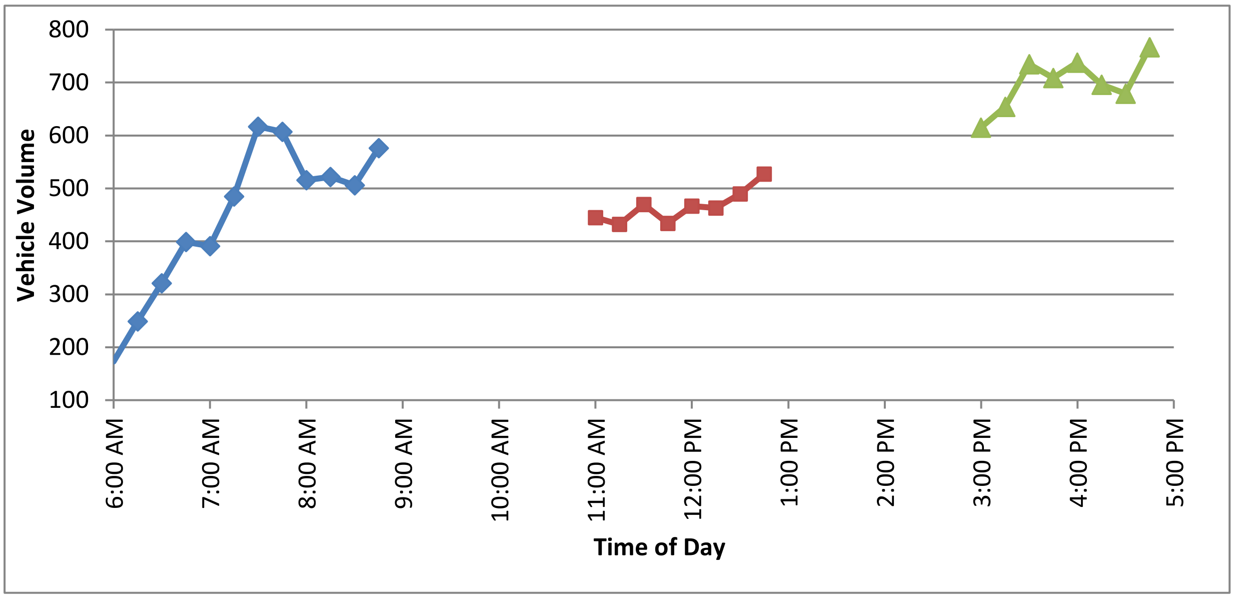
Figure 10 - Lee Road/South Miles Road Collision Diagram



Transportation Analysis

ODOT collected a four-hour turning movement count (7 AM to 9 AM and 4 PM to 6 PM) at the Lee Road/South Miles Road intersection on September 15, 2015. The count was classified by cars, single unit trucks, and heavy trucks which includes tractor trailers. In addition, ODOT provided a seven-hour turning movement count (6 AM to 9 AM, 11 AM to 1 PM, 3 PM to 5 PM) at the SR 43/Lee Road intersection from April 26, 2012, the most recent count at the intersection. The graph below displays total entering intersection volume at SR 43/Lee Road over the course of the seven-hour count.

Figure 11 - Intersection Entering Traffic



The total entering traffic per day is estimated at 25,000 vehicles for the SR 43/Lee Road intersection and 21,000 vehicles for the Lee Road/South Miles Road intersection based on the counts, ODOT hourly and seasonal adjustment factors, and historical information. Lee Road is the major roadway at both intersections with approximately 16,000 vehicles per day. Based on turning movement counts, truck traffic makes up approximately 3% of traffic on all approaches at both intersections.

At the SR 43/Lee Road intersection, over 150 pedestrian crossings were counted during the seven-hour turning movement count. The same pedestrian can cross multiple legs of the intersection so actual number of pedestrians is likely less, however there is still substantial pedestrian traffic through both intersections. Mott MacDonald observed similar pedestrian activity during the field review.

Mott MacDonald utilized Synchro traffic modeling software to analyze the signal operation, specifically the interaction between the two intersections and progression along Lee Road. Mott MacDonald spoke with the Northeast Ohio Areawide Coordinating Agency (NOACA) about forecasting growth in this area and NOACA determined that Mott MacDonald should use existing traffic counts for any future year capacity analysis as NOACA's model is forecasting negative growth in this area.

Volumes on Lee Road from the 2015 traffic count at Lee Road and South Miles Road were 10% to 20% higher than volumes on Lee Road from the 2012 traffic count at SR 43 and Lee. Based on other local counts with data available from 2012 and 2015, the volumes on Lee Road have likely increased since

2012. Mott MacDonald increased volumes on Lee Road at the SR 43/Lee Road intersection in the capacity analysis so that volumes between the two intersections were balanced.

Mott MacDonald obtained the current signal timings and coordination parameters from the City of Cleveland. Below is a summary of current signal parameters.

Both intersections

- Coordinated to end of green for northbound-southbound through phase (phase 2+6 on Lee Road)
- 100 second cycle lengths all day
- Same timing and splits for AM and PM peaks
- Four second yellow time for through movements, three second yellow time for left turn movements
- Two second all red time for all movements

SR 43 / Lee Road intersection

- Six second walk and 19 second flashing don't walk for all crossings
- Ped recall and max vehicle recall turned on for the SR 43 through phases
- Minimum coordination recall for Lee Road through phases

Lee Road / South Miles Road intersection

- Ped recall and max vehicle recall turned on for the South Miles Road phase
- Max vehicle recall turned on the southbound left turn phase
- Minimum coordination recall for Lee Road through phases

The vehicle and pedestrian recalls are turned on all day resulting in lost efficiency at both signals. At the South Miles Road intersection, the pedestrian recall is turned on due to non-functioning pedestrian pushbuttons while the max vehicle recall is turned on due to a lack of functioning vehicle detection. At the SR 43 intersection, it is not clear why the max vehicle recall is turned on for the SR 43 approaches as loop detectors were replaced in 2014 and appear to be working based on a controller inspection.

Based on Synchro analysis, the SR 43/Lee Road and Lee Road/South Miles Road intersections are currently operating with acceptable Level of Service (LOS) C and delay per vehicle around 20 seconds in the AM peak hour. In the PM peak hour, the SR 43/Lee Road intersection is operating at a LOS D with the southbound approach failing while the Lee Road/South Miles Road intersection is operating at a failing LOS E with the southbound approach also failing. Mott MacDonald validated these results based on site observations in the AM and PM peaks across several days.

Mott MacDonald analyzed the following two alternatives to improve operations along Lee Road.

- Alternative A – upgrading vehicle and pedestrian detection at the Lee Road/South Miles Road intersection and optimizing signal timing and coordination parameters
- Alternative B – widening Lee Road to construct an exclusive southbound left turn lane at South Miles, extending the northbound left turn lane at SR 43, and optimizing signal timing and coordination parameters

A summary of the expected LOS and delay for each alternative as compared to the existing conditions is presented in Figure 12.

Figure 12 - Capacity Analysis Summary

CUY-43 2015 Volumes	AM No Build		AM Alt A		AM Alt B		PM No Build		PM Alt A		PM Alt B	
Cycle Length (sec)	100		100		100		100		100		100	
S Miles Rd Offset (sec)	0		36		95		0		19		21	
SR 43 & Lee Road	**C**	**24.6**	**C**	**24.5**	**C**	**23.8**	**D**	**42.7**	**C**	**29.2**	**C**	**28.1**
EB - SR 43	C	21.8	D	35.0	D	35.0	B	19.7	C	31.9	C	31.9
WB - SR 43	C	22.1	C	31.8	C	31.8	C	25.1	D	36.7	D	36.7
NB - Lee Rd	C	22.5	B	18.7	B	16.9	C	29.7	C	23.3	C	20.1
SB - Lee Rd	C	31.7	C	21.9	C	21.9	F*	78.1	C	29.9	C	29.9
Lee Rd & South Miles Rd	**C**	**23.5**	**A**	**7.3**	**A**	**6.4**	**E**	**56.6**	**B**	**13.8**	**A**	**9.5**
EB - private drive	C	23.4	C	33.3	C	31.0	C	23.4	C	30.7	C	32.2
WB - South Miles Rd	A	9.5	B	16.4	C	21.7	B	10.9	C	24.8	B	19.4
NB - Lee Rd	C	24.5	A	5.0	A	5.3	C	24.4	A	5.5	B	12.4
SB - Lee Rd	C	25.6	A	6.9	A	3.2	F	88.4	B	17.0	A	5.2

**F because v/c ratio > 1.0*

Upgrading detection and optimizing signal timing and coordination parameters is expected to have a positive impact on reducing delay at both intersections, most notably in the PM peak hour. The current 100 second cycle length is an ideal cycle length for current conditions and when optimizing the timings as it provides suitable time for good progression along Lee Road while still minimizing delay on SR 43 and South Miles Road. Although not analyzed as part of this study, upgrading detection and removing max recall setting from the controllers will allow the signals to run more efficiently during periods of the day outside of the AM and PM peaks.

From an operational standpoint, adding an exclusive southbound left turn lane at South Miles Road is expected to have a similar impact on reducing delay at both intersections as Alternative A.

Mott MacDonald calculated recommended turn lane lengths for exclusive turn lanes based on the ODOT Location & Design Manual (L&D), Volume 1, Sections 401-9E and 401-10E. At the SR 43/Lee Road intersection, the existing northbound and southbound left turn lanes do not meet L&D criteria. Per Alternative B, a southbound left turn lane length was also calculated at the South Miles Road intersection. The results are below.

Figure 13 - Turn Lane Summary

Intersection	Approach	Direction	Existing (ft)	Calc Length (ft)	Thru Backup (ft)	Recommended
SR 43 @ Lee Rd	SR 43	EB	155	150	175	no change
		WB	200	225	175	no change
	Lee Rd	NB	130	300	325	200' based on spacing with S Miles and RR tracks
		SB	120	200	338	no change, limited by existing pavement
Lee Rd @ S Miles Rd	Lee Rd	SB	-	250	513	150' based on spacing with SR 43 and RR tracks

Mott MacDonald also utilized SimTraffic traffic simulation software to estimate expected queues in the study area.

Figure 14 - Queue Length Summary

SR 43 at Lee Road

95th % Queue (ft)	EB			WB			NB			SB		
Lane	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Exist Storage Length	*155*	-	-	*200*	-	-	*130*	*500*	*500*	*120*	-	-
PM No Build	68	176	217	98	135	137	171	203	204	206	1021	975
PM Alt A	61	166	226	100	146	129	212	324	330	160	568	544
PM Alt B	51	159	283	100	148	163	190	269	281	218	474	430

Lee Road at South Miles Road

95th % Queue (ft)	EB	WB	NB		SB		
Lane	LTR	LTR	LT	TR	L	LT*	TR
Exist Storage Length	-	-	-	-	-	*500*	*500*
PM No Build	46	148	261	251	-	395	403
PM Alt A	59	181	204	174	-	338	343
PM Alt B	51	202	215	208	107	203	235

**Through lane only for Alt B*

On Lee Road, northbound queue lengths at SR 43 and southbound queues lengths at South Miles Road currently extend past the at-grade railroad crossing and are expected to extend past the crossing with Alternatives A and B. In general, queues in Alternatives A and B are expected to decrease or be similar to existing conditions. Notably, southbound queues on Lee Road are expected to decrease by about half for both alternatives at SR 43 and by nearly half for Alternative B at South Miles Road.

Previous and Future Projects

- NOACA led a Road Safety Audit (RSA) with the same limits as this study in 2011. Representatives from the City of Cleveland, Cuyahoga County, and ODOT District 12 were involved along with NOACA. A number of recommendations were made to improve safety and operations and many of the recommendations were implemented. Recommendations that were not implemented include:
    - Provide left turn lane for southbound Lee Road at South Miles Road
    - Add emergency vehicle preemption
    - Upgrade detection at the Lee Road/South Miles Road intersection
    - Provide backplates at the Lee Road/South Miles Road intersection
    - Install "SR 43" junction signs on Lee Road
    - Install lane use signs and pavement marking arrows on southbound Lee Road approaching South Miles Road
    - Improve radii at SR 43/Lee Road intersection
    - Define narrowing of lanes on SR 43
    - Upgrade pedestrian signals and pushbuttons at the Lee Road/South Miles Road intersection
    - Upgrade sidewalks using 10" concrete on all corners
    - Improve the pavement transition and surface at the railroad crossing
    - Narrow the drive on Lee Road at the northwest corner of the SR 43/Lee Road intersection

- In 2014, the traffic signal at SR 43 and Lee Road was reconstructed as part of an ODOT sponsored safety design project (PID 88276). The following improvements were implemented with this project, all of which were recommended in the RSA:

    - Upgraded detection to powerhead loops
    - Added signal backplates
    - Upgraded to LED vehicular signal indications
    - Upgraded pedestrian signals to countdown LED signals
    - Reconstructed curb ramps to meet ADA requirements
    - Upgraded pedestrian pushbuttons
    - Upgraded pavement markings from paint to epoxy
    - Staggered stop lines on SR 43 to allow more space for turning trucks
    - Retimed the signal

- In January of 2016, the controller and UPS at the SR 43/Lee Road intersection located on the northwest corner were hit by a vehicle and both were damaged beyond repair. The City of Cleveland replaced the controller but not the UPS.

Proposed Countermeasures and Design Evaluations

The most frequently occurring crashes within the study area are related to the southbound left turn movement from Lee Road to South Miles Road. A proven safety strategy to address the crashes at this location is to add an exclusive southbound left turn lane. An exclusive left turn lane would eliminate the shared through/left turn lane. This would directly address the rear ends (caused by drivers unexpectedly stopping when the driver in front of them is attempting to turn left from the shared lane during the permissive signal phase) and sideswipes (caused by drivers attempting to switch lanes to avoid a stopped vehicle attempting to turn left from the shared lane during the permissive signal phase).

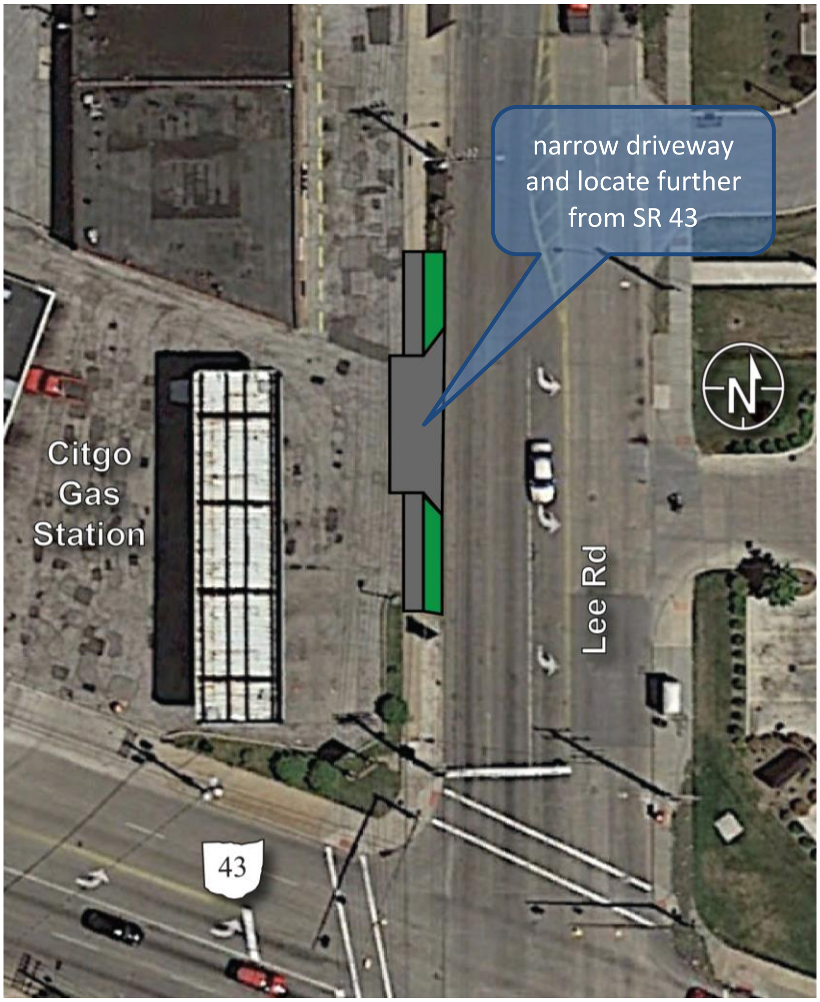
While there appears to be enough room within the right of way to widen Lee Road, there are several utilities that would need to be relocated including overhead power facilities on Lee Road. Furthermore, widening would facilitate the need for new signals at the South Miles Road intersection and would require relocating the railroad crossing gates.

Other safety strategies include retiming the Lee Road/South Miles Road signal (i.e. extending the southbound protected left turn phase) and restriping the southbound approach for one through lane and one exclusive left turn lane. Since left turn vehicles arrive at random and are just as likely to arrive during the permissive phase, extending the southbound protected phase would have little impact on safety while increasing delay for northbound vehicles. Restriping the southbound approach presents several problems, namely it would negatively affect the upstream southbound approach at SR 43 as driver lane preference would shift heavily to the southbound curb lane, reducing efficiency through the intersection. In addition, restriping would add delay at the South Miles Road intersection and may result in more sideswipe crashes as through southbound vehicles from SR 43 in the middle lane would have to shift lanes to continue through at South Miles Road.

Figure 15 - 90-foot drive opening on Lee Road

The location with the most frequently occurring single crash type was the driveway on Lee Road for the gas station at the northwest corner of SR 43/Lee Road. Nine angle crashes occurred when a driver attempted to exit the gas station and was struck by a southbound vehicle. The drive opening at this location is 90 feet long and is shared with a multi-use commercial building. The commercial building has another drive 25 feet to the north. To potentially mitigate this crash, the driveway width should be decreased and moved as far away from the intersection as possible. Access at the other corners is well controlled. The southeast corner is currently vacant and the City of Cleveland should actively control driveway size and location when the property is redeveloped.

Figure 16 - Proposed Access Management on Lee Road



The low cost safety strategy that may reduce rear end crashes and also have a positive impact on improving operations between the two intersections would be to retime the signals and adjust the coordination parameters. Adjusting the timing would improve progression along Lee Road and result in fewer stops for vehicles on Lee Road and is expected to reduce delay to vehicles on all approaches. Currently the signals are coordinated, but the offsets between signals do not appear to be providing optimal progression based on Mott MacDonald field observations, namely in the PM peak. To optimize timings, vehicle detection must be added to the South Miles Road approach so that the controller can be taken off of max recall for that phase.

Currently, all red clearance intervals are set at 2.0 seconds for every phase. Yellow clearance intervals vary from 3.0 seconds for left turn phases to 4.0 seconds for through phases. Mott MacDonald reviewed clearance intervals using ODOT's clearance interval calculation spreadsheet and found existing clearance intervals to be in line with calculated values. As crash data does not indicate insufficient clearance intervals, Mott MacDonald recommends no change to clearance intervals.

In addition, Mott MacDonald reviewed existing pedestrian timing settings per the Ohio Manual of Uniform Traffic Control Devices (OMUTCD). At both intersections, minimum walk times and minimum clearance intervals (flashing don't walk times) are met for all crossings. The only pedestrian timing change Mott MacDonald recommends is to remove the pedestrian recall.

As part of improving progression and traffic flow along Lee Road, the at-grade railroad crossing must be improved. Currently, drivers traveling between the two study intersections must slow down, in both directions, to avoid ruts, holes, and uneven pavement while crossing the tracks. Mott MacDonald gauged driving speeds across the tracks by driving with the flow of traffic and found the most common speed vehicles travel across the tracks was approximately 15 to 20 MPH in the northbound direction and 10 to 15 MPH in the southbound direction. This slow down disrupts platoons formed at each signal and will prevent improved coordination until the crossing is improved.

Figure 17 - NB Queues on Lee Road from SR 43 through South Miles Intersection

As queues extend from one intersection to the other in both directions, Mott MacDonald noted queued vehicles stopping on the railroad tracks nearly every cycle during the PM peak. Based on information from ORDC and PUCO, the tracks see one to two trains per day. Mott MacDonald was unable to obtain any other information on the schedule and timing of train traffic. Because the track is active, the signal spacing between the two intersections and the railroad crossing as well as the observed queues warrants further evaluation for providing railroad preemption at both signals. Railroad preemption would effectively clear queues on Lee Road by taking priority control over the signals and providing green time to the appropriate phases when a train is approaching. Although no crashes involved a train, providing railroad preemption at this location would be a proactive approach to addressing a potentially serious crash.

Figure 18 - SB Queues on Lee Road from South Miles Intersection

At the SR 43/Lee Road intersection, the radii are unsatisfactory as indicated by tire marks on the walk and signs of scraped utility poles, namely on the southwest and southeast corners. Because only one crash noted the tight radii as a contributing factor to a crash, the presence of two receiving lanes to alleviate difficult right turn maneuvers, and potentially longer pedestrian crossings, Mott MacDonald does not recommend increasing radii at this time. Truck turning movements and radii should be further evaluated with any future pavement improvements at the intersection.

Other potential improvements that should be considered include the following:

- Upgrade signals with backplates (may require new mast arm supports) and pedestrian signals with countdown timers at the Lee Road/South Miles Road intersection
- Install SR 43 junction signage on Lee Road and install lane use signs and pavement marking arrows on Lee Road approaching South Miles Road

Recommendations

Mott MacDonald weighed the benefits of each safety strategy given current site conditions, crash patterns, and previously implemented safety improvements. The HSM safety analysis shows that this site is operating with more crashes per year than similar sites. Mott MacDonald believes there are a number of countermeasures that can improve safety while also providing operational benefits.

Short Term Recommendations

- Mott MacDonald recommends upgrading pedestrian and vehicle detection at the South Miles Road intersection and retiming both intersections including: removing unnecessary recalls, programming time-of-day patterns, and optimizing intersection and coordination parameters. This is a lower cost improvement that can have a substantial impact on reducing vehicle delay, improving progression, and reducing rear end crashes along Lee Road. Along with retiming the signal, Mott MacDonald recommends evaluating the need for railroad traffic signal preemption.

Medium Term Recommendations

- Mott MacDonald recommends improving the transition and surface of the at-grade railroad crossing. This will require coordination between the City of Cleveland, the operating railroad company, and the crossing owner. Mott MacDonald believes this recommendation should take priority because of the necessary coordination and because the other improvements cannot be fully realized without removing this impediment to speed and progression. This is considered to be a medium term recommendation due to expected coordination effort.

- Mott MacDonald recommends reconstructing the Lee Road driveway to the gas station on the northwest corner of SR 43/Lee Road to narrow the drive away from the intersection.

Long Term Recommendations

- Mott MacDonald recommends widening Lee Road south of SR 43 to add an exclusive southbound left turn lane at South Miles Road. An exclusive left turn lane will directly address the southbound rear end and sideswipe crashes occurring on Lee Road at South Miles Road. Widening would also facilitate the need for new mast arms, signals with backplates, pedestrian signals, and vehicle detection at the South Miles Road intersection. As part of the widening, extend the northbound left turn lane of Lee Road at SR 43 to just north of the railroad crossing.

Costs and Benefits

The estimated cost for upgrading pedestrian and vehicle detection at the Lee Road/South Miles Road intersection is approximately $25,000. This includes advanced loops on Lee Road, stop bar loops on South Miles Road, video or radar detection for the church drive, and retiming of the two intersections.

The estimated cost for reconstructing the at-grade railroad crossing on Lee Road varies depending on the work required. To replace the surface between the tracks, reconstruct the approaching roadway a few feet on each side of the tracks, and connect the sidewalks is estimated to cost around $150,000. If the railroad tracks need to be repaired, replaced, or reset, the estimated cost to reconstruct the at-grade crossing would increase to around $250,000. These costs are based on research of similar projects in various states.

The estimated cost for reconstructing the Lee Road driveway to the gas station on the northwest corner of SR 43/Lee Road is approximately $12,000.

The estimated cost for widening Lee Road to provide a southbound left turn lane at South Miles Road and reconstructing the signal is approximately $1.99 million. The cost is based on asymmetrical widening of Lee Road seven feet to the west and two feet to the east to minimize utility conflicts and right of way encroachments. No permanent right of way takes are anticipated, however temporary easements may be necessary for grading and tying in driveways. Costs include five utility pole relocations (two with lights) on the west side of Lee Road. Costs also include reconstructing the railroad crossing as described above, assume full replacement of pavement and tracts. Costs do not include relocating or reconstructing the railroad gates and overhead railroad signals.

The cost benefit portion of the ECAT for proposed countermeasures was not completed due to a lack of reliable crash modification factors for the recommended alternatives.

Appendix A
Condition Diagram

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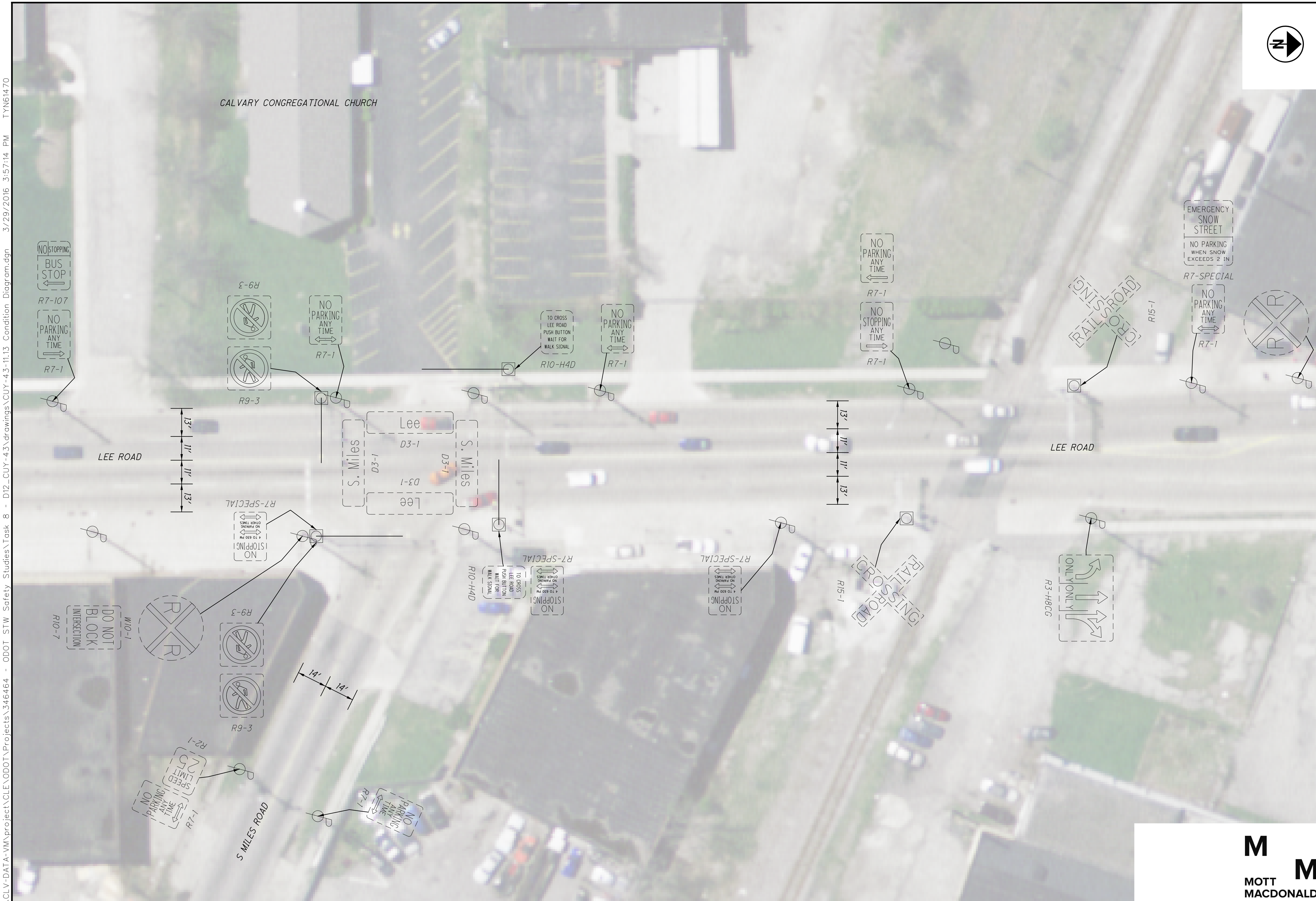


CALCULATED SJT

CHECKED SJB

LEE RD AT S MILES RD CONDITION DIAGRAM

CUY-43-11.13

MOTT MACDONALD

1/2

MOTT MACDONALD

CALCULATED SJT
CHECKED SJB

SR 43 AT LEE RD CONDITION DIAGRAM

CUY-43-11.13

2/2

Appendix B
Traffic Data

		Southbound - Lee Rd					Westbound - SR 43					Northbound - Lee Rd					Eastbound - SR 43						
		RT	THRU	LT	PED	APP TOT	RT	THRU	LT	PED	APP TOT	RT	THRU	LT	PED	APP TOT	RT	THRU	LT	PED	APP TOT	INT TOT	
6:00	AM	4	54	6	3	64	7	6	3	1	16	1	48	9	0	58	16	18	1	0	35	173	
6:15	AM	3	57	11	0	71	7	15	6	0	28	5	73	20	0	98	17	34	1	0	52	249	
6:30	AM	6	63	14	0	83	12	24	6	1	42	4	89	23	0	116	37	42	1	1	80	321	
6:45	AM	4	75	13	2	92	9	34	15	0	58	12	111	35	0	158	30	57	4	0	91	399	
7:00	AM	0	63	5	1	68	17	43	4	6	64	11	126	42	0	179	32	43	5	0	80	391	
7:15	AM	4	106	8	6	118	22	57	9	8	88	15	131	51	0	197	26	49	7	0	82	485	
7:30	AM	6	122	20	7	148	16	60	10	7	86	11	164	74	0	249	35	84	15	0	134	617	
7:45	AM	8	112	15	1	135	17	51	14	4	82	19	176	47	0	242	39	96	13	1	148	607	AM Peak
8:00	AM	14	105	20	0	139	21	59	13	4	93	16	123	33	2	172	44	58	10	2	112	516	
8:15	AM	11	106	21	1	138	15	40	17	3	72	18	148	37	0	203	45	49	15	0	109	522	
8:30	AM	6	88	19	0	113	15	54	12	6	81	17	143	49	0	209	37	56	10	2	103	506	
8:45	AM	17	125	21	0	163	9	33	8	4	50	18	184	47	0	249	50	52	12	2	114	576	
11:00	AM	6	98	18	0	122	23	39	11	1	73	10	119	36	0	165	34	42	9	0	85	445	
11:15	AM	13	110	16	0	139	22	32	11	2	65	13	98	32	0	143	33	42	10	0	85	432	
11:30	AM	12	109	14	2	135	18	40	12	3	70	14	122	45	0	181	38	37	9	0	84	470	
11:45	AM	6	85	20	1	111	20	51	9	3	80	10	94	42	0	146	36	50	11	1	97	434	
12:00	PM	14	91	17	0	122	20	44	13	1	77	16	111	38	0	165	46	41	16	0	103	467	
12:15	PM	12	114	20	1	146	15	29	13	1	57	15	117	33	0	165	38	40	17	0	95	463	
12:30	PM	5	124	17	3	146	25	41	10	2	76	13	112	36	1	161	53	42	12	0	107	490	
12:45	PM	14	139	16	1	169	23	49	16	2	88	14	108	38	0	160	46	52	12	0	110	527	
3:00	PM	8	143	17	1	168	16	75	25	1	116	22	159	43	0	224	42	47	18	1	107	615	
3:15	PM	13	136	24	3	173	32	72	23	0	127	14	161	51	0	226	51	63	14	2	128	654	
3:30	PM	6	176	26	3	208	31	83	30	0	144	25	151	47	0	223	73	73	14	6	160	735	
3:45	PM	9	174	24	4	207	27	74	20	2	121	26	156	58	0	240	62	70	9	1	141	709	
4:00	PM	10	175	21	2	206	33	75	24	3	132	17	165	57	0	239	68	80	13	0	161	738	
4:15	PM	7	163	25	2	195	20	72	31	6	123	24	155	44	0	223	63	79	13	0	155	696	PM Peak
4:30	PM	16	164	20	0	200	20	65	26	1	111	18	161	50	1	229	61	62	16	3	139	679	
4:45	PM	15	186	26	1	227	27	90	36	1	153	25	171	46	2	242	57	68	20	2	145	767	

Study Name Lee Rd @ South Miles TMC
Start Date 9/15/2015
Start Time 7:00 AM
Site Code

All

	Lee Rd			South Miles Rd			Lee Rd			church drive			
	Southbound Approach			Westbound Approach			Northbound Approach			Eastbound Approach			
Start Time	Right	Thru	Left	Right	Thru	Left	Right	Thru	Left	Right	Thru	Left	
7:00 AM	0	123	15	26	0	0	4	203	0	0	0	0	**371**
7:15 AM	0	120	18	37	0	1	3	232	0	0	0	0	**411**
7:30 AM	0	176	22	46	0	1	5	222	0	0	0	0	**472**
7:45 AM	0	127	31	39	0	1	3	238	0	0	0	0	**439**
8:00 AM	0	158	26	33	0	2	3	203	0	0	0	0	**425**
8:15 AM	0	155	28	35	0	4	4	207	0	0	0	0	**433**
8:30 AM	0	153	42	22	0	3	1	206	0	0	0	0	**427**
8:45 AM	0	147	20	40	0	2	3	191	0	0	0	0	**403**
4:00 PM	0	249	43	61	0	7	2	201	0	0	0	0	**563**
4:15 PM	0	261	49	55	0	3	1	228	1	1	0	0	**599**
4:30 PM	0	271	41	51	0	8	1	179	0	0	0	0	**551**
4:45 PM	0	280	33	49	0	4	5	181	0	0	0	0	**552**
5:00 PM	0	277	36	47	0	9	6	222	1	0	0	0	**598**
5:15 PM	0	271	34	40	0	5	4	206	0	0	0	0	**560**
5:30 PM	1	271	46	64	2	7	5	209	0	0	0	0	**605**
5:45 PM	4	271	46	49	0	7	1	210	1	0	0	0	**589**
	5	**3310**	**530**	**694**	**2**	**64**	**51**	**3338**	**3**	**1**	**0**	**0**	**7998**

Appendix C
Capacity Analysis

CUY-43-11.13 Safety Study
Summary of Assumptions for Capacity Analysis

General

- As a basis for traffic volumes, a 2012 and a 2015 turning movement count were used for the SR 43/Lee Road and Lee Road/South Miles Road intersections, respectively.
- HMM balanced the volumes on Lee Road between intersections by increasing volumes from the 2012 count.
- For movements that are allowed but had volumes counted of less than 10 vehicles per hour, HMM increased volumes to 10 vehicles per hour.
- HMM utilized truck percentages from the two traffic counts for each respective intersection.
- Speeds used in the analysis are posted speed limits for intersection approaches and segments.
- LOS E or F were considered failing.
- Approaches with volume to capacity (v/c) ratios of 1.0 or greater for any movement were considered LOS F regardless of delay.

Synchro

- Synchro was used to analyze existing conditions and all alternatives.
- For the existing conditions analysis, HMM used existing signal timing information obtained from the City of Cleveland (current as of February 18, 2016) and record plans.
- HMM validated existing condition results with field observations.
- The model allows right turns on red for all conditions.
- Peak hour factor was set to 0.90.
- At all existing pedestrian crossing locations, HMM input pedestrian parameters as 5 pedestrians per crossing per hour for AM and PM peaks.
- HMM input 2 bus blockages per approach per hour.
- HMM set vehicle arrivals from outside the study area as random.

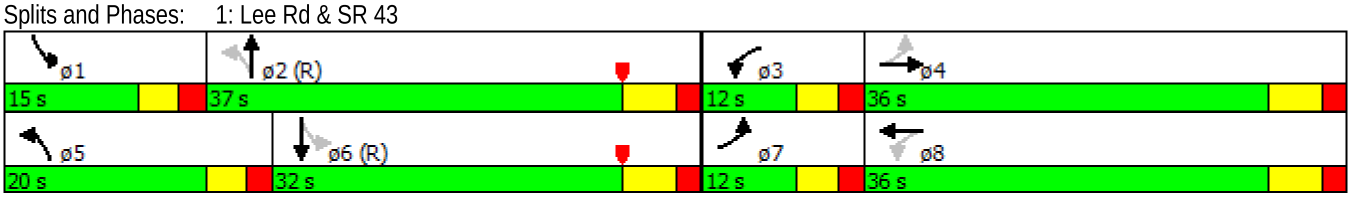
No Build

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	53	287	54	210	191	695	76	481
Turn Type	pm+pt	NA	pm+pt	NA	pm+pt	NA	pm+pt	NA
Protected Phases	7	4	3	8	5	2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	7	4	3	8	5	2	1	6
Switch Phase								
Minimum Initial (s)	6.0	7.0	6.0	7.0	6.0	25.0	6.0	25.0
Minimum Split (s)	12.0	31.0	12.0	31.0	12.0	31.0	12.0	31.0
Total Split (s)	12.0	36.0	12.0	36.0	20.0	37.0	15.0	32.0
Total Split (%)	12.0%	36.0%	12.0%	36.0%	20.0%	37.0%	15.0%	32.0%
Yellow Time (s)	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	Max	None	Max	None	C-Max	None	C-Max
Act Effct Green (s)	39.0	32.5	39.0	32.5	46.7	35.1	37.7	28.6
Actuated g/C Ratio	0.39	0.32	0.39	0.32	0.47	0.35	0.38	0.29
v/c Ratio	0.13	0.44	0.17	0.28	0.56	0.69	0.33	0.58
Control Delay	17.8	22.3	18.3	22.8	28.9	20.9	19.1	33.5
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	17.8	22.3	18.3	22.8	28.9	20.9	19.1	33.5
LOS	B	C	B	C	C	C	B	C
Approach Delay		21.8		22.1		22.5		31.7
Approach LOS		C		C		C		C

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow, Master Intersection
Natural Cycle: 90
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.69
Intersection Signal Delay: 24.6 Intersection LOS: C
Intersection Capacity Utilization 75.6% ICU Level of Service D
Analysis Period (min) 15

Splits and Phases: 1: Lee Rd & SR 43



Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	10	10	10	10	10	870	107	616
Turn Type	Perm	NA	Perm	NA	Perm	NA	pm+pt	NA
Protected Phases		4		8		2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	4	4	8	8	2	2	1	6
Switch Phase								
Minimum Initial (s)	7.0	7.0	23.0	23.0	22.0	22.0	15.0	22.0
Minimum Split (s)	22.0	22.0	29.0	29.0	28.0	28.0	20.0	28.0
Total Split (s)	29.0	29.0	29.0	29.0	51.0	51.0	20.0	71.0
Total Split (%)	29.0%	29.0%	29.0%	29.0%	51.0%	51.0%	20.0%	71.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)		0.0		0.0		0.0		0.0
Total Lost Time (s)		6.0		6.0		6.0		6.0
Lead/Lag					Lag	Lag	Lead	
Lead-Lag Optimize?					Yes	Yes	Yes	
Recall Mode	None	None	Min	Min	C-Max	C-Max	Min	C-Max
Act Effct Green (s)		23.0		23.0		45.0		65.0
Actuated g/C Ratio		0.23		0.23		0.45		0.65
v/c Ratio		0.09		0.39		0.67		0.54
Control Delay		23.4		9.5		24.5		25.6
Queue Delay		0.0		0.0		0.0		0.0
Total Delay		23.4		9.5		24.5		25.6
LOS		C		A		C		C
Approach Delay		23.4		9.5		24.5		25.6
Approach LOS		C		A		C		C

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	
Natural Cycle: 80	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.67	
Intersection Signal Delay: 23.5	Intersection LOS: C
Intersection Capacity Utilization 79.5%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 6: Lee Rd & private drive/S Miles Rd

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	10	10	28	10	10	847	162	1090
Turn Type	Perm	NA	Perm	NA	Perm	NA	pm+pt	NA
Protected Phases		4		8		2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	4	4	8	8	2	2	1	6
Switch Phase								
Minimum Initial (s)	7.0	7.0	23.0	23.0	22.0	22.0	15.0	22.0
Minimum Split (s)	22.0	22.0	29.0	29.0	28.0	28.0	20.0	28.0
Total Split (s)	29.0	29.0	29.0	29.0	51.0	51.0	20.0	71.0
Total Split (%)	29.0%	29.0%	29.0%	29.0%	51.0%	51.0%	20.0%	71.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)		0.0		0.0		0.0		0.0
Total Lost Time (s)		6.0		6.0		6.0		6.0
Lead/Lag					Lag	Lag	Lead	
Lead-Lag Optimize?					Yes	Yes	Yes	
Recall Mode	None	None	Min	Min	C-Max	C-Max	Min	C-Max
Act Effct Green (s)		23.0		23.0		45.0		65.0
Actuated g/C Ratio		0.23		0.23		0.45		0.65
v/c Ratio		0.09		0.50		0.67		0.95
Control Delay		23.4		10.9		24.4		44.0
Queue Delay		0.0		0.0		0.0		44.4
Total Delay		23.4		10.9		24.4		88.4
LOS		C		B		C		F
Approach Delay		23.4		10.9		24.4		88.4
Approach LOS		C		B		C		F

Intersection Summary

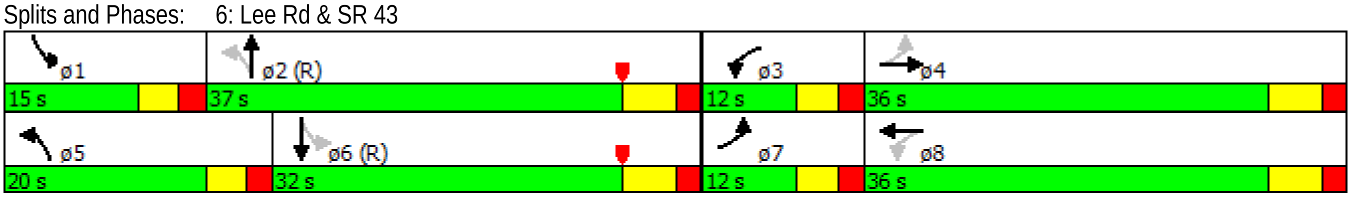
Cycle Length: 100
Actuated Cycle Length: 100
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow
Natural Cycle: 90
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.95
Intersection Signal Delay: 56.6 Intersection LOS: E
Intersection Capacity Utilization 93.5% ICU Level of Service F
Analysis Period (min) 15

Splits and Phases: 1: Lee Rd & private drive/S Miles Rd

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	62	289	117	302	197	776	92	896
Turn Type	pm+pt	NA	pm+pt	NA	pm+pt	NA	pm+pt	NA
Protected Phases	7	4	3	8	5	2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	7	4	3	8	5	2	1	6
Switch Phase								
Minimum Initial (s)	6.0	7.0	6.0	7.0	6.0	25.0	6.0	25.0
Minimum Split (s)	12.0	31.0	12.0	31.0	12.0	31.0	12.0	31.0
Total Split (s)	12.0	36.0	12.0	36.0	20.0	37.0	15.0	32.0
Total Split (%)	12.0%	36.0%	12.0%	36.0%	20.0%	37.0%	15.0%	32.0%
Yellow Time (s)	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	Max	None	Max	None	C-Max	None	C-Max
Act Effct Green (s)	37.8	30.0	39.0	32.4	46.6	34.8	37.9	28.4
Actuated g/C Ratio	0.38	0.30	0.39	0.32	0.47	0.35	0.38	0.28
v/c Ratio	0.18	0.53	0.44	0.40	0.73	0.80	0.45	1.06
Control Delay	18.4	19.7	23.0	25.5	53.2	24.3	22.5	83.5
Queue Delay	0.0	0.2	0.6	0.0	0.0	0.0	0.0	0.0
Total Delay	18.4	19.9	23.6	25.5	53.2	24.3	22.5	83.5
LOS	B	B	C	C	D	C	C	F
Approach Delay		19.7		25.1		29.7		78.1
Approach LOS		B		C		C		E

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow, Master Intersection	
Natural Cycle: 90	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 1.06	
Intersection Signal Delay: 42.7	Intersection LOS: D
Intersection Capacity Utilization 82.9%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 6: Lee Rd & SR 43

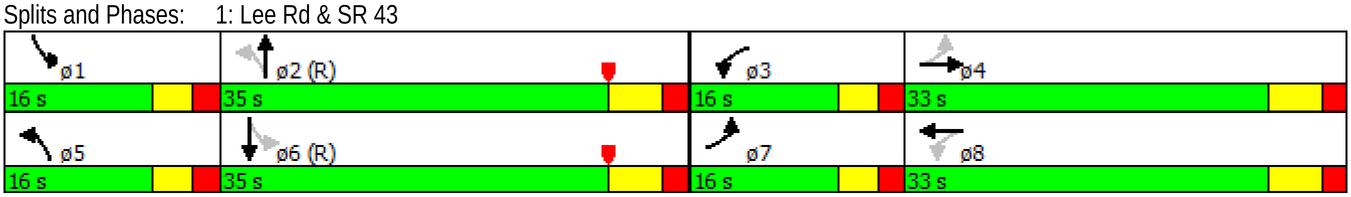


Build A

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	53	287	54	210	191	778	76	516
Turn Type	pm+pt	NA	pm+pt	NA	pm+pt	NA	pm+pt	NA
Protected Phases	7	4	3	8	5	2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	7	4	3	8	5	2	1	6
Switch Phase								
Minimum Initial (s)	6.0	7.0	6.0	7.0	6.0	25.0	6.0	25.0
Minimum Split (s)	12.0	31.0	12.0	31.0	12.0	31.0	12.0	31.0
Total Split (s)	16.0	33.0	16.0	33.0	16.0	35.0	16.0	35.0
Total Split (%)	16.0%	33.0%	16.0%	33.0%	16.0%	35.0%	16.0%	35.0%
Yellow Time (s)	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	None	None	None	None	C-Min	None	C-Min
Act Effct Green (s)	25.6	18.0	25.8	18.1	59.3	48.7	52.1	43.3
Actuated g/C Ratio	0.26	0.18	0.26	0.18	0.59	0.49	0.52	0.43
v/c Ratio	0.20	0.74	0.27	0.48	0.45	0.56	0.26	0.41
Control Delay	23.4	36.4	24.9	33.1	15.3	19.4	13.3	23.1
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	23.4	36.4	24.9	33.1	15.3	19.4	13.3	23.1
LOS	C	D	C	C	B	B	B	C
Approach Delay		35.0		31.8		18.7		21.9
Approach LOS		D		C		B		C

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow, Master Intersection	
Natural Cycle: 90	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.74	
Intersection Signal Delay: 24.5	Intersection LOS: C
Intersection Capacity Utilization 69.2%	ICU Level of Service C
Analysis Period (min) 15	

Splits and Phases: 1: Lee Rd & SR 43



Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	10	10	10	10	10	870	107	616
Turn Type	Perm	NA	Perm	NA	Perm	NA	pm+pt	NA
Protected Phases		4		8		2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	4	4	8	8	2	2	1	6
Switch Phase								
Minimum Initial (s)	7.0	7.0	7.0	7.0	22.0	22.0	5.0	22.0
Minimum Split (s)	22.0	22.0	29.0	29.0	28.0	28.0	10.0	28.0
Total Split (s)	31.0	31.0	31.0	31.0	49.0	49.0	20.0	69.0
Total Split (%)	31.0%	31.0%	31.0%	31.0%	49.0%	49.0%	20.0%	69.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)		0.0		0.0		0.0		0.0
Total Lost Time (s)		6.0		6.0		6.0		6.0
Lead/Lag					Lag	Lag	Lead	
Lead-Lag Optimize?					Yes	Yes	Yes	
Recall Mode	None	None	None	None	C-Min	C-Min	None	C-Min
Act Effct Green (s)		10.8		10.8		77.2		77.2
Actuated g/C Ratio		0.11		0.11		0.77		0.77
v/c Ratio		0.27		0.60		0.39		0.46
Control Delay		33.3		16.4		5.0		6.9
Queue Delay		0.0		0.0		0.0		0.0
Total Delay		33.3		16.4		5.0		6.9
LOS		C		B		A		A
Approach Delay		33.3		16.4		5.0		6.9
Approach LOS		C		B		A		A

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 36 (36%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow
Natural Cycle: 70
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.60
Intersection Signal Delay: 7.3 Intersection LOS: A
Intersection Capacity Utilization 72.8% ICU Level of Service C
Analysis Period (min) 15

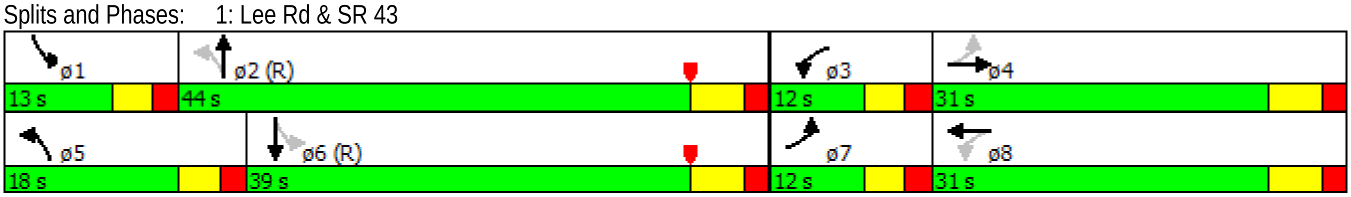
Splits and Phases: 6: Lee Rd & private drive/S Miles Rd

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	62	289	117	302	197	776	92	896
Turn Type	pm+pt	NA	pm+pt	NA	pm+pt	NA	pm+pt	NA
Protected Phases	7	4	3	8	5	2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	7	4	3	8	5	2	1	6
Switch Phase								
Minimum Initial (s)	6.0	7.0	6.0	7.0	6.0	25.0	6.0	25.0
Minimum Split (s)	12.0	31.0	12.0	31.0	12.0	31.0	12.0	31.0
Total Split (s)	12.0	31.0	12.0	31.0	18.0	44.0	13.0	39.0
Total Split (%)	12.0%	31.0%	12.0%	31.0%	18.0%	44.0%	13.0%	39.0%
Yellow Time (s)	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	None	None	None	None	C-Min	None	C-Min
Act Effct Green (s)	26.1	18.3	28.3	21.2	57.8	46.7	48.8	40.2
Actuated g/C Ratio	0.26	0.18	0.28	0.21	0.58	0.47	0.49	0.40
v/c Ratio	0.27	0.79	0.64	0.60	0.72	0.59	0.34	0.75
Control Delay	25.5	32.6	39.8	35.8	39.7	19.5	14.3	31.4
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	25.5	32.6	39.8	35.8	39.7	19.5	14.3	31.4
LOS	C	C	D	D	D	B	B	C
Approach Delay		31.9		36.7		23.3		29.9
Approach LOS		C		D		C		C

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow, Master Intersection
Natural Cycle: 90
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.79
Intersection Signal Delay: 29.2 Intersection LOS: C
Intersection Capacity Utilization 79.0% ICU Level of Service D
Analysis Period (min) 15

Splits and Phases: 1: Lee Rd & SR 43



Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	10	10	28	10	10	847	162	1090
Turn Type	Perm	NA	Perm	NA	Perm	NA	pm+pt	NA
Protected Phases		4		8		2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	4	4	8	8	2	2	1	6
Switch Phase								
Minimum Initial (s)	7.0	7.0	7.0	7.0	22.0	22.0	5.0	22.0
Minimum Split (s)	22.0	22.0	29.0	29.0	28.0	28.0	10.0	28.0
Total Split (s)	29.0	29.0	29.0	29.0	61.0	61.0	10.0	71.0
Total Split (%)	29.0%	29.0%	29.0%	29.0%	61.0%	61.0%	10.0%	71.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)		0.0		0.0		0.0		0.0
Total Lost Time (s)		6.0		6.0		6.0		6.0
Lead/Lag					Lag	Lag	Lead	
Lead-Lag Optimize?					Yes	Yes	Yes	
Recall Mode	None	None	None	None	C-Min	C-Min	None	C-Min
Act Effct Green (s)		12.4		12.4		75.6		75.6
Actuated g/C Ratio		0.12		0.12		0.76		0.76
v/c Ratio		0.24		0.74		0.40		0.83
Control Delay		30.7		24.8		5.5		16.3
Queue Delay		0.0		0.0		0.0		0.7
Total Delay		30.7		24.8		5.5		17.0
LOS		C		C		A		B
Approach Delay		30.7		24.8		5.5		17.0
Approach LOS		C		C		A		B

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 19 (19%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow	
Natural Cycle: 90	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.83	
Intersection Signal Delay: 13.8	Intersection LOS: B
Intersection Capacity Utilization 90.8%	ICU Level of Service E
Analysis Period (min) 15	

Splits and Phases: 6: Lee Rd & private drive/S Miles Rd

Build B

Timings
1: Lee Rd & SR 43

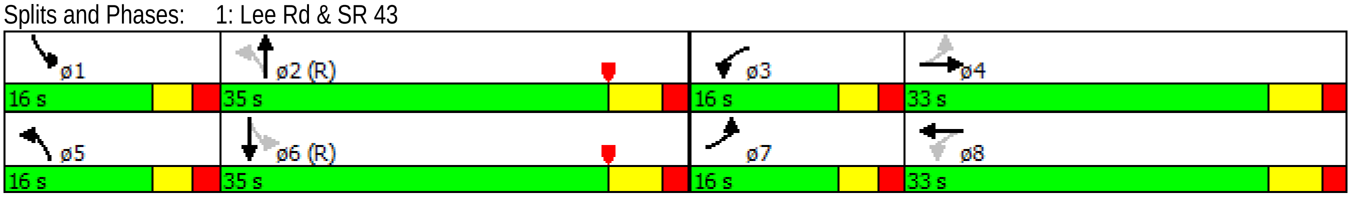
3/31/2016

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	53	287	54	210	191	778	76	516
Turn Type	pm+pt	NA	pm+pt	NA	pm+pt	NA	pm+pt	NA
Protected Phases	7	4	3	8	5	2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	7	4	3	8	5	2	1	6
Switch Phase								
Minimum Initial (s)	6.0	7.0	6.0	7.0	6.0	25.0	6.0	25.0
Minimum Split (s)	12.0	31.0	12.0	31.0	12.0	31.0	12.0	31.0
Total Split (s)	16.0	33.0	16.0	33.0	16.0	35.0	16.0	35.0
Total Split (%)	16.0%	33.0%	16.0%	33.0%	16.0%	35.0%	16.0%	35.0%
Yellow Time (s)	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	None	None	None	None	C-Min	None	C-Min
Act Effct Green (s)	25.6	18.0	25.8	18.1	59.3	48.7	52.1	43.3
Actuated g/C Ratio	0.26	0.18	0.26	0.18	0.59	0.49	0.52	0.43
v/c Ratio	0.20	0.74	0.27	0.48	0.45	0.56	0.26	0.41
Control Delay	23.4	36.4	24.9	33.1	16.8	28.6	13.3	23.1
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	23.4	36.4	24.9	33.1	16.8	28.6	13.3	23.1
LOS	C	D	C	C	B	C	B	C
Approach Delay		35.0		31.8		26.4		21.9
Approach LOS		D		C		C		C

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow, Master Intersection
Natural Cycle: 90
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.74
Intersection Signal Delay: 27.7 — Intersection LOS: C
Intersection Capacity Utilization 69.2% — ICU Level of Service C
Analysis Period (min) 15

Splits and Phases: 1: Lee Rd & SR 43



Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	10	10	10	10	10	870	107	616
Turn Type	Perm	NA	Perm	NA	Perm	NA	Perm	NA
Protected Phases		4		8		2		6
Permitted Phases	4		8		2		6	
Detector Phase	4	4	8	8	2	2	6	6
Switch Phase								
Minimum Initial (s)	7.0	7.0	7.0	7.0	22.0	22.0	22.0	22.0
Minimum Split (s)	22.0	22.0	29.0	29.0	28.0	28.0	28.0	28.0
Total Split (s)	31.0	31.0	31.0	31.0	69.0	69.0	69.0	69.0
Total Split (%)	31.0%	31.0%	31.0%	31.0%	69.0%	69.0%	69.0%	69.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)		0.0		0.0		0.0	0.0	0.0
Total Lost Time (s)		6.0		6.0		6.0	6.0	6.0
Lead/Lag								
Lead-Lag Optimize?								
Recall Mode	None	None	None	None	C-Min	C-Min	C-Min	C-Min
Act Effct Green (s)		11.6		11.6		76.4	76.4	76.4
Actuated g/C Ratio		0.12		0.12		0.76	0.76	0.76
v/c Ratio		0.23		0.63		0.40	0.31	0.26
Control Delay		31.0		21.7		5.3	5.9	2.8
Queue Delay		0.0		0.0		0.0	0.0	0.0
Total Delay		31.0		21.7		5.3	5.9	2.8
LOS		C		C		A	A	A
Approach Delay		31.0		21.7		5.3		3.2
Approach LOS		C		C		A		A

Intersection Summary

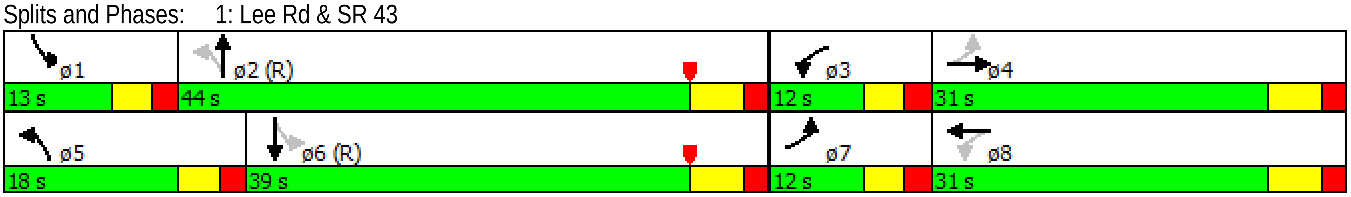
Cycle Length: 100
Actuated Cycle Length: 100
Offset: 95 (95%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow
Natural Cycle: 60
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.63
Intersection Signal Delay: 6.4 Intersection LOS: A
Intersection Capacity Utilization 70.7% ICU Level of Service C
Analysis Period (min) 15

Splits and Phases: 6: Lee Rd & private drive/S Miles Rd

Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	62	289	117	302	197	776	92	896
Turn Type	pm+pt	NA	pm+pt	NA	pm+pt	NA	pm+pt	NA
Protected Phases	7	4	3	8	5	2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	7	4	3	8	5	2	1	6
Switch Phase								
Minimum Initial (s)	6.0	7.0	6.0	7.0	6.0	25.0	6.0	25.0
Minimum Split (s)	12.0	31.0	12.0	31.0	12.0	31.0	12.0	31.0
Total Split (s)	12.0	31.0	12.0	31.0	18.0	44.0	13.0	39.0
Total Split (%)	12.0%	31.0%	12.0%	31.0%	18.0%	44.0%	13.0%	39.0%
Yellow Time (s)	3.0	4.0	3.0	4.0	3.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Lost Time (s)	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0
Lead/Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag
Lead-Lag Optimize?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Recall Mode	None	None	None	None	None	C-Min	None	C-Min
Act Effct Green (s)	26.1	18.3	28.3	21.2	57.8	46.7	48.8	40.2
Actuated g/C Ratio	0.26	0.18	0.28	0.21	0.58	0.47	0.49	0.40
v/c Ratio	0.27	0.79	0.64	0.60	0.72	0.59	0.34	0.75
Control Delay	25.5	32.6	39.8	35.8	33.4	17.0	14.3	31.4
Queue Delay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Delay	25.5	32.6	39.8	35.8	33.4	17.0	14.3	31.4
LOS	C	C	D	D	C	B	B	C
Approach Delay		31.9		36.7		20.1		29.9
Approach LOS		C		D		C		C

Intersection Summary	
Cycle Length: 100	
Actuated Cycle Length: 100	
Offset: 0 (0%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow, Master Intersection	
Natural Cycle: 90	
Control Type: Actuated-Coordinated	
Maximum v/c Ratio: 0.79	
Intersection Signal Delay: 28.1	Intersection LOS: C
Intersection Capacity Utilization 79.0%	ICU Level of Service D
Analysis Period (min) 15	

Splits and Phases: 1: Lee Rd & SR 43



Lane Group	EBL	EBT	WBL	WBT	NBL	NBT	SBL	SBT
Lane Configurations								
Volume (vph)	10	10	28	10	10	847	162	1090
Turn Type	Perm	NA	Perm	NA	Perm	NA	pm+pt	NA
Protected Phases		4		8		2	1	6
Permitted Phases	4		8		2		6	
Detector Phase	4	4	8	8	2	2	1	6
Switch Phase								
Minimum Initial (s)	7.0	7.0	7.0	7.0	22.0	22.0	5.0	22.0
Minimum Split (s)	22.0	22.0	29.0	29.0	28.0	28.0	10.0	28.0
Total Split (s)	31.0	31.0	31.0	31.0	54.0	54.0	15.0	69.0
Total Split (%)	31.0%	31.0%	31.0%	31.0%	54.0%	54.0%	15.0%	69.0%
Yellow Time (s)	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0
All-Red Time (s)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Lost Time Adjust (s)		0.0		0.0		0.0	0.0	0.0
Total Lost Time (s)		6.0		6.0		6.0	5.0	6.0
Lead/Lag					Lag	Lag	Lead	
Lead-Lag Optimize?					Yes	Yes	Yes	
Recall Mode	None	None	None	None	C-Min	C-Min	None	C-Min
Act Effct Green (s)		11.6		11.6		62.7	77.4	76.4
Actuated g/C Ratio		0.12		0.12		0.63	0.77	0.76
v/c Ratio		0.26		0.71		0.48	0.40	0.46
Control Delay		32.2		19.4		12.4	9.2	4.4
Queue Delay		0.0		0.0		0.0	0.0	0.1
Total Delay		32.2		19.4		12.4	9.2	4.6
LOS		C		B		B	A	A
Approach Delay		32.2		19.4		12.4		5.2
Approach LOS		C		B		B		A

Intersection Summary

Cycle Length: 100
Actuated Cycle Length: 100
Offset: 21 (21%), Referenced to phase 2:NBTL and 6:SBTL, Start of Yellow
Natural Cycle: 70
Control Type: Actuated-Coordinated
Maximum v/c Ratio: 0.71
Intersection Signal Delay: 9.5 Intersection LOS: A
Intersection Capacity Utilization 86.1% ICU Level of Service E
Analysis Period (min) 15

Splits and Phases: 6: Lee Rd & private drive/S Miles Rd

Appendix D
Queue Analysis

Intersection: 1: Lee Rd & SR 43

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	57	139	202	41	103	107	178	205	216	60	266	269
Average Queue (ft)	19	72	92	22	59	40	87	94	108	32	123	125
95th Queue (ft)	47	116	171	43	101	85	151	158	172	56	199	218
Link Distance (ft)		1878	1878		1636	1636		538	538		1437	1437
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	155			200			130			120		
Storage Blk Time (%)		0					4	10			8	
Queuing Penalty (veh)		0					12	18			6	

Intersection: 6: Lee Rd & private drive/S Miles Rd

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	69	173	294	278	264	247
Average Queue (ft)	31	64	191	169	168	166
95th Queue (ft)	63	126	271	248	238	232
Link Distance (ft)	1303	2486	1485	1485	538	538
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Network Summary

Network wide Queuing Penalty: 36

Intersection: 1: Lee Rd & private drive/S Miles Rd

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	53	185	277	252	380	409
Average Queue (ft)	18	81	190	167	320	330
95th Queue (ft)	46	148	261	251	395	403
Link Distance (ft)	1303	2486	1485	1485	538	538
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Intersection: 6: Lee Rd & SR 43

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	95	279	305	124	143	154	180	226	245	170	1100	1049
Average Queue (ft)	27	83	117	47	77	74	99	119	137	105	548	527
95th Queue (ft)	68	176	217	98	135	137	171	203	204	206	1021	975
Link Distance (ft)		1878	1878		1636	1636		538	538		1437	1437
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	155			200			130			120		
Storage Blk Time (%)		0					10	11		3	62	
Queuing Penalty (veh)		0					39	21		13	57	

Network Summary

Network wide Queuing Penalty: 130

Intersection: 1: Lee Rd & SR 43

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	61	225	258	82	122	110	179	437	407	169	204	205
Average Queue (ft)	25	78	92	22	60	50	79	147	164	39	116	108
95th Queue (ft)	57	141	174	49	99	105	150	281	279	105	181	182
Link Distance (ft)		1878	1878		1636	1636		538	538		1437	1437
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	155			200			130			120		
Storage Blk Time (%)		1					0	9			5	
Queuing Penalty (veh)		1					2	18			4	

Intersection: 6: Lee Rd & private drive/S Miles Rd

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	53	145	187	124	180	190
Average Queue (ft)	21	61	74	45	85	71
95th Queue (ft)	49	110	146	102	152	144
Link Distance (ft)	1303	2486	1485	1485	538	538
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Network Summary

Network wide Queuing Penalty: 25

Intersection: 1: Lee Rd & SR 43

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	76	183	256	124	164	151	180	339	336	169	763	734
Average Queue (ft)	26	99	144	48	83	73	112	195	208	69	303	290
95th Queue (ft)	61	166	226	100	146	129	212	324	330	160	568	544
Link Distance (ft)		1878	1878		1636	1636		538	538		1437	1437
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	155			200			130			120		
Storage Blk Time (%)		2					4	18		0	41	
Queuing Penalty (veh)		1					16	36		0	39	

Intersection: 6: Lee Rd & private drive/S Miles Rd

Movement	EB	WB	NB	NB	SB	SB
Directions Served	LTR	LTR	LT	TR	LT	TR
Maximum Queue (ft)	72	317	259	231	400	389
Average Queue (ft)	25	89	109	75	211	220
95th Queue (ft)	59	181	204	174	338	343
Link Distance (ft)	1303	2486	1485	1485	538	538
Upstream Blk Time (%)						
Queuing Penalty (veh)						
Storage Bay Dist (ft)						
Storage Blk Time (%)						
Queuing Penalty (veh)						

Network Summary

Network wide Queuing Penalty: 92

Intersection: 1: Lee Rd & SR 43

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	85	238	296	82	136	139	180	364	390	170	290	293
Average Queue (ft)	36	91	102	27	63	50	102	185	199	36	112	164
95th Queue (ft)	75	179	201	66	117	106	183	315	313	101	219	261
Link Distance (ft)		1879	1879		1635	1635		536	536		1437	1437
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	155			200			130			120		
Storage Blk Time (%)		3					1	15			2	
Queuing Penalty (veh)		1					2	30			2	

Intersection: 6: Lee Rd & private drive/S Miles Rd

Movement	EB	WB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	LT	TR	L	T	TR
Maximum Queue (ft)	73	165	156	155	178	198	206
Average Queue (ft)	22	63	78	61	73	52	76
95th Queue (ft)	59	128	149	126	151	144	174
Link Distance (ft)	1297	2479	1482	1482	536	536	536
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)							
Storage Blk Time (%)							
Queuing Penalty (veh)							

Network Summary

Network wide Queuing Penalty: 35

Intersection: 1: Lee Rd & SR 43

Movement	EB	EB	EB	WB	WB	WB	NB	NB	NB	SB	SB	SB
Directions Served	L	T	TR	L	T	TR	L	T	TR	L	T	TR
Maximum Queue (ft)	83	183	397	121	180	179	273	300	298	170	592	538
Average Queue (ft)	21	90	144	49	83	81	93	144	162	109	278	251
95th Queue (ft)	51	159	283	100	148	163	190	269	281	218	474	430
Link Distance (ft)		1878	1878		1636	1636		538	538		1437	1437
Upstream Blk Time (%)												
Queuing Penalty (veh)												
Storage Bay Dist (ft)	155			200			225			120		
Storage Blk Time (%)		1			0			2		1	39	
Queuing Penalty (veh)		0			0			4		4	36	

Intersection: 6: Lee Rd & private drive/S Miles Rd

Movement	EB	WB	NB	NB	SB	SB	SB
Directions Served	LTR	LTR	LT	TR	L	T	TR
Maximum Queue (ft)	52	252	218	202	132	227	245
Average Queue (ft)	25	106	137	119	56	115	139
95th Queue (ft)	51	202	215	208	107	203	235
Link Distance (ft)	1303	2486	1485	1485		538	538
Upstream Blk Time (%)							
Queuing Penalty (veh)							
Storage Bay Dist (ft)					175		
Storage Blk Time (%)						1	
Queuing Penalty (veh)						2	

Network Summary

Network wide Queuing Penalty: 47

Appendix E
Clearance Interval Calculations

TRAFFIC SIGNAL

ASSOCIATED PHASE	DIRECTION	FACTORS: PERCEPTION/REACTION TIME (1s TYP) t (SEC)	FACTORS: APPROACH SPEED V (MPH)	FACTORS: APPROACH SPEED V (FPS)	FACTORS: DECELERATION RATE (10 sq. fps TYP) a (SQ. FPS)	FACTORS: WIDTH OF INTERSECTION W (FT)	FACTORS: LENGTH OF VEHICLE (20 ft TYP) L (FT)	FACTORS: APPROACH GRADE g (%)	CALCULATED: YELLOW Y (SEC)	CALCULATED: ALL RED AR (SEC)	CALCULATED: Y + AR TOTAL (SEC)	FINAL CLEARANCE: YELLOW Y (3-6s TYP) (SEC)	FINAL CLEARANCE: ALL RED AR (1-6s TYP) (SEC)	FINAL CLEARANCE: Y + AR TOTAL (SEC)
1	NB LT	1	25	36.67	10	110	20	0	2.8	3.5	6.3	-	-	-
2	SB	1	25	36.67	10	102	20	0	2.8	3.3	6.1	-	-	-
3	WB LT	1	25	36.67	10	62	20	0	2.8	2.2	5.0	-	-	-
4	EB	1	35	51.33	10	90	20	0	3.6	2.1	5.7	-	-	-
5	SB LT	1	25	36.67	10	109	20	0	2.8	3.5	6.3	-	-	-
6	NB	1	35	51.33	10	103	20	0	3.6	2.4	6.0	-	-	-
7	EB LT	1	25	36.67	10	63	20	0	2.8	2.3	5.1	-	-	-
8	WB	1	35	51.33	10	95	20	0	3.6	2.2	5.8	-	-	-

PEDESTRIAN

ASSOCIATED PHASE (TRAFFIC SIGNAL)	PED MOVEMENT	ASSOCIATED PHASE	CROSSWALK LENGTH L (FT)	PUSHBUTTON PROVIDED	DISTANCE TO PUSHBUTTON P (FT)	OMUTCD 4E.06-12: WALK INTERVAL (4-7s TYP) (SEC)	OMUTCD 4E.06-07: CALCULATED PED CLEARANCE = 3.5 fps WALK TIME (SEC)	PED CHANGE INTERVAL (FDW) = 3.5 fps WALK TIME - 3 sec BUFFER (SEC)	3 fps CHECKS (OMUTCD 4E.06-14): (L+P)/(3 fps) (NOTE: P=6 IF NO PUSHBUTTON) X (SEC)	3 fps CHECKS: WALK + PED CHANGE INTERVALS Y (SEC)	3 fps CHECKS: IS Y>=X?	ADDITIONAL WALK INTERVAL REQUIRED (SEC)	FINAL PED TIMING: FINAL WALK INTERVAL (SEC)	FINAL PED TIMING: FINAL PED CHANGE INTERVAL (FDW) (SEC)
1	NB	6	69	YES	10	4	19.7	16.7	26.3	20.7	NO	5.6	10	17
2	SB	2	72	YES	20	4	20.6	17.6	30.7	21.6	NO	9.1	14	18
3	EB	4	63	YES	15	4	18.0	15.0	26.0	19.0	NO	7.0	11	15
4	WB	8	64	YES	10	4	18.3	15.3	24.7	19.3	NO	5.4	10	16
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		TRAFFIC SIGNAL														PEDESTRIAN														
		FACTORS							CALCULATED			FINAL CLEARANCE								OMUTCD 4E.06-12	OMUTCD 4E.06-07		3 fps CHECKS (OMUTCD 4E.06-14)				FINAL PED TIMING	
ASSOCIATED PHASE	DIRECTION	PERCEPTION/REACTION TIME (1s TYP)	APPROACH SPEED	APPROACH SPEED	DECELERATION RATE (10 sq. fps TYP)	WIDTH OF INTERSECTION	LENGTH OF VEHICLE (20 ft TYP)	APPROACH GRADE	YELLOW	ALL RED	Y + AR	YELLOW	ALL RED	Y + AR	PED MOVEMENT	ASSOCIATED PHASE	CROSSWALK LENGTH	PUSHBUTTON PROVIDED	DISTANCE TO PUSHBUTTON	WALK INTERVAL (4-7s TYP)	CALCULATED PED CLEARANCE	PED CHANGE INTERVAL (FDW)	(L+P)/(3 fps) (NOTE: P=6 IF NO PUSHBUTTON)	WALK + PED CHANGE INTERVALS	IS Y>=X?	ADDITIONAL WALK INTERVAL REQUIRED	FINAL WALK INTERVAL	FINAL PED CHANGE INTERVAL (FDW)
		t	V	V	a	W	L	g	Y	AR	TOTAL	Y (3-6s TYP)	AR (1-6s TYP)	TOTAL			L		P		= 3.5 fps WALK TIME	= 3.5 fps WALK TIME - 3 sec BUFFER	X	Y				
		SEC	MPH	FPS	SQ. FPS	FT	FT	%	SEC	SEC	SEC	SEC	SEC	SEC			FT		FT	SEC	SEC	SEC	SEC	SEC		SEC	SEC	SEC
1	NB LT	1	25	36.67	10	80	20	0	2.8	2.7	5.5	-	-	-	NB	6	52	YES	10	7	14.9	11.9	20.7	18.9	NO	1.8	9	12
2	SB	1	35	51.33	10	60	20	0	3.6	1.6	5.2	-	-	-	SB	6	52	YES	25	7	14.9	11.9	25.7	18.9	NO	6.8	14	12
3	WB LT	1	25	36.67	10	51	20	0	2.8	1.9	4.7	-	-	-	EB	8	48	YES	15	7	13.7	10.7	21.0	17.7	NO	3.3	11	11
4	EB	1	25	36.67	10	71	20	0	2.8	2.5	5.3	-	-	-	WB	8	48	YES	10	7	13.7	10.7	19.3	17.7	NO	1.6	9	11
5	SB LT	1	25	36.67	10	63	20	0	2.8	2.3	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	NB	1	35	51.33	10	70	20	0	3.6	1.8	5.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	EB LT	1	25	36.67	10	51	20	0	2.8	1.9	4.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	WB	1	25	36.67	10	66	20	0	2.8	2.3	5.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix F
Turn Lane Calculations

STORAGE LENGTH CALCULATION WORKSHEET - SIGNALIZED INTERSECTION

From the ODOT Location & Design Manual (Vol. 1) - Sections 401-9E and 401-10E [Oct 2004]

MOTT MACDONALD

Date Competed:	3/25/2016		
Completed by:	SJB	Checked by:	
Project:	CUY-43-11.13		
Intersection:	SR 43 (Miles Ave) @ Lee Rd	Cycle Length Known:	Yes
Approaches Analyzed:	4	Cycle Length (sec):	100
		Signal Phases:	
		Cycles / Hr	36

Approach:	Street Name:	Design Speed:	
Eastbound	SR 43	35	mph
Westbound	SR 43	35	mph
Northbound	Lee Rd	35	mph
Southbound	Lee Rd	25	mph

Notes:

all volumes are 2016 PM peak

	EB - SR 43			WB - SR 43			NB - Lee Rd			SB - Lee Rd		
	Lt	Thru	Rt	Lt	Thru	Rt	Lt	Thru	Rt	Lt	Thru	Rt
Volume:	62	289	249	117	302	100	197	652	84	92	688	48
Demand:	high		high	high		high	high		low	high		low
# Lanes:	1	2		1	2		1	2		1	2	
Avg Veh/Cycle:	2	9	7	4	9	3	6	19	3	3	20	2
Condition:	A		A	A	A	A	A		A	A		A
Thru Backup:		175			175			325			337.5	
L&D Length (ft)[1]:	150		325	225		200	300		200	200		150
95% Queue (ft)[2]:												

	EB Lt	EB Rt	WB Lt	WB Rt	NB Lt	NB Rt	SB Lt	SB Rt
Recommended Turn Length (ft)[1]:								

[1] *includes 50 ft taper* [2] *from SimTraffic*

[created by Hatch Mott MacDonald] *rev. 3/16/2015*

Justification for Turn Lane Length Recommendations

Eastbound

Left: n/a Right: n/a

exist = 155'

Westbound

Left: n/a Right: n/a

exist = 200'

Northbound

Left: n/a Right: n/a

exist = 130'

Southbound

Left: n/a Right: n/a

exist = 120'

STORAGE LENGTH CALCULATION WORKSHEET - SIGNALIZED INTERSECTION
From the ODOT Location & Design Manual (Vol. 1) - Sections 401-9E and 401-10E [Oct 2004]

MOTT MACDONALD

Date Competed:	3/25/2016		
Completed by:	SJB	Checked by:	
Project:	CUY-43-11.13		
Intersection:	Lee Rd @ S Miles Rd	Cycle Length Known:	Yes
Approaches Analyzed:	3	Cycle Length (sec):	100
		Signal Phases:	
		Cycles / Hr	36

Approach:	Street Name:	Design Speed:	
Eastbound	n/a		mph
Westbound	S Miles Rd	25	mph
Northbound	Lee Rd	35	mph
Southbound	Lee Rd	25	mph

Notes:
all volumes are 2016 PM peak

	EB - n/a			WB - S Miles Rd			NB - Lee Rd			SB - Lee Rd		
	Lt	Thru	Rt	Lt	Thru	Rt	Lt	Thru	Rt	Lt	Thru	Rt
Volume:				28	10	200	10	847	16	162	1090	10
Demand:				high		high	low		low	high		low
# Lanes:				1		1	1	2		1	2	
Avg Veh/Cycle:	0	0	0	1	1	6	1	24	1	5	31	1
Condition:				A	A	A	A		A	A		A
Thru Backup:					#DIV/0!			400			512.5	
L&D Length (ft)[1]:				100		300	100		100	250		100
95% Queue (ft)[2]:												

		WB Lt	WB Rt	NB Lt	NB Rt	SB Lt	SB Rt
Recommended Turn Length (ft)[1]:							

[1] includes 50 ft taper *[2] from SimTraffic* *[created by Hatch Mott MacDonald]* *rev. 3/16/2015*

Justification for Turn Lane Length Recommendations

Eastbound
Left: n/a Right: n/a

Westbound
Left: n/a Right: n/a

Northbound
Left: n/a Right: n/a

Southbound
Left: n/a Right: n/a

Appendix G
Cost Estimate

CUY-43-11.13 - Long Term Recommendations - Alternative B
Conceptual Estimate of Probable Costs

Items	Unit	Unit Cost $ (2016)	Quantity	Total $
Primary Cost Drivers				
Roadway				
Clearing and Grubbing	acre	$4,000	0.08	$325
Pavement Removed	sq yd	$17	3,455	$58,735
Walk Removed	sq ft	$4	5,275	$21,100
Curb Removed	foot	$11	1,160	$12,760
Misc Earthwork	lump	$2,150	lump	$2,150
6" Concrete Walk	sq ft	$6	6,540	$39,240
Curb Ramp	sq ft	$15	192	$2,880
Utility / Light Pole Relocation	each	$15,000	5	$75,000
Misc Utility	lump	$20,000	lump	$20,000
Reconstructing At-Grade RR Crossing (does not include gates or overhead signals)	lump	$250,000	lump	$250,000
Drainage				
6" Underdrain	foot	$13	1,250	$16,250
Catch Basin	each	$2,500	6	$15,000
Catch Basin Removed	each	$450	6	$2,700
Manhole Reconstructed to Grade	each	$1,300	19	$24,700
Storm Pipe	ft	$150	650	$97,500
Misc Drainage	lump	$10,000	lump	$10,000
Pavement				
Concrete Pavement (10" Item 452, 6" Agg Base, Subgrade Compaction)	sq yd	$80	3,680	$294,400
Combination Curb and Gutter	foot	$20	1,155	$23,100
Driveway Apron	sq yd	$75	210	$15,750
Traffic Control				
Lane Line	mile	$3,000	0.18	$540
Center Line	mile	$6,000	0.15	$900
Channelizing Line	ft	$1.50	200	$300
Transverse Line	ft	$5.00	150	$750
Stop Line	ft	$5.00	75	$375
Lane Arrow	each	$90.00	4	$360
Crosswalk Line	ft	$3	250	$750
Signs	lump	$10,000	lump	$10,000
Traffic Signals				
Vehicular Signal Head	each	$1,200	8	$9,600
Pedestrian Signal Head	each	$600	6	$3,600
Pedestrian Pushbutton	each	$225	2	$450
Signal Pole Foundation	each	$4,000	4	$16,000
Mast Arm Signal Suport	each	$10,000	4	$40,000
Misc (pullboxes, conduit, conduit jacked or drilled, trench, signal cable, power cable, power service, cabinet, cabinet foundation)	lump	$30,000	lump	$30,000
Misc Detection	lump	$20,000	lump	$20,000
Removal of Traffic Signal Installation	each	$5,000	1	$5,000
Controller Unit	each	$15,000	1	$15,000
Uninterruptable Power Supply (UPS)	each	$5,000	1	$5,000
Erosion Control				
Misc Erosion Control	lump	$8,000	lump	$8,000
Seeding and Mulching	sq yd	$3	250	$750
Topsoil	cu yd	$15	20	$300
Water Work				
New Hydrant / Standpipe	each	$4,500	2	$9,000
Hydrant / Standpipe Removed	each	$500	2	$1,000
Primary Cost Drivers Subtotal				***$1,160,000***
Right of Way (1%)	lump		lump	$12,000
Maintenance of Traffic (MOT) (3%)	lump		lump	$35,000
Construction Layout Stakes (0.75%)	lump		lump	$9,000
Field Office, Type B	month	$1,600	4	$6,400
Mobilization	lump		lump	$40,000
Contingencies (30%)				$379,000
Subtotal				***$1,641,400***
Design (10%)				$165,000
Summary of Probable Total Project Costs 2016				***$1,806,400***
Inflation at 9.9% for 2019 Construction				***$179,000***
Summary of Probable Total Project Costs 2019				***$1,990,000***

FY 2017-2021 Business Plan Inflation Calculator:

Not sure if you have the latest calculator? Click here.

Last Modified: 8/10/2016

Today's Date:
October 31, 2016

Please Enter Values in the Yellow Areas Only:

Estimation Start Date:
Less than or Equal to Today's Date
(mm/dd/yyyy)

10/31/2016
Start Date:

Enter Construction Mid-Point Date:
(cannot exceed 10/31/2041)
(mm/dd/yyyy)

7/29/2019
Construction Mid-Point Date:

Present-Day Estimated Cost:

$100.00
Estimated Dollar Amount:

Estimate Start Date to Construction Mid-Point Date: **33** **Months**

Inflation - Start to Mid-Point of Construction:

(compounded growth rate)

Business Plan **9.9%**

Inflated Dollar Amount:

$109.90

Estimator's Name:

County - Route - Section: CUY-43-11.13 Safety Study

PID:

Estimator's Notes: assume 2019 construction

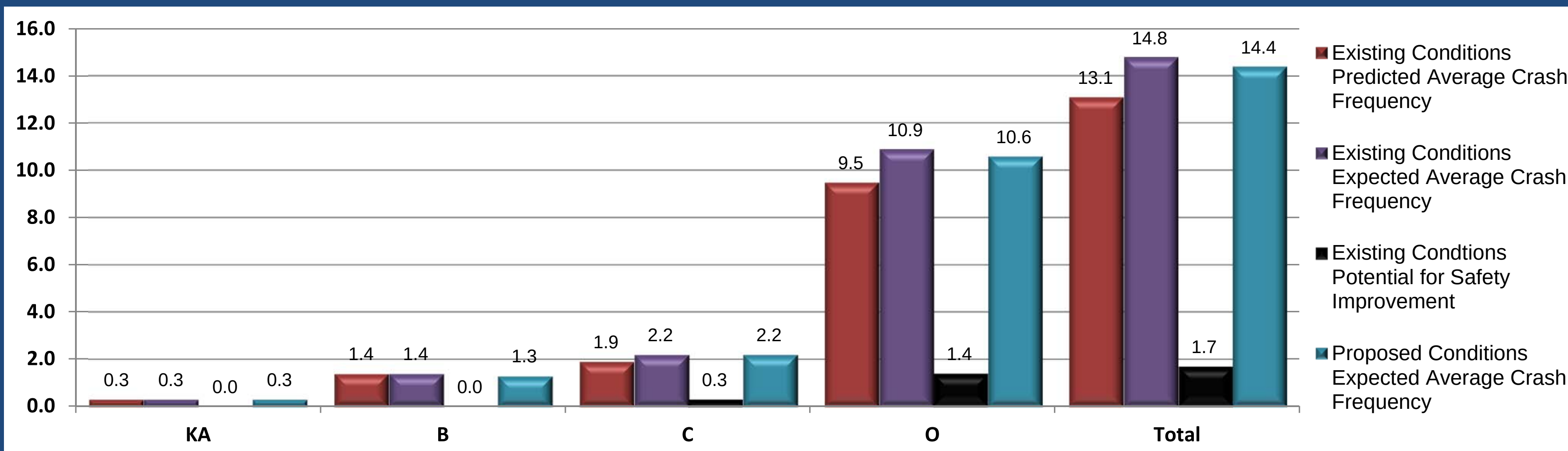
Appendix H
ECAT Analysis

Project Safety Performance Report

General Information

Project Name	CUY-43-11.13	Contact Email	sam.bobko@hatchmott.com
Project Description	SR 43 at Lee Road Safety Study	Contact Phone	216-535-4493
Reference Number		Date Performed	3/18/2016
Analyst	SJB	Analysis Year	2014
Agency/Company	Hatch Mott MacDonald		

Summary of Anticipated Safety Performance of the Project (average crashes/year)



Project Summary Results (Without Animal Crashes)

	KA	B	C	O	Total
$N_{predicted}$ - Existing Conditions	0.3396	1.4172	1.9069	9.4765	13.1402
$N_{expected}$ - Existing Conditions	0.3345	1.3748	2.2412	10.8643	14.8148
$N_{potential\ for\ improvement}$ - Existing Conditions	-0.0051	-0.0424	**0.3343**	**1.3878**	**1.6746**
$N_{expected}$ - Proposed Conditions	0.3273	1.3390	2.1792	10.5586	14.4041