Ohio Department of Transportation

US 42 at Middletown Road

Safety Study

January 18, 2024

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADT	average daily traffic
Arcadis	Arcadis U.S., Inc.
CAM	Crash Analysis Module
DHV	design hourly traffic volume
ECAT	Economic Crash Analysis Tool
HCM	Highway Capacity Manual
HCS	Highway Capacity Software
HSM	Highway Safety Manual
LOS	level of service
mph	miles per hour
$N_{expected}$	expected crash frequency
$N_{predicted}$	predicted crash frequency
NCHRP	National Cooperative Highway Research Program
ODOT	Ohio Department of Transportation
OTO	Office of Traffic Operations
PCR	pavement condition rating
PDO	property damage only
TIMS	Transportation Information Mapping System
TRB	Transportation Research Board
US	United States
v/c	volume to capacity
vpd	vehicles per day

Executive Summary

The Ohio Department of Transportation (ODOT) retained Arcadis U.S., Inc. (Arcadis) to study the overall safety and traffic operations of the unsignalized intersections of United States (US) 42 and Middletown Road and US 42 and Township Line Road in the northeastern portion of the City of Lebanon. The purpose of this safety study is to analyze existing safety conditions, predict future safety conditions, and develop safety improvements that will promote safe and efficient traffic operations now and in the future.

In general, traffic volumes are steady throughout the day and vehicle speeds are high. At US 42 and Township Line Road, trees and buildings, the intersection skew angle, and a vertical sag on US 42 (north of the intersection) limit the intersection sight distance.

ODOT's Crash Analysis Module (CAM) Tool was used to analyze existing crash data. Between 2019 and 2022, 18 crashes occurred at the intersection of US 42 and Middletown Road with 9 being injury crashes. Angle crashes accounted for approximately 56 percent of all crashes and 89 percent of all injuries. Left-turn crashes accounted for approximately 28 percent of all crashes and 11 percent of all injuries. ODOT's Economic Crash Analysis Tool (ECAT) was used to analyze existing and future safety conditions and examine the feasibility of implementing safety countermeasures. ECAT results show that the intersection of US 42 and Middletown Road performs slightly better than similar intersections by 1 to 2 crashes per year. ECAT predicts:

- Converting the intersection to a single-lane modern roundabout would reduce the number of crashes by 4 to 5 per year with a benefit cost of 3.30, meaning this countermeasure provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows all movements will operate at Level of Service (LOS) A, LOS B, or LOS C during the a.m. and p.m. peak hours.
- Closing the west leg of the intersection would reduce the number of crashes by 4 to 5 per year with a benefit cost of 27.93, meaning this countermeasure provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows the remaining three legs will operate at LOS A or LOS C during the a.m. and p.m. peak hours.

Between 2019 and 2022, 16 crashes occurred at the intersection of US 42 and Township Line Road with 5 being injury crashes. Rear-end crashes accounted for approximately 38 percent of all crashes and 60 percent of all injuries. Angle crashes accounted for approximately 19 percent of all crashes and 20 percent of all injuries. . ECAT shows that the intersection of US 42 and Township Line Road performs slightly worse than similar intersections by less than 1 crash per year. ECAT predicts:

- Adding a northbound right-turn lane would reduce the number of crashes by 1 to 2 per year with a benefit cost of 1.54, meaning this countermeasure provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows all movements will operate at LOS A or LOS C during the a.m. and p.m. peak hours.
- Converting the intersection to right-out-only operation would reduce the number of crashes by 1 to 2 per year with a benefit cost of 3.33, meaning this countermeasure provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows Township Line Road will operate at LOS C during the a.m. and p.m. peak hours.
- Converting the intersection to a single-lane modern roundabout would reduce the number of crashes by almost 2 per year with a benefit cost of 0.50, meaning this countermeasure does not provide a sufficient

safety benefit to justify the cost of construction. The capacity analysis shows all movements will operate at LOS A, LOS B, or LOS C during the a.m. and p.m. peak hours.

1 Introduction

The Ohio Department of Transportation (ODOT) retained Arcadis U.S., Inc. (Arcadis) to study the overall safety and traffic operations of the unsignalized intersection of United States (US) 42 and Middletown Road in the northeastern portion of the City of Lebanon. The study area includes the unsignalized intersection of US 42 and Township Line Road.

This safety study was conducted to analyze the existing safety performance of both intersections and to identify potential improvements to reduce crash frequency and improve overall safety. In addition, a traffic analysis was performed to assess current intersection operations and to predict future intersection operations with and without implementation of the proposed countermeasures. This report presents the results of the safety study.

2 Existing Conditions

The existing intersection geometry, crash analysis, traffic volumes, traffic operations, turn lane warrant analysis, and traffic signal warrant analysis are discussed below.

2.1 Intersection Geometry

US 42 is a southwest-northeast minor arterial with a posted speed limit of 45 miles per hour (mph) at Middletown Road and 55 mph at Township Line Road. The average daily traffic (ADT) volume is 8,900 vehicles per day (vpd), of which 2 percent is truck traffic. There is one 12-foot-wide lane in each direction, with a 2-foot-wide asphalt shoulder. The road is striped with a centerline and edge lines. There is no roadway lighting present along the corridor and there are utility poles on both sides of the road. The pavement condition rating (PCR) is 79, according to the ODOT Transportation Information Mapping System (TIMS).

Middletown Road is an east-west major collector with a posted speed limit of 45 mph and an ADT volume of 7,500 vpd west of US 42 and less than 1,000 vpd east of the intersection, of which 10 percent is truck traffic. West of US 42, there is one 12-foot-wide lane in each direction, with a 2-foot-wide asphalt shoulder. The road is striped with a centerline and edge lines. East of US 42, there is one 10-foot-wide lane in each direction with no shoulder. The road is striped with a centerline but no edge lines. There is no roadway lighting present along the corridor and there are utility poles on both sides of the road. The PCR is 95 west of the intersection, according to the ODOT TIMS. TIMS does not provide a PCR for the roadway east of the intersection.

Township Line Road is a north-south local road with no posted speed limit and an ADT volume of 2,800 vpd, of which 1 percent is truck traffic. There is one 12-foot-wide lane in each direction, with a 2-foot-wide asphalt shoulder. The road is striped with a centerline and edge lines. There is no roadway lighting present along the corridor and there are utility poles on both sides of the road.

Both intersections are unsignalized. The intersection of US 42 and Middletown Road has an overhead flashing red light. The approaches are all single lane with no turn lanes. The stop-controlled approaches have dual stop signs with reflective signposts. There are no pedestrian accommodations at either intersection.

The study area is illustrated on Figure 1. An existing conditions diagram for the intersection of US 42 and Middletown Road is included in Appendix A. In addition, photographs of both intersections are included in Appendix A.

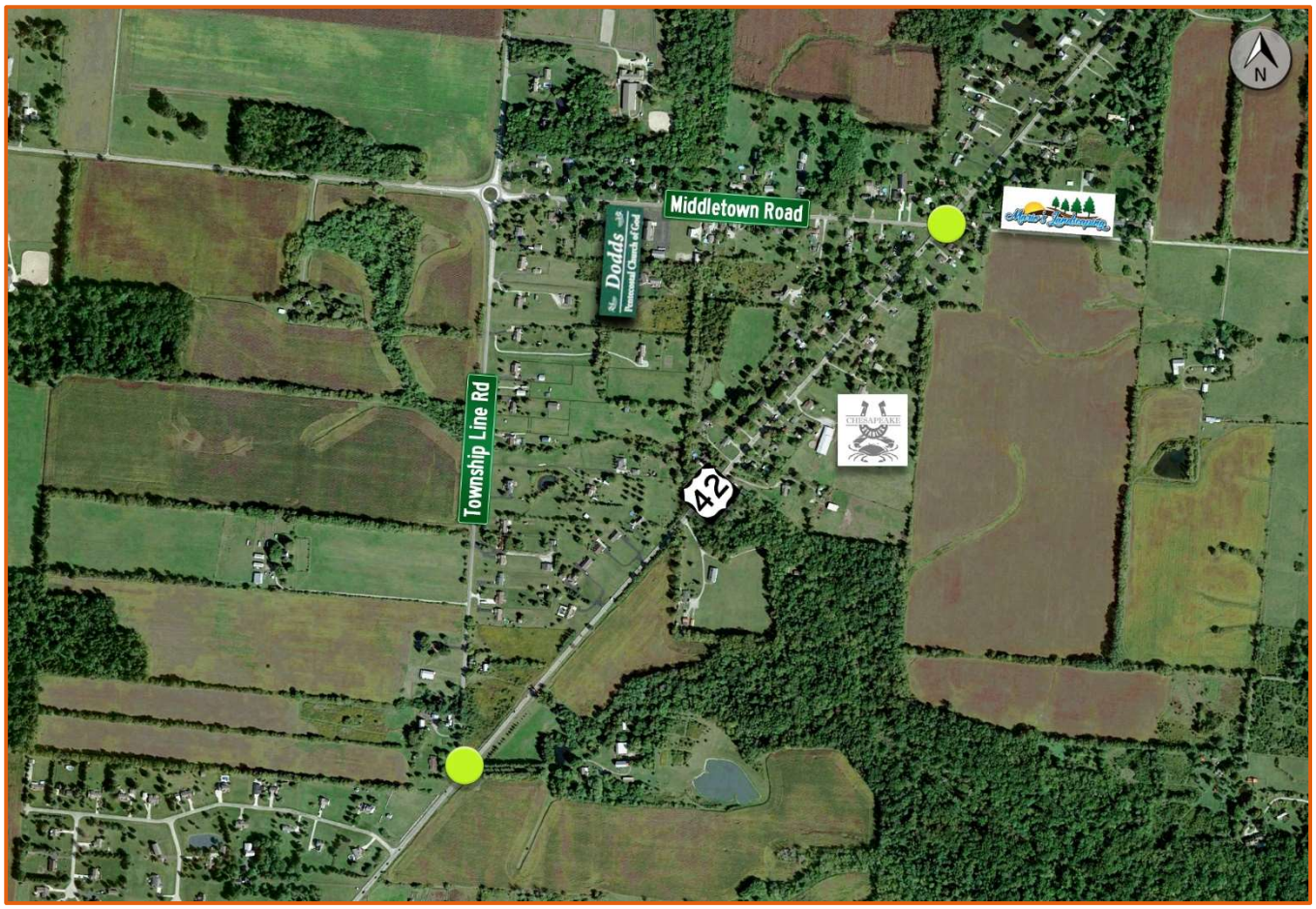

Figure 1. Study Area Map

A field review of the study area was conducted on June 27, 2023, during the a.m. and p.m. peak hours. The a.m. peak hour begins at 8:00 a.m. and the p.m. peak hour begins at 4:45 p.m. Observations of the study area during the field review are summarized below:

- The makeup of vehicular traffic is diverse. Passenger vehicles, single-unit trucks, semi-trucks, and motorcycles were observed during the field review. No pedestrians or bicycles were observed.
- Trees and buildings at the intersection of US 42 and Township Line Road limit the intersection sight distance. Vehicles waiting at the stop sign on Middletown Road have a difficult time seeing traffic on US 42 and vehicles on US 42 have a difficult time seeing vehicles on Middletown Road.
- The intersection skew angle limits the intersection sight distance at the intersection of US 42 and Township Line Road. Vehicles turning left to go northbound on US 42 have a difficult time seeing southbound traffic on US 42. The skew angle also makes a southbound right-turn and an eastbound left-turn movement difficult.
- There is a sag vertical curve on US 42 north of Township Line Road that limits sight distance for vehicles waiting at the stop sign on Township Line Road.
- A 55-mph speed limit sign on US 42 southbound north of Township Line Road is partially blocked by vegetation. Drivers unfamiliar with the area may miss the intersection or slow down abruptly to make a right turn onto Township Line Road.

2.2 Crash Analysis

Crash data from 2019 to 2022 for both intersections were obtained from ODOT's TIMS.

2.2.1 US 42 at Middletown Road Crash Analysis

A total of 18 crashes occurred at the intersection of US 42 and Middletown Road with 9 being injury crashes. The crash data were analyzed using ODOT's Crash Analysis Module (CAM) Tool. The tool compared the study area crash data to statewide averages for rural intersections. The results of the comparision are shown on Figure 2. As indicated on Figure 2, angle, left-turn, rear-end, and fatal and injury crashes occur more frequently at the intersection of US 42 and Middletown Road compared to statewide averages.

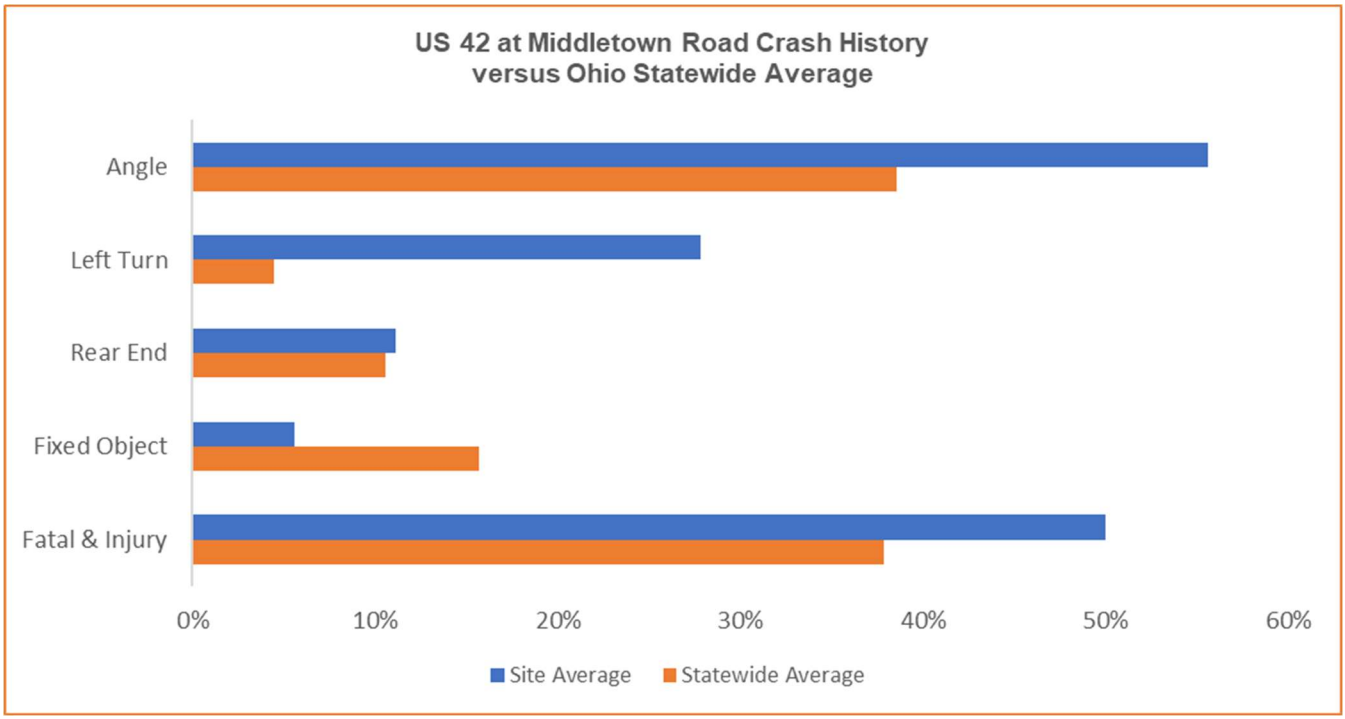

Figure 2. Crash History Compared to Statewide Averages – US 42 and Middletown Road

Additional statistics based on the crash data for US 42 and Middletown Road are summarized in Table 1. As shown in the table, the most common crash types are angle and left turn. None of the crashes resulted in a fatality, and 9 crashes resulted in injuries. Eight of the injuries occurred as a result of angle crashes and one occurred as a result of a left-turn crash. Sixteen crashes occurred on dry pavement, indicating that weather is not typically a contributing factor. All but 2 crashes occurred between 6 a.m. and 7 p.m. on weekdays. More detailed explanations of the crash types that occurred in the study area are provided below:

- *Angle Crashes* – Angle crashes accounted for approximately 56 percent of all crashes and 89 percent of all injuries. Two injury crashes occurred when an eastbound vehicle was struck by a northbound vehicle. One property damage only (PDO) and two injury crashes occurred when an eastbound vehicle was struck by a southbound vehicle. One PDO and four injury crashes occurred when a westbound vehicle was struck by a southbound vehicle. Failure to yield was the contributing factor in all but one crash.

- *Left-Turn Crashes* – Left-turn crashes accounted for approximately 28 percent of all crashes and 11 percent of all injuries. Three PDO crashes and one injury crash occurred when an eastbound vehicle attempted to turn north onto US 42 and was struck by a southbound vehicle. One PDO crash occurred when a northbound vehicle turned left and was struck by a southbound vehicle. Failure to yield was the contributing factor.
- *Rear-End Crashes* – Rear-end crashes accounted for approximately 11 percent of all crashes and no injuries. One of the rear-end crashes occurred on US 42 northbound and one occurred on Middletown Road westbound. Assured clear distance/following too closely was the contributing factor.
- *Fixed Object Crash* – The fixed object crash involved a southbound vehicle that failed to negotiate a right-turn movement to go west on Middletown Road. The vehicle struck the utility pole in the southwest quadrant of the intersection. The driver was drunk.

Table 1. Crash Statistics (2019 to 2022) – US 42 and Middletown Road

Crash Severity	Total	Percentage
Fatal Crash	0	0
Injury Crash	9	50
PDO Crash	9	50

Crash Type	PDO	Injury
Angle	2	8
Left Turn	4	1
Rear End	2	0
Fixed Object	1	0

Weather Condition	PDO	Injury
Dry	7	9
Wet	2	0
Snow and Ice	0	0

Month	PDO	Injury
January	1	0
February	1	1
March	2	2
April	1	0
May	0	1
June	1	1
July	1	0
August	0	0
September	0	3
October	0	1
November	2	0
December	0	0

2.2.2 US 42 at Township Line Road Crash Analysis

A total of 16 crashes occurred at the intersection of US 42 and Township Line Road with 5 being injury crashes. The crash data were analyzed using ODOT's CAM Tool. The tool compared the study area data to statewide averages for rural intersections. The results of the comparision are shown on Figure 3. As indicated on Figure 3, rear-end, angle, other non-collision, and fatal and injury crashes occur more frequently at the intersection of US 42 and Township Line Road compared to statewide averages.

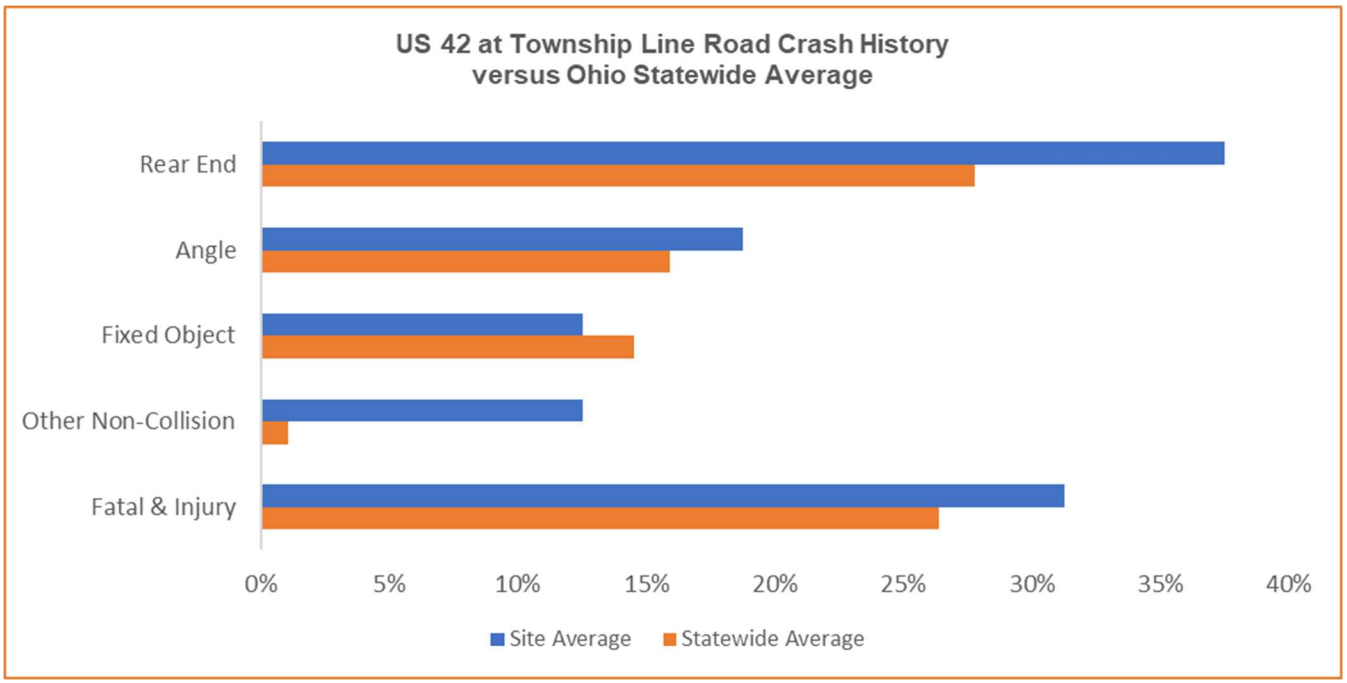

Figure 3. Crash History Compared to Statewide Averages – US 42 and Township Line Road

Additional statistics based on the crash data for US 42 and Township Line Road are summarized in Table 2. As shown in the table, that the most common crash types are rear-end and angle crashes (ignoring animal strikes). None of the crashes resulted in a fatality, and 5 crashes resulted in injuries. Three of the injuries occurred as a result of rear-end crashes, one occurred as a result of an angle crash, and one occurred as a result of a fixed-object crash. Twelve crashes occurred on dry pavement, indicating that weather is not typically a contributing factor. Nine of the crashes and four of the injuries occurred between 6 a.m. and 7 p.m. on weekdays. More detailed explanations of some of the most common crash types are provided below:

- *Rear-End Crashes* – There were six rear-end crashes and three resulted in injuries. One PDO and three injury crashes occurred when a northbound vehicle on US 42 was stopped waiting to turn left onto Township Line Road. One PDO crash occurred when a southbound vehicle on US 42 was turning right onto Township Line Road. One PDO crash occurred on Township Line Road. Assured clear distance/following too closely was the contributing factor.
- *Angle Crashes* – There were three angle crashes and one resulted in an injury. One PDO crash occurred when an eastbound vehicle failed to stop at the stop sign and struck a southbound vehicle on US 42. One injury crash occurred when a vehicle on Township Line Road turned left in front of a southbound vehicle on US 42. One PDO crash occurred when an eastbound vehicle on Township Line Road turned right in front of a southbound vehicle on US 42. Failure to yield was the contributing factor in all but one crash.

- *Fixed Object Crash* – There were two fixed object crashes and one resulted in an injury. One PDO crash occurred when a southbound vehicle lost control north of Township Line Road. One injury crash occurred when a northbound vehicle turning left onto Township Line Road lost control and struck a utility pole.

Table 2. Crash Statistics (2019 to 2022) – US 42 and Township Line Road

Crash Severity	Total	Percentage
Fatal Crash	0	0
Injury Crash	5	31
PDO Crash	11	69

Crash Type	PDO	Injury
Rear End	3	3
Animal	3	0
Angle	2	1
Fixed Object	1	1
Other (Non-Collision)	2	0

Weather Condition	PDO	Injury
Dry	9	3
Wet	2	2
Snow and Ice	0	0

Month	PDO	Injury
January	1	0
February	0	0
March	3	0
April	0	0
May	0	1
June	0	0
July	2	1
August	1	0
September	0	2
October	2	1
November	1	0
December	1	0

A full printout from the ODOT CAM Tool is included in Appendix B. A crash diagram for the intersection of US 42 and Middletown Road is included in Appendix C. A crash diagram was not created for the intersection of US 42 and Township Line Road.

2.3 Traffic Volumes

ODOT District 8 collected vehicle traffic volume data for both intersections. The data for the intersection of US 42 and Middletown Road were collected on Thursday, February 23, 2023, from 6:00 a.m. to 7:00 p.m. The data for the intersection of US 42 and Township Line Road were collected on Wednesday, March 9, 2022, from 12:00 a.m. to 12:00 p.m. The data provided by ODOT District 8 were used to determine the a.m. and p.m. peak hours

and truck percentages. The weekday a.m. peak hour begins at 8:00 a.m. and the weekday p.m. peak hour begins at 4:45 p.m.

A traffic volume forecast was completed by adjusting the counts by 1.28, 1.26, or 1.23 (ODOT's peak hour to design hour factors for rural arterials and collectors taken on a Thursday in February or a Wednesday in March), applying a 1.0 percent background linear annual growth rate to forecast the volumes to design year 2048, and rounding up the result to the nearest 10 vehicles. The 1.0 percent background growth rate was provided by ODOT District 8.

The design hourly traffic volumes (DHVs) are included in Appendix D.

2.4 Highway Capacity Software Analysis

A capacity analysis is the primary method for evaluating the efficiency of an intersection as it relates to vehicular traffic. The Highway Capacity Manual version 6 (HCM), published by the Transportation Research Board (TRB), outlines capacity analysis procedures and the level of service (LOS) criteria used as a qualitive measure to describe operational conditions. The HCM defines six levels of service, designated by the letters A through F. For signalized and unsignalized intersections, LOS is estimated by measuring the control delay per vehicle. The traffic density and vehicular delay conditions for each LOS are defined in Table 3.

Table 3. Level of Service and Delay Thresholds for Intersections

Level of Service	Unsignalized Intersection and Roundabout Delay (seconds)
A	≤ 10
B	> 10 – 15
C	> 15 – 25
D	> 25 – 35
E	> 35– 60
F	> 60 or V/C ratio > 1

Note: V/C = volume to capacity

A capacity analysis for the no-build and build alternatives was conducted using Highway Capacity Software (HCS). The results of the 2023 and 2048 no-build alternative capacity analyses are presented in Tables 4 and 5, respectively. The results of the 2048 build alternative capacity analyses are presented in Tables 10, 15 and 20.

Table 4 shows that the eastbound leg of Middletown Road operates at LOS C during the a.m. peak hour and LOS E during the p.m. peak hour. The westbound leg operates at LOS B during the a.m. peak hour and LOS C during the p.m. peak hour. The queues are generally short except for the eastbound queue, which is 76 feet long during the p.m. peak hour. The table shows that Township Line Road operates at LOS A or LOS B during the a.m. and p.m. peak hours and queues are generally not greater than 30 feet long.

Table 5 shows that the eastbound leg of Middletown Road deteriorates to LOS D during the a.m. peak hour and LOS F during the p.m. peak hour. The westbound leg operates at LOS C during the a.m. peak hour and

deteriorates to LOS E during the p.m. peak hour. The queue lengths increase as well, with the eastbound queue length reaching 282 feet during the p.m. peak hour. The table shows that Township Line Road eastbound deteriorates to LOS D during the p.m. peak hour and the queue is 74 feet long.

Table 4. 2023 No-Build Alternative HCS Analysis Results

Intersection	Direction	Movement	A.M. Peak Hour			P.M. Peak Hour		
			LOS	Delay (seconds)	95th % Queue (feet)	LOS	Delay (seconds)	95th % Queue (feet)
US 42 and Middletown Road	Northbound	L	A	8.4	<20	A	8.4	<20
	Southbound	L	A	7.6	<20	A	8.2	<20
	Eastbound	LTR	C	17.9	25	E	40.4	76
	Westbound	LTR	B	14.5	<20	C	21.4	<20
US 42 and Township Line Road	Northbound	L	A	8.5	<20	A	8.9	<20
	Eastbound	LR	B	12.8	30	B	13.3	30

Table 5. 2048 No-Build Alternative HCS Analysis Results

Intersection	Direction	Movement	A.M. Peak Hour			P.M. Peak Hour		
			LOS	Delay (seconds)	95th % Queue (feet)	LOS	Delay (seconds)	95th % Queue (feet)
US 42 and Middletown Road	Northbound	L	A	8.9	<20	A	8.8	<20
	Southbound	L	A	7.7	<20	A	8.6	<20
	Eastbound	LTR	D	29.6	52	F	291	282
	Westbound	LTR	C	19.2	20	E	43.7	42
US 42 and Township Line Road	Northbound	L	A	9.0	<20	A	9.9	24
	Eastbound	LR	C	17.5	48	D	26.4	74

Outputs from HCS are included in Appendix E.

2.5 Turn Lane Warrant Analysis

Turn lane warrant criteria for free-flow approaches were evaluated according to Figures 401-5b and 401-6b in ODOT's Location and Design Manual. Table 6 identifies locations on US 42 that warrant left- or right-turn lanes. At the intersection of US 42 and Middletown Road, both northbound and southbound left-turn lanes and right-turn lanes are warranted. At the intersection of US 42 and Township Line Road, a northbound left-turn lane is warranted but a southbound right-turn lane is not warranted.

Table 6. Turn Lane Warrant Analysis Results

Intersection	Movement	Turn Lane Warranted?	Turn Lane Length (feet)
US 42 at Middletown Road	Northbound Left Turn	Yes	125
	Northbound Right Turn	Yes	125
	Southbound Left Turn	Yes	125
	Southbound Right Turn	Yes	225
US 42 at Township Line Road	Northbound Left Turn	Yes	275
	Southbound Right Turn	No	N/A

The results of the turn lane warrant analysis are included in Appendix F.

2.6 Traffic Signal Warrant Analysis

A traffic signal warrant analysis was conducted for the intersection of US 42 and Middletown Road. The traffic counts discussed in Section 2.3 were input into ODOT's Office of Traffic Operations (OTO) Signal Warrant Spreadsheet. Traffic signal warrants 1A, 1B, 1C, 2, 3A, and 3B, which compare peak-hour volumes to certain thresholds, were analyzed. The traffic signal warrant analysis results are summarized in Table 7 and indicate that the intersection does not meet the requirements for a traffic signal.

Table 7. Traffic Signal Warrant Analysis Results

Intersection	Warrant 1 Eight-Hour Vehicular Volumes			Warrant 2 Four-Hour Volumes	Warrant 3 Peak-Hour Volumes	
	1A	1B	1C		3A	3B
US 42 at Middletown Road	No	No	No	No	No	No

Outputs from the OTO Signal Warrant Spreadsheet are included in Appendix G.

3 Safety Countermeasures

Three sets of safety countermeasures were evaluated in terms of safety benefits, traffic operations, site impacts, and construction cost.

3.1.1 Northbound Left-Turn Lane at US 42 and Township Line Road

A northbound left-turn lane on US 42 at Township Line Road is recommended to address the PDO rear-end crash and three injury rear-end crashes that occurred when a northbound vehicle on US 42 was stopped waiting to turn left onto Township Line Road.

3.1.1.1 Conceptual Schematic and Conceptual Estimate of Probable Cost

A conceptual schematic of the northbound left-turn lane is included in Appendix H.

A conceptual estimate of probable cost was prepared using ODOT historical bid prices. Estimated construction costs were developed using estimated quantities for items that would be needed for or impacted by implementation of the recommended countermeasure. The following assumptions were used in developing the conceptual estimate of probable cost:

- Unit prices for all items were estimated based on ODOT Estimator libraries and/or ODOT's Historical Bid Data 2019-2023.
- The rate of inflation was calculated using the ODOT Office of Estimating Calendar Year 2023-2027 Business Plan Inflation Calculator. Based on a construction midpoint of spring 2027, a 16.8 percent rate of inflation (to the assumed midpoint of construction) was assumed.

The total 2026 conceptual estimate of probable cost (with inflation) is $$221,499. A detailed cost estimate is included in Appendix I.

3.1.1.2 Safety Analysis

A predictive safety analysis uses the American Association of State Highway and Transportation Officials (AASHTO) Highway Safety Manual (HSM) to determine how a corridor, or intersection, is performing compared to similar locations. The HSM is also used to assess the safety benefits of proposed countermeasures. The HSM Part C discusses use of a predictive model for this type of analysis. The predictive method estimates the predicted crash frequency ($N_{predicted}$) together with observed crash frequency to estimate the expected crash frequency ($N_{expected}$). The difference between predicted and expected crash frequency is explained below:

- $N_{predicted}$ is the anticipated (predicted) crash frequency, which describes how a location is expected to perform relative to similar sites. The calculation of $N_{predicted}$ uses Safety Performance Functions to determine a base condition and applies crash modification factors to account for site-specific features that are different from the base condition. The final value is multiplied by a calibration factor specific to Ohio to normalize the base condition.
- $N_{expected}$ is the estimated expected average crash frequency at a site for a given time period. The calculation of $N_{expected}$ uses the Empirical Bayes method to combine actual crash frequency with $N_{predicted}$.

The difference between $N_{predicted}$ and $N_{expected}$ is the "expected excess crashes." If $N_{expected}$ is greater than $N_{predicted}$, the location may benefit from a safety improvement. If $N_{expected}$ is less than $N_{predicted}$, the site is experiencing fewer crashes than similar sites.

ODOT's Economic Crash Analysis Tool (ECAT) was used to calculate $N_{predicted}$ and $N_{expected}$ based on the existing conditions (traffic control, presence of a median, number of lanes, intersection control, lighting, presence of driveways). ECAT was used to calculate the reduction in crashes that can be expected if the northbound left-turn lane countermeasure is implemented. ODOT's ECAT was also used to perform a benefit-cost analysis for the recommended countermeasure.

Table 8 presents a comparison of the existing intersection ($N_{expected\ existing}$) to similar intersections ($N_{predicted\ existing}$) and to the northbound left-turn lane countermeasure ($N_{predicted\ proposed}$). The table shows that overall, the intersection is functioning worse than similar intersections by 0.72 crashes per year. There is potential for improvement in fatal and incapacitating injury (KA) crashes (0.03), non-incapacitating injury (B) crashes (0.07), possible injury (C) crashes (0.05), and PDO (O) crashes (0.58). The table also shows that if the northbound left-turn lane is constructed, the overall crash frequency is predicted to decrease by 1.26 crashes per year.

Table 8. ECAT Results – Northbound Left-Turn Lane at US 42 and Township Line Road

Level of Service	KA	B	C	O	Total
$N_{predicted}$ (Existing Conditions)	0.11	0.33	0.24	1.43	2.12
$N_{expected}$ (Existing Conditions)	0.14	0.40	0.29	2.01	2.84
$N_{potential\ for\ improvement}$ (Existing Conditions)	0.03	0.07	0.05	0.58	0.73
$N_{predicted}$ (Proposed Conditions)	0.09	0.25	0.18	1.07	1.58

ODOT's ECAT was also used to compare the cost to construct the northbound left-turn lane to the anticipated safety benefit. The results of the benefit-cost analysis are shown in Table 9. The benefit-cost ratio is above one.

Table 9. Benefit-Cost – Northbound Left-Turn Lane at US 42 and Township Line Road

Value	Result
Expected Annual Crash Adjustment	-0.540
Net Present Value of the Build Alternative	$221,499.02
Net Present Value of Safety Benefit	$341,320.84
Benefit-Cost Ratio	**1.54**

The ECAT spreadsheet is included in Appendix J.

3.1.1.3 Highway Capacity Software Analysis

The capacity analysis was completed using the DHVs discussed in Section 2.3. As shown in Table 10, the addition of a northbound left-turn lane at the intersection of US 42 and Township Line Road will allow Township Line Road to operate at LOS C and US 42 to operate at LOS A during both the a.m. and p.m. peak hours.

Table 10. HCS Results (2048) – Northbound Left-Turn Lane at US 42 and Township Line Road

Intersection	Direction	Movement	A.M. Peak Hour			P.M. Peak Hour		
			LOS	Delay (seconds)	95th % Queue (feet)	LOS	Delay (seconds)	95th % Queue (feet)
US 42 and Township Line Road	Northbound	L	A	9.0	<20	A	9.9	24
	Eastbound	LR	C	17.4	48	C	23.8	66

Outputs from HCS are included in Appendix E.

3.1.2 Roundabout at US 42 and Middletown Road

A single-lane modern roundabout at US 42 and Middletown Road is recommended to address the six PDO incidents and nine injuries that occurred as a result of angle and left-turn crashes. According to TRB's National Cooperative Highway Research Program (NCHRP) Report 672, a roundabout intersection is a preferred safety treatment at locations experiencing a high frequency of angle, rear-end, and left-turn crashes. The report indicates that roundabouts provide more time for drivers entering the intersection to adjust their speed and safely merge, and roundabouts reduce the potential for crashes within the intersection by reducing the number of conflict points compared to those associated with a traditional intersection.[1]

Converting the intersection of US 42 and Township Line Road to right-out only operation is recommended to address three of the PDO and four of the injury rear-end and angle crashes.

3.1.2.1 Conceptual Schematic and Conceptual Estimate of Probable Cost

A conceptual schematic showing a single-lane modern roundabout at US 42 and Middletown Road and the conversion of the intersection of US 42 and Township Line Road to right-out only operation is included in Appendix H.

A conceptual estimate of probable cost was prepared using ODOT historical bid prices. Estimated construction costs were developed using estimated quantities for items that would be needed for or impacted by implementation of the recommended countermeasure. The following assumptions were used in developing the conceptual estimate of probable cost:

- Unit prices for all items were estimated based on ODOT Estimator libraries and/or ODOT's Historical Bid Data 2019-2023.

[1] TRB. 2011. Roundabouts: An Informational Guide. TRB Webinar, NCHRP Report 672. Second Edition. March 9.

- The rate of inflation was calculated using the ODOT Office of Estimating Calendar Year 2023-2027 Business Plan Inflation Calculator. Based on a construction midpoint of spring 2030, a 28.1 percent rate of inflation (to the assumed midpoint of construction) was assumed for the roundabout at US 42 and Middletown Road. Based on a construction midpoint of spring 2025, a 6.8 percent rate of inflation (to the assumed midpoint of construction) was assumed for the conversion of Township Line Road to a right-out only movement.

The total 2026 conceptual estimate of probable cost (with inflation) is $1,653.175. A detailed cost estimate is included in Appendix I.

3.1.2.2 Safety Analysis

Table 11 presents a comparison of the existing intersection ($N_{expected\ existing}$) to similar intersections ($N_{predicted\ existing}$) and to the proposed roundabout at US 42 and Middletown Road ($N_{expected\ proposed}$). The table shows that overall, the intersection is functioning better than similar intersections by 1.49 crashes per year. The table also shows that the overall crash frequency is predicted to decrease by 4.17 crashes per year.

Table 11. ECAT Results – Roundabout at US 42 and Middletown Road

Level of Service	KA	B	C	O	Total
$N_{predicted}$ (Existing Conditions)	0.54	1.31	0.88	4.70	7.43
$N_{expected}$ (Existing Conditions)	0.50	1.22	0.81	3.40	5.94
$N_{potential\ for\ improvement}$ (Existing Conditions)	-0.04	-0.09	-0.06	-1.30	-1.49
$N_{expected}$ (Proposed Alternative)	0.07	0.18	0.12	1.41	1.77

ODOT's ECAT was also used to compare the cost to construct the proposed roundabout at US 42 and Middletown Road to the anticipated safety benefit. The results of the benefit-cost analysis are shown in Table 12. The benefit-cost ratio is above one.

Table 12. Benefit-Cost – Roundabout at US 42 and Middletown Road

Value	Result
Expected Annual Crash Adjustment	-5.658
Net Present Value of the Build Alternative	$1,545,538.54
Net Present Value of Safety Benefit	$5,094,253.16
Benefit-Cost Ratio	**3.30**

Table 13 presents a comparison of the existing intersection ($N_{expected\ existing}$) to similar intersections ($N_{predicted\ existing}$) and to conversion of Township Line Road to a right-out only movement ($N_{expected\ proposed}$). The table shows that overall, the intersection is functioning worse than similar intersections by 0.72 crashes per year. There is potential for improvement in fatal and incapacitating injury (KA) crashes (0.03), non-incapacitating injury (B) crashes (0.07),

possible injury (C) crashes (0.05), and PDO (O) crashes (0.58). The table also shows that the overall crash frequency is predicted to decrease by 1.29 crashes per year.

Table 13. ECAT Results – Right-Out Only Operation at US 42 and Township Line Road

Level of Service	KA	B	C	O	Total
$N_{predicted}$ (Existing Conditions)	0.11	0.33	0.24	1.43	2.12
$N_{expected}$ (Existing Conditions)	0.14	0.40	0.29	2.01	2.84
$N_{potential\ for\ improvement}$ (Existing Conditions)	0.03	0.07	0.05	0.58	0.73
$N_{expected}$ (Proposed Alternative)	0.08	0.24	0.18	1.05	1.55

ODOT's ECAT was also used to compare the cost to restrict movements at US 42 and Township Line Road to the anticipated safety benefit. The results of the benefit-cost analysis are shown in Table 14. The benefit-cost ratio is above one.

Table 14. Benefit-Cost – Right-Out Only Operation at US 42 and Township Line Road

Value	Result
Expected Annual Crash Adjustment	-0.569
Net Present Value of the Build Alternative	$107,636.70
Net Present Value of Safety Benefit	$358,875.91
Benefit-Cost Ratio	**3.33**

The ECAT spreadsheet is included in Appendix I.

3.1.2.3 Highway Capacity Software Analysis

The capacity analysis was completed using the DHVs discussed in Section 2.3. The northbound left-turn movement, the southbound right-turn movement, and the eastbound left-turn movement at the intersection of US 42 and Township Line Road were reassigned to the intersection of US 42 and Middletown Road.

As shown in Table 15, conversion of the intersection of US 42 and Middletown Road to a roundabout will allow all movements to operate at LOS A, LOS B, or LOS C during the a.m. and p.m. peak hours. The longest queue on US 42 is predicted to be 164 feet during the p.m. peak hour. Conversion of the intersection of US 42 and Township Line Road to right-out only operation will allow Township Line Road to operate at LOS C during both the a.m. and p.m. peak hours. The longest queue is predicted to be 40 feet.

Table 15. HCS Results (2048) – Roundabout at US 42 and Middletown Road

Intersection	Direction	Movement	A.M. Peak Hour			P.M. Peak Hour		
			LOS	Delay (seconds)	95th % Queue (feet)	LOS	Delay (seconds)	95th % Queue (feet)
US 42 and Middletown Road	Northbound	LTR	A	6.8	34	C	17.8	164
	Southbound	LTR	B	12.2	905	C	15.6	114
	Eastbound	LTR	A	7.2	<20	A	8.0	24
	Westbound	LTR	A	5.4	<20	B	10.2	<20
US 42 and Township Line Road	Eastbound	R	C	15.6	40	C	16.0	40

3.1.3 Roundabout at US 42 and Township Line Road

A single-lane modern roundabout at US 42 and Township Line Road is recommended to address the five PDO incidents and four injuries that occurred as a result of rear-end and angle crashes.

Closing the west leg of the intersection of US 42 and Middletown Road is recommended to address two of the PDO angle crashes and eight of the injury angle crashes, four PDO left-turn crashes and one injury left-turn crash, one PDO rear-end crash, and one PDO fixed object crash.

3.1.3.1 Conceptual Schematic and Conceptual Estimate of Probable Cost

A conceptual schematic showing a single-lane modern roundabout at US 42 and Township Line Road and the closure of the west leg of the intersection of US 42 and Middletown Road is included in Appendix H.

A conceptual estimate of probable cost was prepared using ODOT historical bid prices. Estimated construction costs were developed using estimated quantities for items that would be needed for or impacted by implementation of the recommended countermeasure. The following assumptions were used in developing the conceptual estimate of probable cost:

- Unit prices for all items were estimated based on ODOT Estimator libraries and/or ODOT's Historical Bid Data 2019-2023.
- The rate of inflation was calculated using the ODOT Office of Estimating Calendar Year 2023-2027 Business Plan Inflation Calculator. Based on a construction midpoint of spring 2025, a 6.8 percent rate of inflation (to the assumed midpoint of construction) was assumed to close the west leg of Middletown Road. Based on a construction midpoint of spring 2030, a 28.1 percent rate of inflation (to the assumed midpoint of construction) was assumed for the roundabout at US 42 and Township Line Road.

The total 2026 conceptual estimate of probable cost (with inflation) is $2,065,943. A detailed cost estimate is included in Appendix I.

3.1.3.2 Safety Analysis

Table 16 presents a comparison of the existing intersection ($N_{expected\ existing}$) to similar intersections ($N_{predicted\ existing}$) and toclosure of the west leg of Middletown Road ($N_{expected\ proposed}$). The table shows that overall, the intersection is functioning better than similar intersections by 1.49 crashes per year. The table also shows that the overall crash frequency is predicted to decrease by 4.13 crashes per year.

Table 16. ECAT Results – Closure of West Leg of Middletown Road

Level of Service	KA	B	C	O	Total
$N_{predicted}$ (Existing Conditions)	0.54	1.31	0.88	4.70	7.43
$N_{expected}$ (Existing Conditions)	0.50	1.22	0.81	3.40	5.94
$N_{potential\ for\ improvement}$ (Existing Conditions)	-0.04	-0.09	-0.06	-1.30	-1.49
$N_{expected}$ (Proposed Alternative)	0.10	0.28	0.21	1.22	1.81

ODOT's ECAT was also used to compare the cost to close the west leg of Middletown Road to the anticipated safety benefit. The results of the benefit-cost analysis are shown in Table 17. The benefit-cost ratio is above one.

Table 17. Benefit-Cost – Closure of West Leg of Middletown Road

Value	Result
Expected Annual Crash Adjustment	-5.621
Net Present Value of the Build Alternative	$169,789.91
Net Present Value of Safety Benefit	$4,741,721.02
Benefit-Cost Ratio	**27.93**

Table 18 presents a comparison of the existing intersection ($N_{expected\ existing}$) to similar intersections ($N_{predicted\ existing}$) and to the proposed roundabout at US 42 and Township Line Road ($N_{expected\ proposed}$). The table shows that overall, the intersection is functioning worse than similar intersections by 0.72 crashes per year. There is potential for improvement in fatal and incapacitating injury (KA) crashes (0.03), non-incapacitating injury (B) crashes (0.07), possible injury (C) crashes (0.05), and PDO (O) crashes (0.58). The table also shows that the overall crash frequency is predicted to decrease by 1.73 crashes per year.

Table 18. ECAT Results – Roundabout at US 42 and Township Line Road

Level of Service	KA	B	C	O	Total
$N_{predicted}$ (Existing Conditions)	0.11	0.33	0.24	1.43	2.12
$N_{expected}$ (Existing Conditions)	0.14	0.40	0.29	2.01	2.84
$N_{potential\ for\ improvement}$ (Existing Conditions)	0.03	0.07	0.05	0.58	0.73
$N_{expected}$ (Proposed Alternative)	0.03	0.10	0.07	0.92	1.11

ODOT's ECAT was also used to compare the cost to construct the proposed roundabout at US 42 and Township Line Road to the anticipated safety benefit. The results of the benefit-cost analysis are shown in Table 19. The benefit-cost ratio is below one.

Table 19. Benefit-Cost – Roundabout at US 42 and Township Line Road

Value	Result
Expected Annual Crash Adjustment	-1.004
Net Present Value of the Build Alternative	$1,896,153.15
Net Present Value of Safety Benefit	$952,604.64
Benefit-Cost Ratio	**0.50**

The ECAT spreadsheet is included in Appendix I.

3.1.3.3 Highway Capacity Software Analysis

The capacity analysis was completed using the DHVs discussed in Section 2.3. The northbound left-turn movement, the southbound right-turn movement, the westbound through movement, and all three eastbound movements at the intersection of US 42 and Middletown Road were reassigned to the intersection of US 42 and Township Line Road.

Table 20 shows that closure of the west leg at the intersection of US 42 and Middletown Road will allow the intersection to operate at LOS A or LOS C during both the a.m. and p.m. peak hours, except for the westbound approach, which will operate at LOS E during the p.m. peak hour. The longest queue is predicted to be 42 feet. Conversion of the intersection of US 42 and Township Line Road to a roundabout will allow all movements to operate at LOS A, LOS B, or LOS C during the a.m. and p.m. peak hours. The longest queue on US 42 is predicted to be 168 feet during the p.m. peak hour.

Table 20. HCS Results (2048) – Roundabout at US 42 and Township Line Road

Intersection	Direction	Movement	A.M. Peak Hour			P.M. Peak Hour		
			LOS	Delay (seconds)	95th % Queue (feet)	LOS	Delay (seconds)	95th % Queue (feet)
US 42 and Middletown Road	Southbound	LT	A	8.0	<20	A	9.2	<20
	Westbound	LR	C	19.5	<20	E	42.8	42
US 42 and Township Line Road	Northbound	LT	A	6.9	34	C	17.8	168
	Southbound	TR	B	12.2	96	C	15.9	128
	Eastbound	LR	B	12.9	62	B	14.0	78

Outputs from HCS are included in Appendix E.

4 Countermeasure Considered and Dismissed

Two potential safety countermeasures were considered but dismissed from further evaluation.

4.1 Left- and Right-Turn Lanes at Middletown Road

The traffic volumes at the intersection of US 42 and Middletown Road warrant northbound and southbound left-turn lanes and right-turn lanes on US 42. However, this potential safety countermeasure was not analyzed to evaluate traffic operations, safety benefits, site impacts, or construction cost because the turn lanes would widen the intersection and could potentially increase the frequency and severity of angle and left-turn crashes.

4.2 Traffic Signal at Middletown Road

Table 7 indicates that the traffic demand at the intersection of US 42 and Middletown Road does not satisfy the criteria to warrant a traffic signal. Nonetheless, the feasibility of constructing a new traffic signal at the intersection was evaluated to determine if it could potentially mitigate the frequency of crashes.

Table 21 presents a comparison of the existing intersection ($N_{expected\ existing}$) to similar intersections ($N_{predicted\ existing}$) and to the proposed traffic signal ($N_{expected\ proposed}$). The table shows that the overall crash frequency is predicted to increase by 8 to 9 crashes per year.

A traffic signal has the potential to mitigate left-turn and angle crashes. However, the total number of crashes is predicted to increase. Therefore, construction of a new traffic signal was not analyzed further to evaluate traffic operations, site impacts, or construction cost.

Table 21. ECAT Results – Traffic Signal at US 42 and Middletown Road

Level of Service	KA	B	C	O	Total
$N_{predicted}$ (Existing Conditions)	0.54	1.31	0.88	4.70	7.43
$N_{expected}$ (Existing Conditions)	0.50	1.22	0.81	3.40	5.94
$N_{potential\ for\ improvement}$ (Existing Conditions)	-0.04	-0.09	-0.06	-1.30	-1.49
$N_{expected}$ (Proposed Alternative)	0.29	1.24	1.57	9.36	12.45

5 Conclusions and Recommendations

ODOT's ECAT was used to calculate the reduction in crashes that can be expected if a northbound left-turn lane is constructed at the intersection of US 42 and Township Line Road. ECAT predicts a 1.26 crash per year reduction and a benefit cost of 1.54, meaning that the northbound left-turn lane provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows all movements will operate at LOS A or LOS C during the a.m. and p.m. peak hours.

ODOT's ECAT was used to calculate the reduction in crashes that can be expected if the intersection of US 42 and Middletown Road is converted to a single-lane modern roundabout. ECAT predicts a 4.17 crash per year reduction and a benefit cost of 3.30, meaning that the roundabout provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows all movements will operate at LOS A, LOS B, or LOS C during the a.m. and p.m. peak hours. ODOT's ECAT was also used to calculate the reduction in crashes that can be expected if the intersection of US 42 and Township Line Road is converted to right-out only operation. ECAT predicts a 1.29 crash per year reduction and a benefit cost of 3.33, meaning that restricting movements at this intersection provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows Township Line Road will operate at LOS C during the a.m. and p.m. peak hours.

ODOT's ECAT was also used to calculate the reduction in crashes that can be expected if the west leg of the intersection of US 42 and Middletown Road is closed. ECAT predicts a 4.13 crash per year reduction and a benefit cost of 27.93, meaning that closing the west leg of Middletown Road provides a sufficient safety benefit to justify the cost of construction. The capacity analysis shows the remaining three legs will operate at LOS A or LOS C during the a.m. and p.m. peak hours. ODOT's ECAT was used to calculate the reduction in crashes that can be expected if the intersection of US 42 and Township Line Road is converted to a single-lane modern roundabout. ECAT predicts a 1.73 crash per year reduction and a benefit cost of 0.50, meaning that the roundabout does not provide a sufficient safety benefit to justify the cost of construction. The capacity analysis shows all movements will operate at LOS A, LOS B, or LOS C during the a.m. and p.m. peak hours.

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