October 2017

Mound Road Industrial Corridor Technology and Innovation BENEFIT-COST ANALYSIS

Macomb County Michigan

City of Sterling Heights
Innovating Living

Warren

HRC
HUBBELL, ROTH & CLARK, INC
CONSULTING ENGINEERS SINCE 1915

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Key to Abbreviations

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
AERIS	Applications for the Environment: Real-Time Information Synthesis
BCA	Benefit Cost Analysis
BCR	Benefit Cost Ratio
CMAQ	Congestion Mitigation and Air Quality
CMF	Crash Modification Factor
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DOT	Department of Transportation
DSRC	Dedicated Short Range Communication
EDI	Eberle Design Inc
EIA	Energy Information Administration
EMSI	Economic Modeling Specialists International
EPA	Environmental Protection Agency
FAST (ACT)	Fixing America's Surface Transportation
FAST	Fixed Automated Spray Technology
FCA	Fiat Chrysler Automobiles
FHWA	Federal Highway Administration
GDP	Gross Domestic Product
GM	General Motors
GPS	Global Positioning System
INFRA	Infrastructure for Rebuilding America
ITS	Intelligent Transportation Systems
KABCO	Fatal (K), Incapacitating Injury (A), Non-incapacitating injury (B), Possible Injury (C), No Injury (O)
LED	Light-emitting diode
LOS	Level of Service
MCDR	Macomb County Department of Roads
MDOT	Michigan Department of Transportation
MOE	Measure of Effectiveness
MTIC	Mound Road Industrial Corridor Technology and Innovation
MUTCD	Manual on Uniform Traffic Control Devices
MVMT	Million Vehicle Miles Traveled
NCHRP	National Cooperative Highway Research Program
NHFP	National Highway Freight Program
NHS	National Highway System
NHTSA	National Highway Traffic Safety Administration
NPV	Net Present Value
NOx	Nitrogen Oxide
OEM	Original Equipment Manufacturers
OMB	Office of Management and Budget
PASER	Pavement Surface Evaluation an Rating
PCC	Portland Cement Concrete
PCD	Purdue Coordination Diagram
PM	Particulate Matter
RSU	Road Side Unit
SEMCOG	Southeast Michigan Council of Governments

SPF	Safety Performance Functions
TACOM	Tank-Automotive and Armaments Command
TARDEC	Tank Automotive Research, Development and Engineering Center
TCAT	Traffic Crash Analysis Tool
TIA	Traffic Improvement Association
TRB	Transportation Research Board
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VOC	Volatile Organic Compound

Executive Summary

The Mound Road Industrial Corridor Technology and Innovation (MTIC) Project, also known as Innovating Mound, is a partnership of Macomb County, the City of Sterling Heights and the City of Warren, Michigan, with the objective of transforming nine miles of the Mound Road corridor from a 30-year-old 8-lane roadway in dilapidated and decaying conditions to a next-generation critical commercial corridor of national significance. Mound Road is part of the National Highway System, is the longest non-freeway segment included in the National Highway Freight Program, and is vital to the economic development of southeast Michigan.

The corridor is home to several national automotive, aerospace, defense, and advance manufacturing companies including the General Motors Technical Center, Ford Axle Plant and Transmission Plant, Fiat Chrysler Automobiles Stamping Plant and Assembly Plant, U.S. Army's Tank-Automotive and Armaments Command and Tank Automotive Research, Development and Engineering Center, and BAE Systems. Overall the corridor supports a direct employment total of 20,200 people which support 17,720 jobs in Macomb County and an additional 98,100 jobs in the state of Michigan.

Currently the Mound Road corridor is characterized by substandard infrastructure conditions which are in need of improvement. **Table 1** presents a summary of key baseline problems to be addressed, proposed changes to baseline conditions, and type of projected impacts.

Table 1: Mound Road Baseline, Modifications to Baseline, and Expected Impacts

Current Status/Baseline & Problem to be Addressed	Change to Baseline	Type of Impacts
Deteriorated pavement and infrastructure conditions which have exceeded service life	Reconstruction with high performance concrete pavement (P1 Modified); New drainage; Curb & gutter; Driveways; Restoration & landscaping	Lower operations & maintenance costs; Increased safety from improved pavement friction; Noise reduction; Lower vehicle maintenance costs; Infrastructure conducive to business retention and attraction
Inefficient traffic flow progression; Substandard signal design; Congestion from capacity constraints in the northern end of the corridor	Signal optimization and modernizations; Widening of the roadway between 17 Mile to M-59; Connected Vehicle Technology; Fiber Optic Communications; ITS Technology, FAST system and weather station	Travel Time Savings for passenger vehicles, public transportation, freight, and emergency vehicles; Emission reductions for a wide array of pollutants; Fuel savings; Significant expected crash reductions; Infrastructure conducive to business retention and attraction
Non-MUTCD conforming signing	MUTCD conforming traffic signs	Expected crash reductions
Limited non-motorized user mobility and connectivity	Non-motorized multi-use paths; Two pedestrian bridges	Increase safety, mobility, access & connectivity for non-motorized users; Community integration; Infrastructure conducive to business retention and attraction
Low visibility at night	Energy efficient unified lighting	Increase safety; Lower energy consumption
Overall infrastructure conditions which do not reflect business and employment needs and characteristics of the corridor	ITS and Connected Vehicle Technologies throughout the entire corridor	Travel time savings; Significant safety benefits; Emission reduction; Fuel consumption reduction; Infrastructure conducive to business retention and attraction; Advancement of Connected Vehicle Technology applications and goals

A benefit-cost analysis based on the guidance for INFRA grant application was conducted for those project improvements and benefit/cost categories which are reasonably expected to have an impact on the affected users of the project. The primary items included in this assessment consist of an analysis of the following categories:

- Travel Time Savings
- Safety Benefits
- Emissions Reduction
- Vehicle Operating Cost Savings (i.e. Fuel)
- ITS & Connected Vehicle Technology Savings
- Capital Expenditures
- Operating & Maintenance Expenditures

Table 2 presents key parameters/assumptions used in the BCA analysis to obtained projected benefits and costs, with a more thorough description and information on each parameter/assumption found under each respective chapter and in **Appendix A**.

Table 2: Mound Road BCA Key Parameters

Name	Value	Unit	Reference Source Key[1]
Total Project Cost	$216,960,000	Total ($2016)	na
Construction	3	Years (2020 - 2022)	na
Analysis Period	20	Years (2023 - 2042)	na
Values Expressed in (Baseline)	2016	$	BCA for INFRA (9)
Affected Users	All Existing	Number	2015 Traffic Data (6, Appendix A)
Discount Rate	7%	Percent	BCA for INFRA (9)
Inflation Adjustment	Varies by Year	Ratio	BCA for INFRA (9, Appendix A)
AADT	Varies per Segment	Number	2015 Traffic Data (6, Appendix A)
Percent Buses	Varies per Segment	Percent	2015 Traffic Data (6, Appendix A)
Percent Trucks	Varies per Segment	Percent	2015 Traffic Data (6, Appendix A)
Peak Volume in AM Peak	15.0%	Percent	2015 Traffic Data (6)
Peak Volume in Off Peak	65.0%	Percent	2015 Traffic Data (6)
Peak Volume in PM Peak	20.0%	Percent	2015 Traffic Data (6)
Average Passenger Vehicle Occupancy	1.39	per Passenger Vehicle	BCA for INFRA (9)
Average Truck Vehicle Occupancy	1.00	per Truck Vehicle	BCA for INFRA (9)
Average Vehicle Occupancy for O (No Injury) Crashes	1.39	per Crash	BCA for INFRA (9)
Segment Length	Varies per Segment	Miles	Synchro, SimTraffic Simulation (Appendix B)
No-Build Average Travel Time per Vehicle (AM, PM, Off Peak)	Varies per Segment	Seconds	Synchro, SimTraffic Simulation (Appendix B)
Build Average Travel Time per Vehicle (AM, PM, Off Peak)	Varies per Segment	Seconds	Synchro, SimTraffic Simulation (Appendix B)
No-Build Average Speed per Vehicle (AM, PM, Off Peak)	Varies per Segment	Miles per Hour	Synchro, SimTraffic Simulation (Appendix B)
Build Average Speed per Vehicle (AM, PM, Off Peak)	Varies per Segment	Miles per Hour	Synchro, SimTraffic Simulation (Appendix B)
No-Build Annual Maintenance Cost	$4,930,000	$ per Year ($2016)	Macomb County Department of Roadways
No-Build Annual Maintenance Cost Increase over 2016	2.5%	Percent	Appendix A
Build Annual Maintenance Cost	Varies per Year per Projected PASER conditions	$ per Year ($2016)	Appendix A
Annual Crashes	Varies per Injury & Crash Category	KABCO Scale	2011-2015 (10, Appendix A)

Value of Travel Time Savings - All Purpose	$14.10	per Person-Hour ($2016)	BCA for INFRA (9)
Value of Travel Time Savings - Truck	$27.20	per Person-Hour ($2016)	BCA for INFRA (9)
Value of Travel Time Savings - Bus	$28.30	per Person-Hour ($2016)	BCA for INFRA (9)
KABCO Level Values - O	$3,200	per Individual ($2016)	BCA for INFRA (9)
KABCO Level Values - C	$63,900	per Individual ($2016)	BCA for INFRA (9)
KABCO Level Values - B	$125,000	per Individual ($2016)	BCA for INFRA (9)
KABCO Level Values - A	$459,100	per Individual ($2016)	BCA for INFRA (9)
KABCO Level Values - K	$9,600,000	per Individual ($2016)	BCA for INFRA (9)
Value of Emission - VOC	$1,872	$ per Short Ton ($2016)	BCA for INFRA (9)
Value of Emission - NOx	$7,377	$ per Short Ton ($2016)	BCA for INFRA (9)
Value of Emission - PM	$337,459	$ per Short Ton ($2016)	BCA for INFRA (9)
Value of Emission - CO	$4,697.12	$ per Metric Ton ($2016)	Wang et. al. 1994 (20)
Value of Emission - CO_2	Varies per Year	$ per Short Ton ($2016)	Luckow et. al. 2016 (21, Appendix A)
Value of Gasoline	$2.25	$ per Gallon ($2016)	U.S. EPA 2016 Gasoline - All Grades (25)
Crash Modification Factors (CMF)	Varies per Treatment	Rate	CMF Clearinghouse & MDOT CMFs (13, 14, Appendix A)
Emission Equivalency Factors (VOC, NOx, PM, CO)	Varies per Speed & Pollutant (20 Year Project Life)	Grams per Mile	MDOT CMAQ Emission Factors (17, Appendix A)
CO_2 Emission	Formula Based (Speed Dependent)	Grams per Mile	Barth and Boriboonsomsin 2009 (18, Appendix A)
Fuel Consumption	Formula Based (Speed Dependent)	Milli-Liters per Kilometer	Evans and Herman 1976, 1978 (22, 23, Appendix A)
Growth in AADT over 2015 per year	1.5%	Percent	Historical Spot Volumes (7)
Growth in Annual Travel Times over 2015	1.5%	Percent	Historical Spot Volumes (7)
Growth in Annual Crashes over 2015	1.5%	Percent	Historical Spot Volumes (7)
Growth in Annual Emissions over 2015	1.5%	Percent	Historical Spot Volumes (7)
Growth in Annual Fuel Consumption over 2015	1.5%	Percent	Historical Spot Volumes (7)
Connected Vehicle Market Penetration Rate	Varies per Year (0% to 100%)	Percent	FHWA-JPO-14-125 (26, Appendix A, Appendix C)
Connected Vehicle Mobility Benefit	Varies per Year (0% to 25%)	Percent	Guler et. al. 2014 (28, Appendix A)
Connected Vehicle Safety Benefit	Varies per Year (0% to 80%)	Percent	NHTSA (30, Appendix A)
Connected Vehicle Emission Benefit - VOC	Varies per Year (0% to 10.89%)	Percent	Liu et. al. 2017 (29, Appendix A)
Connected Vehicle Emission Benefit - NOx	Varies per Year (0% to 15.51%)	Percent	Liu et. al. 2017 (29, Appendix A)
Connected Vehicle Emission Benefit - PM	Varies per Year (0% to 19.09%)	Percent	Liu et. al. 2017 (29, Appendix A)
Connected Vehicle Emission Benefit - CO	Varies per Year (0% to 13.23%)	Percent	Liu et. al. 2017 (29, Appendix A)
Connected Vehicle Emission Benefit - CO_2	Varies per Year (0% to 6.55%)	Percent	Liu et. al. 2017 (29, Appendix A)
Connected Vehicle Fuel Benefit	Varies per Year (0% to 13%)	Percent	FHWA-JPO-16-225 (27, Appendix A)

1. Refer to Chapter 6 and Appendix A for additional information

The results of the BCA analysis are based on the key parameters listed on the table above, a 2016 baseline year, 2020 to 2022 construction period, and a 20-year 2023 to 2042 analysis period. The results indicate the following benefits discounted at 7% (**Table 3**):

Table 3: Mound Road BCA Total Benefits at 7% Discount Rate

BCA Category	Total Discounted at 7%	
Travel Time Savings	$	284,943,820
Safety Benefits	$	232,161,183
Emission Reduction Benefits	$	5,136,765
Vehicle Operating Cost Savings	$	17,974,215
ITS & Connected Vehicle Technology Savings	$	289,979,213
Capital Expenditures	$	(154,947,662)
Operating & Maintenance Expenditures	$	46,556,394
NPV at 7%	**$**	**721,803,927**
BCR	**5.66**	

The results of the BCA for the Mound Road project indicate a Net Present Value (NPV) discounted at 7% of $721,803,927. This corresponds to a Benefit-Cost Ratio (BCR) of 5.66.

The BCA analysis indicates that the project yields a return on investment which far surpasses the total project cost.

1.0 Introduction

1.1 Project Description

The Mound Road Industrial Corridor Technology and Innovation (MTIC) Project is a partnership of Macomb County, the City of Sterling Heights and the City of Warren, Michigan, with the objective of transforming nine miles of the Mound Road corridor from a 30-year-old 8-lane roadway in dilapidated and decaying conditions to a next-generation critical commercial corridor of national significance. Mound Road is part of the National Highway System (NHS) and is the longest non-freeway segment included in the National Highway Freight Program (NHFP) in Michigan with approximately 12.24 miles and is vital to the economic development of southeast Michigan.

Mound Road connects state-owned roads/highways Interstate 696 (I-696) to Michigan 59 (M-59) and serves a significant industrial corridor. The corridor acts as the primary transportation route for several national automotive, aerospace, defense, and advanced manufacturing companies. The MTIC Project area is home to the General Motors Technical Center in Warren with over 17,000 employees, Ford Axle Plant and Transmission Plant in Sterling Heights, US Army's Tank-Automotive and Armaments Command (TACOM) and Tank Automotive Research, Development and Engineering Center (TARDEC) in Warren, Fiat Chrysler Automobiles (FCA) Stamping Plant and Assembly Plant in Sterling Heights, and BAE Systems in Sterling Heights. Most of these major employers have been operating in the corridor for decades but demand for redevelopment is growing. For example, global defense contractor BAE Systems moved into their 81 acre campus in March 2012, their first in Michigan. According to the Southeast Michigan Council of Governments (SEMCOG), employment between 2015 and 2040 is forecasted to grow 7% in Sterling Heights and 10% in Warren. These job growth rates meet or exceed the regional forecast of 7% (1).

An economic impact analysis of the Mound Road Corridor was completed in March 2017 by Economic Modeling Specialists International (Emsi). Emsi's analysis found that the Mound Road corridor has a direct employment total of 20,200 people. Moreover these jobs support another 17,720 jobs in Macomb County. Additionally, the 20,200 jobs along Mound Road support another 98,100 jobs in the Michigan economy outside of Macomb County (2).

Given the current dilapidated infrastructure conditions along the corridor and the number of manufacturing and research facilities of vital national importance, the project aims to renovate and establish a next-generation critical commercial corridor via:

- High performance concrete pavement for improved surface rideability and extensive service life
- Intelligent Transportation Systems (ITS) for optimized traffic operations and proactive incident management
- Connected vehicle technology deployment to enhance freight movement and facilitate overall real-time communication between vehicle and infrastructure (V2I)
- Comprehensive signal infrastructure and signage improvements to improve traffic flow and safety along the corridor for passenger and commercial / industrial freight
- Two grade separated pedestrian crossings supplemented by the installation of non-motorized multi-use paths to improve non-motorized user safety, mobility and promote regional trails
- Install energy efficient unified lighting to increase visibility along the corridor and reduce energy consumption

1.2 Project Location

The MTIC Project is located in the cities of Sterling Heights and Warren, Macomb County, Michigan. Within these two cities Mound Road extends for nine miles starting at the intersection with I-696 to the south and proceeds north to the intersection with M-59 (**Figure 1, 2**). This entire nine mile section falls within the Detroit Urbanized Area and is part of the NHS and the NHFP. The corridor is an 8-lane divided roadway for six miles in length between I-696 and 17 Mile Road, and a 6-lane divided roadway for three miles between 17 Mile Road and M-59. Land uses surrounding the corridor are primarily commercial and industrial, with primary manufacturing installations located throughout the extent of the corridor. These employers of vital importance are indicated in red in **Figure 2**.

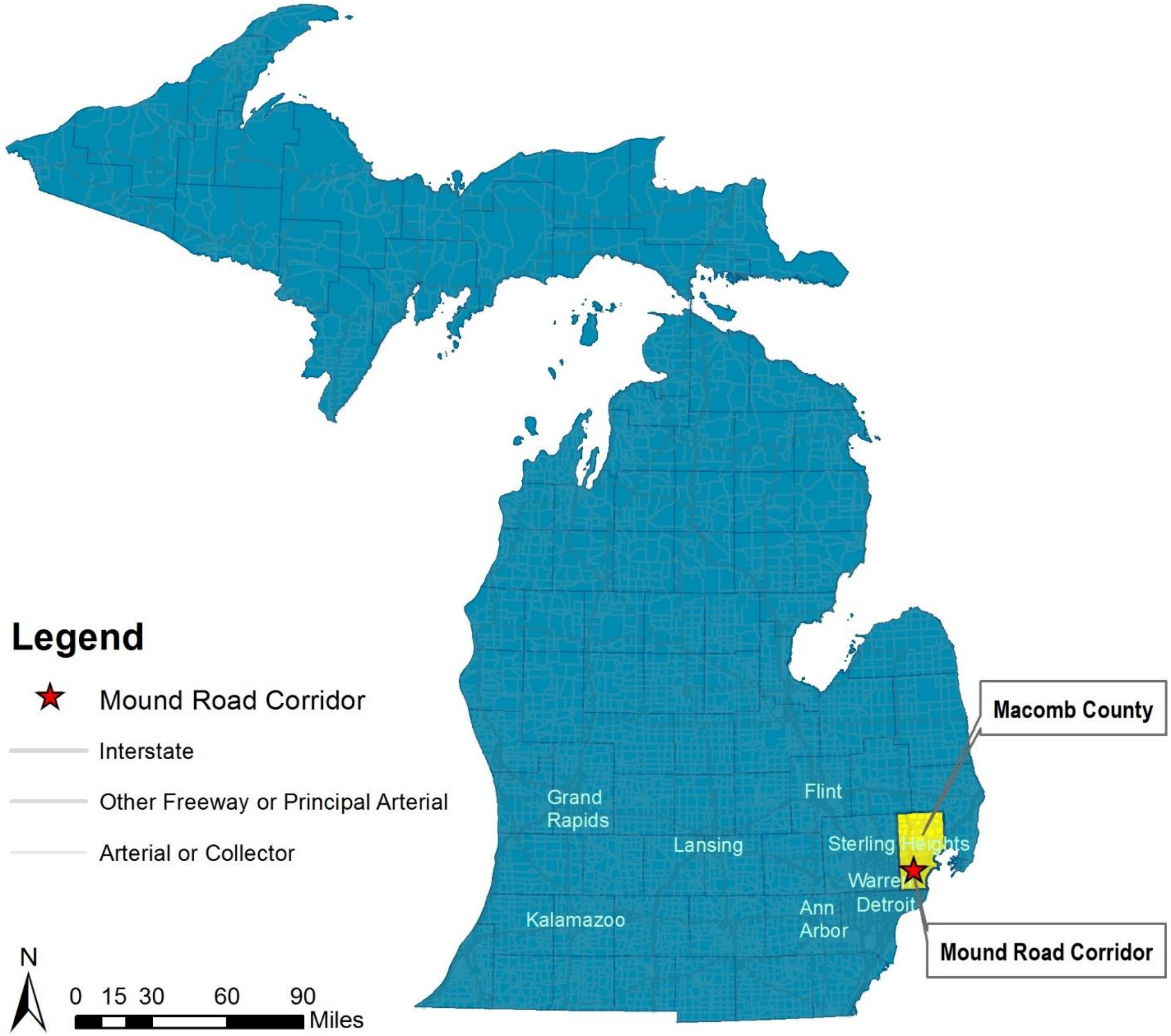

Figure 1: Mound Road Location on a State & Regional Context

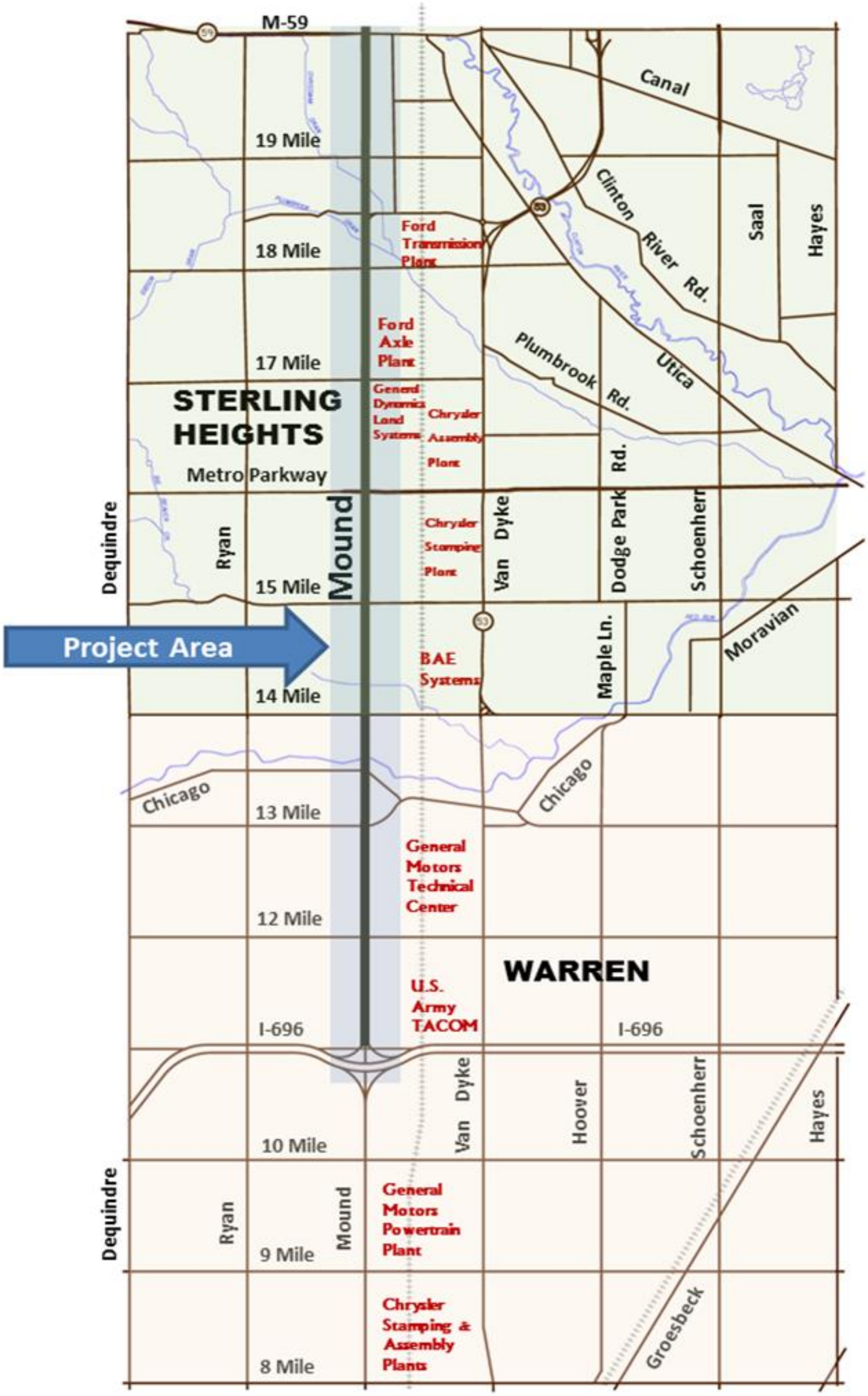

Figure 2: Mound Road Location & Employers

1.3 Project Goals

The Mound Road project is a regionally significant project. Substantial portions of the corridor have been in the Long Range Plan for southeast Michigan for over a decade. The project will further the policies and goals of the federal and state level.

The FAST Act established a national policy of maintaining and improving the condition and performance of the National Multimodal Freight Network ("the Network"), to ensure that the Network provides a foundation for the U.S. to compete in the global economy. The FAST Act specifies goals associated with this national policy related to the condition, safety, security, efficiency, productivity, resiliency, and reliability of the Network, and also to reduce the adverse environmental impacts of freight movement on the Network. These goals are to be pursued in a manner that is not burdensome to State and local governments (3).

The FAST Act also established a new NHFP to improve the efficient movement of freight on the National Highway Freight Network (NHFN) and support several goals, including (4):

- Investing in infrastructure and operational improvements that strengthen economic competitiveness, reduce congestion, reduce the cost of freight transportation, improve reliability, and increase productivity;
- Improving the safety, security, efficiency, and resiliency of freight transportation in rural and urban areas;
- Improving the state of good repair of the NHFN;
- Using innovation and advanced technology to improve NHFN safety, efficiency, and reliability;
- Improving the efficiency and productivity of the NHFN;
- Improving State flexibility to support multi-State corridor planning and address highway freight connectivity; and
- Reducing the environmental impacts of freight movement on the NHFN

The State of Michigan has adopted very similar policies and goals for the roads under its jurisdiction. In a supplement to the 2035 Michigan Transportation Plan, MDOT has proposed its own strategic goals for freight as shown in **Figure 3** (5).

Strategic Goals

2035 MITP Goals → / National Freight Goals ↓	Efficient and Effective Operations	System Improvement	Safety and Security	Stewardship	Modal Choice	Freight Adequacy
Enhance economic efficiency, productivity, and competitiveness	x	x	x	x	x	x
Reduce congestion	x	x	x		x	x
Improve safety, security and resiliency	x	x	x	x	x	x
Improve state of good repair	x	x		x	x	x
Use advanced technology, performance management, innovation, competition and accountability in operation and maintaining network	x	x	x	x	x	x
Reduce adverse environmental and community impacts	x			x	x	x

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Figure 3: MDOT Strategic Freight Goals

The Mound Road project goals align closely with those established by the MDOT and the U.S. DOT. The main goals of the Mound Road project are to:

- Enhance and support national and regional economic efficiency, productivity and competitiveness
- Reduce congestion
- Improve safety and security
- Improve state of good repair
- Implement advance technology for operational, safety and network maintenance improvements

2.0 General Principles

2.1 Baseline Description & Existing Conditions

The MTIC project represents nine miles of primary arterial roadway on the National Highway System within Macomb County in the southeast region of Michigan. The north-south corridor is an 8-lane divided roadway for six miles in length between I-696 and 17 Mile Road, and a 6-lane divided roadway for three miles in length between 17 Mile Road and M-59. The speed limit throughout the entire corridor is 50 mph. The median is 50 feet wide.

2.1.1 Traffic Volumes

According to 2015 traffic volume data, the corridor has an Average Annual Daily Traffic (AADT) of approximately 70,000 vehicles, split almost equally by direction. The AADT varies between mile road cross streets where the highest volumes are typically experienced along the southern section of the corridor (6). Peak volumes occur between 7:00 AM – 9:00 AM and 3:00 PM – 6:00 PM. These hours comprise approximately 15% and 20% of the total daily traffic respectively (6). Historical traffic volumes are not available for the entire corridor, however, historical spot volumes indicate variance in traffic growth ranging from 1% to 6% depending on the location (7). Given the variation in traffic growth projections and the lack of comprehensive historical data points, an annual growth projection of 1.5% is assumed applicable for the entire corridor under existing conditions. This growth is assumed constant and is not expected to be affected by capacity constrains given that Mound Road is a primary arterial road servicing key major commercial and industrial facilities, acts as a primary thoroughfare connecting I-696 and M-59 which experience approximately 170,000 and 90,000 AADT respectively, and is not currently characterized by any intersections with a level of service (LOS) F (**Figure 4**) which would indicate potential intersection operations at full capacity. This value is also suggested as an acceptable expected traffic growth rate by the Macomb County Department of Roads (MCDR).

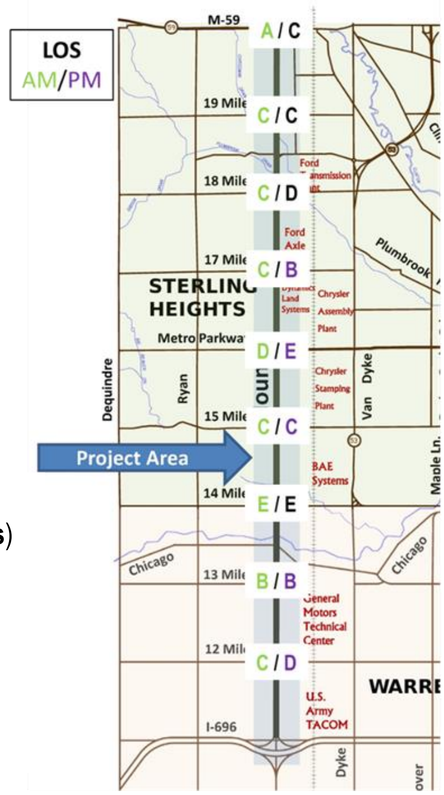
The 2015 traffic data indicates that the average percentage of trucks in the corridor is approximately 4.7%, with the highest percentage of freight traffic occurring in the NB direction of Mound Road between 13 Mile and 18 Mile Roads. Buses, primarily school buses, constitute on average 0.3% of the total traffic in the corridor.

2.1.2 Pavement

Existing pavement throughout the corridor is Portland Cement Concrete (PCC) which has exceeded its service life. Per SEMCOG Pavement Surface Evaluation and Rating (PASER) pavement condition data, the pavement in the majority of the project area is in poor condition with few segments in fair condition. Historical pavement data indicates that pavement conditions in the last ten years have deteriorated throughout the entire corridor, a process which is expected to continue and increase in scope as conditions worsen (8). Damages to the deteriorated pavement are further exacerbated by aggressive freeze-thaw cycles typical of Michigan climatic conditions. As a result, the MCDR is currently budgeting $4.6 million each year for concrete replacement with an additional $0.3 million a year to monitor the corridor for major pavement deficiencies such as significant cracking or pot holes. Additional costs result from the continuous required work zone set ups for the annual pavement maintenance efforts, in particular for user delay costs. While difficult to quantify, given the type of vital commercial/industrial installations along the corridor, user delay costs along with deteriorated infrastructure conditions can be unusually high and potentially hinder further economic development within the corridor. Under a no-built scenario and given the current poor condition of the pavement, it is expected that maintenance costs will increase in the future. In addition, it is likely that user delay will increase proportionally as a result of longer maintenance periods required in order to maintain the roadway.

2.1.3 Traffic Operations

The Mound Road corridor is divided by nine primary signalized intersections and several additional signals located at the main entrances of the larger commercial/industrial installations (i.e. TACOM, GM etc.) and at several median crossovers. A traffic model of existing conditions of the corridor indicates unacceptable LOS E for two primary intersections. **Figure 4** provides the overall intersection level of service for the nine primary intersections.



LOS Control Delay per Vehicle Criteria (seconds)

A	< 10
B	10 to 20
C	20 to 35
D	35 to 50
E	50 to 80
F	> 80

Figure 4: Existing Peak Hour Level of Service

Nearly all of the signals can be upgraded to improve both operational efficiency and safety. Operational inefficiencies in the corridor include but are not limited to:

- Outdated or obsolete vehicle detection system
- Uncoordinated or inadequate signal timing optimization

As a result, travel times through the corridor can be unreasonably excessive with poor traffic progression during the critical peak hours. Additional congestion conditions tend to stem as a result of a bottleneck created at 17 Mile Road. This is a result of a sudden drop in capacity from the transition from an 8-lane divided to a 6-lane divided roadway, despite volumes between the two areas being relatively similar.

2.1.4 Safety

Safety concerns exist throughout the Mound Road corridor. A 5-year crash analysis determined that the average crash rate is greater than that of the State of Michigan, primarily as a result of the high frequency of rear-end crashes. Primary safety concerns in the corridor include but are not limited to:

- Diagonal span signal installation
- Inadequate number of signal heads per approach
- Low signal head visibility (i.e. signal head placement, lack of backplates)
- Poor intersection illumination
- Incandescent 8" signal heads and case signs
- Unmarked or low-visibility crosswalks
- Lack of pedestrian countdown signals
- Non-ADA compliant intersection crossings
- Non-conforming MUTCD signing
- Lack of midblock crossings

With respect to non-motorized users, in several areas along the corridor, pedestrians have to travel to the nearest intersection to cross Mound Road. Depending on the location, these distances can be as much as 0.5 miles, thus resulting in risky pedestrian behaviors associated with crossings at uncontrolled and unmarked locations.

2.1.5 Economic Conditions

The Mound Road corridor is a vitally-important national asset that employs over 20,000 workers and facilitates freight movement for key aerospace, defense and automotive manufacturing/research facilities such as the Warren General Motors Technical Center, the Sterling Height Ford Axle and Transmission Plan, the Sterling Heights FCA Stamping and Assembly Plant, and the U.S. Army's TACOM and TARDEC facilities. As indicated before, a 2017 economic impact analysis found that a total of 20,200 people are employed along the corridor. These jobs support an additional 17,720 jobs in Macomb County alone. The combine earnings total $2.8 billion annually and taxes on production nearing $190 million (2). Given the significant number of employers of national importance that this corridor supports, the costs associated with infrastructure critical deficiencies can result in negative economic outcomes.

2.2 Mound Road Project & Changes to Baseline Conditions

The Mound Road project is designed to rectify existing roadway, operational and safety shortfalls for the corridor, and is expected to have important and long-lasting effects on the baseline conditions of not only the immediate locality, but also the County, Metro Detroit and the State of Michigan. These improvements include but are not limited to critical infrastructure updates including roadway and signal modernization, substantial operational and safety improvements, and implementation of innovative technologies such as deployment of connected vehicle technology (i.e. V2I) and leveraging of automotive assets located along Mound Road to further connected and autonomous vehicle technology.

2.2.1 Pavement

The most critical roadway infrastructure update included in the project is the complete reconstruction of Mound Road with high performance PCC pavement (P1 Modified). The P1 Modified concrete is based on optimized aggregate gradation and 25 to 40 percent replacement of the PCC in the concrete mixture with a supplementary cementituous material (slag cement, fly ash). The mix is more expensive to produce but its benefits are considerable as this mix as the following characteristics:

- More durable
- Easier to place
- Ultimate strength higher than standard aggregate grades mixes
- Superior roadway friction
- Low life-cycle cost
- 30 year minimum service life

Due to its superiority, this high performance concrete mix is now specified exclusively by the Michigan Department of Transportation for high volume concrete roadways.

2.2.2 Segment Improvements, Widening, Signing & Lighting

Additionally the reconstruction will incorporate updates to the curb and gutter along the roadway, improvement to driveways affected by the reconstruction for improved access management, drainage improvements, and landscaping which will increase the corridor's curb appeal. Existing lighting along the corridor will also be upgraded to improve visibility and safety for both motorized and non-motorized users. All signing along the corridor will be replaced with MUTCD conforming signs. This is expected to significantly improve safety by adequately providing drivers with all essential roadway information. The project will additionally eliminate the bottleneck on Mound Road between 17 Mile Road and M-59 where the road capacity narrows from an 8-lane divided highway to a 6-lane divided highway. The widening of this three mile segment has been in the SEMCOG regional long range plan for decades.

2.2.3 Traffic Signalization

Significant signal modernization will be implemented on both the primary intersections and all signalized median crossovers. Primary signal modernization will include the following upgrades:

- Mast arm signal layout
- Intelligent Transportation Systems (ITS) cabinet and controller with battery back-up
- 12" Light-Emitting Diode (LED) signal head
- LED illuminated case signs
- Backplates
- Illuminated mast arm mounted street name signs
- Pedestrian countdown signals (audible)
- ADA compliant pedestrian pushbuttons
- High-visibility crosswalks
- Wireless vehicle detection

2.2.4 ITS and Connected Vehicle Technology

Each primary signal will be equipped with advanced ITS technologies to significantly improve safety and intersection operational efficiency. These include:

- Video surveillance capabilities through closed-circuit televisions
- Performance measures and Purdue Coordination Diagram (PCD) modules and customizations
- Video analytics program running in concert with Oculairs to assist in incident management
- Work zone ITS/connected vehicle technology to enhance safety and improve mobility during construction
- Dilemma zone detection equipment at all of the intersections for the Mound Road approaches
- Eberle Design Inc (EDI) data aggregator to provide cost effective remote access to real-time traffic data and corresponding measures of effectiveness (MOE) for various data points from any isolated or network intersection or arterial roadway.

To support future advancements and innovations in roadway safety and operations, connected vehicle technology will be deployed throughout the corridor. This includes the installation of approximately 50 roadside units (RSU) at strategic locations along all of the nine miles of Mound Road. To make immediate use of the roadside units, up to 50 on-board connected vehicle units will be made available for emergency response vehicles or public transit vehicles. Communications for the technology will be supported via the installation of 12 total miles of fiber optic communication cabling installed along the network. It is the intent of this project that the capabilities of existing automotive facilities will be leveraged in concert with all of the Vehicle to Infrastructure (V2I) deployments to further the advancement of the development of connected vehicles applications and testing with Original Equipment Manufacturers (OEM).

To combat winter icing conditions on bridges, the projected proposes to install an environmental sensing station in the corridor along with Fixed Automated Spray Technology (FAST) units on the bridge decks crossing four separate drains: the Red Run Drain, the Beaver Creek, the Sterling Relief Drain, and the Plumbrook Drain. The FAST system is being deployed to support and supplement winter maintenance operations by monitoring winter weather conditions and preventing snow and ice from bonding to the surface by automatically spraying anti-icing solutions at the applicable areas. The FAST system will improve service delivery to the motoring public with the safe, timely, and rapid application of chemicals on the bridge roadway surfaces. Currently these locations are more prone to crashes when the pavement condition is icy.

2.2.5 Non-Motorized Users

The project consists of the installation of two grade separated non-motorized crossings on Mound Road. The first bridge is proposed near Metro Parkway (16 Mile Road) to facilitate users of the Macomb County Freedom Trail and to improve access to the 1,273 mile Iron Belle Trail which runs from Detroit to the Michigan/Wisconsin border.

The second bridge is proposed to be located on the south end of the corridor near 13 Mile Road. **Figure 5** illustrates a map of the Iron Belle Trail and Freedom Trail in Macomb County and its proximity to Mound Road.

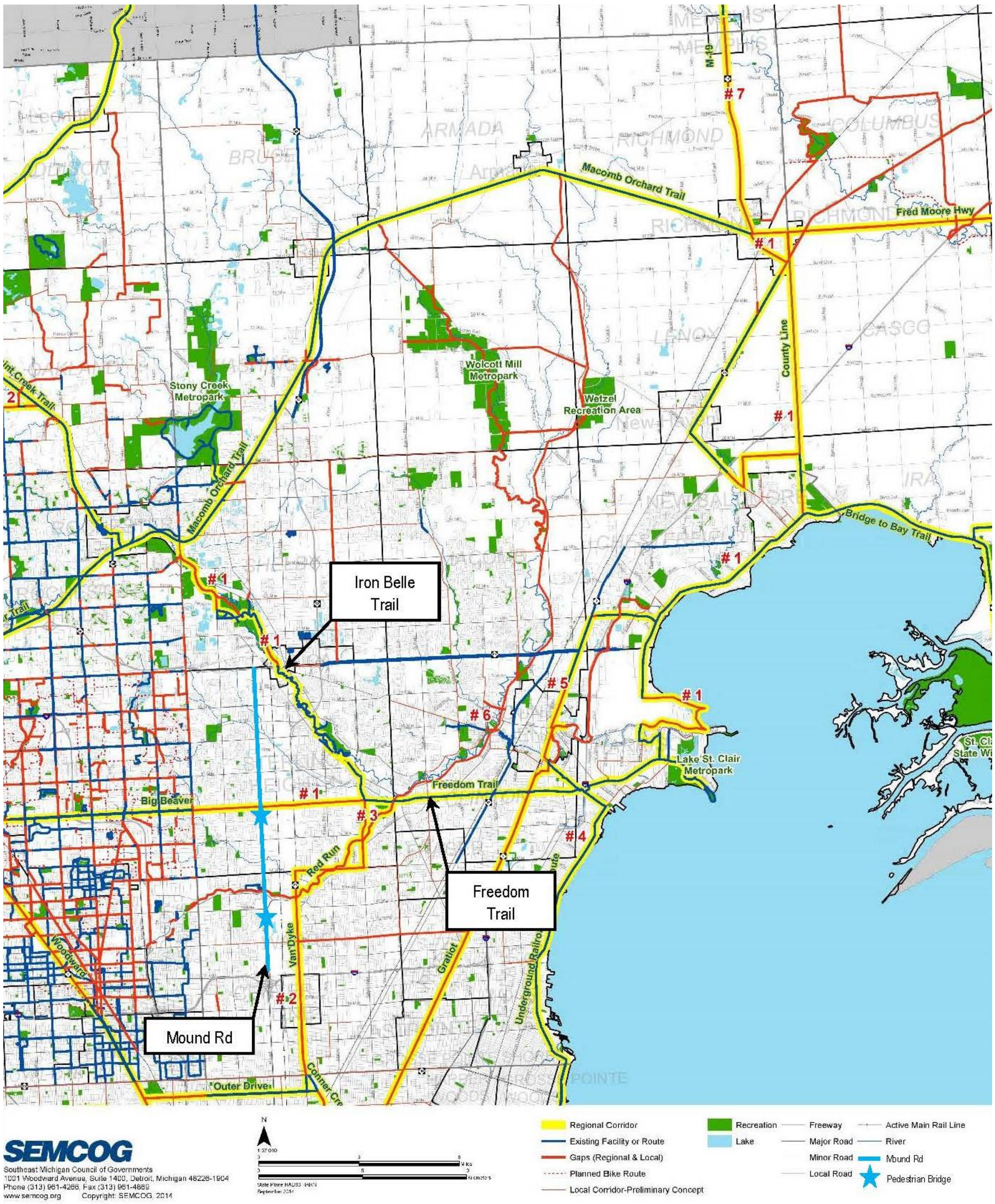


Figure 5: Mound Road Proximity to 1,273 Mile Iron Belle Trail and Freedom Trail

2.3 Analysis Period & General Assumptions

The Mound Road project BCA encompasses all of the components of the project in the assessment of the costs of the project as well as its benefits. The analysis period covers the full initial development and construction period of the project plus 20 years of operations following the completion of construction for the assessment of the costs and benefits. The 20 year period has been selected in order to minimize BCA projection errors resulting from exceedingly long term future uncertainties in the infrastructure, travel patterns, economic conditions etc.

Construction of the project is expected to last three construction seasons with a start date of 2020 and an end date of 2022. The project is expected to be fully operational by 2023. As a result, all benefits are expected to initiate in 2023 and are assessed 20 years following this date with a BCA assessment end date of 2042.

Per the Benefit-Cost Analysis Guidance for INFRA Applications, this BCA utilizes a 2016 base year. Inflation adjustments for the study for values incurred prior to 2016 are based upon the Gross Domestic Product (GDP) deflator adjustment factors. Similarly, in accordance with this guidance and Office of Management and Budget (OMB) Circular A-94, all benefits and costs presented in this BCA use a real discount rate of 7% per year (9).

2.4 Affected Users

The Mound Road project will directly benefit all of the existing users which currently use the facility. This includes both motorized and non-motorized users which on average is approximately 70,000 AADT for both directions. It must be stressed that a significant portion of the users directly benefiting from the project are employees of industries of key national importance, including the U.S. Army's TACOM and TARDEC facilities, GM Tech Center campus, as well as manufacturing plants for the Big Three (i.e. Ford, GM, and FCA). In addition nearly 4.7% of the cumulative 70,000 AADT using the Mound Road corridor are trucks. It is expected that deployment of connected vehicle technologies will significantly improve freight movement along the corridor as well as furthering the development of connected vehicle applications.

While the infrastructure, operational, and safety improvements for the project are significant, this BCA assumes no new additional users will be attracted to the corridor as a result of the improvements. Instead this BCA assumes that the same number of existing users utilizing Mound Road under the no-build scenario will be utilizing the corridor under the build scenario. Similarly to the existing no-build scenario, this BCA assumes a 1.5% annual growth in traffic volumes for the build scenario. This projection is based on the examination of available historical spot volume data along the corridor (7). The growth is assumed constant for the analysis period of the BCA and is not expected to be affected by capacity constraints given that Mound Road is a primary arterial road in the north-south direction servicing key major commercial and manufacturing facilities, acts as a primary thoroughfare connecting I-696 and M-59 both of which are characterized by significant AADT volumes, and is expected to have improved capacity over existing conditions due to signal modernization and optimization as well as the introduction of additional travel lanes in the northern section of the corridor. This value is also suggested as an acceptable expected traffic growth rate by the MCDR.

Lastly, traffic patterns for the project are not expected to change over existing baseline conditions. As a result, AM and PM peak traffic volumes under the built scenario are expected to comprise approximately 15% and 20% of the total daily traffic respectively (6).

3.0 Benefits

The benefits chapter represents a discussion of the analysis conducted for those items which are reasonably expected to result in positive economic value to the affected users of the project and the public at large. These discussions intend to supplement and closely reflect the analysis conducted in the attached BCA spreadsheets (see **Appendix A** for more information). The benefits analysis also acknowledges that transportation improvements may result in a mix of positive and negative outcomes. These nuances are considered throughout this assessment.

The primary items under the benefits analysis include an assessment of:

- Travel times
- Safety
- Emissions
- Vehicle operating costs
- ITS & Connected Vehicle Technology

Additional items are also discussed in qualitative terms due to the difficulties in quantifying certain topics with a high confidence level.

3.1 Value of Travel Time Savings

Travel time savings in transportation infrastructure improvement projects arise from improvements to the traffic flow. For the Mound Road project, travel time savings are expected to be primarily an outcome of signal infrastructure upgrades, operational improvement elements (i.e. vehicle detection upgrades, signal timing improvements), and the additional travel lanes between 17 Mile Road and M-59. While travel time savings are also expected to result from the full reconstruction of the road, its impact has not been accounted for in the travel time savings analysis due to the difficulties in quantifying these elements. Additionally travel time savings solely due to the deployment of connected vehicle technology is not accounted for in this section and is instead included in the connected vehicle section.

Travel time savings for the Mound Road project are based on an extensive micro-simulation analysis of the study area using the Synchro 9 and Simtraffic software, and are based on 2015 intersection specific traffic volumes (6). First, in order to be able to obtain travel times with an acceptable degree of accuracy, existing conditions along the corridor were replicated using Synchro 9. Numerous Simtraffic simulations were conducted on the network to obtain existing average vehicle travel times for the no-built scenario. Existing average vehicle travel times were obtained for three peak traffic hours (AM, PM, and Off Peak) to account for traffic flow variations as well as the different intersection signal timings applicable for each peak hour.

Secondly, modifications to the existing models were made to reflect the infrastructure upgrades. These included modifications to the intersection signal operation modes as well as the modification of the 3-mile section between 17 Mile Road and M-59. Simulations were conducted for AM, PM, and Off peak times to obtain expected average vehicle travel times for the build scenario. The Simtraffic generated average vehicle travel time for the no-build and the build scenarios allowed to calculate annual expected travel time savings using the following formula:

$$TT_{v-\,i} = 365 * \frac{1}{3600}\sum AADT_i * P_v * O_v * (T_{B-n-i} - T_{A-n-i}) * P_{n-\,i}$$

Where, $TT_{v-\,i}$ = annual Total Travel time savings of segment i per vehicle type v in hours, where v is either passenger, bus or truck

$AADT_i$ = 2015 Average Annual Daily Traffic of segment i

365 = number of days in an average year

P_v = proportion of vehicle type v in traffic, where v is either passenger, bus or truck (2015 data)

O_v = average occupancy of vehicle type v, where v is either passenger, bus or truck (based on BCA Guidance provided data)

365 = number of days in an average year

1/3600 = seconds in an hour (conversion from sec to hr)

T_{B-n-i} = average vehicle travel time (in seconds) for no-built scenario of segment i in peak period n

T_{A-n-i} = average vehicle travel time (in seconds) for built scenario of segment i in peak period n

P_{n-i} = proportion of travel of segment i in peak period n, where n is either AM, PM, or OFF peak (based on 2015 data and is 0.15 for AM, 0.2 for PM, and 0.65 for OFF peak)

The total travel time savings for each vehicle type (passenger all purpose trips, bus and tracks) were then multiplied by the individual 2016 dollar amounts provided in the BCA guidance and were summed to obtain a total annual travel time saving value of the project versus the existing conditions. Because the traffic volume data used represents 2015 data, a 1.5% growth factor is initially applied to base year 2016. The 1.5% growth factor is then applied to each additional applicable year with benefits initiating in 2023 (post-construction) and are calculated up until 2042.

The travel time savings analysis resulting from the project indicates an average overall travel time savings improvement of 13.8% over baseline conditions as seen on **Figure 6**. This translates to:

- **$41,709,883** in annual average savings
- **$834,197,659** in total savings over the 20 year operational period of the analysis
- **$284,943,820** in total savings over the 20 year operational period of the analysis when discounted at 7%

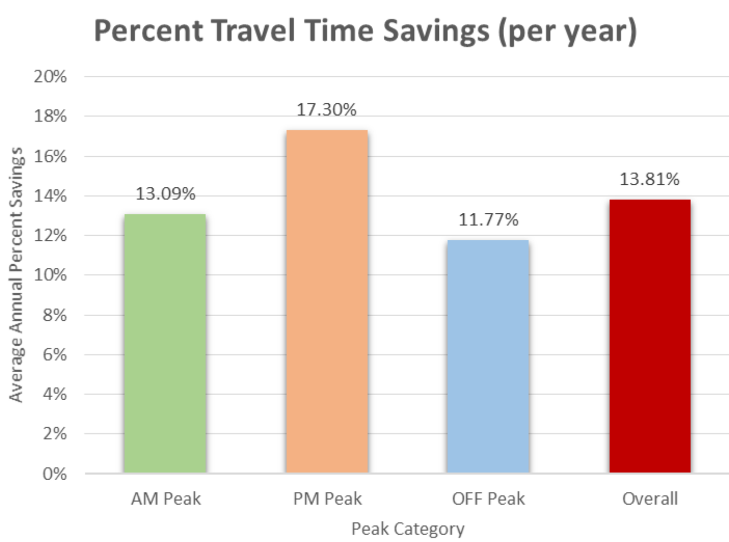


Figure 6: Average Annual Percent Travel Time Savings

It should be noted that the reduction in travel time savings also result in additional benefits, in particular for those corresponding to improved just-in-time deliveries for goods and freight passing through the corridor. The latter comprise approximately 4.7% of the corridor's AADT. Consequently, benefits corresponding to travel times can be expected to be higher.

3.2 Safety Benefits

3.2.1 Existing Safety Conditions

In line with the INFRA grant core principles, the Mound Road project recognizes that safety is a top priority, in particular the elimination of fatal and injury crashes. Consequently effort has been made to design a project which improves safety by incorporating proven as well as innovative safety treatments.

Currently Mound Road is characterized by a relatively high frequency of crashes. A review of 2011-2015 crashes obtained from the Traffic Improvement Association (TIA) Traffic Crash Analysis Tool (TCAT) reported a total of 3,914 total crashes along the subject corridor, 1% of which were reported as fatal and incapacitating injury (type A) crashes and approximately 21% involved some other level of injury (10)[1]. These 3,914 crashes involved 8,209 vehicles, resulted in 10 fatalities, incapacitating injuries to 38 individuals, and included some other form of injury to an additional 1,118 individuals. **Figure 7** presents the 2011-2015 crash distribution by severity along the corridor, while **Figure 8** presents the 2011-2015 number of individuals affected and/or involved in the incidents by crash severity[2].

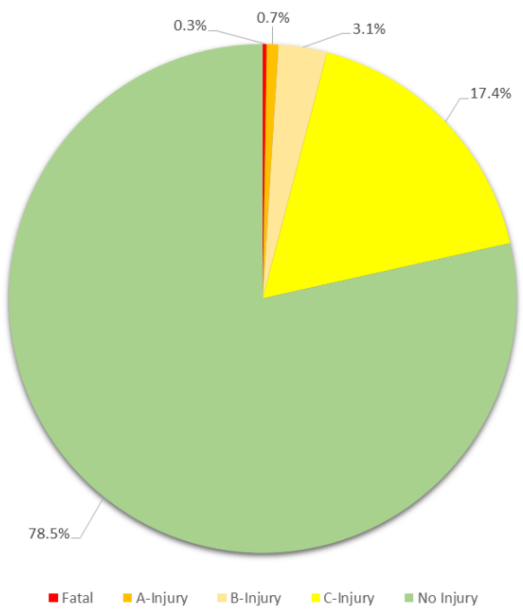


Figure 7: 2011-2015 Mound Road Crash Distribution by Severity

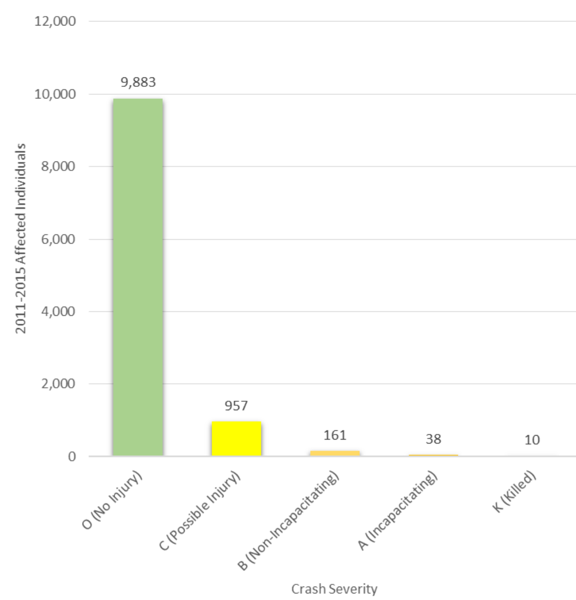


Figure 8: 2011-2015 Mound Road Affected Individuals by Crash Severity

The safety conditions of the corridor are best illustrate via crash rates which normalize the crash data by taking into account exposure variables such as traffic volumes thus providing a more effective comparison between data points. **Figure 9** presents the 2011-2015 historical crash rates per 100 Million Vehicle Miles Traveled (MVMT) for the Mound Road Corridor and the State of Michigan (11). The data indicates that crash rates along the corridor, while exhibiting a similar trend as the State of Michigan, have increased at a much faster rate with an average increase of 8.5% per year as opposed to 1.8% for the state. Similarly, the average crash rate for the corridor for years 2011 to 2015 is nearly 4% higher than that of the state of Michigan at 317.7 per 100 MVMT as opposed to 306.4 per 100 MVMT.

[1] The TIA TCAT is an online search tool for traffic crashes in Michigan. Crashes in Michigan are reported on the KABCO scale and include fatal, injury type A, B, C, or no injury crashes. The severity of a crash is determined by the most severe injury in the crash. A refers to an incapacitating injury that prevents a person from walking, driving or normal activities which he/she was capable of performing prior to the crash. B is described is any injury that is evident at the scene of the crash, but the injury is not fatal or incapacitating. C refers to an injury reported by an occupant, but not visible to the officer completing the crash report.

[2] The Michigan State Police Department reports O (No Injury) crashes on a per vehicle basis. A 1.39 average occupancy rate based on the BCA guidance has been applied to report the number of individuals involved in O (No injury) crashes.

In addition to the trends and average crash rates being higher than that of the State of Michigan, the Southeast Michigan Council of Governments (SEMCOG) lists two-miles of the nine-mile Mound Road corridor between 15 Mile Road to Metro Parkway (16 Mile) and Metro Parkway to 17 Mile Road as the 35th and 64th highest-frequency crash locations within the Southeast Michigan region (12). This condition is particularly significant given that the Southeast Michigan region has the largest and highest density roadway network within Michigan and a population of approximately 4,750,000 (1).

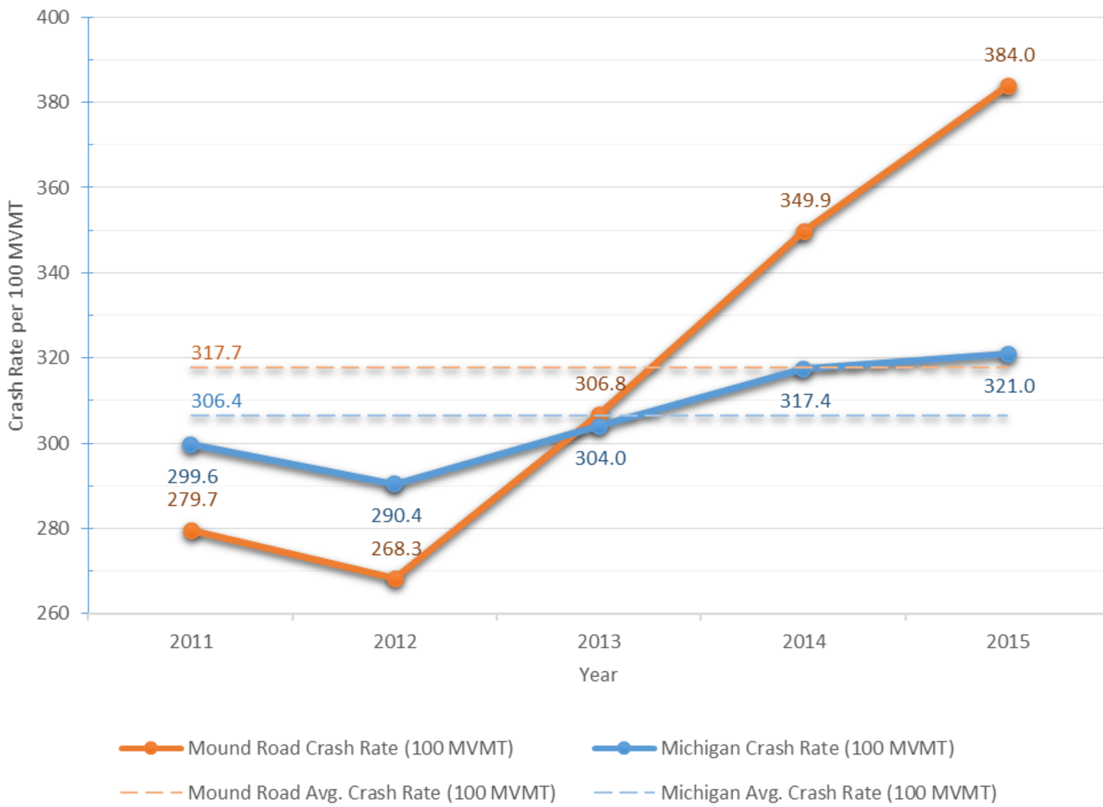


Figure 9: 2011-2015 Mound Road and Michigan Crash Rates

Table 4 indicates a more in-depth assessment of existing crashes. The data indicates that approximately 64.4% of the crashes occurring along Mound Road are segment crashes while the other 35.6% are intersection related crashes. The predominant crash type for both locations are rear end crashes with 53.2% and 49.9% respectively. On segments, sideswipe same crashes comprise more than 25% of all crashes, followed by angle and single vehicle crashes following with approximately 6-7% each. At intersections, 20% of all crashes are angle crashes, followed by sideswipe same crashes with approximately 16.1%. In terms of the time of the day, 1 in 4 of the total crashes occurred during dark conditions. Overall, head-on crashes for the corridor are low because of the boulevard geometry and prohibition of direct left turns at major intersections.

A summary of segment and intersection related crashes by time of day (day/night) and pavement conditions is provided in **Table 5 & 6** respectively. The data indicates little variation between segment and intersection crashes for the two categories. Overall 21.8% of the crashes along the corridor occur at night. In terms of pavement conditions, 18.2% of the total crashes occur on wet pavement (i.e. rainy conditions) and 9.4% occur on snowy, icy or slush conditions.

Table 4: 2011-2015 Mound Road Crash Location by Crash Type

Crash Type	Total	Segment	Intersection
Single Motor Vehicle	5.5%	6.9%	2.9%
Head-On	0.2%	0.3%	0.1%
Head-On Left Turn	0.2%	0.2%	0.1%
Angle	11.5%	6.6%	20.4%
Rear End	52.1%	53.2%	49.9%
Rear End Left Turn	1.3%	1.6%	0.7%
Rear End Right Turn	3.7%	2.0%	6.9%
Sideswipe Same	22.4%	25.9%	16.1%
Sideswipe Opposite	0.2%	0.2%	0.3%
Other	2.9%	3.0%	2.7%
Total	**100.0%**	**64.4%**	**35.6%**

Table 5: 2011-2015 Mound Road Crash Location by Time of Day

Time of the Day	Total	Segment	Intersection
Day	78.2%	76.6%	81.0%
Night	21.8%	23.4%	19.0%
Total	**100.0%**	**64.4%**	**35.6%**

Table 6: 2011-2015 Mound Road Crash Location by Pavement Condition

Pavement Condition	Total	Segment	Intersection
Dry	71.7%	72.3%	70.5%
Wet	18.2%	16.8%	20.9%
Snow/Ice/Slush	9.4%	10.3%	7.9%
Other/Unknown	0.7%	0.6%	0.7%
Total	**100.0%**	**64.4%**	**35.6%**

Crash attributes for the Mound Road corridor appear to be typical for divided roadways. However, the large number of crashes and particular emphasis on specific crash types does present an opportunity to significantly improve safety along the corridor. Specifically an opportunity is presented to significantly reduce rear-end, angle, single vehicle, and sideswipe same crashes, several of which also present a safety risk in terms of fatal and severe injury outcomes.

The review of individual crash reports for the fatal and serious injury incidents indicates that 8 of the 10 fatal crashes are likely correctable. Specifically:

- 3 of the 8 crashes were as a result of red light running which could be corrected by improving signal visibility and signal timing
- 3 crashes were rear end crashes occurring as a result of failure to stop which could be corrected by improving pavement friction performance, signal visibility, signal timing, and traffic flow progression
- 1 fatality involved a single vehicle that was weaving, lost control and rolled over at night which could be corrected by pavement in good repair and improved street lighting
- 1 fatality involved a pedestrian crossing at an uncontrolled midblock location at night which could be corrected with improved street lighting and pedestrian facilities

A similar pattern is reflected on the serious injury crash reports with 22 of the 30 reviewed crash reports being potentially correctable. Specifically:

- 14 of the correctable crashes involved red light running at different intersections along the corridor
- 7 were rear end crashes from failure to stop due to stopped traffic upstream of an intersection or stop and go traffic along the segment
- 1 involved loss of vehicle control due to wet pavement conditions supplemented by stop and go traffic
- 1 involved a pedestrian crossing at a uncontrolled midblock location

Currently the network is characterized by a number of safety deficiencies which contribute to the high number of crashes. Primary network wide safety deficiencies include:

- Poor pavement friction performance due to severely deteriorating pavement conditions
- Low visibility, low reflectivity pavement markings
- Low visibility at night due to poor lighting conditions throughout the corridor
- Inadequate and substandard signs
- Inefficient traffic flow progression

Primary intersection safety deficiencies include:

- Poor placement of signal heads (i.e. diagonal span configuration)
- Inadequate number of signal heads per through movement
- Incandescent overhead case signs
- Lack of backplates
- Poor intersection illumination
- Low visibility crosswalks
- Outdated pedestrian signal infrastructure
- Non-ADA compliant crossings
- Inefficient traffic flow progression

In concert with the existing safety deficiencies and existing crash patterns, significant safety components are designed into the Mound Road project to directly rectify safety deficiencies. Primary network wide safety improvements include:

- New concrete pavement with increased pavement friction performance
- Recessed durable pavement markings
- Improved lighting
- MUTCD conforming signs
- Improved traffic flow progression as a result of signal optimization, signal upgrades, connected vehicle technology, updated signage etc.
- Two new pedestrian bridges at strategic locations along the corridor
- Installation of FAST systems at four locations to apply deicing chemicals to the bridge decks

Primary intersection safety improvements include:

- Mast arm signal configuration with one signal head per lane
- 12" LED signal heads
- LED illuminated case signs
- Backplates
- Pedestrian countdown signals (audible)
- High-visibility crosswalks
- Improved traffic flow progression as a result of signal optimization, signal upgrades, connected vehicle technology etc.

3.2.2 Safety Benefits

Safety benefit calculations for the Mound Road project are based on the existing observed crash patterns with emphasis on the fatal and serious injury crashes, as well as consideration of the existing safety improvement opportunities along the network in direct correlation to the crash patterns. Due to the lack of localized safety performance functions (SPF) to aid in the identification of expected crashes per year, annualized baseline crash conditions are based on the annual average of the 2011-2015 crashes occurring along the network as obtained from the TIA TCAT data source. Per the BCA guidelines, annual crashes are quantified in terms of the number of individual injuries or non-injuries per incident, the breakdown of which is based on the KABCO scale.

Projected crash reductions for the baseline crash conditions were then estimated using crash modification factors (CMF) for each relevant and proven countermeasure. CMFs were obtained from the CMF clearinghouse portal as well as from the Michigan Department of Transportation's (MDOT) approved CMF list (13, 14). A total of 17 individual CMFs were identified based on the proposed safety treatments. These included a combination of network wide treatments, intersection specific treatments, as well as CMFs applicable to specific crash types, severities, and time of day.

Following the identification of the appropriate CMFs, several crash categories were defined to be able to apply the appropriate CMFs. The crash categories were identified in order to fulfill two basic requirements. First each identified crash category provides a direct match to at least one of the identified CMFs (i.e. nightime angle intersection crashes). Secondly, crash categories are isolated to eliminate double counting, meaning that a unique CMF value can be applied to a unique crash only once.

Given the significant number of safety improvements listed under this project, a minimum of 3 CMFs and up to a maximum of 10 CMFs were applicable for each crash category. The Highway Safety Manual (HSM) provides a method for combining multiple CMFs which allows for the multiplication of all applicable CMFs and assumes independence of each treatment (15, 16). While this particular method is acceptable, it requires engineering judgment as it can lead to implausible crash reduction factors. Consequently, this study limits the number of CMFs utilized in calculating the combined CMF value to three to provide a more realistic approach in estimating the crash reduction factor. The method can be expressed as:

$$CMF_t = (CMF_1 * CMF_2 * CMF_3)$$

Where, CMF_t = CMF for combined safety treatments

CMF_1 = CMF for first best safety treatment

CMF_2 = CMF for second best safety treatment

CMF_3 = CMF for third best safety treatment

Following the identification of the CMF for combined safety treatments, the predicted annual crash frequency reduction for each applicable category and severity is identified via the following:

$$N = N_{base} * (1 - CMF_t)$$

Where, N = predicted annual crash frequency reduction for a given crash category and severity

N_{base} = annual crash frequency for baseline conditions for a given crash category and severity

CMF_t = CMF for combined safety treatment

The predicted annual crash reductions for each crash category and severity were then multiplied by the respective monetized values provided in the BCA guidelines for crashes on the KABCO scale. A 1.5% growth factor is additionally applied to the baseline annualized crash frequency starting with base year 2016 and up to 2042. The 1.5% growth factor corresponds to the projected traffic growth rate, thus assumes a direct correlation between AADT and crashes. This assumption is deemed reasonable given that AADT values are one of the primary independent variables in an urban SPF for both segment and intersection locations. Similar to additional benefits associated with the operational timeline of the project, safety benefits initiate in 2023 and are quantified up until the end of the 20 year operational period in 2042.

The safety benefits resulting from the wide array of safety improvements indicate an average annual crash reduction of nearly 60%, with **Figure 10** illustrating annual crash reduction by crash severity in base year. This amounts to approximately:

- **$33,983,596** in annual average savings
- **$679,671,927** in total savings over the 20 year operational period of the analysis
- **$232,161,183** in total savings over the 20 year operational period of the analysis when discounted at 7%

One important item to note under the safety benefits is that it does not take into account safety benefits resulting from connected vehicle technology. This topic is discussed in more detailed under its applicable section.

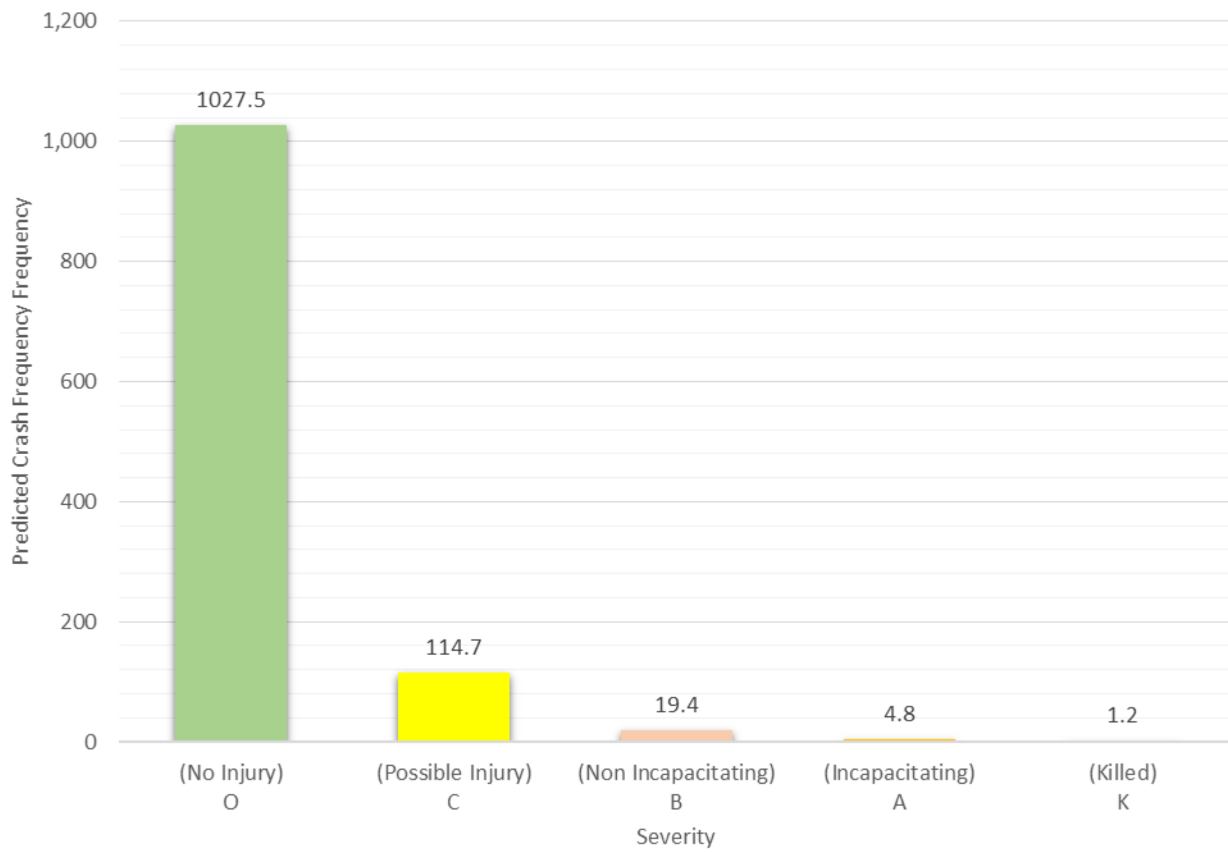


Figure 10: Predicted Annual Crash Frequency Reduction by Crash Severity in Baseline Year (2016)

3.3 Emission Reduction Benefits

Emission reductions in a transportation infrastructure improvement project arise primarily from improvements to the traffic flow such as fewer number of stops, reduced idle time, changes to average travel speeds etc. With respect to the latter, the amount of pollutants released in the atmosphere from the production and combustion of fuels generally follows a concave up curve with emission rates decreasing from low to mid-range speeds and increases again when traveling at higher speeds, with variation in the pattern among the various pollutants (17, 18).

The emission reduction benefits for the Mound Road project are expected to be primarily an outcome of the signal infrastructure upgrades and operational improvement elements (i.e. vehicle detection upgrades, signal timing improvements). Similar to the other benefits, emission reductions are expected from the deployment of connected vehicle technologies, however this impact is not accounted for in this section and instead is assessed in the connected vehicle section.

Emissions reduction benefits are calculated for Volatile Organic Compounds (VOCs), Nitrogen Oxide (NOx), Particulate Matter (PM), Carbon Monoxide (CO) and Carbon Dioxide (CO_2). The first four pollutants also represent the common emission types reported under the MDOT Congestion Mitigation and Air Quality (CMAQ) transportation related projects, while CO_2 is included to quantify benefits stemming from this more common greenhouse gas. Due to the calculation and valuation characteristics between the listed pollutants, two separate methods were implemented to assess the benefits resulting from emission reductions. These include emission reduction benefits from non-CO_2 (VOCs, NOx, PM, CO) pollutants and CO_2.

Emission reduction benefits from non-CO_2 pollutants are based on a micro-simulation analysis of the study area using the Synchro 9 and Simtraffic software based on 2015 intersection specific traffic volumes as well as on the MDOT CMAQ emission factors (6, 17). The MDOT CMAQ emission factors are equivalent values of a particular pollutant (i.e. VOCs, NOX, PM and CO) for the State of Michigan in relationship to the average vehicle speed in increments of 1 mph for a transportation project. Vehicle type and service life of the project are also variables considered in the utilization of the emission factors.

Based on this premise, existing conditions along the Mound Road corridor were replicated using Synchro 9. Several Simtraffic simulations were conducted on the network to obtain existing average vehicle speed for the no-build scenario. Existing average vehicle speeds were obtained for AM peak traffic, PM peak traffic, and Off peak traffic to account for traffic flow variations as well as different existing intersection signal timings applicable for each peak hour. Modifications to the existing models were than conducted to reflect the proposed infrastructure upgrades. These included modifications to the intersection signal operation modes and the modification of the 3-mile section between 17 Mile Road and M-59 from a 6-lane divided to an 8-lane divided roadway. Similarly to the existing conditions, several Simtraffic models were conducted for AM, PM and Off peak times to obtain expected average vehicle speeds for the build scenario.

The obtained average vehicle speeds for the no-build and the built scenarios were utilized in concert with the MDOT CMAQ emission factors and additional network variables using the following formula based on the SEMCOG emission assessment for freeways and arterial travel (19):

$$E_i = 365 * \frac{1}{C} * \sum [AADT_i * L_i * P_{n-i} * (EF_{B-i} - EF_{A-i})]$$

Where, E_i = Non-CO_2 emission reduction for segment i (metric ton or short ton/yr)

$AADT_i$ = 2015 Average Annual Daily Traffic of segment i

L_i = miles of arterial roadway affected for segment i

P_{n-i} = proportion of travel of segment i in peak period n, where n is either AM, PM, or OFF peak (based on 2015 data and is 0.15 for AM, 0.2 for PM, and 0.65 for OFF peak)

EF_{A-i} = emission factor after implementation for segment i (g/mi)

EF_{B-i} = emission factor before implementation for segment i (g/mi)

365 = number of days in an average year

C = variable for converting grams into either short ton (i.e. 1,101,500) or metric ton (i.e. 1,000,000)

The total reduction in emissions for the non-CO_2 pollutants (i.e. VOCs, NOx, PM, CO) were then summed to obtain the total annual emission reduction savings for the project versus the existing conditions and multiplied by the individual 2016 dollar amount provided in the BCA guidance for VOCs, NOx, PM, and the average expected U.S. cost for CO as provided by the Argonne National Lab (20). Because the traffic volume data used represents 2015 data, a 1.5% growth factor is initially applied to base year 2016. The 1.5% growth factor is then applied to each additional applicable year with benefits initiating in 2023 and assessed up until 2042.

In comparison, CO_2 emission reduction benefits are based upon the acceptable concept that the cost of CO_2 is non-linear and increases exponentially with time. Consequently each year has a different cost valuation (21). Prior to estimating the CO_2 emission reduction benefit however and similar to Non-CO_2 calculations, existing baseline conditions and projected conditions in relationship to the project were quantified. Similar to the Non-CO_2 emissions, CO_2 emission also exhibit a concave-up curve in relationship to speed, however MDOT does not provide equivalency factors for this pollutant. In lieu of this omission, CO_2 emissions are quantified based on the CO_2 emission – speed curve as presented by Barth and Boriboonsomsin, 2009 (18). Utilizing the average vehicle travel speeds obtained under the no build and built scenarios, the CO_2 emission benefits are quantified utilizing a similar formula as the prior pollutants:

$$E_i = 365 * \frac{1}{1{,}101{,}500} * \sum [AADT_i * L_i * P_{n-i} * (C_{B-i} - C_{A-i})]$$

Where, E_i = CO_2 emission reduction for segment i (short ton/yr)

$AADT_i$ = 2015 Average Annual Daily Traffic of segment i

L_i = miles of arterial roadway affected for segment i

P_{n-i} = proportion of travel of segment i in peak period n, where n is either AM, PM, or OFF peak (based on 2015 data and is 0.15 for AM, 0.2 for PM, and 0.65 for OFF peak)

C_{A-i} = CO_2 emission after implementation for segment i (g/mi), based on CO_2 emission-speed curve

C_{B-i} = CO_2 emission before implementation for segment i (g/mi), based on CO_2 emission-speed curve

365 = number of days in an average year

$1/1{,}101{,}500$ = conversion factor from grams to short ton

The total reduction in emissions for CO_2 are then summed to obtain the total annual emission reduction saving. Similar to non-CO_2 emissions, a 1.5% growth factor is initially applied to base year 2016 and each corresponding year following up until 2042. Corresponding CO_2 costs applicable for each of the analysis are obtained from the Spring Energy Economics 2016 national CO_2 price forecasts for mid-range predictions (21). These values are multiplied by the corresponding annual CO_2 saving quantities with benefits initiating in 2023 and up until 2042.

The emission reduction benefit analysis indicates an overall reduction of 11.7% for VOCs, 5.3% for NOx, 11.4% for PM, 5.9% for CO, and 4.2% for CO_2. The total emission reduction savings for both non-CO_2 and CO_2 pollutants resulting from the project indicate the following savings:

- **$776,214** in annual average savings
- **$15,524,275** in total savings over the 20 year operational period of the analysis
- **$5,136,765** in total savings over the 20 year operational period of the analysis when discounted at 7%

3.4 Vehicle Operating Cost Savings

Vehicle operating cost savings relate to costs associated with vehicle maintenance, depreciation, fuel consumption etc. This study uses fuel consumption to reflect these cost savings. In transportation improvement projects with no changes to segment lengths or mode variations, fuel consumption savings arise primarily from improvements to the traffic flow due to fewer stops, reduced idle time, or changes to travel speeds. With respect to the later, fuel consumption typically decreases when moving from low to mid-range speeds and increases when traveling at higher speeds.

Based on this premise fuel consumption savings for the Mound Road project are assessed as a function of the average travel speed along the corridor under a no-build and build scenario. The fuel consumption and speed relationship is based upon the fuel-speed function developed by Evans and Herman (1976, 1978) in the Detroit metropolitan area. This function which is applicable for low to mid-range speeds is expressed as (22, 23, 24):

$$F_i = \frac{k_1}{V_i} + k_2$$

Where, F_i = fuel consumption of segment i per unit distance (mL/km)

V_i = average travel speed of segment i (km/h)

k_1 = constant where k_1= 2,722 for medium cars (mL/h)

k_2 = constant where k_2= 85.1 for medium cars (mL/km)

In order to be utilize this relationship, the average vehicle travel speeds was obtained from Synchro 9 and Simtraffic simulations for both no-build and build scenarios, and based on 2015 intersection specific traffic volumes (6). Similar to the prior benefit calculations, average vehicle travel speeds were obtained for AM, PM, and Off peak times to account for variations in signal timings and traffic patterns. The obtained data allowed to quantify fuel consumption savings utilizing the following formula:

$$F_i = 365 * 0.000264172 * \sum [AADT_i * L_i * 1.60934 * P_{n-i} * (F_{B-i} - F_{A-i})]$$

Where, F_i = fuel consumption savings of segment i (gallons/yr)

$AADT_i$ = 2015 Average Annual Daily Traffic of segment i

L_i = miles of arterial roadway affected for segment i

P_{n-i} = proportion of travel of segment i in peak period n, where n is either AM, PM, or OFF peak (based on 2015 data and is 0.15 for AM, 0.2 for PM, and 0.65 for OFF peak)

F_{A-i} = fuel consumption after implementation of segment i (mL/km)

F_{B-i} = fuel consumption before implementation of segment i (mL/km)

365 = number of days in an average year

0.000264172 = conversion factor for mL to gallons

1.60934 = conversion factor for miles to km

The total fuel consumption savings for each segment are then summed to obtain a network wide fuel consumption saving rate and multiplied by the average cost of fuel as reported by the U.S. Energy Information Administration (EIA) for 2016 (25). A 1.5% growth factor is applied to base year 2016 and subsequent years since traffic volumes used are based on 2015 data. Obtained benefits are assessed for 20 year operations between 2023 and 2042. The fuel consumption benefit analysis indicates an overall n reduction of 5.6% along with the following savings:

- **$2,631,053** in annual average savings
- **$52,621,067** in total savings over the 20 year operational period of the analysis
- **$17,974,215** in total savings over the 20 year operational period of the analysis when discounted at 7%

3.5 ITS & Connected Vehicle Technology

Connected vehicles have the potential to fully revolutionize all elements of the transportation system by making use of innovations in technologies such as wireless communications, advanced vehicle-sensors, Global Positioning System (GPS) navigation and smart infrastructure. These advancements have the ability to safely reduce travel times, fuel consumption, emissions, and significantly improve safety for all road users (26, 27). At the core of these innovations is the ability of the vehicles to communicate with each other (V2V), with the infrastructure and vice versa (V2I). These continuous links between vehicles and vehicles and infrastructure allow vehicles to sense and communicate hazards along the roadway, affect traffic operations in real-time through dissemination of critical traffic flow information and consequently impact travel and environmental related elements.

3.5.1 Proposed CV Infrastructure

While V2V technology plays a critical role in attaining projected benefits, only V2I technologies included in this project are considered in quantifying benefits as a result of the Mound Road project. Currently the project includes both segment and intersection ITS and connected vehicle technologies to support the deployment and operations of a future next-generation connected vehicle fleet. Intersection related ITS and connected vehicle infrastructure includes:

- ITS cabinet and controller with battery back-up
- Video surveillance capabilities through closed-circuit televisions
- Performance measures and PCD modules and customizations
- Video analytics program running in concert with Oculairs to assist in incident management
- Work zone ITS/connected vehicle technology to enhance safety and improve mobility during construction
- Dilemma zone detection equipment at all of the intersections for the Mound Road approaches
- EDI data aggregator to provide cost effective remote access to real-time traffic data and corresponding MOE for various data points from any isolated or network intersection or arterial roadway.

To fully support future advancements and innovations in roadway safety and operations, segment related connected vehicle technology will be deployed throughout the corridor. This includes the installation of approximately 50 RSU's at strategic locations along all of the nine miles of Mound Road. To make immediate use of the RSUs, up to 50 on-board connected vehicle units will be made available for emergency response vehicles or public transit vehicles. Communications for the technology will be supported via the installation of 12 total miles of fiber optic communication cabling installed along the network. One environmental remote sensing unit as well as additional FAST units will also be installed on the bridge decks crossing four separate drains to support and supplement winter maintenance operations by monitoring winter weather conditions and preventing snow and ice build-ups on the surface.

The project is also committed to furthering innovations in connected vehicle applications. Consequently, the project intends to leverage the capabilities of the automotive manufacturing centers and facilities located along the corridor to develop and test connected vehicle applications with OEMs.

All of the ITS and connected vehicle technologies proposed for the Mound Road project are in line with and help further the American Association of State Highway and Transportation Officials (AASHTO) Connected Vehicle Deployment Coalition vision to establish a mature connected vehicle environment by 2040 (26).

3.5.2 General CV Assumptions

ITS and connected vehicles have the potential to significantly reduce travel times, emissions, fuel consumption and improve safety. These benefits are primarily associated with the applications developed and supported by such technologies (26, 27). Only those benefits resulting from potential applications which are feasible under the project's proposed V2I infrastructure are considered under this project. Before a discussion of the methodologies used and expected benefits is undertaken however, it should be noted that all benefits stemming from connected vehicle technologies are directly related to the proportion of the connected vehicle fleet on the roadway.

According to NHTSA, vehicles embedded with Dedicated Short Range Communication (DSRC) capabilities to facilitate communication between V2V and V2I are expected to be deployed as soon as 2020 (26). From there on, U.S. DOT and AASHTO have established three separate deployment models (aggressive, moderate and conservative) which predict the market penetration rate of the connected vehicle fleet on the roadway. **Figure 11** illustrates these three models as presented by the two agencies (26).

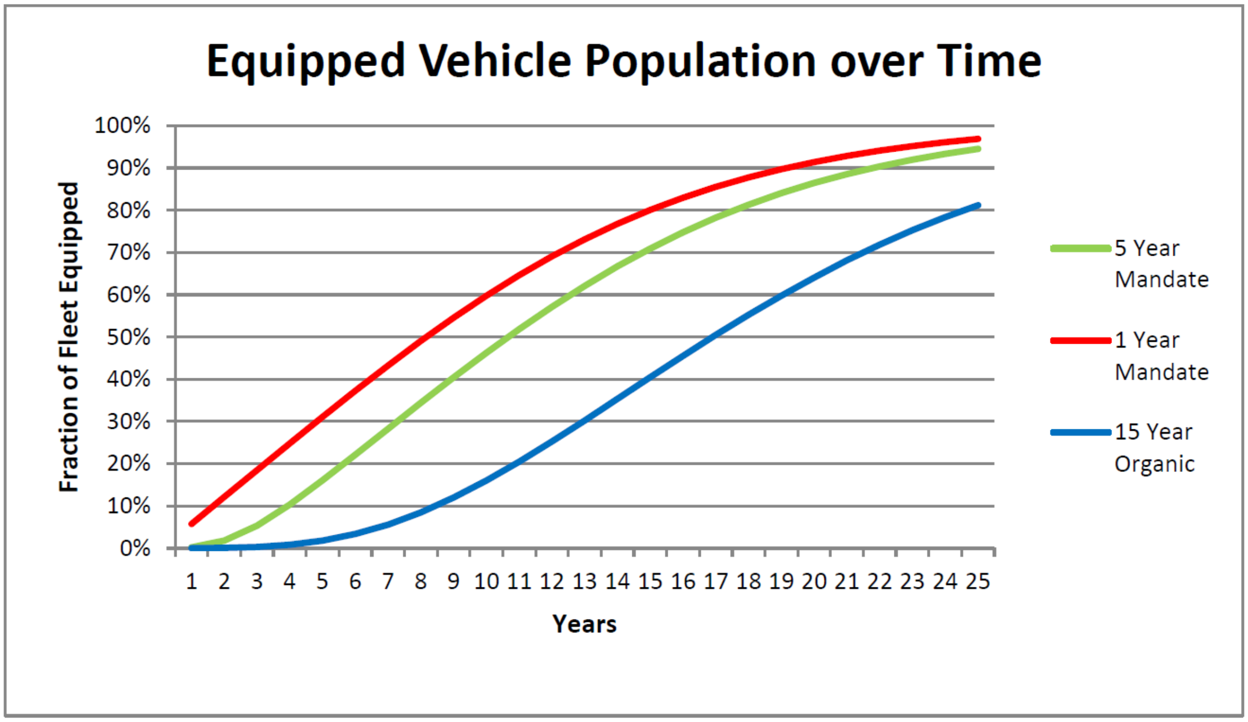


Figure 11: Connected Vehicle Population over Time (26).

The MCDR which maintains the traffic signals along the Mound Road corridor in addition to 1,700 miles of roadway and over 900 traffic signals in the region, is at the forefront of connected vehicle technology infrastructure deployment (V2I) in the state of Michigan. The agency has already deployed DSRC units at strategic locations along main corridors within the County and has plans to systematically integrate its roadway network ahead of most regions in the United States. Recently the agency also partnered with MDOT and GM's Research & Development Center to test and demonstrate successfully V2I capabilities on the Cadillac CTS sedan by sending real-time data using the deployed DSRC units which alerted drivers of potential red light violations at their current speed. These vehicles which are equipped with V2I and V2V technologies can already be found throughout the region's roadway network. **Appendix C** presents a memo from MCDR on its initiatives and successes with deployment and testing of connected vehicle technology in the County.

Given the aggressive timeline which MCDR has established for full scale deployment of V2I technologies within the County, and the availability of V2I and V2V technologies on existing vehicle models, this BCA utilizes the aggressive deployment model (i.e. 1 Year Mandate) in estimating the market penetration rate of connected vehicles for the Mound Road project. The 1 Year Mandate is based on a scenario where car manufactures phase in connected vehicle equipment in all of the new vehicles following a given model year. Under this scenario a 95% connected vehicle fleet deployment is reached by year 2042. This year also corresponds to the last year in the BCA analysis period. The 1 Year Mandate connected vehicle population curve forms the basis of all Mound Road connected vehicle benefits. Under this premise only the proportion of vehicles equipped with connected vehicle technologies can realize those benefits in a particular year.

Secondly, connected vehicle benefits are assumed linearly related to the connected vehicle deployment curve. This means that the full projected benefit is realized only when 100% of the vehicles are equipped with connected vehicle technology. This assumption, which is consistent with applicable research on this topic (27, 28, 29), is expressed as:

$$B_i = \frac{P_i * B_{max}}{P_{max}}$$

Where, B_i = connected vehicle benefit for market penetration rate at year i (Mobility, Safety, Emission, Fuel)

P_i = connected vehicle market penetration rate at year i

B_{max} = maximum potential connected vehicle benefit (Mobility, Safety, Emission, Fuel)

P_{max} = maximum connected vehicle market penetration rate (100%)

3.5.3 CV Benefits

ITS and connected vehicle benefits are assessed in terms of reductions in travel times, emissions, fuel consumption, and improvements in safety. With regards to reductions in travel times, the benefits are expected to be a result of the combination of intelligent traffic signal systems, freight signal priorities, and emergency vehicle preemption which optimizes traffic flow operations through the intersections based on real-time information as well as prioritizing freight and emergency vehicle movements (27). Research on this topic indicates a potential reduction in travel times of 25% at a 100% market penetration rate along an urban network (28). Based on this rate and utilizing existing travel times along the Mound Road corridor obtained as indicated in the prior benefit sections, the connected vehicle mobility benefit was assessed using the following method:

$$T_{v-i} = P_i * B_i * T^e_{v-i}$$

Where, T_{v-i} = annual Total Travel time savings at year i per vehicle type v in hours, where v is either passenger, bus or truck

P_i = connected vehicle market penetration rate at year i (%)

B_i = connected vehicle mobility benefit at year i (%)

T^e_{v-i}= total existing corridor travel time at year i per vehicle type v in hours, where v is either passenger, bus or truck

Emission benefits resulting from connected vehicle technology are assessed in a similar manner as travel times, and are based on expected reductions in emissions of 10.89% for VOCs, 15.51% for NOx, 19.09% for PM, 13.23% for CO, and 6.55% for CO_2 (29). These benefits are an outcome of eco-signal operations (i.e. eco-approach/departure at signalized intersections, eco-traffic signal priority, connected eco-driving, and eco-traffic signal timing) which reduce idle time, the number of stops, and increase traffic flow efficiency along the corridor (27). Given these findings, the connected vehicle emission benefit is then assessed as follows:

$$E_{p-i} = P_i * B_{p-i} * E^e_{p-i}$$

Where, E_{p-i} = annual Emission savings at year i per pollutant p in short ton or metric ton, where p is either VOC, NOx, PM, CO, and CO_2

P_i = connected vehicle market penetration rate at year i (%)

B_{p-i} = connected vehicle emission benefit at year i per pollutant p, where p is either VOC, NOx, PM, CO, and CO_2 (%)

E^e_{p-i} = total existing corridor emissions at year i per pollutant p in short ton or metric ton, where p is either VOC, NOx, PM, CO, and CO_2

Fuel consumptions savings from connected vehicle technology are a result of similar eco-signal operations as those listed under the emissions benefits (27). At 100% market penetration rate, connected vehicle technologies are expected to reduce fuel consumption along a coordinate urban network by 13% (27). Akin to the emission benefits, fuel consumption savings from connected vehicle technology can be expressed as:

$$F_i = P_i * B_i * F_i^e$$

Where, F_i = annual Fuel Consumption savings at year i in gallons

P_i = connected vehicle market penetration rate at year i (%)

B_i = connected vehicle fuel consumption benefit at year i (%)

F_i^e = total existing corridor fuel consumption at year i in gallons

Lastly, safety benefits from connected vehicle technology are a result of applications which provide information and alert vehicles of upcoming hazards or events along the corridor and at intersections (27). According to NHTSA, connected vehicle technology can positively impact up to 80% of non-impaired crashes in both mid-blocks and intersections (30). Using this crash reduction rate as baseline and applying it only to non-impacted crashes from the prior safety benefits, safety benefits from connected vehicle technology can be expressed as:

$$S_{j-i} = P_i * B_i * S_{j-i}^e$$

Where, S_{j-i}= annual Safety benefits at year i in gallons per injury type j, where j is either no injury, injury type C, injury type B, injury type A, or Fatal

P_i = connected vehicle market penetration rate at year i (%)

B_i = connected vehicle safety benefit at year i (%)

S_{j-i}^e = total existing corridor un-impacted and non-impaired crashes at year i per injury type j, where j is either no injury, injury type C, injury type B, injury type A, or Fatal

Following the calculations of travel time savings by vehicle type, emission savings by pollutant type, fuel consumption savings, and safety benefits by injury type, each year of data was multiplied by the applicable dollar amount of each category and summed to obtain the total savings from the connected vehicle technology as a result of infrastructure improvements proposed for the Mound Road project. **Table 7** presents the projected benefits resulting from connected vehicle technology.

Table 7: Mound Road Connected Vehicle Technology Benefits

Benefit Category	Annual Average ($2016)	Total ($2016)	Total Discounted at 7%
Travel Time	$40,264,099	$805,281,976	$218,846,696
Emission	$793,294	$15,865,889	$4,229,470
Fuel	$3,245,978	$64,919,566	$17,642,805
Safety	$9,063,053	$181,261,066	$49,260,242
Total Connected Vehicle Benefits	**$53,366,425**	**$1,067,328,498**	**$289,979,213**

3.6 Additional Benefit Discussion

This section is presented to provide a qualitative discussion on those aspects of the project which are not easily quantifiable but which are believed to have a positive impact on the region and the users of the facility. The qualitative discussion covers both economic related benefits and quality of life benefits. These are associated to overall project improvements and in particular to the pavement reconstruction, the proposed bridges and non-motorized user pathways, truck priority and emergency preemption systems, and ITS.

With regards to the pavement reconstruction, in addition to the safety impacts which have been accounted for under the safety benefits, the existing distressed and deteriorated pavement condition which apply to the entire corridor also has a significant impact on vehicle maintenance, noise, freight and business retention and attraction. A review of existing PASER ratings along the corridor indicate that entire project area is either in poor or fair conditions (**Figure 12**). The worst pavement conditions are found north of Metro Parkway (16 Mile Road), along the northbound direction between 14 Mile Road and Metro Parkway, as well as south of 12 mile road. **Figure 13** presents an image indicating typical pavement conditions along the corridor. These conditions are generally exacerbated following the winter season due to aggressive freeze-thaw cycles which are typical of Michigan's climatic environment.

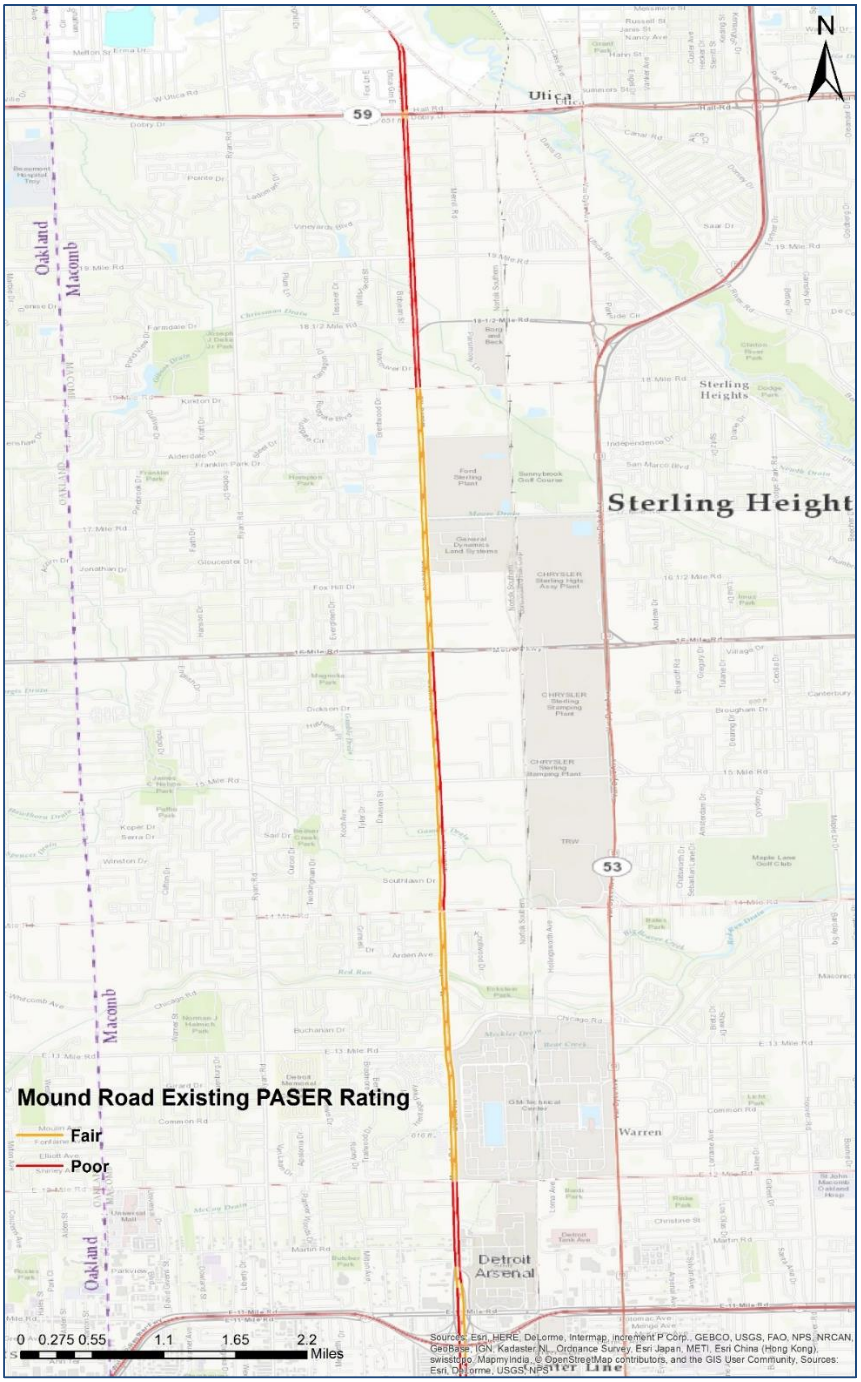


Figure 12: Mound Road Existing PASER Rating

Figure 13: Typical Pavement Conditions along Mound Road (15 Mile Road to Metroparkway)

These excessive poor pavement conditions can have significant detrimental impacts not only on safety but also vehicle maintenance, noise, freight, and business retention and creation. With regards to vehicle maintenance, the correlation between deteriorated pavement condition and vehicle operating costs is well documented (31). A 2012 study by the National Cooperative Highway Research Program (NCHRP) on pavement conditions and its impacts found that a decrease in pavement roughness is directly associated with reductions in fuel consumptions, reductions in tire wear, and reductions in vehicle maintenance and repair. The study estimates that a decrease in pavement roughness of 63.5 in/mi can result in a total of $24 billion in fuel savings, $340 million in tire wear savings, and $24.5 billion to $73.5 billion per year in repair and maintenance costs among the 255 million vehicles in the US for both passenger vehicles and in particular trucks (31). Given the high AADT and in particular the number of trucks which service the large manufacturing facilities along the corridor, improvements in pavement conditions can not only result in significant savings in fuel consumptions, tire wear, and vehicle maintenance and repairs for the users, but also increase efficiency for the vital employment centers located along Mound Road.

Similar to vehicle maintenance costs, pavement conditions also impact noise levels along the corridor. In general, noise can be defined as undesirable or excessive sound which impacts everyday essential activities, where at the higher extreme end exposure can also result in irreparable damage. While most of the noise resulting from a typical roadway is inevitable, as the pavement deteriorates the noise from the friction between the tires and pavement will get louder as the pavement texture becomes rougher and less flat. While difficult to quantify, it is not improbable to assume that the replacement of the existing pavement can lead to lower noise levels and improved quality of life in particular for the residents and noise sensitive facilities located in proximity to the corridor.

Most importantly, and in particular given that Mound Road acts as a primary corridor for several commercial and manufacturing facilities of national importance, the poor and deteriorating pavements conditions can have a detrimental impact on freight movement through the corridor as well as business retention and creation. According to a 2010 study on Michigan’s Roads commissioned by the Michigan Chamber of Commerce the cost of not fully funding infrastructure projects in the state can result in approximately 12,000 lost jobs, while the opposite would result in 15,000 created jobs (32). Similar correlations between good infrastructure conditions and business retention and creation can also be found in additional studies. A report by the Oregon Department of Transportation on

Oregon's road conditions indicated that declining pavement and bridge conditions could reduce the state's future economic growth, result in an estimated 100,000 future lost jobs, and a loss of $94 billion in the state's gross domestic product (GDP) as a result of the higher transportation costs stemming from inadequate road and bridge conditions. The same study noted that deteriorating road conditions will reduce the ability of firms in the state to compete in the global market due to higher user costs and business accessibility, higher truck operating costs and reduced market accessibility and economic competitiveness (33). With regards to truck movements, research on the economic costs of pavement deterioration notes that "at some point truckers will drive a less direct route or choose congestion over a lack of safety and road quality. If the highway is in extremely poor conditions and creates a perceived safety hazard or requires substantially slower speeds to traverse, truck drivers will avoid the roadway" (34).

The above examples stress the importance of roadways in good state of work. This is particularly important for the Mound Road corridor which in addition to being part of the NHS and is the longest non-freeway segment included in the NHFP, also serves as a significant industrial corridor. It is important to reiterate that Mound Road acts as the primary transportation route for several national automotive, aerospace, defense and advanced manufacturing companies including the GM Technical Center, the Ford Axle Plan and Transmission Plant, the FCA Stamping Plant and Assembly Plant, BAE Systems, and the U.S. Army's TACOM and TARDEC facilities, all of which rely on efficient freight movement. In addition the corridor has a direct employment total of 20,200 people which support another 17,720 jobs within the County and another 98,100 jobs in the Michigan economy (2). Thus, given the documented impact which road conditions can have upon the economy, an improved Mound Road corridor in a good state can have long lasting economic impacts on the local, regional, and potentially national economy. The truck priority system proposed under this project aims to further increase economic output along the region, make the corridor more efficient and attractive to freight movement, and help support the many industries located along the corridor.

In concert with the existing deteriorated pavement conditions the project also recognizes the impact which work zones have on the transportation network. Currently, the Mound Road corridor requires annual and extended work zones in order to maintain the pavement in minimal serviceable conditions. The reconstruction of the pavement would eliminate the need for long-term annual work zones thus significantly reducing user delay costs along the corridor. In addition, the project proposes the implementation of work zone ITS technologies in particular to improve safety and alleviate user delays associated with the construction of the project. Examples include ITS technologies for traffic monitoring and management and provide up-to date traveler information in advance of the work zones.

Lastly, the Mound Road project recognizes that an efficient transportation network must adequately service all users of the facility including non-motorized users. Consequently, in addition to the pedestrian improvements at intersections along the corridor (i.e. ADA compliant crossings, high-visibility crossable and audible pedestrian countdown signals) the project includes two new grade separate pedestrian crossings as well as the installation of non-motorized multi-use paths to improve non-motorized user safety, mobility, and promote regional trails. The first of the two bridges is proposed to be located on the south end of the corridor near 13 Mile Road, while the second bridge is to be located near Metro Parkway to provide a direct connection to the Macomb County Freedom Trail and improve access to the Iron Belle Trail. The Iron Belle Trail is a 1,273 miles long trail which runs from Detroit to the Michigan/Wisconsin border (refer to **Figure 5** for the location of Mound Road with respect to the Iron Bell Trail).

In addition both bridges and non-motorized user path improvements significantly increase mobility across the corridor over existing conditions. These benefits are aimed at both the commercial/industrial facilities and the residential neighborhoods located on both sides of Mound Road. The improved mobility is expected to promote and provide safe crossings for the employees on one side of the corridor who intend to utilize commercial/industrial facilities on the opposite side of Mound Road. Similarly, the increased mobility and connectivity is expected to further community integration and improve quality of life between the residential neighborhoods which are currently separate by an 8-lane divided roadway.

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4.0 Costs

The cost chapter represents a discussion of the analysis conducted for those items which represent a cost to the project. These discussions intend to supplement and reflect the analysis conducted in the attached BCA spreadsheets (see **Appendix A** for more information). The primary items under the costs analysis include an assessment of:

- Capital Expenditures
- Operating & Maintenance Expenditures

4.1 Capital Expenditures

Capital expenditures refer to those costs which are necessary for the full realization of the Mound Road project. The project has a total budget of $216,860,000. This includes the full construction cost of the project along with necessary engineering and construction contingencies. **Table 8** presents a full itemized breakdown of the Mound Road project costs.

Table 8: Mound Road Project Costs

Budget Item	Amount ($2016)	% of Budget
Mobilization	$ 10,000,000	4.6%
Earthwork	$ 13,000,000	6.0%
Pavement Base	$ 20,000,000	9.2%
Drainage	$ 15,000,000	6.9%
Curb & Gutter and Driveways	$ 4,500,000	2.1%
Concrete Pavement	$ 46,000,000	21.2%
Temporary Traffic Control	$ 7,000,000	3.2%
Restoration & Landscaping	$ 4,500,000	2.1%
Non-Motorized Multi-Use Path	$ 2,100,000	1.0%
Pedestrian Bridge (2 locations)	$ 10,000,000	4.6%
Signal Modernizations	$ 11,300,000	5.2%
Connected Vehicle Technology	$ 1,500,000	0.7%
Fiber Optic Communication	$ 1,200,000	0.6%
ITS Technology	$ 1,800,000	0.8%
FAST with Weather Station	$ 1,300,000	0.6%
Electrical and Lighting	$ 1,200,000	0.6%
Traffic Signs	$ 4,000,000	1.8%
Permanent Pavement Markings	$ 500,000	0.2%
Construction Costs	**$ 154,900,000**	**71.4%**
Contingencies @ 15% of Construction Costs	**$ 23,235,000**	**10.7%**
Engineering @ 13% of Construction Costs	**$ 20,137,000**	**9.3%**
Construction Engineering @ 12% of Construction Costs	**$ 18,588,000**	**8.6%**
Total Project Costs	**$ 216,860,000**	**100%**

The full project cost of $216,860,000 is expected to be distributed evenly between the three-year construction period of 2020 and 2022 with approximately $72,286,667 per year. In addition, the project consists of an additional $100,000 in expenditures which represent costs accrued in 2017 as part of the planning efforts and pre-construction costs needed to develop the Mound Road project. In total, the Mound Road project costs needed to fully realize the listed benefits amount to a total of $154,947,662 when discounted at 7%.

4.2 Operating & Maintenance Expenditures

According to the Macomb County Department of Roads, the County spends approximately a total of $4,930,00 in annual maintenance for the Mound Road corridor to maintain the roadway in serviceable conditions. $4,600,000 of these are costs incurred on concrete replacement, and $330,000 are costs incurred for monitoring the corridor for major pavement deficiencies such as significant cracking or potholes. A 2.5% increase in maintenance costs is applied to each subsequent year following 2016 to account for the increasing maintenance needs due to continuous pavement deterioration and omission of any significant reconstruction activities from the corridor.

The Mound Road project includes the complete reconstruction of the corridor with high performance P1 Modified PCC pavement. Characteristics of this pavement include increased durability, workability, stress strength, superior roadway friction, low life-cycle cost, and 30 year minimum service life. A deterioration curve was developed based on these pavement characteristics. The curve indicates a drop of approximately 40% over 75% (i.e. 22.5 years) of the pavement conditions life. Utilizing this information along with recommended concrete treatments and associated costs based on pavement PASER ratings (**Table 9**), the maintenance costs for the build scenario were developed.

Table 9: Recommended Concrete Treatments and Associated Costs

PASER Rating	Condition	Treatment	Cost per Lane Mile	No. of Years
9 & 10	Excellent	No maintenance required	$ 0	1 - 8
7 & 8	Very Good	Routine maintenance	$ 2,000	9 - 18
5 & 6	Fair - Good	Surface repairs, sealing, partial depth cracking	$ 250,000	19 - 24
3 & 4	Poor - Fair	Extensive slab or joint replacement	$ 600,000	25 - 29
1 & 2	Failed	Reconstruction	$ 1,900,000	30

Overall total costs under the no-build scenario amount to a total of $149,697,333 over the 20 year period between 2023 to 2042. Total costs under the build scenario for the same 20 year period amount to a total of $18,224,000. This results in:

- **$6,573,667** in annual average savings
- **$131,473,333** in total savings over the 20 year operational period of the analysis
- **$46,556,394** in total savings over the 20 year operational period of the analysis when discounted at 7%

5.0 Results of Benefit-Cost Analysis

The Mound Road benefit-cost analysis presented an analysis of the following benefits and costs:

- Travel Time Savings
- Safety Benefits
- Emission Reduction Benefits
- Vehicle Operating Cost Savings
- ITS & Connected Vehicle Technology Savings
- Capital Expenditures
- Operating & Maintenance Expenditures

Table 10 summarizes the obtained benefit-cost results for all of the above items.

Table 10: Mound Road Benefit-Cost Analysis Results

BCA Category	Total ($2016)		Total Discounted at 7%	
Travel Time Savings	$	834,197,659	$	284,943,820
Safety Benefits	$	679,671,927	$	232,161,183
Emission Reduction Benefits	$	15,524,275	$	5,136,765
Vehicle Operating Cost Savings	$	52,621,067	$	17,974,215
ITS & Connected Vehicle Technology Savings	$	1,067,328,498	$	289,979,213
Capital Expenditures	$	(216,960,000)	$	(154,947,662)
Operating & Maintenance Expenditures	$	131,473,333	$	46,556,394
NPV at 7%			**$**	**721,803,927**
BCR			**5.66**	

The results of the BCA for the Mound Road project indicate a Net Present Value (NPV) discounted at 7% of $721,803,927. This corresponds to a Benefit-Cost Ratio (BCR) of 5.66.

The BCA analysis indicates that the project yields a return on investment which far surpasses the total project cost.

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Appendix A – Benefit-Cost Analysis (BCA) Spreadsheet

The contents of Appendix A – Benefit Cost Analysis (BCA) Spreadsheet are provided electronically as well.

The following is a guide to the contents of the BCA Spreadsheet:

Tab 1. Summary Matrix
- ❖ Summary of key components of the BCA.

Tab 2. BCA Results
- ❖ BCA results including 7% discounted NPV and BCR values.

Tab 3. TOTAL Travel Time
- ❖ Results of travel time savings analysis.

Tab 4. Travel Time – Calc
- ❖ Travel time saving calculations for no-build and build scenario using 2015 traffic data. Output represents 2015 travel time savings in hours.

Tab 5. Travel Time – Value
- ❖ Standard travel time values (cost per unit of travel time and average occupancy rates).

Tab 6. TOTAL Safety Benefits
- ❖ Results of safety benefits analysis.

Tab 7. Safety Benefits – Calc
- ❖ Crash reduction calculations for build scenario using 2011-2015 annualized crash data. Output represents 2015 crash reductions.

Tab 8. CMF – Values
- ❖ Crash Modification Factors utilized in the analysis of the safety benefits.

Tab 9. KABCO Level – Values
- ❖ Standard KABCO level values (cost per level of injury).

Tab 10. TOTAL Emissions
- ❖ Results of emissions savings analysis (VOC, NOx, PM, CO, CO_2).

Tab 11. Emissions – Calc (Non-CO2)
- ❖ Emission saving calculations for VOC, NOx, PM, and CO for no-build and build scenario using 2015 traffic data. Output represents 2015 emission savings in short ton or metric ton.

Tab 12. Emissions – Calc (CO2)
- ❖ Emission saving calculations for CO_2 for no-build and build scenario using 2015 traffic data. Output represents 2015 CO_2 emission savings in short ton.

Tab 13. Emissions – Values
- ❖ Standard emission values (cost per unit of emission for VOC, NOx, PM, CO, and CO_2).

Tab 14. TOTAL Fuel Savings
- ❖ Results of fuel savings analysis.

Tab 15. Fuel Savings – Calc
- ❖ Fuel saving calculations for no-build and build scenario using 2015 traffic data. Output represents 2015 fuel savings in gallons.

Tab 16. Fuel Savings – Values
- ❖ Standard fuel values (value of gasoline price).

Tab 17. ITS & Connected Veh Savings
- ❖ Analysis and results of ITS/Connected Vehicle savings for build scenario.

Tab 18. ITS & Connected Veh – Back Calc
- ❖ ITS/connected vehicle related calculations for no-build scenario. Output represents 2015 existing conditions in terms of travel time, emissions, fuel, and safety.

Tab 19. Operations & Maintenance Costs
- ❖ Analysis and results of operation & maintenance for no-build and build scenario.

Tab 20. Inflation Adjustment – Values
- ❖ Inflation adjustments rates

Current Status/Baseline & Problem to be Addressed	Change to Baseline	Type of Impacts	Population Affected by Impacts
Deteriorated pavement and infrastructure conditions which have exceeded service life	Reconstruction with high performance concrete pavement (P1 Modified); New drainage; Curb & gutter; Driveways; Restoration & landscaping	Lower operations & maintenance costs; Increased safety from improved pavement friction; Noise reduction; Lower vehicle maintenance costs; Infrastructure conducive to business retention and attraction	All existing users of the facility
Inefficient traffic flow progression; Substandard signal design; Congestion from capacity constraints in the northern end of the corridor	Signal optimization and modernizations; Widening of the roadway between 17 Mile to M-59; Connected Vehicle Technology; Fiber Optic Communications; ITS Technology, FAST system and weather station	Travel Time Savings for passenger vehicles, public transportation, freight, and emergency vehicles; Emission reductions for a wide array of pollutants; Fuel savings; Significant expected crash reductions; Infrastructure conducive to business retention and attraction	All existing users of the facility
Non-MUTCD conforming signing	MUTCD conforming traffic signs	Expected crash reductions	All existing users of the facility
Limited non-motorized user mobility and connectivity	Non-motorized multi-use paths; Two pedestrian bridges	Increase safety, mobility, access & connectivity for non-motorized users; Community integration; Infrastructure conducive to business retention and attraction	All existing users of the facility
Low visibility at night	Energy efficient unified lighting	Increase safety; Lower energy consumption	All existing users of the facility
Overall infrastructure conditions which do not reflect business and employment needs and characteristics of the corridor	ITS and Connected Vehicle Technologies throughout the entire corridor	Travel time savings; Significant safety benefits; Emission reduction; Fuel consumption reduction; Infrastructure conducive to business retention and attraction; Advancement of Connected Vehicle Technology applications and goals	All existing users of the facility

Calendar Year	Project Year	Construction Costs ($2016)	Discounted Construction Costs at 7%	Value of Travel Time Savings ($2016)	Discounted Travel Time Savings at 7%	Safety Benefits ($2016)	Discounted Safety Benefits at 7%	Emissions Savings ($2016)	Discounted Emissions Savings at 7%
2016	na	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2017	Planning	$ (100,000)	$ (93,458)	$ -	$ -	$ -	$ -	$ -	$ -
2018	na	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	na	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
(Beg Construction) 2020	Construction	$ (72,286,667)	$ (55,147,152)	$ -	$ -	$ -	$ -	$ -	$ -
2021	Construction	$ (72,286,667)	$ (51,539,394)	$ -	$ -	$ -	$ -	$ -	$ -
(End Construction) 2022	Construction	$ (72,286,667)	$ (48,167,658)	$ -	$ -	$ -	$ -	$ -	$ -
2023	1	$ -	$ -	$ 36,075,492	$ 22,466,003	$ 29,392,913	$ 18,304,429	$ 599,078	$ 373,076
2024	2	$ -	$ -	$ 36,616,624	$ 21,311,209	$ 29,833,806	$ 17,363,547	$ 611,309	$ 355,788
2025	3	$ -	$ -	$ 37,165,873	$ 20,215,773	$ 30,281,313	$ 16,471,028	$ 623,773	$ 339,291
2026	4	$ -	$ -	$ 37,723,361	$ 19,176,644	$ 30,735,533	$ 15,624,387	$ 636,473	$ 323,551
2027	5	$ -	$ -	$ 38,289,212	$ 18,190,929	$ 31,196,566	$ 14,821,264	$ 649,414	$ 308,532
2028	6	$ -	$ -	$ 38,863,550	$ 17,255,881	$ 31,664,515	$ 14,059,423	$ 662,599	$ 294,202
2029	7	$ -	$ -	$ 39,446,503	$ 16,368,896	$ 32,139,482	$ 13,336,743	$ 676,034	$ 280,530
2030	8	$ -	$ -	$ 40,038,201	$ 15,527,505	$ 32,621,575	$ 12,651,209	$ 689,723	$ 267,487
2031	9	$ -	$ -	$ 40,638,774	$ 14,729,362	$ 33,110,898	$ 12,000,913	$ 714,476	$ 258,959
2032	10	$ -	$ -	$ 41,248,356	$ 13,972,245	$ 33,607,562	$ 11,384,044	$ 739,816	$ 250,601
2033	11	$ -	$ -	$ 41,867,081	$ 13,254,046	$ 34,111,675	$ 10,798,883	$ 765,756	$ 242,419
2034	12	$ -	$ -	$ 42,495,087	$ 12,572,763	$ 34,623,350	$ 10,243,800	$ 792,307	$ 234,415
2035	13	$ -	$ -	$ 43,132,513	$ 11,926,499	$ 35,142,700	$ 9,717,250	$ 819,483	$ 226,594
2036	14	$ -	$ -	$ 43,779,501	$ 11,313,455	$ 35,669,841	$ 9,217,765	$ 847,296	$ 218,957
2037	15	$ -	$ -	$ 44,436,194	$ 10,731,922	$ 36,204,889	$ 8,743,954	$ 875,758	$ 211,507
2038	16	$ -	$ -	$ 45,102,736	$ 10,180,281	$ 36,747,962	$ 8,294,499	$ 904,884	$ 204,244
2039	17	$ -	$ -	$ 45,779,278	$ 9,656,996	$ 37,299,181	$ 7,868,146	$ 934,687	$ 197,169
2040	18	$ -	$ -	$ 46,465,967	$ 9,160,608	$ 37,858,669	$ 7,463,709	$ 965,180	$ 190,282
2041	19	$ -	$ -	$ 47,162,956	$ 8,689,736	$ 38,426,549	$ 7,080,060	$ 993,591	$ 183,068
2042	20	$ -	$ -	$ 47,870,401	$ 8,243,067	$ 39,002,947	$ 6,716,132	$ 1,022,637	$ 176,093
TOTALS			**$ (154,947,662)**		**$ 284,943,820**		**$ 232,161,183**		**$ 5,136,765**

Calendar Year	Project Year	Fuel Savings ($2016)	Discounted Fuel Savings at 7%	Operation and Maintenance Costs Savings ($2016)	Discounted Operation and Maintenance at 7%	ITS/Connected Vehicle Savings ($2016)	ITS/Connected Vehicle Savings at 7%	NPV at 7%
2016	na	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2017	Planning	$ -	$ -	$ -	$ -	$ -	$ -	$ (93,458)
2018	na	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2019	na	$ -	$ -	$ -	$ -	$ -	$ -	$ -
(Beg Construction) 2020	Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ (55,147,152)
2021	Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ (51,539,394)
(End Construction) 2022	Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ (48,167,658)
2023	1	$ 2,275,637	$ 1,417,152	$ 5,860,221	$ 3,649,451	$ 4,181,088	$ 2,603,771	$ 48,813,882
2024	2	$ 2,309,771	$ 1,344,308	$ 6,006,726	$ 3,495,969	$ 7,374,443	$ 4,291,993	$ 48,162,813
2025	3	$ 2,344,418	$ 1,275,208	$ 6,156,894	$ 3,348,943	$ 10,903,315	$ 5,930,681	$ 47,580,924
2026	4	$ 2,379,584	$ 1,209,660	$ 6,310,817	$ 3,208,099	$ 15,187,261	$ 7,720,434	$ 47,262,774
2027	5	$ 2,415,278	$ 1,147,481	$ 6,468,587	$ 3,073,179	$ 20,258,008	$ 9,624,434	$ 47,165,818
2028	6	$ 2,451,507	$ 1,088,498	$ 6,630,302	$ 2,943,933	$ 25,170,798	$ 11,176,135	$ 46,818,073
2029	7	$ 2,488,280	$ 1,032,548	$ 6,796,059	$ 2,820,123	$ 30,699,357	$ 12,739,142	$ 46,577,982
2030	8	$ 2,525,604	$ 979,473	$ 6,965,961	$ 2,701,520	$ 36,868,224	$ 14,298,133	$ 46,425,326
2031	9	$ 2,563,488	$ 929,126	$ 7,006,110	$ 2,539,337	$ 43,709,656	$ 15,842,391	$ 46,300,088
2032	10	$ 2,601,940	$ 881,367	$ 7,184,613	$ 2,433,677	$ 49,831,437	$ 16,879,632	$ 45,801,566
2033	11	$ 2,640,969	$ 836,063	$ 7,367,578	$ 2,332,387	$ 56,450,545	$ 17,870,797	$ 45,334,594
2034	12	$ 2,680,584	$ 793,088	$ 7,555,117	$ 2,235,287	$ 63,585,586	$ 18,812,681	$ 44,892,033
2035	13	$ 2,720,793	$ 752,322	$ 7,747,345	$ 2,142,206	$ 69,549,028	$ 19,230,886	$ 43,995,756
2036	14	$ 2,761,605	$ 713,651	$ 7,944,379	$ 2,052,979	$ 75,868,248	$ 19,605,797	$ 43,122,604
2037	15	$ 2,803,029	$ 676,968	$ 8,146,339	$ 1,967,447	$ 80,689,966	$ 19,487,683	$ 41,819,482
2038	16	$ 2,845,074	$ 642,171	$ 8,353,347	$ 1,885,460	$ 85,727,438	$ 19,349,811	$ 40,556,467
2039	17	$ 2,887,750	$ 609,162	$ 8,565,531	$ 1,806,872	$ 90,987,430	$ 19,193,515	$ 39,331,860
2040	18	$ 2,931,066	$ 577,850	$ 8,783,019	$ 1,731,542	$ 96,476,886	$ 19,020,092	$ 38,144,083
2041	19	$ 2,975,032	$ 548,147	$ (7,610,056)	$ (1,402,146)	$ 100,059,052	$ 18,435,798	$ 33,534,663
2042	20	$ 3,019,658	$ 519,971	$ 9,234,443	$ 1,590,129	$ 103,750,731	$ 17,865,408	$ 35,110,802
TOTALS			**$ 17,974,215**		**$ 46,556,394**		**$ 289,979,213**	**$ 721,803,927**
							BCR	**5.66**

Note:

1. Base year is assumed as 2016 per INFRA BCA Guidelines

2. Assumes construction begins in 2020 and ends in 2022.

3. Construction cost expenditures are projected to be incurred evenly over the 3-year period.

4. Assumes a 1.5% annual growth corresponding to projected traffic volume growth for subject corridor. 1.5% Growth is applied to year 2016 (base year) as well since calculations are based on 2015 data. There are no concerns with regards to capacity constraints for this growth rate.

Tab 3. TOTAL Travel Time

Year	Project Year	TOTAL Travel Time Savings for All Purpose (hr/year)	TOTAL Travel Time Savings for Buses (hr/year)	TOTAL Travel Time Savings for Trucks (hr/year)	TOTAL Travel Time Savings for All Purpose ($2016)	TOTAL Travel Time Savings for Buses ($2016)	TOTAL Travel Time Savings for Trucks ($2016)	TOTAL Travel Time Savings ($2016)
2016	na	2,142,175	5,530	78,817	$ -	$ -	$ -	$ -
2017	na	2,174,308	5,613	79,999	$ -	$ -	$ -	$ -
2018	na	2,206,923	5,697	81,199	$ -	$ -	$ -	$ -
2019	na	2,240,026	5,782	82,417	$ -	$ -	$ -	$ -
(Beg Construction) 2020	Construction	2,273,627	5,869	83,653	$ -	$ -	$ -	$ -
2021	Construction	2,307,731	5,957	84,908	$ -	$ -	$ -	$ -
(End Construction) 2022	Construction	2,342,347	6,047	86,182	$ -	$ -	$ -	$ -
2023	1	2,377,482	6,137	87,474	$ 33,522,501	$ 173,686	$ 2,379,305	$ 36,075,492
2024	2	2,413,145	6,229	88,787	$ 34,025,338	$ 176,291	$ 2,414,994	$ 36,616,624
2025	3	2,449,342	6,323	90,118	$ 34,535,719	$ 178,935	$ 2,451,219	$ 37,165,873
2026	4	2,486,082	6,418	91,470	$ 35,053,754	$ 181,619	$ 2,487,988	$ 37,723,361
2027	5	2,523,373	6,514	92,842	$ 35,579,561	$ 184,344	$ 2,525,307	$ 38,289,212
2028	6	2,561,224	6,612	94,235	$ 36,113,254	$ 187,109	$ 2,563,187	$ 38,863,550
2029	7	2,599,642	6,711	95,648	$ 36,654,953	$ 189,916	$ 2,601,635	$ 39,446,503
2030	8	2,638,637	6,811	97,083	$ 37,204,777	$ 192,764	$ 2,640,659	$ 40,038,201
2031	9	2,678,216	6,914	98,539	$ 37,762,849	$ 195,656	$ 2,680,269	$ 40,638,774
2032	10	2,718,389	7,017	100,017	$ 38,329,292	$ 198,591	$ 2,720,473	$ 41,248,356
2033	11	2,759,165	7,123	101,518	$ 38,904,231	$ 201,569	$ 2,761,280	$ 41,867,081
2034	12	2,800,553	7,229	103,040	$ 39,487,794	$ 204,593	$ 2,802,700	$ 42,495,087
2035	13	2,842,561	7,338	104,586	$ 40,080,111	$ 207,662	$ 2,844,740	$ 43,132,513
2036	14	2,885,200	7,448	106,155	$ 40,681,313	$ 210,777	$ 2,887,411	$ 43,779,501
2037	15	2,928,477	7,560	107,747	$ 41,291,533	$ 213,938	$ 2,930,722	$ 44,436,194
2038	16	2,972,405	7,673	109,363	$ 41,910,906	$ 217,148	$ 2,974,683	$ 45,102,736
2039	17	3,016,991	7,788	111,004	$ 42,539,569	$ 220,405	$ 3,019,303	$ 45,779,278
2040	18	3,062,246	7,905	112,669	$ 43,177,663	$ 223,711	$ 3,064,593	$ 46,465,967
2041	19	3,108,179	8,024	114,359	$ 43,825,328	$ 227,067	$ 3,110,562	$ 47,162,956
2042	20	3,154,802	8,144	116,074	$ 44,482,708	$ 230,473	$ 3,157,220	$ 47,870,401
				Average	**$ 38,758,158**	**$ 200,813**	**$ 2,750,913**	**$ 41,709,883**
				Total	**$ 775,163,153**	**$ 4,016,253**	**$ 55,018,253**	**$ 834,197,659**

Note:

1. Assumes a 1.5% annual growth corresponding to projected traffic volume growth for subject corridor. 1.5% Growth is applied to year 2016 (base year) as well since travel time calculations are based on 2015 data. There are no concerns with regards to capacity constraints for this growth rate

2. Savings are based on 2016$

3. Assumes construction begins in 2020 and ends in 2022. Travel time savings are first realized in 2023.

4. Assumes no new additional users. All users are existing regardless of whether the proposal is built or not.

Synchro ID	Aproach	Average Daily Traffic	Percent Bus	Percent Truck	AM Peak Existing - Average Travel Time per Vehicle (second)	AM Peak Proposed - Average Travel Time per Vehicle (second)	PM Peak Existing - Average Travel Time per Vehicle (second)	PM Peak Proposed - Average Travel Time per Vehicle (second)	OFF Peak Existing - Average Travel Time per Vehicle (second)	OFF Peak Proposed - Average Travel Time per Vehicle (second)	TOTAL Travel Time Savings for All Purpose (hr/year)	TOTAL Travel Time Savings for Buses (hr/year)	TOTAL Travel Time Savings for Trucks (hr/year)
9	NB	48682	0.2%	4.2%	10.7	14.5	16.9	16.2	10.7	12.5	-10494.25	-15.79	-331.69
9	SB	1534	0.2%	4.2%	39.5	42.9	39.1	42.6	39.1	41.3	-545.62	-0.82	-17.25
10	NB	49976	0.3%	4.8%	16.1	14	82.9	98.5	157.9	123.9	128966.72	293.30	4692.86
10	SB	50059	0.2%	4.2%	42.2	29.9	34.9	31.8	20.2	19.7	18816.96	28.32	594.74
13	NB	48682	0.2%	4.2%	14.2	17.3	67.1	57.3	62.6	46.1	80149.84	120.63	2533.26
13	SB	1534	0.2%	4.2%	5.3	25.3	5.2	28.6	4.6	8.2	-2070.89	-3.12	-65.45
14	NB	48682	0.2%	4.2%	28.3	35.9	278.9	296	148.1	128.3	54504.52	82.03	1722.70
14	SB	1534	0.2%	4.2%	11.7	54.3	11.4	45.4	11.1	18.3	-3693.29	-5.56	-116.73
22	NB	48682	0.2%	4.2%	4.1	4.1	4.4	7.4	3.4	3.4	-3935.34	-5.92	-124.38
22	SB	1534	0.2%	4.2%	13.6	13.2	13.4	13.2	12.5	12.6	7.23	0.01	0.23
23	NB	44274	0.4%	5.7%	13.7	14.6	16.5	19.7	14.5	13.8	-1874.86	-5.75	-81.88
23	SB	43958	0.2%	4.8%	17.9	20.3	22.1	26.4	16	16.8	-10240.38	-15.51	-372.24
28	NB	41699	0.5%	6.0%	35.9	31.5	36.6	37.5	32.8	29.9	12994.92	49.99	599.93
28	SB	43395	0.3%	5.0%	28.1	25.4	28.8	26.5	24.5	23.9	7268.40	16.57	276.09
31	NB	41767	0.3%	6.2%	27.7	23.2	26.2	25.3	26	25.1	7925.24	18.29	378.07
31	SB	44703	0.4%	4.9%	23.3	19.9	28.8	23.3	20.1	18.9	14259.02	43.33	530.79
34	NB	40658	0.3%	6.2%	39.8	24.3	33.2	32.8	27.3	20.1	37957.94	87.62	1810.79
34	SB	46834	0.4%	5.1%	15.6	14.7	12.8	13.2	11.9	12.4	-1684.08	-5.13	-65.39
35	NB	43413	0.8%	6.0%	21	27.9	27.3	27.9	17.9	18.5	-8809.87	-54.40	-408.03
35	SB	46834	0.4%	5.1%	31.8	26.4	21.1	22.3	18.7	19.8	-904.41	-2.75	-35.11
36	NB	43413	0.8%	6.0%	13.3	15.6	15.4	15.9	12.9	13.4	-4390.68	-27.11	-203.35
36	SB	42974	0.3%	5.1%	49	37.9	37.3	34.6	31	28.4	22315.65	50.91	865.51
41	NB	39444	0.8%	6.0%	13.4	10.5	40.9	26.1	32.5	20.4	58336.51	360.25	2701.85
41	SB	43926	0.3%	5.1%	15.4	15.3	13.8	13.8	14	14.2	-673.47	-1.54	-26.12
42	NB	43926	0.2%	6.3%	18.5	19.1	108	71	100.2	54.9	212742.79	327.38	10312.62
42	SB	47125	0.3%	5.1%	19.8	18.1	17.6	17.1	18.2	17.3	5905.76	13.47	229.05
116	NB	48682	0.2%	4.2%	38.8	41.4	155.7	153.7	38.4	40.2	-7608.33	-11.45	-240.47
116	SB	1534	0.2%	4.2%	28.4	33.9	28.3	34.1	28.3	31.1	-786.40	-1.18	-24.86
275	NB	36956	0.1%	6.2%	19.9	18.6	54.3	19.2	19.8	16	47263.88	36.29	2249.92
275	SB	39336	0.2%	4.9%	21.1	19.3	20.6	19.3	17.6	16.4	6891.80	10.45	256.00
277	NB	42416	0.1%	5.8%	21.9	28.4	38.1	31.4	21.3	23	-4162.52	-3.18	-184.58
277	SB	43514	0.1%	5.0%	80.6	33.4	24	24.3	22	21.9	41254.28	31.26	1547.26
377	NB	37776	0.6%	4.4%	21.9	17	75.3	72.4	18.6	18	8623.21	39.18	287.33
377	SB	38158	0.5%	4.6%	22.3	19.2	286.8	203.4	18.1	17.1	90814.45	344.23	3166.88
457	NB	46261	0.2%	4.2%	18.2	13.7	36.6	31.8	42.3	34.7	40980.18	61.68	1295.24
457	SB	5002	0.2%	4.2%	17.8	16.1	16.5	15.8	11.5	11.4	310.00	0.47	9.80
458	NB	7889	0.3%	4.8%	12.8	12	18.2	18.6	20.5	19.9	453.69	1.03	16.51
458	SB	43978	0.2%	4.8%	54.3	34	85.4	70	33.3	32.9	37594.57	56.94	1366.56
530	NB	32896	0.5%	5.0%	35.5	20.2	37.4	45.9	28.3	21.7	21401.52	81.46	814.64
530	SB	18872	0.6%	3.2%	57.9	46.9	894.1	501.3	50.7	47.5	210545.14	944.73	5038.55
564	NB	2046	0.2%	4.2%	5.7	5.6	6.8	11.9	8.4	8.3	-259.12	-0.39	-8.19
564	SB	26591	0.2%	4.2%	14.7	5.4	15.1	6.6	11.1	4.6	26224.60	39.47	828.87
572	NB	48682	0.2%	4.2%	15.2	12.1	33.1	25.4	49.1	26.6	109074.62	164.17	3447.47
572	SB	1534	0.2%	4.2%	20.3	65.4	18.5	80.5	15.9	17.5	-4175.87	-6.28	-131.98
573	NB	2056	0.2%	4.2%	22	19.4	125.4	72.6	82.5	57	7624.54	11.48	240.99
573	SB	46996	0.2%	4.2%	13.8	24	11.7	31.1	8.8	8.7	-33843.22	-50.94	-1069.67
574	NB	43926	0.2%	6.3%	11.4	11.7	81	53.2	103.5	79.1	123721.32	190.39	5997.34
574	SB	41082	0.1%	5.0%	73.5	66.6	69.8	70.8	70.6	66.2	20312.63	15.39	761.84
590	NB	39661	0.8%	6.0%	24.4	23.2	24.3	24	24.4	23.3	4974.94	30.72	230.41
590	SB	41136	0.3%	5.1%	24.6	24.1	23.6	23.5	23.7	23.8	164.53	0.38	6.38
591	NB	39661	0.8%	6.0%	24.3	24	36	28.3	25.5	24.5	11642.93	71.90	539.24
591	SB	41136	0.3%	5.1%	8.8	8.4	8.4	8	8.8	8.1	3263.14	7.44	126.56
594	NB	16451	0.5%	3.6%	51.6	48.7	50.3	46.1	44.6	42.9	5291.67	19.85	142.91
594	SB	20089	0.7%	3.0%	74.5	69	290.7	72.5	70.9	68.5	125482.62	656.21	2812.31
722	NB	39059	0.2%	6.3%	69.1	56.1	80.7	63.5	76.3	65	65544.59	100.86	3177.25
722	SB	43514	0.1%	5.0%	20.3	17.4	13.8	13.9	13.8	14	1659.49	1.26	62.24
723	NB	42416	0.1%	5.8%	14.6	16.5	22.9	19.9	14.2	15.5	-2981.26	-2.28	-132.20
723	SB	38607	0.2%	4.9%	174.5	68.4	65.6	69	68.6	59.4	109541.95	166.08	4069.07
724	NB	35067	0.1%	5.8%	54.1	50.6	122.4	60.5	62.5	55.7	80568.75	61.60	3572.65
724	SB	39336	0.2%	4.9%	14.1	15.2	13.3	13.4	12.4	12.9	-2683.07	-4.07	-99.67
725	NB	36956	0.1%	6.2%	13.6	12.8	38.6	14.2	13.9	12.8	27889.84	21.41	1327.65
725	SB	36706	0.5%	4.6%	71.7	58.9	65.3	62.7	63.4	55.3	37825.19	143.37	1319.04
726	NB	33868	0.1%	6.2%	54.8	53.2	348.4	272.9	61.2	59.3	74128.95	56.92	3528.78
726	SB	38158	0.5%	4.6%	15.4	12.7	19	14.2	12.9	12.3	8956.41	33.95	312.33
741	NB	37776	0.6%	4.4%	17.9	16.2	279.3	262.1	15.7	15.3	20002.82	90.89	666.51
741	SB	35033	0.6%	3.2%	28.4	22.7	647.8	481.2	26.4	22	175901.65	789.28	4209.50
782	NB	42273	0.3%	4.8%	39	34.6	47.1	37.4	41.2	35.8	34544.24	78.56	1257.00
782	SB	43958	0.2%	4.8%	12.4	14.3	11.8	14.7	11.3	11.7	-6620.93	-10.03	-240.67
783	NB	48682	0.4%	5.7%	12.8	13.2	14.7	16.7	12.5	12.6	-3382.19	-10.37	-147.70
783	SB	41835	0.3%	5.0%	35.4	30.5	52.5	42.6	30.4	30.4	15158.80	34.55	575.80
786	NB	17037	0.2%	1.7%	14.2	6.2	39.9	10.4	17.9	6.4	34330.16	50.35	428.00
786	SB	14202	0.2%	2.3%	9.8	10.3	9.2	9.2	9	9.2	-400.05	-0.59	-6.79
832	NB	16451	0.2%	1.7%	67.3	64.2	81.6	68.5	64.8	63.6	8790.55	12.89	109.59
832	SB	15451	0.5%	3.3%	10.3	6.1	13.5	10.7	12.3	8.3	7939.19	29.69	195.93
922	NB	44086	0.3%	4.8%	20.6	20.2	30.2	30.3	22.5	22.1	1768.86	4.02	64.37
922	SB	42484	0.2%	4.8%	8.6	8.3	12	11.3	9.5	9.8	-56.88	-0.09	-2.07
923	NB	44086	0.3%	4.8%	8.3	8.2	13.2	24	8.6	8.6	-12647.35	-28.76	-460.21
923	SB	42484	0.2%	4.8%	33.6	33.5	47.8	43.9	32.7	33.2	2673.33	4.05	97.18
977	NB	48127	0.2%	4.2%	9.2	8.1	77.4	58.7	57.1	50.5	53137.46	79.98	1679.49
977	SB	46715	0.2%	4.2%	22.1	31.3	22.2	32.3	16.7	16.8	-21808.34	-32.82	-689.29
978	NB	2156	0.2%	4.2%	34.8	20.4	139.7	99.3	140.7	106.8	9375.15	14.11	296.32
978	SB	46715	0.2%	4.2%	7	6.4	11.4	11.1	5.3	5.1	1762.29	2.65	55.70
2091	NB	18401	0.5%	3.1%	6.3	9.3	7.2	9.1	6.6	8.6	-5324.80	-19.87	-123.19
2091	SB	14202	0.5%	2.6%	37.7	67.4	36.4	45.3	26.7	53.9	-46381.93	-172.18	-895.33
2092	NB	18401	0.3%	3.2%	30.5	55.5	22.1	42	17.4	39.7	-55618.04	-124.39	-1326.86
2092	SB	14202	0.2%	2.3%	8	16.7	7.5	8.4	6.9	11.7	-8986.47	-13.26	-152.51

Source:

1. Average Daily Traffic, Percent Bus, Percent Truck -- Kimley-Horn of Michigan, Inc. 2015 Traffic Data Collection by Intersection.

2. Average Vehicle Travel Times -- Synchro & Simtraffic simulation models for corresponding 2015 Traffic Data

Note:

1. Average vehicle travel times for each time period of the day (i.e. AM, PM, Off peak) are calculated using Synchro and Sim Traffic for Existing conditions and Proposed conditions in the subject corridor

2. Based on 2015 Traffic Data by Kimley-Horn of Michigan, Inc., Peak volume (i.e. 7AM-9AM & 3PM-6PM) applys to 35% of the Average Daily Traffic; 15% for AM peak and 20% for PM peak

3. All values presented in the above table are based on and represent 2015 data. A 1.5% annual growth rate will be applied for future years. The 1.5% annual growth corresponds to a projected growth in traffic volumes for the subject coridor.

4. Positive (+) values represent reductions in travel time; Negative (-) values represent increases in travel time

Category	$2016 per Person-hour
Private Vehicle Travel	
Personal	$ 13.60
Business	$ 25.40
All Purposes	$ 14.10
Commercial Vehicle Operators	
Truck Drivers	$ 27.20
Bus Drivers	$ 28.30

Source:

Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis
https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic

Vehicle Type	Occupancy
Passenger Vehicles	1.39
Trucks	1

Source:

Federal Highway Administration Highway Statistics 2015, Table VM1

Tab 6. TOTAL Safety Benefits

Year	Project Year	Estimated Annual Crash Reduction					Safety Benefits ($2016)					TOTAL Safety Benefits ($2016)
		O *No Injury*	C *Possible Injury*	B *Non-Incapacitating*	A *Incapacitating*	K *Killed*	O *No Injury*	C *Possible Injury*	B *Non-Incapacitating*	A *Incapacitating*	K *Killed*	
2016	na	1027.5	114.7	19.4	4.8	1.2	$ -	$ -	$ -	$ -	$ -	$ -
2017	na	1043.0	116.4	19.7	4.9	1.2	$ -	$ -	$ -	$ -	$ -	$ -
2018	na	1058.6	118.2	19.9	4.9	1.2	$ -	$ -	$ -	$ -	$ -	$ -
2019	na	1074.5	120.0	20.2	5.0	1.2	$ -	$ -	$ -	$ -	$ -	$ -
(Beg Construction) 2020	Construction	1090.6	121.8	20.6	5.1	1.2	$ -	$ -	$ -	$ -	$ -	$ -
2021	Construction	1106.9	123.6	20.9	5.2	1.3	$ -	$ -	$ -	$ -	$ -	$ -
(End Construction) 2022	Construction	1123.6	125.4	21.2	5.2	1.3	$ -	$ -	$ -	$ -	$ -	$ -
2023	1	1140.4	127.3	21.5	5.3	1.3	$ 3,649,303	$ 8,135,369	$ 2,686,184	$ 2,441,997	$ 12,480,060	$ 29,392,913
2024	2	1157.5	129.2	21.8	5.4	1.3	$ 3,704,043	$ 8,257,400	$ 2,726,476	$ 2,478,627	$ 12,667,261	$ 29,833,806
2025	3	1174.9	131.2	22.1	5.5	1.3	$ 3,759,604	$ 8,381,261	$ 2,767,373	$ 2,515,806	$ 12,857,270	$ 30,281,313
2026	4	1192.5	133.1	22.5	5.6	1.4	$ 3,815,998	$ 8,506,980	$ 2,808,884	$ 2,553,543	$ 13,050,129	$ 30,735,533
2027	5	1210.4	135.1	22.8	5.6	1.4	$ 3,873,238	$ 8,634,584	$ 2,851,017	$ 2,591,846	$ 13,245,881	$ 31,196,566
2028	6	1228.5	137.2	23.2	5.7	1.4	$ 3,931,336	$ 8,764,103	$ 2,893,783	$ 2,630,724	$ 13,444,569	$ 31,664,515
2029	7	1247.0	139.2	23.5	5.8	1.4	$ 3,990,306	$ 8,895,565	$ 2,937,189	$ 2,670,185	$ 13,646,237	$ 32,139,482
2030	8	1265.7	141.3	23.8	5.9	1.4	$ 4,050,161	$ 9,028,998	$ 2,981,247	$ 2,710,238	$ 13,850,931	$ 32,621,575
2031	9	1284.7	143.4	24.2	6.0	1.5	$ 4,110,913	$ 9,164,433	$ 3,025,966	$ 2,750,891	$ 14,058,695	$ 33,110,898
2032	10	1303.9	145.6	24.6	6.1	1.5	$ 4,172,577	$ 9,301,900	$ 3,071,355	$ 2,792,154	$ 14,269,575	$ 33,607,562
2033	11	1323.5	147.8	24.9	6.2	1.5	$ 4,235,166	$ 9,441,428	$ 3,117,426	$ 2,834,037	$ 14,483,619	$ 34,111,675
2034	12	1343.3	150.0	25.3	6.3	1.5	$ 4,298,693	$ 9,583,050	$ 3,164,187	$ 2,876,547	$ 14,700,873	$ 34,623,350
2035	13	1363.5	152.2	25.7	6.4	1.6	$ 4,363,173	$ 9,726,795	$ 3,211,650	$ 2,919,696	$ 14,921,386	$ 35,142,700
2036	14	1383.9	154.5	26.1	6.5	1.6	$ 4,428,621	$ 9,872,697	$ 3,259,825	$ 2,963,491	$ 15,145,207	$ 35,669,841
2037	15	1404.7	156.8	26.5	6.6	1.6	$ 4,495,050	$ 10,020,788	$ 3,308,722	$ 3,007,943	$ 15,372,385	$ 36,204,889
2038	16	1425.8	159.2	26.9	6.7	1.6	$ 4,562,476	$ 10,171,099	$ 3,358,353	$ 3,053,062	$ 15,602,971	$ 36,747,962
2039	17	1447.2	161.6	27.3	6.7	1.6	$ 4,630,913	$ 10,323,666	$ 3,408,728	$ 3,098,858	$ 15,837,016	$ 37,299,181
2040	18	1468.9	164.0	27.7	6.9	1.7	$ 4,700,377	$ 10,478,521	$ 3,459,859	$ 3,145,341	$ 16,074,571	$ 37,858,669
2041	19	1490.9	166.4	28.1	7.0	1.7	$ 4,770,883	$ 10,635,699	$ 3,511,757	$ 3,192,521	$ 16,315,689	$ 38,426,549
2042	20	1513.3	168.9	28.5	7.1	1.7	$ 4,842,446	$ 10,795,234	$ 3,564,433	$ 3,240,409	$ 16,560,425	$ 39,002,947
						Average	**$ 4,219,264**	**$ 9,405,978**	**$ 3,105,721**	**$ 2,823,396**	**$ 14,429,238**	**$ 33,983,596**
						Total	**$ 84,385,276**	**$ 188,119,569**	**$ 62,114,414**	**$ 56,467,917**	**$ 288,584,751**	**$ 679,671,927**

Note:

1. Assumes a 1.5% annual growth corresponding to projected traffic volume growth for subject corridor. 1.5% Growth is applied to year 2016 (base year) as well since crash data calculations are based on 2015 data. There are no concerns with regards to capacity constraints for this growth rate

2. Savings are based on 2016$

3. Assumes construction begins in 2020 and ends in 2022. Safety benefits are first realized in 2023.

4. Assumes no new additional users. All users are existing regardless of whether the proposal is built or not.

Applicable Crash Category *(based on proposed safety treatment)*					2011-2015 Crashes[3]					Annualized Crashes[3]				
					O[4] *(No Injury)*	C *(Possible Injury)*	B *(Non Incapacitating)*	A *(Incapacitating)*	K *(Killed)*	O[4] *(No Injury)*	C *(Possible Injury)*	B *(Non Incapacitating)*	A *(Incapacitating)*	K *(Killed)*
All Crashes	Segment	Daytime		Rear End	3096	287	34	6	1	619.1	57.4	6.8	1.2	0.2
				Single Vehicle	104	14	3	0	0	20.9	2.8	0.6	0.0	0.0
				Pedestrian Crashes @ Proposed Ped Bridge Locations	1	1	0	0	0	0.3	0.2	0.0	0.0	0.0
				All Other	1845	102	17	5	2	368.9	20.4	3.4	1.0	0.4
		Nighttime		Rear End	753	81	21	4	0	150.7	16.2	4.2	0.8	0.0
				Single Vehicle	95	15	6	0	2	18.9	3.0	1.2	0.0	0.4
				Pedestrian Crashes @ Proposed Ped Bridge Locations	1	1	0	0	0	0.3	0.2	0.0	0.0	0.0
				All Other	571	25	9	2	1	114.3	5.0	1.8	0.4	0.2
	Intersection	Daytime	Angle	Pedestrian Involved	0	4	0	0	0	0.0	0.8	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	1	1	0	0	0	0.3	0.2	0.0	0.0	0.0
				All Other	439	125	28	12	1	87.8	25.0	5.6	2.4	0.2
			Head-On	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				All Other	6	0	0	0	0	1.1	0.0	0.0	0.0	0.0
			Rear End	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	4	3	0	0	0	0.8	0.6	0.0	0.0	0.0
				All Other	1715	200	17	1	0	343.1	40.0	3.4	0.2	0.0
			Single Vehicle	Pedestrian Involved	6	1	3	0	0	1.1	0.2	0.6	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				All Other	33	2	2	0	0	6.7	0.4	0.4	0.0	0.0
			All Other	Pedestrian Involved	3	1	1	0	0	0.6	0.2	0.2	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	6	0	2	0	0	1.1	0.0	0.4	0.0	0.0
				All Other	557	22	3	0	0	111.5	4.4	0.6	0.0	0.0
		Nighttime	Angle	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				All Other	126	37	10	4	2	25.3	7.4	2.0	0.8	0.4
			Head-On	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				All Other	3	0	0	0	0	0.6	0.0	0.0	0.0	0.0
			Rear End	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	1	0	0	0	1	0.3	0.0	0.0	0.0	0.2
				All Other	353	31	2	2	0	70.6	6.2	0.4	0.4	0.0
			Single Vehicle	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	3	0	0	0	0	0.6	0.0	0.0	0.0	0.0
				All Other	10	2	2	0	0	1.9	0.4	0.4	0.0	0.0
			All Other	Pedestrian Involved	0	0	0	0	0	0.0	0.0	0.0	0.0	0.0
				Motorcycle Crashes @ 3-Lane Section	0	0	0	1	0	0.0	0.0	0.0	0.2	0.0
				All Other	150	2	1	1	0	30.0	0.4	0.2	0.2	0.0

Applicable Crash Category *(based on proposed safety treatment)*					Applicable CMF's[8] O *(No Injury)*										
					CMF_1	CMF_2	CMF_3	CMF_4	CMF_5	CMF_6	CMF_7	CMF_8	CMF_9	CMF_{10}	CMFt
All Crashes	Segment	Daytime		Rear End	0.95	0.58	0.93								**0.51**
				Single Vehicle	0.95	0.70	0.93								**0.62**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.93	0.10							**0.07**
				All Other	0.95	0.76	0.93								**0.67**
		Nighttime		Rear End	0.95	0.58	0.93	0.75							**0.40**
				Single Vehicle	0.95	0.70	0.93	0.75							**0.49**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.93	0.75	0.10						**0.06**
				All Other	0.95	0.76	0.93	0.75							**0.53**
	Intersection	Daytime	Angle	Pedestrian Involved	0.95	0.76	0.93	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.93	0.90	0.58	0.85	0.70	0.88			**0.31**
				All Other	0.95	0.76	0.93	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
			Head-On	Pedestrian Involved	0.95	0.76	0.93	0.90	0.90	0.85	0.90				**0.58**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.93	0.90	0.90	0.85	0.90	0.88			**0.57**
				All Other	0.95	0.76	0.93	0.90	0.90	0.85	0.90				**0.58**
			Rear End	Pedestrian Involved	0.95	0.58	0.93	0.90	0.90	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.93	0.90	0.90	0.85	0.70	0.88			**0.35**
				All Other	0.95	0.58	0.93	0.90	0.90	0.85	0.70				**0.35**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.93	0.90	0.90	0.85	0.90	0.60	0.75		**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.93	0.90	0.90	0.85	0.88				**0.53**
				All Other	0.95	0.70	0.93	0.90	0.90	0.85					**0.54**
			All Other	Pedestrian Involved	0.95	0.76	0.93	0.90	0.90	0.85	0.90	0.60	0.75		**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.93	0.90	0.90	0.85	0.88				**0.57**
				All Other	0.95	0.76	0.93	0.90	0.90	0.85					**0.58**
		Nighttime	Angle	Pedestrian Involved	0.95	0.76	0.93	0.90	0.58	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.93	0.90	0.58	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.76	0.93	0.90	0.58	0.85	0.75	0.70			**0.30**
			Head-On	Pedestrian Involved	0.95	0.76	0.93	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.93	0.90	0.90	0.85	0.75	0.90	0.88		**0.48**
				All Other	0.95	0.76	0.93	0.90	0.90	0.85	0.75	0.90			**0.48**
			Rear End	Pedestrian Involved	0.95	0.58	0.93	0.90	0.90	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.93	0.90	0.90	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.58	0.93	0.90	0.90	0.85	0.75	0.70			**0.30**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.93	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.93	0.90	0.90	0.85	0.75	0.88			**0.45**
				All Other	0.95	0.70	0.93	0.90	0.90	0.85	0.75				**0.45**
			All Other	Pedestrian Involved	0.95	0.76	0.93	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.93	0.90	0.90	0.85	0.75	0.88			**0.48**
				All Other	0.95	0.76	0.93	0.90	0.90	0.85	0.75				**0.48**

Applicable Crash Category *(based on proposed safety treatment)*					Applicable CMF's[8] C *(Possible Injury)*										
					CMF_1	CMF_2	CMF_3	CMF_4	CMF_5	CMF_6	CMF_7	CMF_8	CMF_9	CMF_{10}	CMFt
All Crashes	Segment	Daytime		Rear End	0.95	0.58	0.85								**0.47**
				Single Vehicle	0.95	0.70	0.85								**0.57**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.10							**0.06**
				All Other	0.95	0.76	0.85								**0.61**
		Nighttime		Rear End	0.95	0.58	0.85	0.75							**0.37**
				Single Vehicle	0.95	0.70	0.85	0.75							**0.45**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.75	0.10						**0.06**
				All Other	0.95	0.76	0.85	0.75							**0.48**
	Intersection	Daytime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.88			**0.31**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.88			**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.88			**0.35**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.70				**0.35**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.88				**0.51**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85					**0.51**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.88				**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85					**0.55**
		Nighttime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70			**0.30**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.88		**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90			**0.48**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70			**0.30**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.88			**0.45**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85	0.75				**0.45**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.88			**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75				**0.48**

Applicable Crash Category *(based on proposed safety treatment)*					Applicable CMF's[8] B *(Not Incapacitating)*										
					CMF_1	CMF_2	CMF_3	CMF_4	CMF_5	CMF_6	CMF_7	CMF_8	CMF_9	CMF_{10}	CMFt
All Crashes	Segment	Daytime		Rear End	0.95	0.58	0.85								**0.47**
				Single Vehicle	0.95	0.70	0.85								**0.57**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.10							**0.06**
				All Other	0.95	0.76	0.85								**0.61**
		Nighttime		Rear End	0.95	0.58	0.85	0.75							**0.37**
				Single Vehicle	0.95	0.70	0.85	0.75							**0.45**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.75	0.10						**0.06**
				All Other	0.95	0.76	0.85	0.75							**0.48**
	Intersection	Daytime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.88			**0.31**
				All Other	0.95	0.76	0.85	1.00	0.58	0.85	0.70	0.60	0.75		**0.24**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.88			**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.88			**0.35**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.70				**0.35**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.88				**0.51**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85					**0.51**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.88				**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85					**0.55**
		Nighttime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70			**0.30**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.88		**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90			**0.48**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70			**0.30**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.88			**0.45**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85	0.75				**0.45**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.88			**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75				**0.48**

Applicable Crash Category *(based on proposed safety treatment)*					Applicable CMF's[8] A *(Incapacitating)*										
					CMF_1	CMF_2	CMF_3	CMF_4	CMF_5	CMF_6	CMF_7	CMF_8	CMF_9	CMF_{10}	CMFt
All Crashes	Segment	Daytime		Rear End	0.95	0.58	0.85								**0.47**
				Single Vehicle	0.95	0.70	0.85								**0.57**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.10							**0.06**
				All Other	0.95	0.76	0.85								**0.61**
		Nighttime		Rear End	0.95	0.58	0.85	0.75							**0.37**
				Single Vehicle	0.95	0.70	0.85	0.75							**0.45**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.75	0.10						**0.06**
				All Other	0.95	0.76	0.85	0.75							**0.48**
	Intersection	Daytime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.88			**0.31**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.88			**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.88			**0.35**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.70				**0.35**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.88				**0.51**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85					**0.51**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.88				**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85					**0.55**
		Nighttime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70			**0.30**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.88		**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90			**0.48**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70			**0.30**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.88			**0.45**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85	0.75				**0.45**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.88			**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75				**0.48**

Applicable Crash Category *(based on proposed safety treatment)*					Applicable CMF's[8] K *(Killed)*										
					CMF_1	CMF_2	CMF_3	CMF_4	CMF_5	CMF_6	CMF_7	CMF_8	CMF_9	CMF_{10}	CMFt
All Crashes	Segment	Daytime		Rear End	0.95	0.58	0.85								**0.47**
				Single Vehicle	0.95	0.70	0.85								**0.57**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.10							**0.06**
				All Other	0.95	0.76	0.85								**0.61**
		Nighttime		Rear End	0.95	0.58	0.85	0.75							**0.37**
				Single Vehicle	0.95	0.70	0.85	0.75							**0.45**
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.95	0.76	0.85	0.75	0.10						**0.06**
				All Other	0.95	0.76	0.85	0.75							**0.48**
	Intersection	Daytime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.88			**0.31**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.70	0.60	0.75		**0.24**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.88			**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.90				**0.55**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.60	0.75		**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.70	0.88			**0.35**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.70				**0.35**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.88				**0.51**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85					**0.51**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.90	0.60	0.75		**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.88				**0.55**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85					**0.55**
		Nighttime	Angle	Pedestrian Involved	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.76	0.85	0.90	0.58	0.85	0.75	0.70			**0.30**
			Head-On	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.88		**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90			**0.48**
			Rear End	Pedestrian Involved	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.60	0.75	**0.24**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70	0.88		**0.30**
				All Other	0.95	0.58	0.85	0.90	0.90	0.85	0.75	0.70			**0.30**
			Single Vehicle	Pedestrian Involved	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.32**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.70	0.85	0.90	0.90	0.85	0.75	0.88			**0.45**
				All Other	0.95	0.70	0.85	0.90	0.90	0.85	0.75				**0.45**
			All Other	Pedestrian Involved	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.90	0.60	0.75	**0.34**
				Motorcycle Crashes @ 3-Lane Section	0.95	0.76	0.85	0.90	0.90	0.85	0.75	0.88			**0.48**
				All Other	0.95	0.76	0.85	0.90	0.90	0.85	0.75				**0.48**

Applicable Crash Category *(based on proposed safety treatment)*					Estimated Annual Crash Reduction[3] O[4] *(No Injury)*	C *(Possible Injury)*	B *(Non Incapacitating)*	A *(Incapacitating)*	K *(Killed)*	Annual Safety Benefits O[4] *(No Injury)*	C *(Possible Injury)*	B *(Non Incapacitating)*	A *(Incapacitating)*	K *(Killed)*
All Crashes	Segment	Daytime		Rear End	301.9	30.5	3.6	0.6	0.1	$ 965,944	$ 1,950,018	$ 451,903	$ 292,897	$ 1,020,768
				Single Vehicle	8.0	1.2	0.3	0.0	0.0	$ 25,457	$ 77,785	$ 32,606	$ -	$ -
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.3	0.2	0.0	0.0	0.0	$ 827	$ 11,954	$ -	$ -	$ -
				All Other	121.2	7.9	1.3	0.4	0.2	$ 387,841	$ 503,565	$ 164,178	$ 177,350	$ 1,483,392
		Nighttime		Rear End	89.7	10.2	2.6	0.5	0.0	$ 287,104	$ 652,422	$ 330,881	$ 231,478	$ -
				Single Vehicle	9.7	1.7	0.7	0.0	0.2	$ 30,957	$ 106,154	$ 83,063	$ -	$ 2,126,400
				Pedestrian Crashes @ Proposed Ped Bridge Locations	0.3	0.2	0.0	0.0	0.0	$ 839	$ 12,052	$ -	$ -	$ -
				All Other	53.7	2.6	0.9	0.2	0.1	$ 171,807	$ 164,702	$ 115,988	$ 94,666	$ 989,760
	Intersection	Daytime	Angle	Pedestrian Involved	0.0	0.6	0.0	0.0	0.0	$ -	$ 38,667	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.2	0.1	0.0	0.0	0.0	$ 615	$ 8,837	$ -	$ -	$ -
				All Other	66.4	18.9	4.2	1.8	0.2	$ 212,634	$ 1,208,349	$ 529,480	$ 833,432	$ 1,452,288
			Head-On	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				All Other	0.5	0.0	0.0	0.0	0.0	$ 1,490	$ -	$ -	$ -	$ -
			Rear End	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.5	0.4	0.0	0.0	0.0	$ 1,748	$ 25,109	$ -	$ -	$ -
				All Other	224.7	26.2	2.2	0.1	0.0	$ 718,927	$ 1,673,924	$ 278,333	$ 60,133	$ -
			Single Vehicle	Pedestrian Involved	0.8	0.1	0.4	0.0	0.0	$ 2,438	$ 8,754	$ 51,375	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				All Other	3.1	0.2	0.2	0.0	0.0	$ 9,917	$ 12,633	$ 24,713	$ -	$ -
			All Other	Pedestrian Involved	0.4	0.1	0.1	0.0	0.0	$ 1,171	$ 8,409	$ 16,450	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.5	0.0	0.2	0.0	0.0	$ 1,530	$ -	$ 22,545	$ -	$ -
				All Other	46.7	2.0	0.3	0.0	0.0	$ 149,327	$ 126,775	$ 33,818	$ -	$ -
		Nighttime	Angle	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				All Other	17.6	5.1	1.4	0.6	0.3	$ 56,303	$ 328,874	$ 173,875	$ 255,443	$ 2,670,720
			Head-On	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				All Other	0.3	0.0	0.0	0.0	0.0	$ 917	$ -	$ -	$ -	$ -
			Rear End	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.2	0.0	0.0	0.0	0.1	$ 619	$ -	$ -	$ -	$ 1,335,360
				All Other	49.1	4.3	0.3	0.3	0.0	$ 157,154	$ 275,543	$ 34,775	$ 127,722	$ -
			Single Vehicle	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.3	0.0	0.0	0.0	0.0	$ 985	$ -	$ -	$ -	$ -
				All Other	1.1	0.2	0.2	0.0	0.0	$ 3,448	$ 14,154	$ 27,688	$ -	$ -
			All Other	Pedestrian Involved	0.0	0.0	0.0	0.0	0.0	$ -	$ -	$ -	$ -	$ -
				Motorcycle Crashes @ 3-Lane Section	0.0	0.0	0.0	0.1	0.0	$ -	$ -	$ -	$ 47,333	$ -
				All Other	15.5	0.2	0.1	0.1	0.0	$ 49,528	$ 13,176	$ 12,888	$ 47,333	$ -
									TOTAL	$ 3,239,527	$ 7,221,858	$ 2,384,555	$ 2,167,788	$ 11,078,688

Note:

1. 2011 - 2015 crashes for the subject corridor are obtained from the Transportation improvement Association (TIA) TCAT database

2. Annual crashes are obtained via the average of the 2011-2015 crashes. Crashes are increased by 1.5% each year starting with 2016 by assuming a direct correlation between traffic volumes and crash frequency.

3. Crashes reported represent all of the number of injuries, fatalities, or no injuries involved in the accident on a per individual basis

4. The Michigan State Police Department reports O (No Injury) crashes on a per vehicle basis and not on a per individual basis. Consequently a 1.39 average occupancy rate based on the BCA Guidance has been applied to report the number of individuals involved in O (No Injury) cra

5. The impact of multiple safety treatments on crashes is assessed via the multiplication of the best three CMF's. The number of CMF's applied was limited to 3 to avoid unrealistic crash reductions:

$$CMF_t = CMF_1 * CMF_2 * CMF_3$$

Where,
- CMF_t CMF for combined treatments
- CMF_1 CMF for first best treatment
- CMF_2 CMF for second best treatment
- CMF_3 CMF for third best treatment

6. Applicable Crash Categories listed correspond with the identified CMFs based on the proposed safety treatment.

7. In order to avoid double counting which may stem from applying CMF's to overlapping Crash Categories, the Crash Categories have been split and isolated

8. Refer to CMF Tab for applicable CMFs

Tab 8. CMF - Values

CMF ID	Name	CMF	Crash Type	Crash Severity	Area Type	Time of Day	Source
62	Install signs to conform to MUTCD	0.85	All	Injury	Urban	All	http://www.cmfclearinghouse.org/detail.cfm?facid=62
63	Install signs to conform to MUTCD	0.93	All	PDO	Urban	All	http://www.cmfclearinghouse.org/detail.cfm?facid=63
194	Increased pavement friction	0.76	All	All	All	All	http://www.cmfclearinghouse.org/detail.cfm?facid=194
197	Increased pavement friction	0.58	Rear End	All	All	All	http://www.cmfclearinghouse.org/detail.cfm?facid=197
198	Increased pavement friction	0.7	Single Vehicle	All	All	All	http://www.cmfclearinghouse.org/detail.cfm?facid=198
1263	Improve lighting	0.75	All	All	All	Nighttime	http://www.cmfclearinghouse.org/detail.cfm?facid=1263
1410	Add 3-inch yellow retroreflective sheeting to signal backplates	0.85	All	All	Signalized Intersection	All	http://www.cmfclearinghouse.org/detail.cfm?facid=1410
1413	Add signal (additional primary head)	0.9	All	All	Signalized Intersection	All	http://www.cmfclearinghouse.org/detail.cfm?facid=1413
1418	Add signal (additional primary head)	0.58	Angle	All	Signalized Intersection	All	http://www.cmfclearinghouse.org/detail.cfm?facid=1418
1802	Install pedestrian overpass/underpass	0.1	Pedestrian	All	All	All	http://www.cmfclearinghouse.org/detail.cfm?facid=1802
2950	Change no. of lanes on major road of a 4-leg signalized intersection from X to Y	0.9	Motorcycle Crashes	All	Urban Signalized Intersection	All	http://www.cmfclearinghouse.org/detail.cfm?facid=2950
4123	Install high-visibility crosswalk	0.6	Pedestrian	All	Urban Intersection	All	http://www.cmfclearinghouse.org/detail.cfm?facid=4123
MDOT-1	Signal Optimization & Timing Updates	0.9	All	All	Signalized Intersection	All	https://www.michigan.gov/documents/mdot/mdot_Crash_Reduction_Factors_303744_7.pdf
MDOT-2	Ped. Countdown Signals - Upgrade from existing signal	0.75	Pedestrian	All	Signalized Intersection	All	https://www.michigan.gov/documents/mdot/mdot_Crash_Reduction_Factors_303744_7.pdf
MDOT-3	Signing and Pavement Markings - Improve/Upgrade	0.7	Angle, Rear-End	All	Intersection	All	https://www.michigan.gov/documents/mdot/mdot_Crash_Reduction_Factors_303744_7.pdf
MDOT-4	Signing and Pavement Markings - Improve/Upgrade	0.9	Head-On, Pedestrian	All	Intersection	All	https://www.michigan.gov/documents/mdot/mdot_Crash_Reduction_Factors_303744_7.pdf
MDOT-5	Recessed Durable Pavement Markings	0.95	All	All	All	All	https://www.michigan.gov/documents/mdot/mdot_Crash_Reduction_Factors_303744_7.pdf

Tab 9. KABCO Level - Values

KABCO Level	Monetized Value ($2016)
O - No Injury	$ 3,200
C - Possible Injury	$ 63,900
B - Non Incapacitating Injury	$ 125,000
A - Incapacitating	$ 459,100
K - Killed	$ 9,600,000
U - Injured (Severity Unknown)	$ 174,000
# Accidents Reported (Unknown if Injured)	$ 132,200

Note: Michigan State Police UD-10 Forms use KABCO scale for reporting crashes

Property Damage Only (PDO) Crashes ($2016)	$ 4,252

Source:

Guidance on Treatment of the Economic Value of a Statistical Life in U.S. Department of Transportation Analysis (2016)

https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis

Tab 10. TOTAL Emissions

Year	Project Year	TOTAL VOC Savings (short ton/year)	TOTAL Nox Savings (short ton/year)	TOTAL PM Savings (short ton/year)	TOTAL CO Savings (metric ton/year)	TOTAL CO_2 Savings (short ton/year)	TOTAL VOC Savings ($2016)	TOTAL Nox Savings ($2016)	TOTAL PM Savings ($2016)	TOTAL CO Savings ($2016)	TOTAL CO_2 Savings ($2016)	TOTAL Emission Savings ($2016)
2016	na	3.66	4.82	0.70	38.62	3,791	$ -	$ -	$ -	$ -	$ -	$ -
2017	na	3.71	4.89	0.71	39.20	3,848	$ -	$ -	$ -	$ -	$ -	$ -
2018	na	3.77	4.97	0.72	39.78	3,906	$ -	$ -	$ -	$ -	$ -	$ -
2019	na	3.82	5.04	0.73	40.38	3,964	$ -	$ -	$ -	$ -	$ -	$ -
Construction) 2020	Construction	3.88	5.12	0.74	40.99	4,024	$ -	$ -	$ -	$ -	$ -	$ -
2021	Construction	3.94	5.19	0.75	41.60	4,084	$ -	$ -	$ -	$ -	$ -	$ -
onstruction) 2022	Construction	4.00	5.27	0.77	42.22	4,145	$ -	$ -	$ -	$ -	$ -	$ -
2023	1	4.06	5.35	0.78	42.86	4,208	$ 7,599	$ 39,471	$ 262,241	$ 201,307	$ 88,459	$ 599,078
2024	2	4.12	5.43	0.79	43.50	4,271	$ 7,713	$ 40,063	$ 266,175	$ 204,327	$ 93,031	$ 611,309
2025	3	4.18	5.51	0.80	44.15	4,335	$ 7,829	$ 40,664	$ 270,168	$ 207,391	$ 97,720	$ 623,773
2026	4	4.24	5.60	0.81	44.82	4,400	$ 7,947	$ 41,274	$ 274,220	$ 210,502	$ 102,530	$ 636,473
2027	5	4.31	5.68	0.82	45.49	4,466	$ 8,066	$ 41,893	$ 278,333	$ 213,660	$ 107,461	$ 649,414
2028	6	4.37	5.76	0.84	46.17	4,533	$ 8,187	$ 42,522	$ 282,508	$ 216,865	$ 112,517	$ 662,599
2029	7	4.44	5.85	0.85	46.86	4,601	$ 8,310	$ 43,160	$ 286,746	$ 220,118	$ 117,701	$ 676,034
2030	8	4.51	5.94	0.86	47.57	4,670	$ 8,434	$ 43,807	$ 291,047	$ 223,420	$ 123,015	$ 689,723
2031	9	4.57	6.03	0.88	48.28	4,740	$ 8,561	$ 44,464	$ 295,413	$ 226,771	$ 139,267	$ 714,476
2032	10	4.64	6.12	0.89	49.00	4,811	$ 8,689	$ 45,131	$ 299,844	$ 230,172	$ 155,980	$ 739,816
2033	11	4.71	6.21	0.90	49.74	4,883	$ 8,819	$ 45,808	$ 304,342	$ 233,625	$ 173,162	$ 765,756
2034	12	4.78	6.30	0.92	50.48	4,956	$ 8,952	$ 46,495	$ 308,907	$ 237,129	$ 190,824	$ 792,307
2035	13	4.85	6.40	0.93	51.24	5,031	$ 9,086	$ 47,193	$ 313,540	$ 240,686	$ 208,978	$ 819,483
2036	14	4.93	6.49	0.94	52.01	5,106	$ 9,222	$ 47,901	$ 318,244	$ 244,297	$ 227,633	$ 847,296
2037	15	5.00	6.59	0.96	52.79	5,183	$ 9,361	$ 48,619	$ 323,017	$ 247,961	$ 246,800	$ 875,758
2038	16	5.08	6.69	0.97	53.58	5,260	$ 9,501	$ 49,348	$ 327,862	$ 251,680	$ 266,492	$ 904,884
2039	17	5.15	6.79	0.99	54.39	5,339	$ 9,644	$ 50,089	$ 332,780	$ 255,456	$ 286,719	$ 934,687
2040	18	5.23	6.89	1.00	55.20	5,419	$ 9,788	$ 50,840	$ 337,772	$ 259,287	$ 307,492	$ 965,180
2041	19	5.31	7.00	1.02	56.03	5,501	$ 9,935	$ 51,603	$ 342,839	$ 263,177	$ 326,038	$ 993,591
2042	20	5.39	7.10	1.03	56.87	5,583	$ 10,084	$ 52,377	$ 347,981	$ 267,124	$ 345,071	$ 1,022,637
						Average	**$ 8,786**	**$ 45,636**	**$ 303,199**	**$ 232,748**	**$ 185,844**	**$ 776,214**
						Total	**$ 175,727**	**$ 912,723**	**$ 6,063,981**	**$ 4,654,955**	**$ 3,716,889**	**$ 15,524,275**

Note:

1. Assumes a 1.5% annual growth corresponding to projected traffic volume growth for subject corridor. 1.5% Growth is applied to year 2016 (base year) as well since emission data calculations are based on 2015 data. There are no concerns with regards to capacity constraints for this growth rate

2. Savings are based on 2016$

3. Assumes construction begins in 2020 and ends in 2022. Emission savings are first realized in 2023.

4. Assumes no new additional users. All users are existing regardless of whether the proposal is built or not.

Synchro ID	Aproach	Average Daily Traffic	Segment Legth (mi)	AM Peak - Existing					AM Peak - Proposed					OFF Peak - Existing					OFF Peak - Proposed				
				Avg. Speed per Veh (mph)	Equivalency Factors (g/mi) VOC	NOx	CO	PM	Avg. Speed per Veh (mph)	Equivalency Factors (g/mi) VOC	NOx	CO	PM	Avg. Speed per Veh (mph)	Equivalency Factors (g/mi) VOC	NOx	CO	PM	Avg. Speed per Veh (mph)	Equivalency Factors (g/mi) VOC	NOx	CO	PM
9	NB	48682	0.10	49	0.0807	0.3437	2.0550	0.0156	36	0.1021	0.3503	2.3177	0.0206	49	0.0807	0.3437	2.0550	0.0156	42	0.0902	0.3447	2.1410	0.0179
9	SB	1534	0.50	47	0.0830	0.3434	2.0675	0.0162	43	0.0886	0.3442	2.1206	0.0175	48	0.0819	0.3435	2.0612	0.0159	45	0.0854	0.3431	2.0799	0.0168
10	NB	49976	0.10	24	0.1406	0.4056	2.7640	0.0298	27	0.1290	0.3888	2.6279	0.0273	7	0.3894	0.7356	4.8430	0.0718	7	0.3894	0.7356	4.8430	0.0718
10	SB	50059	0.10	11	0.2516	0.5511	3.8606	0.0488	16	0.1899	0.4748	3.4179	0.0386	23	0.1457	0.4128	2.8582	0.0308	24	0.1406	0.4056	2.7640	0.0298
13	NB	48682	0.10	34	0.1073	0.3560	2.3944	0.0218	28	0.1257	0.3841	2.6069	0.0265	8	0.3480	0.6796	4.5466	0.0649	11	0.2516	0.5511	3.8606	0.0488
13	SB	1534	0.10	37	0.1000	0.3492	2.2837	0.0201	8	0.3480	0.6796	4.5466	0.0649	43	0.0886	0.3442	2.1206	0.0175	24	0.1406	0.4056	2.7640	0.0298
14	NB	48682	0.40	50	0.0795	0.3438	2.0488	0.0152	39	0.0956	0.3470	2.2157	0.0191	10	0.2651	0.5677	3.6540	0.0511	11	0.2516	0.5511	3.8606	0.0488
14	SB	1534	0.10	42	0.0902	0.3447	2.1410	0.0179	9	0.3066	0.6237	4.2503	0.0580	44	0.0870	0.3436	2.1003	0.0172	27	0.1290	0.3888	2.6279	0.0273
22	NB	48682	0.01	37	0.1000	0.3492	2.2837	0.0201	37	0.1000	0.3492	2.2837	0.0201	44	0.0870	0.3436	2.1003	0.0172	44	0.0870	0.3436	2.1003	0.0172
22	SB	1534	0.10	38	0.0978	0.3481	2.2497	0.0196	39	0.0956	0.3470	2.2157	0.0191	42	0.0902	0.3447	2.1410	0.0179	41	0.0918	0.3453	2.1613	0.0183
23	NB	44274	0.10	32	0.1132	0.3653	2.4797	0.0234	29	0.1224	0.3793	2.5859	0.0258	30	0.1192	0.3745	2.5650	0.0250	31	0.1162	0.3699	2.5223	0.0242
23	SB	43958	0.10	30	0.1192	0.3745	2.5650	0.0250	26	0.1322	0.3936	2.6488	0.0281	33	0.1103	0.3606	2.437	0.0226	32	0.1132	0.3653	2.4797	0.0234
28	NB	41699	0.40	35	0.1043	0.3514	2.3518	0.0210	40	0.0934	0.3459	2.1817	0.0186	39	0.0956	0.3470	2.2157	0.0191	43	0.0886	0.3442	2.1206	0.0175
28	SB	43395	0.20	30	0.1192	0.3745	2.5650	0.0250	34	0.1073	0.3560	2.3944	0.0218	35	0.1043	0.3514	2.3518	0.0210	36	0.1021	0.3503	2.3177	0.0206
31	NB	41767	0.20	31	0.1162	0.3699	2.5223	0.0242	37	0.1000	0.3492	2.2837	0.0201	33	0.1103	0.3606	2.437	0.0226	34	0.1073	0.3560	2.3944	0.0218
31	SB	44703	0.20	32	0.1132	0.3653	2.4797	0.0234	37	0.1000	0.3492	2.2837	0.0201	37	0.1000	0.3492	2.2837	0.0201	39	0.0956	0.3470	2.2157	0.0191
34	NB	40658	0.20	19	0.1683	0.4446	3.2102	0.0349	31	0.1162	0.3699	2.5223	0.0242	27	0.1290	0.3888	2.6279	0.0273	37	0.1000	0.3492	2.2837	0.0201
34	SB	46834	0.10	31	0.1162	0.3699	2.5223	0.0242	33	0.1103	0.3606	2.4370	0.0226	40	0.0934	0.3459	2.1817	0.0186	39	0.0956	0.3470	2.2157	0.0191
35	NB	43413	0.10	23	0.1457	0.4128	2.8582	0.0308	17	0.1827	0.4647	3.3487	0.0374	27	0.1290	0.3888	2.6279	0.0273	26	0.1322	0.3936	2.6488	0.0281
35	SB	46834	0.10	17	0.1827	0.4647	3.3487	0.0374	20	0.1610	0.4346	3.1409	0.0336	28	0.1257	0.3841	2.6069	0.0265	27	0.1290	0.3888	2.6279	0.0273
36	NB	43413	0.10	40	0.0934	0.3459	2.1817	0.0186	34	0.1073	0.3560	2.3944	0.0218	41	0.0918	0.3453	2.1613	0.0183	39	0.0956	0.3470	2.2157	0.0191
36	SB	42974	0.30	22	0.1508	0.4201	2.9525	0.0317	28	0.1257	0.3841	2.6069	0.0265	34	0.1073	0.3560	2.3944	0.0218	37	0.1000	0.3492	2.2837	0.0201
41	NB	39444	0.10	27	0.1290	0.3888	2.6279	0.0273	34	0.1073	0.3560	2.3944	0.0218	11	0.2516	0.5511	3.8606	0.0488	18	0.1755	0.4547	3.2794	0.0361
41	SB	43926	0.20	38	0.0978	0.3481	2.2497	0.0196	39	0.0956	0.3470	2.2157	0.0191	42	0.0902	0.3447	2.1410	0.0179	42	0.0902	0.3447	2.1410	0.0179
42	NB	43926	0.20	32	0.1132	0.3653	2.4797	0.0234	31	0.1162	0.3699	2.5223	0.0242	9	0.3066	0.6237	4.2503	0.0580	11	0.2516	0.5511	3.8606	0.0488
42	SB	47125	0.10	25	0.1356	0.3983	2.6698	0.0289	27	0.1290	0.3888	2.6279	0.0273	27	0.1290	0.3888	2.6279	0.0273	28	0.1257	0.3841	2.6069	0.0265
116	NB	48682	0.50	48	0.0819	0.3435	2.0612	0.0159	45	0.0854	0.3431	2.0799	0.0168	49	0.0807	0.3437	2.0550	0.0156	46	0.0842	0.3432	2.0737	0.0165
116	SB	1534	0.40	50	0.0795	0.3438	2.0488	0.0152	42	0.0902	0.3447	2.1410	0.0179	50	0.0795	0.3438	2.0488	0.0152	45	0.0854	0.3431	2.0799	0.0168
275	NB	36956	0.20	28	0.1257	0.3841	2.6069	0.0265	30	0.1192	0.3745	2.5650	0.0250	28	0.1257	0.3841	2.6069	0.0265	35	0.1043	0.3514	2.3518	0.0210
275	SB	39336	0.10	25	0.1356	0.3983	2.6698	0.0289	28	0.1257	0.3841	2.6069	0.0265	30	0.1192	0.3745	2.5650	0.0250	33	0.1103	0.3606	2.4370	0.0226
277	NB	42416	0.10	23	0.1457	0.4128	2.8582	0.0308	18	0.1755	0.4547	3.2794	0.0361	24	0.1406	0.4056	2.7640	0.0298	22	0.1508	0.4201	2.9525	0.0317
277	SB	43514	0.20	7	0.3894	0.7356	4.8430	0.0718	17	0.1827	0.4647	3.3487	0.0374	26	0.1322	0.3936	2.6488	0.0281	26	0.1322	0.3936	2.6488	0.0281
377	NB	37776	0.20	25	0.1356	0.3983	2.6698	0.0289	32	0.1132	0.3653	2.4797	0.0234	29	0.1224	0.3793	2.5859	0.0258	30	0.1192	0.3745	2.5650	0.0250
377	SB	38158	0.20	29	0.1224	0.3793	2.5859	0.0258	34	0.1073	0.3560	2.3944	0.0218	36	0.1021	0.3503	2.3177	0.0206	38	0.0978	0.3481	2.2497	0.0196
457	NB	46261	0.01	9	0.3066	0.6237	4.2503	0.0580	12	0.2380	0.5345	3.7673	0.0466	4	0.6836	1.1642	6.9812	0.1217	5	0.4723	0.8474	5.4356	0.0857
457	SB	5002	0.10	21	0.1559	0.4274	3.0467	0.0327	24	0.1406	0.4056	2.7640	0.0298	33	0.1103	0.3606	2.437	0.0226	33	0.1103	0.3606	2.4370	0.0226
458	NB	7889	0.10	37	0.1000	0.3492	2.2837	0.0201	39	0.0956	0.3470	2.2157	0.0191	29	0.1224	0.3793	2.5859	0.0258	28	0.1257	0.3841	2.6069	0.0265
458	SB	43978	0.30	17	0.1827	0.4647	3.3487	0.0374	28	0.1257	0.3841	2.6069	0.0265	28	0.1257	0.3841	2.6069	0.0265	29	0.1224	0.3793	2.5859	0.0258
530	NB	32896	0.20	23	0.1457	0.4128	2.8582	0.0308	40	0.0934	0.3459	2.1817	0.0186	29	0.1224	0.3793	2.5859	0.0258	38	0.0978	0.3481	2.2497	0.0196
530	SB	18872	0.60	38	0.0978	0.3481	2.2497	0.0196	47	0.0830	0.3434	2.0675	0.0162	43	0.0886	0.3442	2.1206	0.0175	46	0.0842	0.3432	2.0737	0.0165
564	NB	2046	0.10	37	0.1000	0.3492	2.2837	0.0201	37	0.1000	0.3492	2.2837	0.0201	46	0.0842	0.3432	2.0737	0.0165	46	0.0842	0.3432	2.0737	0.0165
564	SB	26591	0.01	10	0.2651	0.5677	3.9540	0.0511	28	0.1257	0.3841	2.6069	0.0265	14	0.2108	0.5014	3.5805	0.0421	32	0.1132	0.3653	2.4797	0.0234
572	NB	48682	0.10	13	0.2244	0.5180	3.6739	0.0444	16	0.1899	0.4748	3.4179	0.0386	5	0.4723	0.8474	5.4356	0.0857	9	0.3066	0.6237	4.2503	0.0580
572	SB	1534	0.20	33	0.1103	0.3606	2.4370	0.0226	10	0.2651	0.5677	3.6540	0.0511	42	0.0902	0.3447	2.1410	0.0179	38	0.0978	0.3481	2.2497	0.0196
573	NB	2056	0.20	30	0.1192	0.3745	2.5650	0.0250	34	0.1073	0.3560	2.3944	0.0218	8	0.3480	0.6796	4.5466	0.0649	12	0.2380	0.5345	3.7673	0.0466
573	SB	46996	0.10	23	0.1457	0.4128	2.8582	0.0308	13	0.2244	0.5180	3.6739	0.0444	36	0.1021	0.3503	2.3177	0.0206	36	0.1021	0.3503	2.3177	0.0206
574	NB	43926	0.10	43	0.0886	0.3442	2.1206	0.0175	42	0.0902	0.3447	2.1410	0.0179	38	0.0978	0.3481	2.2497	0.0196	36	0.1021	0.3503	2.3177	0.0206
574	SB	41082	0.70	36	0.1021	0.3503	2.3177	0.0206	39	0.0956	0.3470	2.2157	0.0191	37	0.1000	0.3492	2.2837	0.0201	40	0.0934	0.3459	2.1817	0.0186
590	NB	39661	0.30	44	0.0870	0.3436	2.1003	0.0172	46	0.0842	0.3432	2.0737	0.0165	44	0.0870	0.3436	2.1003	0.0172	46	0.0842	0.3432	2.0737	0.0165
590	SB	41136	0.30	44	0.0870	0.3436	2.1003	0.0172	45	0.0854	0.3431	2.0799	0.0168	45	0.0854	0.3431	2.0799	0.0168	45	0.0854	0.3431	2.0799	0.0168
591	NB	39661	0.30	44	0.0870	0.3436	2.1003	0.0172	45	0.0854	0.3431	2.0799	0.0168	42	0.0902	0.3447	2.1410	0.0179	44	0.0870	0.3436	2.1003	0.0172
591	SB	41136	0.10	41	0.0918	0.3453	2.1613	0.0183	43	0.0886	0.3442	2.1206	0.0175	41	0.0918	0.3453	2.1613	0.0183	44	0.0870	0.3436	2.1003	0.0172
594	NB	16451	0.60	43	0.0886	0.3442	2.1206	0.0175	45	0.0854	0.3431	2.0799	0.0168	49	0.0807	0.3437	2.0550	0.0156	51	0.0787	0.3442	2.0509	0.0150
594	SB	20089	0.90	44	0.0870	0.3436	2.1003	0.0172	47	0.0830	0.3434	2.0675	0.0162	46	0.0842	0.3432	2.0737	0.0165	48	0.0819	0.3435	2.0612	0.0159
722	NB	39059	0.70	38	0.0978	0.3481	2.2497	0.0196	47	0.0830	0.3434	2.0675	0.0162	34	0.1073	0.3560	2.3944	0.0218	40	0.0934	0.3459	2.1817	0.0186
722	SB	43514	0.10	25	0.1356	0.3983	2.6698	0.0289	30	0.1192	0.3745	2.5650	0.0250	37	0.1000	0.3492	2.2837	0.0201	37	0.1000	0.3492	2.2837	0.0201
723	NB	42416	0.20	39	0.0956	0.3470	2.2157	0.0191	35	0.1043	0.3514	2.3518	0.0210	40	0.0934	0.3459	2.1817	0.0186	37	0.1000	0.3492	2.2837	0.0201
723	SB	38607	0.70	15	0.1972	0.4848	3.4871	0.0399	38	0.0978	0.3481	2.2497	0.0196	38	0.0978	0.3481	2.2497	0.0196	43	0.0886	0.3442	2.1206	0.0175
724	NB	35067	0.70	48	0.0819	0.3435	2.0612	0.0159	51	0.0787	0.3442	2.0509	0.0150	41	0.0918	0.3453	2.1613	0.0183	46	0.0842	0.3432	2.0737	0.0165
724	SB	39336	0.20	39	0.0956	0.3470	2.2157	0.0191	37	0.1000	0.3492	2.2837	0.0201	45	0.0854	0.3431	2.0799	0.0168	43	0.0886	0.3442	2.1206	0.0175
725	NB	36956	0.10	39	0.0956	0.3470	2.2157	0.0191	42	0.0902	0.3447	2.1410	0.0179	38	0.0978	0.3481	2.2497	0.0196	42	0.0902	0.3447	2.1410	0.0179
725	SB	36706	0.70	36	0.1021	0.3503	2.3177	0.0206	43	0.0886	0.3442	2.1206	0.0175	40	0.0934	0.3459	2.1817	0.0186	46	0.0842	0.3432	2.0737	0.0165
726	NB	33868	0.70	47	0.0830	0.3434	2.0675	0.0162	48	0.0819	0.3435	2.0612	0.0159	42	0.0902	0.3447	2.1410	0.0179	43	0.0886	0.3442	2.1206	0.0175
726	SB	38158	0.20	36	0.1021	0.3503	2.3177	0.0206	43	0.0886	0.3442	2.1206	0.0175	42	0.0902	0.3447	2.1410	0.0179	44	0.0870	0.3436	2.1003	0.0172
741	NB	37776	0.20	37	0.1000	0.3492	2.2837	0.0201	41	0.0918	0.3453	2.1613	0.0183	42	0.0902	0.3447	2.1410	0.0179	43	0.0886	0.3442	2.1206	0.0175
741	SB	35033	0.20	29	0.1224	0.3793	2.5859	0.0258	36	0.1021	0.3503	2.3177	0.0206	31	0.1162	0.3699	2.5223	0.0242	37	0.1000	0.3492	2.2837	0.0201
782	NB	42273	0.40	37	0.1000	0.3492	2.2837	0.0201	42	0.0902	0.3447	2.1410	0.0179	35	0.1043	0.3514	2.3518	0.0210	40	0.0934	0.3459	2.1817	0.0186
782	SB	43958	0.10	35	0.1043	0.3514	2.3518	0.0210	30	0.1192	0.3745	2.5650	0.0250	38	0.0978	0.3481	2.2497	0.0196	37	0.1000	0.3492	2.2837	0.0201
783	NB	48682	0.10	42	0.0902	0.3447	2.1410	0.0179	40	0.0934	0.3459	2.1817	0.0186	43	0.0886	0.3442	2.1206	0.0175	42	0.0902	0.3447	2.1410	0.0179
783	SB	41835	0.40	36	0.1021	0.3503	2.3177	0.0206	42	0.0902	0.3447	2.1410	0.0179	42	0.0902	0.3447	2.1410	0.0179	42	0.0902	0.3447	2.1410	0.0179
786	NB	17037	0.10	16	0.1899	0.4748	3.4179	0.0386	37	0.1000	0.3492	2.2837	0.0201	13	0.2244	0.5180	3.6739	0.0444	36	0.1021	0.3503	2.3177	0.0206
786	SB	14202	0.10	41	0.0918	0.3453	2.1613	0.0183	39	0.0956	0.3470	2.2157	0.0191	45	0.0854	0.3431	2.0799	0.0168	44	0.0870	0.3436	2.1003	0.0172
832	NB	16451	0.90	49	0.0807	0.3437	2.0550	0.0156	51	0.0787	0.3442	2.0509	0.0150	50	0.0795	0.3438	2.0488	0.0152	51	0.0787	0.3442	2.0509	0.0150
832	SB	15451	0.10	22	0.1508	0.4201	2.9525	0.0317	38	0.0978	0.3481	2.2497	0.0196	19	0.1683	0.4446	3.2102	0.0349	28	0.1257	0.3841	2.6069	0.0265
922	NB	44086	0.30	46	0.0842	0.3432	2.0737	0.0165	47	0.0830	0.3434	2.0675	0.0162	42	0.0902	0.3447	2.1410	0.0179	43	0.0886	0.3442	2.1206	0.0175
922	SB	42484	0.10	42	0.0902	0.3447	2.1410	0.0179	43	0.0886	0.3442	2.1206	0.0175	38	0.0978	0.3481	2.2497	0.0196	37	0.1000	0.3492	2.2837	0.0201
923	NB	44086	0.10	43	0.0886	0.3442	2.1206	0.0175	44	0.0870	0.3436	2.1003	0.0172	42	0.0902	0.3447	2.1410	0.0179	42	0.0902	0.3447	2.1410	0.0179
923	SB	42484	0.40	43	0.0886	0.3442	2.1206	0.0175	43	0.0886	0.3442	2.1206	0.0175	44	0.0870	0.3436	2.1003	0.0172	44	0.0870	0.3436	2.1003	0.0172
977	NB	48127	0.10	34	0.1073	0.3560	2.3944	0.0218	39	0.0956	0.3470	2.2157	0.0191	7	0.3894	0.7356	4.8430	0.0718	9	0.3066	0.6237	4.2503	0.0580
977	SB	46715	0.20	32	0.1132	0.3653	2.4797	0.0234	23	0.1457	0.4128	2.8582	0.0308	42	0.0902	0.3447	2.1410	0.0179	42	0.0902	0.3447	2.1410	0.0179
978	NB	2156	0.20	20	0.1610	0.4346	3.1409	0.0336	35	0.1043	0.3514	2.3518	0.0210	6	0.4308	0.7915	5.1393	0.0788	9	0.3066	0.6237	4.2503	0.0580
978	SB	46715	0.01	22	0.1508	0.4201	2.9525	0.0317	24	0.1406	0.4056	2.7640	0.0298	30	0.1192	0.3745	2.5650	0.0250	31	0.1162	0.3699	2.5223	0.0242
2091	NB	18401	0.01	26	0.1322	0.3936	2.6488	0.0281	18	0.1755	0.4547	3.2794	0.0361	25	0.1356	0.3983	2.6698	0.0289	20	0.1610	0.4346	3.1409	0.0336
2091	SB	14202	0.10	13	0.2244	0.5180	3.6739	0.0444	7	0.3894	0.7356	4.8430	0.0718	19	0.1683	0.4446	3.2102	0.0349	9	0.3066	0.6237	4.2503	0.0580
2092	NB	18401	0.10	13	0.2244	0.5180	3.6739	0.0444	7	0.3894	0.7356	4.8430	0.0718	23	0.1457	0.4128	2.8582	0.0308	10	0.2651	0.5677	3.954	0.0511
2092	SB	14202	0.01	21	0.1559	0.4274	3.0467	0.0327	10	0.2651	0.5677	3.6540	0.0511	24	0.1406	0.4056	2.7640	0.0298	14	0.2108	0.5014	3.5805	0.0421

Synchro ID	Aproach	Average Daily Traffic	Segment Legth (mi)	PM Peak - Existing Avg. Speed per Veh (mph)	Equivalency Factors (g/mi) VOC	NOx	CO	PM	PM Peak - Proposed Avg. Speed per Veh (mph)	Equivalency Factors (g/mi) VOC	NOx	CO	PM	VOC Savings (short ton/yr)	NOx Savings (short ton/yr)	CO Savings (metric ton/yr)	PM Savings (short ton/yr)
9	NB	48682	0.10	31	0.1162	0.3699	2.5223	0.0242	32	0.1132	0.3653	2.4797	0.0234	-0.0142	-0.0012	-0.1542	-0.0034
9	SB	1534	0.50	48	0.0819	0.3435	2.0612	0.0159	44	0.0870	0.3436	2.1003	0.0172	-0.0011	0.0000	-0.0078	-0.0003
10	NB	49976	0.10	7	0.3894	0.7356	4.8430	0.0718	6	0.4308	0.7915	5.1393	0.0788	-0.0108	-0.0143	-0.0709	-0.0017
10	SB	50059	0.10	13	0.2244	0.5180	3.6739	0.0444	15	0.1972	0.4848	3.4871	0.0399	0.0299	0.0378	0.3015	0.0051
13	NB	48682	0.10	7	0.3894	0.7356	4.8430	0.0718	9	0.3066	0.6237	4.2503	0.0580	0.1233	0.1640	0.9463	0.0202
13	SB	1534	0.10	38	0.0978	0.3481	2.2497	0.0196	7	0.3894	0.7356	4.8430	0.0718	-0.0066	-0.0085	-0.0715	-0.0013
14	NB	48682	0.40	5	0.4723	0.8474	5.4356	0.0857	5	0.4723	0.8474	5.4356	0.0857	0.0410	0.0665	-1.1324	0.0059
14	SB	1534	0.10	43	0.0886	0.3442	2.1206	0.0175	11	0.2516	0.5511	3.8606	0.0488	-0.0047	-0.0057	-0.0564	-0.0010
22	NB	48682	0.01	34	0.1073	0.3560	2.3944	0.0218	20	0.161	0.4346	3.1409	0.0336	-0.0017	-0.0025	-0.0265	-0.0004
22	SB	1534	0.10	39	0.0956	0.3470	2.2157	0.0191	40	0.0934	0.3459	2.1817	0.0186	0.0000	0.0000	-0.0001	0.0000
23	NB	44274	0.10	26	0.1322	0.3936	2.6488	0.0281	22	0.1508	0.4201	2.9525	0.0317	-0.0046	-0.0065	-0.0790	-0.0008
23	SB	43958	0.10	24	0.1406	0.4056	2.7640	0.0298	20	0.161	0.4346	3.1409	0.0336	-0.0115	-0.0171	-0.1856	-0.0025
28	NB	41699	0.40	35	0.1043	0.3514	2.3518	0.021	34	0.1073	0.3560	2.3944	0.0218	0.0309	0.0095	0.4798	0.0069
28	SB	43395	0.20	30	0.1192	0.3745	2.565	0.025	32	0.1132	0.3653	2.4797	0.0234	0.0127	0.0153	0.2053	0.0030
31	NB	41767	0.20	33	0.1103	0.3606	2.4370	0.0226	34	0.1073	0.3560	2.3944	0.0218	0.0138	0.0194	0.2195	0.0036
31	SB	44703	0.20	26	0.1322	0.3936	2.6488	0.0281	32	0.1132	0.3653	2.4797	0.0234	0.0256	0.0282	0.3505	0.0062
34	NB	40658	0.20	22	0.1508	0.4201	2.9525	0.0317	23	0.1457	0.4128	2.8582	0.0308	0.0746	0.1035	1.0263	0.0174
34	SB	46834	0.10	38	0.0978	0.3481	2.2497	0.0196	36	0.1021	0.3503	2.3177	0.0206	-0.0022	0.0004	-0.0392	-0.0004
35	NB	43413	0.10	18	0.1755	0.4547	3.2794	0.0361	17	0.1827	0.4647	3.3487	0.0374	-0.0131	-0.0186	-0.1601	-0.0025
35	SB	46834	0.10	25	0.1356	0.3983	2.6698	0.0289	24	0.1406	0.4056	2.7640	0.0298	0.0002	0.0000	-0.0023	-0.0002
36	NB	43413	0.10	34	0.1073	0.3560	2.3944	0.0218	33	0.1103	0.3606	2.4370	0.0226	-0.0074	-0.0051	-0.1201	-0.0017
36	SB	42974	0.30	29	0.1224	0.3793	2.5859	0.0258	31	0.1162	0.3699	2.5223	0.0242	0.0417	0.0500	0.6424	0.0094
41	NB	39444	0.10	9	0.3066	0.6237	4.2503	0.0580	14	0.2108	0.5014	3.5805	0.0421	0.0940	0.1203	0.7872	0.0160
41	SB	43926	0.20	43	0.0886	0.3442	2.1206	0.0175	43	0.0886	0.3442	2.1206	0.0175	0.0010	0.0005	0.0164	0.0002
42	NB	43926	0.20	9	0.3066	0.6237	4.2503	0.0580	11	0.2516	0.5511	3.8606	0.0488	0.1348	0.1776	1.0417	0.0224
42	SB	47125	0.10	28	0.1257	0.3841	2.6069	0.0265	28	0.1257	0.3841	2.6069	0.0265	0.0049	0.0070	0.0343	0.0012
116	NB	48682	0.50	12	0.2380	0.5345	3.7673	0.0466	12	0.2380	0.5345	3.7673	0.0466	-0.0226	0.0031	-0.1329	-0.0058
116	SB	1534	0.40	50	0.0795	0.3438	2.0488	0.0152	41	0.0918	0.3453	2.1613	0.0183	-0.0016	0.0000	-0.0127	-0.0004
275	NB	36956	0.20	11	0.2516	0.5511	3.8606	0.0488	29	0.1224	0.3793	2.5859	0.0258	0.0997	0.1397	1.1521	0.0206
275	SB	39336	0.10	26	0.1322	0.3936	2.6488	0.0281	28	0.1257	0.3841	2.6069	0.0265	0.0112	0.0170	0.1450	0.0029
277	NB	42416	0.10	14	0.2108	0.5014	3.5805	0.0421	16	0.1899	0.4748	3.4179	0.0386	-0.0097	-0.0146	-0.2372	-0.0019
277	SB	43514	0.20	24	0.1406	0.4056	2.7640	0.0298	24	0.1406	0.4056	2.7640	0.0298	0.0894	0.1172	0.7120	0.0149
377	NB	37776	0.20	7	0.3894	0.7356	4.8430	0.0718	8	0.348	0.6796	4.5466	0.0649	0.0343	0.0482	0.2796	0.0068
377	SB	38158	0.20	3	0.81038	1.3542	7.90848	0.1433	4	0.6836	1.1642	6.9812	0.1217	0.0769	0.1086	0.7198	0.0141
457	NB	46261	0.01	4	0.6836	1.1642	6.9812	0.1217	5	0.4723	0.8474	5.4356	0.0857	0.0291	0.0433	0.2341	0.0050
457	SB	5002	0.10	23	0.1457	0.4128	2.8582	0.0308	24	0.1406	0.4056	2.7640	0.0298	0.0005	0.0008	0.0112	0.0001
458	NB	7889	0.10	26	0.1322	0.3936	2.6488	0.0281	25	0.1356	0.3983	2.6698	0.0289	-0.0006	-0.0010	-0.0022	-0.0001
458	SB	43978	0.30	11	0.2516	0.5511	3.8606	0.0488	13	0.2244	0.5180	3.6739	0.0444	0.0705	0.0954	0.7814	0.0130
530	NB	32896	0.20	24	0.1406	0.4056	2.7640	0.0298	27	0.1290	0.3888	2.6279	0.0273	0.0570	0.0734	0.8338	0.0139
530	SB	18872	0.60	2	2.2373	3.7023	21.3167	0.3941	4	0.6836	1.1642	6.9812	0.1217	1.1850	1.9098	12.0886	0.2088
564	NB	2046	0.10	31	0.1162	0.3699	2.5223	0.0242	21	0.1559	0.4274	3.0467	0.0327	-0.0005	-0.0008	-0.0078	-0.0001
564	SB	26591	0.01	10	0.2651	0.5677	3.954	0.0511	23	0.1457	0.4128	2.8582	0.0308	0.0095	0.0130	0.1103	0.0018
572	NB	48682	0.10	6	0.4308	0.7915	5.1393	0.0788	8	0.348	0.6796	4.5466	0.0649	0.2088	0.2811	1.6479	0.0349
572	SB	1534	0.20	36	0.1021	0.3503	2.3177	0.0206	8	0.348	0.6796	4.5466	0.0649	-0.0079	-0.0101	-0.0783	-0.0014
573	NB	2056	0.20	5	0.4723	0.8474	5.4356	0.0857	9	0.3066	0.6237	4.2503	0.0580	0.0145	0.0193	0.1154	0.0024
573	SB	46996	0.10	27	0.1290	0.3888	2.6279	0.0273	10	0.2651	0.5677	3.954	0.0511	-0.0608	-0.0803	-0.6648	-0.0106
574	NB	43926	0.10	32	0.1132	0.3653	2.4797	0.0234	32	0.1132	0.3653	2.4797	0.0234	-0.0044	-0.0022	-0.0758	-0.0010
574	SB	41082	0.70	38	0.0978	0.3481	2.2497	0.0196	37	0.1000	0.3492	2.2837	0.0201	0.0460	0.0231	0.7851	0.0105
590	NB	39661	0.30	44	0.0870	0.3436	2.1003	0.0172	44	0.0870	0.3436	2.1003	0.0172	0.0088	0.0013	0.0924	0.0022
590	SB	41136	0.30	46	0.0842	0.3432	2.0737	0.0165	46	0.0842	0.3432	2.0737	0.0165	0.0010	0.0003	0.0138	0.0002
591	NB	39661	0.30	30	0.1192	0.3745	2.565	0.025	38	0.0978	0.3481	2.2497	0.0196	0.0260	0.0239	0.4020	0.0063
591	SB	41136	0.10	43	0.0886	0.3442	2.1206	0.0175	45	0.0854	0.3431	2.0799	0.0168	0.0058	0.0020	0.0809	0.0013
594	NB	16451	0.60	44	0.0870	0.3436	2.1003	0.0172	48	0.0819	0.3435	2.0612	0.0159	0.0092	-0.0005	0.0598	0.0025
594	SB	20089	0.90	11	0.2516	0.5511	3.8606	0.0488	45	0.0854	0.3431	2.0799	0.0168	0.2117	0.2482	2.4363	0.0416
722	NB	39059	0.70	33	0.1103	0.3606	2.4370	0.0226	41	0.0918	0.3453	2.1613	0.0183	0.1355	0.0936	2.2027	0.0313
722	SB	43514	0.10	37	0.1000	0.3492	2.2837	0.0201	37	0.1000	0.3492	2.2837	0.0201	0.0035	0.0051	0.0250	0.0008
723	NB	42416	0.20	25	0.1356	0.3983	2.6698	0.0289	29	0.1224	0.3793	2.5859	0.0258	-0.0083	0.0028	-0.2165	-0.0018
723	SB	38607	0.70	39	0.0956	0.3470	2.2157	0.0191	37	0.1000	0.3492	2.2837	0.0201	0.1792	0.2024	2.5245	0.0377
724	NB	35067	0.70	21	0.1559	0.4274	3.0467	0.0327	43	0.0886	0.3442	2.1206	0.0175	0.1536	0.1456	2.1835	0.0353
724	SB	39336	0.20	42	0.0902	0.3447	2.1410	0.0179	42	0.0902	0.3447	2.1410	0.0179	-0.0071	-0.0027	-0.1053	-0.0016
725	NB	36956	0.10	16	0.1899	0.4748	3.4179	0.0386	38	0.0978	0.3481	2.2497	0.0196	0.0296	0.0342	0.4256	0.0062
725	SB	36706	0.70	39	0.0956	0.3470	2.2157	0.0191	41	0.0918	0.3453	2.1613	0.0183	0.0746	0.0256	1.0377	0.0169
726	NB	33868	0.70	8	0.348	0.6796	4.5466	0.0649	10	0.2651	0.5677	3.954	0.0511	0.1397	0.1783	1.1485	0.0241
726	SB	38158	0.20	29	0.1224	0.3793	2.5859	0.0258	38	0.0978	0.3481	2.2497	0.0196	0.0228	0.0199	0.3433	0.0055
741	NB	37776	0.20	17	0.1827	0.4647	3.3487	0.0374	14	0.2108	0.5014	3.5805	0.0421	-0.0084	-0.0161	-0.0406	-0.0010
741	SB	35033	0.20	2	2.2373	3.7023	21.3167	0.3941	2	2.2373	3.7023	21.3167	0.3941	0.0315	0.0413	0.4995	0.0080
782	NB	42273	0.40	31	0.1162	0.3699	2.5223	0.0242	39	0.0956	0.3470	2.2157	0.0191	0.0710	0.0495	1.1930	0.0163
782	SB	43958	0.10	37	0.1000	0.3492	2.2837	0.0201	29	0.1224	0.3793	2.5859	0.0258	-0.0119	-0.0149	-0.1837	-0.0030
783	NB	48682	0.10	36	0.1021	0.3503	2.3177	0.0206	32	0.1132	0.3653	2.4797	0.0234	-0.0060	-0.0057	-0.0920	-0.0015
783	SB	41835	0.40	24	0.1406	0.4056	2.7640	0.0298	30	0.1192	0.3745	2.565	0.025	0.0336	0.0391	0.4050	0.0076
786	NB	17037	0.10	6	0.4308	0.7915	5.1393	0.0788	22	0.1508	0.4201	2.9525	0.0317	0.0841	0.1141	0.9259	0.0156
786	SB	14202	0.10	44	0.0870	0.3436	2.1003	0.0172	44	0.0870	0.3436	2.1003	0.0172	-0.0008	-0.0003	-0.0111	-0.0002
832	NB	16451	0.90	40	0.0934	0.3459	2.1817	0.0186	48	0.0819	0.3435	2.0612	0.0159	0.0153	0.0007	0.1262	0.0037
832	SB	15451	0.10	17	0.1827	0.4647	3.3487	0.0374	22	0.1508	0.4201	2.9525	0.0317	0.0215	0.0302	0.3253	0.0043
922	NB	44086	0.30	31	0.1162	0.3699	2.5223	0.0242	31	0.1162	0.3699	2.5223	0.0242	0.0053	0.0013	0.0685	0.0013
922	SB	42484	0.10	30	0.1192	0.3745	2.565	0.025	32	0.1132	0.3653	2.4797	0.0234	0.0000	0.0017	-0.0031	0.0001
923	NB	44086	0.10	34	0.1073	0.3560	2.3944	0.0218	34	0.1073	0.3560	2.3944	0.0218	0.0004	0.0001	0.0049	0.0001
923	SB	42484	0.40	30	0.1192	0.3745	2.565	0.025	33	0.1103	0.3606	2.4370	0.0226	0.0100	0.0157	0.1588	0.0027
977	NB	48127	0.10	4	0.6836	1.1642	6.9812	0.1217	5	0.4723	0.8474	5.4356	0.0857	0.1560	0.2192	1.2668	0.0264
977	SB	46715	0.20	32	0.1132	0.3653	2.4797	0.0234	22	0.1508	0.4201	2.9525	0.0317	-0.0384	-0.0560	-0.5161	-0.0086
978	NB	2156	0.20	5	0.4723	0.8474	5.4356	0.0857	7	0.3894	0.7356	4.8430	0.0718	0.0151	0.0206	0.1282	0.0026
978	SB	46715	0.01	14	0.2108	0.5014	3.5805	0.0421	14	0.2108	0.5014	3.5805	0.0421	0.0005	0.0008	0.0096	0.0001
2091	NB	18401	0.01	23	0.1457	0.4128	2.8582	0.0308	18	0.1755	0.4547	3.2794	0.0361	-0.0018	-0.0025	-0.0326	-0.0003
2091	SB	14202	0.10	14	0.2108	0.5014	3.5805	0.0421	11	0.2516	0.5511	3.8606	0.0488	-0.0578	-0.0748	-0.4704	-0.0096
2092	NB	18401	0.10	18	0.1755	0.4547	3.2794	0.0361	10	0.2651	0.5677	3.954	0.0511	-0.0733	-0.0951	-0.6868	-0.0124
2092	SB	14202	0.01	22	0.1508	0.4201	2.9525	0.0317	20	0.161	0.4346	3.1409	0.0336	-0.0030	-0.0041	-0.0342	-0.0005

Source:

1. Average Daily Traffic -- Kimley-Horn of Michigan, Inc. 2015 Traffic Data Collection by Intersection.
2. Average Vehicle Speed, Segment Length -- Synchro & Simtraffic simulation models for 2015 Traffic Data
3. Emission Equivalency Factors - Michigan Department of Transportation (MDOT). CMAQ Emissions Factors Table (Statewide). Accessed February 2017. http://www.michigan.gov/documents/mdot/MDOT_CMAQ_EmissionFactorsTables_437123_7.pdf
4. Emission Estimations - Michigan Department of Transportation (MDOT) & South Eastern Michigan Council of Govenrments (SEMCOG). Emissions from Freeway and Arterial Travel. http://www.michigan.gov/mdot/0,4616,7-151-9621_11041_60661---,00.htm

Note:

1. Average vehicle speeds for each time period of the day (i.e. AM, PM, Off peak) are calculated using Synchro and Sim Traffic for Existing conditions and Proposed conditions in the subject corridor
2. Based on 2015 Traffic Data by Kimley-Horn of Michigan, Inc., Peak volume (i.e. 7AM-9AM & 3PM-6PM) applys to 35% of the Average Daily Traffic; 15% for AM peak and 20% for PM peak
3. All values presented in the above table are based on and represent 2015 data. A 1.5% annual growth rate will be applied for future years. The 1.5% annual growth corresponds to a projected growth in traffic volumes for the subject coridor
4. Positive (+) values represent reduction in emissions; Negative (-) values represent increases in emissions
5. A linear interpolation is applied to calculate intermediate speeds (i.e. between 2.5 mph to 5 mph) as indidcated in the MDOT emmission equivalency factor guidelines (See Source 2)
6. Equivalency factors represent are based for All Vehicles and assuming a 20 year project life
7. Carbon Monoxide (CO) has been included in the emission calculations as this is common reported pollutant in Michigan transportation projects similar to VOCs, NOx, PM, SO_2, and CO_2 as indicate in Source 2 and 3 above
8. 1 metric ton = 1.1015 short ton
9. Emissions estimations are based on MDOTs and SEMCOG Arterial Travel Emission estimation formula (pg 14 of Appendix D of the following report):
http://www.michigan.gov/documents/deq/deq-aqd-air-aqe-sip-pm25-appendixD_223436_7.pdf

$$E_i = \sum [ADT_i * L_i * P_{n-i} * (EF_{B-i} - EF_{A-i})]$$

Where,
E_i Emission for segment i
ADT_i 2015 Average Annual Daily Traffic of segment i
L_i Miles of arterial roadway affected for segment i
P_{n-i} Proportion of travel of segment I in peak period n (off peak is 1-sum of P)
EF_{A-i} Emission Factor after implemention for segment i
EF_{B-i} Emission Factor before implemention for segment i

Tab 12. Emissions - Calc (CO2)

Synchro ID	Aproach	Average Daily Traffic	Segment Legth (mi)	AM Peak - Existing		AM Peak - Proposed		OFF Peak - Existing		OFF Peak - Proposed		PM Peak - Existing		PM Peak - Proposed		CO_2 Savings (short ton/yr)
				Avg. Speed per Veh (mph)	CO2 Emmission (g/mi)	Avg. Speed per Veh (mph)	CO2 Emmission (g/mi)	Avg. Speed per Veh (mph)	CO2 Emmission (g/mi)	Avg. Speed per Veh (mph)	CO2 Emmission (g/mi)	Avg. Speed per Veh (mph)	CO2 Emmission (g/mi)	Avg. Speed per Veh (mph)	CO2 Emmission (g/mi)	
9	NB	48682	0.10	49	325	36	335	49	325	42	329	31	347	32	344	-5.52506
9	SB	1534	0.50	47	325	43	327	48	325	45	325	48	325	44	326	-0.15885
10	NB	49976	0.10	24	385	27	365	7	958	7	958	7	958	6	1035	-20.70045
10	SB	50059	0.10	11	686	16	510	23	395	24	385	13	609	15	531	80.34748
13	NB	48682	0.10	34	339	28	360	8	880	11	686	7	958	9	803	248.08346
13	SB	1534	0.10	37	334	8	880	43	327	24	385	38	333	7	958	-12.40736
14	NB	48682	0.40	50	325	39	332	10	725	11	686	5	1113	5	1113	155.50838
14	SB	1534	0.10	42	329	9	803	44	326	27	365	43	327	11	686	-8.53971
22	NB	48682	0.01	37	334	37	334	44	326	44	326	34	339	20	425	-2.77463
22	SB	1534	0.10	38	333	39	332	42	329	41	330	39	332	40	331	-0.02351
23	NB	44274	0.10	32	344	29	355	30	350	31	347	26	370	22	405	-9.95788
23	SB	43958	0.10	30	350	26	370	33	342	32	344	24	385	20	425	-18.62653
28	NB	41699	0.40	35	336	40	331	39	332	43	327	35	336	34	339	18.17020
28	SB	43395	0.20	30	350	34	339	35	336	36	335	30	350	32	344	9.77816
31	NB	41767	0.20	31	347	37	334	33	342	34	339	33	342	34	339	11.86795
31	SB	44703	0.20	32	344	37	334	37	334	39	332	26	370	32	344	23.51575
34	NB	40658	0.20	19	446	31	347	27	365	37	334	22	405	23	395	99.26006
34	SB	46834	0.10	31	347	33	342	40	331	39	332	38	333	36	335	-0.34918
35	NB	43413	0.10	23	395	17	489	27	365	26	370	18	468	17	489	-31.01896
35	SB	46834	0.10	17	489	20	425	28	360	27	365	25	375	24	385	6.69266
36	NB	43413	0.10	40	331	34	339	41	330	39	332	34	339	33	342	-4.56743
36	SB	42974	0.30	22	405	28	360	34	339	37	334	29	355	31	347	48.64787
41	NB	39444	0.10	27	365	34	339	11	686	18	468	9	803	14	570	251.71982
41	SB	43926	0.20	38	333	39	332	42	329	42	329	43	327	43	327	0.43667
42	NB	43926	0.20	32	344	31	347	9	803	11	686	9	803	11	686	286.45415
42	SB	47125	0.10	25	375	27	365	27	365	28	360	28	360	28	360	7.41743
116	NB	48682	0.50	48	325	45	325	49	325	46	325	12	648	12	648	0.00000
116	SB	1534	0.40	50	325	42	329	50	325	45	325	50	325	41	330	-0.31770
275	NB	36956	0.20	28	360	30	350	28	360	35	336	11	686	29	355	203.74239
275	SB	39336	0.10	25	375	28	360	30	350	33	342	26	370	28	360	12.52953
277	NB	42416	0.10	23	395	18	468	24	385	22	405	14	570	16	510	-16.69059
277	SB	43514	0.20	7	803	17	489	26	370	26	370	24	385	24	385	135.71953
377	NB	37776	0.20	25	375	32	344	29	355	30	350	7	958	8	880	58.39504
377	SB	38158	0.20	29	355	34	339	36	335	38	333	3	1246	4	1179	43.07483
457	NB	46261	0.01	9	803	12	648	4	1179	5	958	4	1179	5	1113	27.69500
457	SB	5002	0.10	21	415	24	385	33	342	33	342	23	395	24	385	1.07737
458	NB	7889	0.10	37	334	39	332	29	355	28	360	26	370	25	375	-1.03259
458	SB	43978	0.30	17	489	28	360	28	360	29	355	11	686	13	609	166.40348
530	NB	32896	0.20	23	395	40	331	29	355	38	333	24	385	27	365	60.38947
530	SB	18872	0.60	38	333	47	325	43	327	46	325	2	1313	4	1179	110.79719
564	NB	2046	0.10	37	334	37	334	46	325	46	325	31	347	21	415	-0.91866
564	SB	26591	0.01	10	725	28	360	14	570	32	344	10	725	23	395	23.55497
572	NB	48682	0.10	13	609	16	510	5	1113	9	803	6	1035	8	880	398.95402
572	SB	1534	0.20	33	342	10	725	42	329	38	333	36	335	8	880	-17.21793
573	NB	2056	0.20	30	350	34	339	8	880	12	648	5	1113	9	803	29.26478
573	SB	46996	0.10	23	395	13	609	36	335	36	335	27	365	10	725	-162.05540
574	NB	43926	0.10	43	327	42	329	38	333	36	335	32	344	32	344	-2.16515
574	SB	41082	0.70	36	335	39	332	37	334	40	331	38	333	37	334	20.96431
590	NB	39661	0.30	44	326	46	325	44	326	46	325	44	326	44	326	3.94270
590	SB	41136	0.30	44	326	45	325	45	325	45	325	46	325	46	325	0.76675
591	NB	39661	0.30	44	326	45	325	42	329	44	326	30	350	38	333	20.35417
591	SB	41136	0.10	41	330	43	327	41	330	44	326	43	327	45	325	4.51530
594	NB	16451	0.60	43	327	45	325	49	325	51	325	44	326	48	325	2.04424
594	SB	20089	0.90	44	326	47	325	46	325	48	325	11	686	45	325	433.98293
722	NB	39059	0.70	38	333	47	325	34	339	40	331	33	342	41	330	78.14238
722	SB	43514	0.10	25	375	30	350	37	334	37	334	37	334	37	334	5.40715
723	NB	42416	0.20	39	332	35	336	40	331	37	334	25	375	29	355	4.07602
723	SB	38607	0.70	15	531	38	333	38	333	43	327	39	332	37	334	295.85549
724	NB	35067	0.70	48	325	51	325	41	330	46	325	21	415	43	327	168.78083
724	SB	39336	0.20	39	332	37	334	45	325	43	327	42	329	42	329	-5.01833
725	NB	36956	0.10	39	331	42	329	38	333	42	329	16	510	38	333	47.33069
725	SB	36706	0.70	36	335	43	327	40	331	46	325	39	332	41	330	48.31804
726	NB	33868	0.70	47	325	48	325	42	329	43	327	8	880	10	725	249.91582
726	SB	38158	0.20	36	335	43	327	42	329	44	326	29	355	38	333	18.04970
741	NB	37776	0.20	37	334	41	330	42	329	43	327	17	489	14	570	-37.05237
741	SB	35033	0.20	29	355	36	335	31	347	37	334	2	1313	2	1313	26.49699
782	NB	42273	0.40	37	334	42	329	35	336	40	331	31	347	39	332	39.64221
782	SB	43958	0.10	35	336	30	350	38	333	37	334	37	334	29	355	-9.99606
783	NB	48682	0.10	42	329	40	331	43	327	42	329	36	335	32	344	-4.89997
783	SB	41835	0.40	36	335	42	329	42	329	42	329	24	385	30	350	44.22204
786	NB	17037	0.10	16	510	37	334	13	609	36	335	6	1035	22	405	186.37873
786	SB	14202	0.10	41	330	39	332	45	325	44	326	44	326	44	326	-0.54120
832	NB	16451	0.90	49	325	51	325	50	325	51	325	40	331	48	325	6.13272
832	SB	15451	0.10	22	405	38	333	19	446	28	360	17	489	22	405	42.78991
922	NB	44086	0.30	46	325	47	325	42	329	43	327	31	347	31	347	3.56085
922	SB	42484	0.10	42	329	43	327	38	333	37	334	30	350	32	344	0.89746
923	NB	44086	0.10	43	327	44	326	42	329	42	329	34	339	34	339	0.27391
923	SB	42484	0.40	43	327	43	327	44	326	44	326	30	350	33	342	9.29133
977	NB	48127	0.10	34	339	39	332	7	958	9	803	4	1179	5	1113	183.55100
977	SB	46715	0.20	32	344	23	395	42	329	42	329	32	344	22	405	-60.91292
978	NB	2156	0.20	20	425	35	336	6	1035	9	803	5	1113	7	958	27.92512
978	SB	46715	0.01	22	405	24	385	30	350	31	347	14	570	14	570	0.74109
2091	NB	18401	0.01	26	370	18	468	25	375	20	425	23	395	18	468	-3.75757
2091	SB	14202	0.10	13	609	7	803	19	446	9	803	14	570	11	686	-133.59340
2092	NB	18401	0.10	13	609	7	803	23	395	10	725	18	468	10	725	-179.91352
2092	SB	14202	0.01	21	415	10	725	24	385	14	570	22	405	20	425	-8.03561

Source:

1. Average Daily Traffic -- Kimley-Horn of Michigan, Inc. 2015 Traffic Data Collection by Intersection.

2. Average Vehicle Traveled Distance -- Synchro & Simtraffic simulation models for 2015 Traffic Data

3. CO_2 Emissions - M. Barth and K. Borioboonsomsin. Traffic Congestion and Greenhouse Gases. Access 35, 2009.

http://uctc.berkeley.edu/access/35/access35.pdf

Note:

1. CO_2 Emissions are based on the CO2 Emmission - Speed Curve as presented on Page 5 of the following journal: M. Barth and K. Boriboonsomsin. Traffic Congestion and Greenhouse Gases. Access 35, 2009.

2. Based on 2015 Traffic Data by Kimley-Horn of Michigan, Inc., Peak volume (i.e. AM, PM) applys to 35% of the Average Daily Traffic; 15% for AM peak and 20% for PM peai

3. All values presented in the above table are based on and represent 2015 data. A 1.5% annual growth rate will be applied for future years. The 1.5% annual growth corresponds to a projected growth in traffic volumes for the subject corido

4. Positive (+) values represent reductions in CO2; Negative (-) values represent increases in CO2

5. 1 metric ton = 1.1015 short ton

Emission type	$/short ton ($2016)
VOCs	$ 1,872
NOx	$ 7,377
PM	$ 337,459
SOx	$ 43,600

Source:
Corporate Average Fuel Economy For MY2017-2025 Passenger Cars and Light Trucks (August 2012), page 992, Table VIII-16, "Economic Values Used for Benefits Computations (2010 dollars)
http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/FRIA_2017-2025.pdf

Emission type	$/metric ton ($1989)*	$/metric ton ($2016)
CO	$ 2,714	$ 4,697.12

**Average cost of 18 regions in the US for 1989*

Source:
M.Q. Wang, D. J. Santini, and S.A. Warinner (1994), Methods of Valuing Air Poluution and Estimated Monetary Values of Air Pollutant in Various U.S. Regions, Argonne National Lab.
https://www.osti.gov/scitech/servlets/purl/10114725

Year	$/short ton ($2015)*	$/short ton ($2016)
2017	$ -	$ -
2018	$ -	$ -
2019	$ -	$ -
2020	$ -	$ -
2021	$ -	$ -
2022	$ 20.00	$ 20.26
2023	$ 20.75	$ 21.02
2024	$ 21.50	$ 21.78
2025	$ 22.25	$ 22.54
2026	$ 23.00	$ 23.30
2027	$ 23.75	$ 24.06
2028	$ 24.50	$ 24.82
2029	$ 25.25	$ 25.58
2030	$ 26.00	$ 26.34
2031	$ 29.00	$ 29.38
2032	$ 32.00	$ 32.42
2033	$ 35.00	$ 35.46
2034	$ 38.00	$ 38.50
2035	$ 41.00	$ 41.54
2036	$ 44.00	$ 44.58
2037	$ 47.00	$ 47.62
2038	$ 50.00	$ 50.66
2039	$ 53.00	$ 53.70
2040	$ 56.00	$ 56.74
2041	$ 58.50	$ 59.27
2042	$ 61.00	$ 61.81

**Value based on Mid Case*

Source:
P. Luckow, E. Stanton, S. Fields, W. Ong, B. Biewald, S. Jackson, J. Fisher. (2016) Spring 2016 National Carbon Dioxide Price Forecast. Synapse Energy Economics, Inc.
http://www.synapse-energy.com/sites/default/files/2016-Synapse-CO2-Price-Forecast-66-008.pdf

Year	Project Year	TOTAL Fuel Savings (gallons/yr)	TOTAL Fuel Savings ($2016)
2016	na	911,293	$ -
2017	na	924,963	$ -
2018	na	938,837	$ -
2019	na	952,920	$ -
eg Construction) 2020	Construction	967,213	$ -
2021	Construction	981,722	$ -
d Construction) 2022	Construction	996,447	$ -
2023	1	1,011,394	$ 2,275,637
2024	2	1,026,565	$ 2,309,771
2025	3	1,041,963	$ 2,344,418
2026	4	1,057,593	$ 2,379,584
2027	5	1,073,457	$ 2,415,278
2028	6	1,089,559	$ 2,451,507
2029	7	1,105,902	$ 2,488,280
2030	8	1,122,491	$ 2,525,604
2031	9	1,139,328	$ 2,563,488
2032	10	1,156,418	$ 2,601,940
2033	11	1,173,764	$ 2,640,969
2034	12	1,191,371	$ 2,680,584
2035	13	1,209,241	$ 2,720,793
2036	14	1,227,380	$ 2,761,605
2037	15	1,245,790	$ 2,803,029
2038	16	1,264,477	$ 2,845,074
2039	17	1,283,445	$ 2,887,750
2040	18	1,302,696	$ 2,931,066
2041	19	1,322,237	$ 2,975,032
2042	20	1,342,070	$ 3,019,658
		Average	**$ 2,631,053**
		Total	**$ 52,621,067**

Note:

1. Assumes a 1.5% annual growth corresponding to projected traffic volume growth for subject corridor. 1.5% Growth is applied to year 2016 (base year) as well since fuel consumption data calculations are based on 2015 data. There are no concerns with regards to capacity constraints for this growth rate.

2. Savings are based on 2016$

3. Assumes construction begins in 2020 and ends in 2022. Fuel consumption savings are first realized in 2023.

4. Assumes no new additional users. All users are existing regardless of whether the proposal is built or not.

Tab 15. Fuel Savings - Calc

Synchro ID	Aproach	Average Daily Traffic	Segment Legth (mi)	AM Peak - Existing Avg. Speed per Veh (mph)	AM Peak - Existing Fuel Consumption (mL/km)	AM Peak - Proposed Avg. Speed per Veh (mph)	AM Peak - Proposed Fuel Consumption (mL/km)	OFF Peak - Existing Avg. Speed per Veh (mph)	OFF Peak - Existing Fuel Consumption (mL/km)	OFF Peak - Proposed Avg. Speed per Veh (mph)	OFF Peak - Proposed Fuel Consumption (mL/km)	PM Peak - Existing Avg. Speed per Veh (mph)	PM Peak - Existing Fuel Consumption (mL/km)	PM Peak - Proposed Avg. Speed per Veh (mph)	PM Peak - Proposed Fuel Consumption (mL/km)	Fuel Savings (gallons/yr)
9	NB	48682	0.10	49	120	36	132	49	120	42	125	31	140	32	138	-3980
9	SB	1534	0.50	47	121	43	124	48	120	45	123	48	120	44	124	-318
10	NB	49976	0.10	24	156	27	148	7	327	7	327	7	327	6	367	-5335
10	SB	50059	0.10	11	239	16	191	23	159	24	156	13	215	15	198	9841
13	NB	48682	0.10	34	135	28	146	8	297	11	239	7	327	9	273	35218
13	SB	1534	0.10	37	131	8	297	43	124	24	156	38	130	7	327	-2012
14	NB	48682	0.40	50	119	39	128	10	254	11	239	5	423	5	423	25876
14	SB	1534	0.10	42	125	9	273	44	124	27	148	43	124	11	239	-1446
22	NB	48682	0.01	37	131	37	131	44	124	44	124	34	135	20	170	-526
22	SB	1534	0.10	38	130	39	128	42	125	41	126	39	128	40	127	-6
23	NB	44274	0.10	32	138	29	143	30	141	31	140	26	150	22	162	-1377
23	SB	43958	0.10	30	141	26	150	33	136	32	138	24	156	20	170	-3521
28	NB	41699	0.40	35	133	40	127	39	128	43	124	35	133	34	135	8397
28	SB	43395	0.20	30	141	34	135	35	133	36	132	30	141	32	138	3464
31	NB	41767	0.20	31	140	37	131	33	136	34	135	33	136	34	135	3381
31	SB	44703	0.20	32	138	37	131	37	131	39	128	26	150	32	138	6985
34	NB	40658	0.20	19	174	31	140	27	148	37	131	22	162	23	159	21252
34	SB	46834	0.10	31	140	33	136	40	127	39	128	38	130	36	132	-511
35	NB	43413	0.10	23	159	17	185	27	148	26	150	18	179	17	185	-4422
35	SB	46834	0.10	17	185	20	170	28	146	27	148	25	153	24	156	160
36	NB	43413	0.10	40	127	34	135	41	126	39	128	34	135	33	136	-1884
36	SB	42974	0.30	22	162	28	146	34	135	37	131	29	143	31	140	11694
41	NB	39444	0.10	27	148	34	135	11	239	18	179	9	273	14	206	33190
41	SB	43926	0.20	38	130	39	128	42	125	42	125	43	124	43	124	233
42	NB	43926	0.20	32	138	31	140	9	273	11	239	9	273	11	239	39246
42	SB	47125	0.10	25	153	27	148	27	148	28	146	28	146	28	146	1613
116	NB	48682	0.50	48	120	45	123	49	120	46	122	12	226	12	226	-6858
116	SB	1534	0.40	50	119	42	125	50	119	45	123	50	119	41	126	-466
275	NB	36956	0.20	28	146	30	141	28	146	35	133	11	239	29	143	31592
275	SB	39336	0.10	25	153	28	146	30	141	33	136	26	150	28	146	3265
277	NB	42416	0.10	23	159	18	179	24	156	22	162	14	206	16	191	-2770
277	SB	43514	0.20	7	327	17	185	26	150	26	150	24	156	24	156	28792
377	NB	37776	0.20	25	153	32	138	29	143	30	141	7	327	8	297	11166
377	SB	38158	0.20	29	143	34	135	36	132	38	130	3	649	4	508	36810
457	NB	46261	0.01	9	273	12	226	4	508	5	423	4	508	5	423	5666
457	SB	5002	0.10	21	166	24	156	33	136	33	136	23	159	24	156	165
458	NB	7889	0.10	37	131	39	128	29	143	28	146	26	150	25	153	-186
458	SB	43978	0.30	17	185	28	146	28	146	29	143	11	239	13	215	24461
530	NB	32896	0.20	23	159	40	127	29	143	38	130	24	156	27	148	15552
530	SB	18872	0.60	38	130	47	121	43	124	46	122	2	931	4	508	153772
564	NB	2046	0.10	37	131	37	131	46	122	46	122	31	140	21	166	-165
564	SB	26591	0.01	10	254	28	146	14	206	32	138	10	254	23	159	3285
572	NB	48682	0.10	13	215	16	191	5	423	9	273	6	367	8	297	87236
572	SB	1534	0.20	33	136	10	254	42	125	38	130	36	132	8	297	-2539
573	NB	2056	0.20	30	141	34	135	8	297	12	226	5	423	9	273	4905
573	SB	46996	0.10	23	159	13	215	36	132	36	132	27	148	10	254	-21721
574	NB	43926	0.10	43	124	42	125	38	130	36	132	32	138	32	138	-1191
574	SB	41082	0.70	36	132	39	128	37	131	40	127	38	130	37	131	11290
590	NB	39661	0.30	44	124	46	122	44	124	46	122	44	124	44	124	2469
590	SB	41136	0.30	44	124	45	123	45	123	45	123	46	122	46	122	245
591	NB	39661	0.30	44	124	45	123	42	125	44	124	30	141	38	130	6816
591	SB	41136	0.10	41	126	43	124	41	126	44	124	43	124	45	123	1574
594	NB	16451	0.60	43	124	45	123	49	120	51	118	44	124	48	120	2731
594	SB	20089	0.90	44	124	47	121	46	122	48	120	11	239	45	123	69015
722	NB	39059	0.70	38	130	47	121	34	135	40	127	33	136	41	126	34489
722	SB	43514	0.10	25	153	30	141	37	131	37	131	37	131	37	131	1142
723	NB	42416	0.20	39	128	35	133	40	127	37	131	25	153	29	143	-1455
723	SB	38607	0.70	15	198	38	130	38	130	43	124	39	128	37	131	55073
724	NB	35067	0.70	48	120	51	118	41	126	46	122	21	166	43	124	43679
724	SB	39336	0.20	39	128	37	131	45	123	43	124	42	125	42	125	-1817
725	NB	36956	0.10	39	128	42	125	38	130	42	125	16	191	38	130	8866
725	SB	36706	0.70	36	132	43	124	40	127	46	122	39	128	41	126	20555
726	NB	33868	0.70	47	121	48	120	42	125	43	124	8	297	10	254	33765
726	SB	38158	0.20	36	132	43	124	42	125	44	124	29	143	38	130	6039
741	NB	37776	0.20	37	131	41	126	42	125	43	124	17	185	14	206	-3501
741	SB	35033	0.20	29	143	36	132	31	140	37	131	2	931	2	931	8102
782	NB	42273	0.40	37	131	42	125	35	133	40	127	31	140	39	128	18318
782	SB	43958	0.10	35	133	30	141	38	130	37	131	37	131	29	143	-3078
783	NB	48682	0.10	42	125	40	127	43	124	42	125	36	132	32	138	-1575
783	SB	41835	0.40	36	132	42	125	42	125	42	125	24	156	30	141	9934
786	NB	17037	0.10	16	191	37	131	13	215	36	132	6	367	22	162	27504
786	SB	14202	0.10	41	126	39	128	45	123	44	124	44	124	44	124	-192
832	NB	16451	0.90	49	120	51	118	50	119	51	118	40	127	48	120	4695
832	SB	15451	0.10	22	162	38	130	19	174	28	146	17	185	22	162	6708
922	NB	44086	0.30	46	122	47	121	42	125	43	124	31	140	31	140	1490
922	SB	42484	0.10	42	125	43	124	38	130	37	131	30	141	32	138	42
923	NB	44086	0.10	43	124	44	124	42	125	42	125	34	135	34	135	92
923	SB	42484	0.40	43	124	43	124	44	124	44	124	30	141	33	136	2703
977	NB	48127	0.10	34	135	39	128	7	327	9	273	4	508	5	423	39411
977	SB	46715	0.20	32	138	23	159	42	125	42	125	32	138	22	162	-11464
978	NB	2156	0.20	20	170	35	133	6	367	9	273	5	423	7	327	5744
978	SB	46715	0.01	22	162	24	156	30	141	31	140	14	206	14	206	155
2091	NB	18401	0.01	26	150	18	179	25	153	20	170	23	159	18	179	-554
2091	SB	14202	0.10	13	215	7	327	19	174	9	273	14	206	11	239	-19308
2092	NB	18401	0.10	13	215	7	327	23	159	10	254	18	179	10	254	-26813
2092	SB	14202	0.01	21	166	10	254	24	156	14	206	22	162	20	170	-1048

Source:

1. Average Daily Traffic -- Kimley-Horn of Michigan, Inc. 2015 Traffic Data Collection by Intersection.

2. Average Vehicle Traveled Distance -- Synchro & Simtraffic simulation models for 2015 Traffic Data

3. Fuel Consumption -- L. Evans and R. Herman. Urban Fuel Economy - Computer Simulation Calculations Interpreted in Terms of Simple Mode. Transportation Research, 1978 (b).

-- L. Evans and R. Herman. A simplified approach to calculations of fuel consumptions in urban traffic systems. Traffic Eng. Control 17, 18(9), pp. 352-54 1976.

Note:

1 . Based on 2015 Traffic Data by Kimley-Horn of Michigan, Inc., Peak volume (i.e. 7AM-9AM & 3PM-6PM) applys to 35% of the Average Daily Traffic; 15% for AM peak and 20% for PM peak

2. All values presented in the above table are based on and represent 2015 data. A 1.5% annual growth rate will be applied for future years. The 1.5% annual growth corresponds to a projected growth in traffic volumes for the subject coridor.

3. Positive (+) values represent reductions in fuel consumption; Negative (-) values represent increases in fuel consumption

4. Fuel Consumption is based on the Fuel Consumption formula established Evans and Herman (1976, 1978) in the metropolitan Detroit area and which is applicable for low and mid-range speeds, where:

$$F_i = \frac{k_1}{V_i} + k_2$$

Where, F_i Fuel consumption for segment i per unit distance (mL/km)

V_i Average travel speed for segment I in km/h

k_1 Cosntant where k_1 = 2722 for medium cars (mL/h)

k_2 Constant where k_2 = 85.1 for medium cars (mL/km)

Note: 1 mph = 1.609344 kmh

1 mile = 1.60934 km

1 mL = 0.000264172

Retail Gasoline Price Year	$/gallon
2016	$ 2.25

Source:
US. Energy Information Administration (EIA), U.S. Annual Retail Gasoline and Diesel Price, 2016 Gasoline - All Grades, Release Date 8/14/2017, Accessed August, 2017
https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_a.htm

Year	Project Year	Connected Vehicle Market Penetration Rate[1]	TRAVEL TIME: Connected Vehicle MOBILITY Benefit[2]	TRAVEL TIME: TOTAL Travel Time Savings for All Purpose (hr/year)	TRAVEL TIME: TOTAL Travel Time Savings for Buses (hr/year)	TRAVEL TIME: TOTAL Travel Time Savings for Trucks (hr/year)	TRAVEL TIME: TOTAL Travel Time Savings From Connected Vehicles ($2016)	SAFETY: Connected Vehicle SAFETY Benefit[3]	SAFETY: TOTAL Crash Reduction O *(No Injury)*	SAFETY: TOTAL Crash Reduction C *(Possible Injury)*	SAFETY: TOTAL Crash Reduction B *(Non-Incapacitating)*	SAFETY: TOTAL Crash Reduction A *(Incapacitating)*	SAFETY: TOTAL Crash Reduction K *(Killed)*	SAFETY: TOTAL Safety Benefits From Connected Vehicles ($2016)
2016	na	0%	0%	-	-	-	$ -	0%	0.0	0.0	0.0	0.0	0.0	$ -
2017	na	0%	0%	-	-	-	$ -	0%	0.0	0.0	0.0	0.0	0.0	$ -
2018	na	0%	0%	-	-	-	$ -	0%	0.0	0.0	0.0	0.0	0.0	$ -
2019	na	0%	0%	-	-	-	$ -	0%	0.0	0.0	0.0	0.0	0.0	$ -
(Beg Construction) 2020	Construction	0%	0%	-	-	-	$ -	0%	0.0	0.0	0.0	0.0	0.0	$ -
2021	Construction	8%	2%	26,760	64	972	$ -	6%	5.2	0.4	0.1	0.0	0.0	$ -
(End Construction) 2022	Construction	15%	4%	95,491	230	3,469	$ -	12%	18.5	1.5	0.2	0.0	0.0	$ -
2023	1	22%	6%	208,492	501	7,574	**$ 3,159,927**	18%	40.5	3.2	0.5	0.1	0.0	**$ 711,268**
2024	2	29%	7%	367,710	884	13,358	**$ 5,573,059**	23%	71.4	5.7	0.9	0.2	0.0	**$ 1,254,441**
2025	3	35%	9%	543,641	1,307	19,749	**$ 8,239,480**	28%	105.6	8.4	1.3	0.2	0.1	**$ 1,854,626**
2026	4	41%	10%	757,199	1,820	27,507	**$ 11,476,183**	33%	147.1	11.8	1.8	0.3	0.1	**$ 2,583,176**
2027	5	47%	12%	1,009,959	2,427	36,689	**$ 15,307,051**	38%	196.2	15.7	2.4	0.4	0.1	**$ 3,445,467**
2028	6	52%	13%	1,254,818	3,016	45,583	**$ 19,018,162**	42%	243.7	19.5	3.0	0.5	0.2	**$ 4,280,801**
2029	7	57%	14%	1,530,347	3,678	55,593	**$ 23,194,104**	46%	297.2	23.7	3.7	0.7	0.2	**$ 5,220,765**
2030	8	62%	16%	1,837,764	4,417	66,760	**$ 27,853,342**	50%	356.9	28.5	4.4	0.8	0.2	**$ 6,269,514**
2031	9	67%	17%	2,178,321	5,236	79,131	**$ 33,014,869**	54%	423.1	33.8	5.3	0.9	0.3	**$ 7,431,323**
2032	10	71%	18%	2,482,876	5,968	90,195	**$ 37,630,736**	57%	482.2	38.5	6.0	1.1	0.3	**$ 8,470,309**
2033	11	75%	19%	2,812,075	6,759	102,153	**$ 42,620,112**	60%	546.2	43.6	6.8	1.2	0.4	**$ 9,593,369**
2034	12	79%	20%	3,166,829	7,612	115,041	**$ 47,996,800**	63%	615.1	49.1	7.6	1.4	0.4	**$ 10,803,609**
2035	13	82%	21%	3,463,093	8,324	125,803	**$ 52,487,012**	66%	672.6	53.7	8.3	1.5	0.5	**$ 11,814,311**
2036	14	85%	21%	3,776,942	9,078	137,204	**$ 57,243,745**	68%	733.6	58.6	9.1	1.6	0.5	**$ 12,885,005**
2037	15	87%	22%	4,016,123	9,653	145,893	**$ 60,868,799**	70%	780.0	62.3	9.7	1.7	0.5	**$ 13,700,969**
2038	16	89%	22%	4,265,939	10,253	154,968	**$ 64,655,025**	71%	828.5	66.2	10.3	1.9	0.6	**$ 14,553,211**
2039	17	91%	23%	4,526,718	10,880	164,441	**$ 68,607,422**	73%	879.2	70.3	10.9	2.0	0.6	**$ 15,442,857**
2040	18	93%	23%	4,798,799	11,534	174,325	**$ 72,731,117**	74%	932.0	74.5	11.6	2.1	0.6	**$ 16,371,060**
2041	19	94%	24%	4,976,092	11,960	180,765	**$ 75,418,190**	75%	966.5	77.2	12.0	2.2	0.7	**$ 16,975,894**
2042	20	95%	24%	5,158,768	12,399	187,401	**$ 78,186,838**	76%	1001.9	80.1	12.4	2.2	0.7	**$ 17,599,090**
Average							**$ 40,264,099**							**$ 9,063,053**
Total							**$ 805,281,976**							**$ 181,261,066**

Year	Project Year	Connected Vehicle Market Penetration Rate[1]	EMISSIONS: Connected Vehicle VOC EMISSION Benefit[4]	EMISSIONS: Connected Vehicle NOx EMISSION Benefit[4]	EMISSIONS: Connected Vehicle PM EMISSION Benefit[4]	EMISSIONS: Connected Vehicle CO EMISSION Benefit[4]	EMISSIONS: Connected Vehicle CO_2 EMISSION Benefit[4]	EMISSIONS: TOTAL VOC Savings (short ton/year)	EMISSIONS: TOTAL NOx Savings (short ton/year)	EMISSIONS: TOTAL PM Savings (short ton/year)	EMISSIONS: TOTAL CO Savings (metric ton/year)	EMISSIONS: TOTAL CO_2 Savings (short ton/year)	EMISSIONS: TOTAL Emission Savings From Connected Vehicles
2016	na	0%	0%	0%	0%	0%	0%	-	-	-	-	-	$ -
2017	na	0%	0%	0%	0%	0%	0%	-	-	-	-	-	$ -
2018	na	0%	0%	0%	0%	0%	0%	-	-	-	-	-	$ -
2019	na	0%	0%	0%	0%	0%	0%	-	-	-	-	-	$ -
(Beg Construction) 2020	Construction	0%	0%	0%	0%	0%	0%	-	-	-	-	-	$ -
2021	Construction	8%	1%	1%	2%	1%	1%	0.0	0.1	0.0	0.6	37.8	$ -
(End Construction) 2022	Construction	15%	2%	2%	3%	2%	1%	0.1	0.3	0.0	2.1	134.8	$ -
2023	1	22%	2%	3%	4%	3%	1%	0.2	0.8	0.1	4.6	294.4	**$ 55,148**
2024	2	29%	3%	4%	6%	4%	2%	0.3	1.3	0.1	8.2	519.2	**$ 97,658**
2025	3	35%	4%	5%	7%	5%	2%	0.5	2.0	0.2	12.1	767.6	**$ 144,965**
2026	4	41%	4%	6%	8%	5%	3%	0.7	2.8	0.2	16.8	1,069.1	**$ 202,724**
2027	5	47%	5%	7%	9%	6%	3%	0.9	3.7	0.3	22.4	1,426.0	**$ 271,479**
2028	6	52%	6%	8%	10%	7%	3%	1.1	4.6	0.4	27.9	1,771.8	**$ 338,644**
2029	7	57%	6%	9%	11%	8%	4%	1.3	5.6	0.5	34.0	2,160.8	**$ 414,645**
2030	8	62%	7%	10%	12%	8%	4%	1.6	6.7	0.6	40.8	2,594.9	**$ 499,910**
2031	9	67%	7%	10%	13%	9%	4%	1.9	8.0	0.7	48.4	3,075.7	**$ 601,898**
2032	10	71%	8%	11%	14%	9%	5%	2.2	9.1	0.7	55.1	3,505.8	**$ 696,707**
2033	11	75%	8%	12%	14%	10%	5%	2.5	10.3	0.8	62.4	3,970.6	**$ 801,151**
2034	12	79%	9%	12%	15%	10%	5%	2.8	11.6	1.0	70.3	4,471.5	**$ 915,810**
2035	13	82%	9%	13%	16%	11%	5%	3.0	12.7	1.0	76.9	4,889.8	**$ 1,016,349**
2036	14	85%	9%	13%	16%	11%	6%	3.3	13.8	1.1	83.9	5,332.9	**$ 1,124,668**
2037	15	87%	9%	13%	17%	12%	6%	3.5	14.7	1.2	89.2	5,670.7	**$ 1,213,126**
2038	16	89%	10%	14%	17%	12%	6%	3.7	15.6	1.3	94.7	6,023.4	**$ 1,306,895**
2039	17	91%	10%	14%	17%	12%	6%	4.0	16.5	1.4	100.5	6,391.6	**$ 1,406,214**
2040	18	93%	10%	14%	18%	12%	6%	4.2	17.5	1.4	106.6	6,775.8	**$ 1,511,331**
2041	19	94%	10%	15%	18%	12%	6%	4.4	18.2	1.5	110.5	7,026.1	**$ 1,584,965**
2042	20	95%	10%	15%	18%	13%	6%	4.5	18.9	1.6	114.6	7,284.0	**$ 1,661,600**
Average													**$ 793,294**
Total													**$ 15,865,889**

Year	Project Year	Connected Vehicle Market Penetration Rate[1]	FUEL CONSUMPTION: Connected Vehicle FUEL CONSUMPTION Benefit[5]	FUEL CONSUMPTION: TOTAL Fuel Reduction (gallons/yr)	FUEL CONSUMPTION: TOTAL Fuel Consumption Savings From Connected Vehicles ($2016)	TOTAL Connected Vehicles Benefit ($2016)
2016	na	0%	0%	-	$ -	$ -
2017	na	0%	0%	-	$ -	$ -
2018	na	0%	0%	-	$ -	$ -
2019	na	0%	0%	-	$ -	$ -
(Beg Construction) 2020	Construction	0%	0%	-	$ -	$ -
2021	Construction	8%	1%	14,532	$ -	$ -
(End Construction) 2022	Construction	15%	2%	51,855	$ -	$ -
2023	1	22%	3%	113,220	$ **254,744**	$ **4,181,088**
2024	2	29%	4%	199,682	$ **449,284**	$ **7,374,443**
2025	3	35%	5%	295,219	$ **664,244**	$ **10,903,315**
2026	4	41%	5%	411,190	$ **925,178**	$ **15,187,261**
2027	5	47%	6%	548,449	$ **1,234,011**	$ **20,258,008**
2028	6	52%	7%	681,418	$ **1,533,191**	$ **25,170,798**
2029	7	57%	7%	831,042	$ **1,869,843**	$ **30,699,357**
2030	8	62%	8%	997,981	$ **2,245,458**	$ **36,868,224**
2031	9	67%	9%	1,182,918	$ **2,661,566**	$ **43,709,656**
2032	10	71%	9%	1,348,304	$ **3,033,684**	$ **49,831,437**
2033	11	75%	10%	1,527,073	$ **3,435,913**	$ **56,450,545**
2034	12	79%	10%	1,719,719	$ **3,869,367**	$ **63,585,586**
2035	13	82%	11%	1,880,602	$ **4,231,355**	$ **69,549,028**
2036	14	85%	11%	2,051,035	$ **4,614,830**	$ **75,868,248**
2037	15	87%	11%	2,180,921	$ **4,907,071**	$ **80,689,966**
2038	16	89%	12%	2,316,581	$ **5,212,306**	$ **85,727,438**
2039	17	91%	12%	2,458,194	$ **5,530,937**	$ **90,987,430**
2040	18	93%	12%	2,605,946	$ **5,863,378**	$ **96,476,886**
2041	19	94%	12%	2,702,223	$ **6,080,002**	$ **100,059,052**
2042	20	95%	12%	2,801,423	$ **6,303,203**	$ **103,750,731**
Average					$ **3,245,978**	$ **53,366,425**
Total					$ **64,919,566**	$ **1,067,328,498**

1. Connected Vehicle Market Penetration Rate -- J. Wright, J. K. Garret, C. J. Hill, G. D. Krueger, J. H. Evans, S. Andrews, C. K. Wilson, R. Rajbhandari, B. Burkhard. National Connected Vehicle Field Infrastructure Footprint Analysis: Final Report. U.S. Department of Transportation, FHWA-JPO-14-125, 2014.
https://ntl.bts.gov/lib/52000/52600/52602/FHWA-JPO-14-125_v2.pdf
2. Connected Vehicle MOBILITY Benefit -- S. Guler, M. Menendez, and L. Meier. Using Connected Vehicle Technology to Improve the Efficiency of Intersections. Transportation Research Part C, Vol 46, pp. 121-131, 2014
https://trid.trb.org/view.aspx?id=1325264
3. Connected Vehicle SAFETY Benefit -- National Highway Traffic Safety Administration (NHTSA). U.S. DOT advances deployment of Connected Vehicle Technology to prevent hundreds of thousands of crashes, 2016.
https://www.nhtsa.gov/press-releases/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands
4. Connected Vehicle EMISSION Benefit -- J. Liu., K. M. Kockelman, A. Nichols. Anticipating the Emissions Impacts of Smoother Driving by Connected and Autonomous Vehicles, Using the MOVES Model. 96th Annual Meeting of the Transportation Research Board, 2017
http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17CAVEmissions.pdf
5. Connected Vehicle FUEL CONSUMPTION Benefit -- J. Chang, G. Hatcher, D. Hicks, J. Schneeberger, B. Staples, S. Sundarajn, M. Vasudevan, P. Wang, K. Wunderlich. Estimated Benefits of Connected Vehicle Applicaions: Dynamic Mobility Applications, AERIS, V2I Safety, and Road Weather Management. U.S. Department of Transportation, FHWA-JPO-15-255, 2015.
https://ntl.bts.gov/lib/56000/56200/56238/FHWA-JPO-16-255.pdf

Note:
1. Connected Vehicle Market Penetration Rate is based on FHWA's Report (Page 93 of FHWA-JPO-14-125) "Connected Vehicle Equipped Population Over Time" Curve with a 1-Year Mandate assumption, and which assumes an initial deployment start date of 2020.
2.Connected Vehicle MOBILITY Benefit is based on Guler et.al. (2014) which estimates a mobility benefit up to 25% at 100% market penetration rate.
Given the findings, the travel time benefit reaches a maximum of 25% at 100% market penetration rate. A linear relationship is utilzied to extrapolate the expected mobility benefit stemming from connected vehicle technology and ITS between at unknown market penetration rates. Mobility benefit at a particular market penetration rate can be expressed as

$$M_i = \frac{P_i * M_{max}}{P_{max}}$$

Where,
M_i Mobility benefit at market penetration rate of year i (%)
P_i Market penetration rate of year i (%)
M_{max} Maximum mobility benefit, equals 25%
P_{max} Market penetration rate in which the maximum mobility benefit is reached, equals 100%

3. Connected Vehicle SAFETY Benefit is based on NHTSA prediction which states that safety applications as a result of such technology can eliminate or mitigate up to 80% of non-impared crashes.
It is assumed that the 80% crash reduction is fully achieved until 100% connected vehicle market penetration rate is achieved.
A linear relationship is utilized to extrapolate the expected crash reduction at unkown marke penetration rates.

$$S_i = \frac{P_i * S_{max}}{P_{max}}$$

Where,
S_i Safety benefit at market penetration rate of year i (%)
P_i Market penetration rate of year I (%)
S_{max} Maximum safety benefit, equals 80%
P_{max} Market penetration rate in which the maximum mobility benefit is reached, equals 100%

4. Connected Vehicle EMISSION Benefit is based on Liu et. al. (2017), which provides average emission reductions of 10.89% for VOC, 15.51% for NOx, 19.09% for PM, 13.23% for CO, and 6.55% for CO_2 at a 100% market penetration rate. Given the findings, the particular emmission benefit reaches its maximum reduction at 100% market penetration rate. A linear relationship is utilzied to extrapolate the expected mobility benefi stemming from connected vehicle technology and ITS between at unknown market penetration rates

$$E_i = \frac{P_i * E_{max}}{P_{max}}$$

Where,
E_i Emission benefit at market penetration rate of year i (%)
P_i Market penetration rate of year i (%)
E_{max} Maximum emission benefit, equals 10.89% for VOC, 15.51% for NOx, 19.09% for PM, 13.23% for CO, and 6.55% for CO_2
P_{max} Market penetration rate in which the maximum mobility benefit is reached, equals 100%

5. Connected Vehicle FUEL CONSUMPTION Benefit is based on FHWA's Report (FHWA-JPO-15-255), which notes a 13% fuel reduction benefit along a coordinated cooridor.
Given the findings, the maximum fuel reduction benefit of 13% is reached at 100% market penetration rate.
A linear relationship is utilzied to extrapolate the expected mobility benefit stemming from connected vehicle technology and ITS between at unknown market penetration rates

$$F_i = \frac{P_i * F_{max}}{P_{max}}$$

Where,
F_i Fuel reduction benefit at market penetration rate of year i (%)
P_i Market penetration rate of year i (%)
F_{max} Maximum fuel reduction benefit, equals 13%
P_{max} Market penetration rate in which the maximum mobility benefit is reached, equals 100%

6. Assumes a 1.5% annual growth corresponding to projected traffic volume growth for subject corridor. 1.5% Growth is applied to year 2016 (base year) as well since connected vehicle data calculations are based on 2015 data. There are no concerns with regards to capacity constraints for this growth rate
7. Savings are based on 2016$
8. Assumes construction begins in 2020 and ends in 2022. Connected vehicle benefits are first realized in 2023.
9. Assumes no new additional users. All users are existing regardless of whether the proposal is built or not.

Tab 18. ITS & Connected Veh - Back Calc (1)

Synchro ID	Aproach	Average Daily Traffic	Percent Bus	Percent Truck	Segment Length (mi)	TRAVEL TIME[1]			EMISSIONS[2]					FUEL CONSUMPTION[3]
						TOTAL EXISTING Travel Time for All Purpose (hr/year)	TOTAL EXISTING Travel Time for Buses (hr/year)	TOTAL EXISTING Travel Time for Trucks (hr/year)	TOTAL EXISTING VOC (short ton/yr)	TOTAL EXISTING NOx (short ton/yr)	TOTAL EXISTING CO (metric ton/yr)	TOTAL EXISTING PM (short ton/yr)	TOTAL EXISTING CO_2 (short ton/yr)	TOTAL EXISTING Fuel Consumption (gallons/yr)
9	NB	48682	0.2%	4.2%	0.10	78313	118	2475	0.1	0.6	3.8	0.0	503	93391
9	SB	1534	0.2%	4.2%	0.50	8093	12	256	0.0	0.1	0.6	0.0	78	14336
10	NB	49976	0.3%	4.8%	0.10	812968	1849	29582	0.6	1.1	8.3	0.1	1364	233470
10	SB	50059	0.2%	4.2%	0.10	178323	268	5636	0.3	0.8	5.8	0.1	748	141366
13	NB	48682	0.2%	4.2%	0.10	368873	555	11659	0.5	1.0	7.6	0.1	1236	210245
13	SB	1534	0.2%	4.2%	0.10	997	2	32	0.0	0.0	0.1	0.0	16	3009
14	NB	48682	0.2%	4.2%	0.40	1025092	1543	32400	1.8	3.8	26.8	0.3	4432	809124
14	SB	1534	0.2%	4.2%	0.10	2325	3	73	0.0	0.0	0.1	0.0	16	2952
22	NB	48682	0.2%	4.2%	0.01	24301	37	768	0.0	0.1	0.4	0.0	50	9586
22	SB	1534	0.2%	4.2%	0.10	2655	4	84	0.0	0.0	0.1	0.0	16	3014
23	NB	44274	0.4%	5.7%	0.10	86595	265	3782	0.2	0.6	4.2	0.0	491	98029
23	SB	43958	0.2%	4.8%	0.10	103022	156	3745	0.2	0.5	4.0	0.0	484	96157
28	NB	41699	0.5%	6.0%	0.40	186956	719	8631	0.5	1.9	13.8	0.1	1751	337004
28	SB	43395	0.3%	5.0%	0.20	150001	342	5698	0.3	1.0	7.7	0.1	931	183491
31	NB	41767	0.3%	6.2%	0.20	144718	334	6904	0.3	1.0	7.5	0.1	901	177392
31	SB	44703	0.4%	4.9%	0.20	133164	405	4957	0.3	1.1	7.8	0.1	961	188339
34	NB	40658	0.3%	6.2%	0.20	162627	375	7758	0.4	1.1	8.3	0.1	983	195014
34	SB	46834	0.4%	5.1%	0.10	78809	240	3060	0.2	0.5	3.8	0.0	493	94239
35	NB	43413	0.8%	6.0%	0.10	115441	713	5347	0.2	0.6	4.4	0.0	527	104851
35	SB	46834	0.4%	5.1%	0.10	131888	402	5121	0.2	0.6	4.7	0.0	564	111062
36	NB	43413	0.8%	6.0%	0.10	76751	474	3555	0.1	0.5	3.5	0.0	453	86369
36	SB	42974	0.3%	5.1%	0.30	200297	457	7769	0.5	1.6	11.8	0.1	1428	281344
41	NB	39444	0.8%	6.0%	0.10	162239	1002	7514	0.3	0.7	5.4	0.1	812	142019
41	SB	43926	0.3%	5.1%	0.20	82983	189	3218	0.3	1.0	6.9	0.1	911	171525
42	NB	43926	0.2%	6.3%	0.20	518067	797	25113	0.8	1.7	12.8	0.2	2019	344590
42	SB	47125	0.3%	5.1%	0.10	115099	263	4464	0.2	0.6	4.5	0.0	543	108263
116	NB	48682	0.2%	4.2%	0.50	406128	611	12836	0.9	3.1	21.3	0.2	2880	532624
116	SB	1534	0.2%	4.2%	0.40	5852	9	185	0.0	0.1	0.5	0.0	63	11324
275	NB	36956	0.1%	6.2%	0.20	130372	100	6206	0.4	1.0	7.7	0.1	957	188302
275	SB	39336	0.2%	4.9%	0.10	98511	149	3659	0.2	0.5	3.7	0.0	442	88451
277	NB	42416	0.1%	5.8%	0.10	139219	106	6173	0.2	0.6	4.6	0.0	555	109328
277	SB	43514	0.1%	5.0%	0.20	181612	138	6811	0.5	1.3	9.5	0.1	1207	240010
377	NB	37776	0.6%	4.4%	0.20	153928	699	5129	0.4	1.1	8.4	0.1	1078	212770
377	SB	38158	0.5%	4.6%	0.20	369841	1402	12897	0.6	1.4	9.7	0.1	1158	280839
457	NB	46261	0.2%	4.2%	0.01	234008	352	7396	0.1	0.2	1.1	0.0	163	33934
457	SB	5002	0.2%	4.2%	0.10	9061	14	286	0.0	0.1	0.5	0.0	57	11271
458	NB	7889	0.3%	4.8%	0.10	19926	45	725	0.0	0.1	0.7	0.0	88	17491
458	SB	43978	0.2%	4.8%	0.30	275968	418	10031	0.7	1.9	14.3	0.1	1794	348125
530	NB	32896	0.5%	5.0%	0.20	136689	520	5203	0.3	0.8	6.4	0.1	758	151238
530	SB	18872	0.6%	3.2%	0.60	564063	2531	13499	2.0	3.8	24.7	0.3	1725	503376
564	NB	2046	0.2%	4.2%	0.10	2116	3	67	0.0	0.0	0.2	0.0	21	4025
564	SB	26591	0.2%	4.2%	0.01	44567	67	1409	0.0	0.0	0.4	0.0	52	9194
572	NB	48682	0.2%	4.2%	0.10	267702	403	8461	0.7	1.3	9.1	0.1	1564	287724
572	SB	1534	0.2%	4.2%	0.20	3530	5	112	0.0	0.0	0.2	0.0	32	6111
573	NB	2056	0.2%	4.2%	0.20	22716	34	718	0.0	0.1	0.7	0.0	108	19056
573	SB	46996	0.2%	4.2%	0.10	64141	97	2027	0.2	0.6	4.2	0.0	517	101513
574	NB	43926	0.2%	6.3%	0.10	493062	759	23901	0.1	0.5	3.6	0.0	462	88955
574	SB	41082	0.1%	5.0%	0.70	389623	295	14613	1.0	3.3	24.0	0.2	3026	583527
590	NB	39661	0.8%	6.0%	0.30	127004	784	5882	0.3	1.4	9.1	0.1	1222	228098
590	SB	41136	0.3%	5.1%	0.30	130608	298	5066	0.3	1.4	9.4	0.1	1263	234877
591	NB	39661	0.8%	6.0%	0.30	142841	882	6616	0.4	1.4	9.6	0.1	1242	236919
591	SB	41136	0.3%	5.1%	0.10	47823	109	1855	0.1	0.5	3.2	0.0	427	80411
594	NB	16451	0.5%	3.6%	0.60	104033	390	2810	0.3	1.1	7.5	0.1	1012	185526
594	SB	20089	0.7%	3.0%	0.90	314627	1645	7051	0.7	2.3	16.1	0.1	2176	408268
722	NB	39059	0.2%	6.3%	0.70	391672	603	18986	1.0	3.2	23.8	0.2	2914	570064
722	SB	43514	0.1%	5.0%	0.10	86031	65	3227	0.2	0.5	3.7	0.0	467	90552
723	NB	42416	0.1%	5.8%	0.20	90000	69	3991	0.3	1.0	7.1	0.1	903	174582
723	SB	38607	0.2%	4.9%	0.70	433133	657	16089	1.0	3.3	24.0	0.2	3100	585512
724	NB	35067	0.1%	5.8%	0.70	340505	260	15099	0.8	2.9	20.8	0.2	2648	507787
724	SB	39336	0.2%	4.9%	0.20	67524	102	2508	0.2	0.9	6.1	0.0	809	151491
725	NB	36956	0.1%	6.2%	0.10	91722	70	4366	0.1	0.5	3.3	0.0	420	81249
725	SB	36706	0.5%	4.6%	0.70	319219	1210	11132	0.8	3.0	20.7	0.2	2686	511575
726	NB	33868	0.1%	6.2%	0.70	526304	404	25054	1.1	3.2	22.6	0.2	3099	584788
726	SB	38158	0.5%	4.6%	0.20	73973	280	2580	0.2	0.9	6.3	0.1	802	153938
741	NB	37776	0.6%	4.4%	0.20	347710	1580	11586	0.3	0.9	6.6	0.1	844	161827
741	SB	35033	0.6%	3.2%	0.20	717095	3218	17161	1.3	2.4	16.1	0.2	1105	324494
782	NB	42273	0.3%	4.8%	0.40	237739	541	8651	0.6	2.0	14.7	0.1	1797	352340
782	SB	43958	0.2%	4.8%	0.10	68063	103	2474	0.1	0.5	3.6	0.0	462	88965
783	NB	48682	0.4%	5.7%	0.10	83653	256	3653	0.1	0.6	3.8	0.0	504	95263
783	SB	41835	0.3%	5.0%	0.40	198600	453	7544	0.6	2.0	14.0	0.1	1784	343855
786	NB	17037	0.2%	1.7%	0.10	51218	75	639	0.1	0.3	2.4	0.0	354	63953
786	SB	14202	0.2%	2.3%	0.10	17875	26	303	0.0	0.2	1.1	0.0	146	27197
832	NB	16451	0.2%	1.7%	0.90	155876	229	1943	0.4	1.7	11.2	0.1	1519	277364
832	SB	15451	0.5%	3.3%	0.10	25640	96	633	0.1	0.2	1.8	0.0	217	41813
922	NB	44086	0.3%	4.8%	0.30	140064	319	5097	0.4	1.5	10.7	0.1	1378	262091
922	SB	42484	0.2%	4.8%	0.10	56111	85	2040	0.1	0.5	3.6	0.0	448	86592
923	NB	44086	0.3%	4.8%	0.10	55866	127	2033	0.1	0.5	3.5	0.0	458	86968
923	SB	42484	0.2%	4.8%	0.40	203941	309	7413	0.5	2.0	13.6	0.1	1766	335592
977	NB	48127	0.2%	4.2%	0.10	349981	527	11062	0.6	1.2	8.6	0.1	1356	249577
977	SB	46715	0.2%	4.2%	0.20	117129	176	3702	0.3	1.1	7.7	0.1	982	188151
978	NB	2156	0.2%	4.2%	0.20	36198	54	1144	0.1	0.1	0.8	0.0	129	23330
978	SB	46715	0.2%	4.2%	0.01	42641	64	1348	0.0	0.1	0.5	0.0	58	11413
2091	NB	18401	0.5%	3.1%	0.01	16687	62	386	0.0	0.0	0.2	0.0	22	4384
2091	SB	14202	0.5%	2.6%	0.10	58746	218	1134	0.1	0.2	1.7	0.0	220	41132
2092	NB	18401	0.3%	3.2%	0.10	50813	114	1212	0.1	0.3	2.1	0.0	255	48887
2092	SB	14202	0.2%	2.3%	0.01	14021	21	238	0.0	0.0	0.1	0.0	18	3490
TOTAL						**15295920**	**36765**	**555651**	**30.8**	**90.1**	**641.8**	**6.0**	**82433**	**15973683**

	SAFETY[4]				
	O (No Injury)	**C** (Possible Injury)	**B** (Non-Incapacitating)	**A** (Incapacitating)	**K** (Killed)
2011-2015 Non-Impaired Crashes[6]	9704	936.0	153.0	34.0	9.0
Annualized Non-Impaired Crashes[6]	1941	187	31	7	2
Annual Crash Reduction from traditional safety treatments[6, 7]	1012	113	19	5	1
Connected Vehicle Applicable Non-Impared Crashes[6, 7]	928	74	12	2	1

Note:

1. Refer to TRAVEL TIME tabs for travel time calculations, sources and notes

2. Refer to EMISSION tabs for emmission calculations, sources and notes

3. Refer to FUEL tabs for emmission calculations, sources and notes

4. Refer to SAFETY tabs for safety calculations, sources and notes

5. TRAVEL TIME, EMMISSION, FUEL CONSUMPTION, and SAFETY values represent 2015 data. A 1.5% annual growth rate will be applied for future years. The 1.5% annual growth corresponds to a projected growth in traffic volumes for the subject corridor

6. Crashes reported represent all of the number of injuries, fatalities, or no injuries involved in the accident on a per individual basis

7. To avoid double counting of crash benefits only those crashes not affected by traditional safety treatments as listed under the SAFETY tabs are considered under the connected vehicle safety benefits

Tab 19. Operations & Maintenance Costs

Year	Project Year	No Build Scenario		Build Scenario			Operations & Maintenance Savings
		Infrastructure Condition	Maintenance Cost ($2016)[3]	Infrastructure Condition	Cost per Lane Mile ($2016)[4]	Maintenance Cost ($2016)[5, 6]	
2016	na	Poor - Fair	$ 4,930,000	na	$ -	$ -	$ -
2017	na	Poor - Fair	$ 5,053,250	na	$ -	$ -	$ -
2018	na	Poor - Fair	$ 5,179,581	na	$ -	$ -	$ -
2019	na	Poor - Fair	$ 5,309,071	na	$ -	$ -	$ -
(Beg Construction) 2020	Construction	Poor - Fair	$ 5,441,798	na	$ -	$ -	$ -
2021	Construction	Poor - Fair	$ 5,577,842	na	$ -	$ -	$ -
(End Construction) 2022	Construction	Poor - Fair	$ 5,717,289	na	$ -	$ -	$ -
2023	1	Poor - Fair	$ 5,860,221	Excellent	$ -	$ -	$ 5,860,221
2024	2	Poor - Fair	$ 6,006,726	Excellent	$ -	$ -	$ 6,006,726
2025	3	Poor - Fair	$ 6,156,894	Excellent	$ -	$ -	$ 6,156,894
2026	4	Poor - Fair	$ 6,310,817	Excellent	$ -	$ -	$ 6,310,817
2027	5	Poor - Fair	$ 6,468,587	Excellent	$ -	$ -	$ 6,468,587
2028	6	Poor - Fair	$ 6,630,302	Excellent	$ -	$ -	$ 6,630,302
2029	7	Poor - Fair	$ 6,796,059	Excellent	$ -	$ -	$ 6,796,059
2030	8	Poor - Fair	$ 6,965,961	Excellent	$ -	$ -	$ 6,965,961
2031	9	Poor - Fair	$ 7,140,110	Very Good	$ 2,000	$ 134,000	$ 7,006,110
2032	10	Poor - Fair	$ 7,318,613	Very Good	$ 2,000	$ 134,000	$ 7,184,613
2033	11	Poor - Fair	$ 7,501,578	Very Good	$ 2,000	$ 134,000	$ 7,367,578
2034	12	Poor - Fair	$ 7,689,117	Very Good	$ 2,000	$ 134,000	$ 7,555,117
2035	13	Poor - Fair	$ 7,881,345	Very Good	$ 2,000	$ 134,000	$ 7,747,345
2036	14	Poor - Fair	$ 8,078,379	Very Good	$ 2,000	$ 134,000	$ 7,944,379
2037	15	Poor - Fair	$ 8,280,339	Very Good	$ 2,000	$ 134,000	$ 8,146,339
2038	16	Poor - Fair	$ 8,487,347	Very Good	$ 2,000	$ 134,000	$ 8,353,347
2039	17	Poor - Fair	$ 8,699,531	Very Good	$ 2,000	$ 134,000	$ 8,565,531
2040	18	Poor - Fair	$ 8,917,019	Very Good	$ 2,000	$ 134,000	$ 8,783,019
2041	19	Poor - Fair	$ 9,139,944	Fair - Good	$ 250,000	$ 16,750,000	$ (7,610,056)
2042	20	Poor - Fair	$ 9,368,443	Very Good	$ 2,000	$ 134,000	$ 9,234,443
Average			**$ 7,484,867**			**$ 911,200**	**$ 6,573,667**
Total			**$ 149,697,333**			**$ 18,224,000**	**$ 131,473,333**

Note:

1. Savings are based on 2016$

2. Assumes construction begins in 2020 and ends in 2022. New infrastructure enters in operations in 2023

3. According to Macomb County Department of Roads, the County spends the following on annual maintenance on Mound Road:

Maintenance Type	Annual Cost
Concrete Replacement	$ 4,600,000
Patrol Patching	$ 330,000
Total	**$ 4,930,000**

A 2.5% increase in maintenance costs is applied to each subsequent year following 2016 to account for the increasing maintenance needs due to continous pavement deterioration and omission of any significant reconstruction activities from the corridor.

4. Recommended Concrete Treatments and Associated Costs:

PASER Rating	Condition	Treatment	Cost per Lane Mile	No. of Years
9 & 10	Excellent	No maintenance required	$ -	1 - 8
7 & 8	Very Good	Routine maintenance	$ 2,000	9 - 18
5 & 6	Fair - Good	Surface repairs, sealing, partial depth patching	$ 250,000	19 - 24
3 & 4	Poor - Fair	Extensive slab or joint rehabilitation	$ 600,000	25 - 29
1 & 2	Failed	Reconstruction	$ 1,900,000	30

5. Pavement quality for new pavement (Build) drops approximately 40% over 75% from its initial life (i.e. 22.5 years)
Southeast Michigan Council of Governments (SEMCOG). Status of Pavement Management Systems (PMS) in Southeast Michigan. May 2003.

6. Total Mound Road Lane Miles = 67

Base Year of Nominal Dollar	Multiplier to Adjust to Real $2016
1989	1.7307
2001	1.3306
2002	1.3105
2003	1.2849
2004	1.2505
2005	1.2115
2006	1.1754
2007	1.1449
2008	1.1229
2009	1.1145
2010	1.1010
2011	1.0787
2012	1.0592
2013	1.0424
2014	1.0240
2015	1.0132
2016	1.0000

Source:

Bureau of Economic Analysis, National Income and Product Accounts, Table 1.1.9, "Implicit Price Deflators for Gross Domestic Product" (March 2016)

http://www.bea.gov/iTable/iTable.cfm?ReqID=9&step=1

Appendix B – Synchro/SimTraffic Mound Road Arterial Report

Arterial Level of Service: NB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
XON of 10 Mile	564	1.6	5.7	0.1	37
11 Mile Road Ramps	22	1.0	4.1	0.0	37
I-696 Ramps	9	0.3	10.7	0.1	49
11 Mile Road Ramps	116	1.7	38.8	0.5	48
I-696 Ramps	14	1.5	28.3	0.4	50
11 Mile Road Ramps	13	4.1	14.2	0.1	34
XOS of Martin Rd	572	10.4	15.2	0.1	13
XON of Martin Rd	573	7.8	22.0	0.2	30
TACOM Main Gate	977	2.9	9.2	0.1	34
XON TACOM	978	20.6	34.8	0.2	20
XOS 12 Mile Road	457	15.1	18.2	0.0	9
12 Mile Road	10	8.1	16.1	0.1	24
XON of 12 Mile	458	2.8	12.8	0.1	37
GM Technical Center	922	2.3	20.6	0.3	46
XON of GM Tech Cente	923	0.8	8.3	0.1	43
XOS of 13 Mile	782	10.5	39.0	0.4	37
13 Mile Road	23	4.8	13.7	0.1	32
XON of 13 Mile	783	1.9	12.8	0.1	42
Chicago Road	28	12.3	35.9	0.4	35
Arden Avenue	31	9.9	27.7	0.2	31
XOS of 14 Mile	34	25.4	39.8	0.2	19
14 Mile Road	35	10.9	21.0	0.1	23
XON of 14 Mile	36	2.8	13.3	0.1	40
XOS of Sterling Dr	590	3.3	24.4	0.3	44
XON of Sterling Dr	591	2.3	24.3	0.3	44
XOS of 15 Mile	41	6.2	13.4	0.1	27
15 Mile Road	42	6.0	18.5	0.2	32
XON of 15 Mile	574	1.7	11.4	0.1	43
XOS of Metro Pkwy	722	21.4	69.1	0.7	38
Metro Parkway	277	11.4	21.9	0.1	23
XON of Metro Pkwy	723	2.5	14.6	0.2	39
XOS of 17 Mile	724	8.7	54.1	0.7	48
17 Mile Road	275	7.4	19.9	0.2	28
XON of 17 Mile	725	3.0	13.6	0.1	39
XOS of 18 Mile	726	8.4	54.8	0.7	47
18 Mile Road	377	10.2	21.9	0.2	25
XON of 18 Mile	741	4.5	17.9	0.2	37
18 1/2 Mile Road	530	19.7	35.5	0.2	23
19 Mile Road	594	10.9	51.6	0.6	43
Forum at Gateways Sh	832	6.5	67.3	0.9	49
XOS of Hall Road	786	9.4	14.2	0.1	16
Hall Road South (Dob	2092	22.4	30.5	0.1	13
Hall Road North	2091	2.4	6.3	0.0	26
Total		327.6	1047.4	10.3	35

Arterial Level of Service: SB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Hall Road North	2091	28.5	37.7	0.1	13
Hall Road South (Dob	2092	4.1	8.0	0.0	21
XOS of Hall Road	786	1.9	9.8	0.1	41
Forum at Gateways Sh	832	6.1	10.3	0.1	22
19 Mile Road	594	13.0	74.5	0.9	44
18 1/2 Mile Road	530	15.6	57.9	0.6	38
XON of 18 Mile	741	11.6	28.4	0.2	29
18 Mile Road	377	8.6	22.3	0.2	29
XOS of 18 Mile	726	4.4	15.4	0.2	36
XON of 17 Mile	725	21.5	71.7	0.7	36
17 Mile Road	275	10.0	21.1	0.1	25
XOS of 17 Mile	724	2.7	14.1	0.2	39
XON of Metro Pkwy	723	125.0	174.5	0.7	15
Metro Parkway	277	68.9	80.6	0.2	7
XOS of Metro Pkwy	722	9.1	20.3	0.1	25
XON of 15 Mile	574	22.8	73.5	0.7	36
15 Mile Road	42	9.2	19.8	0.1	25
XOS of 15 Mile	41	3.4	15.4	0.2	38
XON of Sterling Dr	591	1.6	8.8	0.1	41
XOS of Sterling Dr	590	3.0	24.6	0.3	44
XON of 14 Mile	36	27.9	49.0	0.3	22
14 Mile Road	35	20.6	31.8	0.1	17
XOS of 14 Mile	34	5.9	15.6	0.1	31
	31	8.9	23.3	0.2	32
Chicago Road	28	11.1	28.1	0.2	30
XON of 13 Mile	783	11.8	35.4	0.4	36
13 Mile Road	23	7.2	17.9	0.1	30
XOS of 13 Mile	782	3.2	12.4	0.1	35
XON of GM Tech Cente	923	4.9	33.6	0.4	43
GM Technical Center	922	1.5	8.6	0.1	42
XON of 12 Mile	458	35.2	54.3	0.3	17
12 Mile Road	10	32.3	42.2	0.1	11
XOS 12 Mile Road	457	9.7	17.8	0.1	21
XON TACOM	978	3.8	7.0	0.0	22
TACOM Main Gate	977	7.8	22.1	0.2	32
XON of Martin Rd	573	7.2	13.8	0.1	23
XOS of Martin Rd	572	6.7	20.3	0.2	33
11 Mile Road Ramps	13	1.3	5.3	0.1	37
I-696 Ramps	14	2.1	11.7	0.1	42
11 Mile Road Ramps	116	1.3	28.4	0.4	50
I-696 Ramps	9	2.0	39.5	0.5	47
11 Mile Road Ramps	22	2.5	13.6	0.1	38
XON of 10 Mile	564	11.2	14.7	0.0	10
Total		597.1	1335.3	10.3	28

Arterial Level of Service: NB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
XON of 10 Mile	564	0.7	8.4	0.1	46
11 Mile Road Ramps	22	0.5	3.4	0.0	44
I-696 Ramps	9	0.3	10.7	0.1	49
11 Mile Road Ramps	116	1.5	38.4	0.5	49
I-696 Ramps	14	123.0	148.1	0.4	10
11 Mile Road Ramps	13	53.1	62.6	0.1	8
XOS of Martin Rd	572	33.2	49.1	0.1	5
XON of Martin Rd	573	68.1	82.5	0.2	8
TACOM Main Gate	977	40.0	57.1	0.1	7
XON TACOM	978	98.5	140.7	0.2	6
XOS 12 Mile Road	457	39.2	42.3	0.0	4
12 Mile Road	10	48.9	157.9	0.1	7
XON of 12 Mile	458	6.5	20.5	0.1	29
GM Technical Center	922	3.9	22.5	0.3	42
XON of GM Tech Cente	923	1.1	8.6	0.1	42
XOS of 13 Mile	782	12.0	41.2	0.4	35
13 Mile Road	23	5.9	14.5	0.1	30
XON of 13 Mile	783	2.1	12.5	0.1	43
Chicago Road	28	9.6	32.8	0.4	39
Arden Avenue	31	8.2	26.0	0.2	33
XOS of 14 Mile	34	12.9	27.3	0.2	27
14 Mile Road	35	7.9	17.9	0.1	27
XON of 14 Mile	36	2.6	12.9	0.1	41
XOS of Sterling Dr	590	2.9	24.4	0.3	44
XON of Sterling Dr	591	3.1	25.5	0.3	42
XOS of 15 Mile	41	25.4	32.5	0.1	11
15 Mile Road	42	51.6	100.2	0.2	9
XON of 15 Mile	574	2.8	103.5	0.1	38
XOS of Metro Pkwy	722	24.9	76.3	0.7	34
Metro Parkway	277	10.4	21.3	0.1	24
XON of Metro Pkwy	723	2.4	14.2	0.2	40
XOS of 17 Mile	724	12.8	62.5	0.7	41
17 Mile Road	275	8.1	19.8	0.2	28
XON of 17 Mile	725	3.0	13.9	0.1	38
XOS of 18 Mile	726	12.7	61.2	0.7	42
18 Mile Road	377	6.8	18.6	0.2	29
XON of 18 Mile	741	3.1	15.7	0.2	42
18 1/2 Mile Road	530	12.8	28.3	0.2	29
19 Mile Road	594	5.1	44.6	0.6	49
Forum at Gateways Sh	832	5.0	64.8	0.9	50
XOS of Hall Road	786	12.9	17.9	0.1	13
Hall Road South (Dob	2092	8.9	17.4	0.1	23
Hall Road North	2091	2.6	6.6	0.0	25
Total		797.0	1807.2	10.3	24

Arterial Level of Service: SB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Hall Road North	2091	17.5	26.7	0.1	19
Hall Road South (Dob	2092	2.9	6.9	0.0	24
XOS of Hall Road	786	1.4	9.0	0.1	45
Forum at Gateways Sh	832	8.1	12.3	0.1	19
19 Mile Road	594	8.8	70.9	0.9	46
18 1/2 Mile Road	530	10.6	50.7	0.6	43
XON of 18 Mile	741	9.9	26.4	0.2	31
18 Mile Road	377	4.9	18.1	0.2	36
XOS of 18 Mile	726	2.1	12.9	0.2	42
XON of 17 Mile	725	13.8	63.4	0.7	40
17 Mile Road	275	6.6	17.6	0.1	30
XOS of 17 Mile	724	1.5	12.4	0.2	45
XON of Metro Pkwy	723	20.9	68.6	0.7	38
Metro Parkway	277	9.6	22.0	0.2	26
XOS of Metro Pkwy	722	2.8	13.8	0.1	37
XON of 15 Mile	574	20.4	70.6	0.7	37
15 Mile Road	42	6.7	18.2	0.1	27
XOS of 15 Mile	41	2.0	14.0	0.2	42
XON of Sterling Dr	591	1.5	8.8	0.1	41
XOS of Sterling Dr	590	1.6	23.7	0.3	45
XON of 14 Mile	36	9.8	31.0	0.3	34
14 Mile Road	35	7.2	18.7	0.1	28
XOS of 14 Mile	34	2.1	11.9	0.1	40
	31	5.8	20.1	0.2	37
Chicago Road	28	7.8	24.5	0.2	35
XON of 13 Mile	783	5.3	30.4	0.4	42
13 Mile Road	23	4.9	16.0	0.1	33
XOS of 13 Mile	782	2.0	11.3	0.1	38
XON of GM Tech Cente	923	4.6	32.7	0.4	44
GM Technical Center	922	1.2	9.5	0.1	38
XON of 12 Mile	458	15.0	33.3	0.3	28
12 Mile Road	10	9.2	20.2	0.1	23
XOS 12 Mile Road	457	3.3	11.5	0.1	33
XON TACOM	978	2.1	5.3	0.0	30
TACOM Main Gate	977	2.7	16.7	0.2	42
XON of Martin Rd	573	2.3	8.8	0.1	36
XOS of Martin Rd	572	2.5	15.9	0.2	42
11 Mile Road Ramps	13	0.6	4.6	0.1	43
I-696 Ramps	14	1.5	11.1	0.1	44
11 Mile Road Ramps	116	1.0	28.3	0.4	50
I-696 Ramps	9	1.3	39.1	0.5	48
11 Mile Road Ramps	22	1.4	12.5	0.1	42
XON of 10 Mile	564	7.7	11.1	0.0	14
Total		254.9	991.6	10.3	38

Arterial Level of Service: NB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
XON of 10 Mile	564	2.6	6.8	0.1	31
11 Mile Road Ramps	22	1.3	4.4	0.0	34
I-696 Ramps	9	6.5	16.9	0.1	31
11 Mile Road Ramps	116	120.6	155.7	0.5	12
I-696 Ramps	14	254.3	278.9	0.4	5
11 Mile Road Ramps	13	57.2	67.1	0.1	7
XOS of Martin Rd	572	28.3	33.1	0.1	6
XON of Martin Rd	573	111.5	125.4	0.2	5
TACOM Main Gate	977	71.2	77.4	0.1	4
XON TACOM	978	125.9	139.7	0.2	5
XOS 12 Mile Road	457	33.5	36.6	0.0	4
12 Mile Road	10	45.3	82.9	0.1	7
XON of 12 Mile	458	8.1	18.2	0.1	26
GM Technical Center	922	12.2	30.2	0.3	31
XON of GM Tech Cente	923	3.3	13.2	0.1	34
XOS of 13 Mile	782	19.0	47.1	0.4	31
13 Mile Road	23	8.0	16.5	0.1	26
XON of 13 Mile	783	3.7	14.7	0.1	36
Chicago Road	28	12.9	36.6	0.4	35
Arden Avenue	31	8.7	26.2	0.2	33
XOS of 14 Mile	34	18.9	33.2	0.2	22
14 Mile Road	35	16.9	27.3	0.1	18
XON of 14 Mile	36	4.6	15.4	0.1	34
XOS of Sterling Dr	590	3.0	24.3	0.3	44
XON of Sterling Dr	591	14.5	36.0	0.3	30
XOS of 15 Mile	41	33.2	40.9	0.1	9
15 Mile Road	42	52.3	108.0	0.2	9
XON of 15 Mile	574	5.3	81.0	0.1	32
XOS of Metro Pkwy	722	34.3	80.7	0.7	33
Metro Parkway	277	28.0	38.1	0.1	14
XON of Metro Pkwy	723	10.7	22.9	0.2	25
XOS of 17 Mile	724	74.4	122.4	0.7	21
17 Mile Road	275	42.0	54.3	0.2	11
XON of 17 Mile	725	23.4	38.6	0.1	16
XOS of 18 Mile	726	277.3	348.4	0.7	8
18 Mile Road	377	62.3	75.3	0.2	7
XON of 18 Mile	741	24.3	279.3	0.2	17
18 1/2 Mile Road	530	17.2	37.4	0.2	24
19 Mile Road	594	10.7	50.3	0.6	44
Forum at Gateways Sh	832	21.9	81.6	0.9	40
XOS of Hall Road	786	34.4	39.9	0.1	6
Hall Road South (Dob	2092	13.5	22.1	0.1	18
Hall Road North	2091	3.3	7.2	0.0	23
Total		1760.3	2892.2	10.3	15

Arterial Level of Service: SB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Hall Road North	2091	27.1	36.4	0.1	14
Hall Road South (Dob	2092	3.5	7.5	0.0	22
XOS of Hall Road	786	1.2	9.2	0.1	44
Forum at Gateways Sh	832	9.3	13.5	0.1	17
19 Mile Road	594	239.5	290.7	0.9	11
18 1/2 Mile Road	530	855.4	894.1	0.6	2
XON of 18 Mile	741	525.8	647.8	0.2	2
18 Mile Road	377	228.6	286.8	0.2	3
XOS of 18 Mile	726	8.0	19.0	0.2	29
XON of 17 Mile	725	15.5	65.3	0.7	39
17 Mile Road	275	7.4	20.6	0.1	26
XOS of 17 Mile	724	2.0	13.3	0.2	42
XON of Metro Pkwy	723	20.0	65.6	0.7	39
Metro Parkway	277	10.7	24.0	0.2	24
XOS of Metro Pkwy	722	2.7	13.8	0.1	37
XON of 15 Mile	574	18.5	69.8	0.7	38
15 Mile Road	42	6.1	17.6	0.1	28
XOS of 15 Mile	41	1.9	13.8	0.2	43
XON of Sterling Dr	591	1.3	8.4	0.1	43
XOS of Sterling Dr	590	1.6	23.6	0.3	46
XON of 14 Mile	36	16.4	37.3	0.3	29
14 Mile Road	35	9.9	21.1	0.1	25
XOS of 14 Mile	34	3.0	12.8	0.1	38
	31	15.1	28.8	0.2	26
Chicago Road	28	11.8	28.8	0.2	30
XON of 13 Mile	783	28.2	52.5	0.4	24
13 Mile Road	23	10.8	22.1	0.1	24
XOS of 13 Mile	782	2.5	11.8	0.1	37
XON of GM Tech Cente	923	19.3	47.8	0.4	30
GM Technical Center	922	3.5	12.0	0.1	30
XON of 12 Mile	458	66.6	85.4	0.3	11
12 Mile Road	10	24.3	34.9	0.1	13
XOS 12 Mile Road	457	8.3	16.5	0.1	23
XON TACOM	978	8.2	11.4	0.0	14
TACOM Main Gate	977	7.5	22.2	0.2	32
XON of Martin Rd	573	5.1	11.7	0.1	27
XOS of Martin Rd	572	4.8	18.5	0.2	36
11 Mile Road Ramps	13	1.1	5.2	0.1	38
I-696 Ramps	14	1.9	11.4	0.1	43
11 Mile Road Ramps	116	1.2	28.3	0.4	50
I-696 Ramps	9	1.7	39.1	0.5	48
11 Mile Road Ramps	22	2.4	13.4	0.1	39
XON of 10 Mile	564	11.6	15.1	0.0	10
Total		2251.2	3128.7	10.3	13

Arterial Level of Service: NB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
XON of 10 Mile	564	1.6	5.6	0.1	37
11 Mile Road Ramps	22	1.0	4.1	0.0	37
I-696 Ramps	9	4.2	14.5	0.1	36
11 Mile Road Ramps	116	4.3	41.4	0.5	45
I-696 Ramps	14	9.4	35.9	0.4	39
11 Mile Road Ramps	13	7.1	17.3	0.1	28
XOS of Martin Rd	572	7.4	12.1	0.1	16
XON of Martin Rd	573	5.2	19.4	0.2	34
TACOM Main Gate	977	1.8	8.1	0.1	39
XON TACOM	978	6.1	20.4	0.2	35
XOS 12 Mile Road	457	10.5	13.7	0.0	12
12 Mile Road	10	5.6	14.0	0.1	27
XON of 12 Mile	458	2.0	12.0	0.1	39
GM Technical Center	922	1.8	20.2	0.3	47
XON of GM Tech Cente	923	0.7	8.2	0.1	44
XOS of 13 Mile	782	6.0	34.6	0.4	42
13 Mile Road	23	5.6	14.6	0.1	29
XON of 13 Mile	783	2.3	13.2	0.1	40
Chicago Road	28	8.0	31.5	0.4	40
Arden Avenue	31	5.4	23.2	0.2	37
XOS of 14 Mile	34	9.7	24.3	0.2	31
14 Mile Road	35	17.9	27.9	0.1	17
XON of 14 Mile	36	5.2	15.6	0.1	34
XOS of Sterling Dr	590	2.1	23.2	0.3	46
XON of Sterling Dr	591	1.9	24.0	0.3	45
XOS of 15 Mile	41	3.3	10.5	0.1	34
15 Mile Road	42	6.8	19.1	0.2	31
XON of 15 Mile	574	2.1	11.7	0.1	42
XOS of Metro Pkwy	722	8.0	56.1	0.7	47
Metro Parkway	277	18.0	28.4	0.1	18
XON of Metro Pkwy	723	4.4	16.5	0.2	35
XOS of 17 Mile	724	5.5	50.6	0.7	51
17 Mile Road	275	6.4	18.6	0.2	30
XON of 17 Mile	725	2.3	12.8	0.1	42
XOS of 18 Mile	726	6.6	53.2	0.7	48
18 Mile Road	377	5.5	17.0	0.2	32
XON of 18 Mile	741	3.1	16.2	0.2	41
18 1/2 Mile Road	530	4.4	20.2	0.2	40
19 Mile Road	594	7.3	48.7	0.6	45
Forum at Gateways Sh	832	3.5	64.2	0.9	51
XOS of Hall Road	786	1.4	6.2	0.1	37
Hall Road South (Dob	2092	47.3	55.5	0.1	7
Hall Road North	2091	5.3	9.3	0.0	18
Total		273.9	993.7	10.3	37

Arterial Level of Service: SB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Hall Road North	2091	58.3	67.4	0.1	7
Hall Road South (Dob	2092	12.8	16.7	0.0	10
XOS of Hall Road	786	2.5	10.3	0.1	39
Forum at Gateways Sh	832	1.8	6.1	0.1	38
19 Mile Road	594	7.7	69.0	0.9	47
18 1/2 Mile Road	530	5.0	46.9	0.6	47
XON of 18 Mile	741	5.5	22.7	0.2	36
18 Mile Road	377	5.0	19.2	0.2	34
XOS of 18 Mile	726	1.7	12.7	0.2	43
XON of 17 Mile	725	9.3	58.9	0.7	43
17 Mile Road	275	8.0	19.3	0.1	28
XOS of 17 Mile	724	3.7	15.2	0.2	37
XON of Metro Pkwy	723	18.0	68.4	0.7	38
Metro Parkway	277	21.3	33.4	0.2	17
XOS of Metro Pkwy	722	6.2	17.4	0.1	30
XON of 15 Mile	574	15.7	66.6	0.7	39
15 Mile Road	42	7.6	18.1	0.1	27
XOS of 15 Mile	41	3.3	15.3	0.2	39
XON of Sterling Dr	591	1.1	8.4	0.1	43
XOS of Sterling Dr	590	2.5	24.1	0.3	45
XON of 14 Mile	36	16.7	37.9	0.3	28
14 Mile Road	35	15.2	26.4	0.1	20
XOS of 14 Mile	34	5.0	14.7	0.1	33
	31	5.5	19.9	0.2	37
Chicago Road	28	8.3	25.4	0.2	34
XON of 13 Mile	783	6.9	30.5	0.4	42
13 Mile Road	23	9.7	20.3	0.1	26
XOS of 13 Mile	782	5.1	14.3	0.1	30
XON of GM Tech Cente	923	4.8	33.5	0.4	43
GM Technical Center	922	1.2	8.3	0.1	43
XON of 12 Mile	458	14.9	34.0	0.3	28
12 Mile Road	10	20.2	29.9	0.1	16
XOS 12 Mile Road	457	8.0	16.1	0.1	24
XON TACOM	978	3.3	6.4	0.0	24
TACOM Main Gate	977	17.1	31.3	0.2	23
XON of Martin Rd	573	17.4	24.0	0.1	13
XOS of Martin Rd	572	52.0	65.4	0.2	10
11 Mile Road Ramps	13	21.3	25.3	0.1	8
I-696 Ramps	14	44.8	54.3	0.1	9
11 Mile Road Ramps	116	6.8	33.9	0.4	42
I-696 Ramps	9	5.5	42.9	0.5	43
11 Mile Road Ramps	22	2.2	13.2	0.1	39
XON of 10 Mile	564	1.9	5.4	0.0	28
Total		490.8	1229.3	10.3	30

Arterial Level of Service: NB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
XON of 10 Mile	564	0.8	8.3	0.1	46
11 Mile Road Ramps	22	0.4	3.4	0.0	44
I-696 Ramps	9	2.2	12.5	0.1	42
11 Mile Road Ramps	116	3.2	40.2	0.5	46
I-696 Ramps	14	102.7	128.3	0.4	11
11 Mile Road Ramps	13	36.6	46.1	0.1	11
XOS of Martin Rd	572	17.2	26.6	0.1	9
XON of Martin Rd	573	42.7	57.0	0.2	12
TACOM Main Gate	977	30.5	50.5	0.1	9
XON TACOM	978	65.6	106.8	0.2	9
XOS 12 Mile Road	457	31.6	34.7	0.0	5
12 Mile Road	10	45.3	123.9	0.1	7
XON of 12 Mile	458	6.7	19.9	0.1	28
GM Technical Center	922	3.5	22.1	0.3	43
XON of GM Tech Cente	923	1.1	8.6	0.1	42
XOS of 13 Mile	782	7.1	35.8	0.4	40
13 Mile Road	23	5.1	13.8	0.1	31
XON of 13 Mile	783	2.2	12.6	0.1	42
Chicago Road	28	6.7	29.9	0.4	43
Arden Avenue	31	7.4	25.1	0.2	34
XOS of 14 Mile	34	5.7	20.1	0.2	37
14 Mile Road	35	8.5	18.5	0.1	26
XON of 14 Mile	36	3.3	13.4	0.1	39
XOS of Sterling Dr	590	1.9	23.3	0.3	46
XON of Sterling Dr	591	2.2	24.5	0.3	44
XOS of 15 Mile	41	13.3	20.4	0.1	18
15 Mile Road	42	42.1	54.9	0.2	11
XON of 15 Mile	574	3.4	79.1	0.1	36
XOS of Metro Pkwy	722	13.9	65.0	0.7	40
Metro Parkway	277	12.3	23.0	0.1	22
XON of Metro Pkwy	723	3.6	15.5	0.2	37
XOS of 17 Mile	724	6.1	55.7	0.7	46
17 Mile Road	275	4.7	16.0	0.2	35
XON of 17 Mile	725	2.0	12.8	0.1	42
XOS of 18 Mile	726	11.6	59.3	0.7	43
18 Mile Road	377	6.4	18.0	0.2	30
XON of 18 Mile	741	2.7	15.3	0.2	43
18 1/2 Mile Road	530	6.2	21.7	0.2	38
19 Mile Road	594	3.4	42.9	0.6	51
Forum at Gateways Sh	832	2.8	63.6	0.9	51
XOS of Hall Road	786	1.5	6.4	0.1	36
Hall Road South (Dob	2092	31.3	39.7	0.1	10
Hall Road North	2091	4.6	8.6	0.0	20
Total		612.1	1524.3	10.3	28

Arterial Level of Service: SB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Hall Road North	2091	44.7	53.9	0.1	9
Hall Road South (Dob	2092	7.7	11.7	0.0	14
XOS of Hall Road	786	1.6	9.2	0.1	44
Forum at Gateways Sh	832	4.1	8.3	0.1	28
19 Mile Road	594	5.1	68.5	0.9	48
18 1/2 Mile Road	530	7.2	47.5	0.6	46
XON of 18 Mile	741	5.1	22.0	0.2	37
18 Mile Road	377	3.6	17.1	0.2	38
XOS of 18 Mile	726	1.6	12.3	0.2	44
XON of 17 Mile	725	5.6	55.3	0.7	46
17 Mile Road	275	5.2	16.4	0.1	33
XOS of 17 Mile	724	2.1	12.9	0.2	43
XON of Metro Pkwy	723	11.7	59.4	0.7	43
Metro Parkway	277	9.4	21.9	0.2	26
XOS of Metro Pkwy	722	3.1	14.0	0.1	37
XON of 15 Mile	574	16.1	66.2	0.7	40
15 Mile Road	42	5.8	17.3	0.1	28
XOS of 15 Mile	41	2.1	14.2	0.2	42
XON of Sterling Dr	591	1.0	8.1	0.1	44
XOS of Sterling Dr	590	1.7	23.8	0.3	45
XON of 14 Mile	36	7.2	28.4	0.3	37
14 Mile Road	35	8.4	19.8	0.1	27
XOS of 14 Mile	34	2.6	12.4	0.1	39
	31	4.7	18.9	0.2	39
Chicago Road	28	7.2	23.9	0.2	36
XON of 13 Mile	783	5.2	30.4	0.4	42
13 Mile Road	23	5.5	16.8	0.1	32
XOS of 13 Mile	782	2.4	11.7	0.1	37
XON of GM Tech Cente	923	5.0	33.2	0.4	44
GM Technical Center	922	1.5	9.8	0.1	37
XON of 12 Mile	458	14.4	32.9	0.3	29
12 Mile Road	10	8.6	19.7	0.1	24
XOS 12 Mile Road	457	3.2	11.4	0.1	33
XON TACOM	978	1.9	5.1	0.0	31
TACOM Main Gate	977	2.6	16.8	0.2	42
XON of Martin Rd	573	2.3	8.7	0.1	36
XOS of Martin Rd	572	3.8	17.5	0.2	38
11 Mile Road Ramps	13	4.2	8.2	0.1	24
I-696 Ramps	14	8.7	18.3	0.1	27
11 Mile Road Ramps	116	3.6	31.1	0.4	45
I-696 Ramps	9	3.5	41.3	0.5	45
11 Mile Road Ramps	22	1.4	12.6	0.1	41
XON of 10 Mile	564	1.3	4.6	0.0	32
Total		253.7	994.0	10.3	37

Arterial Level of Service: NB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
XON of 10 Mile	564	5.9	11.9	0.1	21
11 Mile Road Ramps	22	4.3	7.4	0.0	20
I-696 Ramps	9	5.8	16.2	0.1	32
11 Mile Road Ramps	116	119.2	153.7	0.5	12
I-696 Ramps	14	271.7	296.0	0.4	5
11 Mile Road Ramps	13	47.3	57.3	0.1	9
XOS of Martin Rd	572	20.6	25.4	0.1	8
XON of Martin Rd	573	59.0	72.6	0.2	9
TACOM Main Gate	977	52.4	58.7	0.1	5
XON TACOM	978	85.3	99.3	0.2	7
XOS 12 Mile Road	457	28.7	31.8	0.0	5
12 Mile Road	10	50.7	98.5	0.1	6
XON of 12 Mile	458	8.5	18.6	0.1	25
GM Technical Center	922	12.3	30.3	0.3	31
XON of GM Tech Cente	923	3.4	24.0	0.1	34
XOS of 13 Mile	782	9.4	37.4	0.4	39
13 Mile Road	23	11.2	19.7	0.1	22
XON of 13 Mile	783	5.7	16.7	0.1	32
Chicago Road	28	13.9	37.5	0.4	34
Arden Avenue	31	7.9	25.3	0.2	34
XOS of 14 Mile	34	18.4	32.8	0.2	23
14 Mile Road	35	17.5	27.9	0.1	17
XON of 14 Mile	36	5.1	15.9	0.1	33
XOS of Sterling Dr	590	2.6	24.0	0.3	44
XON of Sterling Dr	591	6.7	28.3	0.3	38
XOS of 15 Mile	41	18.3	26.1	0.1	14
15 Mile Road	42	39.5	71.0	0.2	11
XON of 15 Mile	574	5.2	53.2	0.1	32
XOS of Metro Pkwy	722	16.9	63.5	0.7	41
Metro Parkway	277	21.2	31.4	0.1	16
XON of Metro Pkwy	723	7.7	19.9	0.2	29
XOS of 17 Mile	724	10.7	60.5	0.7	43
17 Mile Road	275	8.2	19.2	0.2	29
XON of 17 Mile	725	3.4	14.2	0.1	38
XOS of 18 Mile	726	218.2	272.9	0.7	10
18 Mile Road	377	59.0	72.4	0.2	8
XON of 18 Mile	741	32.1	262.1	0.2	14
18 1/2 Mile Road	530	14.4	45.9	0.2	27
19 Mile Road	594	5.8	46.1	0.6	48
Forum at Gateways Sh	832	8.1	68.5	0.9	48
XOS of Hall Road	786	5.4	10.4	0.1	22
Hall Road South (Dob	2092	33.5	42.0	0.1	10
Hall Road North	2091	5.1	9.1	0.0	18
Total		1386.1	2455.7	10.3	18

Arterial Level of Service: SB Mound Road

Cross Street	Node	Delay (s/veh)	Travel time (s)	Dist (mi)	Arterial Speed
Hall Road North	2091	36.0	45.3	0.1	11
Hall Road South (Dob	2092	4.4	8.4	0.0	20
XOS of Hall Road	786	1.2	9.2	0.1	44
Forum at Gateways Sh	832	6.4	10.7	0.1	22
19 Mile Road	594	9.5	72.5	0.9	45
18 1/2 Mile Road	530	462.7	501.3	0.6	4
XON of 18 Mile	741	404.1	481.2	0.2	2
18 Mile Road	377	142.5	203.4	0.2	4
XOS of 18 Mile	726	3.3	14.2	0.2	38
XON of 17 Mile	725	13.4	62.7	0.7	41
17 Mile Road	275	6.3	19.3	0.1	28
XOS of 17 Mile	724	2.1	13.4	0.2	42
XON of Metro Pkwy	723	22.8	69.0	0.7	37
Metro Parkway	277	11.3	24.3	0.2	24
XOS of Metro Pkwy	722	2.9	13.9	0.1	37
XON of 15 Mile	574	19.5	70.8	0.7	37
15 Mile Road	42	5.8	17.1	0.1	28
XOS of 15 Mile	41	1.9	13.8	0.2	43
XON of Sterling Dr	591	0.9	8.0	0.1	45
XOS of Sterling Dr	590	1.6	23.5	0.3	46
XON of 14 Mile	36	13.6	34.6	0.3	31
14 Mile Road	35	11.1	22.3	0.1	24
XOS of 14 Mile	34	3.6	13.2	0.1	36
	31	9.6	23.3	0.2	32
Chicago Road	28	9.4	26.5	0.2	32
XON of 13 Mile	783	18.2	42.6	0.4	30
13 Mile Road	23	15.2	26.4	0.1	20
XOS of 13 Mile	782	5.4	14.7	0.1	29
XON of GM Tech Cente	923	15.4	43.9	0.4	33
GM Technical Center	922	3.0	11.3	0.1	32
XON of 12 Mile	458	51.2	70.0	0.3	13
12 Mile Road	10	21.2	31.8	0.1	15
XOS 12 Mile Road	457	7.7	15.8	0.1	24
XON TACOM	978	7.9	11.1	0.0	14
TACOM Main Gate	977	17.6	32.3	0.2	22
XON of Martin Rd	573	24.6	31.1	0.1	10
XOS of Martin Rd	572	67.0	80.5	0.2	8
11 Mile Road Ramps	13	24.6	28.6	0.1	7
I-696 Ramps	14	35.9	45.4	0.1	11
11 Mile Road Ramps	116	7.0	34.1	0.4	41
I-696 Ramps	9	5.2	42.6	0.5	44
11 Mile Road Ramps	22	2.1	13.2	0.1	40
XON of 10 Mile	564	3.2	6.6	0.0	23
Total		1538.1	2384.2	10.3	16

Appendix C – MCDR Connected Vehicles Initiative Memo

Project Memorandum

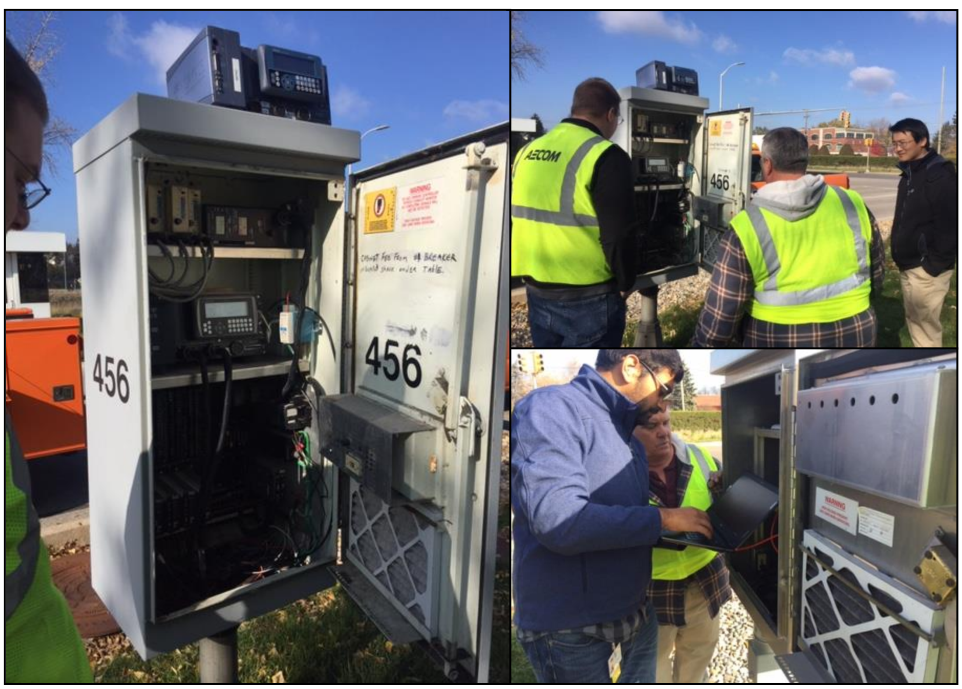
Project Name: **Connected Vehicles Initiative** Issue Date: **December 5, 2016**

This year, the Macomb County Department of Roads (MCDR) Traffic Division, Electrical Department, and Traffic Operations Center (TOC) staff has been involved in assisting General Motors (GM) with a research project pertaining to connected vehicles. The effort has been two-legged, as both the Michigan Department of Transportation (MDOT) and Macomb County have joined forces to help the initiative at multiple locations in the County with different General Motors personnel.

The first initiative involved the MCDR working directly with GM engineers at a signalized location located on the General Motors Technical Center campus in Warren. The signalized location was slated to be removed several years ago until General Motors decided to use it for connected vehicles as an on-campus test bed. After multiple meetings and consultation from contractors assisting MDOT, a road side unit (RSU) was successfully deployed by MCDR Electricians, MCDR TOC Engineers, and MCDR TOC IT/ITS Technicians on November 23. The RSU is connected to the standard SEPAC-driven traffic controller in the existing cabinet and sends SPaT (Signal Phase and Timing) messages to the vehicle. Photos below depict moments captured on the day of implementation.

The second initiative, on a separate schedule under different directives, occurred at two individual locations – 12 Mile and Mound Road and 13 Mile and Mound Road in Warren. Consultant Mixon-Hill was primarily responsible for development, along with MDOT Engineers, with input from all other parties noted in this document. After a few software tweaks and new iterations, the successful installation of an RSU at each location on November 16, and now are streaming SpaT messages correctly. This now sets the platform upon which numerous safety and mobility applications can be implemented as illustrated in the next page.

MCDR will continue to be offering technical assistance while GM tests connected vehicle infrastructure in the near future.



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The Macomb County Connected Vehicle Intersection