MEMORANDUM

TO: Mayor and Council
FROM: John Fournier, Acting City Administrator
DATE: October 12, 2021
SUBJECT: E. Medical Center Drive Bridge Rehabilitation & Widening

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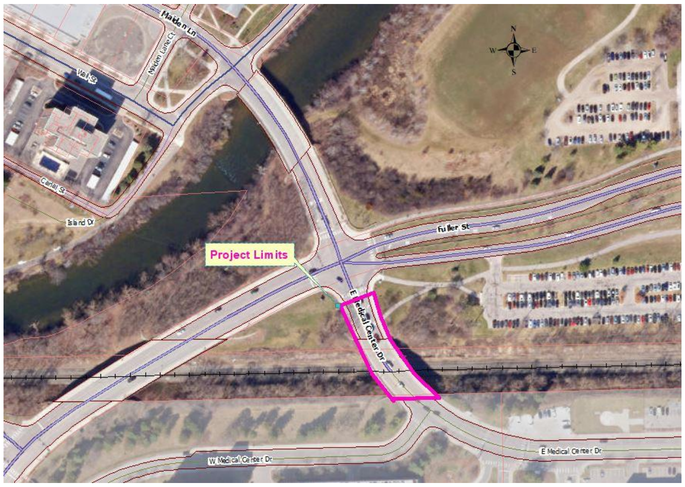
This memorandum is in response to questions that arose regarding the Resolution to Approve a Professional Services Agreement with DLZ Michigan, Inc. for Engineering Design Services for the E. Medical Center Drive Bridge Rehabilitation and Widening Project presented to Council on September 20, 2021 (Legistar File No. 21-1442).

Background & Scope

The limits for this project are shown in the below map:



The bridge, as well as the short section of East Medical Center Drive between the bridge and Fuller Road, are under the City's jurisdiction. The rest of East Medical Center Drive (beginning immediately south of the bridge) is under the University of Michigan's jurisdiction.

The existing East Medical Center Drive bridge over the railroad is currently rated in poor condition. The proposed rehabilitation work is necessary to return it to a State of Good Repair. Delays to this work will lead to further deterioration of the structure and likely higher cost to repair, although it would be difficult to attempt to quantify the increased costs. According to the most recent inspection report (from February 19, 2021; see Attachment #1), if the bridge is not rehabilitated soon, it may lead to the need to post weight limits. A new inspection will be performed this autumn. If weight limits need to be imposed, it would have a significant impact on vehicle access to the hospital area.

The proposed scope also includes the widening of the bridge to add future capacity to the intersection. This is discussed further below.

Benefits of Widening

East Medical Center Drive is the primary entrance to the University of Michigan medical center campus, a regional medical facility that treats patients from around the state and the Midwest. From 2016 through 2019 the two Emergency Departments averaged 75,854 visits per calendar year. In 2020, with the full impact of the pandemic limiting some hospital services, both emergency rooms still totaled 65,707 visits. Since 70% of UM hospital patients are admitted from communities outside Ann Arbor, most of the trips to the hospital campus come from patients travelling by automobile. In recent years, the University has incrementally reallocated some employee parking as the demand for patient parking has increased. Thus, the increase in total activity associated with the medical campus is the primary consideration in the widening of the East Medical Center Drive bridge.

The intersection of Fuller Road, Maiden Lane, and East Medical Center Drive has experienced congestion issues for some time, and future traffic models predict that this condition will worsen. Various studies have been undertaken over the last couple decades by the City and the University to develop solutions to this issue (See Attachment #2). The following is a quote from the May 21, 2018 memo:

"Significant vehicle queueing occurs along southbound EMCD during the AM peak hour between the Cancer Center Drive intersection and the intersection of Fuller/Maiden Lane/EMCD. This is due to the capacity constraint of a single lane along southbound EMCD. Approximately 1170 vehicles are trying to head southbound on EMCD during the AM peak hour compared to 550 in the PM peak hour. The queuing on this stretch of EMCD heavily impacts operations at the Fuller/Maiden Lane/EMCD intersection."

Capacity at this intersection is constrained by the bridges bordering it on the north, west, and south. In order to maintain adequate access for patients to the hospital campus, the City and University will continue discussions on how best to address capacity at this intersection in the future. In most of the scenarios evaluated to date, additional capacity on the East Medical Center Drive bridge is key to the intersection functioning at an acceptable level and maintaining adequate access to the hospital. Also, with only one current southbound lane, the additional width on the bridge will also provide more space for vehicles to pull over when ambulances are accessing the hospital in emergency situations.

While the final configuration of the vehicular turning lanes will ultimately be determined by the design of the forthcoming intersection reconstruction project, the current preferred concept includes an additional southbound lane over the East Medical Center Drive bridge, which will address the constraint cited in the May 21, 2018 memo quoted above.

The rehabilitation work on the East Medical Center Drive bridge presents an opportunity to widen the bridge and add future capacity and flexibility to the intersection. Performing the widening now while the bridge is already under construction will be more cost effective, will avoid the need rip apart a newly rehabilitated bridge, and will result in fewer disruptions to the transportation network, as compared to widening the bridge later as part of a future intersection reconstruction project.

The University has agreed to pay for 100% of the cost of widening the bridge, in addition to 50% of the cost to rehabilitate the existing structures. Their funding participation in this project is predicated upon the assumption that the bridge will be widened to add one additional travel lane to address the clinical enterprise access needs of the medical campus.

North-South Non-motorized Connection

Having an adequate north-south connection in this area is critical for non-motorized traffic travelling between the hospital and Lowertown area. Pedestrians and bikes traveling through the intersection currently must pass over the Maiden Lane bridge as well as the East Medical Center Drive bridge.

The East Medical Center Drive bridge cross section currently consists of four 11-foot wide lanes and two 10½-foot wide sidewalks. Given this cross section, and adding the proposed travel lane, it is feasible to make modifications to the configuration of the sidewalks to create improvements to the surface non-motorized facilities on the bridge utilizing the 21 feet of existing sidewalk space. Such improvements will be included in the design of this project and vetted through the Transportation Commission. Presently, the University’s funding commitment to this project is predicated that lane widths will be maintained at 11 feet.

However, in order to extend such improvements through the intersection to connect to the Lowertown area, similar changes would need to be made to the Maiden Lane bridge, which is beyond the scope of the current project. Improvements to the south of East Medical Center Drive bridge are also not part of the scope of the project.

Previously, some concepts have been developed for north-south connections through the intersection utilizing pathways under the bridges, which could provide non-motorized traffic alternatives to crossing the intersection at grade (See Attachment #3), although with significantly longer walking distances. Implementation of such concepts are beyond the scope of the current project and would likely need to be coordinated with any future intersection reconstruction project. There is also no funding source currently identified for such a project.

East-West Connections

The Capital Improvements Plan currently contains two projects to create east-west non-motorized connections through or around the intersection:

- Border to Border (B2B) Trail: Fuller/Maiden Lane (TR-AT-18-22) which would create a connection from the northeast corner of the intersection under the Maiden Lane bridge, across the river on a non-motorized bridge, and connect with the B2B Trail near Riverside Park.
- Non-Motorized Connection under E. Medical Center Dr Along S Side of Fuller (TR-AT-16-04) which would create a path from the southeast corner of the intersection under the East Medical Center Drive Bridge and then connect with the B2B trail above and/or return to grade along the south side of Fuller Road.

A concept drawing of how these two paths could align and potentially connect is attached (See Attachment #4). The current proposed project includes design work to modify the area under the East Medical Center Drive Bridge to have enough width to accommodate this future connection. However, the full design and construction is not included in the scope of the current project for either of these paths, nor has funding been identified for these projects.

From a technical standpoint, the ideal time to construct these connections would be with a future intersection reconstruction where all motorized and non-motorized elements could be designed and built in conjunction with one another. However, it could be feasible to design and construct the southerly connection under the East Medical Center Drive Bridge with the current project, provided a funding source could be identified. If Council desires to add this work, staff recommends approval of the current Resolution with the following amendment:

RESOLVED, That Council directs the City Administrator to negotiate an amendment to the contract with DLZ to design the east-west pathway connection under the East Medical Center Drive Bridge and develop a cost estimate for construction, and that the City Administrator be authorized to approve this amendment to the contract;

As always, please do not hesitate to contact me if I can be of further assistance on this matter.

Attachment #1 – Bridge Inspection Report
Attachment #2 – Previous Studies/Reports/Memos
Attachment #3 – North/South Pedestrian Concepts
Attachment #4 – East/West Pedestrian Concepts

cc: C. Hupy
N. Hutchinson
F. Chan

Attachment #1

Bridge Inspection Report

ARCHITECTURE • ENGINEERING • PLANNING
SURVEYING • CONSTRUCTION SERVICES

INNOVATIVE IDEAS
EXCEPTIONAL DESIGN
UNMATCHED CLIENT SERVICE

FINAL REPORT
2020 BRIDGE INSPECTION PROJECT

EAST MEDICAL CENTER DRIVE OVER NORFOLK SOUTHERN RAILROAD

CITY OF ANN ARBOR, MICHIGAN

Mark T. Lessens, P.E.
Registered Professional Engineer
State of Michigan No. 36092

MARK T.
LESSENS
ENGINEER
No.
36092

Prepared For:

CITY OF ANN ARBOR, MICHIGAN

Prepared By:

DLZ MICHIGAN, INC.

DLZ Job No. 2041-7169-00

February 19, 2021

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Structure Description

The existing bridge carrying East Medical Center Drive over Norfolk Southern Railroad is located in the City of Ann Arbor, Michigan. East Medical Center Drive is a collector street. The bridge carries a four lane road and is located immediately south of the East Medical Center Drive/Fuller Road intersection and north of the East Medical Center Drive/West Medical Center Drive intersection. The road is the primary access to the University of Michigan Hospital.

The three span bridge was constructed in 1982 with twelve rolled steel wide flange beams with welded coverplates and a composite, reinforced concrete deck. The bridge length is 160'-0" from reference line to reference line with an out-to-out width of 70'-11 ¼" and an approximate skew of 36^o left. The alignment of East Medical Center Drive is in a horizontal curve across the bridge. To accommodate the curve, the alignment of the beams changes direction at both piers. The cross section includes two sidewalks, four lanes of traffic consisting of three northbound lanes (right turn, through and left turn lanes) and one southbound lane, with 3 tube steel railings mounted to the top of concrete parapet railings. The clear roadway width is 47'-0". There is a deck expansion joint device located above the south pier and a rubber seal joint located above the north pier.

The existing substructure consists of two, reinforced concrete stub abutments and two, reinforced concrete column bent piers with crashwalls. The abutment substructure units are supported on piles and the two piers are supported on spread footings.

Inspection Findings

The in-depth visual inspection of the bridge was performed on October 18, 2020. The overall condition of the structure is poor.

DECK AND SIDEWALKS

The concrete deck is in fair condition ***(Photo 4).*** There are multiple longitudinal and transverse cracks and several delaminated areas in the driving lanes and sidewalks. The largest area of concrete deterioration is present in the north span. The deck surface deterioration in the north span alone amounts to 45.4% of the area of the driving lanes. The acute angle corners of the deck have diagonal cracking at approximately 3' spacing.

The bottom side of the deck has approximately 5-10% of the total area consisting of spalls (some with exposed reinforcement), delaminations, cracks with moisture and efflorescence, and rust stains ***(Photos 12 and 13).*** The soffit of the east deck fascia has cracks with stalactites. The north span is in the worst condition which corresponds with the condition on the top of the deck. There is a concrete spall that has occurred along the west deck fascia above the south pier, and one of the anchor bolts for the light pole is exposed ***(Photo 25***).

There is a concrete spall that has occurred along the east deck fascia above the north pier ***(Photo 26***).

The sidewalks are in fair condition***.*** There is cracking, minor spalls and delaminations totaling 5.85% of the total sidewalk area (244.7 sft).

The expansion joints located over the piers are in poor condition. The glands are torn and debris filled ***(Photo 7).*** The joints leak causing corrosion at the beam ends and end diaphragms located below. There are spalls along the concrete in the deck at the joints ***(Photo 8).***

STRINGERS

The existing structural steel is in fair condition overall, but poor condition at several beam ends, below the deck joints at the piers. The paint has failed throughout ***(Photo 12).*** In locations where the paint is present, the top coat is blistering. The beam ends at the expansion joints are corroding, and there is measurable section loss at the ends or along the beams, including in the beam webs and the beam flanges ***(Photos 15-16).*** The end diaphragms under the expansion joints also have corrosion with measurable section loss ***(Photo 16)***.

ABUTMENTS

The abutments were found to be in good condition. The abutments have hairline cracks present. There were no concrete delaminations noted on either abutment ***(Photos 17-18).*** Both abutments are covered with graffiti.

PIERS

The piers were found to be in fair to poor condition. The lower half of the south and north pier columns and the crashwalls are covered with graffiti. The south pier (Pier 1) has several areas of delaminated concrete on the south face and on the north face ***(Photos 22-24).***

The north pier (Pier 2) has several areas of delaminated concrete on both the south face and on the north face ***(Photos 19-21).*** An area of bottom cap resteel is exposed and rusting. The concrete delaminations and spalled areas are primarily located on the pier cap, especially on the north face. The delaminations on the north face have reached the depth where the top edge (top surface of the pier cap) of the area is at the front corner of the skewed bearing plate ***(Photo 16).*** This situation will need to be closely monitored and the addition of temporary supports may be warranted to assure the beam ends are supported in case additional concrete material is lost at the bearings.

MISCELLANEOUS FINDINGS

The bridge railings are in fair condition with vertical cracking at approximately 5' increments ***(Photo 9).*** The northwest, northeast, and southeast railing end walls have spalled concrete and exposed anchor bolts ***(Photo 10).***

The bearings are in fair condition. The east fascia beam bearing pad (Beam M) at the south pier (Pier 1), north span, is tilting south. For cold weather conditions, the bearing should be positioned vertical or tilted inward to the north. There is no evidence of bulging or distress in the elastomeric bearing pad. The portion of the east fascia beam bearing that is visible at the north abutment (Abutment B) on the corresponding beam appears to be upright. The bearing tilt may be a result of incorrect positioning during construction or due to longitudinal grade on the bridge sloping south.

The concrete approach sidewalk in the northeast quadrant of the bridge is heavily cracked***.***

There is heavy vegetation present in all quadrants***.*** There are trees growing through the slope paving.

The HMA approach pavements are in good condition with most cracks sealed ***(Photos 2 and 3).***

See Appendix A for the updated Bridge Safety Inspection Report which details the condition of numerous bridge elements.

Bridge Compliance with Current Standards

The bridge has the following feature that does not meet current standards:

- The 3-Tube parapet mounted galvanized steel railings are not approved, crash tested railings that satisfy AASHTO and MDOT standards.
- Guardrail – the approach guardrail does not have standard anchorages or terminals.

Load Rating Analysis

DLZ prepared a computer model of this structure using AASHTOWare Bridge Rating software (BrR) for the purpose of completing load rating calculations. Existing beam conditions obtained during the field inspection, including deterioration at the beam ends/bearings (webs) and along the length of the beams (bottom flange) were included in the model. This software is specifically written to load rate structures, and includes all 28 Michigan Legal trucks, as well as the design vehicles. The results of the computer analysis indicate that all Rating Factors (RF's) are above 1.0, which indicates the bridge has the capacity to carry all Michigan legal live loads and the bridge does not require live load restrictions. The Assumption and Summary forms in MiBridge were updated to reflect the new modeling effort and the output from the program. The BrR computer model can be revised, as necessary, to reflect any future deterioration or repairs made to load carrying members, or changes in geometry or dead loads.

Recommendations

The inspection of the East Medical Center Drive Bridge found the structure to be in fair to poor condition. We understand that a rehabilitation project is currently being considered for this structure but is also on hold. There are several repairs that should be completed in the short-term (noted as High Priority, below) if a major reconstruction or rehabilitation project is postponed beyond 1-2 years (beyond 2021-2022). Recommendations listed below are prioritized with low, medium, or high priority:

- Remove and replace the expansion and construction joints (High).
- Install beam end repairs, if determined to be needed based on the outcome of the Load Rating Analysis (TBD)
- Replace the pier cap at the north pier (Pier 2) (High).
- Perform substructure repairs at the south pier (Pier 1) (High).
- Paint the existing structural steel (High).
- Remove vegetation overgrowth from all quadrants and slope paving (High).
- Place a deep overlay on the deck travel surface and complete full depth deck patching, as needed (Medium).
- Remove and replace the bridge railings and install approach guardrail to satisfy AASHTO standards (Medium).
- Chip and patch areas of delaminated concrete on the bridge sidewalks (Low).

The joints are in poor condition and do not perform as they were designed. Removing and replacing the leaking expansion joints located over the piers is the highest priority. The leaking joints cause deterioration of the steel, rusting of the bearings, failure of the paint system, and deterioration of the pier caps, columns and crashwalls. Some diaphragms located under the joints may warrant replacement due to deterioration caused by the leaking deck joints.

The current inspection found 575 sft of delaminations at the pier caps and columns. If substructure deterioration exceeds 30% of the structural element, replacement is advised. The areas of delamination are over 40% of the north pier cap over 15% of the south pier cap. The north pier cap deterioration warrants replacement. The south pier cap can be repaired at this time. However, if the joint replacements are not performed, pier cap deterioration will continue and replacement of both pier caps may be warranted.

The structural steel is in fair condition with a failed paint system and heavy surface rust and some section loss at the beam ends. MDOT guidelines recommend complete painting be performed when steel beams have greater than 15% of the existing paint area failing. This structure has the majority of the top coat peeling or missing thus warranting coating and cleaning of the steel. It may be acceptable and more feasible to perform zone painting at the beam ends at the piers due to the difficulty of painting over active train tracks. Painting the structure will extend the life of the bridge by providing protection to the primary load carrying members of the bridge.

Remove vegetation overgrowth in all quadrants and in the slope paving. The vegetation encroaches on the structure and prohibits full access using reach-all equipment. In addition, vegetation traps moisture at the bridge which could contribute to the corrosion of the steel superstructure and deterioration of the paint system.

From our field inspection and the SI&A traffic counts, it is evident that this roadway is heavily traveled by both vehicular and pedestrian traffic. It is our opinion that the safety of this structure could be improved by replacing the substandard railing and guardrail. The existing railing is substandard and has spalled concrete with exposed anchor bolts in the northwest, northeast, and southeast quadrants. The railing and guardrail replacement can be postponed; however, if other items of work are being performed, it is economical to perform these repairs as well. However, rehabilitation of the railings similar to what was completed on the Fuller Road and Maiden Lane bridges in 2015, is feasible and may be more desirable then complete replacement.

Summary of Repair Costs

A breakdown of the cost of the recommended repairs is shown in Appendix C. The estimated cost to remove vegetation, repair slope paving, replace the deck joints, replace railings and guardrail, paint structural steel, complete pier cap replacement, substructure repairs, removal of existing latex overlay and placement of a deep overlay and approach work is $3,883,000.

APPENDIX A - SI&A and BSIR Forms

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 BRIDGE SAFETY INSPECTION REPORT

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

NBI INSPECTION OVJS

Inspector Name	Agency / Company Name	Insp. Freq.	Insp. Date
Mark Lessens	DLZ Michigan, Inc.	12	10/18/2020

GENERAL NOTES

Due to the poor condition of the north pier cap, the bridge deck and the leaking deck joints, it is recommended to maintain the inspection frequency at 12 months.

Detailed inspection completed using MDOT reach all, traffic control and Amtrak flagger. Completed on a Sunday to limit impacts to motoring public, which was very successful.

Remove vegetation and trees in all quadrants.

NS/Amtrak Contractor Safety Orientation Training required prior to detailed inspection. Railroad flagging required during detailed inspection.

DECK

	10/17	10/19	10/20	
1. Surface (SIA-58A)	5	5	5	Longitudinal and transverse full depth cracking and delaminated areas and spalls. Heaviest concentration of delaminations in the north span. Diagonal cracking at skewed ends spaced at 3'. Approx. 1152 sft of surface defects, or approx. 12% of the deck and sidewalk areas. Some HMA patches noted. (10/20) Longitudinal and transverse full depth cracking and delaminated areas and spalls. Heaviest concentration of delaminations in the north span. Diagonal cracking at skewed ends spaced at 3'. Approx. 1152 sft of surface defects, or approx. 12% of the deck and sidewalk areas. Some HMA patches noted. (10/19) Longitudinal and transverse full depth cracking and delaminated areas and spalls. Heaviest concentration of delaminations in the north span. Diagonal cracking at skew ends spaced at 3'. Approx. 1152 sft of surface defects noted, or approx. 12% of the deck and sidewalk areas. (10/17)
2. Expansion Joints	4	4	4	Leaking below onto pier and beam ends. Joints are debris filled and partially broken. Spalls and delaminations along joint. East end at curb line is spalled and filled with debris. Light is visible through the joint from below the bridge. Areas of joint header move under traffic load. (10/20) Leaking below onto substructure. Joints are debris filled and partially broken. Spalls and delaminations along joint. East end at curb line is spalled and filled with debris. Light is visible through the joint from below the bridge. Areas of joint header move under traffic load. (10/19) Leaking below onto substructure. Joints are debris filled and partially broken. Spalls along joint. East end at curb line is spalled and filled with debris. Light is visible through the joint from below the bridge. (10/17)
3. Other Joints	5	5	5	Leaking below joints at north pier onto beam ends and pier. Joint filler present at north pier. Joint is broken at north reference line. Large spall at south reference line joint. (10/20) Leaking below joints. Joint filler present at north pier. Joint is broken at north reference line. Large spall at south reference line joint. (10/19) Leaking below joints. Joint filler present at north pier. Joint is broken at north reference line. Large spall at south reference line joint. (10/17)
4. Railings	6	6	6	The concrete railing has vertical cracks with some rust staining and is spalled at the steel tube connections to the concrete end wall at all quadrants. (10/20) The concrete railing has vertical cracks with some rust staining and is spalled at the steel tube connections to the concrete end wall at all quadrants. (10/19) The concrete railing has vertical cracks with some rust staining and is spalled at the steel tube connections to the concrete end wall at the SE, NE and NW quadrants. (10/17)

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5. Sidewalks or Curbs	5	5	5	Cracking and minor spalls. Several large areas of delaminated concrete on sidewalks. Some leaching and rust stains. Differential settlement at reference lines in NW and NE quadrants. (10/20) Cracking and minor spalls. Several large areas of delaminated concrete on sidewalks. Some leaching and rust stains. Differential settlement at reference lines in NW and NE quadrants. (10/19) Cracking and minor spalls. Several large areas of delaminated concrete totaling 1.43% of sidewalk area. Some leaching and rust stains. Differential settlement at reference lines in NW, SW, and SE quadrants. (10/17)
6. Deck Bottom Surface (SIA-58B)	5	5	5	Many leaching cracks, wet areas, delaminated and spalled concrete areas. Several areas of exposed reinforcement. (10/20) Many leaching cracks, wet areas, delaminated and spalled concrete areas. Several areas of exposed reinforcement. (10/19) Leaching cracks, delaminated and spalled areas. Several areas of exposed reinforcement. (10/17)
7. Deck (SIA-58)	5	5	5	Multiple cracks, spalls, and delaminated areas totaling 12% of the deck area. Largest concentration of deterioration is in the north span. Diagonal cracking at skew ends spaced at 3'. Approx. 1152 sft of surface defects noted, or approx. 12% of the deck and sidewalk areas. (10/20) Multiple cracks, spalls, and delaminated areas totaling 12% of the deck area. Largest concentration of deterioration is in the north span. Diagonal cracking at skew ends spaced at 3'. Approx. 1152 sft of surface defects noted, or approx. 12% of the deck and sidewalk areas. (10/19) Multiple cracks, spalls, and delaminated areas totaling 12% of the deck area. Largest concentration of deterioration in the north span. Diagonal cracking at skew ends spaced at 3'. Approx. 1152 sft of surface defects noted, or approx. 12% of the deck and sidewalk areas. (10/17)
8. Drainage				(10/20) (10/19) (10/17)

SUPERSTRUCTURE

	10/17	10/19	10/20	
9. Stringer (SIA-59)	5	5	5	Most of the beam ends at joints have corrosion. Diaphragms under joints have corrosion, surface rust and paint failure. These diaphragms are non-structural secondary members. The majority of the beam length, away from the beam ends at the piers, are in good condition. The north span beams away from the north pier joint have more corrosion than other spans. (10/20) Beam ends at joints are rusted. Diaphragms under joints have minor deterioration, surface rust and paint failure. These diaphragms are non-structural secondary members. (10/19) Beam ends at joints are rusted. Diaphragms under joints have minor deterioration, surface rust and paint failure. These diaphragms are non-structural secondary members. (10/17)
10. Paint (SIA-59A)	5	4	4	Paint system has failed. Top coat is blistering in areas where it has not peeled off. Paint failure exceeds 15%. (10/20) Paint system has failed. Top coat is blistering in areas where it has not peeled off. Paint failure exceeds 15%. (10/19) Paint system has failed. Top coat is blistering in areas where it has not peeled off. Paint failure exceeds 15%. (10/17)
11. Section Loss	2	2	1	Beam ends at both piers have heavy surface rust with section loss. (10/20) Beam ends have heavy surface rust with minor section loss. (10/19) Beam ends have heavy surface rust with minor section loss. (10/17)
12. Bearings	6	6	6	Paint cracking due to movement on elastomeric pads. Rusted sole plates at Pier 2. Minor deformation in some elastomeric pads at piers. (10/20) Paint cracking due to movement on elastomeric pads. Rusted sole plates at Pier 2. Minor deformation in some elastomeric pads at piers. (10/19) Paint cracking due to movement on elastomeric pads. Rusted sole plates at Pier 2. Minor deformation in some elastomeric pads at piers. (10/17)

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SUBSTRUCTURE

	10/17	10/19	10/20	
13. Abutments (SIA-60)	7	7	7	Few hairline cracks. Graffiti covered surface. No delaminations found. (10/20) Few hairline cracks. Graffiti covered surface. No delaminations found. (10/19) Few hairline cracks. Graffiti covered surface. No delaminations found. (10/17)
14. Piers (SIA-60)	4	4	4	Cracked, spalled and delaminated concrete totaling 260 sft for south pier (Pier 1) and 290 sft for north pier (Pier 2). Exposed bottom steel in north pier cap. Graffiti covered surface. Water on surfaces from leaking joints above. Vertical cracks in 2nd column from east end in south pier. (10/20) Cracked, spalled and delaminated concrete totaling 260 sft for south pier (Pier 1) and 290 sft for north pier (Pier 2). Exposed bottom steel in north pier cap. Graffiti covered surface. Water on surfaces from leaking joints above. Vertical cracks in 2nd column from east end in south pier. (10/19) Cracked, spalled and delaminated concrete totaling 260 sft for south pier (Pier 1) and 290 sft for north pier (Pier 2). Exposed bottom steel in north pier cap. Graffiti covered surface. (10/17)
15. Slope Protection	7	7	7	Trees growing in slope paving. Slope paving is steep. (10/20) Trees growing in slope paving. Slope paving is steep. (10/19) Trees growing in slope paving. Slope paving is steep. (10/17)
16. Channel (SIA-61)	N	N	N	(10/20) (10/19) (10/17)
17. Scour Inspection	N	N	N	(10/20) (10/19) (10/17)

APPROACH

	10/17	10/19	10/20	
18. Approach Pavement	7	7	7	No patches on south approach, some sealed cracks. North approach has some cracks but is in good condition. (10/20) No patches on south approach, some sealed cracks. North approach has some cracks but is in good condition. (10/19) No patches on south approach, some cracking. North approach has been replaced recently and is in good condition. (10/17)
19. Approach Shoulders Sidewalks			6	HMA patches and spalls in SE, NE, and NW quadrants. Elevation difference between the approach curb line and bridge sidewalk exceeds 1" in NW, SW and SE quadrants. (10/20) HMA patches and spalls in SE, NE, and NW quadrants. Elevation difference between the approach curb line and bridge sidewalk exceeds 1" in NW, SW and SE quadrants. (10/19) Sidewalk in SE quadrant has been repaired. HMA patches and spalls in SE, NE, and NW quadrants. Elevation difference between the approach curbline and bridge sidewalk exceeds 1" in NW, SW and SE quadrants. (10/17)
20. Approach Slopes				(10/20) (10/19) (10/17)
21. Utilities				Lights along bridge on west and east sides. Plans indicate conduits in sidewalks. (10/20) Lights along bridge on west and east sides. (10/19) Lights along bridge on west and east sides. (10/17)
22. Drainage Culverts				(10/20) (10/19) (10/17)

MISCELLANEOUS

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 BRIDGE SAFETY INSPECTION REPORT

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4) 🚦
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

Guard Rail

Item	Rating
36A. Bridge Railings	0
36B. Transitions	0
36C. Approach Guardrail	0
36D. Approach Guardrail Ends	0

Other Items

Item	Rating
71. Water Adequacy	N
72. Approach Alignment	8
Temporary Support	0 No Temporary Supports
High Load Hit (M)	No
Special Insp. Equipment	
Underwater Insp. Method	0

False Decking (Timber) Removed to Complete Inspection N/A - No False Decking

Critical Feature Inspections (SIA-92)

	Freq	Date
92A. Fracture Critical		
92B. Underwater		
92C. Other Special		
92D. Fatigue Sensitive		

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 STRUCTURE INVENTORY AND APPRAISAL

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

Bridge History, Type, Materials

27 - Year Built	1982	
106 - Year Reconstructed		
202 - Year Painted	1982	
203 - Year Overlay	1982	
43 - Main Span Bridge Type	3	32
44 - Appr Span Bridge Type		
77 - Steel Type	5	
78 - Paint Type	2	
79 - Rail Type	3	
80 - Post Type	3	
107 - Deck Type	1	
108A - Wearing Surface	3	
108B - Membrane	0	
108C - Deck Protection	1	

Structure Dimensions

34 - Skew	36
35 - Struct Flared	N
45 - Num Main Spans	3
46 - Num Apprs Spans	0
48 - Max Span Length	62
49 - Structure Length	160
50A - Width Left Curb/SW	10.5
50B - Width Right Curb/SW	10.5
33 - Median	0
51 - Width Curb to Curb	46.9
52 - Width Out to Out	70.9
112 - NBIS Length	Y

Inspection Data

90 - Inspection Date	10/18/2020	
91 - Inspection Freq	12	
92A - Frac Crit Req/Freq	N	
93A - Frac Crit Insp Date		
92B - Und Water Req/Freq	N	
93B - Und Water Insp Date		
92C - Oth Spec Insp Req/Freq	N	
93C - Oth Spec Insp Date		
92D - Fatigue Req/Freq	N	
93D - Fatigue Insp Date		
176A - Und Water Insp Method	0	
58 - Deck Rating	5	
58A/B - Deck Surface/Bottom	5	5
59 - Superstructure Rating	5	
59A - Paint Rating	4	
60 - Substructure Rating	4	
61 - Channel Rating	N	
62 - Culvert Rating	N	

Navigation Data

38 - Navigation Control	N
39 - Vertical Clearance	0
40 - Horizontal Clearance	0
111 - Pier Protection	
116 - Lift Brdg Vert Clear	0

Route Carried By Structure(ON Record)

5A - Record Type	1	
5B - Route Signing	5	
5C - Level of Service	0	
5D - Route Number	00000	
5E - Direction Suffix	0	
10L - Best 3m Unclr-Lt	0	0
10R - Best 3m Unclr-Rt	99	99
PR Number		
Control Section		
11 - Mile Point	0	
12 - Base Highway Network	1	
13 - LRS Route-Subroute	0000018392 04	
19 - Detour Length	2	
20 - Toll Facility	3	
26 - Functional Class	14	
28A - Lanes On	4	
29 - ADT	17220	
30 - Year of ADT	2014	
32 - Appr Roadway Width	46.9	
32A/B - Ap Pvt Type/Width	5	47.01
42A - Service Type On	5	
47L - Left Horizontal Clear	0.0	
47R - Right Horizontal Clear	46.9	
53 - Min Vert Clr Ov Deck	99	99
100 - STRAHNET	0	
102 - Traffic Direct	2	
109 - Truck %	5	
110 - Truck Network	0	
114 - Future ADT	15356	
115 - Year Future ADT	2030	
Freeway	0	

Structure Appraisal

36A - Bridge Railing	0
36B - Rail Transition	0
36C - Approach Rail	0
36D - Rail Termination	0
67 - Structure Evaluation	4
68 - Deck Geometry	2
69 - Underclearance	6
71 - Waterway Adequacy	N
72 - Approach Alignment	8
103 - Temporary Structure	
113 - Scour Criticality	N

Miscellaneous

37 - Historical Significance	5
98A - Border Bridge State	
98B - Border Bridge %	0
101 - Parallel Structure	N
EPA ID	
Stay in Place Forms	
143 - Pin & Hanger Code	
148 - No. of Pin & Hangers	

Route Under Structure (UNDER Record)

5A - Record Type		
5B - Route Signing		
5C - Level of Service		
5D - Route Number		
5E - Direction Suffix		
10L - Best 3m Unclr-Lt		
10R - Best 3m Unclr-Rt		
PR Number		
Control Section		
11 - Mile Point		
12 - Base Highway Network		
13 - LRS Route-Subroute		
19 - Detour Length		
20 - Toll Facility		
26 - Functional Class		
28B - Lanes Under		
29 - ADT		
30 - Year of ADT		
42B - Service Type Under	2	
47L - Left Horizontal Clear		
47R - Right Horizontal Clear		
54A - Left Feature		
54B - Left Underclearance	99	99
54C - Right Feature		
54D - Right Clearance	99	99
Under Clearance Year		
55A - Reference Feature	R	
55B - Right Horiz Clearance	18	
56 - Left Horiz Clearance	0	
100 - STRAHNET		
102 - Traffic Direct		
109 - Truck %		
110 - Truck Network		
114 - Future ADT		
115 - Year Future ADT		
Freeway		

Proposed Improvements

75 - Type of Work	36	1
76 - Length of Improvement	656.2	
94 - Bridge Cost	2062	
95 - Roadway Cost	0	
96 - Total Cost	2062	
97 - Year of Cost Estimate	2017	

Load Rating and Posting

31 - Design Load	9
41 - Open, Posted, Closed	A
63 - Fed Oper Rtg Method	6
64F - Fed Oper Rtg Load	2.56
64MA - Mich Oper Rtg Method	6
64MB - Mich Oper Rtg	1.61
64MC - Mich Oper Truck	17
65 - Inv Rtg Method	6
66 - Inventory Load	1.53
70 - Posting	5
141 - Posted Loading	
193 - Overload Class	

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 WORK RECOMMENDATIONS

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
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Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

WORK RECOMMENDATIONS OVJS

Inspector Name	Agency / Company Name	Insp. Freq.	Insp. Date
Mark Lessens	DLZ Michigan, Inc.	12	10/18/2020

RECOMMENDATIONS & ACTION ITEMS

Recommendation Type	Priority	Description
Brush Cut	H	Remove vegetation overgrowth from all quadrants and slope paving.
Railing Repair	M	Remove and replace bridge railings. Repair tube railings to concrete end wall attachment bolts.
Joint Repair	H	Replace all deck joints
Deep Overlay	M	Place concrete deck overlay or replace deck.
Full Paint	H	Paint structure, at least at joints (zone paint) ASAP.
Super Repair	L	Chip and patch areas of delaminated concrete on bridge sidewalks.
Substr Repair	H	Replace north pier cap and make substructure repairs to south pier cap and column.
Other	M	Upgrade guardrail anchorage.

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 **LOAD RATING ASSUMPTIONS**

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

Rating Considers Field Condition of Members: Yes **Inspection Date:** 10/18/2020

Deterioration:

Beam Deterioration (2020 Inspections): Span 1: Beam Webs = 25% Section Loss, 2' Length at Beam Ends (Pier 1) Beam Bottom Flange = 10% Section Loss, half span length (North half of span) Span 2: Beam Webs = 25% Section Loss, 2' Length at Beam Ends (Pier 1 and Pier 2) Beam Bottom Flange = 10% Section Loss, half span length (South half of span) Span 3: Beam Webs = 25% Section Loss, 2'

Most Recent Year Construct / Reconstruct / Overlay: 1982

History of Work Impacting Load Rating:

None..

Superstructure Component: 3 Steel **Beam fy:** 50.0 **ksi** **Beam f'c / fb:** **ksi**

Composite: Yes **Number of Beams:** 12 **Shop Drawings Verified:** No

Beam Size(s) & Names (each span): Span 1: W27x94 w/ bottom flange cover plate; 55'-0 9/16". Span 2: @27x102 w/ bottom flange cover plate; 61'-8 5/8". Span 3: W27x84; 42'-7 1/16".

Deck: **Thickness (in.):** 9.0 **Fy / f'c:** 60.0 / 3.0 ksi **Deck Design Load > H15:** Yes

Wearing Surface: **Mat'l:** **Thickness (in.):** **Unit Weight (pcf.):**

	LEFT	**CENTER**	**RIGHT**
Barrier: Type / Weight (plf.):	Steel/Conc / 506.0	/	Steel/Conc / 506.0
Sidewalk: Width / Thick (in.):	141.13 / 12.3	/	144.13 / 12.3

Clear Roadway (ft.):

Additional Loads:

Diaphragms: third points in spans 1 and 2; midspan in Span 3. 0.325k max diaphragm load

Unique Factors That Affect Capacity:

8 1/2" x 3/4" cover plate on bottom of beams, Span 1 8 1/2" x 1" cover plate on bottom of beams, Span 2

Analyzed By: Carrie Hamel **Date:** 01/18/2021

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 **LOAD RATING SUMMARY**

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

Compliance Issue: None
Compliance Verified: No
Analysis Program: AASHTOWare Bridge Rating (BrR)
Analysis Program Version: 6.8.4.3001
Rating Considers Field Condition of Members: Yes **Inspection Date:** 10/18/2020
Controlling component and failure mode:

Span 2, strength, Beam 2W, midspan, Design Flexure-Steel, Truck 17 (64MB). Span 3, serviceability, Beam 12W, midspan, Design Flexure-Steel, HS-20 (64F).

NEW INVENTORY CODING

NBI Item 63 - Operating Rating Method 6 LFR in Rating Factor
NBI Item 64F - Federal Operating Ratings 2.56

MDOT Item 64MA - Michigan Operating Method 6 LFR in Rating Factor
MDOT Item 64MB - Michigan Operating Rating 1.61
MDOT Item 64MC - Michigan Operating Truck 17

NBI Item 65 - Inventory Rating Method 6 LFR in Rating Factor
NBI Item 66 - Federal Inventory Rating 1.53

NBI Item 41 - Structure Open Posted Closed A A Open, no restriction
NBI Item 70 - Bridge Posting 5 5 - 100% or more
Posted By No Posting
MDOT Item 141 - Posted Loading

MDOT Item 193A - Michigan Overload Class
MDOT Item 193C - Overload Status

Analyzed By: Carrie Hamel **Date:** 01/18/2021
Checked By: Mark Lessens **Date:** 01/22/2021

MICHIGAN DEPARTMENT OF TRANSPORTATION

STR 11065 **OUTSTANDING WORK**

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

WORK RECOMMENDATIONS

DECKS/SLABS

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Deep Overlay				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Place concrete deck overlay or replace deck. (Mark Lessens 11/03/2020)

JOINTS

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Joint Repair				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Replace all deck joints (Mark Lessens 11/03/2020)

SUPERSTRUCTURE

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Full Paint				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Paint structure, at least at joints (zone paint) ASAP. (Mark Lessens 11/03/2020)

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Super Repair				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Chip and patch areas of delaminated concrete on bridge sidewalks. (Mark Lessens 11/03/2020)

SUBSTRUCTURE

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Substr Repair				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

STR 11065 OUTSTANDING WORK

Facility	**Latitude / Longitude**	**MDOT Structure ID**	**Structure Condition**
E MEDICAL CENTER	42.2858 / -83.7321	814021200000R01	Poor Condition(4)
Feature	**Length / Width / Spans**	**Owner**	
NORFOLK SOUTHERN RR	160 / 70.9 / 3	City: ANN ARBOR(0212)	
Location	**Built / Recon. / Paint / Ovly.**	**TSC**	**Operational Status**
0.9 MI E OF US-23 BR	1982 / / 1982 / 1982	Brighton(3)	A Open, no restriction(A)
Region / County	**Material / Design**	**Last NBI Inspection**	**Scour Evaluation**
University(6) / Washtenaw(81)	3 Steel / 32 Multi Str Comp	10/18/2020 / OVJS	N Not Over Waterway

Replace north pier cap and make substructure repairs to south pier cap and column. (Mark Lessens 11/03/2020)

OTHER

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Brush Cut				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Remove vegetation overgrowth from all quadrants and slope paving. (Mark Lessens 11/03/2020)

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Railing Repair				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Remove and replace bridge railings. Repair tube railings to concrete end wall attachment bolts. (Mark Lessens 11/03/2020)

Request For	**Contact/User**	**Agency/Company Name**	**Estimated Quantity**	**Unit**
Other				
Activity	**Material**	**Other Material**	**Actual Quantity**	**Unit**
Personnel Hours	**Equipment**		**Complete Date**	

Comments

Upgrade guardrail anchorage. (Mark Lessens 11/03/2020)

APPENDIX B - Photographs

Photograph No. 1
West Elevation Looking East

Photograph No. 2
South Approach Looking South

Photograph No. 3
North Approach Looking North

Photograph No. 4
View of Deck Looking North

Photograph No. 5
Newer Approach Pavement and Unfilled Joint at North Reference Line, Looking East

Photograph No. 6
Joint at Approach Pavement at South Reference Line, Looking East

Photograph No. 7
Spalling and Delamination along South Expansion Joint Looking East

Photograph No. 8
Loose South Expansion Joint

Photograph No. 9
Typical Vertical Cracking in Railing

Photograph No. 10
Spalling in Railing End Wall at the Northeast Quadrant

Photograph No. 11
Typical Cracking in Deck

Photograph No. 12
Delaminations on Bottom of Deck with Moisture, Leaching, and Exposed Rebar

Photograph No. 13
Spalled Concrete with Exposed Deteriorating Reinforcement on Bottom of Deck

Photograph No. 14
Spalled Crashwall and Exposed Reinforcement on North Side of South Pier under Column 2 (Pier 1)

Photograph No. 15
Deteriorated Beam End and Diaphragm at Pier

Photograph No. 16
Location of Spall on North Face of North Pier at Edge of Bearing Pad

Photograph No. 17
North Abutment and Slope Paving

Photograph No. 18
South Abutment and Slope Paving

Photograph No. 19
South Side of North Pier (Pier 2)

Photograph No. 20
East Portion of North Side of North Pier (Pier 2)

Photograph No. 21
West Portion of North Side of North Pier (Pier 2)

Photograph No. 22
South Side of South Pier (Pier 1)

Photograph No. 23
North Side of South Pier (Pier 1)

Photograph No. 24
North Side of South Pier (Pier 1), Center Portion

Photograph No. 25
West Sidewalk Fascia Spall at South Pier

Photograph No. 26
East Deck Fascia Spall at North Pier

APPENDIX C – Repair Cost Estimate

2020

LAP - BRIDGE COST ESTIMATE WORKSHEET

- CPM, REHAB, REPLACE -

REV. 2/1/2020

								DATE:	11/3/2020
OWNER:	Ann Arbor	FISCAL YEAR:	2020			Out to Out	Curb to Curb	ENGINEER:	
REGION:	University				LENGTH	WIDTH	WIDTH		
TSC:	Brighton	PR: #N/A	MP: #N/A		160.0	70.9	46.9	STRUCTURE ID:	11065
								BRIDGE ID:	N/A

LOCATION: E MEDICAL CENTER over NORFOLK SOUTHERN RR

PRIMARY WORK ACTIVITY Substructure Repair

Replace Expansion Joints & Bridge Railing,
Paint Structural Steel, Remove Vegetation,
OTHER WORK: Deep Overlay

DECK AREA: 11,344 SFT

CLEAR ROADWAY: 7,504 SFT

STR. TYPE: Steel

Multi-Stringer, W or I-Bean

WORK ACTIVITY		Michigan Bridge Design Manual	QUANTITY	UNIT	UNIT COST		TOTAL
NEW BRIDGE		(increase deck area based on design standards and hydraulic requirements)					
Single or Multiple Spans, Grade Separation		(add demo, approach, MOT)		SFT	$220.00	/SFT	
Single Span, Over Water	Length < 100ft	(add demo, approach, MOT)		SFT	$350.00	/SFT	
Multiple Spans, Over Water	Length > 100ft	(add demo, approach, MOT)		SFT	$220.00	/SFT	
Precast Culvert	Length < 40ft	(add demo, approach, MOT)		SFT	$350.00	/SFT	
NEW SUPERSTRUCTURE							
New Superstructure, Grade Separation		(incl. remove exist deck/super; add MOT & approach)		SFT	$170.00	/SFT	
New Superstructure, Over Water		(incl. remove exist deck/super; add MOT & approach)		SFT	$200.00	/SFT	
WIDENING							
Structure Widening, _____ ft		(incl. deck/super/sub widening, add approach transition)		SFT	$270.00	/SFT	
NEW DECK							
New Bridge Deck & Barrier		(incl. remove exist deck/railing, add approach, MOT)		SFT	$75.00	/SFT	
DEMOLITION							
Entire Structure, Grade Separation				SFT	$33.00	/SFT	
Entire Structure, Over Water				SFT	$46.00	/SFT	
DECK REPAIR / TREATMENTS							
Bridge Railing Replacement		(incl. removal and replacement)	322.0	FT	$500.00	/FT	$161,000
Concrete Brush Block / Curb Patch		(incl. hand chipping and formwork)		FT	$24.00	/FT	
Concrete Barrier Patch		(incl. hand chipping and formwork)		SFT	$45.00	/SFT	
Concrete Deck Patch		(incl. hand chipping)		SFT	$30.00	/SFT	
Deep Overlay		(incl. joint repl & hydro)	7,632.0	SFT	$45.00	/SFT	$343,440
Epoxy Overlay		(incl. warranty)		SYD	$30.00	/SYD	
Expansion Joint Gland Replacement		(remove and replace elastomeric gland)		FT	$85.00	/FT	
Expansion Joint Replacement		(incl. removal)	165.0	FT	$700.00	/FT	$115,500
Full Depth Patch				SFT	$76.00	/SFT	
Healer / Sealer		(penetrates cracks in bridge deck)		SYD	$15.00	/SYD	
HMA Overlay with WP membrane				SYD	$53.00	/SYD	
Overlay Removal		(Epoxy: $8/syd | Latex: $16/syd | HMA: $7/syd)	848.0	SYD	$25.00	/SYD	$21,200
Reseal Bridge Joints				FT	$16.00	/FT	
Shallow Overlay		(incl. joint repl & hydro)		SFT	$22.00	/SFT	
SUPERSTRUCTURE REPAIR							
Bearing Realignment / Replacement		(incl. temporary supports)		EA	$5,000.00	EA	
Heat Straightening		(incl. clean and coat)		EA	$50,000.00	EA	
Pack Rust Repair		(greater than 3/8" separation)		FT	$500.00	/FT	
Paint - Complete		(incl. clean & coat)	16,300.0	SFT	$40.00	/SFT	$652,000
Paint - Partial / Spot / Zone		(incl. clean & coat - $20k minimum)		SFT	$60.00	/SFT	
PCI Beam End Blockout		(incl. temporary supports)		EA	$7,200.00	EA	
Pin & Hanger Replacement		(incl. temporary supports)		EA	$8,000.00	EA	
Structural Steel Repair		(based on 6ft length; for stiffeners use $1,200 ea)	25.0	EA	$5,000.00	EA	$125,000
SUBSTRUCTURE REPAIR							
Substructure Patching		(measured x 2) replace if repair area > 30%	270.0	CFT	$450.00	/CFT	$121,500
Substructure Replacement		(incl. temporary supports, excavation)		CFT	$180.00	/CFT	
Substructure Horizontal Surface Sealer				SYD	$40.00	/SYD	
Pier Replacement			2,643.0	CFT	$125.00	/CFT	$330,375
Temporary Supports		(add $1,200 for ea steel beam - stiffeners)	24.0	EA	$3,000.00	EA	$72,000
Other Remove Vegetation			1.0	LSUM	$5,000.00	LSUM	$5,000
MISCELLANEOUS							
Articulating Concrete Block System (ACB)				SYD	$150.00	/SYD	
Concrete Surface Coating				SYD	$28.00	/SYD	
Culvert Cleanout				FT	$30.00	/FT	
Epoxy Crack Injection		(structural crack repair)		FT	$50.00	/FT	
Metal Mesh Panels		(48" width, max 6'-6" length)		SFT	$20.00	/SFT	
Pressure Relief Joint		(use when approach concrete roadway exceeds 1,000ft)		FT	$100.00	/FT	
Riprap		(assume 10ft distance around perimeter of substructure)		SYD	$175.00	/SYD	
Silane Treatment		(penetrating sealer for concrete surfaces)		SFT	$4.50	/SFT	
Slope Protection Repairs			25.0	SYD	$150.00	/SYD	$3,750
Other							
					STRUCTURE CONSTRUCTION BUDGET		$1,950,765
ROAD WORK							
Approach Pavement, 12" RC		(incl. removal; add curb, gutter, guardrail) 20' ea. end	222.2	SYD	$200.00	/SYD	$44,444
Approach Curb & Gutter		(incl. removal) 20' ea. quadrant	80.0	FT	$75.00	/FT	$6,000
Guardrail Anchorage to Bridge		(each quadrant)	4.0	EA	$2,000.00	/EA	$8,000
Guardrail		(incl. removal) < 200ft beyond reference line		FT	$28.00	/FT	
Guardrail Terminal		(each quadrant)	4.0	EA	$2,500.00	/EA	$10,000
Roadway Approach Work		(beyond approach pavement)	1.0	LSUM	$500,000.00	LSUM	$500,000
Utilities			1.0	LSUM	$100,000.00	LSUM	$100,000
TRAFFIC CONTROL		*Unit Cost to be determined by Region or TSC Traffic & Safety*					
Part Width Construction			1.0	LSUM	$250,000.00	LSUM	$250,000
Crossovers				EA	$300,000.00	/EA	
Temporary Traffic Signals				set	$25,000.00	/set	
RR Flagging			1.0	LSUM	$75,000.00	LSUM	$75,000
Detour				LSUM		LSUM	
					RELATED ROAD/TRAFFIC CONSTRUCTION BUDGET		$993,444
CONTINGENCY		(10% - 20%) (use higher contingency for small projects)	10	%	$2,944,000.00		$294,000
MOBILIZATION		(estimate at 10%)	10	%	$3,238,000.00		$324,000
INFLATION		(assume 3% per year, beginning in 2021)	9	%	$3,562,000.00		$321,000

(Does not include PE or CE)

TOTAL CONSTRUCTION BUDGET **$3,883,000**

APPENDIX D – Deck Delamination Survey

LEGEND:

- ▩ – 2009 DECK DELAMINATION
- ▨ – 2011 DECK DELAMINATION
- ▤ – 2013 DECK DELAMINATION
- ▩ – 2015 DECK DELAMINATION
- ▥ – 2017 DECK DELAMINATION
- ▤ – JAN 2020 DECK DELAMINATION
- ▩ – OCT 2020 DECK DELAMINATION

2009 TOTAL DECK DELAMINATION = 200.75 SFT
2011 TOTAL DECK DELAMINATION = 270.75 SFT
2013 TOTAL DECK DELAMINATION = 522.66 SFT
2013 TOTAL SIDEWALK DELAMINATION = 23.7 SFT
2015 TOTAL DECK DELAMINATION = 862.72 SFT
2015 TOTAL SIDEWALK DELAMINATION = 244.73 SFT
2017 TOTAL DECK DELAMINATION = 1152.27 SFT
2017 TOTAL SIDEWALK DELAMINATION = 244.73 SFT
JAN 2020 TOTAL DECK DELAMINATION = 1281.77 SFT
JAN 2020 TOTAL SIDEWALK DELAMINATION = 244.73 SFT
OCT 2020 TOTAL DECK DELAMINATION = 1320.27 SFT
OCT 2020 TOTAL SIDEWALK DELAMINATION = 244.73 SFT

DLZ

E. MEDICAL CENTER DRIVE
DECK DELAMINATION SURVEY

Attachment #2

Studies and Reports

DLZ

MEMORANDUM

Date: December 3, 2014
To: David Dykman, P.E., Project Manager, City of Ann Arbor
From: Wes Butch, Consultant Team Project Manager
Subject: Preliminary Technical Memo – Fuller Road/Maiden Lane/East Medical Center Drive Intersection Improvement Project

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INTRODUCTION

Purpose and Scope of Memo

The purpose of this memo is to evaluate conceptual design options and determine the optimal roundabout concept design for the intersection of Fuller Road and Maiden Lane / East Medical Center Drive (subsequently referred to as "the intersection" or "the study intersection" in the remainder of this memo) in Ann Arbor, Michigan. In order to accomplish this purpose, several work tasks were undertaken by the consultant team comprised of DLZ Michigan, Inc. (DLZ, the prime consultant) and OPUS International Consultants (OPUS, subconsultant that performed the VISSIM modeling of the intersection). The results of these tasks are described in this memo.

The memo includes the following main sections: (1) Introduction, (2) Review of Guidelines, Standards, Plans, and Previous Studies; (3) Additional Considerations; (4) Traffic Forecast and Capacity Analysis Screening; (5) VISSIM Model Analysis; (6) East Medical Center Drive Improvements, and; (7) Conclusions and Recommendations.

A key goal of the project is to achieve an optimum balance between automobile and pedestrian operations at the study intersection. Key design considerations assessed in this memo include which roundabout intersection layout would perform best for both pedestrian and vehicular traffic, how various pedestrian crossing facilities would affect traffic flows, and the implications of using right turn bypass lanes. Ultimately, six different scenarios were modeled in VISSIM to evaluate these issues.

The conclusions from this study will ultimately be presented to project stakeholders for their consideration and input. In addition to various departments, committees, and elected officials within the City of Ann Arbor (the City), the primary stakeholders for the study include the University of Michigan (U of M, which has jurisdiction over East Medical Center Drive and administers the nearby North Campus and the Medical Center Campus), members of the public, interest groups, and the Ann Arbor Area Transportation Authority (AAATA).

Project Timeline and Background

The City has undertaken a series of previous studies at this intersection since 2006. The first of these studies was performed by the consulting firm Orchard, Hiltz & McCliment (OHM) in 2006 to investigate the feasibility of installing a roundabout. Subsequently, the Fuller Intermodal Transportation Station (FITS) was proposed for construction in the southeast quadrant of the intersection. The FITS project was expected to be a traffic generator and could affect vehicular and pedestrian traffic volumes/patterns in the study area. Studies regarding the impact of the FITS development on the surrounding roadway network were prepared by the consulting firms JJR and URS Corporation (URS) in 2009 and 2010. The roundabout concept was analyzed as part of these studies, along with other potential intersection improvement options such as an improved signalized intersection. The U of M and other stakeholders provided input during these studies.

As a result of these studies, the roundabout design concept was identified as the preferred improvement for the intersection. However, to verify the conclusions of previous studies, it was recognized that the roundabout design concept would require more detailed analysis regarding vehicular and pedestrian operations. Providing accessible accommodations for mobility and visually disabled pedestrians (likely using Pedestrian Hybrid Beacon signals – PHBs) has always been an important design element and is a major consideration in the performance of the proposed roundabout. This analysis would entail microsimulation modeling to evaluate pedestrian and vehicular interaction and performance. In the autumn of 2010, the City contracted with the DLZ team to perform additional detailed studies of the roundabout design concept. The results of these additional studies are documented in this memo.

In 2011, the City retained the Institute for Transportation Research and Education (ITRE) under a separate contract to prepare VISSIM models which included High Intensity Activated Crosswalk (HAWK) signals (a type of PHB) at the roundabout. VISSIM is a microsimulation software program that can model the interaction of vehicles and pedestrians to predict expected operations (i.e., delays and queuing) for both vehicular and pedestrian traffic. Based on ITRE's extensive knowledge regarding the operation of HAWK signals at roundabouts, VISSIM models were established with driver and pedestrian behavior settings which would most accurately represent the expected conditions. The ITRE study provided valuable information regarding these settings, and this information was ultimately used by the DLZ team in the VISSIM modeling work. A more detailed description of the ITRE study is provided below.

Early in the study process, the City sought and received input from the U of M regarding issues they would like to see addressed as part of the current study. These issues included:

- Recommended improvements should be consistent with U of M master planning documents and transit plans. The study should consider how the proposed improvements fit into the overall area network (both current and future).
- There should be an assessment of how the intersection will serve medical center patients who are unfamiliar with the area, especially those who need to access the medical center under emergency conditions. This item could include integrating wayfinding signing into the roundabout design.
- Study should consider how the intersection will serve emergency vehicles and buses.
- Study should consider pedestrian movements through the intersection, especially north-south movements. The study should note that pedestrian volumes could increase in the future.Pedestrian accommodations could include the possibility of grade separations.
- Potential impacts to adjacent downstream traffic signals on East Medical Center Drive should be assessed.
- ITRE's conclusions and results should be factored into the study process.

Beginning in 2011 and continuing until the present time, there have been several important developments related to the FITS project. First, the project was renamed as the "Ann Arbor Station" (AAS) project. Second, the U of M decided not to construct a multi-level parking deck at the FITS site, opting instead to construct the deck along Wall Street to the north of the study intersection. Two traffic impact studies were prepared related to the new parking deck on Wall Street. Third, in 2013, the City decided to reconsider whether the AAS facility would be constructed at the same location as envisioned for the FITS project. Specifically, the City is currently undertaking a study that has evaluated numerous potential site locations, only one of which is the previous FITS site. As a result, it is currently unknown where the AAS will be constructed.

Finally, the Ann Arbor Connector Feasibility Study was completed in 2011 and identified the need for advanced transit service in the vicinity of the project area. The Ann Arbor Connector Feasibility Study was a joint undertaking by the City, U of M, AAATA, and the Ann Arbor Downtown Development Authority. This study identified the need to connect the U of M North Campus and East Medical Campus with downtown Ann Arbor, the Medical Center Campus, and U of M Central Campus (this transit service is also referred to in other previous studies as a "Signature Transit Corridor" or "Signature Service Line"). The Ann Arbor Connector is currently being studied in more detail as part of an Alternatives Analysis study. The Alternatives Analysis study identifies three potential transit corridor alignments that traverse the general project area. These are discussed in more detail below.

REVIEW OF GUIDELINES, STANDARDS, PLANS, AND PREVIOUS STUDIES

This section summarizes relevant design guidelines, standards, plans, and previous studies that were performed for the study intersection. The design guidelines and standards are evaluated considering how they pertain to the proposed roundabout. While these guidelines will be utilized during the design phase of the project, important sections from each of the documents are highlighted for consideration in determining the optimal roundabout concept design. Relevant planning documents are noted with applicability discussed. Previous studies are then presented in chronological order with each one having a summary and an assessment of the relevance/lack thereof to the current study. Note that this section of the memo is not intended to be an exhaustive listing of all design and permitting requirements that are applicable during the detailed design process. Instead, this memo includes only those standards, guidelines, plans, and studies that are immediately relevant to the evaluation and optimization of an early roundabout concept design at the study intersection.

Review of Applicable Design Guidelines and Standards

This section summarizes relevant federal, state, and local design guidelines and standards relating to roundabout design.

Roundabouts: an Informational Guide (NCHRP Report 672)

Overview

Published in 2010, this document is the most comprehensive guide to roundabout design available and defines typical roundabout design features and techniques. Primary design objectives are identified as providing adequate speed reduction on the entries using geometric constraints (horizontal curvature) and accommodating the design vehicle (typically a truck, such as a WB-62 as classified by AASHTO). Roundabouts must also be designed with sufficient traffic capacity to serve the expected demand, typically by including an adequate number of entry, circulating, and exiting lanes. The guide provides considerations and trade-offs for roundabouts compared to other intersection types, operational and safety goals for planning purposes (including listing benefits to both motorists and non-motorized users), geometric design principles, pavement marking and signing recommendations, as well as considerations for lighting, landscaping, construction, and maintenance.

Relevance to This Project

An evaluation of the various capacity analysis methods is important to this project because the models produce different results for roundabout geometrics and operations, therefore the designer must have a broad understanding of the various models and their specific limitations. The NCHRP guide outlines roundabout capacity analysis methods, such as the Highway Capacity Manual (HCM) method, deterministic software methods (RODEL) and simulation methods (VISSIM). The HCM method determines entry capacity based on an equation relating entering flows, circulating flows, and the number of lanes provided. This capacity is modified based on the presence of bypass lanes and the effect of pedestrians crossing an entry. The HCM method then calculates control delay, based on the ratio of volume to capacity, and assigns a Level-of-Service (LOS) based on the calculated delay. Queue lengths are also determined using the volume to capacity ratio. RODEL, a deterministic model, is based on empirical research that establishes the sensitivity of roundabout capacity to the roundabout geometry (i.e., approach width, entry width, and approach effective flare length) and the entering and circulating traffic flows. The model can evaluate right-turn bypass lanes and the vehicular delay caused by unsignalized pedestrian crossings. The research that this analysis method is based on was primarily performed on British roundabouts during the 1980s; however the capacity analysis program has been widely accepted by reviewing agencies for design purposes in the United States. Finally, simulation methods such as VISSIM use capacity models that are sensitive to driver behavior such as car following, lane changing, and gap acceptance. VISSIM is superior to HCM and RODEL for modeling complex interactions of pedestrians and vehicles, as well as the relationship between roundabout operational performance and the proposed PHB operations. An important consideration when using simulation models is that whenever possible, the driver behavior parameters should be calibrated to observed/expected local conditions rather than using the software's default parameters.

Distinctions between these capacity analysis methods are important to this project since: (1) the different models can lead to different recommended roundabout geometrics; (2) ITRE calibrated their VISSIM models to the results that would be expected using both the HCM and deterministic (RODEL) methods; and (3) the models differ in their ability to model complex interactions between vehicles and pedestrians.

Regarding pedestrian signals at roundabouts, the NCHRP 672 Report states that high vehicular volumes, high pedestrian volumes, and accessibility at more complex crossing situations are reasons that signalized crossings (PHBs) may be beneficial. The report states that two-stage pedestrian crossings, as proposed for this project, can significantly decrease delay to motorists while providing appropriate signalization for pedestrians, including those who are blind or have low vision. The report advises that with two-stage signals, care must be taken in placing the signals in order to prevent pedestrians from seeing the wrong signal and inadvertently crossing when the signal is not activated. The first method is to use right-angle crossings combined with audible cues for each signal. In other situations, it may be more advantageous to provide an offset between crossings along the splitter island, in which case landscaping or barriers should be used to channelize pedestrians and delineate the pathway.

Below is a list of other considerations or recommendations from the NCHRP 672 Report which are relevant to the project:

- Geometrics and Design – The report provides geometric design, pavement marking, signing, lighting, and landscaping guidance for all types of roundabouts. This guidance will need to be followed during the design phase.
- Safety benefits – Roundabouts provide safety benefits to both pedestrians and vehicles relative to other intersection types.
- Right-Turn Bypass Lanes- Although a useful vehicular capacity improvement, free flowing right-turn bypass lanes are not as pedestrian-friendly as bypass lanes that are under yield control.
- Bicyclists – These users require particular attention at two-lane roundabouts, especially in areas with moderate to heavy bicycle traffic such as the study intersection. For safety reasons, on street bike lanes are recommended to be routed onto multi-use paths in the vicinity of the intersection, giving bicyclists the option of traversing the roundabout on multi-use paths or in the roadway travel lanes.

- Emergency Vehicles – The design of a roundabout may require large emergency vehicles to use a traversable apron. Roundabouts typically provide emergency vehicles the benefit of lower vehicle speeds, increasing the potential for visibility and reducing the likelihood of a crash.
- Transit - Typically, it is undesirable for the design to require transit vehicles to traverse an apron as it reduces passenger comfort. Bus stops should be located carefully in the vicinity of the roundabout to avoid causing backups into the circulatory roadway.
- Older Drivers – Given the proximity to hospital and health care facilities, older drivers and drivers generally not familiar with the area may frequently use the proposed roundabout. The report discusses how roundabouts provide slower and consistent speeds (allowing drivers more time to react and make decisions), provide less complicated situations to interpret, and reduce the need to make gap acceptance decisions quickly.

Michigan Department of Transportation (MDOT) Roundabout Guidance Document

Overview

This document was prepared in 2007 and references the first version of the FHWA Roundabout Guide (from year 2000) for more detailed information regarding most topics. NCHRP 672 (discussed in the preceding section) has since superseded the first version of the FHWA guide. The information presented for NCHRP 672 would adequately cover applicable information in the MDOT guide.

Relevance to This Project

The MDOT guide states that roundabout capacity analysis should be conducted using RODEL software. However, in recent years MDOT has considered other analysis methods (HCM or microsimulation) on a case-by-case basis.

The MDOT guide also allows that multi-lane roundabout designs can be laid out such that large trucks overlap into adjacent lanes as they navigate a roundabout.

United States Department of Transportation Proposed Rules in Federal Register

Overview

The draft Public Rights-of-Way Accessibility Guidelines (PROWAG) was published as a draft rule in the Federal Register in July of 2011, with the public comment period ending in February of 2012. It is currently unknown when the final rule will be published, and it is also unknown what changes will be made based on comments received. Once the final rule is approved, the PROWAG will become enforceable standards under title II of the Americans with Disabilities Act (ADA). The proposed rule states that roundabout pedestrian crossings must include: accessibility features such as sidewalks, ramps and crosswalks that meet surface, slope, and clearance requirements; detectable edge treatments and landscaping to guide pedestrians to the proper and safe crossing location; and a pedestrian activated signal for each multi-lane segment of each crossing at a roundabout. The draft PROWAG includes a requirement to install accessible pedestrian signals at all crosswalks across any roundabout approach with two or more lanes in one direction.

Relevance to This Project

Because the PROWAG remains a draft rule at this point in time, it is currently considered a best practice. For this project, the minimum action which would support this best practice would be to install conduit under each roundabout entry and exit so that if required in the future, PHBs could be installed with minimal reconstruction. Installation of PHB signals would be fully consistent with the PROWAG and would be considered full implementation of the best practice. The use of countdown pedestrian signal heads and non-visual cues, such as audible tones, would follow the best practice procedures discussed in PROWAG.

Michigan Manual of Uniform Traffic Control Devices (MMUTCD)

Overview
The MMUTCD provides standards for the use of traffic control devices such as traffic signals, pavement markings and signage. The Federal MUTCD was updated in 2009, and from there each state added provisions and requirements unique to their jurisdiction. Therefore, the current MMUTCD published in 2011 is considered the standard for design of roadways and public parking areas in the State of Michigan.

Relevance to This Project
It is recommended that the selected roundabout layout follow, at a minimum, the standards for signing and pavement marking for multi-lane roundabouts found in section 2B.45 and chapter 3C of the MMUTCD, respectively. The MMUTCD provides standards for the required signage and cross walk pavement markings associated with a PHB, as shown in section 3B.18. If bike ramps are to be provided approaching and departing the roundabout, section 9B.04 should be followed for signing and section 9C.04 for pavement markings. Section 4E.09 describes the design standards for accessible pedestrian signal accommodations. Section 4F.02 describes the design of PHBs.

City of Ann Arbor and University of Michigan Design Standards and Guidelines

Overview
The City and U of M have extensive design standards for transportation facilities, including the City's recently adopted (02/18/2014) Stormwater Management Guidelines for Public Street Construction and Reconstruction.

Relevance to this Project
The applicable standards and guidelines will be utilized during the design phase of the project.

Review of Planning Documents

This section summarizes relevant planning documents as they relate to the existing and future conditions at the study intersection. Readers should note that park/trail planning issues are not included in this memo. Instead, these are discussed in the separate report entitled *Pedestrian Underpass Study* (DLZ, 2014). This report is also summarized in the next section of this memo.

Ann Arbor Connector Feasibility Study and Alternatives Analysis

Overview
The City, U of M, AAATA, and the Ann Arbor Downtown Development Authority collaborated to conduct a feasibility study, completed in 2011, for advanced transit service in the vicinity of the study intersection as well as other locations. This study evaluated the need for such service and identified possible alternatives. Following Federal Transit Administration requirements, a second study called an "Alternatives Analysis" (AA study) is currently being conducted. The purpose of the AA study is to identify and evaluate transit alternatives and their costs, benefits, and impacts in order to define a "Locally Preferred Alternative" in coordination with the community. Funding sources are also being identified with the AA study. If advanced, construction of the transit line is expected sometime between 2020 and 2035. In the AA study, there are three corridors under consideration that are in the general vicinity of the Fuller Road & East Medical Center Drive/Maiden Lane intersection. These options

connect the northeast side of Ann Arbor to downtown. One of the route options would utilize the Fuller Road alignment, and the other two would utilize the alignment of the existing railroad tracks beneath East Medical Center Drive. Currently, the AA study is assessing streetcars (single and two-car), bus rapid transit, and bus services as possible modes.

Relevance to this Project
Some of the transit alternatives still under consideration could potentially have an impact upon the design of the study intersection. This includes potential impacts that the Connector could have upon design and traffic operations at the study intersection. Close coordination between the two projects will be important.

City of Ann Arbor Non-Motorized Transportation Plan

Overview
This document, prepared in 2007 and updated in 2013, states that the purpose of the plan is to provide a general background on issues related to non-motorized transportation and to identify how to address them through policies, programs and design guidelines for facility improvements. The goal of the plan is "to help Ann Arbor once again become a national leader in high quality non-motorized transportation". Key safety and design issues for bicyclists and pedestrians are identified. To accommodate non-motorized users, the preferred cross section for all road classifications under most circumstances includes sidewalk and bike lanes on both sides of the roadway. For corridors, cross sections identifying widths of travel lanes, bike lanes, sidewalks, parking, offsets, and green space are provided for typical roadway categories. Standards for bike ramps (transitions from on-road bike lanes to off-road side paths) are also provided. For travel across roadways, specifically at intersections, standard drawings are provided which detail signage and pavement markings to be used.

The plan proposes "near-term opportunities", which are projects that could be completed with minimal changes to existing roadway infrastructure, and a "long-term plan", which identifies the vision of the completed non-motorized system with improvements possibly requiring reconstruction of infrastructure, right-of-way acquisition, or significant capital investments.

Relevance to this Project
The following near-term opportunities near the study intersection were identified:

1. No changes to the off-street bike facilities are proposed in the study area (the existing multi-use path on both sides of Fuller Road is retained).
2. The plan proposes to address sidewalk bicycle use at the study intersection by creating separate ramps for bicyclists and having bicyclists use traffic signals rather than the pedestrian activated signals which can require bicyclists to dismount.
3. Major mid-block crossings on Maiden Lane north of Fuller Road (high priority) and on East Medical Center Drive south of Fuller Road (medium priority) are proposed. Also, the existing mid-block crossing on Fuller Road east of the study intersection if identified for "upgrade".

The long-term plan calls for the following improvements near the study intersection:

1. In-road bike lanes on both Fuller Road and Maiden Lane/East Medical Center Drive, with minor widening required for both roadways.
2. Changes to the shared-use paths within the City's Fuller Park are also proposed along the Huron River and crossing Fuller Road east of the study intersection.

3. As part of the border-to-border trail, creation of underpasses along the railroad right-of-way beneath Fuller Road and East Medical Center Drive to the west and south of the intersection respectively, and beneath Maiden Lane near the Huron River north of the intersection. This facility would be an eight to ten foot wide shared-use path.

Funding for these capital improvements has not been identified. However, the plan states that these facilities should be included as the City designs reconstruction projects of major streets (e.g., this project). For additional related information, see the summary of the *Pedestrian Underpass Study* (DLZ 2014) which is provided later in this report.

City of Ann Arbor Complete Streets Planning Direction

Overview
An Ann Arbor City Council resolution passed on March 7, 2011, commits the City to a Complete Streets philosophy for transportation planning, project development, and delivery. As far as current policies within the City, complete streets elements include providing sidewalks on both sides of streets, defining an appropriate accommodation for bicyclists within the right-of-way, receiving community input on planning activities, administering a transit millage, and allocating funding for the maintenance of a non-motorized transportation program.

Relevance to this Project
All these considerations should be included in the process of selecting the best option for the study intersection.

City of Ann Arbor Community Engagement Process

Overview
The City has a prescribed public outreach process that includes developing a thorough understanding of the project, determining community impacts and interest, identifying stakeholders, and exploring various methods and strategies to communicate and connect with the public in order to best solicit their input.

Relevance to this Project
This project, as with most if not all, will have impacts on the community. Consequently, public outreach early and throughout the project will be an important component to its success. The consultant team together with City staff is in the initial stage of working through this multi-step community engagement process to prepare and implement an action plan.

University of Michigan Medical Center Campus and East Medical Campus Master Plan Update

Overview
This plan update from 2007 focuses on proposed changes in land use and mobility or access between locations within the Medical Center Campus (adjacent to the project) and the East Medical Campus, which is located east of US-23 on Plymouth Road (note that East Medical Center Drive which is one leg of the study intersection is actually located within the Medical Center Campus and not at the East Medical Campus). The plan does not address potential capacity improvements to adjacent roadways and intersections. Proposed parking structures along Wall Street and six buildable zones for future research, clinical, education, and administrative uses in the Wall Street district are identified. The plan recommends enhancement of pedestrian and transit connections between Maiden Lane and East Medical Center Drive. Maiden Lane is labeled as a primary pedestrian circulation path to and from the Medical

Center campus. The plan proposes three transit centers on the Medical Center Campus, one on Ann Street, one on Hospital Drive, and one north of the Huron River near the intersection of Wall Street and Nielson Court near the project.

Relevance to this Project
Connectivity between the Medical Center Campus and land uses north of the Huron River via Maiden Lane will be very important for both transit and non-motorized users. Pedestrian and transit accommodations, operations, and accessibility will be very important at the study intersection.

University of Michigan North Campus Master Plan Update

Overview
This plan, updated in 2008, identifies functional linkages (enhanced connections between pedestrian, bicycle, transit, and vehicular systems) between the Wall Street district and the Medical Center along Maiden Lane and East Medical Center Drive, between the Wall Street District and North Campus from Maiden Lane to Fuller Road, and between Central Campus and North Campus along Fuller Road. Non-motorized linkages are also identified for the same routes. The plan also identifies a future high capacity transit route (for more information, see the section above regarding the Connector study) connecting Central Campus and North Campus via Fuller Road and Bonisteel Boulevard. The plan anticipates that this transit line will traverse the study intersection. Finally, Maiden Lane and East Medical Center Drive are labeled as a primary bus route.

Relevance to this Project
This plan reinforces the fact that the study intersection is of high importance due to its location between major traffic generators (North Campus and Medical Center Campus) and that it provides a connection between these land uses. The intersection also accommodates traffic using several crucial pedestrian, bicyclist, commuter, and transit routes.

Review of Previous Studies

This section summarizes relevant information from previous studies of the intersection. The purpose of this section is to clearly delineate how these previous studies do or do not factor into the current decision-making process.

Title: Engineering Study for Roundabout Analysis	Date: 8/17/06	Consultant: OHM
Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive		
Pedestrian and Vehicular Volumes Source/Years: Volumes were developed from previous URS study (2005), Broadway Village TIS (2003), U of M Medical Center Transportation Planning Study (2005), and the Northeast Ann Arbor Transportation Plan (2005). Volumes projected to 2030 using a 1.9 percent compounded annual growth rate from Washtenaw Area Transportation Study (WATS) TransCAD forecasting model. The 2030 projected traffic volumes included 4,000 entering vehicles during the AM peak hour and 4,460 entering vehicles during the PM peak hour. Pedestrian volumes were not used.		
Summary: This document was prepared to evaluate the feasibility of constructing a roundabout. The elements considered in this feasibility analysis were accommodating pedestrian and vehicular demand, as well as safety, drainage, and aesthetics considerations. Conceptual constructability and utility conflict considerations were also discussed, and a conceptual project cost estimate was developed. The 85 percent confidence level RODEL roundabout capacity analysis shows a LOS A/6.5 seconds of delay and LOS B/14.2 seconds of delay overall during the AM and PM peak hours, respectively. The capacity analysis performed did not consider the influence of pedestrians on intersection operations, although they recommended the implementation of HAWK signals. The estimated total cost including construction,		

<table>
<tr><td>construction engineering, and design engineering was $1,670,000.</td></tr>
<tr><td>Applicability: This was the first study to evaluate a roundabout at the project intersection. It identified that pedestrian volumes were a concern and that HAWK signals for the crossing may provide benefits/should be investigated further. The study used RODEL to analyze the roundabout, which has been identified as providing optimistic estimates of capacity in some situations. In addition, the complex interaction of the roundabout operations with the HAWK signal operations is not captured by RODEL. The analysis did not consider traffic from later proposed developments (FITS, Wall Street parking structures). The peak hour traffic volumes used for this study are higher than the current projections for the 2035 forecast year.</td></tr>
</table>

<table>
<tr><td>Title: Intermodal Station Phase 1 Traffic and Pedestrian Study</td><td>Date: 9/23/2009</td><td>Consultant: JJR and URS</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive, Glen Avenue & Huron Street, Glenn Avenue & Ann Street, Glen Avenue & Catherine Street, Glen Avenue & Fuller Street, Fuller Road & Cedar Bend Drive, Fuller Road & Bonisteel Boulevard, Maiden Lane & Broadway Street, Main Street & Depot Street</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: Existing peak hour vehicular turning movement and pedestrian counts were performed in 2009. For the 2012 No Build scenario, background traffic was assumed from 200 parking spaces on Wall Street, the Children’s and Women’s Hospital-generated traffic, and assumed infill traffic from other U of M developments nearby (totaling approximately 400 new trips during both the AM and PM peak hours). Citing low growth rates provided by WATS, no additional background growth was added. Trip generation for the development consisted of approximately 110 new trips during both the AM and PM peak hours. The roundabout analysis assumed 2,960 entering vehicles during the AM peak hour and 3,295 entering vehicles during the PM peak hour in the planned 2012 opening year of FITS.</td></tr>
<tr><td colspan="3">Summary: The purpose of this study was to analyze the localized transportation impacts of the proposed Fuller Intermodal Transportation Station (FITS), which would house AAATA and U of M bus services, as well as Amtrak/future commuter rail service. The study examined two improvement scenarios, one that mitigates the impact of the development only and one that mitigates all intersections to acceptable overall operations. Recommendations included improvements to mitigate existing and no build conditions. A roundabout at the Fuller Road / EMCD / Maiden Lane intersection was recommended because adding lanes or widening required to keep the signalized intersection at acceptable operations would require costly widening of adjacent bridges. To mitigate the impact of the first phase of the project, signal timing and phasing modifications were recommended at the other study intersections. These changes resulted in acceptable LOS for the other signalized intersections. The 85 percent confidence level RODEL roundabout capacity analysis indicates LOS A/5.1 seconds of average delay during the AM peak hour and LOS A/7.0 seconds of average delay during the PM peak hour. These results reflected the use of capacity reduction factors (delay increased by zero to nine percent depending on pedestrian volumes) to account for pedestrian crossings on all legs.</td></tr>
<tr><td colspan="3">Applicability: The study used RODEL to analyze the roundabout, which has been identified as providing optimistic estimates of capacity in some situations. In addition, the complex interaction of the roundabout operations with the HAWK signal operations is not captured by RODEL. It is also important to note that the study recommended signal timing changes at adjacent intersections to mitigate failing LOS. The study also recommends overhead signage for the roundabout due to high rate of unfamiliar drivers using the intersection and recommends transitions from on-street bike lanes to multi-use crossings at the roundabout. The 2012 Build Scenario peak hour traffic volumes used for this study are approximately equal to the current projections for the 2014 forecast year.</td></tr>
</table>

<table>
<tr><td>Title: FITS Phase 2 Traffic and Pedestrian Study – Preliminary Analysis</td><td>Date: 9/29/2009</td><td>Consultant: URS</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive, Glen Avenue & Huron Street, Glenn Avenue & Ann Street, Glen Avenue & Catherine Street, Glen Avenue & Fuller Street, Fuller Road & Cedar Bend Drive, Fuller Road & Bonisteel Boulevard, Maiden Lane & Broadway Street, Main Street & Depot Street</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: This study built upon the Phase 1 study by adding traffic from the Lowertown Development (900 AM trips and 1,205 PM trips) and projecting background growth to 2035. Although WATS indicated eight percent total background growth, the study reasons that this growth in vehicular trips will be cancelled out by expanded transit service. Otherwise, the study included reduction of M71 lot and FITS parking as a result of increased development footprint with Phase 2, and additional traffic from the parking areas for AMTRAK, commuter rail, Signature Transit Service Line, and U of M facilities. The total new trips for Phase 2, not including shifts in traffic patterns, were 305 AM peak hour trips and 295 PM peak hour trips. Total entering volumes for the Fuller Road & Maiden Lane/East Medical Center Drive intersection were not provided.</td></tr>
<tr><td colspan="3">Summary: The purpose of this memo was to identify potential trouble spots in the study area roadway network that could result from the additional traffic volumes from Phase 2 of the FITS. Mitigation recommendations to accommodate Phase 2 of the FITS development were provided in a later document not reviewed for this report. The memo suggested that nearly all of the study intersections would have failing movements under the 2035 no build scenario, even with the recommended mitigation. The roundabout capacity analysis was not addressed in this memo.</td></tr>
<tr><td colspan="3">Applicability: The memo demonstrated that the second phase of FITS would generate considerably less additional traffic than the background Lowertown Development. It also identified the Signature Transit Service Line as potentially reducing traffic at the project intersection, which is discussed in subsequent reports, specifically the Ann Arbor Connector Feasibility Study.</td></tr>
</table>

<table>
<tr><td>Title: Fuller Road Station Concept Plan Report</td><td>Date: 10/9/2009</td><td>Consultant: JJR</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive, Glen Avenue & Huron Street, Glenn Avenue & Ann Street, Glen Avenue & Catherine Street, Glen Avenue & Fuller Street, Fuller Road & Cedar Bend Drive, Fuller Road & Bonisteel Boulevard, Maiden Lane & Broadway Street, Main Street & Depot Street</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: This study utilized the 2035 traffic forecast and pedestrian volumes developed in Phase 2 of the FITS study.</td></tr>
<tr><td colspan="3">Summary: The purpose of this report was to present the work completed at the time of submittal, including the transportation studies and site development concept plan. Section 6 of the report summarizes the transportation impact study. The report sites opportunities for the site development to have an impact on regional mobility, including potential connectivity with the Signature Transit Service Line, potential of an off-street interface for users of the U of M and AAATA bus systems, as well as a number of non-motorized facilities. Previous recommendations for background roadway and intersection improvements (from Phase 2 of the FITS Study) were cited. The report states that all intersections (including the 2035 traffic operations of the intersection of Fuller Road & Maiden Lane/East Medical Center Drive), traffic operations will be acceptable assuming the study intersection is converted to a roundabout and recommended mitigation measures are implemented at other intersections.</td></tr>
<tr><td colspan="3">Applicability: The report noted that the inclusion of the Signature Service Transit Line was pending the conclusions and recommendations of the Connector Study, which is addressed earlier in this memo. The report also stated that the conversion of the intersection to a roundabout is not included in the FITS project. It is assumed that the conclusion about the roundabout functioning acceptably 2035 is based on</td></tr>
</table>

RODEL analysis (not provided), which had been the only capacity analysis software program used for the project to this point.

Title: Meeting Report for Ann Arbor Roundabout Meeting	Date: 11/10/2009	Consultant: URS
Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive		
Pedestrian and Vehicular Volumes Source/Years: The work discussed in these meeting minutes utilized the 2035 traffic and pedestrian forecast developed in Phase 2 of the FITS study.		
Summary: The purpose of this meeting was to discuss the layout of the proposed roundabout and the next steps in the design process. The roundabout was identified as having superior operations and safety compared to keeping the traffic signal and adding lanes, although concerns about emergency vehicles, wayfinding, and pedestrian crossings were discussed. Although the roundabout was expected to operate acceptably in 2035, it was noted that a westbound to northbound right-turn bypass lane could be added in the future if needed. Similarly, pending the results of the litigation against the Road Commission for Oakland County (RCOC), the need to implement accessible pedestrian signals was recognized, and the consultant noted that the concept includes underground conduit for future installation of such devices.		
Applicability: These minutes document the beginning of the development of a conceptual roundabout layout which was performed in order to better understand costs, impacts, and performance of the improvements. The minutes indicate uncertainty with the operations of the roundabout PHBs and the implications of the RCOC lawsuit. The minutes document the roundabout option as being superior to upgraded traffic signal options.		

Title: Fuller Road Roundabout Concept Study (includes preliminary draft, response to comments memo, and final draft)	Date: 11/2009	Consultant: URS
Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive		
Pedestrian and Vehicular Volumes Source/Years: This study utilized the 2012 and 2035 traffic forecasts developed in the FITS study.		
Summary: This report documents the analysis and development of a conceptual roundabout layout which was performed in order to better understand costs, impacts, and operational performance. This report updates the previous concept prepared by OHM in 2006 to account for the Fuller Intermodal Transportation Station (FITS), the Lowertown Development, and the need to provide signalized pedestrian crossings at the roundabout. To be conservative, the study did not include any reduction in vehicular trips which could occur due to construction of the Signature Transit Service Line. Subsequent to submitting the draft study in November of 2009, the City reviewed the draft and provided comments which were addressed in a letter from URS dated 11/19/2009. The first comment from the City asked for clarification on how pedestrian and bike volumes were developed for the analysis. URS replied that the total bike and pedestrian volumes from the FITS Phase 2 study were used, and a sensitivity analysis was performed with double and triple those volumes. Furthermore, URS switched to using ARCADY for the roundabout analysis citing "software limitations associated with RODEL". ARCADY is a deterministic model based on UK research similar to RODEL. The report does not describe how the PHBs are accounted for in ARCADY analysis. The results show that even with non-motorized activity tripled, the roundabout would maintain good operations with no worse than LOS B and a queue of six vehicles on any leg with PHBs in place. The second question from the City related to how much of the increased traffic is attributable to the Lowertown Development. The answer was twenty-three percent of all traffic growth including the Signature Transit Service Line, and eighteen percent without it. URS estimated that the reduction in traffic on Fuller Road from the transit service would be greater than reflected in the study. Next the City asked when the existing intersection configuration		

would fail. URS replied that the traffic signal controlled intersection would fail upon build out of either the Lowertown Development or FITS, or by 2026 without those developments. Next the City asked if the WB bypass lane was needed for the roundabout to work, and the reply was that the roundabout could work without it if the Signature Transit Service Line is deployed. Finally, the City asked if any bridge structure would need to be modified, and the answer was that minor adjustments in the roundabout geometry would probably result in no modifications to the bridges.

The estimated total cost including construction, construction engineering, and design engineering was $2,752,500, with an additional $225,000 for the installation of PHBs. A cost-benefit comparison was performed indicating significant savings in emissions and fuel costs if the roundabout were implemented. The study also noted savings due to reduced crash frequency and lower operating costs.

The study noted the implications of the PROWAG and RCOC litigation and recommended two-stage pedestrian signals with Z-style crosswalks to accommodate all pedestrians. The study recommended that bicyclists are removed from the circulatory roadway through the use of ramps on the approaches and exits of the roundabout. The study noted that the design cannot accommodate extra width on the bridges north and south of the intersection for the bike lanes that are shown as long-term improvements in the City Non-Motorized Transportation Plan.

Applicability: This study cited deficiencies in the performance of the previously used roundabout capacity software, RODEL, although those specific deficiencies were not identified. The comments on the draft study from the City point toward concern about how non-motorized traffic affects the operation of the roundabout as well as how sensitive the roundabout is to fluctuations in traffic (resulting in the possible need for the bypass lane). The study states implementation of the Signature Transit Service Line would result in lower traffic and pedestrian volumes, thereby improving the operation of the roundabout compared to the conditions without the transit line. This document identifies the roundabout as providing superior traffic operations, safety, and impacts compared to widening or adding lanes under the existing traffic signal control. The report dismisses the traffic signal option from further consideration.

<table>
<tr><td>Title: Fuller/EMDC/Maiden Roundabout Simulation Summary</td><td>Date: 1/11/2010</td><td>Consultant: URS</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive, Maiden Lane & Broadway Street, Fuller Street & Glen Avenue, East Medical Center Drive & Cancer Center Drive, Fuller Road & Cedar Bend Drive</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: This study utilized the 2012 and 2035 traffic and pedestrian forecasts developed in the FITS study.</td></tr>
<tr><td colspan="3">Summary: Subsequent to preparing the Fuller Road Roundabout Concept Study, the City asked URS to model the proposed roundabout with the microsimulation software program VISSIM, which is capable of modeling roundabouts and signals together in one network. The purpose of this memo was to summarize the VISSIM capacity analysis of the proposed roundabout and the next adjacent signalized intersection on each leg, and to discuss any differences in results relative to previous analysis. The modeling did not include PHBs at the roundabout crosswalks. Rather, the crossings were “on demand”, meaning that as pedestrians arrived at the crossings vehicles were required to yield. The memo stated that it was more likely that pedestrians would pause when approaching the crosswalk, and that they would also cross in clusters. Therefore, URS decreased the pedestrian volumes to represent the number of pedestrian groups that would cross. The report states that had this adjustment not been made, VISSIM would overestimate the impact of pedestrian crossings due to a higher number of crossings than would realistically occur. Default driver behavior parameters were used in the VISSIM modeling (i.e., the model was not calibrated to observed/expected conditions). URS concluded that under the saturated 2035 conditions, RODEL</td></tr>
</table>

likely underestimates actual delay, whereas VISSIM likely overestimates delays and queues.

The VISSIM simulation results showed that additional road improvements would be needed compared to those suggested in previous studies. Specifically, an additional lane was recommended on eastbound East Medical Center Driver beginning at Fuller Road and terminating after Cancer Center Drive. This lane would be needed to prevent queues from the East Medical Center Drive & Cancer Center Drive traffic signal from backing into the roundabout. At the Fuller Road & Maiden Lane/East Medical Center Drive intersection, an eastbound right-turn bypass lane was also recommended to prevent queues from the roundabout from reaching the Fuller Street & Glen Avenue traffic signal. Finally, to mitigate the queues at the east leg of the roundabout, right-turn bypass lanes were recommended on the south and east legs. The study also suggested that the Signature Transit Service Line be implemented, timing at adjacent signals be adjusted, and PHBs be installed at the roundabout crossings in order to optimize roundabout operations.

Applicability: This document concluded that both RODEL and VISSIM may not be accurately predicting delays and queues at the intersection. The report suggests that eastbound, westbound, and northbound right turn bypass lanes may be needed, and an additional eastbound lane is required on East Medical Center Drive between the roundabout and the Cancer Center Drive intersection. The study suggested that pedestrians would cross in groups, and therefore reduced the pedestrian volumes to represent the number of crossing occurrences. Future studies would also reduce pedestrian volumes in this manner. Finally, the study suggested that the acceptable performance of this roundabout may be tied to the assumption that transit service (once implemented) will reduce traffic volumes.

Title: Effect of Pedestrian Signals on Roundabout Operations: A Case Study in Ann Arbor, Michigan	Date: 4/15/2011	Consultant: ITRE

Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive

Pedestrian and Vehicular Volumes Source/Years: The City of Ann Arbor provided traffic and pedestrian volumes to ITRE

Summary: The purpose of this study was to evaluate the performance of the roundabout using VISSIM models that: (a) were more detailed than those previously developed, and (b) fully account for PHB operation and pedestrian behaviors at the roundabout. The VISSIM models for this study were calibrated to: (1) HCM capacity equations, (2) actual HCM delay predictions, and (3) RODEL delay predictions. The study team recommended the use of the model calibrated to the HCM capacity predictions, as this model was described as based on the most recent and relevant research. The study evaluated the performance of a roundabout with two circulating lanes and two entering and exiting lanes on all legs. The roundabout also included a right-turn bypass lane for the east leg of the intersection. Measures of Effectiveness (MOEs) for the analysis included vehicular delay and pedestrian delay.

Eight scenarios were run for each of the three calibration models and the base geometry, with pedestrian conditions varying for each scenario as described below:

1. No pedestrians
2. Pedestrians at unsignalized crossings and vehicles yielding to pedestrians 100 percent of the time (pedestrians do not have to wait to find a gap)
3. Pedestrians at unsignalized crossings and vehicles yielding fifty percent of the time
4. Pedestrians at unsignalized crossings and vehicles not yielding at all (pedestrians must find an acceptable gap in traffic in order to cross)
5. Pedestrians at conventional signal (green, yellow, red) controlled crossings and all pedestrians waiting for "walk" signal to cross

6. Pedestrians at conventional signal controlled crossings with half of the pedestrians waiting for "walk" signal to cross and the other half crossing when there is an acceptable gap in traffic
7. Pedestrians at PHB controlled crossings and all pedestrians waiting for "walk" signal to cross
8. Pedestrians at PHB controlled crossings with half of the pedestrians waiting for "walk" signal to cross and the other half crossing when there is an acceptable gap in traffic

The report defined all of the VISSIM parameters that were calibrated for each model.

The report concluded that a PHB signal is recommended rather than a conventional traffic signal because with a PHB, vehicles are not delayed during the "flashing don't walk" phase if no pedestrians are present. The results also indicate that a two-stage PHB signal would provide operational benefits (i.e., reduced delays) for both pedestrians and vehicles compared to unsignalized crosswalks with high driver yielding compliance. The study assumed that drivers are familiar with the operating procedures of a PHB signal, and an extensive public education and awareness program was recommended in order to achieve this situation in reality.

Applicability: The study results indicate that pedestrian crossings with PHB signals would provide the best overall operations for both pedestrians and vehicles. Because the study evaluated existing traffic volumes only and did not assess right turn bypass lanes in detail, these issues would require additional analysis. The study also provided very valuable conclusions about the optimal VISSIM model settings that should be used for additional modeling efforts.

<table>
<tr><td>Title: Supplemental Analysis for HAWK Signal – With and Without Slip Lane</td><td>Date: 5/6/2011</td><td>Consultant: ITRE</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volume Source/Years: The City of Ann Arbor provided traffic and pedestrian volumes to ITRE</td></tr>
<tr><td colspan="3">Summary: ITRE provided this supplemental analysis to investigate the roundabout operations with and without a westbound right-turn bypass lane (referred to as a "slip lane" in the report) using PHB signals for the pedestrian crossings and analyzing two scenarios – one assuming all pedestrians only cross during the "walk" signal phase, and one assuming half wait for the "walk" phase and half will cross when an acceptable gap in traffic is available. The report concludes that without a bypass lane, the westbound approach delay would operate at LOS F under the unsignalized criteria and as LOS E under the signalized criteria.</td></tr>
<tr><td colspan="3">Review of Applicability: The analysis shows that the westbound bypass lane is needed to mitigate unacceptable delays on the westbound approach under the existing conditions. These delays are attributable to vehicular volumes and not caused by pedestrian volumes/PHB signals.</td></tr>
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<table>
<tr><td>Title: Wall Street East Parking Structure Traffic Study</td><td>Date: 6/13/2012</td><td>Consultant: URS</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive, Maiden Lane & Island Drive, Maiden Lane & Maiden Lane Court, Maiden Lane & Nielsen Court, Maiden Lane & Broadway Street/Plymouth Road, Wall Street & Broadway Street</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: New peak hour turning movement counts were performed at the intersections listed above in March of 2012. Tube counts were also performed in the study area. Background traffic growth was estimated at one percent per year. The development, which consists of removing 210 existing surface lot parking spaces and replacing them with 725 parking spaces in the proposed parking deck, was expected to generate a net increase of 318 trips during the AM peak</td></tr>
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hour and 318 trips during the PM peak hour in the opening year of 2014. The development is expected to add 159 new trips to the study intersection during both the AM and PM peak hours.
Summary: The study identified failing movements and approaches as well as queuing issues at all study intersections under the no build conditions. The report cited the ongoing study being conducted by the City for the intersection of Fuller Road and East Medical Center Drive/Maiden Lane. The report did not recommend any physical improvements to mitigate the impact of the development. The study recommended minor signal timing changes, which would result in very little change in delay comparing the Build scenario to the No Build scenario.
Applicability: Previous studies estimated that this project would increase parking by 200 spaces, whereas this study indicates the net increase may be closer to 525 spaces. The development would result in approximately 159 new trips through the project intersection during both the AM and PM peak hours by 2014.

<table>
<tr><td>Title: Wall Street District Roadway Improvement Options</td><td>Date: 6/14/2012</td><td>Consultant: URS</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive, Maiden Lane & Island Drive, Maiden Lane & Maiden Lane Court, Maiden Lane & Nielsen Court, Maiden Lane & Broadway Street/Plymouth Road, Wall Street & Broadway Street</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: The same intersection turning movement volumes from the Wall Street Parking Structure Traffic Study were utilized for the analysis of 2014 conditions.</td></tr>
<tr><td colspan="3">Summary: At the request of the U of M, URS completed this study to determine potential roadway improvements that do not result from any particular development, but would benefit traffic flow in the district. The improvement options were recommended to be implemented when practical and justified to do so. The following improvements were recommended: add right-turn lane on Maiden Lane at Broadway Street/Plymouth Road, remove Island Drive south of Maiden Lane and reconfigure Maiden Lane Court to accommodate two-way operation, extend Nielson Court between Maiden Lane and Wall Street, and construct a roundabout at the intersection of Wall Street and Nielson Court.</td></tr>
<tr><td colspan="3">Applicability: Direct applicability to the study intersection is limited; however the suggested system improvements in the Wall Street district may improve traffic flow to and from the study intersection. The study also recommended adding right-turn lanes on both Fuller Road approaches at the study intersection. These improvements could be considered short term improvements which would help operations until a roundabout can be constructed at the study intersection.</td></tr>
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<table>
<tr><td>Title: Pedestrian Underpass Study</td><td>Date: October 2014</td><td>Consultant: DLZ</td></tr>
<tr><td colspan="3">Study Intersections: Fuller Road & Maiden Lane/East Medical Center Drive</td></tr>
<tr><td colspan="3">Pedestrian and Vehicular Volumes Source/Years: Traffic analysis not performed, as this study focused on the engineering feasibility of constructing pedestrian underpass facilities which utilize existing bridge structures.</td></tr>
<tr><td colspan="3">Summary: This study inventoried the existing pedestrian pathway and crosswalk facilities and potential future multi-use paths that are proposed as part of various park and recreation plans. These include the “border-to-border” trail project, a regional trail that would provide a route through the county from the Wayne County border to the Livingston County border, as well as local trails near Fuller Park and along the Huron River. These trails are proposed to cross under existing bridges on East Medical Center Drive, the west leg of Fuller Road, and Maiden Lane. These proposed pedestrian facilities would use the space between the existing paved concrete slopes and the bridge piers.

The study evaluated the engineering feasibility of potential design concepts for (1) pedestrian facilities under the three existing bridges and (2) ADA compliant sidewalk ramps to connect paths/sidewalks that</td></tr>
</table>

are at grade along the existing roads to the border-to-border paths which are at a lower elevation. Three designs were assessed, two which employ switchbacks adjacent to stairways, but at different angles and grades.

Finally, the study evaluated the total distance required to travel using various pedestrian origins and destinations. The study found that the Z-style roundabout crossings would slightly increase the total crossing distance, the option with six ramps increased the distance by nearly 40 percent, while the "low cost" option with four ramps increased the distance by nearly 80 percent.

Applicability: Pedestrian underpasses appear to be technically feasible at the three existing bridges. However, routing pedestrians through the intersection via grade separations appears undesirable for several reasons: (1) at grade crossings with PHB's are projected to operate efficiently for both vehicles and pedestrians, making this a very viable option; (2) due to the increased travel distance involved, it is not clear whether underpass facilities would be used by most pedestrians in lieu of crossing the intersection at grade; (3) pedestrian grade separations would add substantial cost to the project, both to construct and for ongoing maintenance; (4) some pedestrians perceive grade separations to be not as safe as crossing at grade. The City may, however, still desire to consider pedestrian underpasses at these three bridges as part of their trail system, either with or without a connection to the at grade sidewalk system at the intersection.

ADDITIONAL CONSIDERATIONS

In addition to the information provided above, several other factors were considered relative to the proposed concept design at the study intersection. These are discussed below.

Accommodation of Buses

In general, the roundabout option would provide lower delays to bus traffic than the no build scenario. The proposed design would accommodate buses in their lane on the entry, circulatory roadway, and on the roundabout exits. Buses would not need to utilize the central island truck apron, which can cause passenger discomfort if traversed. Roundabouts built at other locations in the Ann Arbor Area (including Maple Road at M-14, Geddes Road at US-23, Huron and Nixon Roads) have demonstrated that good designs will accommodate buses without issue. Bus stops should be located carefully to minimize the potential for queuing to spill back into the roundabout circulatory roadway.

Emergency Vehicles

Although some types of large emergency vehicles (e.g., fire trucks) may need to utilize the central island truck apron to traverse the intersection, the design would likely accommodate a typical fire truck within the circulatory roadway. In terms of response times, the proposed roundabout would result in significantly lower motorist delays than the No Build condition (during both peak and off peak traffic periods), though during peak traffic periods, emergency vehicles could still experience longer than desirable delays at the roundabout (see below in the VISSIM results section of the memo for more details about traffic operations). If a roundabout is constructed here, a public education effort should be undertaken in order to inform drivers not to enter a roundabout when an emergency vehicle is approaching on another leg and to exit the circulatory roadway if an emergency vehicle enters. In addition, compared to a signalized intersection, the roundabout option would eliminate the possibility of a collision when an emergency vehicle proceeds through the intersection against a red light.

Wayfinding

Because some drivers are not used to navigating roundabouts, orientation relative to destinations/exits may be a challenge for a percentage of the motoring public. This is a potential concern at the study intersection because it is an access point to the U of M Medical Center and will be used by motorists who are unfamiliar with the location and/or driving in emergency conditions. Wayfinding signs on the roundabout entries and exits can be implemented to assist drivers in identifying routes to key destinations, including emergency rooms or parking areas. Wayfinding information can also be incorporated into the standard signs that would be constructed for the roundabout. Roundabouts have been implemented near hospital entrances in multiple locations in the U.S. Below are example photos from the Good Samaritan Hospital in Puyallup, Washington and the Medical Center of the Rockies in Loveland, Colorado. Wayfinding signs distinguishing the hospital main entrance and the emergency entrance (red sign) are shown. For the project intersection, wayfinding signs identifying the Cancer Center, Mott's Hospital, the emergency entrance, and other destinations could be implemented similar to those shown below. Wayfinding information could also be incorporated into the standard signing scheme which would be designed for the project. Also, utilization of overhead signing could be considered as an option to provide maximum direction to unfamiliar drivers.

Figure 1. Entrance at Good Samaritan Hospital, Puyallup, Washington.

Figure 2. Roundabout Exit near Medical Center of the Rockies in Loveland, Colorado.

Figure 3. Roundabout Exit near Medical Center of the Rockies in Loveland, Colorado.

Recently, a multi-lane roundabout was also opened at the entrance to the University of New Mexico Hospital in Albuquerque, New Mexico.

Bridge Constraints

Bridges on three of the intersection legs are within 250 feet of the existing stop lines. The City desires to implement intersection improvements without incurring costs associated with bridge widening. This factor is one of the main reasons that the roundabout option is preferable to other potential improvements at the intersection (such as retaining traffic signal control and adding lanes). The City also is planning to rehabilitate these three bridges in 2015. As currently scoped, the rehabilitation project will not add any width to the structures, and therefore will have no capacity implications on the study intersection.

Safety Considerations

Roundabouts have been well documented in numerous U.S. and international studies to have safety benefits relative to other types of intersections including those with traffic signal control. This is true for both pedestrians and automobiles, with the greatest benefits due to reduction of crash severity. Single lane roundabouts generally provide the greatest safety benefits, but multi-lane roundabouts (such as the one proposed for the study intersection) also provide substantial reductions in crash severity. It should be noted that one report, *Evaluating the Performance and Safety Effectiveness of Roundabouts* (MDOT 2011), has identified that at some multi-lane roundabout installations, the total number of crashes per year has increased (but severity has still decreased substantially) relative to a “before” condition of traffic signal control.

TRAFFIC FORECAST AND CAPACITY ANALYSIS SCREENING

Taking into consideration all of the previously discussed information and direction from the City, the DLZ team commenced a new traffic analysis for the study intersection. This process entailed five main steps. First, a framework was developed for the overall traffic modeling process. This framework was approved by City staff prior to commencing subsequent steps. This framework is included in Appendix A. Second, an updated traffic forecast was developed by City staff with input from the DLZ team. Third, a capacity analysis screening was undertaken using HCM and RODEL to determine the base roundabout geometry that would be used in more detailed modeling. The fourth step in this process entailed detailed VISSIM microsimulation modeling. The fifth and final step was capacity analysis, concept designs, and cost estimation for East Medical Drive, which the VISSIM modeling (step 4) showed may need an additional eastbound travel lane. Steps two through five are discussed below.

Development of Updated Traffic Forecast

City staff carefully evaluated previous traffic forecast information and applicable factors that could change the forecast (these factors are noted in earlier portions of this memo). After considering these factors and various potential development scenarios in the area, City staff developed AM and PM peak hour vehicular and pedestrian volumes for the existing (2012), near-term (2014), and long-term (2035) horizon years. The year 2035 forecasted volumes account for potential traffic growth in the area and are robust enough to accommodate many different development scenarios. These volumes are included in Appendix B. These updated traffic volumes were subsequently used for the traffic analyses discussed below.

Capacity Analysis Screening

Using the updated traffic forecast, the project team performed a preliminary capacity analysis using HCS and RODEL to determine the base geometry to be advanced for further study using VISSIM. The analysis considered various Peak Hour Factors (PHFs), gap parameters, and other model settings to determine how sensitive the roundabout geometry would be to different traffic characteristics. This analysis took into account the desire to avoid costly widening of existing bridges adjacent to the intersection. As a result of this analysis, the recommended roundabout base geometry included two circulating lanes, two entering and exiting lanes on each leg of the roundabout, and a right-turn bypass for the westbound approach. This bypass lane would be under yield control. This model work demonstrated that the proposed geometry is robust enough to accommodate the 2035 forecast that reflects a variety of possible traffic scenarios.

VISSIM MODEL ANALYSIS

Methodology

Scenario Descriptions

The VISSIM modeling efforts were built upon the previously completed URS VISSIM model for the study area road network. A validation effort was carried out to ensure that the model has been established in an appropriate manner. It should be noted the previous ITRE study reports referenced above were also used as guidance. Seven scenarios were analyzed using the VISSIM software tool (version 5.4) to compare the performance of each roundabout. Six scenarios represented conditions under forecast 2035 traffic/pedestrian volumes for the weekday AM and PM peak hours, as well as one scenario under 2014 “opening day” conditions. A description for each of the seven evaluation scenarios and their corresponding lane configurations are provided below.

Scenario 0 This Scenario represented the baseline 2035 conditions using the forecast 2035 traffic volumes. One right turn by-pass lane was coded in the northeast quadrant to accommodate the westbound right turn movement. The right turn bypass lane was terminated in a yield condition. The pedestrian crosswalks at the roundabout were coded as standard, unsignalized crosswalks. All arriving pedestrians were coded to proceed across the roadway, and 50% of all conflicting drivers are to yield to these pedestrians (i.e., 50% driver compliance). The remaining 50% of drivers were coded as being non-compliant and given the right-of-way. Therefore, pedestrians in the crosswalk yielded to these non-compliant drivers. The lane configuration is illustrated below in Figure 4.

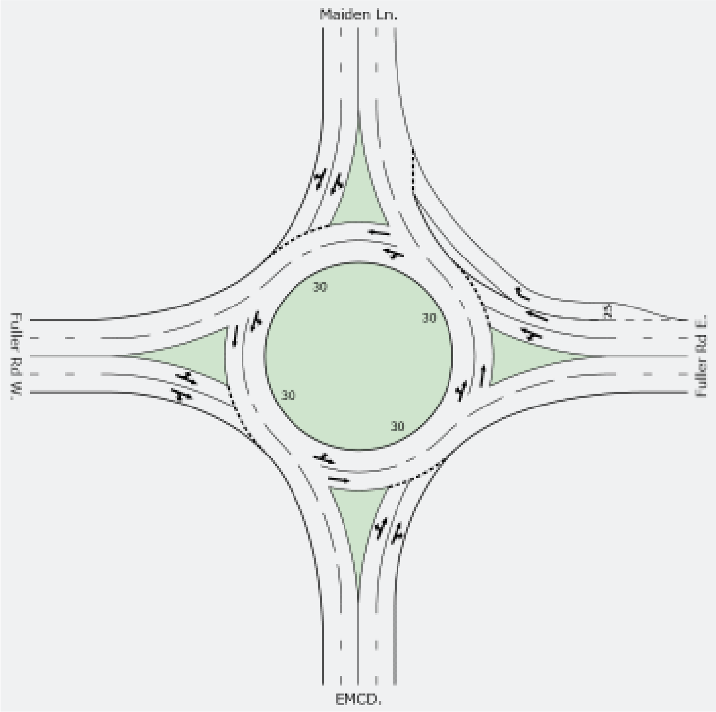
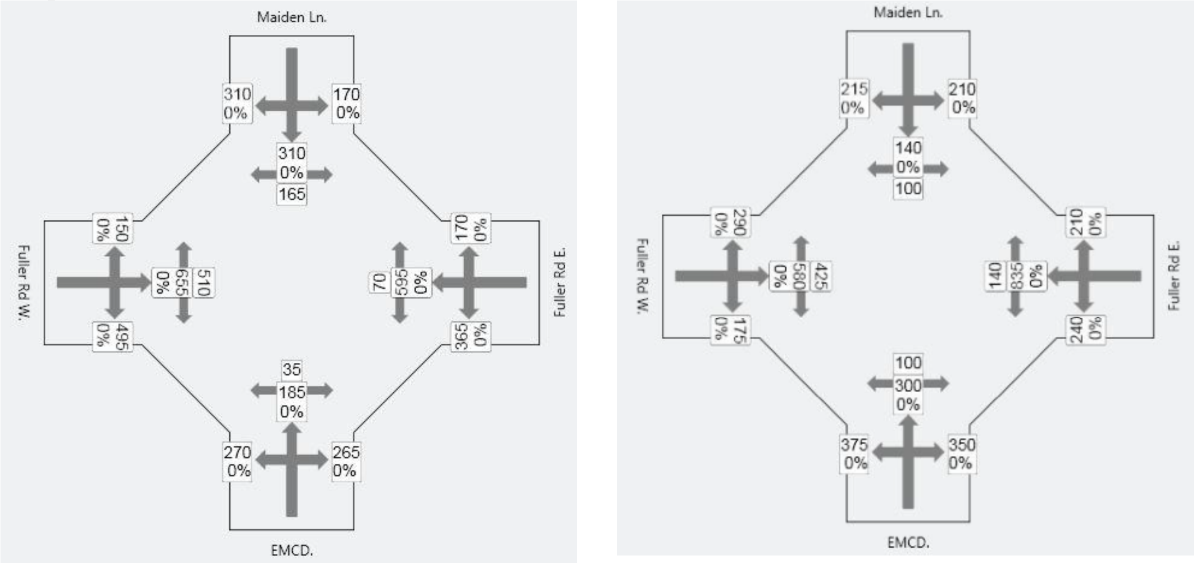


Figure 4: Scenarios 0 and 1 Roundabout Lane Configuration

The forecast traffic volumes for the 2035 planning horizon are illustrated in Figure 5. These volumes have been provided by the City and are to be applied to the analysis of the Fuller Road roundabout. A peak hour factor (PHF) of 0.92 was applied to the traffic volumes, which is consistent with the HCS modeling. This was accomplished by inputting the 2035 peak hour traffic volumes in 15-minute intervals to replicate a PHF of 0.92.



AM Peak Hour

PM Peak Hour

Figure 5: Forecast 2035 Traffic and Pedestrian Volumes

Heavy vehicle percentages are not included in Figure 5. The heavy vehicle percentages coded into the URS VISSIM model were utilized and ranged between 2% and 10%, depending on the entry point to the study area road network.

Scenario 1 This Scenario built upon Scenario 0 by using the same forecast 2035 traffic volumes and roundabout lane configuration. However, under Scenario 1, the pedestrian crosswalks at the roundabout were assumed to be under signal control (i.e., a pedestrian hybrid beacon or PHB). It is assumed that pedestrians had a 50% compliance rate, meaning 50% of pedestrians stopped and waited for a “walk” phase (i.e., compliant). The remaining 50% (i.e., non-compliant) crossed the roadway when a suitable gap was presented to them. The lane configuration for this Scenario is illustrated above in Figure 4.

Scenario 2 Scenario 2 applied the same traffic volumes and driver/pedestrian compliance conditions at the roundabout crosswalks as coded in the Scenario 1 model. A sensitivity analysis approach was then undertaken to determine the need for additional right turn bypass lanes in the other three quadrants. Given the sensitivity of roundabout operational results to minor changes in both the entry and circulating flows, it was necessary to test specific combinations with and without right turn bypass lanes in various quadrants of the roundabout. Scenario 2a included westbound and southbound right turn slip lanes. Scenario 2b included westbound, southbound and northbound right turn slip lanes. The Scenario 2b lane configuration is illustrated below in Figure 6.

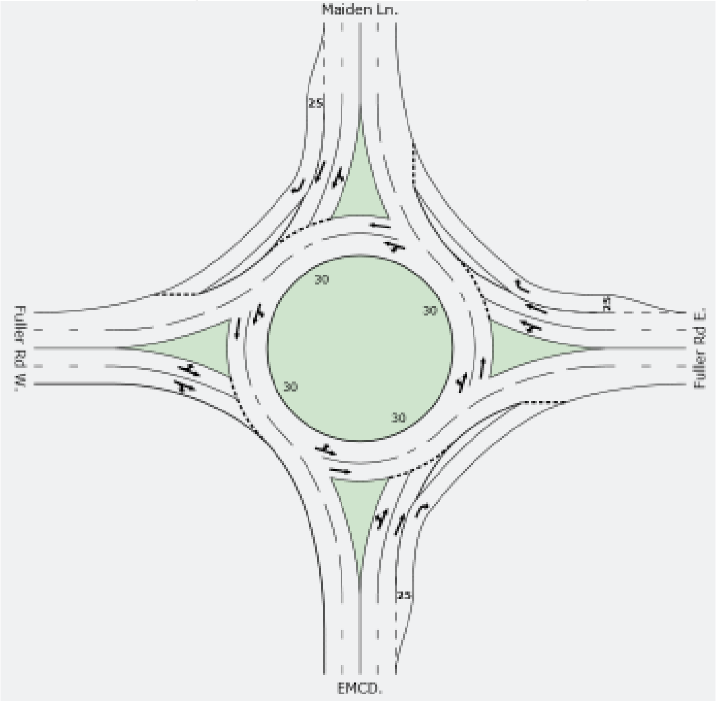


Figure 6: “Scenario 2b” Roundabout Lane Configuration

Scenario 3 The goal of the Scenario 3 analysis was to identify the approximate timing of the need for additional right turn slip lanes. The analysis results of Scenario 2b indicated that southbound and northbound right turn slip lanes would be required by the 2035 planning horizon. These results were compared with the 2014 planning horizon analysis results flowing from Scenario 6 (discussed below). The comparative analysis allowed the study team to carry out a qualitative assessment of vehicle delay times to identify the approximate timing of the need for these additional lanes.

Scenario 4 Scenario 4 focused on the impact of pedestrian volumes, pedestrian delay and the impact these pedestrian volumes had on vehicle delay. As such, this Scenario used the same model structure as in Scenario 1. To accomplish this scenario a sensitivity analysis approach was performed to determine the need for, and timing of, pedestrian grade separation at the roundabout crosswalks. The need for pedestrian grade separation considered the combination of increased pedestrian crossings (i.e., the number of times the PHB is activated during the simulation period) and the vehicle queues and delays on the corresponding roundabout approach. The sensitivity analysis evaluated the impacts associated with a 50% and 100% increase in pedestrian volumes.

Scenario 5 The goal of Scenario 5 was to assess the impacts associated with optimized signal timing and phasing at the upstream traffic signals and how these timings impacted pedestrian/vehicle delays and queues at the roundabout. A set of optimized signal timing and phasing adjustments were based on a network traffic signal optimization process carried out using the Synchro 8 software tool. This information was then coded into the VISSIM model and minor adjustments were made, as necessary.

Scenario 6 This Scenario represented "opening day" conditions and built upon the Scenario 1 model structure. Under these conditions 2014 planning horizon traffic and pedestrian volumes were used. It was assumed that the traffic routing details and vehicle composition remained constant for the 2014 and 2035 planning horizons.

Roundabout Assumptions

Parameter Settings

A summary of the VISSIM software parameter settings that were utilized in the analysis are summarized in Table 1. It should be noted that this list of settings was focused on parameters associated with the operational characteristics of the Fuller Road roundabout and was not intended to be a comprehensive list of all VISSIM network parameter settings.

Table 1: VISSIM Software Input Parameter Settings

Feature	Description	Parameter Setting
1 - Approach link speed	The approach link speed setting in VISSIM represents the free-flow vehicle operating speed where traffic is unimpeded by other vehicles, traffic control devices and the geometric design features of the roadway.	North leg = 27.5-32.5 mph South leg = 22.5-27.5 mph East Leg = 32.5-37.5 mph West Leg = 32.5-37.5 mph
2 –Roundabout Entry radius speed	The vehicle speed at a roundabout entry point is dictated by the radius of the horizontal deflection at this location. Therefore, the actual vehicle operating speed will depend on the final design. For the purposes of this planning-level analysis, the entry speed identified in the April 2011 ITRE report was used. Although these speeds are lower than the expected fastest path speeds, they appear suitable for this planning-level assessment.	The following speeds reported in the ITRE study was coded in VISSIM using "reduced speed areas": Cars/light trucks = 15mph Heavy vehicles = 10mph

Feature	Description	Parameter Setting
3 - Circulating lane speed	Similar to entry speed, the vehicle operating speed in the circulating lanes of the roundabout will be dictated by the final geometric design. For the purposes of this planning-level analysis, the entry speed identified in the April 2011 ITRE report was used. Although these speeds are lower than the expected fastest path speeds, they appear suitable for this planning-level assessment.	The following speeds reported in the ITRE study was coded in VISSIM using "reduced speed areas": Cars/light trucks = 20mph Heavy vehicles = 15mph *Note: The "desired speed" setting was not used in the analysis. The "reduced speed areas" was used to adjust speed due to specific changes in geometry.*
4 –Roundabout entry gap acceptance time	As discussed in Section A.3 below, there are two methods in the VISSIM software tool to define vehicle right-of-way at an intersection. The "priority rules" method was applied in this study. This method allows the users to apply a calculated critical gap value directly into the VISSIM software. Based on past research and empirical studies critical gap values at roundabout entries vary. However, the results generally indicated that a 3.9s gap is appropriate for uncongested multi-lane roundabouts and gap values of 3.1s are more appropriate for roundabouts with higher flows and longer delays.	**2014 Planning Horizon:** Cars / light trucks = 3.9s Heavy vehicles = 5.0s **2035 Planning Horizon:** Cars / light trucks = 3.1s Heavy vehicles = 5.0s
5 – Vehicle Routing	The vehicle routing feature in VISSIM was used to define specific routes through a network including turning movements at intersections.	The vehicle routing settings ensured that vehicles entering the roundabout are in the proper approach lane that corresponds with the necessary turning movement and no lane changes were permitted within the circulating lanes.
6 - Vehicle composition	The vehicle composition describes the percentage of each vehicle category coded into the VISSIM model.	The VISSIM model has nine (9) vehicle "gateway" entry points. There are two vehicle classes including cars / light trucks and transit buses (heavy vehicle). The heavy vehicle percentages range between 2% and 10%, depending on the "gateway" location.

Feature	Description	Parameter Setting
7 - Simulation period	The total simulation time coded into the VISSIM model spanned 4,500s (75 minutes). This included an initial 900s (15 minute) "seed" time followed by a 3,600s (60 minute) simulation period. The 3,600s period was used for the calculation of results.	Total of 4,500 seconds including an initial 15 minute "seed" time and a 60 minute simulation time.
8 - Number of simulation runs	For each Scenario, the VISSIM simulation was executed using five different random number seeds to provide a range of results. A random number generator was utilized to provide a 2 digit random number (i.e., between 10 and 99). The same five (5) random numbers generated was used for each analysis scenario for consistency and comparative purposes.	Five (5) different random number seeds.

Gap Acceptance Parameters
Current Research: The results of several research reports from the United States, Canada, Australia and Europe have been summarized in Table 2 to identify best practices in the area of vehicle gap acceptance at multi-lane roundabout entry points. In support of this effort, an empirical gap survey was carried out in January 2013 at three multi-lane roundabouts in Halifax, Canada.

Table 2: Roundabout Entry Gap Acceptance Values

		Multi-lane Roundabout Entry	
Source	**Description**	**Critical Gap, t_c (s)**	**Follow-up Gap, t_f (s)**
Empirical Data- US	California Survey[i]	4.4-4.7[A]	1.8-2.7 (2.2)
	NCHRP Report 572[ii]	3.4-5.5 (4.5)	2.7-4.7 (3.4)
Empirical Data- Canada	Halifax, Novi Scotia[iii]	3.0-3.9 (3.1)	2.2-2.7 (2.4)
Software Models	Australian[iv]	1.6-4.1 (2.9)	1.8-4.0 (2.9)
	Germany[v]	4.4	3.2
	Average	**3.9**	**2.8**

A- No average value provided in report.

The results of the Halifax survey yielded a range of critical gap values from 3.0s to 3.9s. Three multi-lane roundabouts were evaluated. One location had high vehicle demand and long delay times at the entry points (3.0s critical gap). The other two locations were relatively new installations with lower volumes and thus lower delay times (3.9s critical gap).

Generally, the results of the literature review show the gap acceptance values vary by location. However, it is interesting to note that the two newer roundabout installations in Halifax yield the same critical gap values as the average shown in Table 1 above (i.e., 3.9s). This indicates that multi-lane roundabouts with relatively lower volumes and delay times can result in larger critical gap values. Therefore, a critical gap value of 3.9s appears appropriate for use at new roundabout installations.

Conversely, the high-volume, high-delay roundabout in the Halifax survey yielded similar critical gap values (i.e., 3.0s) as the Australian software model (which was based on empirical surveys conducted in Australia). These lower gap acceptance values appear more appropriate for multi-lane roundabouts that have been in place for some time and drivers have adjusted their behavior accordingly. Therefore, the average critical gap value from the Halifax survey (i.e., 3.1s) appears appropriate for use at roundabout installations with higher volumes and delay times.

Modeling Gaps in VISSIM: Two methods can be utilized to model the vehicle-to-vehicle interactions at a roundabout entry using VISSIM. The first method, referred to as "priority rules", is the original method that uses a gap value and approach speed to define when a waiting vehicle can enter the main stream of traffic. The "priority rules" method allows the user to define a gap value and this generally corresponds to the critical gap time.

In recent years, the VISSIM software was updated to also include a new method to define vehicle-to-vehicle interactions, called "conflict areas". This new method simplifies the coding effort, however, is based on a slightly different gap methodology. Therefore, it does not directly relate to the critical gap value. The work carried out by ITRE calibrated a VISSIM model to the HCM capacity algorithm using the "conflict area" method.

In order to apply the results of the current research discussed above, the "priority rules" method was applied in the analysis of the proposed Fuller Road roundabout. Although this approach varied from the earlier ITRE study, the "priority rules" method is appropriate due to the following:

- Its compatibility with empirical gap survey results;
- Its compatibility with the HCM gap acceptance theory; and
- Simplifies the calibration process for the proposed Fuller Road roundabout

Pedestrian Assumptions

For this study, the original URS VISSIM model crosswalk locations and link structure were used as a starting point and evaluated for appropriateness. For each roadway entrance and exit to the roundabout, two distinct and separate pedestrian links were established. These links accommodated the movement of pedestrians across the subject roadways – one link dedicated to one travel direction and another link dedicated to the other travel direction. This is illustrated in Figure 7 below.

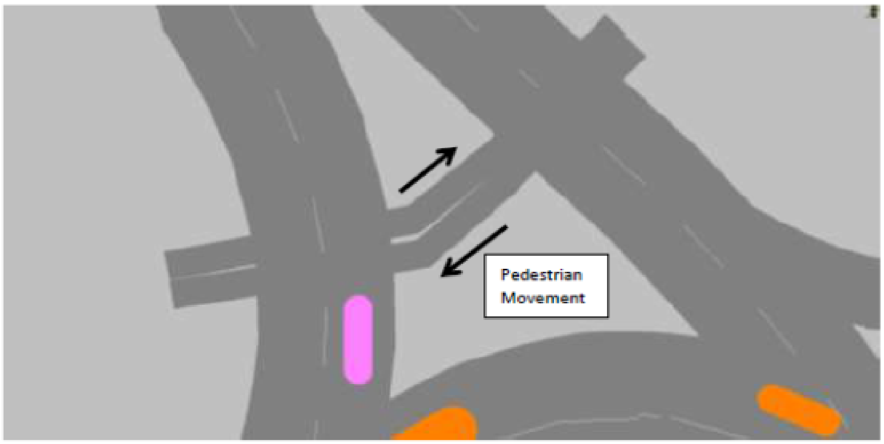


Figure 7: Basic Crosswalk Link

This model pedestrian crosswalk link/connector structure is an appropriate method for modeling pedestrian crosswalks and follows the guidelines provided in the VISSIM software manual.

Unsignalized Pedestrian Crosswalks

Unsignalized pedestrian crosswalks were modeled in Scenario 0. The pedestrian crosswalks at the roundabout were coded as standard, unsignalized crosswalks. Therefore, all arriving pedestrians will proceed across the roadway, and 50% of all conflicting drivers will yield to these pedestrians (i.e., 50% driver compliance). The remaining 50% of drivers were coded as being non-compliant and given the right-of-way. Therefore, pedestrians in the crosswalk will yield to these non-compliant drivers.

Based on the pedestrian-vehicle interaction required to model the Scenario 0 conditions as previously described in this memo, there were two potential approaches that could have been applied. These two approaches included:

1. Having two separate driver types distributed throughout the model network; one type yielding to pedestrians in crosswalks (i.e., compliant) and another type that do not yield to pedestrians in crosswalks (i.e., non-compliant); or
2. Having two separate pedestrian types using the roundabout crosswalks; one type that has the right-of-way over vehicles (i.e., simulated driver compliance) and another type that yielded to vehicles (i.e., simulated driver non-compliance).

The latter pedestrian-vehicle interaction method was applied to this study as it was more efficient to establish within the model structure, was compatible with the signalized crosswalk conditions in the other Scenarios, did not impact the other study area intersections, and was expected to provide similar operational results (e.g. delay time) as method #1.

A detailed description of method #2 is provided in the following:

- For each leg of the roundabout, one crosswalk link accommodated 50% of the pedestrian volume. This pedestrian type had the right-of-way over vehicles. As such, these pedestrians were modeled to proceed across the roadway once they arrived at the curb. This resulted in very little delay for this pedestrian type while delay was incurred by the drivers that had to stop and wait.
- Conversely, for each leg of the roundabout, the other crosswalk link accommodated the remaining 50% of pedestrians. This pedestrian type did not have the right-of-way. Under these conditions, this pedestrian type incurred a much longer delay than their counterparts as they waited for a suitable gap to cross the roadway. This resulted in pedestrian groupings on the curb as they waited to cross. For example, this pedestrian type waited for a suitable gap to cross the two exit lanes of the roundabout leg and then crossed to the splitter island. Once on the splitter island this process began again as these pedestrians waited for a suitable gap to cross the two entry lanes.

It is understood that both pedestrian types will cross the roundabout legs in both directions and that the visual representation in the VISSIM model is not completely accurate. However, the number of pedestrian-vehicle interactions would be the same if modeled as described above, or if modeled to be visually accurate. Therefore, the operational results – and in particular the average delay times – are expected to be the same under either condition.

Signalized Pedestrian Crosswalks

Signalized pedestrian crosswalks (i.e., a pedestrian hybrid beacon or PHB), were modeled in Scenarios 1, 2, 3, 4, 5, and 6. It is assumed that pedestrians will have a 50% compliance rate. This means that 50% of pedestrians will stop and wait for a "walk" phase (i.e., compliant). The remaining 50% (i.e., non-compliant) will cross the roadway when a suitable gap is presented to them and vehicles will have the right-of-way.

The signalized crosswalks - including detection, timing and phasing - were developed following the guidance provided in the ITRE studies. Sensitivity testing with different signal configurations was performed to determine the most efficient operations. The signal operations that were coded into the model use the same timing as described in Table 1 of the ITRE Report, and are summarized in Table 3Table 3. The PHB's rest in dark mode (for vehicles) until the pedestrian actuation is activated. The maximum time that a pedestrian will wait between calls, is the minimum "green" time for vehicles which is 45 seconds.

Table 3: PHB Operations

Pedestrian Hybrid Beacon (PHB)		
Vehicular Interval	**Pedestrian Interval**	**Time (sec)**
Dark	Don't Walk	-
Flashing Yellow		-
Steady Yellow		3
Steady Red		1
	Walk	8
Alternating Flashing Red	Flashing Don't Walk	8
Red	Don't Walk	1
Dark		45

These Scenarios, similar to Scenario 0, used two pedestrian types to simulate a 50% pedestrian compliance rate as described in the study terms of reference. A detailed description of the modeled approach is provided below:

- For each leg of the roundabout, one crosswalk link accommodated 50% of the pedestrian volume. This pedestrian type was coded as "compliant". As such, these pedestrians were modeled to enter the link, proceed to the curb and activate the PHB signal. Once the conflicting vehicles stopped for the red phase, the pedestrians crossed the two entry lanes to the splitter island. Once there, the process started over again to cross the two exit lanes.
- Conversely, for each leg of the roundabout, the other crosswalk link accommodated the remaining 50% of pedestrians who represented the "non-compliant" type. This pedestrian type did not activate the PHB signal upon arriving at the curb. Rather, they waited for a suitable gap in the conflicting traffic flow. Once a suitable gap was present, these non-compliant pedestrians crossed the roadway regardless of the PHB signal phase. It should be noted that if these non-compliant pedestrians were waiting to cross and the PHB signal stopped traffic, these pedestrians would also cross the roadway as there was a suitable gap created by the signal.

Similar to Scenario 0, both pedestrian types will cross the roundabout legs in both directions and that the visual representation in the VISSIM model is not completely accurate. However, the number of pedestrian-vehicle interactions would be the same if modeled as described above, or if modeled to be visually accurate. Therefore, the operational results – and in particular the average delay times – are expected to be the same under either condition.

VISSIM Measures of Effectiveness (MOEs)

As identified in Table 1 Table 1 above, the VISSIM software was executed using five different random number seeds to provide a range of results for each analysis scenario. The results from each of the five simulation runs were collated. Average values and standard deviations were calculated for each measure of effectiveness, for each scenario, at each of the roundabout entry points.

The operational analysis results from the simulation effort focused on the roundabout entry points. Typical traffic engineering operational measures of effectiveness were used to compare the performance of the roundabout between the seven analysis Scenarios. A summary of the measures of effectiveness utilized in this study are contained in Table 4.

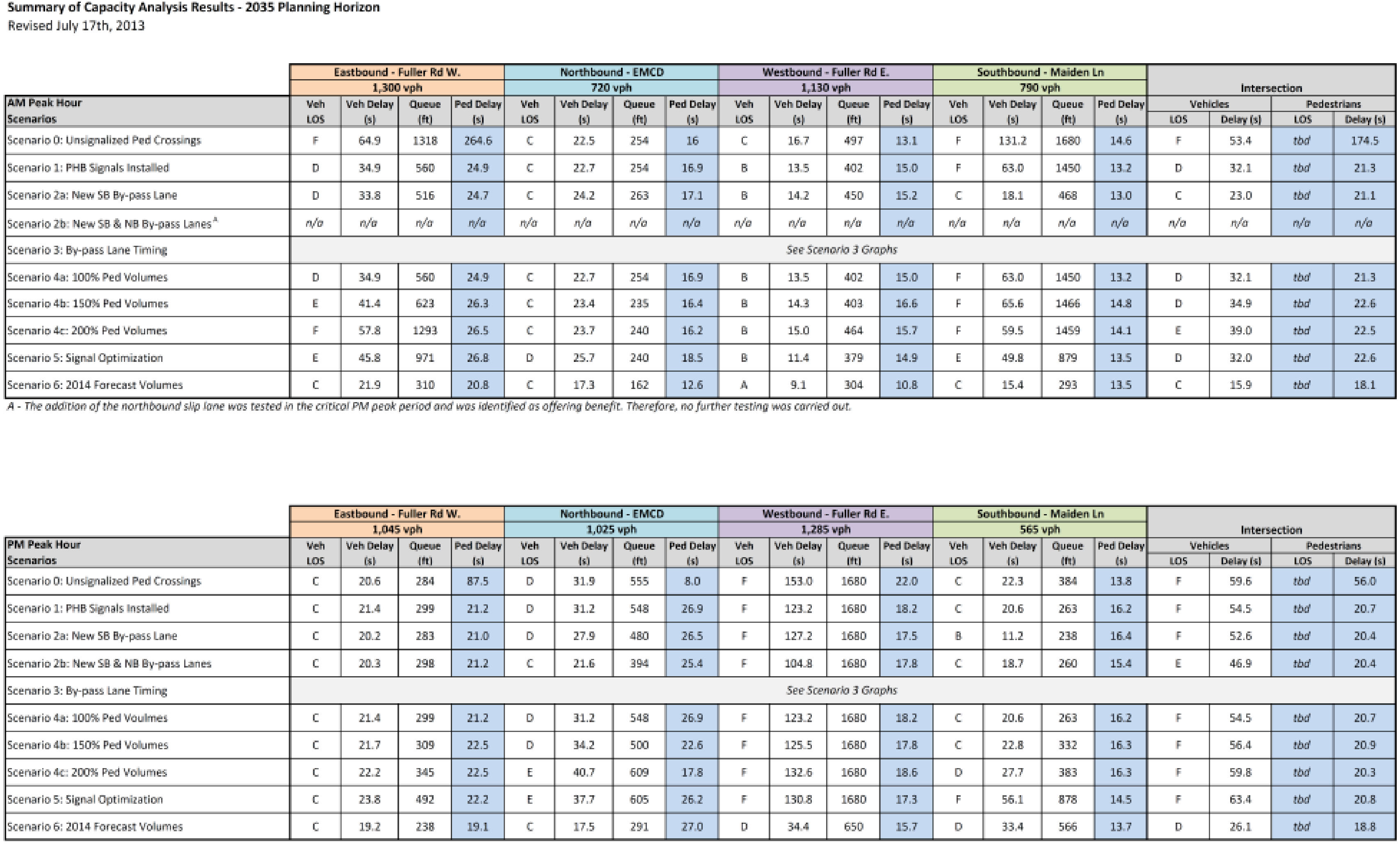
Table 4: Summary of Roundabout Measures of Effectiveness

Measure of Effectiveness	Description
Roundabout entry delay & level of service (LOS)	The average vehicle delay times were calculated for each simulation run, under each analysis Scenario. The Transportation Research Board (TRB) Highway Capacity Manual (HCM) definition of Level of Service (LOS) for an unsignalized intersection was used to determine the LOS for each simulation run, under each analysis scenario.
Roundabout entry queue length	The maximum vehicle queue lengths were calculated for each simulation run, under each analysis Scenario.
Pedestrian / Bicycle delay & level of service (LOS)	The URS VISSIM model has not been coded to explicitly model bicycles. From a road safety perspective a roundabout of this size is not a location where a road agency will want to encourage bicyclists to use the circulating lanes. As such, the same crosswalk delay times will be experienced by both pedestrians and cyclists. The average pedestrian delay time will be calculated at each crosswalk, for each simulation run, under each analysis Scenario. The TRB's Highway Capacity Manual definition of LOS for pedestrians will be used to determine the LOS. As specific bicycle counts were not provided, bicycle delay and LOS was not calculated.

Results

A roundabout capacity analysis process was carried out using the VISSIM software tool (version 5.4). The results flowing from the evaluation of each scenario are provided in Table 5Table 5. Measures of effectiveness used to describe the operational performance included the average vehicle delay, corresponding level of service for unsignalized intersections (per Transportation Research Board's Highway Capacity Manual) and maximum queue length, by approach. In addition, the pedestrian average delay times for each crossing were collected. It should be noted that Table 5Table 5 provides a summary and comparison between all scenarios. The results for each individual simulation run are provided in Appendix C.

Table 5: Summary of Capacity Analysis



Summary of Capacity Analysis Results - 2035 Planning Horizon

Revised July 17th, 2013

	Eastbound - Fuller Rd W.				Northbound - EMCD				Westbound - Fuller Rd E.				Southbound - Maiden Ln				Intersection			
	1,300 vph				720 vph				1,130 vph				790 vph							
AM Peak Hour Scenarios	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Vehicles		Pedestrians	
																	LOS	Delay (s)	LOS	Delay (s)
Scenario 0: Unsignalized Ped Crossings	F	64.9	1318	264.6	C	22.5	254	16	C	16.7	497	13.1	F	131.2	1680	14.6	F	53.4	*tbd*	174.5
Scenario 1: PHB Signals Installed	D	34.9	560	24.9	C	22.7	254	16.9	B	13.5	402	15.0	F	63.0	1450	13.2	D	32.1	*tbd*	21.3
Scenario 2a: New SB By-pass Lane	D	33.8	516	24.7	C	24.2	263	17.1	B	14.2	450	15.2	C	18.1	468	13.0	C	23.0	*tbd*	21.1
Scenario 2b: New SB & NB By-pass Lanes[A]	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
Scenario 3: By-pass Lane Timing	*See Scenario 3 Graphs*																			
Scenario 4a: 100% Ped Volumes	D	34.9	560	24.9	C	22.7	254	16.9	B	13.5	402	15.0	F	63.0	1450	13.2	D	32.1	*tbd*	21.3
Scenario 4b: 150% Ped Volumes	E	41.4	623	26.3	C	23.4	235	16.4	B	14.3	403	16.6	F	65.6	1466	14.8	D	34.9	*tbd*	22.6
Scenario 4c: 200% Ped Volumes	F	57.8	1293	26.5	C	23.7	240	16.2	B	15.0	464	15.7	F	59.5	1459	14.1	E	39.0	*tbd*	22.5
Scenario 5: Signal Optimization	E	45.8	971	26.8	D	25.7	240	18.5	B	11.4	379	14.9	E	49.8	879	13.5	D	32.0	*tbd*	22.6
Scenario 6: 2014 Forecast Volumes	C	21.9	310	20.8	C	17.3	162	12.6	A	9.1	304	10.8	C	15.4	293	13.5	C	15.9	*tbd*	18.1

A - The addition of the northbound slip lane was tested in the critical PM peak period and was identified as offering benefit. Therefore, no further testing was carried out.

	Eastbound - Fuller Rd W.				Northbound - EMCD				Westbound - Fuller Rd E.				Southbound - Maiden Ln				Intersection			
	1,045 vph				1,025 vph				1,285 vph				565 vph							
PM Peak Hour Scenarios	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh LOS	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Vehicles		Pedestrians	
																	LOS	Delay (s)	LOS	Delay (s)
Scenario 0: Unsignalized Ped Crossings	C	20.6	284	87.5	D	31.9	555	8.0	F	153.0	1680	22.0	C	22.3	384	13.8	F	59.6	*tbd*	56.0
Scenario 1: PHB Signals Installed	C	21.4	299	21.2	D	31.2	548	26.9	F	123.2	1680	18.2	C	20.6	263	16.2	F	54.5	*tbd*	20.7
Scenario 2a: New SB By-pass Lane	C	20.2	283	21.0	D	27.9	480	26.5	F	127.2	1680	17.5	B	11.2	238	16.4	F	52.6	*tbd*	20.4
Scenario 2b: New SB & NB By-pass Lanes	C	20.3	298	21.2	C	21.6	394	25.4	F	104.8	1680	17.8	C	18.7	260	15.4	E	46.9	*tbd*	20.4
Scenario 3: By-pass Lane Timing	*See Scenario 3 Graphs*																			
Scenario 4a: 100% Ped Voulmes	C	21.4	299	21.2	D	31.2	548	26.9	F	123.2	1680	18.2	C	20.6	263	16.2	F	54.5	*tbd*	20.7
Scenario 4b: 150% Ped Volumes	C	21.7	309	22.5	D	34.2	500	22.6	F	125.5	1680	17.8	C	22.8	332	16.3	F	56.4	*tbd*	20.9
Scenario 4c: 200% Ped Volumes	C	22.2	345	22.5	E	40.7	609	17.8	F	132.6	1680	18.6	D	27.7	383	16.3	F	59.8	*tbd*	20.3
Scenario 5: Signal Optimization	C	23.8	492	22.2	E	37.7	605	26.2	F	130.8	1680	17.3	F	56.1	878	14.5	F	63.4	*tbd*	20.8
Scenario 6: 2014 Forecast Volumes	C	19.2	238	19.1	C	17.5	291	27.0	D	34.4	650	15.7	D	33.4	566	13.7	D	26.1	*tbd*	18.8

The following conclusions were reached based on the VISSIM analysis results of the proposed multi-lane roundabout:

Pedestrian Delay

- The analysis results demonstrate the pedestrian delay times are greatly improved (reduced) when PHB signals are implemented.
- The pedestrian delay times remained relatively unchanged in Scenarios 2, 3, 4, and 5, which suggests the PHB signals offer a good solution to managing pedestrian delay times out to the 2035 planning horizon.

Scenario 0

- Pedestrians using the unsignalized crosswalk across the west leg of the roundabout experience very high delay times.
- The overall intersection level of service (LOS) is LOS F for the AM and PM peak hours.

Scenario 1

- Pedestrian delay times across the west leg of the roundabout are noticeably reduced.
- The vehicle delay times for the southbound Maiden Lane entry are greatly reduced for the AM peak hour, although it remains at LOS F. The reduction in delay is due in part to the addition of the PHB signals that reduce queuing on the westbound exit. Vehicle queues spillback from the westbound exit crosswalk due to the high number of pedestrian crossings on the exit lanes. These queues frequently extend upstream into the circulating lanes and block the southbound entry.
- The vehicle delay times and vehicle queue lengths for the westbound approach during the PM peak hour remain relatively high (LOS F). This is due to a combination of high circulating flows across this entry, high entering demand, and large platoons from the upstream signal.

Scenario 2

- A sensitivity analysis approach was carried out to determine the need for right turn slip lanes on the other three roundabout approaches (in addition to the westbound approach). Based on the traffic operational results from Scenario 1, two combinations were examined that comprised of having westbound, southbound and northbound right turn slip lanes in place. The results of the Scenario 2b analysis indicated that having all three of these right turn slip lanes in place would moderately improve the operational results.
- The most notable impact associated with the addition of the southbound and northbound right turn slip lanes was the reduction in delay times on the southbound approach, during the AM peak hour (i.e., LOS F to LOS C). In addition, the overall intersection LOS during the PM peak hour was improved from LOS F to LOS E.

Scenario 3

- The results of the qualitative assessment carried out for Scenario 3 are contained in the Technical Appendix. The comparison of vehicle entry delay times for Scenarios 6/1/2a/2b indicates that the timing of the need for the southbound and northbound right turn slip lanes should be based on the combined performance (i.e., LOS) of the westbound entry and the overall intersection. Therefore, the westbound entry and intersection vehicle delay times should be monitored after the opening of the roundabout. It is recommended that when the westbound entry delay exceeds 40s and/or the intersection average delay exceeds 35s the bypass lanes could be considered. This is likely to occur between 2020 and 2025, but will depend on traffic volume growth, etc. Considering the moderate benefit to traffic operations and the potentially substantial construction costs of widening the bridges to accommodate the northbound and southbound bypass lanes, the cost effectiveness of making these improvements must be assessed in more detail should traffic operations eventually warrant their consideration.

- It would be prudent for these additional lanes to be considered in the original design of the roundabout so they could be more readily installed if needed. Further, right-of-way for the eastbound right turn slip lane could be preserved in the event this lane is required beyond the 2035 planning horizon.

Scenario 4

- Two separate sets of pedestrian volumes were evaluated as part of Scenario 4: a 50% increase and 100% increase. The comparison of pedestrian delay times showed very little change and indicated the PHB signals will be able to manage the pedestrian delay times under these conditions.
- With a 100% increase in pedestrian volumes, the average intersection vehicle delay increased by 7s and 5s for the AM and PM peaks, respectively. The most notable change during the AM peak was the eastbound entry where the LOS D deteriorated to LOS F. This crossing had significantly higher pedestrian volumes relative to the other crossings.
- Although the vehicle delay times increased, these increases are generally not considered to be significant.

Scenario 5

- A signal timing and phasing optimization process was carried out using the Synchro 8 software tool. This information was then coded into the VISSIM model and verified to ensure the signalized intersections were operating reasonably well with no significant queuing. Minor adjustments were made and the signal timings used in the analysis are contained in Appendix C.
- A comparison of the Scenario 1 and Scenario 5 average intersection vehicle delay times indicate no change during the AM peak and about a 9s increase in delay during the PM peak. Overall, the VISSIM model showed very little sensitivity to the changes in signal timing at adjacent intersections.

Scenario 6

- Scenario 6 represented “opening day” or 2014 planning horizon conditions with the Scenario 1 lane configuration and PHB signals installed. The AM peak hour results indicate the roundabout will operate with vehicle entry LOS C or better and pedestrian delay times of 21s or better. During the PM peak hour, the critical westbound and southbound entries are forecast to operate at LOS D or better. The PM peak pedestrian delays are forecast to be 27s or better. These delay times are substantially less than those currently being experienced at the existing traffic signal controlled intersection (current average delays have been identified in previous reports as being in the range of 50 to 60 seconds per vehicle).
- The comparison of intersection vehicle delay times between Scenario 6 and Scenario 1 suggest delay times will double between 2014 and the 2035 planning horizon.

EAST MEDICAL CENTER DRIVE IMPROVEMENTS

VISSIM analysis indicated that with the current lane configurations at the East Medical Center Drive & Cancer Center Drive intersection, construction of the roundabout would likely result in significant traffic backups for the eastbound approach in the AM peak hour. These queues would likely back into the roundabout, causing gridlock and extensive delays. For this reason, construction of the roundabout would also likely require adding an additional eastbound through lane on East Medical Center Drive. This lane would carry through the East Medical Center Drive & Cancer Center Drive intersection and be terminated east of the intersection. Adding this lane would not require widening of the bridge on East Medical Center Drive.

Three possible alternatives for this lane addition were identified, each with their own advantages and disadvantages. All three of these alternatives would provide acceptable traffic operations at the East Medical Center Drive and Cancer Center Drive intersection and would not backup traffic into the roundabout (see Appendix D for Synchro information related to the capacity analysis for these options). This traffic analysis was based on the assumption that vehicles will utilize both eastbound lanes equally on East Medical Center Drive. The degree to which the new second lane on eastbound East Medical Center Drive would be utilized is a very important issue, especially in the AM peak hour. While some degree of unbalanced lane utilization could occur without traffic queuing back into the roundabout, substantial underutilization of one lane could be problematic. With this in mind, the Synchro analysis conducted for all three alternatives shows that additional signal green time can be provided for the eastbound approach if unbalanced lane utilization is a problem in the AM peak hour. This can be done while still providing acceptable operations for the intersection overall and for each approach. Alternatives #2 and #3 have the most flexibility to provide additional green time for this movement, but Alternative #1 could also provide meaningful additional green time. In addition to signal timing adjustments, a queue detector could be placed in the pavement near the eastbound departure from the roundabout. If traffic were to queue back near the roundabout, the detector would trigger the signal to change to green for the eastbound approach. Finally, it is desirable that the second eastbound lane is carried as far east on East Medical Center Drive as is reasonably possible before being dropped. The conceptual designs for Alternatives #1, #2, and #3 in Appendix D illustrate this objective. Further detailed analysis of this issue is recommended during the design phase of the project.

Alternative #1 would entail only pavement marking changes and would cost approximately $21,000. This alternative may require prohibition of westbound left turns from East Medical Center Drive onto West Medical Center Drive, at least during peak traffic periods, since a left turn lane would not be available for this movement. A conceptual design drawing and planning level construction cost information for this alternative are included in Appendix D.

Alternative #2 would entail widening East Medical Center Drive to the south and would cost approximately $168,000. This alternative would likely have negative impacts to existing parking lots south of East Medical Center Drive, which is highly undesirable. Like Alternative #1, this alternative may require prohibition of westbound left turns onto West Medical Center Drive, at least during peak traffic periods, since a left turn lane would not be available for this movement. A conceptual design drawing and planning level construction cost information for this alternative are included in Appendix D.

Alternative #3 would entail widening East Medical Center Drive to both the north and south and would cost approximately $300,000. This alternative could have impacts to existing parking lots south of East Medical Center Drive, but not to the same degree as Alternative #2. Alternative #3 could also have minor impacts to existing landscaping and driveways along the north side of East Medical Center Drive. Like Alternatives #1 and #2, this alternative may require prohibition of westbound left turns onto West Medical Center Drive, at least during peak traffic periods, since a left turn lane would not be available for this movement. A conceptual design drawing and planning level construction cost information for this alternative are included in Appendix D.

All three of these options would require considerable coordination with the U of M to assure that all of their requirements and objectives for this area are still met. In addition, more detailed engineering would be needed to confirm the preliminary information generated for this study.

CONCLUSIONS AND RECOMMENDATIONS

Based on the information and analysis presented in this memo, the DLZ Team has developed the following conclusions and recommendations for consideration by the City of Ann Arbor. Please note that this information is subject to change based on continuing input and direction from the City.

1. Past Studies, Plans, Guidelines, and Standards – Relevant information was carefully assessed and factored into the new analysis. The new analysis builds upon and is consistent with these documents.
2. The Connector Study – Some of the transit alternatives still under consideration could potentially have an impact upon the design of the study intersection. It is recommended that a coordinated approach be developed that takes into account the needs of both projects. This includes potential impacts that the Connector could have upon design and traffic operations at the intersection, as applicable.
3. Ann Arbor Station – The preferred location of this intermodal station has not yet been selected, with studies ongoing. One of the locations still under consideration is situated adjacent to the study intersection. However, regardless of where this station is eventually located, the proposed roundabout geometry is robust enough to adequately accommodate the resulting traffic volumes and patterns.
4. Comparison Against Other Intersection Improvement Options – Assuming that it is not practical to widen the bridges adjacent to the intersection, installation of a roundabout with PHB's at pedestrian crossings appears to be the best overall improvement option and should be the preferred strategy. The roundabout with PHB's offers the following advantages relative to an improved intersection under traffic signal control:
    - The roundabout would provide substantially better operations (for both pedestrians and vehicles) than an improved intersection with traffic signal control. The roundabout is also predicted to have substantially lower delays than the No Build condition (i.e., maintaining the current traffic signal control without improvements).
    - The roundabout would provide better safety performance than a traffic signal intersection, especially due to the reduction in injury crashes that would be expected.
    - The roundabout would be more cost effective than an improved traffic signal option, since the signal option would require bridge widening in order to provide acceptable traffic operations.
    - With lower vehicle delays, the roundabout would result in less tailpipe emissions and potential air quality benefits.
    - The roundabout would improve response times for emergency vehicles navigating the intersection because delays would be lower.
5. Recommended Roundabout Geometry – If a roundabout is to be designed and constructed without incurring significant costs related to bridge widening, it should have the following characteristics (Note: As described elsewhere in this report, it is possible that northbound and southbound bypass lanes may provide incremental benefits to traffic operations prior to year 2035, but because these require bridge widening, they are not included in the bullet list below):

    - An inscribed circle diameter of 160 to 180 feet
    - Two-lane entries and exits on all legs
    - Two circulating lanes
    - PHB signals for pedestrians
    - Westbound right turn bypass lane

6. Off-Peak Traffic Operations – During off-peak travel times (which comprise approximately 18 to 20 hours of each day), the roundabout would experience very low delays for both pedestrians and vehicles. These delays are expected to be lower than other improvement options based on the professional judgment of the project study team.
7. PHB Signals Effect on Delays – Pedestrian Hybrid Beacon (PHB) signals would provide significant operational benefits (i.e., lower delays) for both vehicles and pedestrians, and are recommended for inclusion at the intersection. A comparison between Scenario 0 (year 2035 traffic without PHB's) and Scenario 1 (year 2035 traffic with PHB's) shows that adding PHB's decreases vehicle delays by 40% in the AM peak hour and 9% in the PM peak hour, while pedestrian delays are decreased by 88% in the AM peak hour and 63% in the PM peak hour. It is highly probable that year 2014 delays would be reduced by similar relative percentages by installing PHB's. PHB signals also provide benefits for visually and mobility impaired pedestrians.
8. PHB Signal Timings - The optimal signal timings and coordination for PHB's should be investigated in more detail during the design phase of the project in order to find the most advantageous balance between pedestrian and vehicle delays. It is possible that increasing the length of time between pedestrian calls could improve vehicle operations without substantially degrading pedestrian operations. Coordination among the PHB signals could also be evaluated to provide optimal operations.
9. Additional Pedestrian Volumes – Pedestrian volumes at the study intersection could increase substantially (at least 100% above year 2035 projected volumes) without causing meaningful increases in delays experienced by pedestrians. For vehicles, delays would not appreciably increase as a result of the higher pedestrian volumes except on the west leg of the intersection. During the design stage of the project, optimal pedestrian path widths should be investigated, since the relatively high volumes at this location could possibly warrant consideration of paths of 10' or wider.
10. Compliance with ADA/Accessibility – All facilities that are being proposed would be ADA compliant, and the intersection should be designed in accordance with best practices for accessibility, including PROWAG.
11. Pedestrian Grade Separations – Pedestrian underpasses appear to be technically feasible at the three existing bridges. However, routing pedestrians through the intersection via grade separations is undesirable for several reasons: (1) at grade crossings with PHB's are projected to operate efficiently for both vehicles and pedestrians, making this a very viable option, and precluding the need to use grade separations of any type; (2) due to the increased travel distance involved, it is not clear whether underpass facilities would be used by most pedestrians in lieu of crossing the intersection at grade; (3) pedestrian grade separations would add substantial cost to the project, both to construct and for ongoing maintenance; (4) some pedestrians perceive grade separations to pose a safety risk due to criminal activity. For these reasons, we recommend against implementing underpasses to carry pedestrians through the intersection. The City may, however, still desire to consider pedestrian underpasses at these three bridges as part of their trail system, either with or without a connection to the at grade sidewalk system at the intersection.
12. Roundabout Operations Scenario 1 (Year 2035 Forecast Volumes) – Scenario 1 is the same recommended geometry as noted in item #5 above. The roundabout would provide acceptable operations for pedestrians in both peak hours. For vehicles, overall intersection operations would be acceptable (i.e., LOS D or better) in the AM peak hour, with one approach (southbound) experiencing unacceptable delays (LOS F). In the PM peak hour, overall intersection delays are projected to be unacceptable (LOS F) with the westbound approach at LOS F and exhibiting fairly long queues and delays. However, Scenario 1 operations are expected to be significantly

better than the No Build condition for both vehicles and pedestrians. They are also expected to be significantly better than other improvement options.

13. Roundabout Operations Scenario 6 (Year 2014 Forecast Volumes) – The recommended roundabout geometry modeled in Scenario 1 would also provide acceptable operations on opening day (year 2014). Scenario 6 operations are expected to be significantly better than the No Build condition for both vehicles and pedestrians. They are also expected to be significantly better than other improvement options.
14. Additional Right Turn Bypass Lanes – Adding bypass lanes for the northbound and southbound approaches would provide a moderate/incremental level of benefit for vehicle operations. These lanes would require modifications to the adjacent bridge structures. Considering the moderate benefit to traffic operations and the potentially substantial construction costs of widening the bridges, the cost effectiveness of making these improvements must be assessed in more detail should traffic operations eventually warrant their consideration.
15. Timing of Bypass Lanes – The westbound bypass lane that is included in Scenario 1 should be constructed on opening day. The timing of northbound and southbound bypass lanes would depend on when traffic-generating growth actually occurs. Although it is somewhat speculative, these improvements could be needed between years 2020 and 2025.
16. Adjacent Traffic Signals – Adjustments to the timing of traffic signals at adjacent intersections is not expected to provide meaningful benefits to operations at the study intersection. Construction of the roundabout is not expected to have a significant negative impact on the operation of any adjacent intersection, with the exception of the East Medical Drive & Cancer Center Drive intersection which is discussed in the next item below.
17. East Medical Center Drive & Cancer Center Drive Intersection – With the current lane configurations at this intersection, construction of the roundabout would likely result in significant traffic backups for the eastbound approach in the AM peak hour. These queues would likely back into the roundabout, possibly causing gridlock and extensive delays. For this reason, construction of the roundabout would also likely require an additional eastbound through lane on East Medical Center Drive. This lane would carry through the East Medical Center Drive & Cancer Center Drive intersection and be terminated east of the intersection. Adding this lane would not require widening of the bridge on East Medical Center Drive. Three possible options for this lane addition have been identified, each with their own advantages and disadvantages. One issue associated with all of the options is the degree to which the new second lane on eastbound East Medical Center Drive would be utilized by drivers, since underutilization could still result in traffic backing up into the roundabout. Potential countermeasures have been identified to minimize the likelihood of this problem. All three of these options would require coordination with the U of M.
18. Consistency with U of M Plans – It appears that the roundabout option would be generally consistent with various U of M planning documents, with one exception. As noted above, constructing the roundabout would likely necessitate the addition of a second eastbound through lane at the East Medical Center Drive & Cancer Center Drive intersection (this improvement is not currently identified in U of M planning documents). This conclusion also assumes that analysis and design of intersection improvements are coordinated with the Connector Study (see item #2 above).
19. Wayfinding Signage – It would be feasible to implement wayfinding signage at the roundabout to assist unfamiliar drivers who desire to access the U of M medical facilities adjacent to the intersection. Wayfinding information could also be incorporated into the standard signing scheme which would be designed for the project. Also, utilization of overhead signing could be considered as an option to provide maximum direction to unfamiliar drivers.

20. Emergency Vehicle Access – Emergency vehicles would be reasonably accommodated by the roundabout option. During peak hour travel periods, it is possible that emergency vehicles could experience delays negotiating the intersection. However, any delays experienced are expected to be substantially less than what would be experienced under the No Build condition or other improvement options.
21. Bus Accommodations – Buses would be fully accommodated by the roundabout option. These vehicles would experience substantially less delay than what would be experienced under the No Build condition.
22. Bicycle Facilities – Studies have shown that bicycle crashes can be a concern at some multi-lane roundabouts without proper design accommodations. Because of this, design guidelines recommend allowing bicyclists who are traveling in the roadway approaching the roundabout to exit the roadway prior to the roundabout and navigate the roundabout as a pedestrian would. To facilitate this concept, roundabout approaches should include bicycle entrance and exit ramps to give bicyclists the option of biking on a sidewalk bikeway as well as the roadway (see NCHRP 672). More confident bicyclists may remain in the roadway and merge with the motor vehicles.

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[i] Xu, F. and Tian, Z., *Driver Behaviour and Gap-Acceptance Characteristics at Roundabouts in California*. Transportation Research Record: Journal of the Transportation Research Board, No. 2071. Transportation Research Board of the National Academies, Washington, D.C., 2008.

[ii] *Roundabouts in the United States*. National Cooperative Highway Research Program Report 572. Transportation Research Board of the National Academies, Washington, D.C., 2007.

[iii] Copeland, J., *Kearney Lake Road Roundabout: Traffic Operational Review*. Prepared by the GRIFFIN transportation group for the Halifax Regional Municipality, March 2013.

[iv] As cited in *Roundabouts in the United States*. National Cooperative Highway Research Program Report 572. Transportation Research Board of the National Academies, Washington, D.C., 2007.

[v] Ibid.

Appendix A

Proposed Methodology for Fuller Road Roundabout Traffic Studies
(Revised September 2012)

1. City of Ann Arbor (City) provides the ***"Year 2035 Forecast"*** of traffic and pedestrian projections for use by consultant team in the analysis. All analysis described in this methodology will use the Year 2035 Forecast, with the exception of item 6 below. The Year 2035 Forecast will consist of the following two main components:
    a. Auto traffic volumes – year 2035 peak hour turning movements which will account for most recent site plan at intermodal station property as well as for the new U of M parking deck on Wall St. and background growth from other sources.
    b. Pedestrian volumes - peak hour crossing volumes by leg. These will be the actual numbers in the most recent peak hour counts available and will be assumed to be representative of year 2035 conditions (Note: pedestrian volumes will be one factor evaluated in the sensitivity testing described below).
2. Using the Year 2035 Forecast (which has slightly different volumes than previous forecast), perform RODEL and HCS capacity analysis to verify the "baseline" roundabout geometrics are the same as all previous analyses to date (i.e., two-lane entries for all approaches, ICD = 160', yielding semi-bypass lane for WB approach). If analysis verifies previous baseline geometrics, skip to step #4 below. If baseline geometrics are different, proceed to step #3.
3. If baseline geometrics are different than previous analyses, scenarios below are updated as needed, and City provides approval to move ahead with subsequent steps of analysis.
4. City approves recommended scenarios for modeling (see table below for definition of recommended scenarios)
5. City approves recommended performance measures that will be used for the roundabout:
    a. Delay per vehicle and LOS (overall and by leg)
    b. Delay per pedestrian and LOS (overall and by leg)
    c. Queue lengths (as compared to available storage length)
6. For each scenario, use URS VISSIM model as starting point and customize all parameters/settings for the situation at hand. The final model settings/parameters will be based on the following:
    a. Model will reflect all relevant info and conclusions from the ITRE modeling process (including the draft report and memo) as well as supplemental information supplied to the City by ITRE, if such information is eventually supplied
    b. Model will reflect other applicable studies and research
    c. Model will reflect professional judgment of consultant team regarding settings/parameters and roundabout geometrics that affect capacity
    d. Model will include surrounding road/signal network from URS model, updated as needed
    e. Model will be calibrated for HCM capacity
7. Run VISSIM model for scenarios 0, 1, 2 (identify potential problems and adjust elements of scenario definitions as part of this step)
8. Perform VISSIM sensitivity testing for scenarios 3, 4, 5 which address the following questions:
    a. When are bypass lanes needed during the 20-year planning horizon, assuming uniform growth in auto traffic from year 2014 to year 2035 traffic forecast, with pedestrian volumes held constant (i.e., year 5, year 10, etc.)? (scenario 3)
    b. How much could pedestrian volumes increase before pedestrians would need to be grade separated from auto traffic, assuming year 2035 auto traffic? (scenario 4) (note: this scenario will not involve determination of preferred grade separation strategy, only what volumes trigger need for a separation)
    c. Do adjustments to signal phasing/timing at adjacent intersections result in improvements to the roundabout operations, assuming the Year 2035 Forecast? (scenario 5)
9. Run VISSIM model for scenario 6 which is year 2014 (opening day) traffic.
10. Prepare draft technical memo with modeling methods, results
11. City review of draft technical memo and model files
12. Update/run VISSIM models based on comments
13. Prepare final technical memo based on comments
14. Agreement on preferred design characteristics and elements

Scenario Definition Table

Scenario	No PHB with 50% Driver Yielding	PHB (50% ped compliance)	Bypass Lane NE Quadrant	Bypass Lane Other Quadrants	Timing of Bypass Lane Necessity**	Pedestrian Grade Separations**	Adjustments to Signal Timing at Adjacent Intersections**	2014 (Opening Day) Traffic Forecast
0	X		X					
1		X	X					
2		X	X	X				
3		X	X		X			
4		X*	X			X		
5		X	X				X	
6		X	X					X

* PHB only present on legs where at-grade pedestrian crossings are maintained
** Sensitivity testing

Common characteristics for all scenarios:

- Year 2035 Forecast (except for scenario #6)
- HCM capacity calibration
- AM and PM peak hours
- Network includes adjacent roads and intersections

Appendix B

12/7/2012

Fuller Road - Maiden Lane - East Medical Center Drive Intersection

2012 Existing Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	70	490	275	835	70
Fuller Road	West (East Bound)	390	495	80	965	270
Maiden Lane	North (South Bound)	255	245	105	605	165
East Medical Center Drive	South (North Bound)	205	115	190	510	35
					2915	

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	145	665	190	1000	140
Fuller Road	West (East Bound)	105	480	230	815	185
Maiden Lane	North (South Bound)	140	80	105	325	100
East Medical Center Drive	South (North Bound)	255	220	285	760	100
					2900	

2014 Forecast Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	150	500	295	945	70
Fuller Road	West (East Bound)	405	505	135	1045	510
Maiden Lane	North (South Bound)	275	270	135	680	165
East Medical Center Drive	South (North Bound)	215	155	195	565	35
					3235	

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	175	680	200	1055	140
Fuller Road	West (East Bound)	110	490	250	850	425
Maiden Lane	North (South Bound)	195	120	190	505	100
East Medical Center Drive	South (North Bound)	275	245	295	815	100
					3225	

11.0% Percent increase in AM Peak Hour Volumes - 2012 to 2014
11.2% Percent increase in PM Peak Hour Volumes - 2012 to 2014

2035 Forecast Peak Hour Vehicular Traffic and Pedestrian Volumes

(0.29% per year growth rate of base year (2014) background traffic plus Ann Arbor Station & other development traffic)

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	170	595	365	1130	70
Fuller Road	West (East Bound)	495	655	150	1300	510
Maiden Lane	North (South Bound)	310	310	170	790	165
East Medical Center Drive	South (North Bound)	265	185	270	720	35
					3940	

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	210	835	240	1285	140
Fuller Road	West (East Bound)	175	580	290	1045	425
Maiden Lane	North (South Bound)	215	140	210	565	100
East Medical Center Drive	South (North Bound)	350	300	375	1025	100
					3920	

21.8% Percent increase in AM Peak Hour Volumes - 2014 to 2035

21.6% Percent increase in PM Peak Hour Volumes - 2014 to 2035

12/7/2012

Fuller Road - Bonisteel Boulevard - Fuller Court Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	30	745	30	805	-
Fuller Road	West (East Bound)	125	585	150	860	-
Bonisteel Boulevard	North (South Bound)	195	110	30	335	-
Fuller Court	South (North Bound)	5	15	40	60	-
					2060	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	55	565	10	630	-
Fuller Road	West (East Bound)	85	770	225	1080	-
Bonisteel Boulevard	North (South Bound)	245	25	35	305	-
Fuller Court	South (North Bound)	25	95	95	215	-
					2230	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	30	760	30	820	-
Fuller Road	West (East Bound)	130	595	155	880	-
Bonisteel Boulevard	North (South Bound)	200	110	30	340	-
Fuller Court	South (North Bound)	5	15	40	60	-
					2100	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	55	575	10	640	-
Fuller Road	West (East Bound)	85	785	230	1100	-
Bonisteel Boulevard	North (South Bound)	250	25	35	310	-
Fuller Court	South (North Bound)	25	95	95	215	-
					2265	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	35	795	35	865	-
Fuller Road	West (East Bound)	135	555	150	840	-
Bonisteel Boulevard	North (South Bound)	215	120	35	370	-
Fuller Court	South (North Bound)	5	15	45	65	-
					2140	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	60	605	10	675	-
Fuller Road	West (East Bound)	95	690	210	995	-
Bonisteel Boulevard	North (South Bound)	270	30	40	340	-
Fuller Court	South (North Bound)	30	105	105	240	-
					2250	-

Fuller Road - Miller Fields Driveway - Cedar Bend Drive Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	0	935	10	945	-
Fuller Road	West (East Bound)	20	815	0	835	-
Miller Fields Driveway	South (North Bound)	5	0	10	15	
Cedar Bend Drive	North (South Bound)	0	0	0	0	-
					1795	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	5	915	0	920	-
Fuller Road	West (East Bound)	30	1005	5	1040	-
Miller Fields Driveway	South (North Bound)	15	0	45	60	
Cedar Bend Drive	North (South Bound)	5	0	0	5	-
					2025	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	0	950	10	960	-
Fuller Road	West (East Bound)	20	830	0	850	-
Miller Fields Driveway	South (North Bound)	5	0	10	15	
Cedar Bend Drive	North (South Bound)	0	0	0	0	-
					1825	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	5	930	0	935	-
Fuller Road	West (East Bound)	30	1025	5	1060	-
Miller Fields Driveway	South (North Bound)	15	0	45	60	
Cedar Bend Drive	North (South Bound)	5	0	0	5	-
					2060	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	0	1045	10	1055	-
Fuller Road	West (East Bound)	20	835	0	855	-
Miller Fields Driveway	South (North Bound)	5	0	10	15	
Cedar Bend Drive	North (South Bound)	0	0	0	0	-
					1925	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	5	975	0	980	-
Fuller Road	West (East Bound)	30	980	5	1015	-
Miller Fields Driveway	South (North Bound)	15	0	45	60	
Cedar Bend Drive	North (South Bound)	5	0	0	5	-
					2060	-

Fuller Road - Glen Avenue - Fuller Street Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Street	West (East Bound)	195	-	450	645	-
Fuller Road	East (West Bound)	145	650	-	795	-
Glen Avenue	South (North Bound)	-	440	70	510	-
					1950	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Street	West (East Bound)	90	-	310	400	-
Fuller Road	East (West Bound)	365	690	-	1055	-
Glen Avenue	South (North Bound)	-	600	210	810	-
					2265	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Street	West (East Bound)	200	-	460	660	-
Fuller Road	East (West Bound)	150	660	-	810	-
Glen Avenue	South (North Bound)	-	450	70	520	-
					1990	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Street	West (East Bound)	90	-	315	405	-
Fuller Road	East (West Bound)	370	705	-	1075	-
Glen Avenue	South (North Bound)	-	610	215	825	-
					2305	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Street	West (East Bound)	195	-	610	805	-
Fuller Road	East (West Bound)	235	940	-	1175	-
Glen Avenue	South (North Bound)	-	690	55	745	-
					2725	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Street	West (East Bound)	80	-	345	425	-
Fuller Road	East (West Bound)	490	935	-	1425	-
Glen Avenue	South (North Bound)	-	650	210	860	-
					2710	-

12/7/2012

Glen Avenue - Catherine Street Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Catherine Street	East (West Bound)	75	120	50	245	-
Catherine Street	West (East Bound)	10	-	15	25	-
Glen Avenue	North (South Bound)	120	725	-	845	-
Glen Avenue	South (North Bound)	-	425	40	465	-
					1580	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Catherine Street	East (West Bound)	175	170	90	435	-
Catherine Street	West (East Bound)	55	-	50	105	-
Glen Avenue	North (South Bound)	130	650	-	780	-
Glen Avenue	South (North Bound)	-	580	30	610	-
					1930	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Catherine Street	East (West Bound)	75	120	50	245	-
Catherine Street	West (East Bound)	10	-	15	25	-
Glen Avenue	North (South Bound)	120	740	-	860	-
Glen Avenue	South (North Bound)	-	435	40	475	-
					1605	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Catherine Street	East (West Bound)	180	175	90	445	-
Catherine Street	West (East Bound)	55	-	50	105	-
Glen Avenue	North (South Bound)	135	660	-	795	-
Glen Avenue	South (North Bound)	-	590	30	620	-
					1965	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Catherine Street	East (West Bound)	80	130	55	265	-
Catherine Street	West (East Bound)	10	-	35	45	-
Glen Avenue	North (South Bound)	170	965	-	1135	-
Glen Avenue	South (North Bound)	-	630	45	675	-
					2120	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Catherine Street	East (West Bound)	190	185	100	475	-
Catherine Street	West (East Bound)	55	-	65	120	-
Glen Avenue	North (South Bound)	175	840	-	1015	-
Glen Avenue	South (North Bound)	-	605	35	640	-
					2250	-

12/7/2012

Glen Avenue - Ann Street Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Ann Street	East (West Bound)	50	-	45	95	-
Ann Street	West (East Bound)	45	190	35	270	-
Glen Avenue	North (South Bound)	-	575	215	790	-
Glen Avenue	South (North Bound)	50	370	-	420	-
					1575	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Ann Street	East (West Bound)	115	-	140	255	-
Ann Street	West (East Bound)	25	55	50	130	-
Glen Avenue	North (South Bound)	-	700	90	790	-
Glen Avenue	South (North Bound)	20	470	-	490	-
					1665	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Ann Street	East (West Bound)	50	-	45	95	-
Ann Street	West (East Bound)	45	195	35	275	-
Glen Avenue	North (South Bound)	-	585	220	805	-
Glen Avenue	South (North Bound)	50	375	-	425	-
					1600	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Ann Street	East (West Bound)	115	-	145	260	-
Ann Street	West (East Bound)	25	55	50	130	-
Glen Avenue	North (South Bound)	-	715	90	805	-
Glen Avenue	South (North Bound)	20	480	-	500	-
					1695	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Ann Street	East (West Bound)	50	-	50	100	-
Ann Street	West (East Bound)	40	205	50	295	-
Glen Avenue	North (South Bound)	-	810	220	1030	-
Glen Avenue	South (North Bound)	55	575	-	630	-
					2055	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Ann Street	East (West Bound)	120	-	150	270	-
Ann Street	West (East Bound)	55	60	30	145	-
Glen Avenue	North (South Bound)	-	900	95	995	-
Glen Avenue	South (North Bound)	25	490	-	515	-
					1925	-

12/7/2012

Huron Street - Glen Avenue Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Huron Street	East (West Bound)	150	475	-	625	-
Huron Street	West (East Bound)	-	510	270	780	-
Glen Avenue	South (North Bound)	305	-	350	655	-
					2060	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Huron Street	East (West Bound)	285	595	-	880	-
Huron Street	West (East Bound)	-	545	205	750	-
Glen Avenue	South (North Bound)	475	-	415	890	-
					2520	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Huron Street	East (West Bound)	155	485	-	640	-
Huron Street	West (East Bound)	-	520	275	795	-
Glen Avenue	South (North Bound)	310	-	355	665	-
					2100	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Huron Street	East (West Bound)	290	605	-	895	-
Huron Street	West (East Bound)	-	555	210	765	-
Glen Avenue	South (North Bound)	485	-	425	910	-
					2570	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Huron Street	East (West Bound)	250	510	-	760	-
Huron Street	West (East Bound)	-	545	380	925	-
Glen Avenue	South (North Bound)	425	-	475	900	-
					2585	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Huron Street	East (West Bound)	295	635	-	930	-
Huron Street	West (East Bound)	-	585	220	805	-
Glen Avenue	South (North Bound)	590	-	515	1105	-
					2840	-

12/7/2012

Broadway Street - Plymouth Road - Maiden Lane - Moore Street Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Maiden Lane	East (West Bound)	100	60	40	200	-
Moore Street	West (East Bound)	-	-	-	-	-
Plymouth Road	North (South Bound)	10	355	245	610	-
Broadway Street	South (North Bound)	210	435	75	720	-
					1530	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Maiden Lane	East (West Bound)	275	240	80	595	-
Moore Street	West (East Bound)	-	-	-	-	-
Plymouth Road	North (South Bound)	15	405	145	565	-
Broadway Street	South (North Bound)	65	490	280	835	-
					1995	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Maiden Lane	East (West Bound)	115	60	60	235	-
Moore Street	West (East Bound)	-	-	-	-	-
Plymouth Road	North (South Bound)	10	365	370	745	-
Broadway Street	South (North Bound)	220	470	80	770	-
					1750	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Maiden Lane	East (West Bound)	325	245	140	710	-
Moore Street	West (East Bound)	-	-	-	-	-
Plymouth Road	North (South Bound)	15	415	185	615	-
Broadway Street	South (North Bound)	70	630	285	985	-
					2310	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Maiden Lane	East (West Bound)	235	60	140	435	-
Moore Street	West (East Bound)	-	-	-	-	-
Plymouth Road	North (South Bound)	30	575	395	1000	-
Broadway Street	South (North Bound)	430	525	105	1060	-
					2495	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Maiden Lane	East (West Bound)	305	320	300	925	-
Moore Street	West (East Bound)	-	-	-	-	-
Plymouth Road	North (South Bound)	40	765	185	990	-
Broadway Street	South (North Bound)	220	745	375	1340	-
					3255	-

12/7/2012

Main Street - Depot Street Intersection

2012 Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Depot Street	East (West Bound)	220	-	35	255	-
Main Street	North (South Bound)	-	960	755	1715	-
Main Street	South (North Bound)	170	390	-	560	-
					2530	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Depot Street	East (West Bound)	560	-	85	645	-
Main Street	North (South Bound)	-	575	235	810	-
Main Street	South (North Bound)	65	1065	-	1130	-
					2585	-

2014 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Depot Street	East (West Bound)	225	-	35	260	-
Main Street	North (South Bound)	-	980	770	1750	-
Main Street	South (North Bound)	175	400	-	575	-
					2585	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Depot Street	East (West Bound)	570	-	85	655	-
Main Street	North (South Bound)	-	585	240	825	-
Main Street	South (North Bound)	65	1085	-	1150	-
					2630	-

2035 Forecast Peak Hour Vehicular Traffic Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Depot Street	East (West Bound)	330	-	40	370	-
Main Street	North (South Bound)	-	1040	960	2000	-
Main Street	South (North Bound)	185	420	-	605	-
					2975	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Depot Street	East (West Bound)	680	-	95	775	-
Main Street	North (South Bound)	-	620	290	910	-
Main Street	South (North Bound)	70	1150	-	1220	-
					2905	-

1/27/2013

East Medical Center Drive - Cancer Center Drive Intersection

2012 Existing Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
East Medical Center Drive	East (West Bound)	-	410	30	440	-
East Medical Center Drive	West (East Bound)	70	835	-	905	-
Cancer Center Drive	South (North Bound)	50	-	20	70	-
					1415	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
East Medical Center Drive	East (West Bound)	-	660	25	685	-
East Medical Center Drive	West (East Bound)	50	325	-	375	-
Cancer Center Drive	South (North Bound)	50	-	20	70	-
					1130	-

2014 Forecast Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
East Medical Center Drive	East (West Bound)	-	460	35	495	-
East Medical Center Drive	West (East Bound)	75	885	-	960	-
Cancer Center Drive	South (North Bound)	50	-	20	70	-
					1525	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
East Medical Center Drive	East (West Bound)	-	715	30	745	-
East Medical Center Drive	West (East Bound)	60	370	-	430	-
Cancer Center Drive	South (North Bound)	50	-	20	70	-
					1245	-

2035 Forecast Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
East Medical Center Drive	East (West Bound)	-	590	45	635	-
East Medical Center Drive	West (East Bound)	95	1065	-	1160	-
Cancer Center Drive	South (North Bound)	65	-	25	90	-
					1885	-

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
East Medical Center Drive	East (West Bound)	-	900	35	935	-
East Medical Center Drive	West (East Bound)	75	475	-	550	-
Cancer Center Drive	South (North Bound)	65	-	25	90	-
					1575	-

Appendix C

TECHNICAL APPENDIX

VISSIM Analysis Results

Table 1: Fuller Road Roundabout - City of Ann Arbor
Summary of Capacity Analysis Results - 2035 Planning Horizon
Revised July 17th, 2013

	Eastbound - Fuller Rd W.				Northbound - EMCD				Westbound - Fuller Rd E.				Southbound - Maiden Ln				Intersection			
	1,300 vph				720 vph				1,130 vph				790 vph							
AM Peak Hour	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Vehicles**		**Pedestrians**	
Scenarios	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**Delay (s)**	**LOS**	**Delay (s)**
Scenario 0: Unsignalized Ped Crossings	F	64.9	1318	264.6	C	22.5	254	16	C	16.7	497	13.1	F	131.2	1680	14.6	F	53.4	*tbd*	174.5
Scenario 1: PHB Signals Installed	D	34.9	560	24.9	C	22.7	254	16.9	B	13.5	402	15.0	F	63.0	1450	13.2	D	32.1	*tbd*	21.3
Scenario 2a: New SB By-pass Lane	D	33.8	516	24.7	C	24.2	263	17.1	B	14.2	450	15.2	C	18.1	468	13.0	C	23.0	*tbd*	21.1
Scenario 2b: New SB & NB By-pass Lanes[A]	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
Scenario 3: By-pass Lane Timing	*See Scenario 3 Graphs*																			
Scenario 4a: 100% Ped Volumes	D	34.9	560	24.9	C	22.7	254	16.9	B	13.5	402	15.0	F	63.0	1450	13.2	D	32.1	*tbd*	21.3
Scenario 4b: 150% Ped Volumes	E	41.4	623	26.3	C	23.4	235	16.4	B	14.3	403	16.6	F	65.6	1466	14.8	D	34.9	*tbd*	22.6
Scenario 4c: 200% Ped Volumes	F	57.8	1293	26.5	C	23.7	240	16.2	B	15.0	464	15.7	F	59.5	1459	14.1	E	39.0	*tbd*	22.5
Scenario 5: Signal Optimization	E	45.8	971	26.8	D	25.7	240	18.5	B	11.4	379	14.9	E	49.8	879	13.5	D	32.0	*tbd*	22.6
Scenario 6: 2014 Forecast Volumes	C	21.9	310	20.8	C	17.3	162	12.6	A	9.1	304	10.8	C	15.4	293	13.5	C	15.9	*tbd*	18.1

A - The addition of the northbound slip lane was tested in the critical PM peak period and was identified as offering benefit. Therefore, no further testing was carried out.

	Eastbound - Fuller Rd W.				Northbound - EMCD				Westbound - Fuller Rd E.				Southbound - Maiden Ln				Intersection			
	1,045 vph				1,025 vph				1,285 vph				565 vph							
PM Peak Hour	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Veh**	**Veh Delay**	**Queue**	**Ped Delay**	**Vehicles**		**Pedestrians**	
Scenarios	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**(s)**	**(ft)**	**(s)**	**LOS**	**Delay (s)**	**LOS**	**Delay (s)**
Scenario 0: Unsignalized Ped Crossings	C	20.6	284	87.5	D	31.9	555	8.0	F	153.0	1680	22.0	C	22.3	384	13.8	F	59.6	*tbd*	56.0
Scenario 1: PHB Signals Installed	C	21.4	299	21.2	D	31.2	548	26.9	F	123.2	1680	18.2	C	20.6	263	16.2	F	54.5	*tbd*	20.7
Scenario 2a: New SB By-pass Lane	C	20.2	283	21.0	D	27.9	480	26.5	F	127.2	1680	17.5	B	11.2	238	16.4	F	52.6	*tbd*	20.4
Scenario 2b: New SB & NB By-pass Lanes	C	20.3	298	21.2	C	21.6	394	25.4	F	104.8	1680	17.8	C	18.7	260	15.4	E	46.9	*tbd*	20.4
Scenario 3: By-pass Lane Timing	*See Scenario 3 Graphs*																			
Scenario 4a: 100% Ped Voulmes	C	21.4	299	21.2	D	31.2	548	26.9	F	123.2	1680	18.2	C	20.6	263	16.2	F	54.5	*tbd*	20.7
Scenario 4b: 150% Ped Volumes	C	21.7	309	22.5	D	34.2	500	22.6	F	125.5	1680	17.8	C	22.8	332	16.3	F	56.4	*tbd*	20.9
Scenario 4c: 200% Ped Volumes	C	22.2	345	22.5	E	40.7	609	17.8	F	132.6	1680	18.6	D	27.7	383	16.3	F	59.8	*tbd*	20.3
Scenario 5: Signal Optimization	C	23.8	492	22.2	E	37.7	605	26.2	F	130.8	1680	17.3	F	56.1	878	14.5	F	63.4	*tbd*	20.8
Scenario 6: 2014 Forecast Volumes	C	19.2	238	19.1	C	17.5	291	27.0	D	34.4	650	15.7	D	33.4	566	13.7	D	26.1	*tbd*	18.8

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 0 - Unsignalized Pedestrian Crosswalks

AM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,300 vph			720 vph			1,130 vph			790 vph			~	
Alternative	Random Number	Critical Gap	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Ped Delay (s)
VISSIM Run #1	34	3.1	69.1	**1660**	684.7	23.7	340	14.3	14.3	500	12.6	135.1	**1680**	14.6	55.7	450.4
VISSIM Run #2	53	3.1	64.4	720	495.3	22.6	220	16.5	16.7	445	10.6	116.5	**1680**	15.1	50.4	313.4
VISSIM Run #3	60	3.1	45.8	850	136.5	20.1	230	13.9	13.8	315	12.9	120	**1680**	15.4	44.8	90.9
VISSIM Run #4	87	3.1	72.6	**1680**	0.2	25.0	245	16.9	19.7	570	16.9	143.2	**1680**	15.1	58.5	8.0
VISSIM Run #5	28	3.1	72.7	**1680**	6.2	21	235	18.6	19.2	655	12.3	141.2	**1680**	12.7	57.5	9.7
		AVERAGE	**64.9**	**1318**	**264.6**	**22.5**	**254**	**16.0**	**16.7**	**497**	**13.1**	**131.2**	**1680**	**14.6**	**53.4**	**174.5**

PM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,045 vph			1,025 vph			1,285 vph			565 vph			~	
Alternative	Random Number	Critical Gap	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Ped Delay (s)
VISSIM Run #1	34	3.1	19.8	270	80.8	31.6	665	8.3	156.5	**1680**	19	28.9	650	11.1	61.7	51.0
VISSIM Run #2	53	3.1	20.3	265	63.5	30.2	325	6	159.4	**1680**	23	24.8	325	13	59.9	42
VISSIM Run #3	60	3.1	21.8	295	105.6	27.8	450	7.1	142	**1680**	26.8	26.3	400	13.5	57.2	67.1
VISSIM Run #4	87	3.1	20.8	310	102.5	37	675	9.9	148	**1680**	21.2	16.7	280	12.3	58.9	64.7
VISSIM Run #5	28	3.1	20.3	280	85.1	32.7	660	8.5	158.9	**1680**	20	14.8	265	19.3	60.5	55.1
		AVERAGE	**20.6**	**284**	**87.5**	**31.9**	**555**	**8**	**153**	**1680**	**22**	**22.3**	**384**	**13.8**	**59.6**	**56.0**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 1 - PHB Signals installed

AM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,300 vph			720 vph			1,130 vph			790 vph			~	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	30.8	430	25.6	22.4	285	18.2	11.2	330	13.1	79.0	**1680**	13.7	33.7	21.7
VISSIM Run #2	53	3.1	34.7	715	23.4	22.3	225	16.3	12.8	330	13.9	83.3	**1660**	13.7	35.7	20.2
VISSIM Run #3	60	3.1	37.4	545	22.5	21.6	265	15.5	12.0	405	14.5	45.9	975	13.5	28.7	19.6
VISSIM Run #4	87	3.1	32.3	590	24.6	24.4	225	17.3	15.1	400	14.7	57.7	**1660**	11.8	30.9	20.8
VISSIM Run #5	28	3.1	39.1	520	28.4	22.6	270	17.2	16.4	545	18.7	49.3	**1275**	13.5	31.3	24.0
AVERAGE			**34.9**	**560**	**24.9**	**22.7**	**254**	**16.9**	**13.5**	**402**	**15**	**63**	**1450**	**13.2**	**32.1**	**21.3**

PM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,045 vph			1,025 vph			1,285 vph			565 vph			~	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	22.2	330	22.5	32.5	530	19.7	118.8	**1680**	18.9	24.1	300	14.7	53.6	20.5
VISSIM Run #2	53	3.1	21.7	330	20.5	29.0	570	27.3	121.5	**1680**	16.5	22.5	255	17.3	53.1	20.2
VISSIM Run #3	60	3.1	21.8	330	20.4	33.9	575	23.5	122.8	**1680**	18.1	19.9	245	16.0	55.4	19.8
VISSIM Run #4	87	3.1	21	270	21.7	30.4	405	28.7	112.8	**1680**	19.9	22.6	305	17.7	52.4	21.7
VISSIM Run #5	28	3.1	20.1	235	20.7	30.4	660	35.3	139.9	**1680**	17.7	13.8	210	15.3	58.2	21.4
AVERAGE			**21.4**	**299**	**21.2**	**31.2**	**548**	**26.9**	**123.2**	**1680**	**18.2**	**20.6**	**263**	**16.2**	**54.5**	**20.7**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 2a - Right Turn Slip Lane Sensitivity Analysis (WB & SB slip lanes)

AM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,300 vph			**720 vph**			**1,130 vph**			**790 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	32.4	520	23.7	22.7	255	12.9	10.8	365	12.3	17.7	325	12.8	21.2	19.9
VISSIM Run #2	53	3.1	34.1	605	23.5	26.4	370	21.8	14.8	550	13.9	14.5	245	12.1	22.8	20.2
VISSIM Run #3	60	3.1	27.4	465	27.0	22.2	245	17.5	13.4	550	16.2	20.2	580	13.6	20.7	22.9
VISSIM Run #4	87	3.1	35.2	515	27.1	27.8	190	19.6	15	370	15.3	26.7	1020	11.7	26.1	22.5
VISSIM Run #5	28	3.1	39.9	475	22.0	22.1	255	13.9	16.8	415	18.1	11.4	170	14.9	24.1	19.8
		AVERAGE	**33.8**	**516**	**24.7**	**24.2**	**263**	**17.1**	**14.2**	**450**	**15.2**	**18.1**	**468**	**13.0**	**23.0**	**21.1**

PM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,045 vph			**1,025 vph**			**1,285 vph**			**565 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	20	260	22	24	405	18.7	106.5	**1680**	18.0	11.9	275	14	46.2	19.8
VISSIM Run #2	53	3.1	20.2	350	20.3	28.8	460	25.3	126.8	**1680**	15.9	12.2	205	16.1	52.0	19.6
VISSIM Run #3	60	3.1	21.4	305	20.7	29.2	475	24.4	131.5	**1680**	17.8	9.9	220	17.3	54.1	20.2
VISSIM Run #4	87	3.1	19.5	260	21.3	29.5	530	28.5	123.5	**1680**	17.6	12.5	280	16.6	52.3	20.9
VISSIM Run #5	28	3.1	20.0	240	20.5	28	530	35.4	147.7	**1680**	18.1	9.7	210	18.1	58.5	21.7
		AVERAGE	**20.2**	**283**	**21**	**27.9**	**480**	**26.5**	**127.2**	**1680**	**17.5**	**11.2**	**238**	**16.4**	**52.6**	**20.4**

Fuller Road Roundabout - City of Ann Arbor

Capacity Analysis Results - 2035 Planning Horizon

Scenario 2b - Right Turn Slip Lane Sensitivity Analysis (WB, SB & NB slip lanes)

AM Peak Hour[A]

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,300 vph			**720 vph**			**1,130 vph**			**790 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1														
VISSIM Run #2	53	3.1														
VISSIM Run #3	60	3.1														
VISSIM Run #4	87	3.1														
VISSIM Run #5	28	3.1														
		AVERAGE	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**

A - The addition of the northbound slip lane was tested in the critical PM peak period and was identified as offering benefit. Therefore, no further testing was carried out

PM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,045 vph			**1,025 vph**			**1,285 vph**			**565 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	20.1	295	22.7	21.1	365	17.5	94.8	**1680**	19.6	14.6	300	14.6	42.6	20.5
VISSIM Run #2	53	3.1	21.6	400	20.1	21.7	570	25.9	105.8	**1680**	18.6	17.1	265	13.5	46.8	19.7
VISSIM Run #3	60	3.1	20.0	285	20.4	23.4	385	21.8	106.4	**1680**	16.6	24.7	285	15.1	49.0	19.2
VISSIM Run #4	87	3.1	19.2	235	21.5	21.1	290	27.5	86.9	**1680**	17.3	28.0	280	17.2	43.2	21.0
VISSIM Run #5	28	3.1	20.6	275	21.4	20.7	360	34.4	130.2	**1680**	17.0	9.1	170	16.7	52.9	21.7
		AVERAGE	**20.3**	**298**	**21.2**	**21.6**	**394**	**25.4**	**104.8**	**1680**	**17.8**	**18.7**	**260**	**15.4**	**46.9**	**20.4**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 4a: 100% pedestrian volumes (same as Scenario 1)

AM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,300 vph			**720 vph**			**1,130 vph**			**790 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	30.8	430	25.6	22.4	285	18.2	11.2	330	13.1	79.0	**1680**	13.7	33.7	21.7
VISSIM Run #2	53	3.1	34.7	715	23.4	22.3	225	16.3	12.8	330	13.9	83.3	**1660**	13.7	35.7	20.2
VISSIM Run #3	60	3.1	37.4	545	22.5	21.6	265	15.5	12.0	405	14.5	45.9	975	13.5	28.7	19.6
VISSIM Run #4	87	3.1	32.3	590	24.6	24.4	225	17.3	15.1	400	14.7	57.7	**1660**	11.8	30.9	20.8
VISSIM Run #5	28	3.1	39.1	520	28.4	22.6	270	17.2	16.4	545	18.7	49.3	**1275**	13.5	31.3	24.0
		AVERAGE	**34.9**	**560**	**24.9**	**22.7**	**254**	**16.9**	**13.5**	**402**	**15**	**63**	**1450**	**13.2**	**32.1**	**21.3**

PM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,045 vph			**1,025 vph**			**1,285 vph**			**565 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	22.2	330	22.5	32.5	530	19.7	118.8	**1680**	18.9	24.1	300	14.7	53.6	20.5
VISSIM Run #2	53	3.1	21.7	330	20.5	29.0	570	27.3	121.5	**1680**	16.5	22.5	255	17.3	53.1	20.2
VISSIM Run #3	60	3.1	21.8	330	20.4	33.9	575	23.5	122.8	**1680**	18.1	19.9	245	16.0	55.4	19.8
VISSIM Run #4	87	3.1	21	270	21.7	30.4	405	28.7	112.8	**1680**	19.9	22.6	305	17.7	52.4	21.7
VISSIM Run #5	28	3.1	20.1	235	20.7	30.4	660	35.3	139.9	**1680**	17.7	13.8	210	15.3	58.2	21.4
		AVERAGE	**21.4**	**299**	**21.2**	**31.2**	**548**	**26.9**	**123.2**	**1680**	**18.2**	**20.6**	**263**	**16.2**	**54.5**	**20.7**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 4b: 150% pedestrian volumes

AM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,300 vph			720 vph			1,130 vph			790 vph			~	
Alternative	Random Number	Critical Gap	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Ped Delay (s)
VISSIM Run #1	34	3.1	33.6	630	24.3	22.7	240	16.1	13.6	380	14.0	72.0	**1680**	14.3	33.7	20.9
VISSIM Run #2	53	3.1	42.9	705	27	23.8	205	19.7	12.9	365	16.7	86.7	**1680**	14.2	39.0	23
VISSIM Run #3	60	3.1	37.4	565	25.6	20.7	230	16.3	11.0	365	16.6	58.2	**1345**	15.2	30.8	22.2
VISSIM Run #4	87	3.1	49.7	595	27.2	26.5	230	16	16.5	450	16.6	60.1	**1655**	14.8	37.6	23.2
VISSIM Run #5	28	3.1	43.5	620	27.6	23.3	270	13.7	17.5	455	19.3	51.2	970	15.6	33.5	23.8
AVERAGE			**41.4**	**623**	**26.3**	**23.4**	**235**	**16.4**	**14.3**	**403**	**16.6**	**65.6**	**1466**	**14.8**	**34.9**	**22.6**

PM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,045 vph			1,025 vph			1,285 vph			565 vph			~	
Alternative	Random Number	Critical Gap	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Queue (ft)	Ped Delay (s)	Veh Delay (s)	Ped Delay (s)
VISSIM Run #1	34	3.1	20.6	280	22.4	26.2	300	29	125.6	**1680**	18.2	17.0	235	17.6	52.5	21.9
VISSIM Run #2	53	3.1	21.0	325	22.1	31.4	415	19.9	128.1	**1680**	17.4	28.5	545	18.1	55.5	20.5
VISSIM Run #3	60	3.1	21.4	310	21.8	38.3	555	20.2	125.0	**1680**	17.6	26.7	285	16.1	58.0	20.1
VISSIM Run #4	87	3.1	23.3	335	24.5	42.8	705	20.9	116.1	**1680**	17.5	24.4	290	13.2	57.6	21.3
VISSIM Run #5	28	3.1	22.2	295	21.6	32.5	525	23.2	132.7	**1680**	18.1	17.2	305	16.6	58.3	20.5
AVERAGE			**21.7**	**309**	**22.5**	**34.2**	**500**	**22.6**	**125.5**	**1680**	**17.8**	**22.8**	**332**	**16.3**	**56.4**	**20.9**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 4c: 200% pedestrian volumes

AM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,300 vph			720 vph			1,130 vph			790 vph			~	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	76.5	**1680**	26.6	24.7	270	21.3	14.6	430	14.9	57.5	**1335**	12.9	44.8	22.5
VISSIM Run #2	53	3.1	58.9	**1660**	24.8	23.1	225	16.6	14.7	425	16.3	64.6	**1645**	12.5	40.1	21.1
VISSIM Run #3	60	3.1	53.4	**1680**	25.0	22.1	240	14.8	12.3	475	15.7	56.4	**1680**	14.3	35.7	21.5
VISSIM Run #4	87	3.1	54.7	635	27.3	24.7	205	13.5	16.5	430	15.8	63.9	**1660**	15.1	39.6	23.2
VISSIM Run #5	28	3.1	45.5	810	28.9	23.9	260	14.9	16.8	560	16.0	55.1	975	15.5	34.8	24.3
		AVERAGE	**57.8**	**1293**	**26.5**	**23.7**	**240**	**16.2**	**15.0**	**464**	**15.7**	**59.5**	**1459**	**14.1**	**39.0**	**22.5**

PM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,045 vph			1,025 vph			1,285 vph			565 vph			~	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	20.8	260	22.4	36.5	715	16.8	119.8	**1680**	19.5	34.6	730	15.5	55.6	20.2
VISSIM Run #2	53	3.1	24.7	465	25.3	30.3	360	15.1	155.0	**1680**	18.4	25.9	285	17.3	60.9	21.6
VISSIM Run #3	60	3.1	21.4	345	21.3	33.8	525	18	133.9	**1680**	19.6	29.2	270	16.8	58.5	20
VISSIM Run #4	87	3.1	22.2	375	21.9	58.4	785	19.4	109.7	**1680**	16.7	33.7	430	15.5	60.2	19.8
VISSIM Run #5	28	3.1	21.9	280	21.7	44.7	660	19.5	144.5	**1680**	18.6	15.3	200	16.3	63.6	20.1
		AVERAGE	**22.2**	**345**	**22.5**	**40.7**	**609**	**17.8**	**132.6**	**1680**	**18.6**	**27.7**	**383**	**16.3**	**59.8**	**20.3**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 5 - Optimized traffic signal timing

AM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,300 vph			**720 vph**			**1,130 vph**			**790 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	60.4	**1275**	26.6	23.4	320	18.0	9.4	350	11.3	28.3	400	15.0	28.3	22.5
VISSIM Run #2	53	3.1	36.3	565	25.4	27.6	190	15.2	11.8	380	12.0	39.8	460	13.2	28.1	21.2
VISSIM Run #3	60	3.1	45.3	**1680**	22.4	22.2	225	18.4	9.6	390	14.1	65.7	**1420**	13.7	34.6	19.7
VISSIM Run #4	87	3.1	31.3	385	29.0	29.6	240	21.7	12.2	440	20.6	73.7	**1645**	11.7	33.9	24.4
VISSIM Run #5	28	3.1	55.9	950	30.4	25.8	225	19.1	14.1	335	16.3	41.4	**470**	13.7	35.2	25.3
		AVERAGE	**45.8**	**971**	**26.8**	**25.7**	**240**	**18.5**	**11.4**	**379**	**14.9**	**49.8**	**879**	**13.5**	**32**	**22.6**

PM Peak Hour

			Eastbound - Fuller Rd			**Northbound - EMCD**			**Westbound - Fuller Rd**			**Southbound - Maiden Ln**			**Intersection**	
			1,045 vph			**1,025 vph**			**1,285 vph**			**565 vph**			**~**	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	17.0	225	20.9	32.3	665	18.7	123.9	**1680**	17.6	33.9	605	14.7	54.9	19.2
VISSIM Run #2	53	3.1	21.3	310	22.2	31.6	430	26.7	136.1	**1680**	17.4	24.3	305	13.9	57.0	20.8
VISSIM Run #3	60	3.1	36.6	930	24.9	40.3	550	24.3	129.9	**1680**	17.0	101.6	1625	15.4	74.5	22.2
VISSIM Run #4	87	3.1	22.5	530	22.0	50.3	745	26.4	123.8	**1680**	16.9	105.6	1680	14.1	71.7	20.6
VISSIM Run #5	28	3.1	21.7	465	21.2	33.9	635	34.7	140.5	**1680**	17.4	15.0	175	14.6	59.1	21.4
		AVERAGE	**23.8**	**492**	**22.2**	**37.7**	**605**	**26.2**	**130.8**	**1680**	**17.3**	**56.1**	**878**	**14.5**	**63.4**	**20.8**

Fuller Road Roundabout - City of Ann Arbor
Capacity Analysis Results - 2035 Planning Horizon
Scenario 6: 2014 Forecast Traffic and Pedestrian Volumes

AM Peak Hour

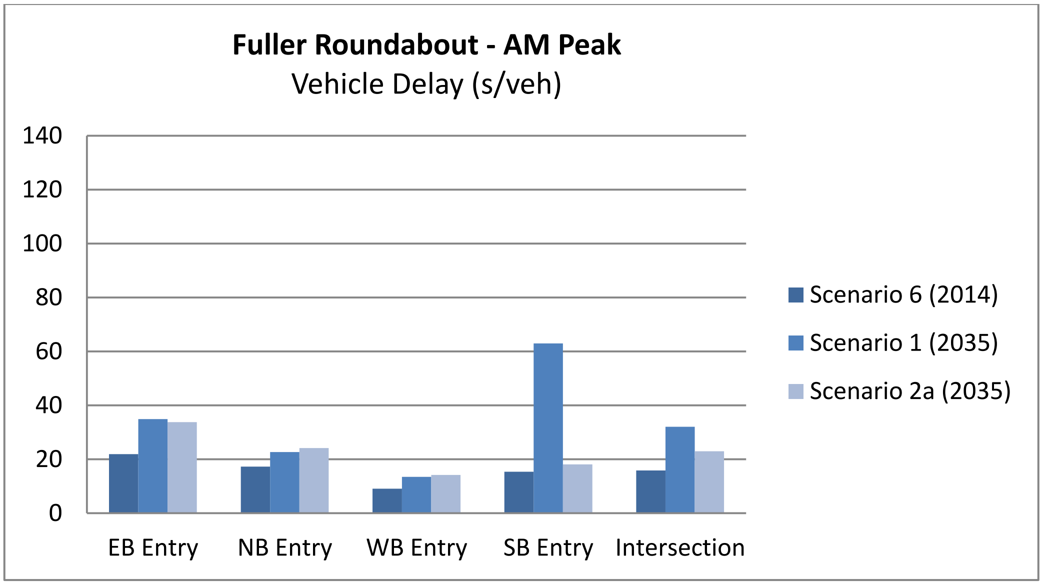
			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			945 vph			565 vph			1,045 vph			680 vph			~	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	25.6	480	20.9	17.6	175	15	8.5	315	9.4	15.9	275	13.3	17.1	18.1
VISSIM Run #2	53	3.1	21.3	330	21.2	18.2	130	11.6	8.5	275	9.7	18.5	460	12.4	16.4	18.0
VISSIM Run #3	60	3.1	20.7	230	20.4	14.7	165	8.7	9.5	305	10.5	16.5	270	15.0	15.3	17.9
VISSIM Run #4	87	3.1	21.0	220	20.7	19.0	185	13.3	8.9	275	12.0	11.8	230	12.2	15.0	17.9
VISSIM Run #5	28	3.1	20.9	290	20.9	16.9	155	14.4	10.1	350	12.6	14.4	230	14.8	15.7	18.7
AVERAGE			**21.9**	**310**	**20.8**	**17.3**	**162**	**12.6**	**9.1**	**304**	**10.8**	**15.4**	**293**	**13.5**	**15.9**	**18.1**

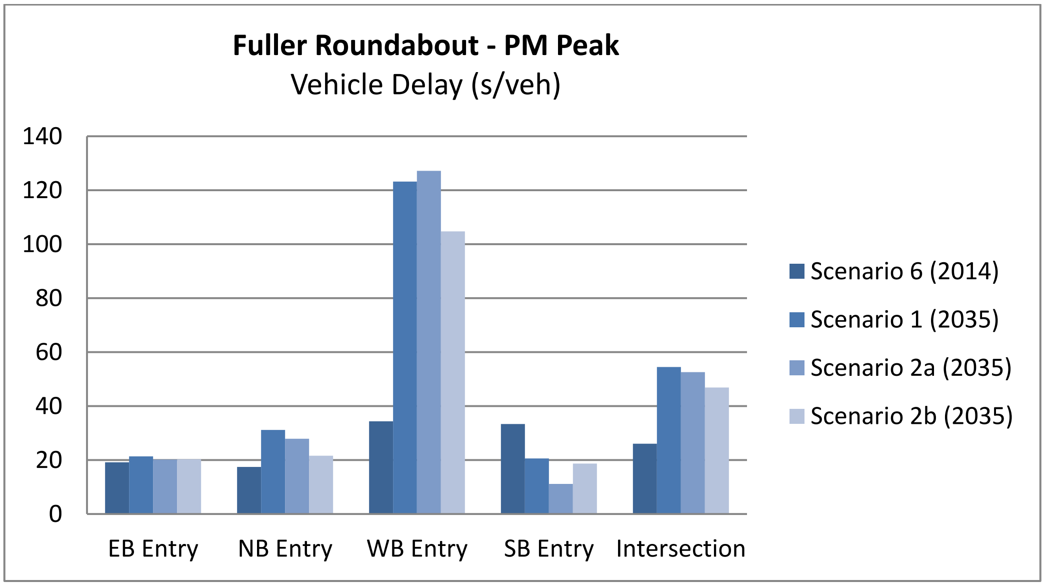
PM Peak Hour

			Eastbound - Fuller Rd			Northbound - EMCD			Westbound - Fuller Rd			Southbound - Maiden Ln			Intersection	
			1,045 vph			1,025 vph			1,285 vph			565 vph			~	
Alternative	**Random Number**	**Critical Gap**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Queue (ft)**	**Ped Delay (s)**	**Veh Delay (s)**	**Ped Delay (s)**
VISSIM Run #1	34	3.1	17.5	200	19.9	16.9	255	18.8	27.5	535	18.1	26.9	505	13.0	22.1	18.5
VISSIM Run #2	53	3.1	20.0	360	18.2	18.2	245	28.6	35.8	730	14.3	30.1	335	13.7	26.6	18.2
VISSIM Run #3	60	3.1	19.7	220	18.0	17.0	280	25.1	33.7	695	16.3	60.1	**1250**	13.1	30.1	18.0
VISSIM Run #4	87	3.1	19.9	230	19.9	17.2	210	27.7	30.4	535	14.9	29.8	485	14.6	24.3	19.3
VISSIM Run #5	28	3.1	18.9	180	19.3	18.4	465	34.9	44.6	755	14.8	19.9	255	14.0	27.5	19.8
AVERAGE			**19.2**	**238**	**19.1**	**17.5**	**291**	**27**	**34.4**	**650**	**15.7**	**33.4**	**566**	**13.7**	**26.1**	**18.8**

TECHNICAL APPENDIX

Scenario 3 Vehicle Delay Results


Fuller Roundabout - AM Peak
Vehicle Delay (s/veh)
140
120
100
80
60
40
20
0
EB Entry
NB Entry
WB Entry
SB Entry
Intersection
Scenario 6 (2014)
Scenario 1 (2035)
Scenario 2a (2035)


Fuller Roundabout - PM Peak
Vehicle Delay (s/veh)
140
120
100
80
60
40
20
0
EB Entry
NB Entry
WB Entry
SB Entry
Intersection
Scenario 6 (2014)
Scenario 1 (2035)
Scenario 2a (2035)
Scenario 2b (2035)

TECHNICAL APPENDIX

Scenario 5 Signal Timing

NOTES:

The optimized signal timing and phasing plans for the study area intersections developed using the Synchro 8 software tool are contained in the following pages. These timing and phasing plans were applied to the VISSIM analysis in Scenario 5 with the exception of the following intersections:

AM Peak Hour:

- Fuller Road/Bonisteel Blvd – the north-south main phase was reduced by 6s and this time was added to the east-west advance phase. This minor adjustment was made to ensure the east-west left turn movement cleared with each cycle and minimized the potential for vehicle queues to form in the VISSIM software.

PM Peak Hour:

- Fuller Road/Bonisteel Blvd – the cycle length was increased from 90s to 100s. In addition, the north-south main phase was reduced by 3s and this time was added to the east-west main phase. Similar to the AM peak, these minor adjustments were made to balance the green time between the conflicting movements and minimize the potential for queuing in the VISSIM software.

Lanes, Volumes, Timings
1: Broadway St/Plymouth Rd & Maiden Lane & Moore St

7/9/2013

Lane Group	WBL	WBR	WBR2	NBL	NBT	NBR	SBL	SBT	SBR	SEL	SER
Lane Configurations											
Volume (vph)	140	60	235	105	525	430	395	575	30	0	0
Satd. Flow (prot)	1704	0	1504	1770	3302	0	1770	3511	0	0	0
Flt Permitted	0.970			0.318			0.133				
Satd. Flow (perm)	1704	0	1504	592	3302	0	248	3511	0	0	0
Satd. Flow (RTOR)	109		227		246			6			
Lane Group Flow (vph)	245	0	227	114	1038	0	429	658	0	0	0
Turn Type	NA		Perm	pm+pt	NA		pm+pt	NA			
Protected Phases	8			5	2		1	6			
Permitted Phases			8	2			6	6			
Detector Phase	8		8	5	2		1	6			
Switch Phase											
Minimum Initial (s)	4.0		4.0	4.0	4.0		4.0	4.0			
Minimum Split (s)	27.0		27.0	22.0	24.0		22.0	24.0			
Total Split (s)	27.0		27.0	27.0	36.0		27.0	36.0			
Total Split (%)	30.0%		30.0%	30.0%	40.0%		30.0%	40.0%			
Yellow Time (s)	3.5		3.5	3.5	3.5		3.5	3.5			
All-Red Time (s)	2.5		2.5	2.5	2.5		2.5	2.5			
Lost Time Adjust (s)	0.0		0.0	0.0	0.0		0.0	0.0			
Total Lost Time (s)	6.0		6.0	6.0	6.0		6.0	6.0			
Lead/Lag				Lag	Lead		Lag	Lead			
Lead-Lag Optimize?				Yes	Yes		Yes	Yes			
Recall Mode	None		None	Max	Max		Max	Max			
Act Effct Green (s)	12.3		12.3	51.2	30.1		51.2	30.1			
Actuated g/C Ratio	0.15		0.15	0.63	0.37		0.63	0.37			
v/c Ratio	0.70		0.54	0.17	0.76		0.78	0.51			
Control Delay	28.8		9.5	7.0	21.9		34.8	22.3			
Queue Delay	0.0		0.0	0.0	0.0		0.0	0.0			
Total Delay	28.8		9.5	7.0	21.9		34.8	22.3			
LOS	C		A	A	C		C	C			
Approach Delay	19.5				20.4			27.2			
Approach LOS	B				C			C			

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 81.6

Natural Cycle: 80

Control Type: Semi Act-Uncoord

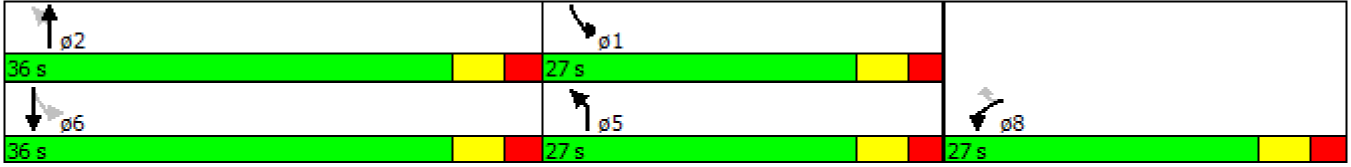
Maximum v/c Ratio: 0.78

Intersection Signal Delay: 23.0 Intersection LOS: C

Intersection Capacity Utilization 81.4% ICU Level of Service D

Analysis Period (min) 15

Splits and Phases: 1: Broadway St/Plymouth Rd & Maiden Lane & Moore St



Lanes, Volumes, Timings
5: Cancer Center Dr & E Medical Center Dr

7/9/2013

	→	↘	↙	←	↖	↗
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱		↰	↑↑	↰	↱
Volume (vph)	1065	95	45	590	25	65
Satd. Flow (prot)	3497	0	1770	3539	1770	1583
Flt Permitted			0.205		0.950	
Satd. Flow (perm)	3497	0	382	3539	1770	1583
Satd. Flow (RTOR)	17					71
Lane Group Flow (vph)	1261	0	49	641	27	71
Turn Type	NA		Perm	NA	NA	Perm
Protected Phases	4			8	2	
Permitted Phases			8			2
Detector Phase	4		8	8	2	2
Switch Phase						
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	27.0		27.0	27.0	26.0	26.0
Total Split (s)	57.0		57.0	57.0	33.0	33.0
Total Split (%)	63.3%		63.3%	63.3%	36.7%	36.7%
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	2.5		2.5	2.5	2.5	2.5
Lost Time Adjust (s)	0.0		0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0		6.0	6.0	6.0	6.0
Lead/Lag						
Lead-Lag Optimize?						
Recall Mode	Max		Max	Max	None	None
Act Effct Green (s)	63.0		63.0	63.0	6.8	6.8
Actuated g/C Ratio	0.81		0.81	0.81	0.09	0.09
v/c Ratio	0.45		0.16	0.22	0.17	0.35
Control Delay	3.8		4.4	2.8	34.4	13.7
Queue Delay	0.0		0.0	0.0	0.0	0.0
Total Delay	3.8		4.4	2.8	34.4	13.7
LOS	A		A	A	C	B
Approach Delay	3.8			2.9	19.4	
Approach LOS	A			A	B	

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 78.1

Natural Cycle: 60

Control Type: Semi Act-Uncoord

Maximum v/c Ratio: 0.45

Intersection Signal Delay: 4.3

Intersection LOS: A

Intersection Capacity Utilization 50.7%

ICU Level of Service A

Analysis Period (min) 15

Splits and Phases: 5: Cancer Center Dr & E Medical Center Dr

Lane Group	WBL	WBR	SEL	SER	NEL	NER
Lane Configurations	↰↰		↰↰		↰	↱↱
Volume (vph)	940	235	610	195	55	690
Satd. Flow (prot)	3035	0	3019	0	1593	2508
Flt Permitted	0.962		0.963		0.134	
Satd. Flow (perm)	3035	0	3019	0	225	2508
Satd. Flow (RTOR)	53		54			148
Lane Group Flow (vph)	1277	0	875	0	60	750
Turn Type	NA		NA		NA	custom
Protected Phases	6		4			2
Permitted Phases					2	
Minimum Split (s)	30.0		26.0		30.1	30.1
Total Split (s)	53.0		37.0		53.0	53.0
Total Split (%)	58.9%		41.1%		58.9%	58.9%
Yellow Time (s)	3.5		3.5		3.6	3.6
All-Red Time (s)	2.5		2.5		2.5	2.5
Lost Time Adjust (s)	0.0		0.0		0.0	0.0
Total Lost Time (s)	6.0		6.0		6.1	6.1
Lead/Lag						
Lead-Lag Optimize?						
Act Effct Green (s)	47.0		31.0		46.9	46.9
Actuated g/C Ratio	0.52		0.34		0.52	0.52
v/c Ratio	0.79		0.81		0.51	0.54
Control Delay	21.3		32.5		33.5	13.0
Queue Delay	0.0		0.0		0.0	0.0
Total Delay	21.3		32.5		33.5	13.0
LOS	C		C		C	B
Approach Delay	21.3		32.5		14.5	
Approach LOS	C		C		B	

Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 90
Offset: 0 (0%), Referenced to phase 2:NEL and 6:WBL, Start of Green
Natural Cycle: 60
Control Type: Pretimed
Maximum v/c Ratio: 0.81
Intersection Signal Delay: 22.8 Intersection LOS: C
Intersection Capacity Utilization 82.6% ICU Level of Service E
Analysis Period (min) 15

Splits and Phases: 7: Glen Ave & Fuller Rd & Fuller St

9: Fuller Ct/Bonisteel Blvd & Fuller Rd

	↗	→	↘	↙	←	↖	↖	↑	↗	↘	↓	↙
Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↱		↰	↑	↱
Volume (vph)	150	555	135	35	795	35	45	15	5	35	120	215
Satd. Flow (prot)	1770	3437	0	1770	3518	0	1770	1796	0	1770	1863	1583
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1770	3437	0	1770	3518	0	1770	1796	0	1770	1863	1583
Satd. Flow (RTOR)		33			5			5				234
Lane Group Flow (vph)	163	750	0	38	902	0	49	21	0	38	130	234
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	Perm
Protected Phases	8	4		3	7		5	2		1	6	
Permitted Phases												6
Minimum Split (s)	18.0	27.1		10.0	27.1		10.0	29.0		10.0	29.0	29.0
Total Split (s)	18.0	31.0		18.0	31.0		12.0	29.0		12.0	29.0	29.0
Total Split (%)	20.0%	34.4%		20.0%	34.4%		13.3%	32.2%		13.3%	32.2%	32.2%
Yellow Time (s)	3.6	3.6		3.5	3.6		3.5	3.5		3.5	3.5	3.5
All-Red Time (s)	2.5	2.5		2.5	2.5		2.5	2.5		2.5	2.5	2.5
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Lost Time (s)	6.1	6.1		6.0	6.1		6.0	6.0		6.0	6.0	6.0
Lead/Lag	Lag	Lead		Lag	Lead		Lag	Lead		Lag	Lead	Lead
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	Yes
Act Effct Green (s)	11.9	24.9		12.0	24.9		6.0	23.0		6.0	23.0	23.0
Actuated g/C Ratio	0.13	0.28		0.13	0.28		0.07	0.26		0.07	0.26	0.26
v/c Ratio	0.70	0.77		0.16	0.92		0.42	0.05		0.32	0.27	0.40
Control Delay	62.9	28.0		36.5	47.9		51.4	21.5		47.7	28.7	6.1
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Delay	62.9	28.0		36.5	47.9		51.4	21.5		47.7	28.7	6.1
LOS	E	C		D	D		D	C		D	C	A
Approach Delay		34.2			47.5			42.4			17.4	
Approach LOS		C			D			D			B	

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 90

Offset: 39 (43%), Referenced to phase 2:NBT and 6:SBT, Start of Green

Natural Cycle: 85

Control Type: Pretimed

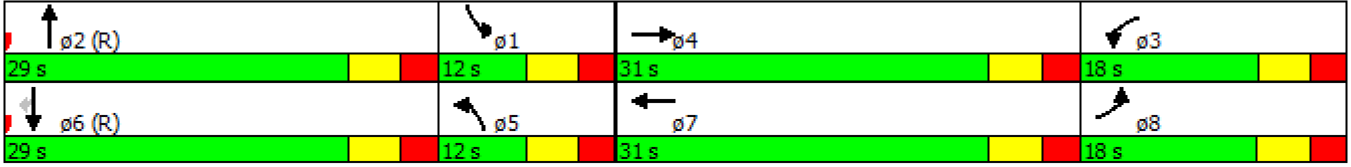
Maximum v/c Ratio: 0.92

Intersection Signal Delay: 36.9 Intersection LOS: D

Intersection Capacity Utilization 55.7% ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 9: Fuller Ct/Bonisteel Blvd & Fuller Rd



Lanes, Volumes, Timings
1: Broadway St/Plymouth Rd & Maiden Lane & Moore St

7/9/2013

Lane Group	WBL	WBR	WBR2	NBL	NBT	NBR	SBL	SBT	SBR	SEL	SER
Lane Configurations	↰↱		↱	↰	↑↱		↰	↑↱			
Volume (vph)	300	320	305	375	745	220	185	765	40	0	0
Satd. Flow (prot)	1672	0	1504	1770	3419	0	1770	3514	0	0	0
Flt Permitted	0.977			0.154			0.174				
Satd. Flow (perm)	1672	0	1504	287	3419	0	324	3514	0	0	0
Satd. Flow (RTOR)	109		299		43			6			
Lane Group Flow (vph)	707	0	299	408	1049	0	201	875	0	0	0
Turn Type	NA		Perm	pm+pt	NA		pm+pt	NA			
Protected Phases	8			5	2		1	6			
Permitted Phases			8	2			6	6			
Detector Phase	8		8	5	2		1	6			
Switch Phase											
Minimum Initial (s)	4.0		4.0	4.0	4.0		4.0	4.0			
Minimum Split (s)	27.0		27.0	22.0	24.0		20.0	24.0			
Total Split (s)	38.0		38.0	23.0	32.0		20.0	29.0			
Total Split (%)	42.2%		42.2%	25.6%	35.6%		22.2%	32.2%			
Yellow Time (s)	3.5		3.5	3.5	3.5		3.5	3.5			
All-Red Time (s)	2.5		2.5	2.5	2.5		2.5	2.5			
Lost Time Adjust (s)	0.0		0.0	0.0	0.0		0.0	0.0			
Total Lost Time (s)	6.0		6.0	6.0	6.0		6.0	6.0			
Lead/Lag				Lag	Lead		Lag	Lead			
Lead-Lag Optimize?				Yes	Yes		Yes	Yes			
Recall Mode	None		None	Max	Max		Max	Max			
Act Effct Green (s)	32.0		32.0	43.0	26.0		37.0	23.0			
Actuated g/C Ratio	0.36		0.36	0.48	0.29		0.41	0.26			
v/c Ratio	1.06		0.41	0.98	1.03		0.56	0.97			
Control Delay	79.4		4.4	72.4	67.9		31.9	57.7			
Queue Delay	0.0		0.0	0.0	0.0		0.0	0.0			
Total Delay	79.4		4.4	72.4	67.9		31.9	57.7			
LOS	E		A	E	E		C	E			
Approach Delay	57.1				69.2			52.9			
Approach LOS	E				E			D			

Intersection Summary

Cycle Length: 90

Actuated Cycle Length: 90

Natural Cycle: 100

Control Type: Semi Act-Uncoord

Maximum v/c Ratio: 1.06

Intersection Signal Delay: 60.8 Intersection LOS: E

Intersection Capacity Utilization 100.7% ICU Level of Service G

Analysis Period (min) 15

Splits and Phases: 1: Broadway St/Plymouth Rd & Maiden Lane & Moore St

Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱		↰	↑↑	↰	↱
Volume (vph)	475	75	35	900	25	65
Satd. Flow (prot)	3465	0	1770	3539	1770	1583
Flt Permitted			0.426		0.950	
Satd. Flow (perm)	3465	0	794	3539	1770	1583
Satd. Flow (RTOR)	32					71
Lane Group Flow (vph)	598	0	38	978	27	71
Turn Type	NA		Perm	NA	NA	Perm
Protected Phases	4			8	2	
Permitted Phases			8			2
Detector Phase	4		8	8	2	2
Switch Phase						
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	27.0		27.0	27.0	26.0	26.0
Total Split (s)	57.0		57.0	57.0	33.0	33.0
Total Split (%)	63.3%		63.3%	63.3%	36.7%	36.7%
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	2.5		2.5	2.5	2.5	2.5
Lost Time Adjust (s)	0.0		0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0		6.0	6.0	6.0	6.0
Lead/Lag						
Lead-Lag Optimize?						
Recall Mode	Max		Max	Max	None	None
Act Effct Green (s)	63.0		63.0	63.0	6.8	6.8
Actuated g/C Ratio	0.81		0.81	0.81	0.09	0.09
v/c Ratio	0.21		0.06	0.34	0.17	0.35
Control Delay	2.6		2.9	3.3	34.4	13.7
Queue Delay	0.0		0.0	0.0	0.0	0.0
Total Delay	2.6		2.9	3.3	34.4	13.7
LOS	A		A	A	C	B
Approach Delay	2.6			3.3	19.4	
Approach LOS	A			A	B	

Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 78.1
Natural Cycle: 55
Control Type: Semi Act-Uncoord
Maximum v/c Ratio: 0.35
Intersection Signal Delay: 4.0 Intersection LOS: A
Intersection Capacity Utilization 38.2% ICU Level of Service A
Analysis Period (min) 15

Splits and Phases: 5: Cancer Center Dr & E Medical Center Dr

Lane Group	WBL	WBR	SEL	SER	NEL	NER
Lane Configurations						
Volume (vph)	935	490	345	80	210	650
Satd. Flow (prot)	2985	0	3038	0	1593	2508
Flt Permitted	0.968		0.961		0.110	
Satd. Flow (perm)	2985	0	3038	0	184	2508
Satd. Flow (RTOR)	219		30			230
Lane Group Flow (vph)	1549	0	462	0	228	707
Turn Type	NA		NA		NA	custom
Protected Phases	6		4			2
Permitted Phases					2	
Minimum Split (s)	30.0		26.0		30.1	30.1
Total Split (s)	63.0		27.0		63.0	63.0
Total Split (%)	70.0%		30.0%		70.0%	70.0%
Yellow Time (s)	3.5		3.5		3.6	3.6
All-Red Time (s)	2.5		2.5		2.5	2.5
Lost Time Adjust (s)	0.0		0.0		0.0	0.0
Total Lost Time (s)	6.0		6.0		6.1	6.1
Lead/Lag						
Lead-Lag Optimize?						
Act Effct Green (s)	57.0		21.0		56.9	56.9
Actuated g/C Ratio	0.63		0.23		0.63	0.63
v/c Ratio	0.79		0.63		1.97	0.42
Control Delay	13.8		33.4		483.4	6.1
Queue Delay	0.0		0.0		0.0	0.0
Total Delay	13.8		33.4		483.4	6.1
LOS	B		C		F	A
Approach Delay	13.8		33.4		122.5	
Approach LOS	B		C		F	

Intersection Summary	
Cycle Length: 90	
Actuated Cycle Length: 90	
Offset: 85 (94%), Referenced to phase 2:NEL and 6:WBL, Start of Green	
Natural Cycle: 130	
Control Type: Pretimed	
Maximum v/c Ratio: 1.97	
Intersection Signal Delay: 51.4	Intersection LOS: D
Intersection Capacity Utilization 88.5%	ICU Level of Service E
Analysis Period (min) 15	

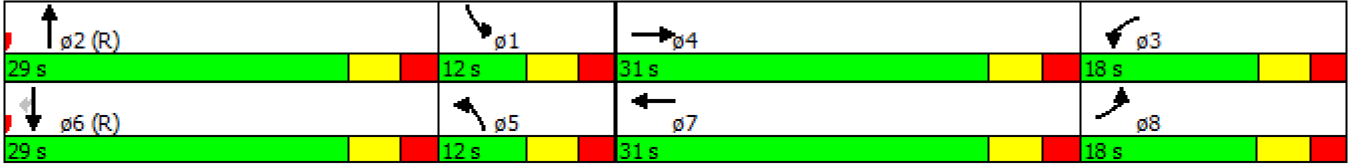
Splits and Phases: 7: Glen Ave & Fuller Rd & Fuller St

Lane Group	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations	↰	↑↱		↰	↑↱		↰	↱		↰	↑	↱
Volume (vph)	210	690	95	10	605	60	40	30	270	105	105	30
Satd. Flow (prot)	1770	3476	0	1770	3462	0	1770	1611	0	1770	1863	1583
Flt Permitted	0.950			0.950			0.950			0.950		
Satd. Flow (perm)	1770	3476	0	1770	3462	0	1770	1611	0	1770	1863	1583
Satd. Flow (RTOR)		16			11			293				184
Lane Group Flow (vph)	228	853	0	11	723	0	43	326	0	114	114	33
Turn Type	Prot	NA		Prot	NA		Prot	NA		Prot	NA	Perm
Protected Phases	8	4		3	7		5	2		1	6	
Permitted Phases												6
Minimum Split (s)	18.0	27.1		10.0	27.1		10.0	29.0		10.0	29.0	29.0
Total Split (s)	18.0	31.0		18.0	31.0		12.0	29.0		12.0	29.0	29.0
Total Split (%)	20.0%	34.4%		20.0%	34.4%		13.3%	32.2%		13.3%	32.2%	32.2%
Yellow Time (s)	3.6	3.6		3.5	3.6		3.5	3.5		3.5	3.5	3.5
All-Red Time (s)	2.5	2.5		2.5	2.5		2.5	2.5		2.5	2.5	2.5
Lost Time Adjust (s)	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Lost Time (s)	6.1	6.1		6.0	6.1		6.0	6.0		6.0	6.0	6.0
Lead/Lag	Lag	Lead		Lag	Lead		Lag	Lead		Lag	Lead	Lead
Lead-Lag Optimize?	Yes	Yes		Yes	Yes		Yes	Yes		Yes	Yes	Yes
Act Effct Green (s)	11.9	24.9		12.0	24.9		6.0	23.0		6.0	23.0	23.0
Actuated g/C Ratio	0.13	0.28		0.13	0.28		0.07	0.26		0.07	0.26	0.26
v/c Ratio	0.97	0.88		0.05	0.75		0.36	0.52		0.97	0.24	0.06
Control Delay	94.5	31.4		34.7	34.9		49.3	8.2		119.5	28.2	0.2
Queue Delay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	0.0
Total Delay	94.5	31.4		34.7	34.9		49.3	8.2		119.5	28.2	0.2
LOS	F	C		C	C		D	A		F	C	A
Approach Delay		44.7			34.9			13.0			64.6	
Approach LOS		D			C			B			E	

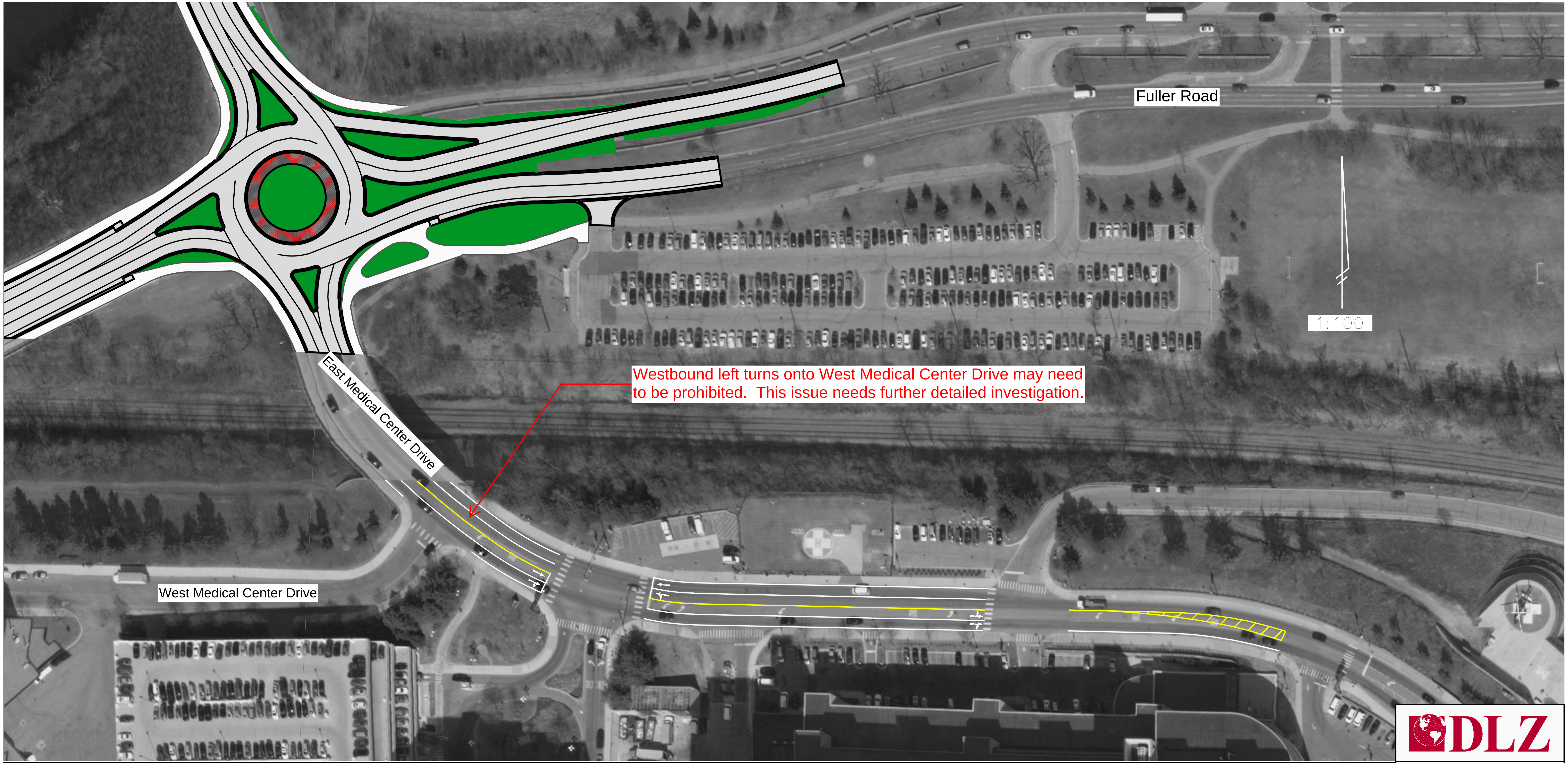
Intersection Summary

Cycle Length: 90
Actuated Cycle Length: 90
Offset: 41 (46%), Referenced to phase 2:NBT and 6:SBT, Start of Green
Natural Cycle: 85
Control Type: Pretimed
Maximum v/c Ratio: 0.97
Intersection Signal Delay: 39.1 Intersection LOS: D
Intersection Capacity Utilization 74.5% ICU Level of Service D
Analysis Period (min) 15

Splits and Phases: 9: Fuller Ct/Bonisteel Blvd & Fuller Rd



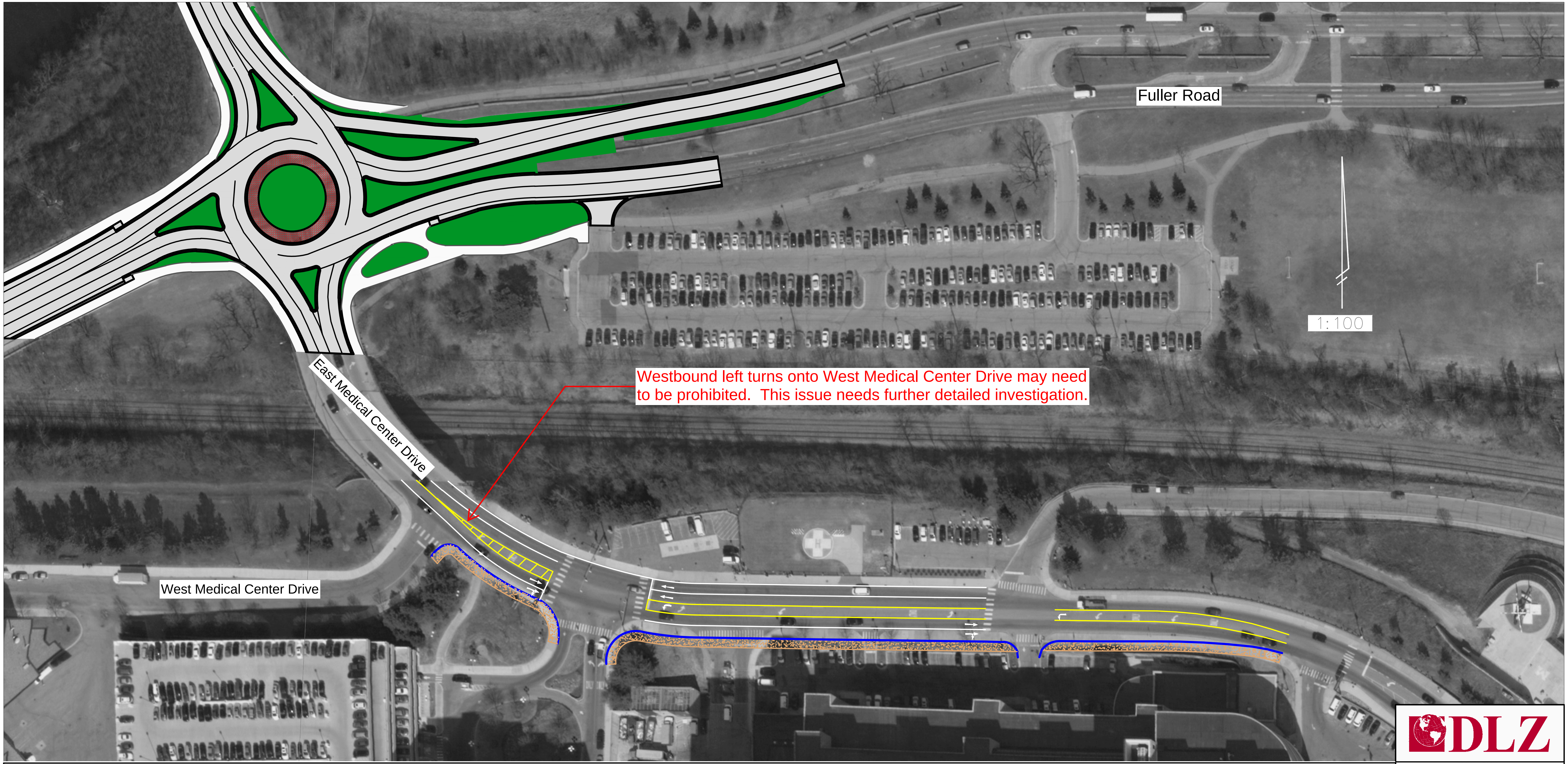
Appendix D



Westbound left turns onto West Medical Center Drive may need to be prohibited. This issue needs further detailed investigation.

EAST MEDICAL CENTER DRIVE - ALTERNATIVE #1 - PAVEMENT MARKING CHANGES

Proposed Pavement Markings
Proposed Pavement Markings



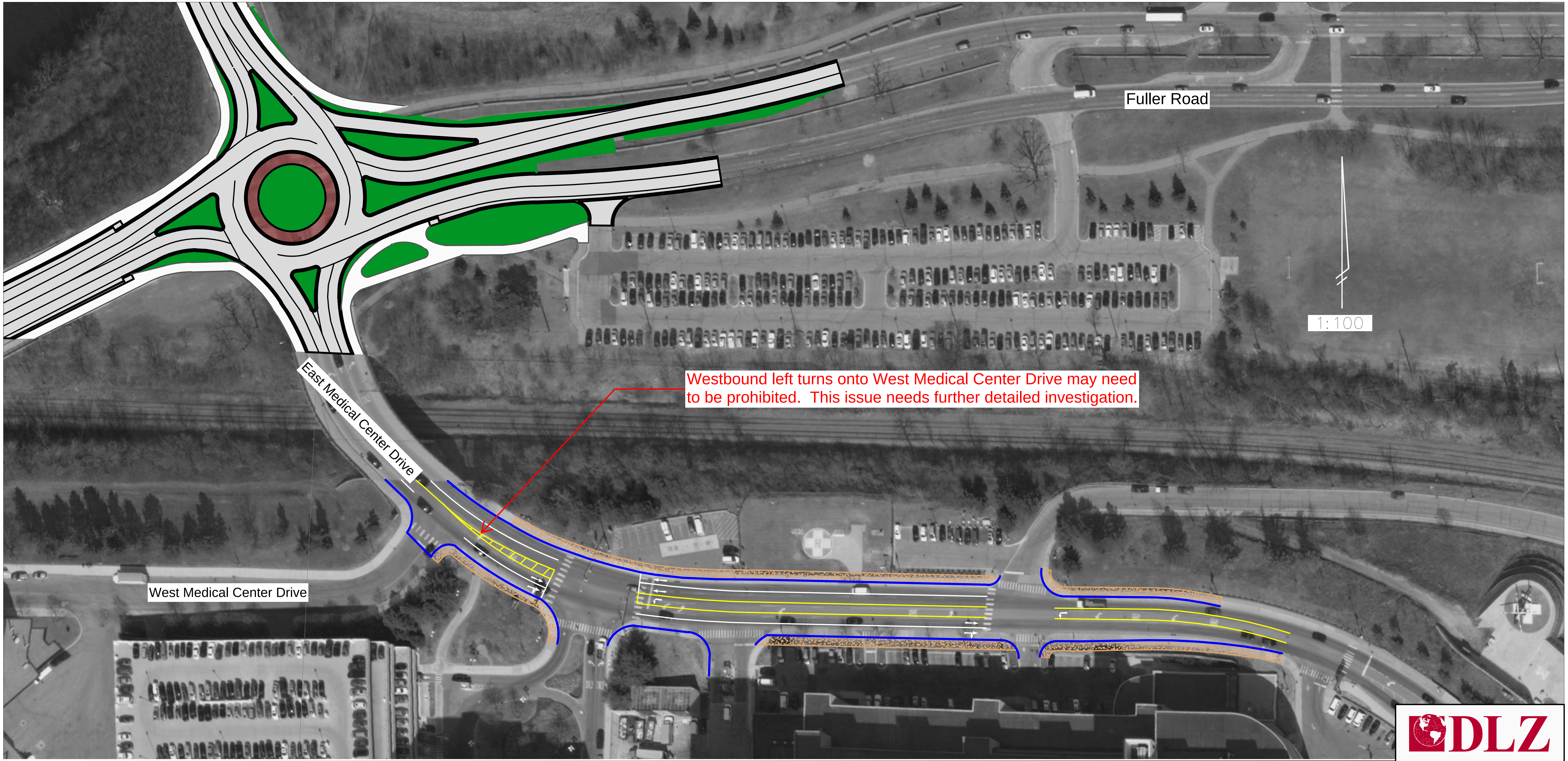
Westbound left turns onto West Medical Center Drive may need to be prohibited. This issue needs further detailed investigation.

DLZ

EAST MEDICAL CENTER DRIVE - ALTERNATIVE #2 - WIDEN ON SOUTH SIDE ONLY

Proposed Pavement Markings	Proposed New Curb
Proposed Pavement Markings	Proposed New Sidewalk

CITY OF ANN ARBOR MICHIGAN



Westbound left turns onto West Medical Center Drive may need to be prohibited. This issue needs further detailed investigation.

DLZ

EAST MEDICAL CENTER DRIVE - ALTERNATIVE #3 - WIDEN TO BOTH SIDES

▬	Proposed Pavement Markings	▬	Proposed New Curb
▬	Proposed Pavement Markings	▨	Proposed New Sidewalk

CITY OF ANN ARBOR MICHIGAN

East Medical Center Drive Revision Cost Estimate

Fuller Rd Intersection Improvements
1041-6384-00

Item Number	Description	Unit	Item Cost	Parameter	Measurements			Total Qty	Cost
2040020	Curb and Gutter, Rem	Ft	$6	Lengths:				0	$0
2050016	Excavation, Earth	Cyd	$5	Area:				0	$0
				Lengths:					
				Widths:					
				Depths:					
3010003	Subbase, LM	Cyd	$7	Area:				0	$0
				Lengths:					
				Widths:					
				Depths:					
3020016	Aggregate Base, 6 inch	Syd	$5	Area:				0	$0
				Lengths:					
				Widths:					
4040063	Underdrain, Subbase, 6 inch	Ft	$4	Lengths:				0	$0
5010005	HMA Surface, Rem	Syd	$3	Area:				0	$0
				Lengths:					
				Widths:					
5010061	HMA Approach	Ton	$80	Tons				0	$0
				Lengths:					
				Widths:					
				#/Syds:					
8020038	Curb and Gutter, Conc, Det F4	Ft	$15	Lengths:				0	$0
8030034	Sidewalk Ramp, Conc, 4 inch	Sft	$5	Area:				0	$0
				Lengths:					
				Widths:					
8030044	Sidewalk, Conc, 4 inch	Sft	$4	Area:				0	$0
				Lengths:					
				Widths:					
8160101	Slope Restoration, Type B	Syd	$3	Area:				0	$0
				Lengths:					
				Widths:					
8107051	Signing	LS	$1,000	New Sign:	Merge	Misc		1	$1,000
				Cost:	$250	$750			
				$/Ea:	250	250			
				#:	1	3			
8117051	Pavement Marking	LS	$7,392	Type	Longit	Stop Bar	Special	1	$7,392
				Cost:	$4,040	$352	$3,000		
				Lengths/#:	2020	44	6		
				$/Ft or Ea:	2	8	500		
8127051	MOT	LS	$3,000	Scheme:	Lane Shift/Closure			1	$3,000
				Cost:	$3,000				
				Price:	$3,000				
				#:	1				
8207051	Signal Modifications	LS	$5,000	Estimated Cost				1	$5,000
	Subtotal								$16,392
	Contingency	30%							$4,918
	TOTAL								**$21,310**
								$/sft	

ALTERNATIVE #2 - WIDEN ON SOUTH SIDE ONLY 8/23/2013 1:17 PM

East Medical Center Drive Revision Cost Estimate

Fuller Rd Intersection Improvements
1041-6384-00

Item Number	Description	Unit	Item Cost	Parameter	Measurements				Total Qty	Cost
2040020	Curb and Gutter, Rem	Ft	$6	Lengths:	190	465	265		920	$5,520
2040055	Sidewalk, Rem	Syd	$6	Area:	212	517	295		1024	$6,144
				Lengths:	190	465	265			
				Widths:	10	10	10			
2050016	Excavation, Earth	Cyd	$5	Volumes (CYD):	215	620	300		1135	$5,675
				Lengths:	190	465	265			
				Widths:	15.25	18	15.25			
				Depths:	2	2	2			
3010003	Subbase, LM	Cyd	$7	Volumes (CYD):	108	310	150		568	$3,976
				Lengths:	190	465	265			
				Widths:	15.25	18	15.25			
				Depths:	1	1	1			
3020016	Aggregate Base, 6 inch	Syd	$5	Area:	322	930	450		1702	$8,510
				Lengths:	190	465	265			
				Widths:	15.25	18	15.25			
4040063	Underdrain, Subbase, 6 inch	Ft	$4	Lengths:	190	465	265		920	$3,680
5010005	HMA Surface, Rem	Syd	$3	Area:					0	$0
				Lengths:						
				Widths:						
5010061	HMA Approach	Ton	$80	Tons	23	110	32		165	$13,200
				Lengths:	190	465	265			
				Widths:	2.75	5.5	2.75			
			7"	#/Syds:	770	770	770			
8020038	Curb and Gutter, Conc, Det F4	Ft	$15	Lengths:	190	465	265		920	$13,800
8030034	Sidewalk Ramp, Conc, 4 inch	Sft	$5	Area:	450				450	$2,250
				Area/Ramp:	50					
				# Ramps:	9					
8030044	Sidewalk, Conc, 4 inch	Sft	$4	Area:	1900	4650	2650		9200	$36,800
				Lengths:	190	465	265			
				Widths:	10	10	10			
8160101	Slope Restoration, Type B	Syd	$3	Area:	760	1860	1060		3680	$11,040
				Lengths:	190	465	265			
				Widths:	4	4	4			
8107051	Signing	LS	$1,000	New Sign:	Merge	Misc			1	$1,000
				Cost:	$250	$750				
				$/Ea:	250	250				
				#:	1	3				
8117051	Pavement Marking	LS	$9,398	Type	Longit	Stop Bar	Special	X Walk	1	$9,398
				Cost:	$5,060	$528	$3,000	$810		
				Lengths/#:	2530	66	6	162		
				$/Ft or Ea:	2	8	500	5		
8127051	MOT	LS	$3,000	Scheme:	Lane Shift/Closure				1	$3,000
				Cost:	$3,000					
				Price:	$3,000					
				#:	1					
8207051	Signal Modifications	LS	$5,000	Estimated Cost					1	$5,000
	Subtotal									$128,993
	Contingency	30%								$38,698
	TOTAL									**$167,691**
									$/sft	$11

East Medical Center Drive Revision Cost Estimate

Fuller Rd Intersection Improvements
1041-6384-00

Item Number	Description	Unit	Item Cost	Parameter	Measurements					Total Qty	Cost
2040020	Curb and Gutter, Rem	Ft	$6	Lengths:	190	465	265	610	210	1740	$10,440
2040055	Sidewalk, Rem	Syd	$6	Area:	212	517	295	678	234	1936	$11,616
				Lengths:	190	465	265	610	210		
				Widths:	10	10	10	10	10		
2050016	Excavation, Earth	Cyd	$6	Volumes (CYD):	215	620	300	690	238	2063	$12,378
				Lengths:	190	465	265	610	210		
				Widths:	15.25	18	15.25	15.25	15.25		
				Depths:	2	2	2	2	2		
3010003	Subbase, LM	Cyd	$7	Volumes (CYD):	108	310	150	345	119	1032	$7,224
				Lengths:	190	465	265	610	210		
				Widths:	15.25	18	15.25	15.25	15.25		
				Depths:	1	1	1	1	1		
3020016	Aggregate Base, 6 inch	Syd	$5	Area:	322	930	450	1034	356	3092	$15,460
				Lengths:	190	465	265	610	210		
				Widths:	15.25	18	15.25	15.25	15.25		
4040063	Underdrain, Subbase, 6 inch	Ft	$4	Lengths:	190	465	265	610	210	1740	$6,960
5010005	HMA Surface, Rem	Syd	$3	Area:						0	$0
				Lengths:							
				Widths:							
5010061	HMA Approach	Ton	$80	Tons	23	110	32	72	25	262	$20,960
				Lengths:	190	465	265	610	210		
				Widths:	2.75	5.5	2.75	2.75	2.75		
			7"	#/Syds:	770	770	770	770	770		
8020038	Curb and Gutter, Conc, Det F4	Ft	$15	Lengths:	190	465	265	610	210	1740	$26,100
8030034	Sidewalk Ramp, Conc, 4 inch	Sft	$5	Area:	450	250				700	$3,500
				Area/Ramp:	50	50					
				# Ramps:	9	5					
8030044	Sidewalk, Conc, 4 inch	Sft	$4	Area:	1900	4650	2650	6100	2100	17400	$69,600
				Lengths:	190	465	265	610	210		
				Widths:	10	10	10	10	10		
8160101	Slope Restoration, Type B	Syd	$3	Area:	760	1860	1060	2440	840	6960	$20,880
				Lengths:	190	465	265	610	210		
	Assume 4' behind S/W			Widths:	4	4	4	4	4		
8107051	Signing	LS	$1,000	New Sign:	Merge	Misc				1	$1,000
				Cost:	$250	$750					
				$/Ea:	250	250					
				#:	1	3					
8117051	Pavement Marking	LS	$10,553	Type	Longit	Stop Bar	Special	X Walk		1	$10,553
				Cost:	$5,060	$528	$3,000	$1,965			
				Lengths/#:	2530	66	6	393			
				$/Ft or Ea:	2	8	500	5			
8127051	MOT	LS	$3,000	Scheme:	Lane Shift/Closure					1	$3,000
				Cost:	$3,000						
				Price:	$3,000						
				#:	1						
8207051	Signal Modifications	LS	$5,000	Estimated Cost						1	$5,000
8087051	Fence Relocate	LS	$6,000	Estimated Cost		160ft - $5 Remove/Ft - $20/Ft for Fence - $2,00				1	$6,000
	Subtotal										$230,671
	Contingency	30%									$69,201
	TOTAL										**$299,872**
										$/sft	$11

5: Cancer Center Dr & E Medical Center Dr

	→	↘	↙	←	↖	↗
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱			↰↑	↰	↱
Volume (vph)	1065	95	45	590	25	65
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12
Grade (%)	0%			0%	0%	
Storage Length (ft)		0	50		0	0
Storage Lanes		0	0		1	1
Taper Length (ft)			25		25	
Lane Util. Factor	0.95	0.95	0.95	0.95	1.00	1.00
Ped Bike Factor						
Frt	0.988					0.850
Flt Protected				0.996	0.950	
Satd. Flow (prot)	3497	0	0	3525	1770	1583
Flt Permitted				0.789	0.950	
Satd. Flow (perm)	3497	0	0	2792	1770	1583
Right Turn on Red		Yes				Yes
Satd. Flow (RTOR)	19					71
Link Speed (mph)	25			25	25	
Link Distance (ft)	561			755	213	
Travel Time (s)	15.3			20.6	5.8	
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)	0%			0%	0%	
Adj. Flow (vph)	1158	103	49	641	27	71
Shared Lane Traffic (%)						
Lane Group Flow (vph)	1261	0	0	690	27	71
Turn Type	NA		Perm	NA	Prot	Perm
Protected Phases	4			8	2	
Permitted Phases			8			2
Detector Phase	4		8	8	2	2
Switch Phase						
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	27.0		27.0	27.0	26.0	26.0
Total Split (s)	61.0		61.0	61.0	29.0	29.0
Total Split (%)	67.8%		67.8%	67.8%	32.2%	32.2%
Maximum Green (s)	55.0		55.0	55.0	23.0	23.0
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	2.5		2.5	2.5	2.5	2.5
Lost Time Adjust (s)	0.0			0.0	0.0	0.0
Total Lost Time (s)	6.0			6.0	6.0	6.0
Lead/Lag						
Lead-Lag Optimize?						
Vehicle Extension (s)	3.0		3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0		3.0	3.0	3.0	3.0

Lanes, Volumes, Timings
5: Cancer Center Dr & E Medical Center Dr

10/21/2014

Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Time Before Reduce (s)	0.0		0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0		0.0	0.0	0.0	0.0
Recall Mode	Max		Max	Max	None	None
Walk Time (s)	4.0		4.0	4.0	4.0	4.0
Flash Dont Walk (s)	16.0		16.0	16.0	15.0	15.0
Pedestrian Calls (#/hr)	0		0	0	0	0
Act Effct Green (s)	67.0			67.0	6.9	6.9
Actuated g/C Ratio	0.82			0.82	0.08	0.08
v/c Ratio	0.44			0.30	0.18	0.36
Control Delay	3.7			3.1	36.7	14.3
Queue Delay	0.0			0.0	0.0	0.0
Total Delay	3.7			3.1	36.7	14.3
LOS	A			A	D	B
Approach Delay	3.7			3.1	20.5	
Approach LOS	A			A	C	
Queue Length 50th (ft)	90			43	14	0
Queue Length 95th (ft)	138			70	35	36
Internal Link Dist (ft)	481			675	133	
Turn Bay Length (ft)						
Base Capacity (vph)	2854			2275	497	495
Starvation Cap Reductn	0			0	0	0
Spillback Cap Reductn	0			0	0	0
Storage Cap Reductn	0			0	0	0
Reduced v/c Ratio	0.44			0.30	0.05	0.14

Intersection Summary

Area Type: Other

Cycle Length: 90

Actuated Cycle Length: 82.2

Natural Cycle: 60

Control Type: Semi Act-Uncoord

Maximum v/c Ratio: 0.44

Intersection Signal Delay: 4.3 Intersection LOS: A

Intersection Capacity Utilization 63.9% ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 5: Cancer Center Dr & E Medical Center Dr

Lanes, Volumes, Timings

5: Cancer Center Dr & E Medical Center Dr

10/21/2014

	→	↘	↙	←	↖	↗
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱			↰↑	↰	↱
Volume (vph)	475	75	35	900	25	65
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12
Grade (%)	0%			0%	0%	
Storage Length (ft)		0	50		0	0
Storage Lanes		0	0		1	1
Taper Length (ft)			25		25	
Lane Util. Factor	0.95	0.95	0.95	0.95	1.00	1.00
Ped Bike Factor						
Frt	0.979					0.850
Flt Protected				0.998	0.950	
Satd. Flow (prot)	3465	0	0	3532	1770	1583
Flt Permitted				0.913	0.950	
Satd. Flow (perm)	3465	0	0	3231	1770	1583
Right Turn on Red		Yes				Yes
Satd. Flow (RTOR)	34					71
Link Speed (mph)	25			25	25	
Link Distance (ft)	561			755	213	
Travel Time (s)	15.3			20.6	5.8	
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)	0%			0%	0%	
Adj. Flow (vph)	516	82	38	978	27	71
Shared Lane Traffic (%)						
Lane Group Flow (vph)	598	0	0	1016	27	71
Turn Type	NA		Perm	NA	Prot	Perm
Protected Phases	4			8	2	
Permitted Phases			8			2
Detector Phase	4		8	8	2	2
Switch Phase						
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	27.0		27.0	27.0	26.0	26.0
Total Split (s)	59.0		59.0	59.0	31.0	31.0
Total Split (%)	65.6%		65.6%	65.6%	34.4%	34.4%
Maximum Green (s)	53.0		53.0	53.0	25.0	25.0
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	2.5		2.5	2.5	2.5	2.5
Lost Time Adjust (s)	0.0			0.0	0.0	0.0
Total Lost Time (s)	6.0			6.0	6.0	6.0
Lead/Lag						
Lead-Lag Optimize?						
Vehicle Extension (s)	3.0		3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0		3.0	3.0	3.0	3.0

Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Time Before Reduce (s)	0.0		0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0		0.0	0.0	0.0	0.0
Recall Mode	Max		Max	Max	None	None
Walk Time (s)	4.0		4.0	4.0	4.0	4.0
Flash Dont Walk (s)	16.0		16.0	16.0	15.0	15.0
Pedestrian Calls (#/hr)	0		0	0	0	0
Act Effct Green (s)	65.0			65.0	6.9	6.9
Actuated g/C Ratio	0.81			0.81	0.09	0.09
v/c Ratio	0.21			0.39	0.18	0.35
Control Delay	2.6			3.5	35.6	14.1
Queue Delay	0.0			0.0	0.0	0.0
Total Delay	2.6			3.5	35.6	14.1
LOS	A			A	D	B
Approach Delay	2.6			3.5	20.0	
Approach LOS	A			A	B	
Queue Length 50th (ft)	31			68	14	0
Queue Length 95th (ft)	52			108	34	35
Internal Link Dist (ft)	481			675	133	
Turn Bay Length (ft)						
Base Capacity (vph)	2817			2620	554	544
Starvation Cap Reductn	0			0	0	0
Spillback Cap Reductn	0			0	0	0
Storage Cap Reductn	0			0	0	0
Reduced v/c Ratio	0.21			0.39	0.05	0.13

Intersection Summary

Area Type: Other

Cycle Length: 90

Actuated Cycle Length: 80.1

Natural Cycle: 55

Control Type: Semi Act-Uncoord

Maximum v/c Ratio: 0.39

Intersection Signal Delay: 4.1 Intersection LOS: A

Intersection Capacity Utilization 59.7% ICU Level of Service B

Analysis Period (min) 15

Splits and Phases: 5: Cancer Center Dr & E Medical Center Dr

Lanes, Volumes, Timings
5: Cancer Center Dr & E Medical Center Dr

10/21/2014

	→	↘	↙	←	↖	↗
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱		↰	↑↑	↰	↱
Volume (vph)	1065	95	45	590	25	65
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12
Grade (%)	0%			0%	0%	
Storage Length (ft)		0	50		0	0
Storage Lanes		0	1		1	1
Taper Length (ft)			25		25	
Lane Util. Factor	0.95	0.95	1.00	0.95	1.00	1.00
Ped Bike Factor						
Frt	0.988					0.850
Flt Protected			0.950		0.950	
Satd. Flow (prot)	3497	0	1770	3539	1770	1583
Flt Permitted			0.206		0.950	
Satd. Flow (perm)	3497	0	384	3539	1770	1583
Right Turn on Red		Yes				Yes
Satd. Flow (RTOR)	18					71
Link Speed (mph)	25			25	25	
Link Distance (ft)	561			755	213	
Travel Time (s)	15.3			20.6	5.8	
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)	0%			0%	0%	
Adj. Flow (vph)	1158	103	49	641	27	71
Shared Lane Traffic (%)						
Lane Group Flow (vph)	1261	0	49	641	27	71
Turn Type	NA		Perm	NA	Prot	Perm
Protected Phases	4			8	2	
Permitted Phases			8			2
Detector Phase	4		8	8	2	2
Switch Phase						
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	27.0		27.0	27.0	26.0	26.0
Total Split (s)	60.0		60.0	60.0	30.0	30.0
Total Split (%)	66.7%		66.7%	66.7%	33.3%	33.3%
Maximum Green (s)	54.0		54.0	54.0	24.0	24.0
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	2.5		2.5	2.5	2.5	2.5
Lost Time Adjust (s)	0.0		0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0		6.0	6.0	6.0	6.0
Lead/Lag						
Lead-Lag Optimize?						
Vehicle Extension (s)	3.0		3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0		3.0	3.0	3.0	3.0

	→	↘	↙	←	↖	↗
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Time Before Reduce (s)	0.0		0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0		0.0	0.0	0.0	0.0
Recall Mode	Max		Max	Max	None	None
Walk Time (s)	4.0		4.0	4.0	4.0	4.0
Flash Dont Walk (s)	16.0		16.0	16.0	15.0	15.0
Pedestrian Calls (#/hr)	0		0	0	0	0
Act Effct Green (s)	66.0		66.0	66.0	6.9	6.9
Actuated g/C Ratio	0.81		0.81	0.81	0.09	0.09
v/c Ratio	0.44		0.16	0.22	0.18	0.36
Control Delay	3.7		4.2	2.7	36.1	14.2
Queue Delay	0.0		0.0	0.0	0.0	0.0
Total Delay	3.7		4.2	2.7	36.1	14.2
LOS	A		A	A	D	B
Approach Delay	3.7			2.8	20.3	
Approach LOS	A			A	C	
Queue Length 50th (ft)	90		5	36	14	0
Queue Length 95th (ft)	138		17	58	34	35
Internal Link Dist (ft)	481			675	133	
Turn Bay Length (ft)			50			
Base Capacity (vph)	2847		312	2878	525	519
Starvation Cap Reductn	0		0	0	0	0
Spillback Cap Reductn	0		0	0	0	0
Storage Cap Reductn	0		0	0	0	0
Reduced v/c Ratio	0.44		0.16	0.22	0.05	0.14

Intersection Summary

Area Type: Other
Cycle Length: 90
Actuated Cycle Length: 81.1
Natural Cycle: 60
Control Type: Semi Act-Uncoord
Maximum v/c Ratio: 0.44
Intersection Signal Delay: 4.2 Intersection LOS: A
Intersection Capacity Utilization 50.7% ICU Level of Service A
Analysis Period (min) 15

Splits and Phases: 5: Cancer Center Dr & E Medical Center Dr

Lanes, Volumes, Timings
5: Cancer Center Dr & E Medical Center Dr

10/21/2014

	→	↘	↙	←	↖	↗
Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations	↑↱		↰	↑↑	↰	↱
Volume (vph)	475	75	35	900	25	65
Ideal Flow (vphpl)	1900	1900	1900	1900	1900	1900
Lane Width (ft)	12	12	12	12	12	12
Grade (%)	0%			0%	0%	
Storage Length (ft)		0	50		0	0
Storage Lanes		0	1		1	1
Taper Length (ft)			25		25	
Lane Util. Factor	0.95	0.95	1.00	0.95	1.00	1.00
Ped Bike Factor						
Frt	0.979					0.850
Flt Protected			0.950		0.950	
Satd. Flow (prot)	3465	0	1770	3539	1770	1583
Flt Permitted			0.426		0.950	
Satd. Flow (perm)	3465	0	794	3539	1770	1583
Right Turn on Red		Yes				Yes
Satd. Flow (RTOR)	34					71
Link Speed (mph)	25			25	25	
Link Distance (ft)	561			755	213	
Travel Time (s)	15.3			20.6	5.8	
Confl. Peds. (#/hr)						
Confl. Bikes (#/hr)						
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92
Growth Factor	100%	100%	100%	100%	100%	100%
Heavy Vehicles (%)	2%	2%	2%	2%	2%	2%
Bus Blockages (#/hr)	0	0	0	0	0	0
Parking (#/hr)						
Mid-Block Traffic (%)	0%			0%	0%	
Adj. Flow (vph)	516	82	38	978	27	71
Shared Lane Traffic (%)						
Lane Group Flow (vph)	598	0	38	978	27	71
Turn Type	NA		Perm	NA	Prot	Perm
Protected Phases	4			8	2	
Permitted Phases			8			2
Detector Phase	4		8	8	2	2
Switch Phase						
Minimum Initial (s)	4.0		4.0	4.0	4.0	4.0
Minimum Split (s)	27.0		27.0	27.0	26.0	26.0
Total Split (s)	59.0		59.0	59.0	31.0	31.0
Total Split (%)	65.6%		65.6%	65.6%	34.4%	34.4%
Maximum Green (s)	53.0		53.0	53.0	25.0	25.0
Yellow Time (s)	3.5		3.5	3.5	3.5	3.5
All-Red Time (s)	2.5		2.5	2.5	2.5	2.5
Lost Time Adjust (s)	0.0		0.0	0.0	0.0	0.0
Total Lost Time (s)	6.0		6.0	6.0	6.0	6.0
Lead/Lag						
Lead-Lag Optimize?						
Vehicle Extension (s)	3.0		3.0	3.0	3.0	3.0
Minimum Gap (s)	3.0		3.0	3.0	3.0	3.0

Lane Group	EBT	EBR	WBL	WBT	NBL	NBR
Time Before Reduce (s)	0.0		0.0	0.0	0.0	0.0
Time To Reduce (s)	0.0		0.0	0.0	0.0	0.0
Recall Mode	Max		Max	Max	None	None
Walk Time (s)	4.0		4.0	4.0	4.0	4.0
Flash Dont Walk (s)	16.0		16.0	16.0	15.0	15.0
Pedestrian Calls (#/hr)	0		0	0	0	0
Act Effct Green (s)	65.0		65.0	65.0	6.9	6.9
Actuated g/C Ratio	0.81		0.81	0.81	0.09	0.09
v/c Ratio	0.21		0.06	0.34	0.18	0.35
Control Delay	2.6		2.9	3.2	35.6	14.1
Queue Delay	0.0		0.0	0.0	0.0	0.0
Total Delay	2.6		2.9	3.2	35.6	14.1
LOS	A		A	A	D	B
Approach Delay	2.6			3.2	20.0	
Approach LOS	A			A	B	
Queue Length 50th (ft)	31		4	62	14	0
Queue Length 95th (ft)	52		11	97	34	35
Internal Link Dist (ft)	481			675	133	
Turn Bay Length (ft)			50			
Base Capacity (vph)	2817		644	2870	554	544
Starvation Cap Reductn	0		0	0	0	0
Spillback Cap Reductn	0		0	0	0	0
Storage Cap Reductn	0		0	0	0	0
Reduced v/c Ratio	0.21		0.06	0.34	0.05	0.13

Intersection Summary

Area Type: Other
Cycle Length: 90
Actuated Cycle Length: 80.1
Natural Cycle: 55
Control Type: Semi Act-Uncoord
Maximum v/c Ratio: 0.35
Intersection Signal Delay: 3.9 Intersection LOS: A
Intersection Capacity Utilization 38.2% ICU Level of Service A
Analysis Period (min) 15

Splits and Phases: 5: Cancer Center Dr & E Medical Center Dr

MEMO

TO: Wes Butch (DLZ)

FROM: Matt Hill, PE, PTOE (WSP)

SUBJECT: ***Revised VISSIM Future No-Build Models for City Review (Fuller Road/Maiden Lane/EMCD Project) (Revised Memo of same name dated 5/10/2018)***

DATE: **May 21, 2018**

This memorandum is to accompany the following deliverables to the City of Ann Arbor for their review:

- VISSIM Future No-Build Model (AM & PM peak hour)
- VISTRO Future No-Build Model (AM & PM peak hour)

The following notes the steps taken for the development of the models.

MODEL DEVELOPMENT

The development of the Future No-Build models used the 2035 Base Model (as submitted in a May 9, 2018 deliverable to the City) as a starting point for both the AM and PM peak hours. Several modifications were made to the 2035 Base Model in VISSIM version 10.00-6 for both the AM and PM peak hours. These modifications include:

- Removing the roundabout geometry at the Fuller/Maiden Lane/EMCD intersection.
- Coding the existing geometry and signal control at the Fuller/Maiden Lane/EMCD intersection.
- Removing one thru lane on southbound EMCD and adding left turn lanes as appropriate, to match the existing lane designations.
- Corrected NB Maiden Lane/Plymouth laneage to a shared thru/left and right turn lane (previously modeled laneage was left, thru and right turn lanes).
- Updated all pedestrian links to a width of 8 feet to match the width of the crosswalks. The pedestrian links were placed on top of each other in order realistic the pedestrian influence area.

Peak Hour Turning-Movement Counts

2035 forecasted auto and pedestrian volumes were provided by the City of Ann Arbor for all intersections except for the following EMCD intersections, where forecasted volumes were provided by DLZ:

- EMCD at West Medical Center Drive
- EMCD at Nichols Drive
- EMCD at Psychiatric Emergency Children and Adult Drive
- EMCD at University Hospital/Taubman Center Entrance
- EMCD at University Hospital Mid-Block Pedestrian Crossing (located between the Taubman Center entrance and exit)
- EMCD at University Hospital/Taubman Center Exit
- EMCD at Parking Garage (P2) Entrance

The traffic impact study for the proposed Ann Arbor Station on Fuller Road was also incorporated into the model for the volumes forecasted in and out of the station driveways.

Intersection Geometrics

Intersection geometries were based on Google Earth and Bing Map aerials to replicate existing conditions. Field measurements were made as necessary.

Signal Timings

The existing signal timing plans for all signalized intersections were obtained from the City of Ann Arbor.

FUTURE NO-BUILD OPERATIONS ANALYSIS

This section details the analysis of the current roadway network with projected 2035 volumes. These results provide a baseline from which to compare the effects of subsequent roadway improvement alternatives.

VISSIM 10.00-06 software was used for the traffic operations analysis of the future no-build condition. VISSIM is a microsimulation model where traffic movements are explicitly modeled based on geometric parameters, traffic volumes, vehicle types, intersection control, and driver behavior and interaction. VISSIM assesses the roadway network in a dynamic fashion, instead of analyzing each intersection or each roadway segment in isolation. VISSIM can provide measures of effectiveness (MOEs) such as vehicle delay, travel time, queuing, and fuel consumption on a network-wide basis, so that the effects of improvements at a single location may be measured throughout the network. This ability makes VISSIM an ideal tool for testing and comparing alternatives to determine the most effective combination of elements in facilitating traffic flow. In addition, the sensitivity of the VISSIM model allows the user to test more subtle changes to the roadway system, such as adjustments in traffic signalization, changes in transit operations, laneage, and others.

VISTRO models were also prepared for the Future No-Build AM and PM peak hours as a supplement to the VISSIM models, but it was agreed upon with the City that only the VISSIM results would be summarized so that an equal comparison could be made between the No-Build scenario and the various design alternatives that are to be modeled in VISSIM. There is still value in the VISTRO models, as they are more adept in quickly screening different signal timing strategies that can then be incorporated in the VISSIM models.

MEASURES OF EFFECTIVENESS

After creating the 2035 Future No-Build Model in VISSIM 10.00-6 per the modifications listed in the previous section, the models (AM and PM peak hour) were run to identify MOEs for the Fuller/Maiden Lane/EMCD intersection as well as intersections along EMCD. All MOE’s summarized are the average of five (5) runs with different random number seeds.

It became apparent quickly that the existing stop signs along EMCD at the Psychiatric Emergency Drive become a capacity constraint in the Future No-Build models. This prevents some vehicles from entering northbound EMCD and causes backups for southbound traffic to the Fuller/Maiden Lane/EMCD intersection, leading to network gridlock in the microsimulation model. Figures 1 and 2 illustrate what this looks like.

Figure 1: System Gridlock in the AM Peak Hour

Figure 2: System Gridlock in the PM Peak Hour

In order to fully test the effectiveness of the existing geometry and signal control for the Fuller/Maiden Lane/EMCD intersection, the full peak hour traffic demand needs to be able to reach the intersection. This led to WSP performing an additional modification to the model whereby the stop signs are removed along EMCD to allow the full vehicular demand in and out of the intersection at Fuller/Maiden Lane/EMCD. It is acknowledged that there is a capacity constraint along EMCD at the stop signs that will need to be dealt with in some capacity, but for the purpose of this planning stage, this potential mitigation is not defined.

After removing the stop signs, the MOEs were summarized for the study area and are shown in Tables 1 thru 6.

The Fuller Road/Maiden Lane/EMCD intersection is forecasted to operate at a LOS F during both AM and PM peak, with long queues and delays for autos. Queues still form that spill back to the adjacent intersections and out of the network as illustrated in Figures 3 and 4.

Tables 5 and 6 show the delay and the number of pedestrians serviced on each leg of the study intersections. Unsignalized pedestrian crossing behavior was split 50/50 between pedestrians yielding to passing vehicles or pedestrians proceeding freely across the intersection and conflicting vehicles yielding. Therefore, at each unsignalized intersection, half of the modeled pedestrians crossed the intersection with little to no delay. The pedestrians that were forced to find an acceptable gap in the traffic stream and yield to vehicles experienced the largest delays and are what are reported in Tables 5 and 6. Signalized intersections were modeled to have all pedestrians proceed across the intersection during the protected pedestrian phase.

The Fuller Road/Maiden Lane/EMCD intersection has the highest pedestrian volumes in the study area. The west leg is forecasted to have 770 and 660 pedestrians in the AM and PM peak hours, respectively. The model was only able to service 65 percent of AM pedestrians and 81 percent of PM pedestrians on this leg. The poor serviceability of west crosswalk can be seen in the average pedestrian delay at this location. It is expected to incur a 305 or 281 second delay during the AM and PM peak, respectively. These delays translate into a pedestrian waiting 2 to 3 cycles to cross Fuller Road.

Significant vehicle queueing occurs along southbound EMCD during the AM peak hour between the Cancer Center Drive intersection and the intersection of Fuller/Maiden Lane/EMCD. This is due to the capacity constraint of a single lane along southbound EMCD. Approximately 1170 vehicles are trying to head southbound on EMCD during the AM peak hour compared to 550 in the PM peak hour. The queuing on this stretch of EMCD heavily impacts operations at the Fuller/Maiden Lane/EMCD intersection. It was often observed in the model that there would be a green light for movements wishing to head southbound on EMCD (such as the eastbound right-turn from Fuller), but these vehicles could not go because the queue on southbound EMCD had spilled all the way back to the Fuller/Maiden Lane/EMCD intersection. This led to excessive delays and backups within the models as noted in Tables 1 and 2.

Table 1: Future No-Build Delay Results: AM Peak

Intersection	AM Peak Hour Delay (s)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD*	151.4/F	62.3/E	20.6/C	78.8/E	437.7/F	403.4/F	367.9/F	396.4/F	649.2/F	743.2/F	744.2/F	731.8F	523.3/F	397.3/F	387.0/F	435.7/F	416.0/F
EMCD/West Medical Center	16.2/C	-	-	-	-	-	-	-	2350/F	-	1797/F	1990/F	-	-	-	-	-
EMCD/Cancer Center*	75.7/E	97.5/F	-	95.9/F	-	4.8/A	7..1/A	5.0/A	73.5/E	-	13.8/B	30.6/C	-	-	-	-	48.3/D
EMCD/Nichols	0.0/A	-	-	-	1.0/A	-	-	-	90.4/F	0.0/A	14.4/B	77.7/F	27.8/D	0.0/A	34.4/D	30.7/D	-
EMCD/Psychiatric Emerg.	8.6/A	-	-	-	-	-	-	-	60.4/F	-	15.6/C	43.6/E	-	-	-	-	-
EMCD/Taubman Entrance	11.0/B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	41.8/E	-	10.3/B	20.4/C	-	-	-	-	-
EMCD/P2 Entrance	20.0/C	-	-	-	-	-	-	-	0.0/A	-	7.4/A	7.4/A	-	-	-	-	-

**Signalized Intersection*

Table 2: Future No-Build Delay Results: PM Peak

Intersection	PM Peak Hour Delay (s)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD*	113.0/F	67.3/E	41.9/D	73.6/E	211.3/F	162.4/F	140.5/F	171.7/G	184.2/F	182.1/F	174.9/F	181.5/F	455.3/F	560.8/F	556.0/F	539.4/F	254.9/F
EMCD/West Medical Center	9.8/A	-	-	-	-	-	-	-	1598/F	-	1260/F	1503/F	-	-	-	-	-
EMCD/Cancer Center*	31.4/C	73.0/E	-	71.3/E	-	6.1/A	5.5/A	6.0/A	53.4/D	-	15.4/B	25.6/C	-	-	-	-	46.1
EMCD/Nichols	15.2/C	-	-	-	2.4/A	-	-	-	65.9/F	0.0/A	8.3/A	46.7/E	19.5/C	0.0/A	28.3/D	25.5/D	-
EMCD/Psychiatric Emerg.	5.4/A	-	-	-	-	-	-	-	51.2/F	-	22.2/C	47.6/E	-	-	-	-	-
EMCD/Taubman Entrance	6.1/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	40.2/E	-	14.3/B	32.5/D	-	-	-	-	-
EMCD/P2 Entrance	14.6/B	-	-	-	-	-	-	-	97.7/F	-	19.1/C	93.3/F	-	-	-	-	-

**Signalized Intersection*

Table 3: Future No-Build Queue Results: AM Peak

INTERSECTION	AM PEAK HOUR QUEUE (FT)							
	NORTHBOUND		SOUTHBOUND		EASTBOUND		WESTBOUND	
	AVG.	MAX	AVG.	MAX	AVG.	MAX	AVG.	MAX
FULLER/MAIDEN LN/EMCD*	280	376	2012	3191	2016	2118	2296	4002
EMCD/WEST MEDICAL CENTER	4	130	-	-	556	585	-	-
EMCD/CANCER CENTER*	290	482	32	155	3	69	-	-
EMCD/NICHOLS	132	340	0	0	2	37	1	50
EMCD/PSYCHIATRIC EMERG.	0	29	-	-	3	46	-	-
EMCD/TAUBMAN ENTRANCE	0	35	-	-	-	-	-	-
EMCD/TAUBMAN EXIT	-	-	-	-	5	68	-	-
EMCD/P2 ENTRANCE	4	132	-	-	0	45	-	-

**Signalized Intersection*

Table 4: Future No-Build Queue Results: PM Peak

INTERSECTION	PM PEAK HOUR QUEUE (FT)							
	NORTHBOUND		SOUTHBOUND		EASTBOUND		WESTBOUND	
	AVG.	MAX	AVG.	MAX	AVG.	MAX	AVG.	MAX
FULLER/MAIDEN LN/EMCD*	248	370	485	1579	847	1673	2832	4572
EMCD/WEST MEDICAL CENTER	2	114	-	-	552	587	-	-
EMCD/CANCER CENTER*	277	480	32	213	5	75	-	-
EMCD/NICHOLS	108	338	0	0	1	33	2	77
EMCD/PSYCHIATRIC EMERG.	0	29	-	-	19	136	-	-
EMCD/TAUBMAN ENTRANCE	0	40	-	-	-	-	-	-
EMCD/TAUBMAN EXIT	-	-	-	-	27	142	-	-
EMCD/P2 ENTRANCE	0	34	-	-	16	97	-	-

**Signalized Intersection*

Table 5: Future No-Build Pedestrian Delay Results: AM Peak

AM PEAK PEDESTRIAN DELAY

	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
INTERSECTION	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD*	137		153	165	90		32	35	82		64	70	305		499	730
EMCD/West Medical Center	-	-	-	-	0	-	0	0	-	-	-	-	11	-	528	531
EMCD/Cancer Center*	56		64	70	49		81	84	-	-	-	-	42		577	579
EMCD/Nichols	0	-	0	3	0	-	0	3	0	-	0	3	9	-	48	52
EMCD/Psychiatric Emerg.	0	-	0	2	0	-	0	3	-	-	-	-	3	-	48	49
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	14	-	8	10
Taubman Mid-Block	-	-	-	-	12	-	24	30	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	12	-	56	63	-	-	-	-	1	-	24	27
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	6	-	8	13

**Signalized Intersection*

Table 6: Future No-Build Pedestrian Delay Results: PM Peak

PM PEAK PEDESTRIAN DELAY

	North Leg				South Leg				East Leg				West Leg			
	Crossing Type		Ped. Totals		Crossing Type		Ped. Totals		Crossing Type		Ped. Totals		Crossing Type		Ped. Totals	
INTERSECTION	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD*	109		90	100	118		87	100	105		134	140	281		537	660
EMCD/West Medical Center	-	-	-	-	0	-	0	2	-	-	-	-	6	-	464	467
EMCD/Cancer Center*	51		73	73	35		189	199	-	-	-	-	44		413	419
EMCD/Nichols	14	-	8	9	0	-	0	0	6		16	19	7	-	40	40
EMCD/Psychiatric Emerg.	0	-	0	4	11	-	8	10	-	-	-	-	3	-	24	28
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	7	-	32	33
Taubman Mid-Block	-	-	-	-	11	-	72	79	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	11	-	287	288	-	-	-	-	1	-	96	99
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	5	-	24	27

**Signalized Intersection*

Figure 3: System Gridlock in the AM Peak Hour

Figure 4: System Gridlock in the PM Peak Hour

NEXT STEPS

- WSP will explore if there are signal phasing/timing modifications under the Future No-Build scenario that will provide better overall operations at the Fuller/Maiden Lane/EMCD intersection.
- WSP will move on to other roundabout model groups which are the PHB signals, EMCD queue detection, Maiden Lane/Fuller Road/EMCD bypass lanes, pedestrian grade separation alternatives, and signal with indirect left-turns (if needed).

MEMO

TO: Wes Butch (DLZ)

FROM: Matt Hill, PE, PTOE (WSP)

SUBJECT: **Pedestrian Hybrid Beacon Analysis (Fuller/Maiden Lane/EMCD Project)**

DATE: **May 18, 2018**

This memorandum is to accompany the following deliverables to the City of Ann Arbor for their review:

- VISSIM Pedestrian Hybrid Beacon (PHB) Analysis Models
    - Scenario 1 – Free PHB operations with no lockout
    - Scenario 2 – Free PHB operations with a 30-second lockout period
    - Scenario 3 – Coordinated PHB operations with a 60-second lockout period

These models were developed specifically for testing PHB scenarios with the goal of finding an optimal operational scenario for servicing pedestrians and vehicles at the intersection of Fuller/Maiden Lane/EMCD. Both the AM and PM peak hours were analyzed. The following notes the steps taken for the development of the models.

MODEL MODIFICATIONS

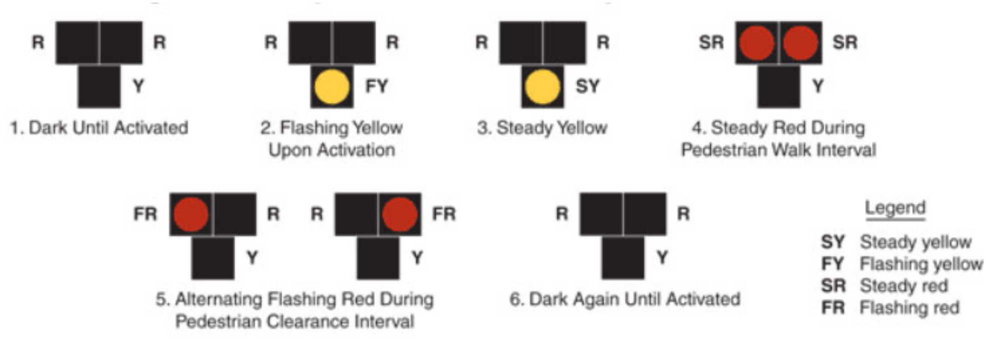
The Base Model (without stop signs at Psychiatric Emergency Drive) was used as the starting point for this analysis. Several modifications were made to the Base Model to reflect the PHB scenarios modeled. These modifications include:

- Added PHB signal and controller logic for crossing of each leg of the Fuller/Maiden Lane/EMCD roundabout
- Revised pedestrian crossing behavior at the roundabout such that 50 percent of the pedestrians cross according to the PHB signal indication and 50 percent cross when there is an appropriate gap in the vehicle traffic stream (regardless of PHB indication)

PEDESTRIAN HYBRID BEACON OPERATIONS

Pedestrian Hybrid Beacons are used to warn and control traffic at an unsignalized location to assist pedestrians in crossing a street at a marked crosswalk. General operations of a PHB are shown in Figure 1 below, which is a direct excerpt from FHWA's *Manual on Uniform Traffic Control Devices*.

Figure 1: Sequence for a Pedestrian Hybrid Beacon



The following assumptions were made for this analysis:

- The pedestrian clearance interval of the PHB would be timed to clear a pedestrian across the entire leg of the intersection; NOT just crossing one direction of traffic to the splitter island. This assumption was used because there is limited pedestrian storage available at the splitter islands, and the number of pedestrians forecasted is large, particularly on the west leg of the intersection.
- PHBs would be push-button actuated
- Solid yellow and all-red clearance intervals for vehicle traffic are based on the assumed speed limit of 35 mph as well as the crossing width of an eight-foot crosswalk.

The following describes the various operational scenarios investigated for the PHBs and the measures of effectiveness for each one of these. Scenario 1 represents a conventional operating strategy for a PHB. An iterative process was followed to develop subsequent scenarios where Scenario 2 was developed based on observations and refinements of Scenario 1, and Scenario 3 was developed based on the observations and refinements of Scenario 2 with the purpose of identifying an optimal operating strategy for the PHBs.

SCENARIO 1: FREE PHB OPERATIONS WITH **NO** LOCKOUT

Scenario 1 allowed the PHBs on each of the four legs of the roundabout to operate freely with no coordination with each other. When a pedestrian pressed a push-button, a call was placed immediately to start servicing the PHB signal routine. A five second buffer from when the PHB routine was serviced to when it could start another one was modeled. This five seconds is essentially a marginal time period, so the PHBs do a full cycle of their routine and return to dark before servicing another pedestrian call. For all intents and purposes, the PHB operates as if there is no lockout period after servicing a pedestrian call and can begin servicing another pedestrian call within five seconds of cycling through the previous pedestrian routine. Tables 1 through 6 provide the operational results for Scenario 1.

This scenario performed the worst of the three scenarios for overall vehicle operations, but the best overall for pedestrian operations. Compared to the Base Model with no PHBs, vehicle operations are worse in Scenario 1 and pedestrian operations are significantly better, with the pedestrian demand serviced effectively.

Table 1: Scenario 1 Vehicle Delay and LOS Results- AM Peak

INTERSECTION	AM PEAK HOUR DELAY (S)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD	97.8/F	26.1/D	13./B	49.2/E	2314/F	2237/F	2319/F	2285/F	860/F	847/F	834/F	843/F	1798/F	1515/F	1402F	1588/F	813.3/F
EMCD/West Medical Center	8.9/A	-	-	-	-	-	-	-	242.7/F	-	165.7/F	198.9/F	-	-	-	-	-
EMCD/Cancer Center*	39.9/D	25.9/C	-	26.9/C	-	7.5/A	11.0/B	7.7/A	30.9/C	-	14.6/B	19.3/B	-	-	-	-	18.6/B
EMCD/Nichols	0.0/A	-	-	-	18.2/B	-	-	-	31.1/D	0.0/A	8.1/A	27.2/D	17.6/C	0.0/A	6.8/A	12.8/B	-
EMCD/Psychiatric Emerg.	6.5/A	-	-	-	-	-	-	-	16.4/C	-	11.2/B	14.4/B	-	-	-	-	-
EMCD/Taubman Entrance	4.1/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	16.5/C	-	10.3/B	12.3/B	-	-	-	-	-
EMCD/P2 Entrance	8.6/A	-	-	-	-	-	-	-	0.0/A	-	7.5/A	7.5/A	-	-	-	-	-

**Signalized Intersection*

Table 2: Scenario 1 Vehicle Delay and LOS Results- PM Peak

INTERSECTION	PM PEAK HOUR DELAY (S)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD	100.4/F	45.8/E	40.3/E	63.0/F	1848/F	1791/F	1752/F	1796/F	788/F	738/F	698/F	745/F	1619/F	1273/F	1257/F	1336/F	651.7/F
EMCD/West Medical Center	10.0/B	-	-	-	-	-	-	-	934/F	-	665/F	853/F	-	-	-	-	-
EMCD/Cancer Center*	54.3/D	54.3/D	-	54.3/D	-	9.1/A	7.8/A	8.9/A	34.3/D	-	16.2/B	21.2/C	-	-	-	-	43.6/D
EMCD/Nichols	9.4/A	-	-	-	16.9/C	-	-	-	22.5/C	0.0/A	6.7/A	17.3/C	18.6/C	0.0/A	11.1/B	13.5/B	-
EMCD/Psychiatric Emerg.	2.8/A	-	-	-	-	-	-	-	38.2/E	-	19.9/C	36.0/E	-	-	-	-	-
EMCD/Taubman Entrance	3.0/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	32.8/D	-	10.9/B	26.6/D	-	-	-	-	-
EMCD/P2 Entrance	9.4/A	-	-	-	-	-	-	-	95.5/F	-	87.2/F	95.1/F	-	-	-	-	-

**Signalized Intersection*

Table 3: Scenario 1 Queuing Results- AM Peak

INTERSECTION	AM PEAK HOUR QUEUE (FT)							
	Northbound		Southbound		Eastbound		Westbound	
	Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Fuller/Maiden Ln/EMCD	104	333	3091	3195	2016	2086	4581	5175
EMCD/West Medical Center	32	201	-	-	349	589	-	-
EMCD/Cancer Center*	59	377	17	160	3	75	-	-
EMCD/Nichols	6	206	0	102	1	33	1	50
EMCD/Psychiatric Emerg.	0	35	-	-	1	45	-	-
EMCD/Taubman Entrance	0	41	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	3	64	-	-
EMCD/P2 Entrance	3	87	-	-	0	45	-	-

**Signalized Intersection*

Table 4: Scenario 1 Queuing Results- PM Peak

INTERSECTION	PM PEAK HOUR QUEUE (FT)							
	Northbound		Southbound		Eastbound		Westbound	
	Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Fuller/Maiden Ln/EMCD	241	342	2974	3197	1874	2082	4595	5180
EMCD/West Medical Center	83	204	-	-	540	588	-	-
EMCD/Cancer Center*	176	477	8	108	3	74	-	-
EMCD/Nichols	35	326	0	28	1	33	2	70
EMCD/Psychiatric Emerg.	0	29	-	-	10	125	-	-
EMCD/Taubman Entrance	0	48	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	18	125	-	-
EMCD/P2 Entrance	0	29	-	-	10	92	-	-

**Signalized Intersection*

Table 5: Scenario 1 Pedestrian Service and Delay Results- AM Peak

INTERSECTION	AM PEAK PEDESTRIAN DELAY (S)															
	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD**	24	44	158	165	8	18	32	35	12	21	64	70	12	22	730	730
EMCD/West Medical Center	-	-	-	-	0	-	0	0	-	-	-	-	11	-	528	531
EMCD/Cancer Center*	16		65	70	15		81	84	-	-	-	-	17		577	579
EMCD/Nichols	0	-	0	3	0	-	0	3	0	-	0	3	11	-	48	52
EMCD/Psychiatric Emerg.	0	-	0	2	0	-	0	3	-	-	-	-	2	-	48	49
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	13	-	8	10
Taubman Mid-Block	-	-	-	-	20	-	24	30	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	18	-	57	63	-	-	-	-	0	-	24	27
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	4	-	8	13

**Signalized Intersection*

***NOTE: Roundabout crosswalks are controlled with a pedestrian hybrid beacon (PHB). Yield Column: Pedestrians cross once acceptable gap is available in vehicle stream, Free Column: Pedestrians cross only when PHB walk phase is called.*

Table 6: Scenario 1 Pedestrian Service and Delay Results- PM Peak

INTERSECTION	PM PEAK PEDESTRIAN DELAY (S)															
	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD**	16	64	95	100	7	26	96	100	17	33	137	140	1.8	22	656	660
EMCD/West Medical Center	-	-	-	-	0	-	0	2	-	-	-	-	9	-	460	467
EMCD/Cancer Center*	48		72	73	37		192	199	-	-	-	-	53		415	419
EMCD/Nichols	10	-	8	9	0	-	0	0	9	-	16	19	8	-	40	40
EMCD/Psychiatric Emerg.	0	-	0	4	11	-	8	10	-	-	-	-	3	-	24	28
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	5	-	32	33
Taubman Mid-Block	-	-	-	-	25	-	72	79	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	14	-	287	288	-	-	-	-	1	-	96	99
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	4	-	24	27

**Signalized Intersection*

***NOTE: Roundabout crosswalks are controlled with a pedestrian hybrid beacon (PHB). Yield Column: Pedestrians cross once acceptable gap is available in vehicle stream, Free Column: Pedestrians cross only when PHB walk phase is called.*

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SCENARIO 2: FREE PHB OPERATIONS WITH **30-SECOND** LOCKOUT

Scenario 2 allowed the PHBs on each of the four legs of the roundabout to operate freely with no coordination with each other. When a pedestrian detection occurred, a call was placed immediately to start servicing the PHB signal routine. A 30-second lockout from when the PHB routine was completed to when it could begin servicing another PHB call was modeled. This 30-second lockout period was modeled to see if vehicle operations could be improved without significantly compromising pedestrian operations. Tables 7 through 12 provide the operational results for Scenario 2.

This scenario performed the second best of the three scenarios for overall vehicle and pedestrian operations. Compared to the Base Model with no PHBs, vehicle operations are slightly worse in Scenario 2, and pedestrian operations are significantly better, with the pedestrian demand serviced effectively.

Table 7: Scenario 2 Vehicle Delay and LOS Results- AM Peak

INTERSECTION	AM PEAK HOUR DELAY (S)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD	24.3/C	14.8/B	9.5/A	16.5/C	878/F	858/F	862/F	863/F	663/F	624/F	564/F	606/F	377/F	332/F	264/F	336/F	382.7/F
EMCD/West Medical Center	8.7/A	-	-	-	-	-	-	-	86.1/F	-	57.1/F	69.4/F	-	-	-	-	-
EMCD/Cancer Center*	27.6/C	13.4/B	-	14.4/B	-	8.1/A	11.4/B	8.4/A	18.6/B	-	15.6/B	16.4/B	-	-	-	-	11.3/B
EMCD/Nichols	0.0/A	-	-	-	3.9/A	-	-	-	22.6/C	0.0/A	6.6/A	19.9/C	23.2/C	0.0/A	6.7/A	15.8/C	-
EMCD/Psychiatric Emerg.	16.1/C	-	-	-	-	-	-	-	30.0/D	-	17.0/C	25.1/D	-	-	-	-	-
EMCD/Taubman Entrance	8.3/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	16.1/C	-	13.5/B	14.3/B	-	-	-	-	-
EMCD/P2 Entrance	14.7/B	-	-	-	-	-	-	-	0.0/A	-	7.5/A	7.5/A	-	-	-	-	-

**Signalized Intersection*

Table 8: Scenario 2 Vehicle Delay and LOS Results- PM Peak

INTERSECTION	PM PEAK HOUR DELAY (S)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD	66.9/F	47.2/E	42.6/E	52.5/F	243/F	247/F	249/F	246/F	426/F	395/F	371/F	399/F	893/F	827/F	762/F	830/F	375.1/F
EMCD/West Medical Center	10.7/B	-	-	-	-	-	-	-	643/F	-	435/F	580/F	-	-	-	-	-
EMCD/Cancer Center*	68.1/E	64.7/E	-	64.8/E	-	9.0/A	9.4/A	9.1/A	37.8/D	-	17.3/B	23.0/C	-	-	-	-	45.8/D
EMCD/Nichols	9.2/A	-	-	-	18.3/C	-	-	-	25.6/D	0.0/A	10.5/B	20.5/C	22.9/C	0.0/A	10.0/A	14.0/B	-
EMCD/Psychiatric Emerg.	6.5/A	-	-	-	-	-	-	-	35.4/E	-	13.8/B	32.8/D	-	-	-	-	-
EMCD/Taubman Entrance	4.1/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	31.6/D	-	11.0/B	25.8/D	-	-	-	-	-
EMCD/P2 Entrance	43.7/E	-	-	-	-	-	-	-	725/F	-	6.4/A	725/F	-	-	-	-	-

**Signalized Intersection*

Table 9: Scenario 2 Queuing Results- AM Peak

INTERSECTION	AM PEAK HOUR QUEUE (FT)							
	Northbound		Southbound		Eastbound		Westbound	
	Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Fuller/Maiden Ln/EMCD	25	315	2813	3191	1986	2086	1816	3289
EMCD/West Medical Center	8	178	-	-	98	530	-	-
EMCD/Cancer Center*	36	278	27	162	3	74	-	-
EMCD/Nichols	0	95	0	104	1	33	1	50
EMCD/Psychiatric Emerg.	1	32	-	-	2	48	-	-
EMCD/Taubman Entrance	1	42	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	3	67	-	-
EMCD/P2 Entrance	7	103	-	-	0	45	-	-

**Signalized Intersection*

Table 10: Scenario 2 Queuing Results- PM Peak

INTERSECTION	PM PEAK HOUR QUEUE (FT)							
	Northbound		Southbound		Eastbound		Westbound	
	Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Fuller/Maiden Ln/EMCD	243	343	645	1378	1414	1888	3876	5056
EMCD/West Medical Center	100	205	-	-	457	586	-	-
EMCD/Cancer Center*	203	480	14	136	4	73	-	-
EMCD/Nichols	45	340	0	48	1	33	2	89
EMCD/Psychiatric Emerg.	0	28	-	-	9	121	-	-
EMCD/Taubman Entrance	0	70	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	17	137	-	-
EMCD/P2 Entrance	6	78	-	-	101	167	-	-

**Signalized Intersection*

Table 11: Scenario 2 Pedestrian Service and Delay Results- AM Peak

INTERSECTION	AM PEAK PEDESTRIAN DELAY (S)															
	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD**	10	51	159	165	9	27	32	35	15	33	64	70	14	50	730	730
EMCD/West Medical Center	-	-	-	-	0	-	0	0	-	-	-	-	8	-	528	531
EMCD/Cancer Center*	15		64	70	14		81	84	-	-	-	-	17		576	579
EMCD/Nichols	0	-	0	3	0	-	0	3	0	-	0	3	12	-	48	52
EMCD/Psychiatric Emerg.	0	-	0	2	0	-	0	3	-	-	-	-	1	-	48	49
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	17	-	8	10
Taubman Mid-Block	-	-	-	-	31	-	24	30	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	22	-	57	63	-	-	-	-	1	-	24	27
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	8	-	8	13

**Signalized Intersection*

***NOTE: Roundabout crosswalks are controlled with a pedestrian hybrid beacon (PHB). Yield Column: Pedestrians cross once acceptable gap is available in vehicle stream, Free Column: Pedestrians cross only when PHB walk phase is called.*

Table 12: Scenario 2 Pedestrian Service and Delay Results- PM Peak

INTERSECTION	PM PEAK PEDESTRIAN DELAY (S)															
	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD**	11	63	95	100	8	50	96	100	13	57	137	140	7.4	39	655	660
EMCD/West Medical Center	-	-	-	-	0	-	0	2	-	-	-	-	10	-	461	467
EMCD/Cancer Center*	53		72	73	34		191	199	-	-	-	-	57		417	419
EMCD/Nichols	13	-	8	9	0	-	0	0	7	-	16	19	9	-	40	40
EMCD/Psychiatric Emerg.	0	-	0	4	12	-	8	10	-	-	-	-	3	-	24	28
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	9	-	32	33
Taubman Mid-Block	-	-	-	-	31	-	72	79	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	15	-	288	288	-	-	-	-	1	-	96	99
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	23	-	24	27

**Signalized Intersection*

***NOTE: Roundabout crosswalks are controlled with a pedestrian hybrid beacon (PHB). Yield Column: Pedestrians cross once acceptable gap is available in vehicle stream, Free Column: Pedestrians cross only when PHB walk phase is called.*

SCENARIO 3: COORDINATED PHB OPERATIONS WITH **60-SECOND** LOCKOUT

Scenario 3 had all the PHBs coordinated on the same controller, such that a call on any one of the PHBs triggered a call on all four approaches, so that all PHB's were stopping traffic and servicing pedestrians simultaneously. This was limited to servicing a call once every 60 seconds. This scenario was explored to determine if limiting the number of times vehicles must stop during the servicing of the pedestrian calls in a coordinated effort on all legs could improve operations over the free running PHB scenarios. Tables 13 through 18 provide the operational results for Scenario 3.

This scenario performed slightly better than Scenario 2 for vehicle operations and slightly worse for pedestrian operations, but still effectively serviced the pedestrian demand. Compared to the Base Model with no PHBs, vehicle operations are slightly worse in Scenario 3, and pedestrian operations are significantly better, with the pedestrian demand serviced effectively.

Figures 2 and 3 illustrate the gridlock on the roadway network anticipated under this alternative, which was the best of the three scenarios for vehicle operations.

Table 13: Scenario 3 Vehicle Delay and LOS Results- AM Peak

INTERSECTION	AM PEAK HOUR DELAY (S)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD	33.1/D	16.0/C	12.9/B	21.2/C	658/F	639/F	656/F	650/F	497/F	464/F	396/F	442/F	451/F	389/F	319/F	399/F	353.5/F
EMCD/West Medical Center	15.5/C	-	-	-	-	-	-	-	185/F	-	185/F	157/F	-	-	-	-	-
EMCD/Cancer Center*	31.0/C	15.3/B	-	16.4/B	-	8.0/A	11.6/B	8.3/A	19.9/B	-	15.3/B	16.6/B	-	-	-	-	12.0/B
EMCD/Nichols	0.0	-	-	-	7.0/A	-	-	-	24.6/C	0.0/A	5.7/A	21.5/C	23.0/C	0.0/A	6.8/A	15.8/C	-
EMCD/Psychiatric Emerg.	16.3/C	-	-	-	-	-	-	-	24.2/C	-	15.8/C	20.9/C	-	-	-	-	-
EMCD/Taubman Entrance	5.7/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	16.5/C	-	12.7/B	13.9/B	-	-	-	-	-
EMCD/P2 Entrance	15.4/C	-	-	-	-	-	-	-	0.0/A	-	7.4/A	7.4/A	-	-	-	-	-

**Signalized Intersection*

Table 14: Scenario 3 Vehicle Delay and LOS Results- PM Peak

INTERSECTION	PM PEAK HOUR DELAY (S)																
	Northbound				Southbound				Eastbound				Westbound				Overall Intersection
	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	Left	Thru	Right	Appr.	
Fuller/Maiden Ln/EMCD	76.5/F	47.4/E	39.7/E	54.8/E	152/F	149/F	145/F	149/F	214/F	192/F	173/F	194/F	944/F	853/F	778/F	860/F	308.1/F
EMCD/West Medical Center	14.7/B	-	-	-	-	-	-	-	969/F	-	714/F	886/F	-	-	-	-	-
EMCD/Cancer Center*	81.4/F	72.5/E	-	72.8/E	-	8.7/A	9.4/A	8.8/A	40.4/D	-	17.2/B	23.6/B	-	-	-	-	49.7/D
EMCD/Nichols	9.8/A	-	-	-	16.1/C	-	-	-	28.8/D	0.0/A	7.7/A	21.8/C	23.5/C	0.0/A	10.1/B	14.7/B	-
EMCD/Psychiatric Emerg.	4.9/A	-	-	-	-	-	-	-	38.1/E	-	21.8/C	36.2/E	-	-	-	-	-
EMCD/Taubman Entrance	4.7/A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	-	-	-	-	34.3/D	-	10.7/B	27.6/D	-	-	-	-	-
EMCD/P2 Entrance	59.2/F	-	-	-	-	-	-	-	1170/F	-	1400/F	1171/F	-	-	-	-	-

**Signalized Intersection*

Table 15: Scenario 3 Queuing Results- AM Peak

INTERSECTION	AM PEAK HOUR QUEUE (FT)							
	Northbound		Southbound		Eastbound		Westbound	
	Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Fuller/Maiden Ln/EMCD	55	323	2559	3192	1821	2094	2136	3612
EMCD/West Medical Center	12	183	-	-	295	596	-	-
EMCD/Cancer Center*	40	281	30	163	3	72	-	-
EMCD/Nichols	0	54	0	43	1	33	1	50
EMCD/Psychiatric Emerg.	1	30	-	-	1	44	-	-
EMCD/Taubman Entrance	1	42	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	3	65	-	-
EMCD/P2 Entrance	7	127	-	-	0	45	-	-

**Signalized Intersection*

Table 16: Scenario 3 Queuing Results- PM Peak

INTERSECTION	PM PEAK HOUR QUEUE (FT)							
	Northbound		Southbound		Eastbound		Westbound	
	Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Fuller/Maiden Ln/EMCD	261	342	331	977	870	1705	3964	5126
EMCD/West Medical Center	111	210	-	-	511	590	-	-
EMCD/Cancer Center*	225	480	14	123	4	74	-	-
EMCD/Nichols	54	332	0	41	1	40	2	79
EMCD/Psychiatric Emerg.	0	27	-	-	10	123	-	-
EMCD/Taubman Entrance	0	54	-	-	-	-	-	-
EMCD/Taubman Exit	-	-	-	-	19	112	-	-
EMCD/P2 Entrance	9	123	-	-	112	165	-	-

**Signalized Intersection*

Table 17: Scenario 3 Pedestrian Service and Delay Results- AM Peak

INTERSECTION	AM PEAK PEDESTRIAN DELAY (S)															
	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD**	12	73	163	165	7	39	32	35	11	44	65	70	18	119	730	730
EMCD/West Medical Center	-	-	-	-	0	-	0	0	-	-	-	-	8	-	528	531
EMCD/Cancer Center*	14		64	70	15		81	84	-	-	-	-	17		576	579
EMCD/Nichols	0	-	0	3	0	-	0	3	0	-	0	3	14	-	48	52
EMCD/Psychiatric Emerg.	0	-	0	2	0	-	0	3	-	-	-	-	1	-	48	49
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	26	-	8	10
Taubman Mid-Block	-	-	-	-	34	-	24	30	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	22	-	57	63	-	-	-	-	1	-	24	27
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	10	-	8	13

**Signalized Intersection*

***NOTE: Roundabout crosswalks are controlled with a pedestrian hybrid beacon (PHB). Yield Column: Pedestrians cross once acceptable gap is available in vehicle stream, Free Column: Pedestrians cross only when PHB walk phase is called.*

Table 18: Scenario 3 Pedestrian Service and Delay Results- PM Peak

INTERSECTION	PM PEAK PEDESTRIAN DELAY (S)															
	North Leg				South Leg				East Leg				West Leg			
	Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals		Delay (s)		Ped. Totals	
	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand	Yield	Free	Serviced	Demand
Fuller/Maiden Ln/EMCD**	10	93	98	100	8	74	97	100	16	66	139	140	8	67	656	660
EMCD/West Medical Center	-	-	-	-	0	-	0	2	-	-	-	-	7	-	464	467
EMCD/Cancer Center*	44		73	73	34		192	199	-	-	-	-	55		416	419
EMCD/Nichols	10	-	8	9	0	-	0	0	7	-	16	19	8	-	40	40
EMCD/Psychiatric Emerg.	0	-	0	4	9	-	8	10	-	-	-	-	4	-	24	28
EMCD/Taubman Entrance	0	-	0	0	-	-	-	-	-	-	-	-	8	-	32	33
Taubman Mid-Block	-	-	-	-	24	-	72	79	-	-	-	-	-	-	-	-
EMCD/Taubman Exit	0	-	0	0	14	-	287	288	-	-	-	-	1	-	96	99
EMCD/P2 Entrance	0	-	0	0	0	-	0	0	-	-	-	-	37	-	24	27

**Signalized Intersection*

***NOTE: Roundabout crosswalks are controlled with a pedestrian hybrid beacon (PHB). Yield Column: Pedestrians cross once acceptable gap is available in vehicle stream, Free Column: Pedestrians cross only when PHB walk phase is called.*

Figure 2: Scenario 3 AM Peak Hour Modeling Screenshot

Figure 3: Scenario 3 PM Peak Hour Modeling Screenshot

SUMMARY & RECOMMENDATION

- The three scenarios tested do not adequately meet operational needs for both pedestrians and automobiles based on the results summarized. Additional PHB scenarios testing different lockout periods or PHB coordination options are not anticipated to meet the operational needs of both pedestrians and vehicles with the current geometric configuration of the Base Model.
- Of the three scenarios tested, Scenario 3 showed the best results for balancing delay between motorists and pedestrians and is the recommended PHB scenario to advance with the subsequent modeling groups.

Attachment #3

Previously Studied Grade Separated Crossing Alternatives

Pedestrian Underpass Study (DRAFT)

Fuller Road/Maiden Lane/East Medical Center Drive Improvement Project

Ann Arbor, Michigan

August 2013

Prepared by:

DLZ Michigan, Inc

For:

City of Ann Arbor

TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND

Purpose and Scope of Report

The City of Ann Arbor (City) has contracted with DLZ Michigan, Inc. (DLZ) to study and design for improvements to the intersection at Fuller Road, Maiden Lane and Medical Center Drive (referred to as the "project intersection" in this report). The project is intended to address traffic congestion and safety concerns at this intersection. Traffic and pedestrian congestion at the intersection is expected to worsen substantially in the future due to anticipated volume growth.

The intersection improvement engineering work is comprised of two major parts: the study phase and the design phase. The study phase includes review of the previous studies performed at the intersection and surrounding areas, analysis of vehicular and pedestrian traffic operations, and evaluation of evaluation of proposed design options for the intersection. The design phase will focus on implementation of the chosen study alternative through design plans and specifications for construction. In addition to this report, the DLZ team has also prepared a separate report entitled the *Preliminary Technical Memo* (DLZ 2013) which provides considerable background information on other parts of the study.

This report focuses on one important element of the study phase which is pedestrian access at the intersection. This report assesses the technical feasibility and characteristics of various options for pedestrian access, with a primary focus upon pedestrian underpasses using the three existing bridges that are adjacent to the project intersection. The project intersection is at a relatively high elevation compared to the immediate surroundings, with a bridge to the north spanning the Huron River, and bridges to the south and west spanning railroad tracks. The east leg of the intersection slopes downgrade away from the intersection to match the existing elevation of the surrounding Fuller Park. The intersection is currently signalized with at-grade pedestrian crosswalks across each leg. There are sidewalk facilities along both sides of each intersection approach and along both sides of the roadway across each of the bridges in the project area.

The three roadway bridges near the intersection were designed and built in the early 1980s. Modifications/widenings to the bridge structures are not intended to be part of the intersection improvement project. Each of the bridges was designed and constructed to eventually accommodate pedestrian pathways routed under the bridges (referred to in this report as "underpasses"). The City is planning to rehabilitate these three bridges in 2015 or 2016. As currently scoped, the rehabilitation project will not add any width to the structures, and therefore will have no capacity implications on the intersection. Ideally the City would like to construct the Fuller Road & East Medical Center Drive/Maiden Lane intersection improvements at the same time as the bridge rehabilitation is completed. However, since funding for the intersection is not yet secured, this may not be possible.

Previous Studies and Plans

There have been several studies and plans produced for this intersection and surrounding area including non-motorized plans, parks and recreation plans, trail system plans, and development plans. The following are brief summaries of applicable studies and plans concerning pedestrian mobility in the project area.

- **Washtenaw County Parks and Recreation Commission Border-to-Border Trail – Washtenaw County 2007 –** This is a partially constructed trail way that is proposed to span 35 miles across Washtenaw County from Livingston County to Wayne County along the Huron River. A segment of the proposed trail was planned to run along the east side of the Huron River and along the north side of the railroad tracks under the three bridges located near the project intersection. The three bridges were constructed with accommodations for this proposed future pathway.
- **City of Ann Arbor Non-Motorized Plan – Ann Arbor 2006 –** The City of Ann Arbor created a comprehensive non-motorized plan in 2006. The plan details the general guidelines for the development of non-motorized facilities in the City and provides detailed design guidance for non-motorized features to be included in future roadway and land development in the City. The plan recognizes the proposed trail way under the bridges near the project intersection (included as part of the Washtenaw County Border-to-Border Trail).
- **City of Ann Arbor Parks, Recreation and Open Space Plan – Ann Arbor 2011-2015 –** This is the City's plan for the long term development of park lands within the City. This plan recognizes the proposed trail way under the project intersection bridges (included as part of the Washtenaw County Border-to-Border Trail).
- **City of Ann Arbor Bikeway System Map – Ann Arbor 2005 –** A cooperative effort by bicycle advocacy groups and the City of Ann Arbor. This plan recognizes the proposed trail way under the project intersection bridges (included as part of the Washtenaw County Border-to-Border Trail).
- **City of Ann Arbor Intermodal Transportation Station Phase 1 Traffic and Pedestrian Study – JJR 2009** – This study was initiated by the City of Ann Arbor to evaluate the impact of known developments in the vicinity of the project intersection. The study briefly touches upon improvement options at the intersection to address future development traffic demands. A roundabout is shown to be the recommended improvement alternative, and pedestrian access is described as an important factor in the future operations of the intersection. The study states that whether or not a roundabout is constructed at the project intersection, finding alternate routes for pedestrians to cross at the project intersection (other than at-grade) would be beneficial.

Proposed Intersection Improvements

The intersection has been the focus of numerous studies over the past several years. The results of these studies indicate that a roundabout is the likely configuration that would be constructed at the intersection. The intersection has been analyzed to determine what configuration of roundabout will be required. It has been determined that two-lane entries are needed at all four approaches and exits. It has also been determined that a by-pass lane will be needed for the east leg of the intersection, and additional bypass lanes may be required at other approaches (See Figure 1). Pedestrian Hybrid Beacon (PHB) signals have been recommended for the at-grade pedestrian crossings.

At-grade pedestrian crossings will reduce the vehicular capacity and operations of the roundabout to some degree. Construction of pedestrian facilities under the existing bridges could allow for elimination of all or some of the at-grade pedestrian crossings. This would improve the function of the project intersection for vehicles, but would increase the travel time and distance for pedestrians.

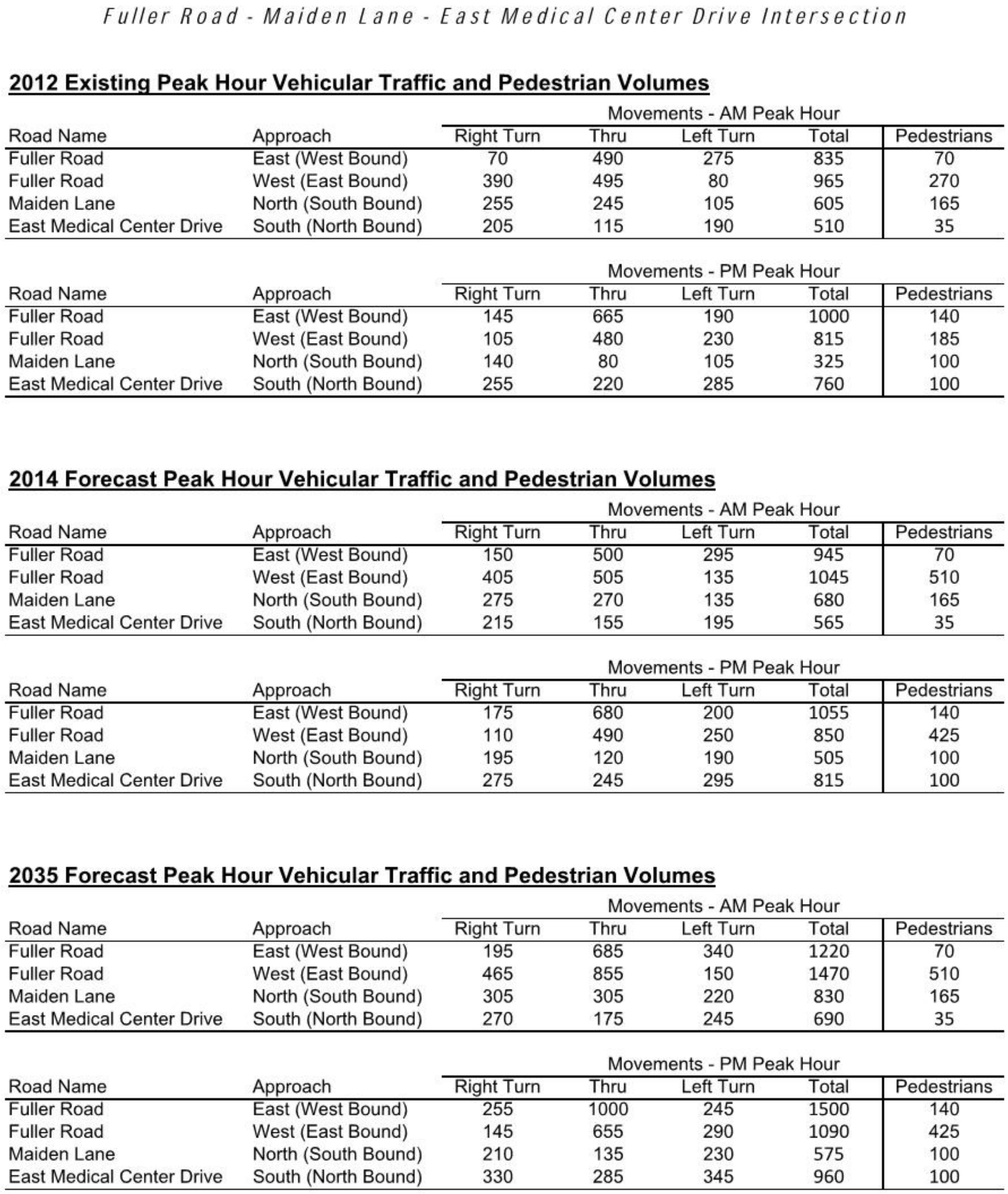
Figure 1: Proposed Roundabout Geometrics

Pedestrian Routes and Volumes

Origins and Destinations – The major movements for pedestrians through the project intersection are from the north and east through the intersection to the south and west. Some of the origins and destinations involved in these movements are parking and residential areas to the north and east, and U of M Medical Center and to Downtown Ann Arbor to the south and west. There is also Fuller Park and Pool to the east that serves as another destination for pedestrians traveling from the west. The City is in the process of determining the location and configuration for the “Ann Arbor Station,” an intermodal transportation station. One potential location under consideration for the station is in the southeast quadrant of the project intersection. If eventually constructed at that location, this facility would become a pedestrian origin and destination. There is a large development, Broadway Village, being planned to north of the intersection along Maiden Lane. The proposed development would include approximately 150,000 square feet of medical and office space, 138,000 square feet of retail space and 185 apartments.

As part of the current study, the City of Ann Arbor has provided existing, opening day (year 2014) and future (year 2035) pedestrian and automobile volumes for the AM and PM peak hours at the project intersection (Table 1). The west and north legs of the intersection have the most pedestrian traffic.

Table 1: Auto and Pedestrian Volumes



Fuller Road - Maiden Lane - East Medical Center Drive Intersection

2012 Existing Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	70	490	275	835	70
Fuller Road	West (East Bound)	390	495	80	965	270
Maiden Lane	North (South Bound)	255	245	105	605	165
East Medical Center Drive	South (North Bound)	205	115	190	510	35

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	145	665	190	1000	140
Fuller Road	West (East Bound)	105	480	230	815	185
Maiden Lane	North (South Bound)	140	80	105	325	100
East Medical Center Drive	South (North Bound)	255	220	285	760	100

2014 Forecast Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	150	500	295	945	70
Fuller Road	West (East Bound)	405	505	135	1045	510
Maiden Lane	North (South Bound)	275	270	135	680	165
East Medical Center Drive	South (North Bound)	215	155	195	565	35

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	175	680	200	1055	140
Fuller Road	West (East Bound)	110	490	250	850	425
Maiden Lane	North (South Bound)	195	120	190	505	100
East Medical Center Drive	South (North Bound)	275	245	295	815	100

2035 Forecast Peak Hour Vehicular Traffic and Pedestrian Volumes

		Movements - AM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	195	685	340	1220	70
Fuller Road	West (East Bound)	465	855	150	1470	510
Maiden Lane	North (South Bound)	305	305	220	830	165
East Medical Center Drive	South (North Bound)	270	175	245	690	35

		Movements - PM Peak Hour				
Road Name	Approach	Right Turn	Thru	Left Turn	Total	Pedestrians
Fuller Road	East (West Bound)	255	1000	245	1500	140
Fuller Road	West (East Bound)	145	655	290	1090	425
Maiden Lane	North (South Bound)	210	135	230	575	100
East Medical Center Drive	South (North Bound)	330	285	345	960	100

EXISTING PEDESTRIAN FACILITIES

Intersection

The existing intersection is under traffic signal control and has pedestrian crosswalks across each leg. There are sidewalks along each side of all legs of the intersection. These sidewalks extend across the bridges on the north, south, and west legs of the intersection. The existing crosswalks have pedestrian signals with push-button activation. See Figure 2 for the existing intersection configuration.

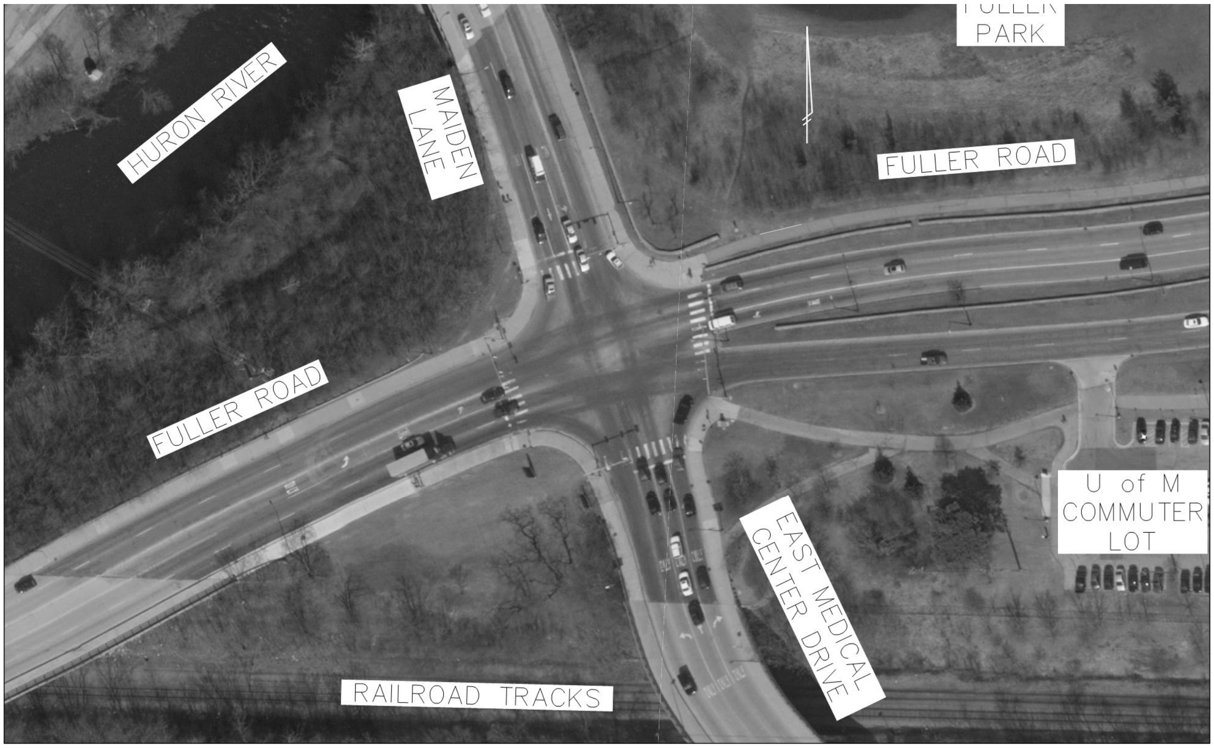


Figure 2: Existing Intersection

Bridges

The three existing bridges were each constructed in the early 1980s and include sidewalk facilities on each side of the superstructures over the Huron River and the railroad tracks. The bridges were constructed to accommodate pedestrian underpasses between the bridge piers and the slope paving. For the East Medical Center Drive and Fuller Road bridges, the pedestrian underpass facilities are located between the northern piers and the northern slope paving/abutments. These locations could serve a trail running along the north side of the railroad tracks. The available area for pedestrian facilities under the Maiden Lane bridge is located between the southern/eastern pier and the southern/eastern sidewalls/abutments. This location could serve a trail running along the southern/eastern shore of the Huron River. The areas available for pedestrian paths are generally 10’ to 15’ wide. Figures 3, 4, and 5 show the original construction plans for the thre bridges with highlighting of the areas available for pedestrian facilities.

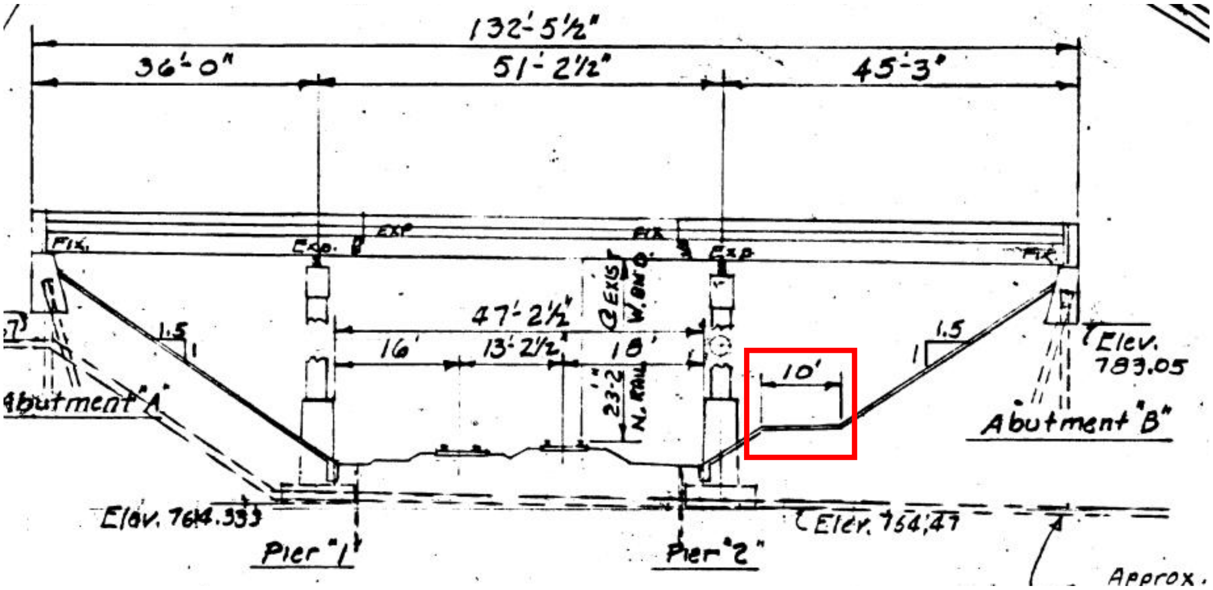


Figure 3: East Medical Center Drive over Railroad (1982 plans)

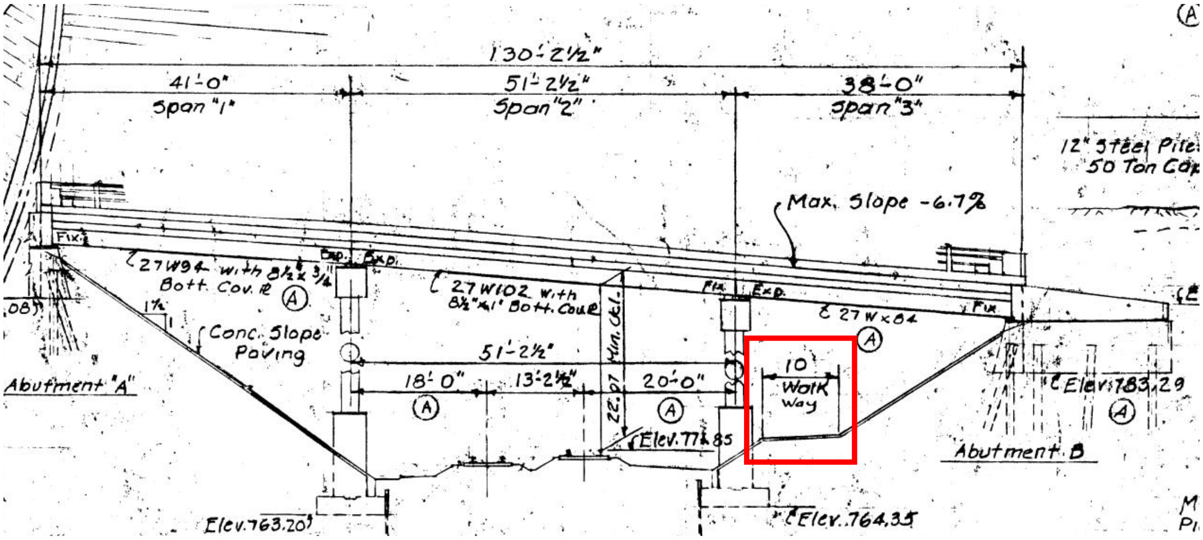


Figure 4: Fuller Road over Railroad (1982 plans)

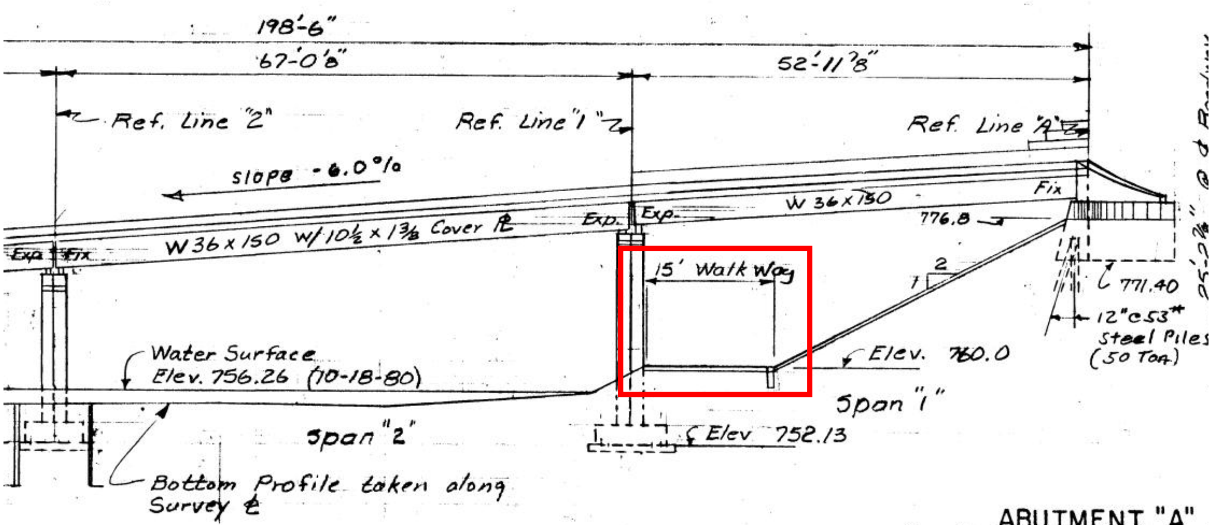


Figure 5: Maiden Lane over Huron River (1982 plans)

Pedestrian Mobility

The existing intersection was analyzed to identify a baseline with regards to pedestrian mobility. This included measuring the total distance that pedestrians currently travel for various movements through the intersection. Each leg of the intersection was assigned two origin and destination locations on either side of the roadway at the approximate construction limits of the proposed intersection improvement. This results in eight (8) total pedestrian movements that can be measured for existing conditions and the various alternatives under consideration. Figure 6 shows the potential pedestrian routes and nodes for the existing intersection configuration. Table 2 presents a summary of pedestrian travel distances for the various existing node combinations. Based on these potential pedestrian routes, the combined travel distance (adding each movement together) is 17,491 ft. The longest pedestrian movements are along Fuller Rd, particularly crossing from the north to south side and vice-versa.

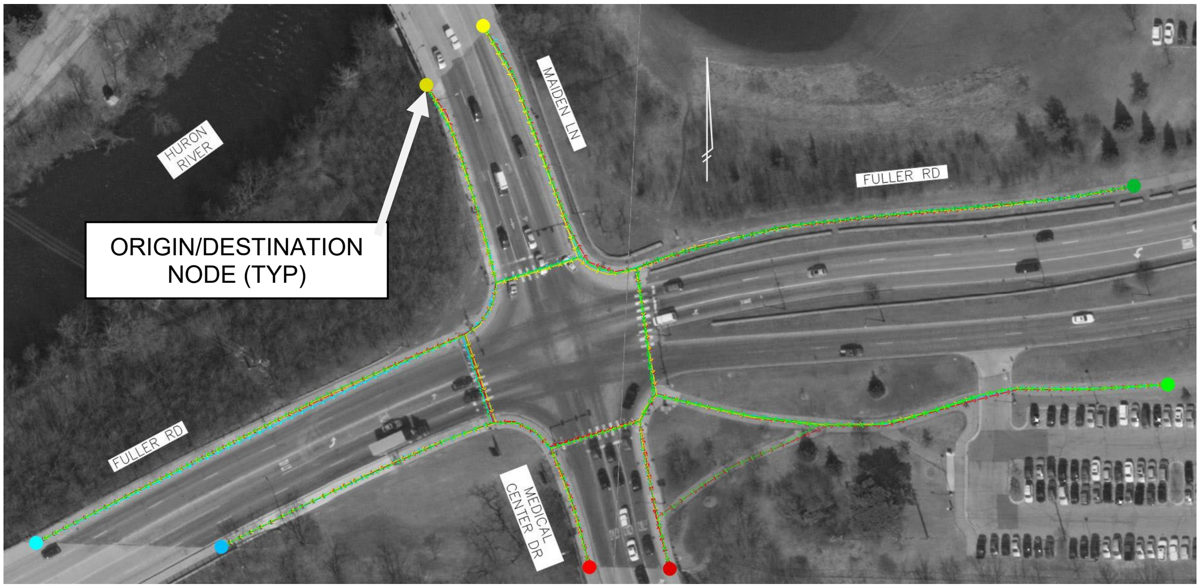


Figure 6: Origin and Destination Node Locations for Existing Intersection

Table 2: Pedestrian Travel Distances for Existing Intersection

EXISTING PEDESTRIAN MOBILITY			STREET	FULLER	FULLER	E MED CNTR	E MED CNTR	FULLER	FULLER	MAIDEN LN	MAIDEN LN
			LEG	W	W	S	S	E	E	N	N
			SIDE	N	S	W	E	N	S	W	E
STREET	LEG	SIDE	TO								
FULLER	W	N	WALKING DISTANCE	(FT)							
FULLER	W	S		668							
E MED CNTR	S	W		585	379						
E MED CNTR	S	E		678	472	287					
FULLER	E	N		986	869	684	631				
FULLER	E	S		924	781	597	459	893			
MAIDEN LN	N	W		570	516	433	524	670	777		
MAIDEN LN	N	E		681	614	532	479	635	742	425	

ROUNDABOUT WITH AT-GRADE PEDESTRIAN CROSSINGS

Studies of the intersection suggest that at-grade pedestrian crossings at the roundabout will likely include PHB signals (See the *Preliminary Technical Memo*, DLZ 2013). If implemented, PHB signals would result in pedestrian crossing configurations similar to those shown in Figure 7. Table 3 presents a summary of pedestrian travel distances for the various node combinations for this option. Based on these potential pedestrian routes, the combined travel distance (adding each movement together) is 17,714 ft, or 223 feet more than the existing total distance. The longest pedestrian movements are along Fuller Rd, particularly crossing from the north to south side and vice-versa. The approximate planning level construction cost associated with installing a sidewalk and crosswalk network with pedestrian signals would be approximately $550,000. This includes the sidewalk around the roundabout and across each splitter island and 9 pedestrian signal installations. This cost is the baseline against which other options will be compared.

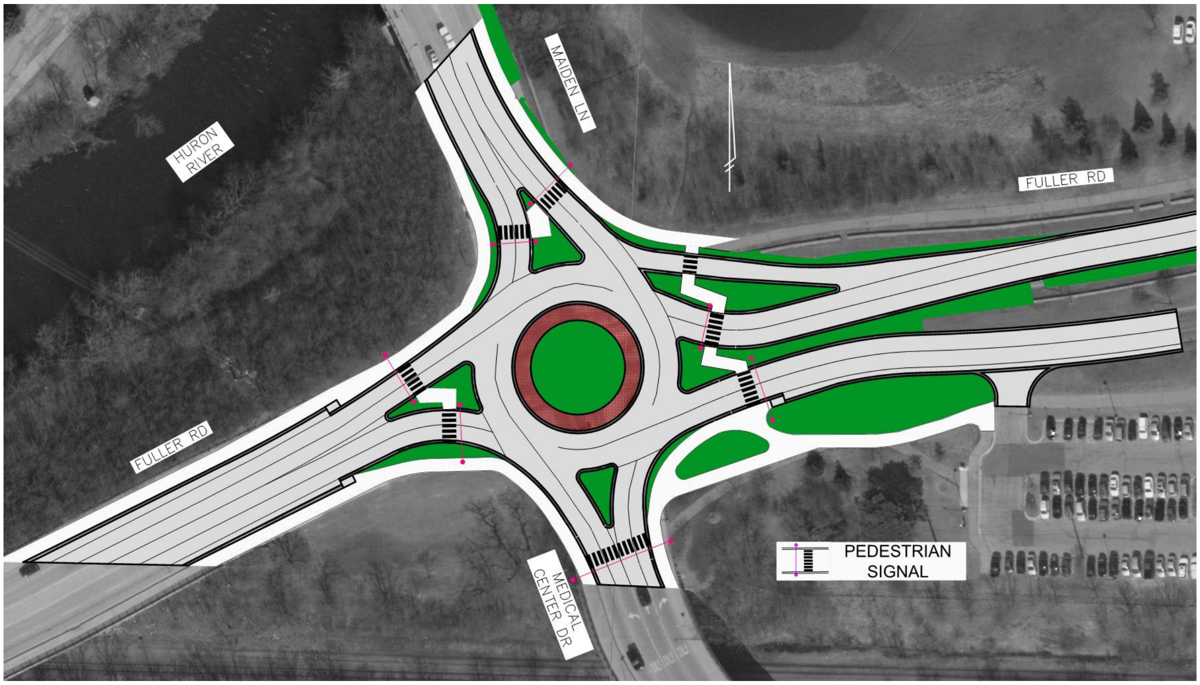
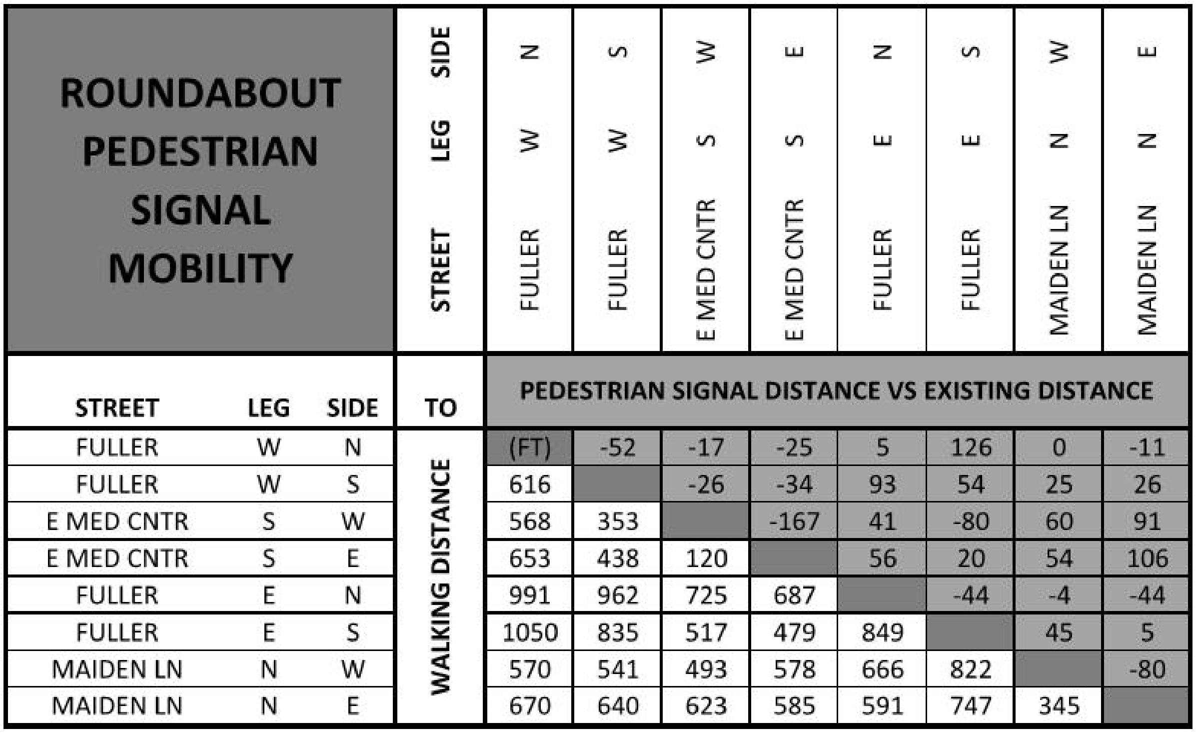


Figure 7: Roundabout with At-Grade Pedestrian Crossings

Table 3: Pedestrian Travel Distances for At-Grade Crossings at Roundabout (including change relative to existing intersection)



ROUNDABOUT PEDESTRIAN SIGNAL MOBILITY			STREET	FULLER	FULLER	E MED CNTR	E MED CNTR	FULLER	FULLER	MAIDEN LN	MAIDEN LN
			LEG	W	W	S	S	E	E	N	N
			SIDE	N	S	W	E	N	S	W	E
STREET	LEG	SIDE	TO	PEDESTRIAN SIGNAL DISTANCE VS EXISTING DISTANCE							
FULLER	W	N	WALKING DISTANCE	(FT)	-52	-17	-25	5	126	0	-11
FULLER	W	S		616		-26	-34	93	54	25	26
E MED CNTR	S	W		568	353		-167	41	-80	60	91
E MED CNTR	S	E		653	438	120		56	20	54	106
FULLER	E	N		991	962	725	687		-44	-4	-44
FULLER	E	S		1050	835	517	479	849		45	5
MAIDEN LN	N	W		570	541	493	578	666	822		-80
MAIDEN LN	N	E		670	640	623	585	591	747	345	

PEDESTRIAN UNDERPASS ALTERNATIVES

General Information

The existing pedestrian facilities are located at the same elevation as the existing roadways and bridges over the railroad tracks and the Huron River. In order to utilize existing bridge underpasses to convey pedestrians through the intersection, it would be necessary to design a sidewalk/path network with ADA-compliant ramps to connect the underpass sidewalks with the sidewalks along each roadway. Stairs could also be included as a supplement to the ramps to provide a more direct connection. Current ADA guidelines require that ramp grades do not exceed 1:12 or 8.33%. The ramps must have a 5' landing of no more than 2% grade spaced at every 30'. The elevation differential that needs to be addressed for each of the bridges is approximately 20' vertically (this is from the sidewalks along existing roads to the bridge underpasses). The approximate length of ramp required to negotiate this grade change is approximately 240' in total. Figures 8, 9, and 10 show possible ramp configurations which could be implemented, depending on a variety of criteria.

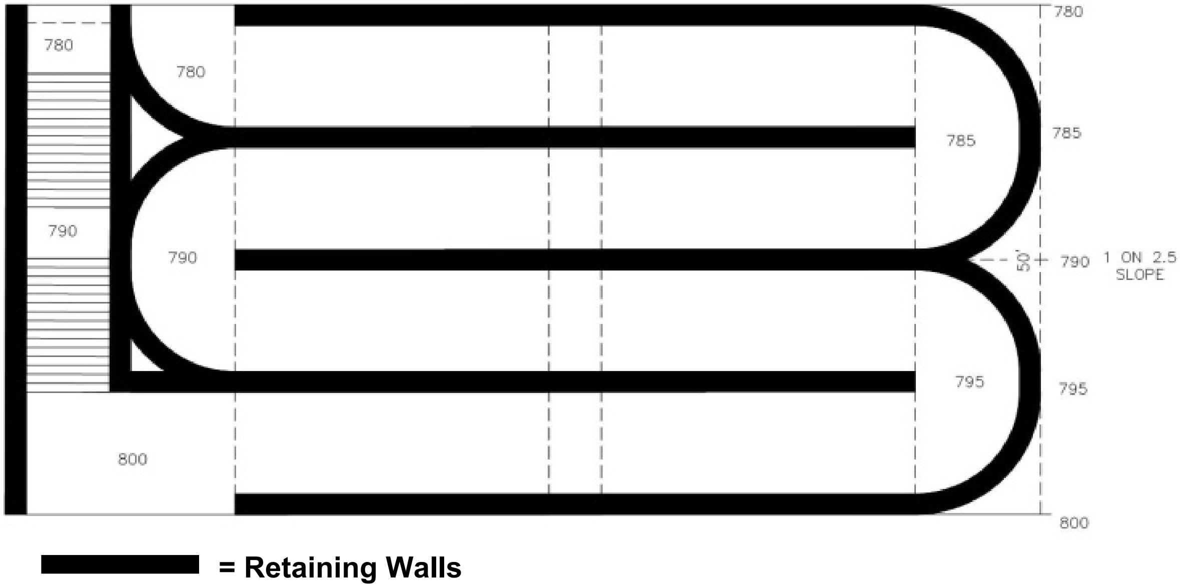


Figure 8: Case 1 Example Ramp Configuration

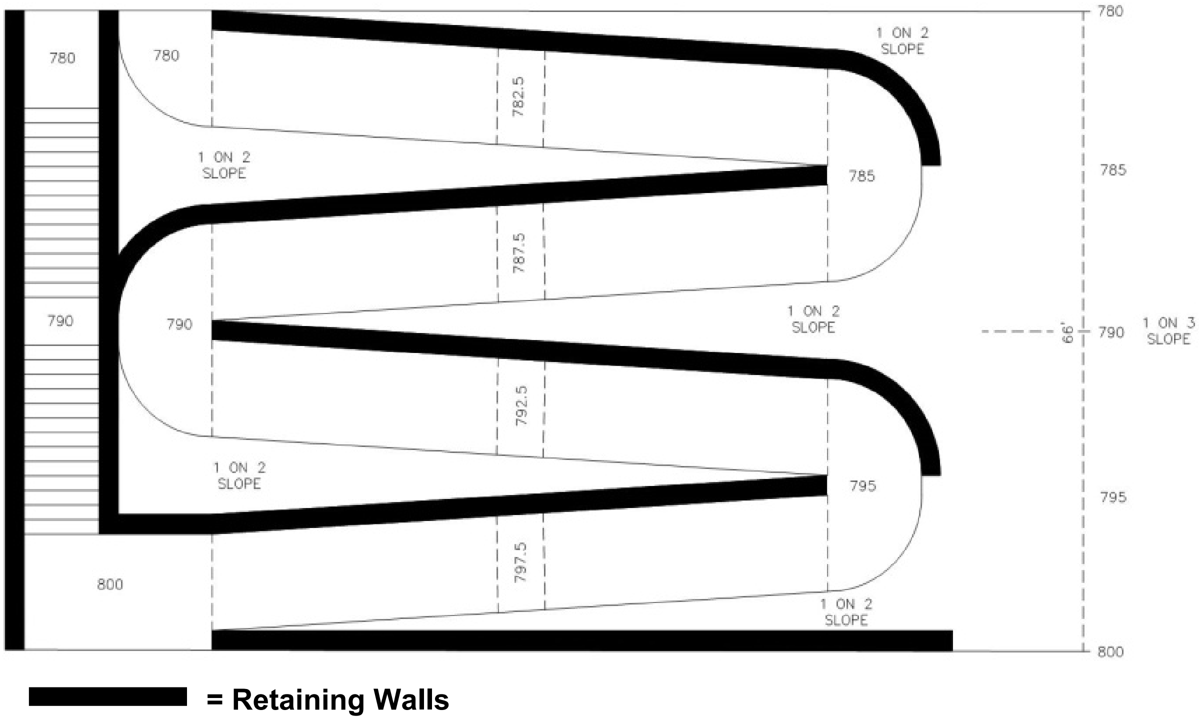


Figure 9: Case 2 Example Ramp Configuration

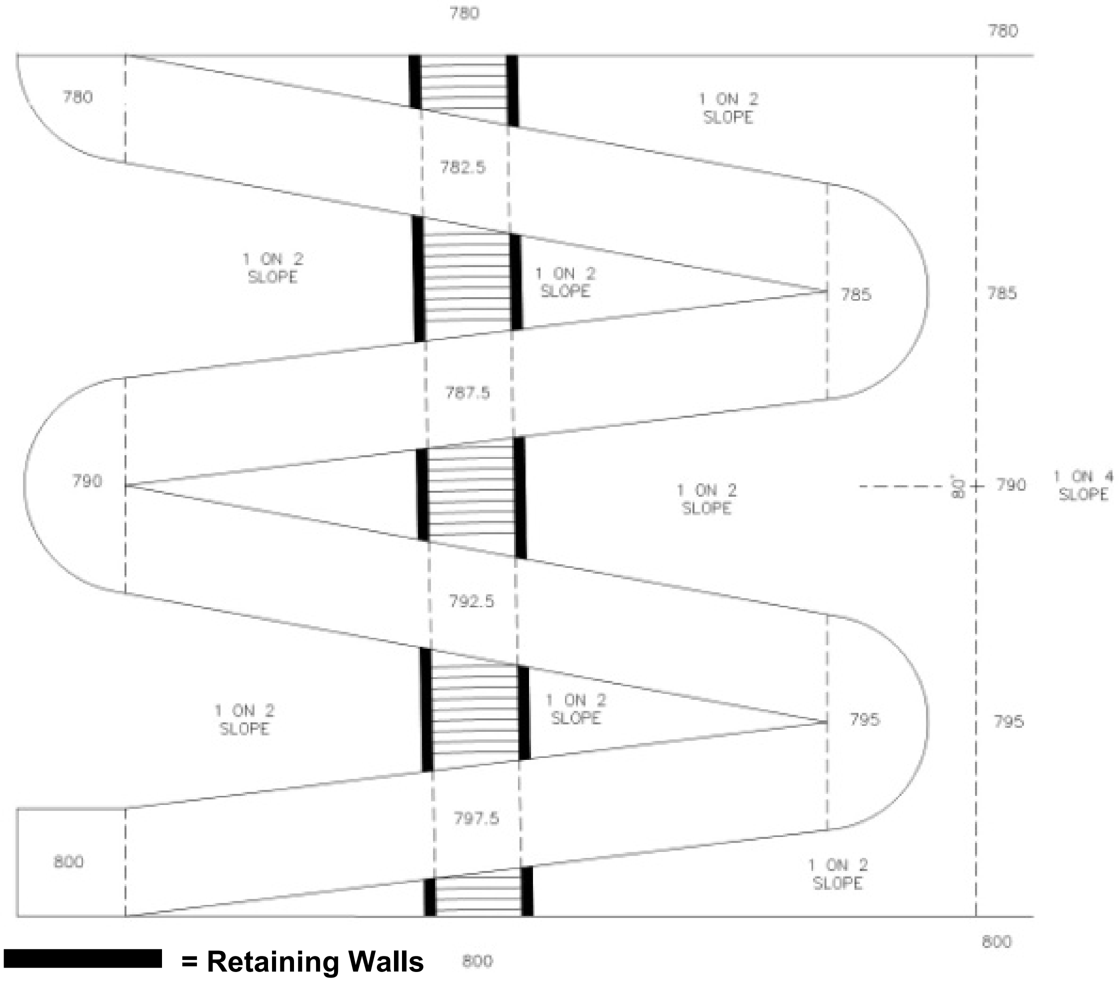


Figure 10: Case 3 Example Ramp Configuration

Underpass Alternative 1

The first pedestrian underpass alternative analyzed assumes that there would be no at-grade crossings at the intersection for the north, west and south legs of the intersection. There would be a Z-style crosswalk across the east leg located approximately 200' from the roundabout. Ramps and stairs would be constructed as close as possible to each of the bridges to minimize the extra distance that pedestrians would need to travel to reach their intended destination. Figure 11 shows the likely layout of this alternative.

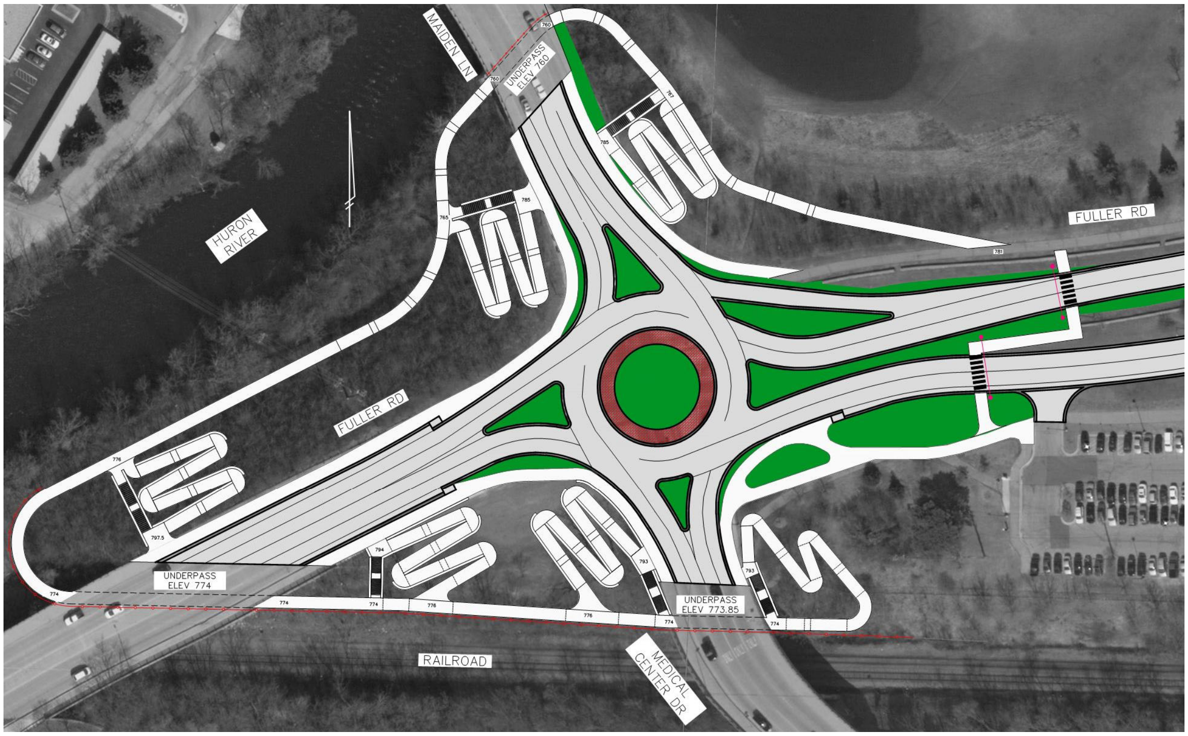


Figure 11: Underpass Alternative 1

Pedestrians would utilize the underpass facilities for crossing the west leg of Fuller Road, Maiden Lane, and East Medical Center Drive. Table 4 presents a summary of pedestrian travel distances for the various node combinations for this alternative. For this alternative, the combined pedestrian travel distance (adding each movement together) is 24,292 ft, or 6,801 feet more than the existing total distance. The approximate planning level construction cost associated with alternative 1 would be $1,130,000. This includes the sidewalk around the roundabout, ramp and stair structures, retaining walls as necessary, fencing along the railroad right-of-way and at each underpass, and additional lighting for those areas not illuminated by lighting at the intersection. This alternative could be linked to the border-to-border trail system or other paths/trails in the vicinity. It is possible that negotiations would need to be undertaken to secure an easement or similar agreement to locate the trail in the railroad right-of-way.

Table 4: Pedestrian Travel Distances for Underpass Alternative 1 (including change relative to existing intersection)

UNDERPASS ALT 1 PEDESTRIAN MOBILITY			STREET	FULLER	FULLER	E MED CNTR	E MED CNTR	FULLER	FULLER	MAIDEN LN	MAIDEN LN
			LEG	W	W	S	S	E	E	N	N
			SIDE	N	S	W	E	N	S	W	E
STREET	LEG	SIDE	TO	UNDERPASS ALT 1 DISTANCE VS EXISTING DISTANCE							
FULLER	W	N	WALKING DISTANCE	(FT)	-43	274	245	252	458	0	202
FULLER	W	S		625		57	28	239	178	515	703
E MED CNTR	S	W		859	436		-37	174	112	831	720
E MED CNTR	S	E		923	500	250		-3	20	804	544
FULLER	E	N		1238	1108	858	628		-375	224	-43
FULLER	E	S		1382	959	709	479	518		438	170
MAIDEN LN	N	W		570	1031	1264	1328	894	1215		114
MAIDEN LN	N	E		883	1317	1252	1023	592	912	539	

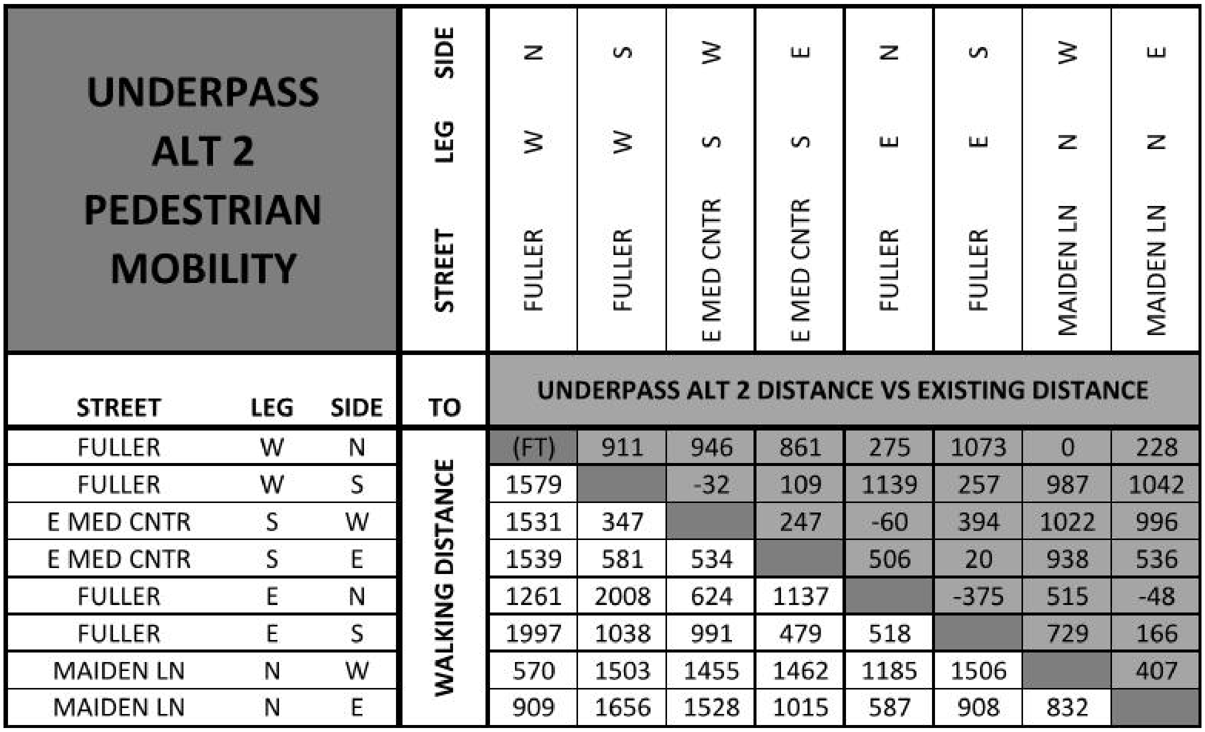
Underpass Alternative 2

The second pedestrian underpass alternative analyzed assumes that there will be no at-grade crossings at the intersection for the north, west and south legs of the intersection. There will be a Z-style crosswalk across the east leg located approximately 200’ from the roundabout. Ramps and stairs would be constructed to provide access for pedestrians to the proposed underpasses for crossing the north, west, and south legs. Only one ramp/stair facility will be constructed in the northwest and southwest quadrants to reduce construction costs, at the expense of increased pedestrian travel time. Figure 12 shows the likely layout of this alternative.

Figure 12: Underpass Alternative 2

Pedestrians would utilize the underpass facilities for crossing the west leg of Fuller Road, Maiden Lane, and East Medical Center Drive. Table 5 presents a summary of pedestrian travel distances for the various node combinations for this alternative. For this alternative, the combined pedestrian travel distance (adding each movement together) is 31,280 ft, or 13,789 feet more than the existing total distance. The approximate planning level construction cost associated with Alternative 2 would be $560,000. This includes the sidewalk around the roundabout, ramp and stair structures, retaining walls as necessary, fencing along the railroad right-of-way and at each underpass, and additional lighting for those areas not illuminated by lighting at the intersection. This alternative could be linked to the border-to-border trail system or other paths/trails in the vicinity. It is possible that negotiations would need to be undertaken to secure an easement or similar agreement to locate the trail in the railroad right-of-way.

Table 5: Pedestrian Travel Distances for Underpass Alternative 2 (including change relative to existing intersection)



UNDERPASS ALT 2 PEDESTRIAN MOBILITY			STREET	FULLER	FULLER	E MED CNTR	E MED CNTR	FULLER	FULLER	MAIDEN LN	MAIDEN LN
			LEG	W	W	S	S	E	E	N	N
			SIDE	N	S	W	E	N	S	W	E
STREET	LEG	SIDE	TO	UNDERPASS ALT 2 DISTANCE VS EXISTING DISTANCE							
FULLER	W	N	WALKING DISTANCE	(FT)	911	946	861	275	1073	0	228
FULLER	W	S		1579		-32	109	1139	257	987	1042
E MED CNTR	S	W		1531	347		247	-60	394	1022	996
E MED CNTR	S	E		1539	581	534		506	20	938	536
FULLER	E	N		1261	2008	624	1137		-375	515	-48
FULLER	E	S		1997	1038	991	479	518		729	166
MAIDEN LN	N	W		570	1503	1455	1462	1185	1506		407
MAIDEN LN	N	E		909	1656	1528	1015	587	908	832	

ANALYSIS OF PRIMARY ROUTES

Projected future pedestrian volumes for the intersection indicate that three potential routes could account for the majority of the pedestrian travel through the intersection. These routes include:

- Route #1 - Along the north side of Fuller Rd across the intersection.
- Route #2 - Along the west side of Maiden Lane across the intersection to the west side of East Medical Center Drive.
- Route #3 - Along the east side of Maiden Lane to the north side of Fuller Rd west of the intersection.

Each of these potential routes has been analyzed in more detail below.

Route #1 - North Side along Fuller Road

The existing distance that a pedestrian travels along this route is 986 ft, crossing Maiden Lane at the existing traffic signal. If the roundabout was constructed with at-grade pedestrian crosswalks, the distance would be increased to 991 ft, or 5 ft more than existing. With Underpass Alternative #1, a pedestrian would need to travel north along Maiden Lane, under the Maiden Lane bridge, and back to the west leg of Fuller Road. The travel distance would be 1238 ft, or an increase of 252 ft from existing. If the roundabout was constructed with Underpass Alternative #2, a pedestrian would travel a path similar to Underpass Alternative #1, and would travel a distance of 1261 ft, for an increase of 275 ft from existing.

Route #2 - West Side along Maiden Lane to East Medical Center Drive

The existing distance that a pedestrian travels along this route is 681 ft, crossing Maiden Lane at the existing traffic signal. If the roundabout was constructed with at-grade pedestrian crosswalks, the distance would be decreased to 6701 ft, or 11 ft less than existing. If the roundabout was constructed with Underpass Alternative #1, the travel distance would be 883 ft, or an increase of 202 ft from existing. If the roundabout was constructed with Underpass Alternative #2, a pedestrian would travel a path similar to underpass alternative #1, and would need to travel a distance of 909 ft, for an increase of 230 ft from existing.

Route #3 - East Side along Maiden Lane to the North Side of Fuller Road West of the Intersection

The existing distance that a pedestrian travels along this route is 433 ft, crossing Fuller Road at the existing traffic signal. If the roundabout was constructed with at-grade pedestrian crosswalks, the distance would be increased to 493 ft, or 60 ft more than existing. If the roundabout was constructed with Underpass Alternative #1, a pedestrian would travel a distance of 1264 ft, or an increase of 831 ft above existing. If the roundabout was constructed with Underpass Alternative #2, a pedestrian would travel a path similar to Underpass Alternative #1, and would cover a distance of 1455 ft, for an increase of 1022 ft from existing.

CONCLUSIONS AND RECOMMENDATIONS

Based on the information and analysis presented in this report, the DLZ Team has developed the following preliminary conclusions for consideration by the City of Ann Arbor. Please note that these conclusions are draft only and subject to change based on input and direction from the City.

1. Technical Feasibility of Underpasses – Underpasses are technically feasible and could be constructed at each of the three bridges adjacent to the intersection. These could be designed in such a way that they comply with current design standards.
2. Compliance with ADA/Accessibility – All facilities that are evaluated in this report would be ADA compliant, and facilities would be consistent with best practices for accessibility, including PROWAG.
3. Construction Cost – Construction costs for the at-grade crossings (with PHB signals) and Underpass Alternative 2 would be similar at $550,000 to $560,000. Underpass Alternative #1 would cost approximately $1,130,000 to construct.
4. Bicycle Facilities – At roundabouts, on-street bicycle lanes should be transitioned onto multi-use paths via ramps in the vicinity of the intersection, consistent with NCHRP 672. Bicycles should be discouraged from traversing the roundabout on the roadway. For Underpass Alternatives 1 and 2, the result would be that bicycles would likely be using the switchback ramps and underpasses. This could be considered a negative characteristic for these two options.
5. Travel Distance – due to the increased travel distances associated with Underpass Alternatives 1 and 2, it is not clear whether such facilities would be used by most pedestrians in lieu of crossing the intersection at grade. Instead, pedestrians may choose to cross at-grade at various unmarked/undesignated locations. While landscaping and other barriers can be used to discourage such crossings, it may be difficult to significantly reduce their frequency. If this were to occur, pedestrian safety and automobile operations at the intersection could be affected.
6. Additional Options/Studies – The City could consider performing a more detailed comparison among various options for accommodating pedestrians. In addition to the options noted in this report, other options could include grade separations using new tunnels, grade separations using an overpass structure, or some combination of these elements. The combination approach would focus on removing pedestrians from the west leg of the intersection where traffic analyses show there is the most potential benefit.
7. Connections to other Planned Non-Motorized Facilities – The pedestrian underpasses evaluated in this report could be connected to other pedestrian trails in the vicinity including the border-to-border trail.
8. Railroad Right-of-Way - It is possible that negotiations would need to be undertaken to secure an easement or similar agreement to locate the trail in the railroad right-of-way.
9. Pedestrian Safety – Any underpass option that is considered in more detail should include coordination with public safety officials and planning for security measures to assure protection for users of the facility.

10. Main Routes – For the more heavily traveled pedestrian crossings at the intersection, Underpass Alternatives 1 and 2 would add similar additional travel distances.

APPENDICES

1. **PEDESTRIAN ACCOMMODATION ALTERNATIVES**
   A. EXISTING CONDITIONS
   B. ROUNDABOUT WITH AT GRADE CROSSINGS
   C. ROUNDABOUT WITH UNDERPASS ALTERNATIVE 1
   D. ROUNDABOUT WITH UNDERPASS ALTERNATIVE 2

2. **PEDESTRIAN MOBILITY**
   A. EXISTING CONDITIONS
   B. ROUNDABOUT WITH AT GRADE CROSSINGS
   C. ROUNDABOUT WITH UNDERPASS ALTERNATIVE 1
   D. ROUNDABOUT WITH UNDERPASS ALTERNATIVE 2

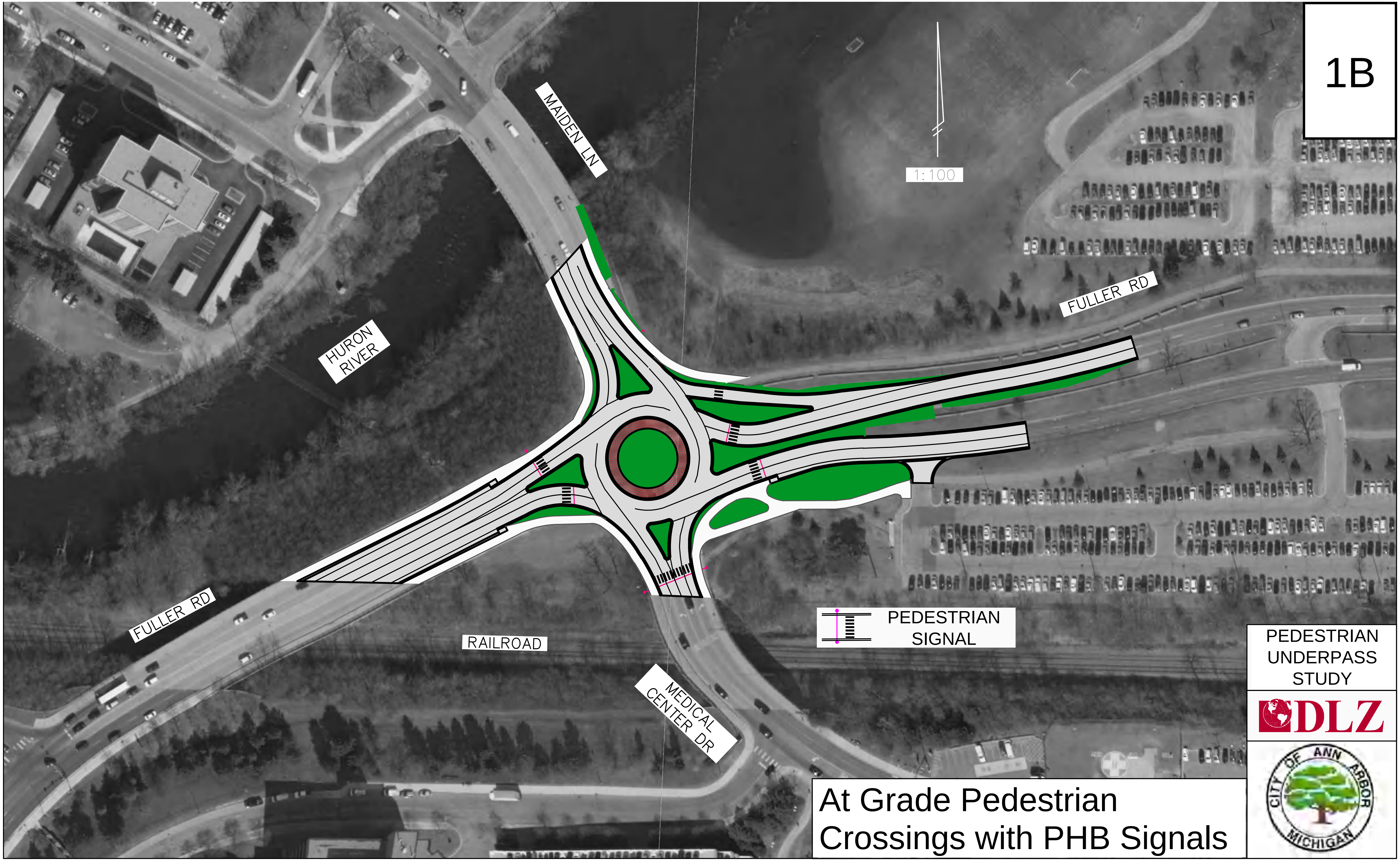
3. **PLANNING LEVEL COST ESTIMATES**
   A. ROUNDABOUT WITH AT GRADE CROSSINGS
   B. ROUNDABOUT WITH UNDERPASS ALTERNATIVE 1
   C. ROUNDABOUT WITH UNDERPASS ALTERNATIVE 2

1A

PEDESTRIAN UNDERPASS STUDY

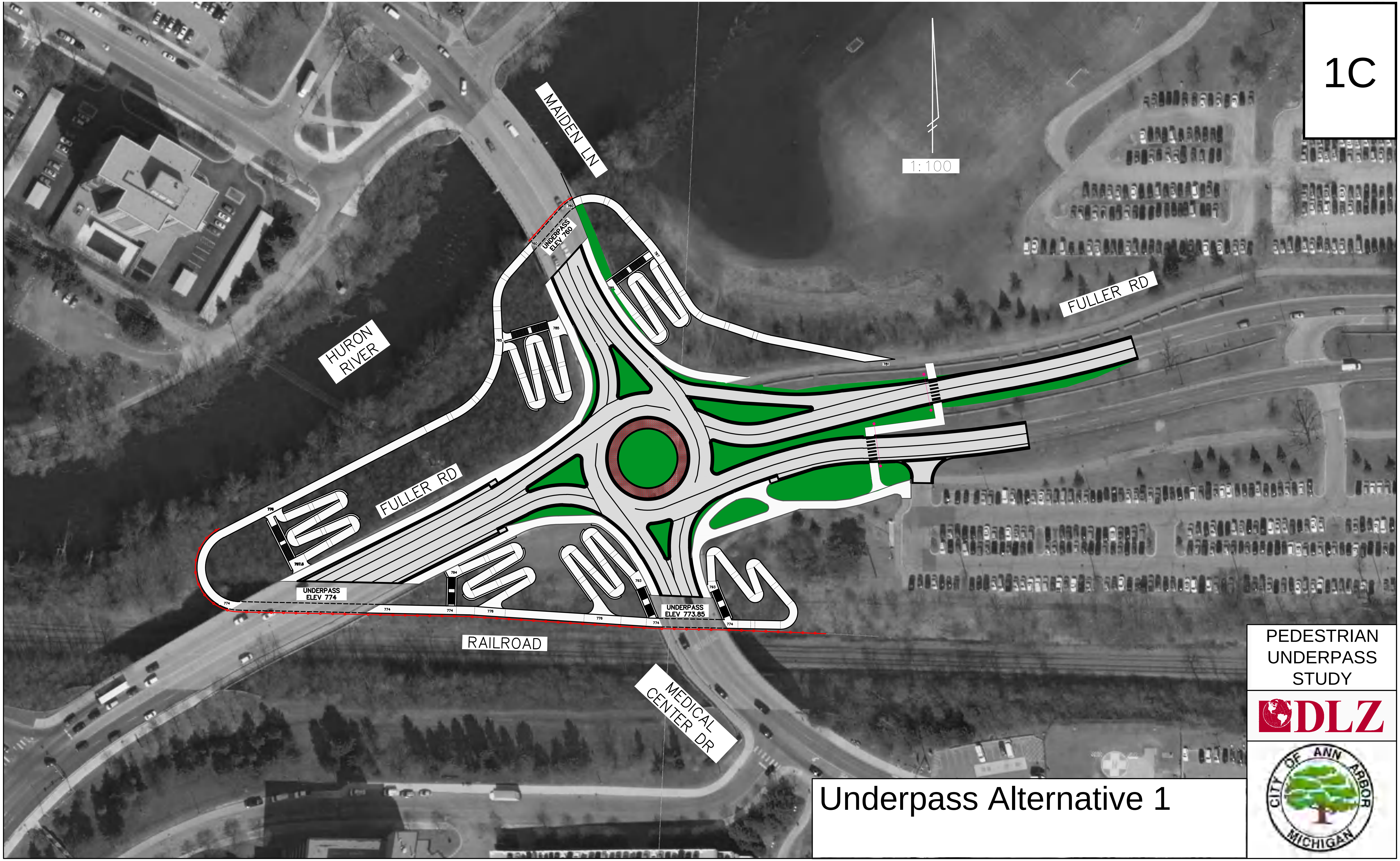
EXISTING PEDESTRIAN FACILITIES

1B



PEDESTRIAN UNDERPASS STUDY

At Grade Pedestrian Crossings with PHB Signals



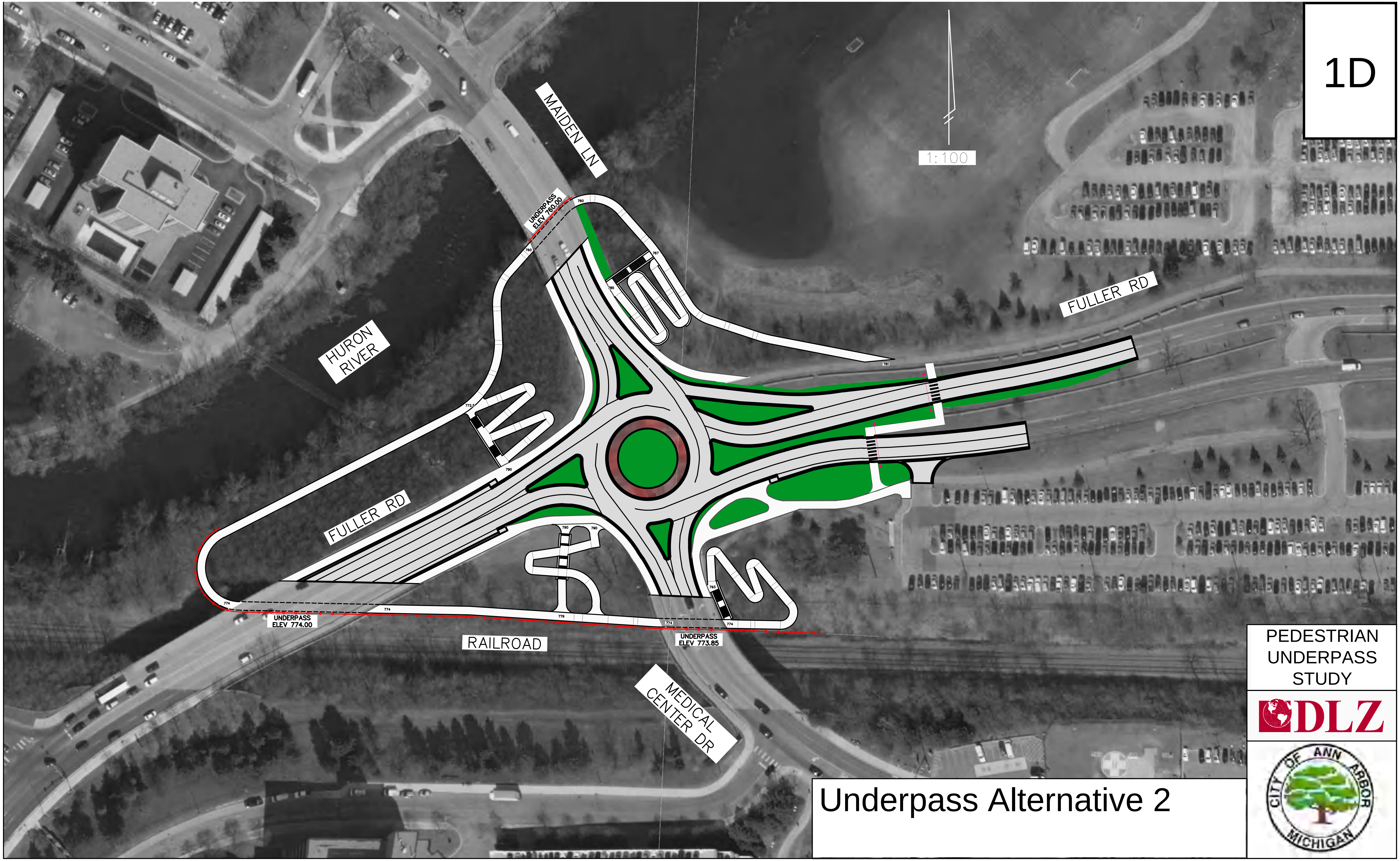
1C

PEDESTRIAN UNDERPASS STUDY

DLZ

CITY OF ANN ARBOR MICHIGAN

Underpass Alternative 1



1D

PEDESTRIAN
UNDERPASS
STUDY

DLZ

CITY OF ANN ARBOR MICHIGAN

Underpass Alternative 2

2. PEDESTRIAN MOBILITY

🟨 SHORTEST DISTANCE OF ALL ALTERNATIVES
🟥 LONGEST DISTANCE OF ALL ALTERNATIVES

A. EXISTING CONDITIONS

EXISTING PEDESTRIAN MOBILITY			STREET	FULLER	FULLER	E MED CNTR	E MED CNTR	FULLER	FULLER	MAIDEN LN	MAIDEN LN		
			LEG	W	W	S	S	E	E	N	N		
			SIDE	N	S	W	E	N	S	W	E		
STREET	LEG	SIDE	TO										
FULLER	W	N	WALKING DISTANCE	(FT)									
FULLER	W	S		668								668	FT
E MED CNTR	S	W		585	379							964	
E MED CNTR	S	E		678	472	287						1437	
FULLER	E	N		986	869	684	631					3170	
FULLER	E	S		924	781	597	459	893				3654	
MAIDEN LN	N	W		570	516	433	524	670	777			3490	
MAIDEN LN	N	E		681	614	532	479	635	742	425		4108	
												17491	FT

B. PEDESTRIAN SIGNAL

ROUNDABOUT PEDESTRIAN SIGNAL MOBILITY			STREET	FULLER	FULLER	E MED CNTR	E MED CNTR	FULLER	FULLER	MAIDEN LN	MAIDEN LN		
			LEG	W	W	S	S	E	E	N	N		
			SIDE	N	S	W	E	N	S	W	E		
STREET	LEG	SIDE	TO	PEDESTRIAN SIGNAL DISTANCE VS EXISTING DISTANCE									
FULLER	W	N	WALKING DISTANCE	(FT)	-52	-17	-25	5	126	0	-11		
FULLER	W	S		616		-26	-34	93	54	25	26	616	FT
E MED CNTR	S	W		568	353		-167	41	-80	60	91	921	
E MED CNTR	S	E		653	438	120		56	20	54	106	1211	
FULLER	E	N		991	962	725	687		-44	-4	-44	3365	
FULLER	E	S		1050	835	517	479	849		45	5	3730	
MAIDEN LN	N	W		570	541	493	578	666	822		-80	3670	
MAIDEN LN	N	E		670	640	623	585	591	747	345		4201	
												17714	FT

2. PEDESTRIAN MOBILITY

🟨 SHORTEST DISTANCE OF ALL ALTERNATIVES
🟥 LONGEST DISTANCE OF ALL ALTERNATIVES

C. PEDESTRIAN UNDERPASS ALTERNATIVE #1

UNDERPASS ALT 1 PEDESTRIAN MOBILITY			STREET LEG SIDE	FULLER W N	FULLER W S	E MED CNTR S W	E MED CNTR S E	FULLER E N	FULLER E S	MAIDEN LN N W	MAIDEN LN N E		
STREET	LEG	SIDE	TO	UNDERPASS ALT 1 DISTANCE VS EXISTING DISTANCE									
FULLER	W	N	WALKING DISTANCE	(FT)	-43	274	245	252	458	0	202		
FULLER	W	S		625		57	28	239	178	515	703	625	FT
E MED CNTR	S	W		859	436		-37	174	112	831	720	1295	
E MED CNTR	S	E		923	500	250		-3	20	804	544	1673	
FULLER	E	N		1238	1108	858	628		-375	224	-43	3832	
FULLER	E	S		1382	959	709	479	518		438	170	4047	
MAIDEN LN	N	W		570	1031	1264	1328	894	1215		114	6302	
MAIDEN LN	N	E		883	1317	1252	1023	592	912	539		6518	
												24292	FT

D. PEDESTRIAN UNDERPASS ALTERNATIVE #2

UNDERPASS ALT 2 PEDESTRIAN MOBILITY			STREET LEG SIDE	FULLER W N	FULLER W S	E MED CNTR S W	E MED CNTR S E	FULLER E N	FULLER E S	MAIDEN LN N W	MAIDEN LN N E		
STREET	LEG	SIDE	TO	UNDERPASS ALT 2 DISTANCE VS EXISTING DISTANCE									
FULLER	W	N	WALKING DISTANCE	(FT)	911	946	861	275	1073	0	228		
FULLER	W	S		1579		-32	109	1139	257	987	1042	1579	FT
E MED CNTR	S	W		1531	347		247	-60	394	1022	996	1878	
E MED CNTR	S	E		1539	581	534		506	20	938	536	2654	
FULLER	E	N		1261	2008	624	1137		-375	515	-48	5030	
FULLER	E	S		1997	1038	991	479	518		729	166	5023	
MAIDEN LN	N	W		570	1503	1455	1462	1185	1506		407	7681	
MAIDEN LN	N	E		909	1656	1528	1015	587	908	832		7435	
												31280	FT

3A. Pedestrian Signals

Existing Total Walking Distance (ft) = 17491 (Sum of All Pedestrian Movements through Intersection)
Pedestrian Signal Total Walking Distance (ft) = 17714
Increase (ft) = 223

						Ramp Case #1		Ramp Case #2		Ramp Case #3		Miscellaneous	
Item #	**Item Description**	**Units**	**Unit Price**	**Qty**	**Cost**	**#**	**Qty**	**#**	**Qty**	**#**	**Qty**	**Qty**	**Calc**
3010002.00	Subbase, CIP	Cyd	$8.00	31	$248.00	0	0	0	0	0	0	31	=S/W Area/9 x 6"/12/3
2050016.00	Excavation, Earth	Cyd	$8.00	0	$0.00	0	0	0	0	0	0		
3010002.00	Subbase, CIP	Cyd	$8.00	0	$0.00	0	0	0	0	0	0		
8030044.00	Sidewalk, Conc, 4 inch	Sft	$3.00	1640	$4,920.00	0	0	0	0	0	0	1640	From Hawk Signal CAD
6027021.00	Misc Concrete	Cyd	$400.00	0	$0.00	0	0	0	0	0	0		
7060090.00	Reinforcement, Steel	Lb	$1.10	0	$0.00	0	0	0	0	0	0		
7117001.00	Pedestrian Railing	Ft	$5.00	0	$0.00	0	0	0	0	0	0		
4040063.00	Underdrain, Subbase, 6 inch	Ft	$4.00	0	$0.00	0	0	0	0	0	0		
4040093.00	Underdrain Outlet, 6 inch	Ft	$8.00	0	$0.00	0	0	0	0	0	0		
4040113.00	Underdrain, Outlet Ending, 6 inch	Ea	$150.00	0	$0.00	0	0	0	0	0	0		
6027050.00	Conc Stairs	Ea	$300.00	0	$0.00	0	0	0	0	0	0		
8197050.00	Pedestrian Lighting	Ea	$10,000.00	0	$0.00	0	0	0	0	0	0	0	
8080011.00	Fence, Chain Link, 48 inch	Ft	$20.00	0	$0.00							0	No work along railroad or under bridges
8207050.00	Hawk Signal-One Direction	Ea	$50,000.00	9	$450,000.00							9	
8117001.04	Pavt Mrkg, Inlay Cold Plastic, 12 inch, Crosswalk, White	Ft	$5.00	208	$1,040.00							208	

20% Contingency $91,241.60

Total $547,449.60

3B. Alternative #1
No Cross-walks/Minimize Pedestrian Delays

Existing Total Walking Distance (ft) = 17491 (Sum of All Pedestrian Movements through Intersection)
Alt #1 Total Walking Distance (ft) = 24292
Increase (ft) = 6801

						Ramp Case #1		Ramp Case #2		Ramp Case #3		Miscellaneous	
Item #	**Item Description**	**Units**	**Unit Price**	**Qty**	**Cost**	**#**	**Qty**	**#**	**Qty**	**#**	**Qty**	**Qty**	**Calc**
2050010.00	Embankment, CIP	Cyd	$6.00	2492	$14,952.00	0	0	5	1855	1	371	266	=S/W Area/9 x 6"/12/3
2050016.00	Excavation, Earth	Cyd	$8.00	2226	$17,808.00	0	0	5	1855	1	371		
3010002.00	Subbase, CIP	Cyd	$8.00	373	$2,984.00	0	0	5	310	1	63		
8030044.00	Sidewalk, Conc, 4 inch	Sft	$3.00	34187	$102,561.00	0	0	5	16500	1	3373	14314	From Alt #1 CAD
6027021.00	Misc Concrete	Cyd	$400.00	786	$314,400.00	0	0	5	780	1	6		
7060090.00	Reinforcement, Steel	Lb	$1.10	71526	$78,678.60	0	0	5	70980	1	546		
7117001.00	Pedestrian Railing	Ft	$5.00	3453.5	$17,267.50	0	0	5	2892.5	1	561		
4040063.00	Underdrain, Subbase, 6 inch	Ft	$4.00	1848	$7,392.00	0	0	5	1540	1	308		
4040093.00	Underdrain Outlet, 6 inch	Ft	$8.00	120	$960.00	0	0	5	100	1	20		
4040113.00	Underdrain, Outlet Ending, 6 inch	Ea	$150.00	6	$900.00	0	0	5	5	1	1		
6027050.00	Conc Stairs	Ea	$300.00	162	$48,600.00	0	0	5	135	1	27		
8197050.00	Pedestrian Lighting	Ea	$10,000.00	32	$320,000.00	0	0	5	20	1	4	8	Misc Qty = (S/W Sft) / 10' (Width) / 200Ft (Light Spacing)
8080011.00	Fence, Chain Link, 48 inch	Ft	$20.00	831	$16,620.00							831	
8207050.00	Hawk Signal-One Direction	Ea	$75,000.00	0	$0.00							0	
8117001.04	Pavt Mrkg, Inlay Cold Plastic, 12 inch, Crosswalk, White	Ft	$5.00	0	$0.00							0	

20% Contingency $188,624.62

Total $1,131,747.72

3C. Alternative #2
No Cross-walks/Minimize Pedestrian Ramps

Existing Total Walking Distance (ft) = 17491 (Sum of All Pedestrian Movements through Intersection)
Alt #2 Total Walking Distance (ft) = 31280
Increase (ft) = 13789

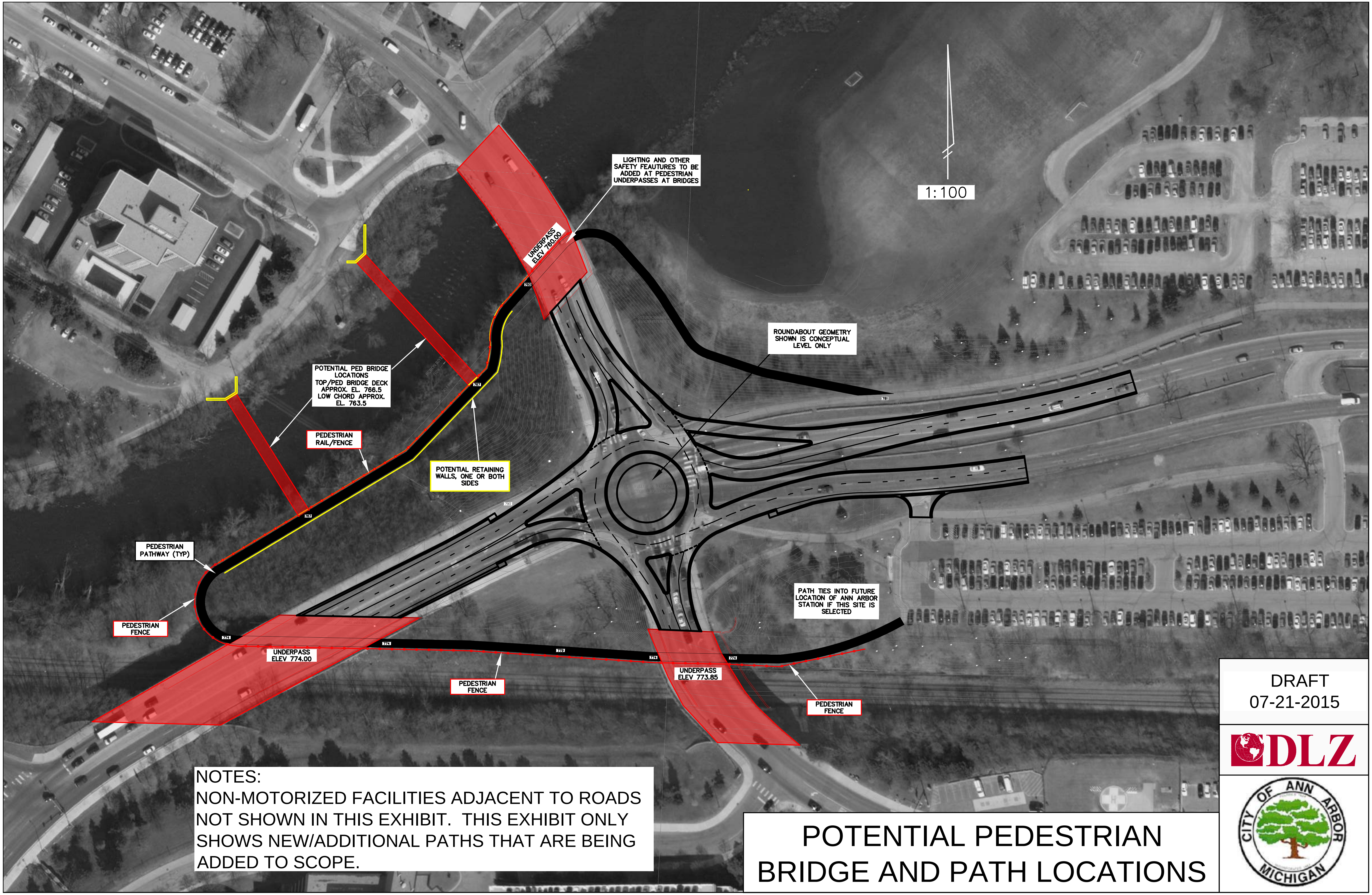
						Ramp Case #1		Ramp Case #2		Ramp Case #3		Miscellaneous	
Item #	**Item Description**	**Units**	**Unit Price**	**Qty**	**Cost**	**#**	**Qty**	**#**	**Qty**	**#**	**Qty**	**Qty**	**Calc**
2050010.00	Embankment, CIP	Cyd	$6.00	1564.5	$9,387.00	0	0	1	371	2.5	927.5	266	=S/W Area/9 x 6"/12/3
2050016.00	Excavation, Earth	Cyd	$8.00	1298.5	$10,388.00	0	0	1	371	2.5	927.5		
3010002.00	Subbase, CIP	Cyd	$8.00	219.5	$1,756.00	0	0	1	62	2.5	157.5		
8030044.00	Sidewalk, Conc, 4 inch	Sft	$3.00	26046.5	$78,139.50	0	0	1	3300	2.5	8432.5	14314	From Alt #1 CAD
6027021.00	Misc Concrete	Cyd	$400.00	171	$68,400.00	0	0	1	156	2.5	15		
7060090.00	Reinforcement, Steel	Lb	$1.10	15561	$17,117.10	0	0	1	14196	2.5	1365		
7117001.00	Pedestrian Railing	Ft	$5.00	1981	$9,905.00	0	0	1	578.5	2.5	1402.5		
4040063.00	Underdrain, Subbase, 6 inch	Ft	$4.00	1078	$4,312.00	0	0	1	308	2.5	770		
4040093.00	Underdrain Outlet, 6 inch	Ft	$8.00	70	$560.00	0	0	1	20	2.5	50		
4040113.00	Underdrain, Outlet Ending, 6 inch	Ea	$150.00	3.5	$525.00	0	0	1	1	2.5	2.5		
6027050.00	Conc Stairs	Ea	$300.00	94.5	$28,350.00	0	0	1	27	2.5	67.5		
8197050.00	Pedestrian Lighting	Ea	$10,000.00	22	$220,000.00	0	0	1	4	2.5	10	8	Misc Qty = (S/W Sft) / 10' (Width) / 200Ft (Light Spacing)
8080011.00	Fence, Chain Link, 48 inch	Ft	$20.00	831	$16,620.00							831	
8207050.00	Hawk Signal-One Direction	Ea	$75,000.00	0	$0.00							0	
8117001.04	Pavt Mrkg, Inlay Cold Plastic, 12 inch, Crosswalk, White	Ft	$5.00	0	$0.00							0	

20% Contingency $93,091.92

Total $558,551.52

Attachment #4

Border-To-Border Trail Connection Concepts



LIGHTING AND OTHER SAFETY FEAUTURES TO BE ADDED AT PEDESTRIAN UNDERPASSES AT BRIDGES

UNDERPASS ELEV 760.00

ROUNDABOUT GEOMETRY SHOWN IS CONCEPTUAL LEVEL ONLY

POTENTIAL PED BRIDGE LOCATIONS
TOP/PED BRIDGE DECK APPROX. EL. 766.5
LOW CHORD APPROX. EL. 763.5

PEDESTRIAN RAIL/FENCE

POTENTIAL RETAINING WALLS, ONE OR BOTH SIDES

PEDESTRIAN PATHWAY (TYP)

PEDESTRIAN FENCE

UNDERPASS ELEV 774.00

PEDESTRIAN FENCE

UNDERPASS ELEV 773.85

PEDESTRIAN FENCE

PATH TIES INTO FUTURE LOCATION OF ANN ARBOR STATION IF THIS SITE IS SELECTED

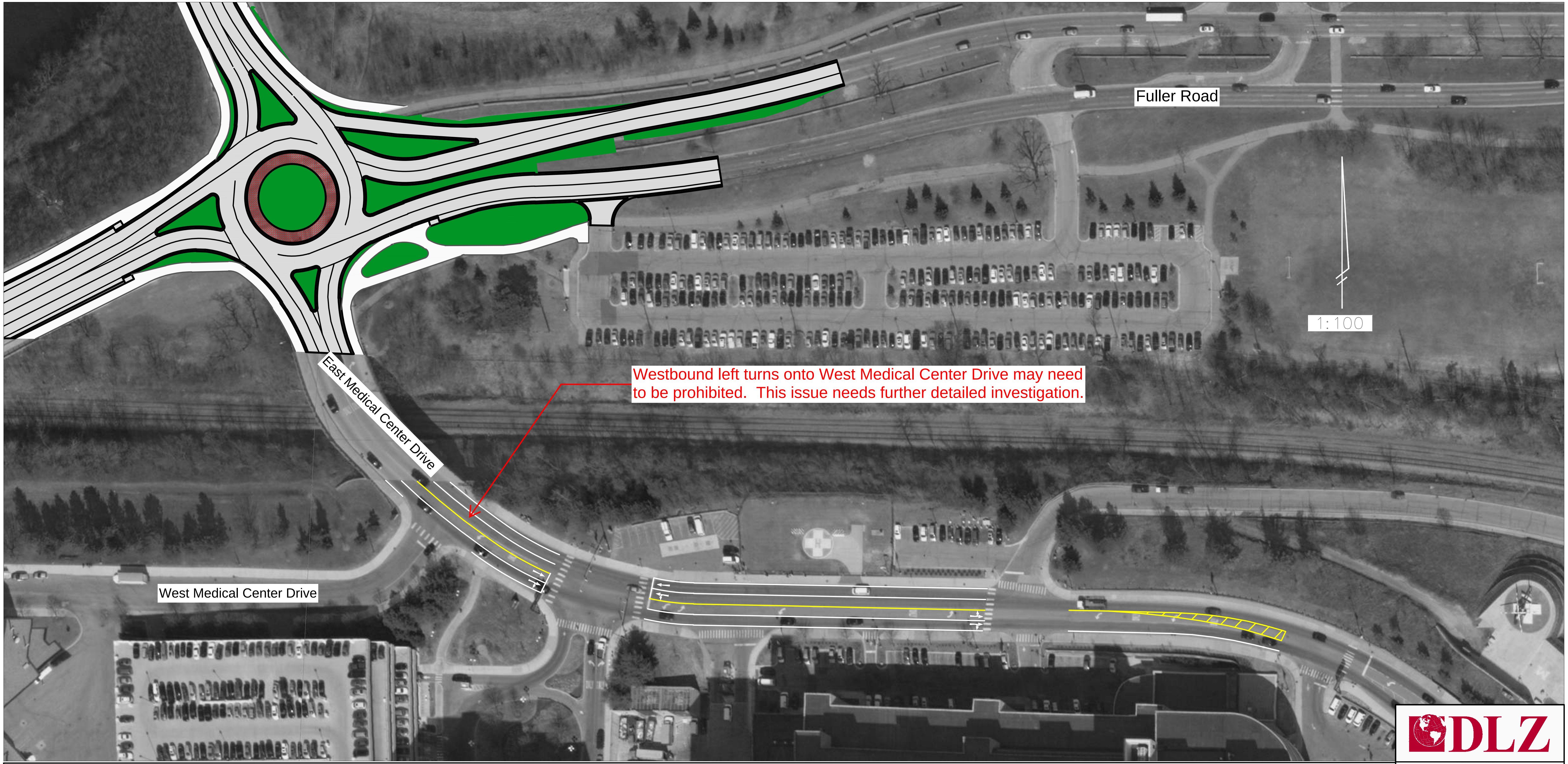
NOTES:
NON-MOTORIZED FACILITIES ADJACENT TO ROADS NOT SHOWN IN THIS EXHIBIT. THIS EXHIBIT ONLY SHOWS NEW/ADDITIONAL PATHS THAT ARE BEING ADDED TO SCOPE.

POTENTIAL PEDESTRIAN BRIDGE AND PATH LOCATIONS

DRAFT
07-21-2015

DLZ

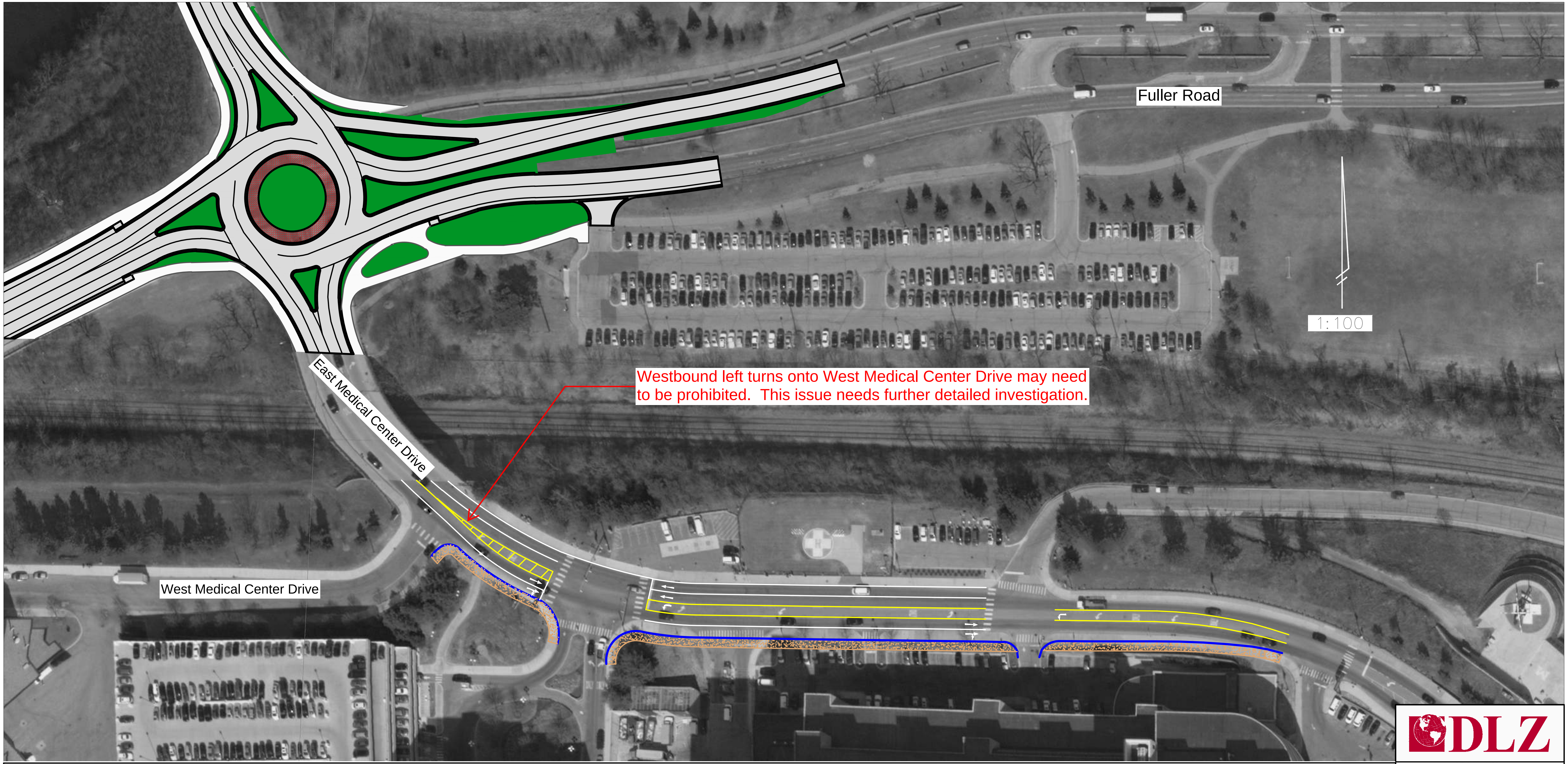
CITY OF ANN ARBOR MICHIGAN



Westbound left turns onto West Medical Center Drive may need to be prohibited. This issue needs further detailed investigation.

EAST MEDICAL CENTER DRIVE - ALTERNATIVE #1 - PAVEMENT MARKING CHANGES

Proposed Pavement Markings
Proposed Pavement Markings



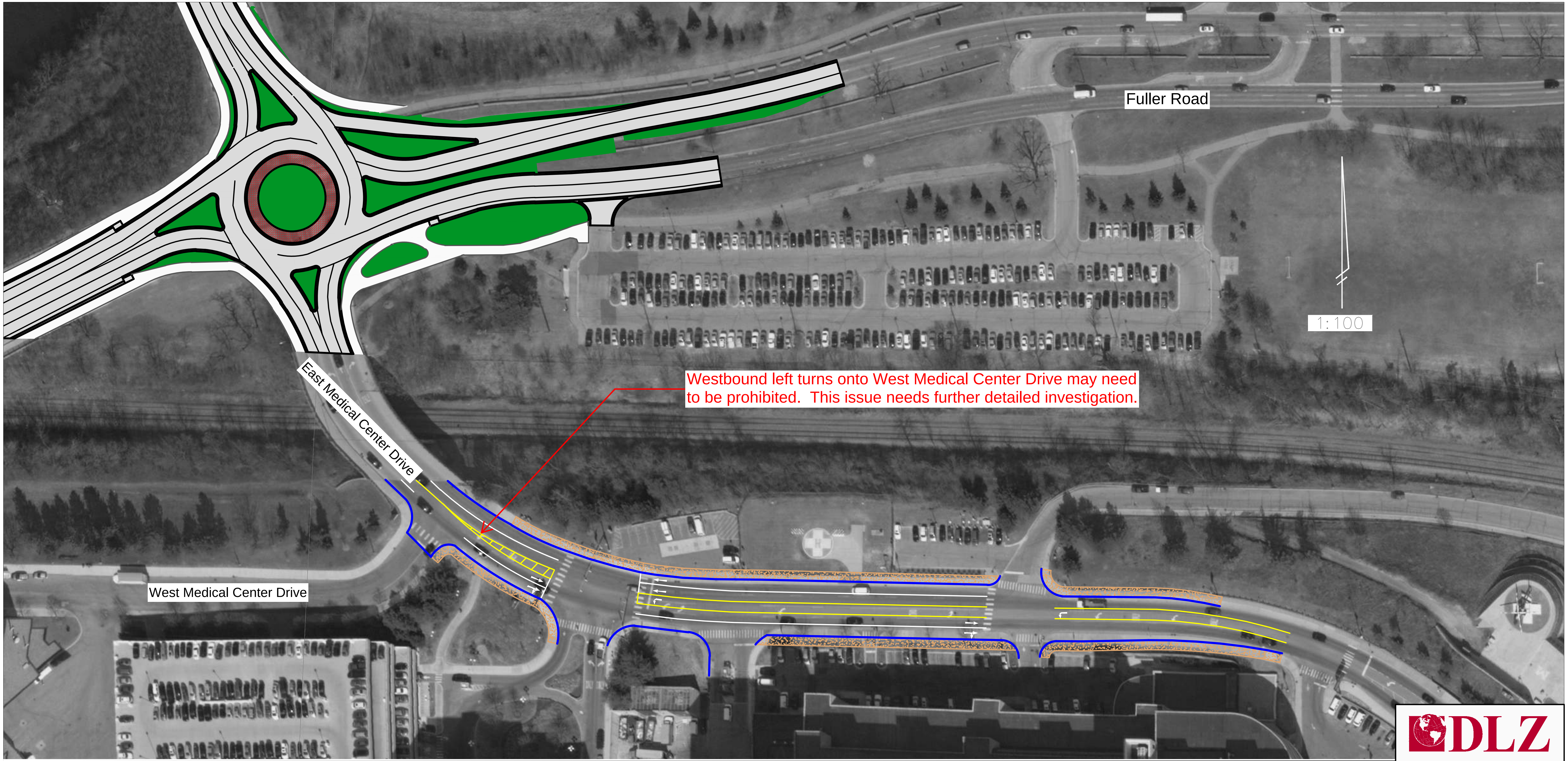
Westbound left turns onto West Medical Center Drive may need to be prohibited. This issue needs further detailed investigation.

DLZ

CITY OF ANN ARBOR MICHIGAN

EAST MEDICAL CENTER DRIVE - ALTERNATIVE #2 - WIDEN ON SOUTH SIDE ONLY

Proposed Pavement Markings
Proposed Pavement Markings
Proposed New Curb
Proposed New Sidewalk



Westbound left turns onto West Medical Center Drive may need to be prohibited. This issue needs further detailed investigation.

EAST MEDICAL CENTER DRIVE - ALTERNATIVE #3 - WIDEN TO BOTH SIDES

Proposed Pavement Markings	Proposed New Curb
Proposed Pavement Markings	Proposed New Sidewalk