

WISCONSIN DEPARTMENT OF TRANSPORTATION

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**USH 41 EXPANSION -  
BROWN COUNTY:  
ROAD SAFETY AUDIT**

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# USH 41 EXPANSION – BROWN COUNTY: ROAD SAFETY AUDIT

Opus International Consultants Inc.

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*USH 41 EXPANSION – BROWN COUNTY  
ROAD SAFETY AUDIT*

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The expansion and upgrades, described in Section 1.4 below, are currently in the planning and early design phases. The expansion and upgrades are scheduled for construction beginning in 2011 to 2014. Programmed construction costs are about \$450 million, excluding land acquisition costs.

Opus International Consultants was retained by WisDOT to perform a road safety audit (RSA) of the proposed improvements to USH-41 and interchanges along USH-41 from Orange Lane in De Pere to CTH M in Suamico. This report discusses the findings of the RSA.

## **1.2 Road Safety Audits**

A RSA is a formal safety performance examination of an existing or future road or intersection by an independent audit team. RSAs help to promote road safety by identifying safety issues at the design and implementation stages, promoting awareness of safe design practices, integrating multimodal safety concerns, and considering human factors in the design.

## **1.3 Reminder**

The RSA team has conducted this audit to the best of its professional abilities within the time available and by referring to available information. While every attempt has been made to identify significant safety issues, the design team and the project owner are reminded that responsibility for the design, construction, and performance of the project remains with the engineers of record.

## **1.4 Audit Scope**

The Wisconsin Department of Transportation (WisDOT) is currently planning to expand USH-41 and upgrade interchanges between Orange Lane and CTH M. This staged project is currently at various design stages ranging from 50 percent complete on the south end and about 15 percent complete towards the north end. The following nine interchanges will be designed to meet current standards:

- CTH F (Scheuring Road)
- CTH G (Main Avenue)
- Business 41/STH 32(Ashland Avenue)
- CTH AAA (Oneida Street/Waube Lane)
- CTH VK (Lombardi Avenue)

- STH 54 (Mason Street)
- STH 29/STH 32 (Shawano Avenue/Dousman Street)
- USH 141/CTH HS (Velp Avenue)
- IH-43

The STH 29 interchange includes:

- A grade separation of the CTH J/STH 29 intersection
- A frontage road between CTH J and Packerland Drive (CTH EB)
- An interchange at Packerland Drive (CTH EB).
- STH 29 will connect to US 41 with a free flow systems interchange.

## **1.5 Audit Team and Process**

The audit team and the project material on which the audit was based are described in *Section 1*.

Site visits were conducted in August 2007 to gain an understanding of the existing conditions and surroundings, as well as to identify existing safety concerns. Notes of the site visits are included in *Section 2*.

A road safety audit framework was applied in both the audit analysis and presentation of findings. The expected frequency and severity of crashes caused by each safety issue have been identified and rated according to the categories shown in TABLES 1.1 and 1.2. These two risk elements were then combined to obtain a risk assessment on the basis of the matrix shown in TABLE 1.3. Consequently, each safety issue is assessed on the basis of a ranking between F (highest risk and highest priority) and A (lowest risk and lowest priority).

For each safety issue identified, possible mitigation measures have been suggested. The suggestions have focused on measures that can be cost-effectively implemented at the current design stage, and consequently include few geometric changes.

**TABLE 1.1 FREQUENCY RATING**

ESTIMATED		EXPECTED CRASH FREQUENCY (per audit item)	FREQUENCY RATING
EXPOSURE	PROBABILITY		
high	high	10 or more crashes per year	<i>Frequent</i>
medium	high		
high	medium	1 to 9 crashes per year	<i>Occasional</i>
medium	medium		
low	high		
high	low	less than 1 crash per year, but more than 1 crash every 5 years	<i>Infrequent</i>
low	medium		
medium	low	less than 1 crash every 5 years	<i>Rare</i>
low	low		

**TABLE 1.2 SEVERITY RATING**

TYPICAL CRASHES EXPECTED (per audit item)	EXPECTED CRASH SEVERITY	SEVERITY RATING
crashes involving high speeds or heavy vehicles, pedestrians, or bicycles	probable fatality or incapacitating injury	<i>Extreme</i>
crashes involving medium to high speed; head-on, crossing, or off-road crashes	moderate to severe injury	<i>High</i>
crashes involving medium to low speeds; left-turn and right-turn crashes	minor to moderate injury	<i>Moderate</i>
crashes involving low to medium speeds; rear-end or sideswipe crashes	property damage only or minor injury	<i>Low</i>

**TABLE 1.3 CRASH RISK ASSESSMENT**

FREQUENCY RATING	SEVERITY RATING			
	<i>Low</i>	<i>Moderate</i>	<i>High</i>	<i>Extreme</i>
<i>Frequent</i>	<b>C</b>	<b>D</b>	<b>E</b>	<b>F</b>
<i>Occasional</i>	<b>B</b>	<b>C</b>	<b>D</b>	<b>E</b>
<i>Infrequent</i>	<b>A</b>	<b>B</b>	<b>C</b>	<b>D</b>
<i>Rare</i>	<b>A</b>	<b>A</b>	<b>B</b>	<b>C</b>

Crash Risk Ratings:

A: minimal risk level

B: low risk level

C: moderate risk level

D: significant risk level

E: high risk level

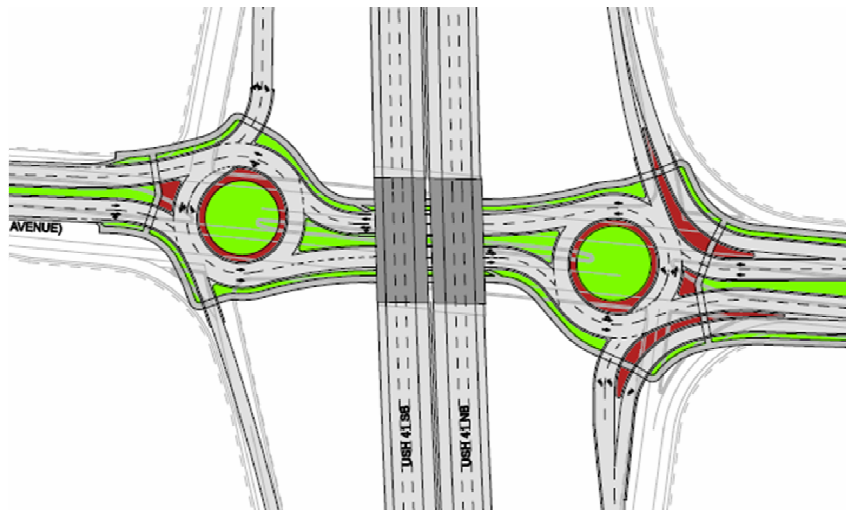
F: extreme risk level

## 2.0 AUDIT FINDINGS

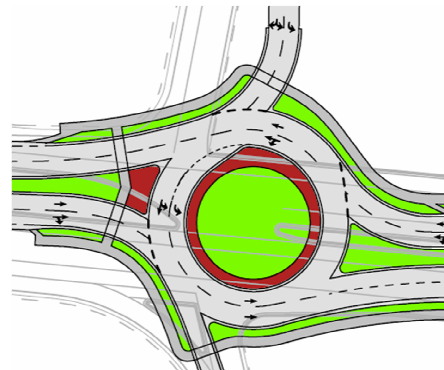
### 2.1 Safety Benefits of the New Design

Improvements to USH 41 are motivated by the goal of reducing congestion and traffic crashes between long-distance/industrial traffic and local/pedestrian traffic in Brown County. In addition, the freeway and many features of its design already incorporate many features that are expected to substantially improve traffic safety in the area:

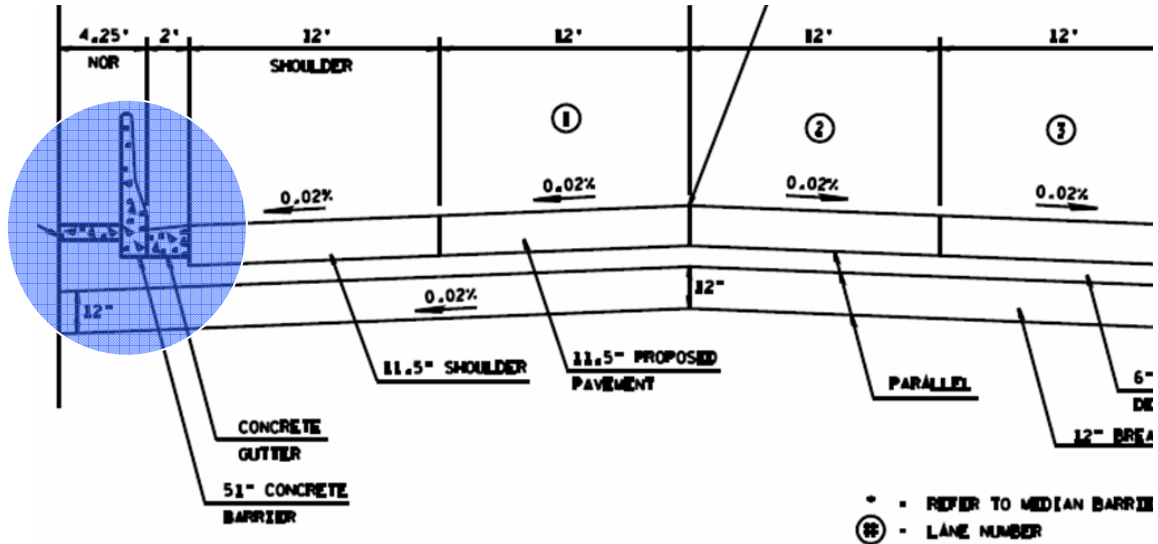
*Use of innovative interchange design:* The design includes sixteen roundabouts at interchanges and intersections along USH 41, all of which are planned to improve both safety and operations. Although some safety issues associated with roundabout configurations have been identified, the use of the roundabouts should reduce both the potential for high-speed conflicts and delays at associated at-grade intersections. Roundabouts result in a moderate reduction in crash frequency, especially for left-turn and angle crashes, and a high reduction of the severity of all crashes.



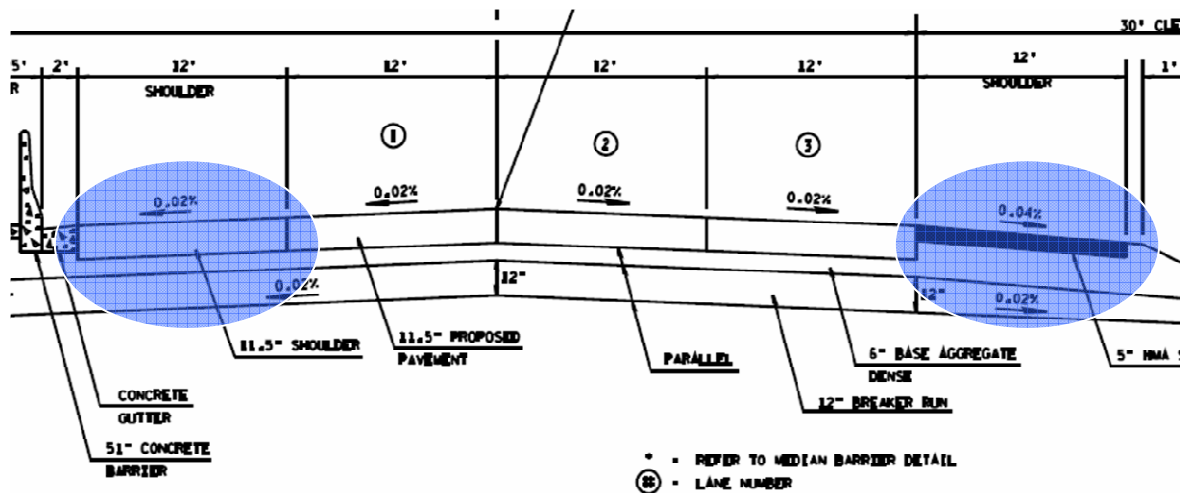
*Proposed pavement markings:* The multi-lane roundabouts will utilize a spiral striping pattern. These types of markings have been found to be extremely effective in guiding drivers through multi-lane roundabout.



*Median barriers:* USH 41 in Brown County was identified<sup>1</sup> as having a disproportionately high number of median crossover crashes. The implementation of continuous concrete median barriers on the corridor should significantly reduce the number of median crossover crashes and their severity throughout the corridor. Specifically, the median barrier will help to prevent head-on crashes associated with median crossover crashes.



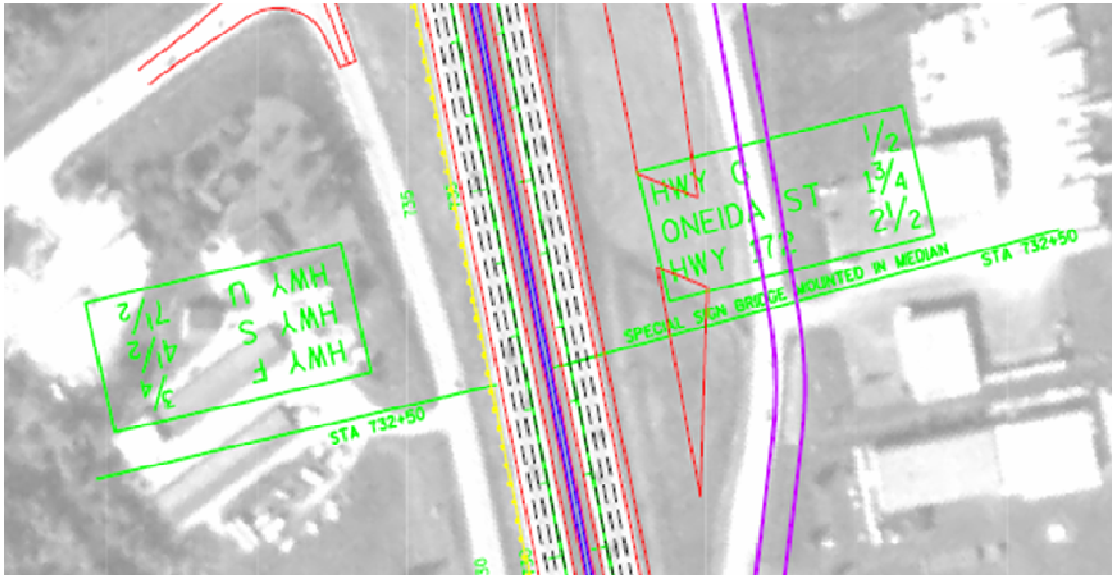
*Generous geometry and a roadside clear zone on USH 41:* The USH 41 corridor includes a wider twelve foot shoulder. This is wider than the existing six foot shoulder. These design elements can be expected to contribute to safety by a moderate reduction in crash frequency and a high reduction in crash severity due to the recovery room/refuge.



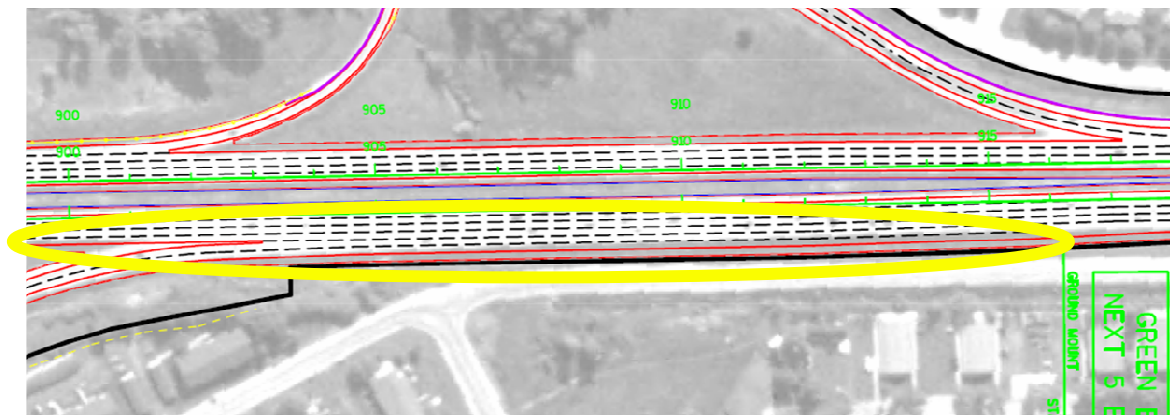
<sup>1</sup> Noyce, D.A., R.J. McKendry; *Analysis of Median Crossover Crashes in Wisconsin*; Traffic Operations and Safety Laboratory, University of Wisconsin-Madison, 2005.



**Signing Improvements:** Improvements to guide signage on USH 41 will improve driver awareness, by providing advance information regarding upcoming interchanges which should reduce weaving near the exit ramps.

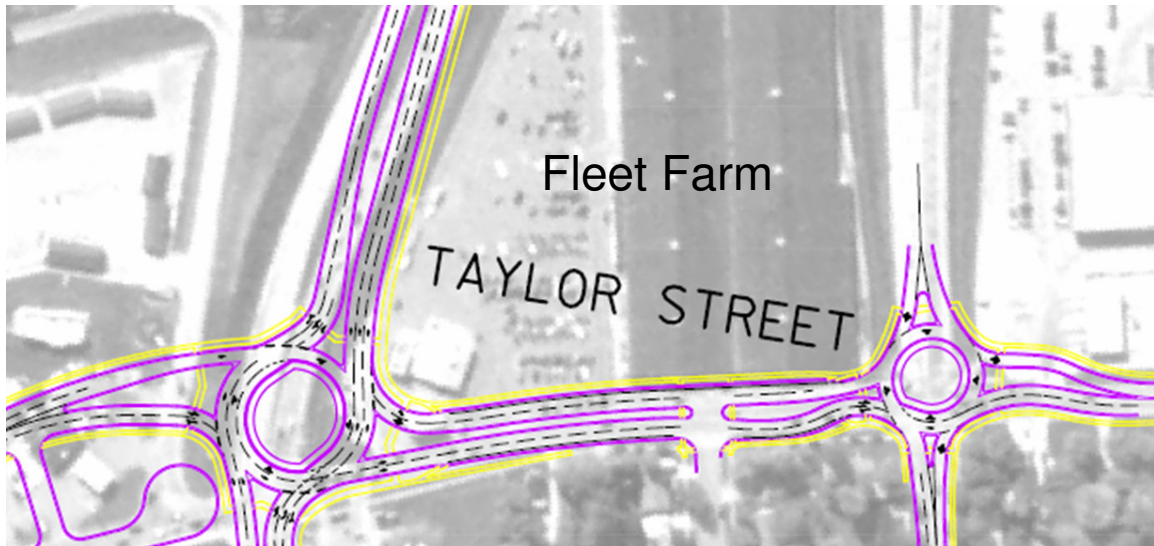


**Ramp upgrades:** Auxiliary lanes and longer acceleration / deceleration lanes at ramp entrances and exits will be implemented to reduce rear-end, weaving, and truck crashes. An auxiliary lane is also useful to reduce traffic hop on/hop off at the frontage road between CTH F and CTH G.

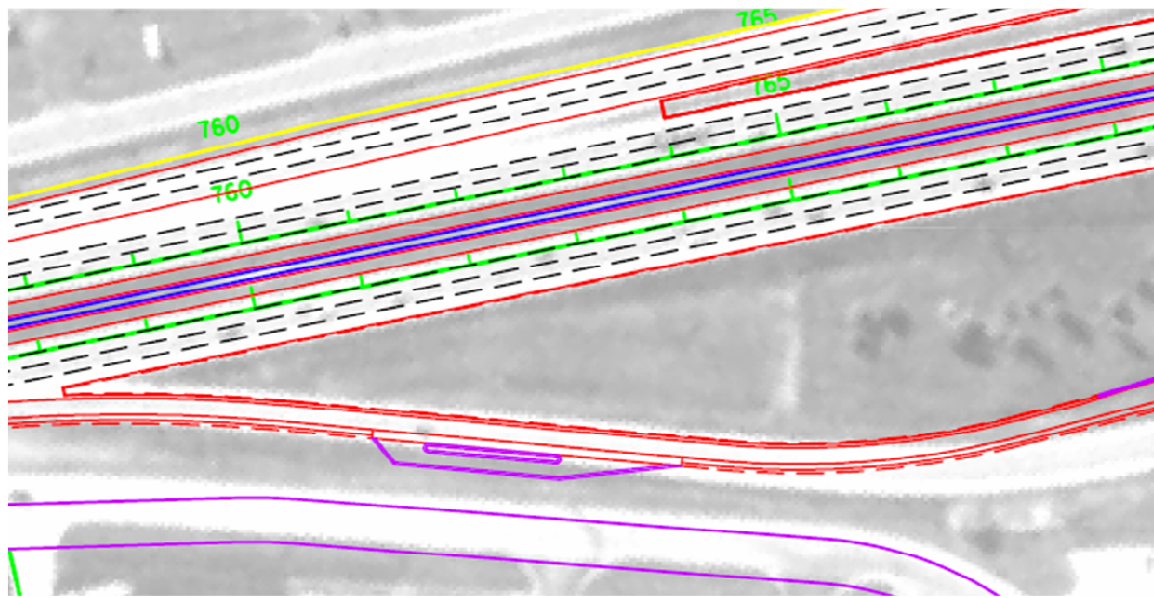


- **Non-motorized facilities:** The planned improvements will provide a more complete and continuous network of sidewalks near all roundabout interchanges. Crosswalks and bicycle facilities will be provided at each of the intersections. These improvements are expected to improve comfort and safety for non-motorized road users.

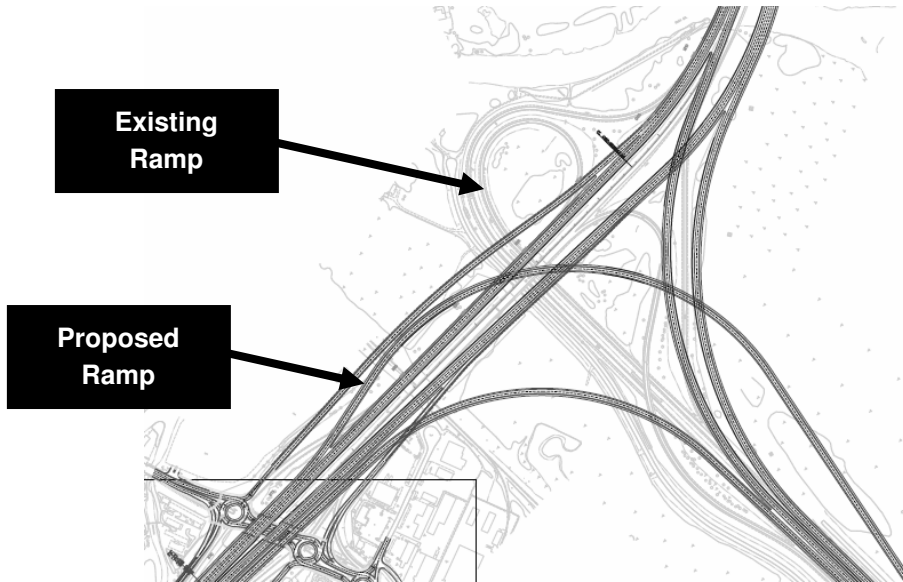
*Access management:* Consolidation of access locations within the study area will result in a reduction in congestion and driver confusion. Access management improvements will also improve safety by limiting turning movements to fewer locations. Restrictions to turning movements will result in fewer conflict points.



*Speed and incident management:* Enforcement will allow reasonable speeds and reduce hazardous driving.



*Ramp Design – IH-43 Interchange:* Several of the existing ramps on the of the USH 41 and IH-43 interchange have extremely tight radii. This includes the ramp from northbound IH-43 to southbound USH-41 and the northbound ramp from USH-41 to southbound IH-43. The replacement of these ramps with ones having larger-radius curves can be expected to reduce the risk of crashes resulting from failure to follow the tight horizontal alignment and truck rollover crashes.



## 2.2 Summary of Audit Findings

Seven main safety issues were identified, all of which have a moderate to high risk rating. The seven main issues and suggested alternatives are described in detail in *Section 3 (Issues and Suggestions)*, and are summarized in TABLE 2.1.

**TABLE 2.1 SUMMARY OF RSA SAFETY ISSUES AND SUGGESTIONS**

SAFETY ISSUE (Number and Description)		Risk Rating	Suggestions
<b>1. Decision Sight Distance</b>			
1a	Bridge obstructions limit drivers' ability to see roundabout.	<b>E</b>	<ul style="list-style-type: none"> <li>▪ Lighting Under Bridges</li> <li>▪ High Visibility Pavement Markings</li> <li>▪ Lane Use Signs</li> </ul>
1b	The view of merge and diverge points is obstructed by horizontal and vertical curves.		<ul style="list-style-type: none"> <li>▪ Re-grade Ramps</li> <li>▪ Lighting</li> </ul>
1c	Closely spaced ramps		<ul style="list-style-type: none"> <li>▪ Model Weave Interaction</li> <li>▪ Consolidate Ramps</li> <li>▪ Consider Collector-Distributor Lanes</li> <li>▪ Lane Reduction Arrows</li> </ul>
<b>2. Pedestrians</b>			
2a	High speed right-turns	<b>D</b>	<ul style="list-style-type: none"> <li>▪ Offset Pedestrian Crossings</li> <li>▪ Removal of Bypass Lanes</li> </ul>
2b	Pedestrian conflicts at three lane approaches		<ul style="list-style-type: none"> <li>▪ Median Refuge</li> <li>▪ Active Pedestrian Traffic Control</li> </ul>
<b>3. Right-turn Lanes</b>			
3a	Conflicts between right-turns and the traffic exiting the roundabout	<b>D</b>	<ul style="list-style-type: none"> <li>▪ Add merge lane</li> </ul>
3b	Southbound right-turn volume		<ul style="list-style-type: none"> <li>▪ Revise analysis</li> </ul>
<b>4. STH 29 Interchange</b>			
4a	Unfamiliar Drivers Guide Signing: USH 41 SB	<b>D</b>	<ul style="list-style-type: none"> <li>▪ Consider guide sign requirements before finalizing interchange design</li> </ul>

SAFETY ISSUE (Number and Description)		Risk Rating	Suggestions
4b	Merge on curve	<b>D</b>	<ul style="list-style-type: none"> <li>▪ Relocate Merges to Tangent Sections</li> <li>▪ Extend Merge Distance</li> <li>▪ Merge Arrows</li> </ul>
4c	Merge on bridge		<ul style="list-style-type: none"> <li>▪ Relocate Merge off of the Bridge</li> <li>▪ High Friction Pavement on the Bridge</li> </ul>
<b>5. Trucks</b>			
Heavy truck volume		<b>C</b>	<ul style="list-style-type: none"> <li>▪ Review Design Vehicle</li> <li>▪ Review Turning Templates</li> </ul>
<b>6. Access Management</b>			
6a	Mid Valley Drive south of CTH G	<b>C</b>	<ul style="list-style-type: none"> <li>▪ Relocate Driveways</li> <li>▪ Review Vertical Alignment</li> </ul>
6b	Taylor north of Mason		<ul style="list-style-type: none"> <li>▪ Left-Turn Lanes at Major Driveways</li> </ul>
<b>7. Railroad Crossing at CTH EB</b>			
Close proximity of railroad track to roundabout		<b>C</b>	<ul style="list-style-type: none"> <li>▪ Pursue Track Relocation</li> <li>▪ Active Warning Signs</li> <li>▪ Gates</li> <li>▪ Changeable Message Signs</li> </ul>

## 2.3 CONCLUSION

Seven safety issues have been identified in this design-stage road safety audit. Suggestions for improvements have been identified and are described in this report. The owner and design team are invited to consider the suggested changes. To complete the audit process, the owner and design team may prepare a short written response to the issues and options outlined in this report.

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### 3.0 ROAD SAFETY AUDIT TEAM AND MATERIALS

<b>Project:</b>	USH 41 Capacity Expansion Study, Brown County, WI	
<b>RSA Team Members:</b>	Jeffrey S. Bagdade, P.E.	Opus International Consultants
	Cory Wilson, PEng	Opus International Consultants
	Joyce Abinader	Opus International Consultants
	Scott Nelson, P.E.	WisDOT NE Region
	Dan Segerstrom, P.E.	WisDOT NE Region
	Marie Treazise, EIT	WisDOT BHO
<b>Project Owner:</b>	Wisconsin Department of Transportation	
<b>Design Team:</b>	Wisconsin Department of Transportation, HNTB, GAS, Bloom Consultants, and Ayres	
<b>Review Date:</b>	July 30 - August 2, 2007	
<b>Review Stage:</b>	Planning-level design	
<b>Start Up Meeting:</b>	July 30, 2007	
<b>Preliminary Findings Meeting:</b>	August 2, 2007	
<b>Attended by:</b>	Wisconsin Department of Transportation Opus International Consultants	

#### Project Documents Available for the Audit:

- USH 41 Capacity Expansion Study (Orange Lane to GTH M) dated April 2003
- Plan and Profile Drawings dated January 2007-May 2007
- Aerial photographs of site
- Roundabout feasibility study completed by Ourston Roundabout Engineering and Strand.
- WisDOT Photo Log
- Year 2035 Traffic Operational Analysis – included traffic counts and forecasts
- USH 41 Crash Analysis (2003-2005) – included collision diagrams and trend summary sheets for each intersection and interchange ramp.

All documents were provided prior to or at the start-up meeting of July 30, 2007.

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## 4.0 SITE VISIT NOTES

**Project Name:** USH 41 - Brown County Capacity Expansion Study

**Site Visit Date:** July 30 - August 1, 2007

**Land Uses:** USH 41 runs through residential, industrial, and commercial areas through the City of Green Bay and the Villages of De Pere, Ashwaubenon and Howard, Wisconsin. Both agricultural, forests and wetlands are also present along the corridor. Wetlands and developments are a significant constraint at many of the sites.

### Road User Characteristics:

A high proportion of trucks were observed at interchanges that will be connecting with USH 41. Trucks are currently not able to reach speed on the southbound on-ramp at STH 29 (Shawano Avenue) due to the hill which has a grade of about 6 percent (*right*). The proposed loop ramp is proposed to have a 1.5 percent grade.



During the morning and afternoon peak periods, congestion and directional queuing was observed (*right*) several of the interchanges. Few pedestrians or bicyclists were observed on the connecting roads during site visits.



**CTH AAA (Waube Lane/Oneida Street)  
left-turn lane onto northbound USH 41**

**Road and Roadside Physical Characteristics:**

A four lane divided highway, USH 41, accommodates entering and exiting traffic using short acceleration and deceleration lanes. A six foot wide shoulder exists on either side in each direction (*right*). The posted speed limit is 65 mph. Approach alignments are generally straight and level. A frontage road in close proximity to the freeway exists between CTH F (Scheuring Road) and CTH G. All of the interchanges except CTH F (Scheuring road) and STH 54 (Mason Street) are located underneath the freeway bridges.



**Night-time Conditions:** Overhead lighting is provided at the signalized intersections.

**Adjacent Network and Connectivity:** USH 41 provides access to several state highways, county primaries and city arterials. It also provides connections from the western side of Green Bay with the Marinette (to the north), Shawno (to the west) Fox Valley cities of Appleton, Oshkosh and Fond du Lac (to the south), and Milwaukee via IH-43 (also the south).

**Other Comments:**

Taylor street at STH 29 (Shawano Avenue) has multiple driveway access contributing to many collisions due to the number of conflict points and a high volume of traffic (*right*). Driveways will be consolidated to reduce conflict points.

Constraints at STH 29 include Duck creek, and the Memorial drive railroad crossing. Everything north of the railroad is wetlands. The railroad crossing is also in close proximity to Ulmer Road.



Illegal left-turns were being made into the Menards parking lot on CTH AAA (Waube Lane/Oneida Street) (*right*). The median will be extended to eliminate illegal left-turn movements.

County F (Scheuring Road) is at a skew contributing to 90 degree horizontal curves at ramps in the proposed design. Left turning traffic is also heavy at CTH F.

## 5.0 RSA ISSUES AND SUGGESTIONS

### 5.1 Safety Issue 1: Decision Sight Distance

**Safety Issue 1(a): Bridge obstructions limit driver’s ability to see roundabout.**

**Safety Issue 1(a) Description:** The bridges may limit sight distance of the roundabouts at several of the freeway interchange due to the large structure casting shadows in daylight and limiting visibility in the dark.

**Safety Issue 1(b): The view of merge and diverge points are obstructed by horizontal and vertical curves.**

**Safety Issue 1(b) Description:** The limited sight distance due to horizontal and vertical curves may increase the risk of sideswipe and rear-end collisions for vehicles:

- Vehicles merging on to USH 41; and
- Exiting USH 41.



***Lombardi Northbound On-ramp***

The vertical and horizontal curve at this merge point reduces decision sight distance. Decision sight distance is extremely important at freeway on-ramps due to through vehicles traveling at high speed.



***Lombardi Southbound Off-ramp***

A vertical curve reduces intersection conspicuity on the above off-ramp. This is likely a cause of the trend of rear-end collisions occurring on this off ramp. This vertical curve will also likely obstruct the view of the proposed roundabout.



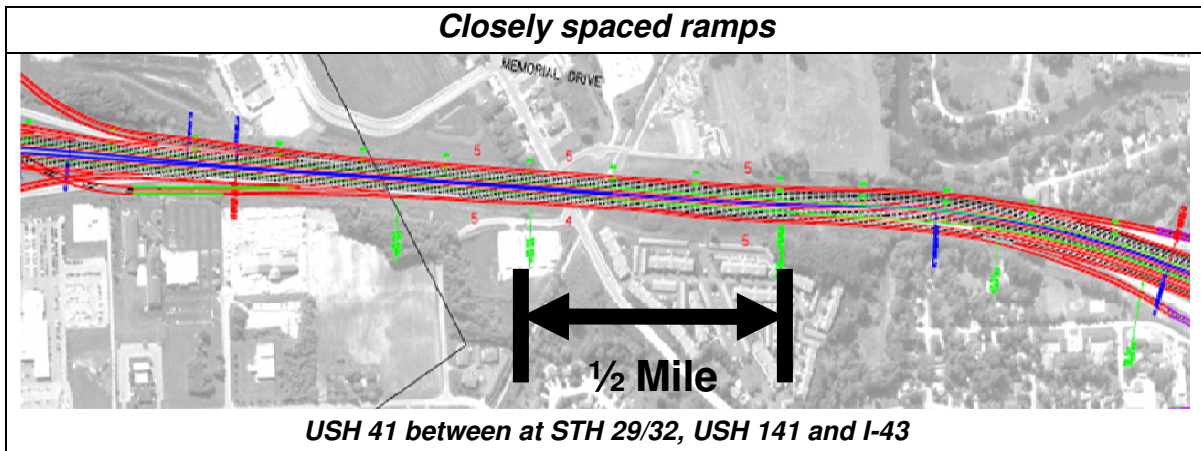
**Safety Issue 1(c): Closely spaced ramps**

**Safety Issue 1(c) Description:** Closely spaced ramps decreases driver’s decision time, and may contribute to weaving increasing the risk of sideswipe collisions. On both northbound and USH 41 at STH 29/32 there are separate systems and service exit ramps on.

Drivers from the service and systems ramps connecting eastbound STH 29/32 with northbound USH-41 ramp must merge into a single lane when before joining the mainline (westbound USH-41), then must weave left into the adjacent lane since the right lane becomes an exit-only lane at USH 141/IH-43, located ½ mile feet downstream.

At the same time, traffic from northbound USH-41 meets the traffic from the STH 29/32 systems ramp and the STH 29/32 service ramps about ¾ mile from the start of the Exit USH-141/IH-43 exit ramp. Within this distance, drivers on USH-41 wanting to exit at USH-141/IH-43 must weave over at least two lanes to reach the right exit lane. The weave can be expected to experience issues with operations due to anticipated volumes on the STH 29 connector ramps.

The high volume of left- and right-weaving traffic (traffic from the STH 29/32 ramps weaving left out of the exit lane, combined with USH-41 traffic weaving right into the exit lane) increases the potential for high-speed sideswipe collisions in the second lane, which must accommodate vehicles weaving in both directions.



**Expected Crash Types:** intersection and freeway collisions

**Expected Frequency:** frequent

**Expected Severity:** high

**Risk Rating:** E (high risk level)

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**Suggestions:**

The following table summarizes at which intersections each element should be considered at.

ELEMENT	INTERCHANGES (from south to north on USH 41)									
	CTH F	CTH G	CTH AAA	Bus 41	CTH VK	STH 54	STH 29/32	CTH EB	USH 141	I-43
Lighting under bridges		√	√		√		√	√	√	
High visibility pavement markings		√	√		√		√	√	√	
Lane use signs	√	√	√		√	√	√	√	√	
Re-grade ramps	√				√					
Model weave interaction				√			√			
Consolidate ramps							√			
Collector-distributor lanes							√			
Merge arrows							√			



1. *Lighting Under Bridges:* Lighting is generally considered beneficial on the approaches to intersections as a means of improving sight distance and night-time visibility.
2. *High Visibility Pavement Markings: Six-inch edgeline:* To assist drivers, particularly during the day where shadows may be cast, a wide retroreflective edgeline may be used along the roundabout interchanges and underneath the bridges. A typical edgeline is four to six inches wide; the design team may consider using a width of six inches (i.e., the upper end of this range).
3. *Lane Use Signs:* Lane use signs will direct drivers in the correct travel lane before entering the roundabout, reducing weaving between roundabouts and underneath bridges. It is suggested that these lane use signs be placed overhead on the bridge approaches. Below is an example of overhead lane use signs which were recently placed at the interchange in Milwaukee to reduce weaving.



*Westbound Silver Spring Drive at USH 45 in Milwaukee*

4. *Re-grade Ramps:* Reducing vertical and horizontal grades will improve sight distance on on-ramps and off-ramps, and will increase decision sight distance. This is particularly an issue at the Lombardi Avenue (CTH VK) interchange. The 22 rear end collisions which occurred on the southbound off-ramp at Lombardi may be prevented by leveling the vertical curve.
5. *Lighting* should also be considered on the 90 degree curve on the northbound off ramp to CTH F.

6. *Model Weave Interaction:* It is suggested that simulation modeling be used to analyze the weave interaction on USH-41 between the STH 29/32 interchange and the IH-43 interchange. This will help to verify the design capability of this weave section.
7. *Consolidate Ramps:* It is suggested that collector-distributor lanes be considered on USH 41 between STH 29 and IH-43. The use consolidation of ramps at the STH 29/32 will help to eliminate the proposed short weave sections. Several of these weave maneuvers on northbound USH-41 would likely be eliminated if the systems and service ramps to/from STH 29/32 were consolidated. A similar design is proposed for northbound USH-41 at USH-141 and IH-43.
8. *Consider Collector-Distributor Lanes:* It is suggested that collector-distributor lanes be considered on USH 41 between STH 29/32 and IH-43. The use of collector-distributor lanes will help to eliminate the proposed short weave section.
9. *Lane Reduction Arrows:* Lane Reduction arrows and LANE ENDS MERGE LEFT signs are suggested for use at the merge points, to stress to drivers that ramp traffic must merge.

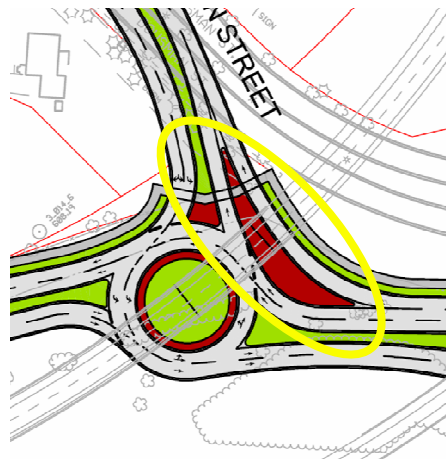
## 5.2 Safety Issue 2: Pedestrians

### Safety Issue 2(a): High speed right-turns

**Safety Issue 2(a) Description:** High speed right-turn bypass lanes are planned at several of the proposed roundabouts on the corridor. These are primarily being utilized on the on- and off-ramps to maximize the operational performance of the roundabouts.

On several of the bypass lanes which are being planned for freeway on-ramps, crosswalks are proposed to be located near the end of these high speed right-turn lanes. The location of these

crosswalks may result in conflicts with pedestrians due to the limited sight distance visibility of the crosswalk and the increased speeds. In addition drivers will be accelerating as they approach these crosswalks. For this reason, several WisDOT regions are proactively removing these types of high speed right turn lanes at existing traditional intersections.



**STH 29 & Old Dousman Street**



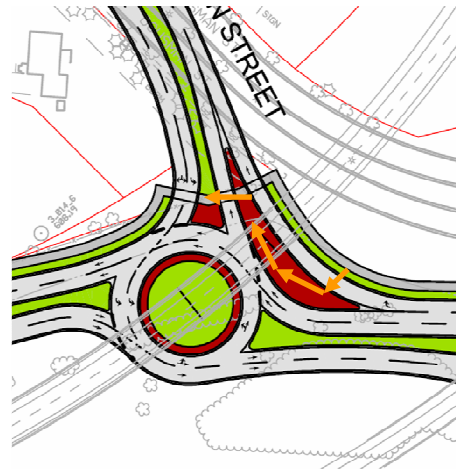
NCHRP 572<sup>2</sup> states roundabout exits have a higher percentage of vehicles that do not yield to pedestrians than roundabout entries, suggesting that the design of the exit should be carefully considered to ensure vehicle speeds are reasonable and that good sight lines exist between drivers and pedestrians.

Roundabouts of which these observations apply are located at the following interchanges (from south to north):

- CTH G (Main Avenue)
- CTH AAA (Oneida Street/Waube Lane)
- CTH VK (Lombardi Avenue)
- STH 54 (Mason Street)
- STH 29/32 (Shawano Avenue and Old Dousman Street)
- US 141/CTH HS (Velp Avenue)

### Suggestions:

1. *Offset Pedestrian Crossings:* Offsetting the pedestrian crosswalk will improve the visibility of the crosswalk and alert drivers of pedestrians before accelerating speeds on the on-ramp (*right*). If offset pedestrian crossings are utilized, fencing or other similar barriers are suggested as a means to channelize pedestrians to the designated crossing area.



2. *Removal of Bypass Lanes:* High-speed rights are being eliminated throughout intersections in Wisconsin because of increased pedestrian risks. The bypass lanes may be removed as a way to prevent pedestrian conflicts.

### Safety Issue 2(b): Pedestrian conflicts at three lane approaches

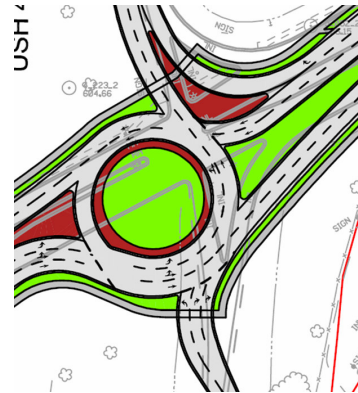
**Safety Issue 2(b) Description:** During site visits, light pedestrian volumes were observed, associated mainly with nearby restaurants, shopping centers, and transit bus stops. Pedestrians who cross without pedestrian signal heads may unintentionally enter the crosswalk with insufficient time to clear it before conflicting traffic. The risk of a potentially high-severity pedestrian or bicycle collision is increased by the absence of signal heads that indicated to pedestrians when then can safely cross the three-lane approach. This risk is increased when visually impaired pedestrians. NCHRP Report 572

<sup>2</sup> Rodegerds, L., et al; *NCHRP 572: Roundabouts in the United States* Transportation Research Board of the National Academies, Washington, DC, 2007.

states that more lanes resulted in a higher number of vehicles not yielding to crossing/waiting pedestrians (43% on two-lane sites versus 17% on one-lane sites)<sup>3</sup>. The increase of lanes makes it more difficult for pedestrians to cross, mainly because of non-yielding drivers.

Roundabouts of which these observations apply are located at the following interchanges (from south to north):

- County AAA (Oneida Street/Waube Lane)
- STH 54 (Mason Street)
- STH 29/STH 32 (Shawano Avenue/Dousman Street)
- CTH EB (Packerland Drive)

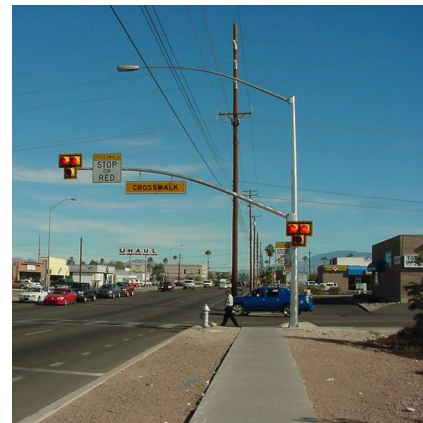


**USH 41 NB Off-Ramp  
at Onieda/Waube**

### Suggestions:

1. *Median Refuge:* A median refuge may be used to allow pedestrians to clear traffic in one lane and then the next two lanes. This will decrease crossing distance and pedestrian workload resulting in fewer conflicts.

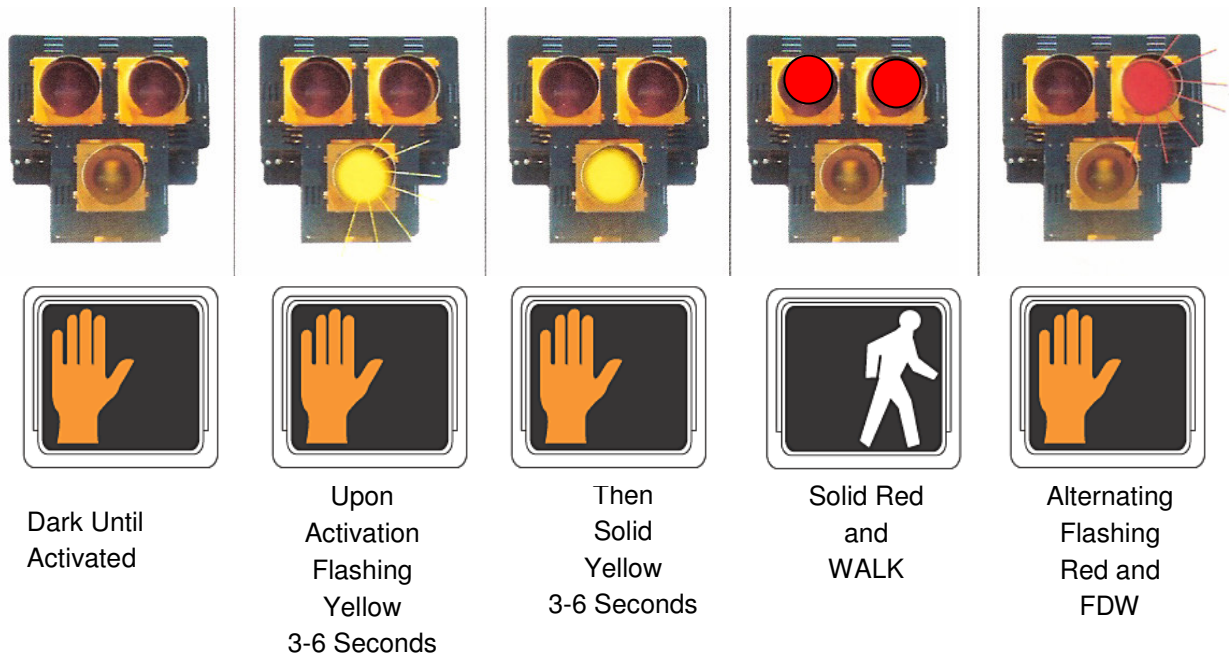
2. *Active Pedestrian Traffic Control:* A HAWK (High-Intensity Activated crosswalk) signal may be used to control traffic and safely direct pedestrians across a three-lane crosswalk. The HAWK signal, developed by the City of Tucson Arizona, is dark until activated by a pedestrian and then it cycles through flashing yellow, steady yellow, steady red, and then flashing red. The traffic and pedestrian signal displays are shown below in FIGURE 2.1. NCHRP 562<sup>4</sup> states that drivers are more likely to stop for a device that displays a red indication, resulting in a driver's average compliance rate of 96 percent with the installation of a HAWK signal. Verse a driver's average compliance rate of 17 percent to 62 percent depending on speed limit (25 mph of 35 mph respectively), with the installation of high visibility signs and markings. HAWK signals improve pedestrian safety and improve drivers stopping behavior.



<sup>3</sup> Based on a study by the Transportation Research Board of The National Academies, *Roundabouts in the United States* p. 89

<sup>4</sup> Fitzpatrick, K., et al; *NCHRP 562: Improving Pedestrian Safety at Unsignalized Crossings* Transportation Research Board of the National Academies, Washington, DC, 2006.

The HAWK signal will most likely be included within the next version of the MUTCD. This edition will have been adopted by WisDOT prior to construction of the USH-41 Expansion Project.



**FIGURE 2.1 HAWK SIGNAL OPERATIONS**

**Expected Crash Types:** pedestrian collisions

**Expected Frequency:** infrequent

**Expected Severity:** extreme

**Risk Rating:** D (significant risk level)

**Suggestions:** Suggestions for each intersection are discussed separately above. The design team may consider the advisability of widespread adoption of some improvement measures (at most or all roundabout intersections) to maintain consistency for drivers throughout the interchanges.

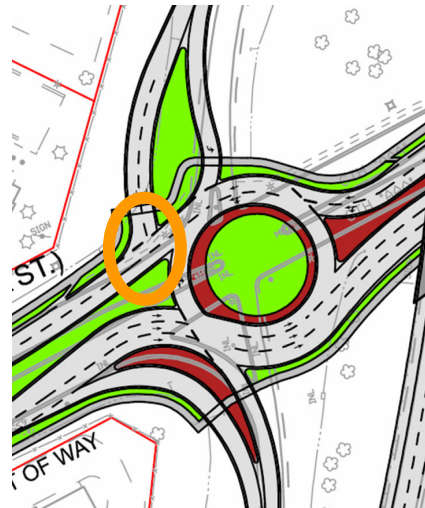
### 5.3 Safety Issue 3: Right-turn Lanes

#### Safety Issue 3(a): Conflicts between right-turns and the traffic exiting the roundabout

**Safety Issue 3(a) Description:** Interference between right-turn movements from the ramp and traffic exiting the roundabout at the interchange can be anticipated, since a limited deceleration and acceleration taper is provided. Interference between right-turning and through traffic is likely at this intersection, since the ramp provides access to trucks (which typically have slow acceleration characteristics) associated with the surrounding industries.

#### Safety Issue 3(b): Southbound right-turn volume

**Safety Issue 3(b) Description:** Southbound right-turn volume of 1150 vehicles per hour at CTH AAA (Oneida Street/Waube Lane) was not considered in roundabout analysis. As a result, this high volume right turning movement may be a major impact to the design. Furthermore, there may be issues with sight distance potentially resulting in angle crashes between southbound vehicles turning right and westbound vehicles exiting the roundabout.



**Onieda/Waube SB Exit Ramp**

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**Expected Crash Types:** roundabout collisions

**Expected Frequency:** frequent

**Expected Severity:** moderate

**Risk Rating:** D (significant risk level)

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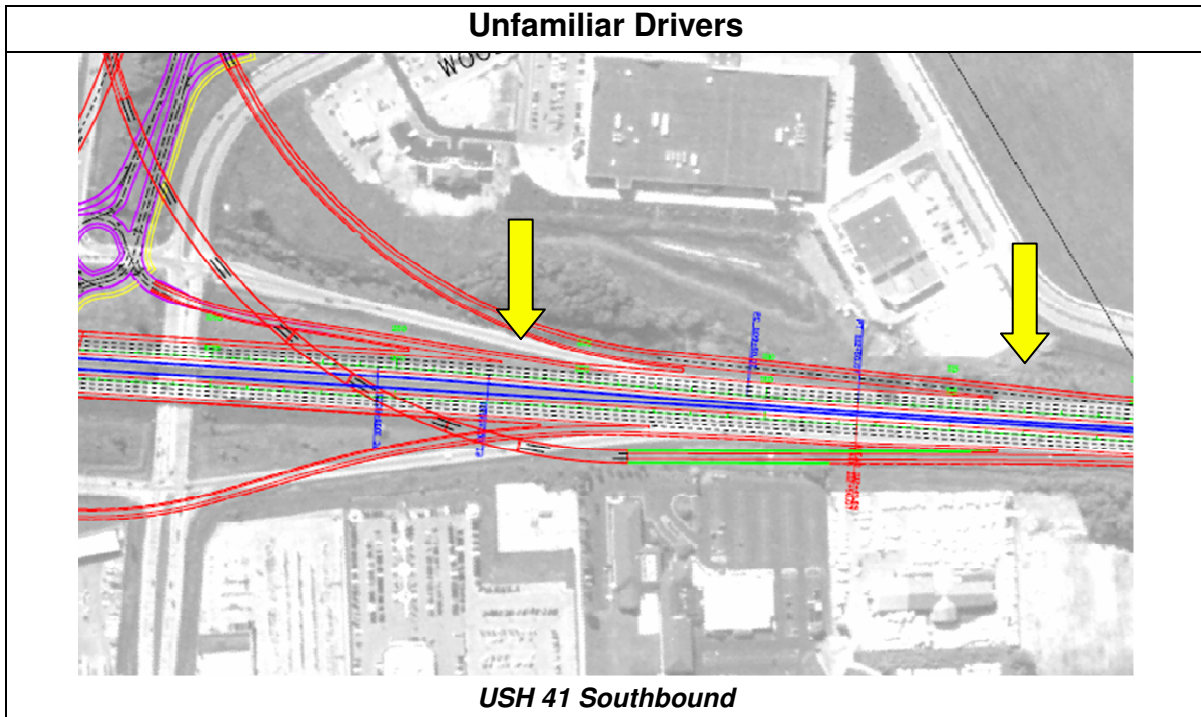
**Suggestions:**

1. *Add merge lane:* A parallel acceleration lane for right-turning traffic may be considered to allow right-turning drivers to accelerate for a longer distance before merging into the flow of traffic. At this location, a longer acceleration lane may require widening of the adjacent overpass structure.
2. *Revise analysis:* Include right-turn volume in analysis and redesign intersection if necessary.

**5.4 Safety Issue 4: STH 29 Interchange**

**Safety Issue 4(a): Unfamiliar Drivers-Guide Signing**

**Safety Issue 4(a) Description:** Guide signing of USH 41 southbound may cause confusion to unfamiliar drivers due to the close proximity of the ramps to each other and similar signing messages. Many of the unfamiliar drivers are truck drivers trying to access the nearby industrial areas. Weaving may become an issue with unfamiliar drivers who are unclear about their desired lane.



**Suggestions:**

*Consider guide sign requirements before finalizing interchange design:* Guide signing of exits to STH 29 should be considered before finalizing interchange design. Improved signing would reduce weaving and conflict points. An example of signing is shown below:





### Safety Issue 4(b): Merge on curve

**Safety Issue 4(b) Description:** Acceleration and merging on a curved roadway contribute to a high driver workload, which may be aggravated by poor visibility or pavement conditions due to rain or ice.



### Suggestions:

1. *Relocate Merges to Tangent Sections:* Relocating the merge to the tangent section would improve visibility and decrease driver workload.
2. *Extend Merge Distance:* Extending the merge will give drivers more distance to accelerate to the speed of the flow of traffic and give drivers more time to merge.
3. *Merge Arrows:* W4-1 Merge signs may be used on the ramp and mainline, to advise drivers that ramp traffic must merge. Due to the high driver workload for this curve, it is suggested that all advisory panels on guide signs use brighter fluorescent yellow sheeting as a means to encourage drivers to slow down.

### Safety Issue 4(c): Merge on bridge

**Safety Issue 4(c) Description:** Drivers entering the systems ramp from southbound USH 41 to eastbound STH 29/32 are required to merge on a bridge where icy conditions may prevail. The challenging geometric features are in part the result of severe constraints reflecting limited right-of-way and environmental limitations.



### Suggestions:

1. *Relocate Merge off of the Bridge:* Relocating merge off of the bridge may reduce sideswipe conflicts and loss of control of vehicle due to wet or icy pavement.

2. *High Friction Pavement on the Bridge:* If merge can not be relocated off of the bridge, high friction pavement on the bridge is recommended. High friction pavement would decrease loss of control of vehicle on wet and icy pavement.

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**Expected Crash Types:** sideswipe, rear end and loss control

**Expected Frequency:** occasional

**Expected Severity:** high

**Risk Rating:** D (significant risk level)

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**Suggestions:** Suggestions for each intersection are discussed separately above. The design team may consider the advisability of widespread adoption of some improvement measures (at most or all roundabout intersections) to maintain consistency for drivers throughout the interchanges.

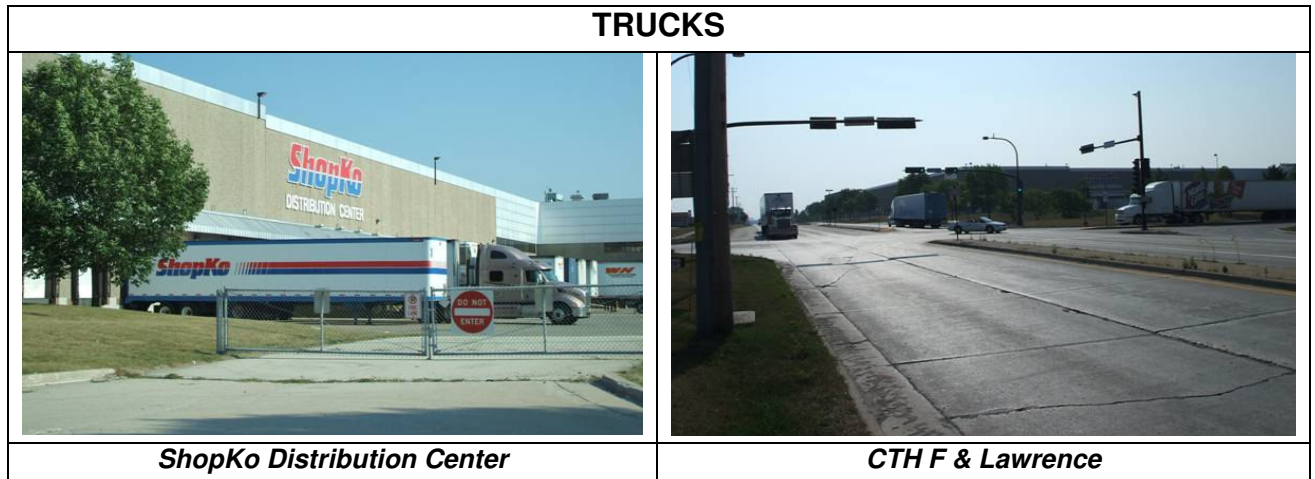
## 5.5 Safety Issue 5: Trucks

### Safety Issue 5: Heavy truck volume

**Safety Issue 5 Description:** Several distribution centers or industrial areas which generate significant commercial vehicle traffic are located nearby to the corridor. These include ShopKo (CTH F), Schneider (CTH AAA), Fleet Farm (STH 29/32), and Spancrete (STH 29/32). An average of twelve percent trucks is forecasted for the USH-41 corridor. As a result, in several cases, significant volumes of trucks will be required to make left-turn maneuvers around multi-lane roundabouts. While it is understood that fairly wide truck aprons will be provided within these roundabouts, there is still an increased risk of crashes involving trucks within several of the roundabouts along the corridor where this is the case.

The design vehicle utilized was WB-67 while larger vehicles such as a WB-100 may utilize the roundabouts to access the industrial areas. For example, at the proposed roundabouts near the Spancrete site, will trucks with a full load be able to maneuver through the roundabouts it must utilize to access Spancrete from USH-41. This instance would occur if a truck left the Spancrete site with the wrong load and needed to return.





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**Expected Crash Types:** roundabout collisions

**Expected Frequency:** occasional

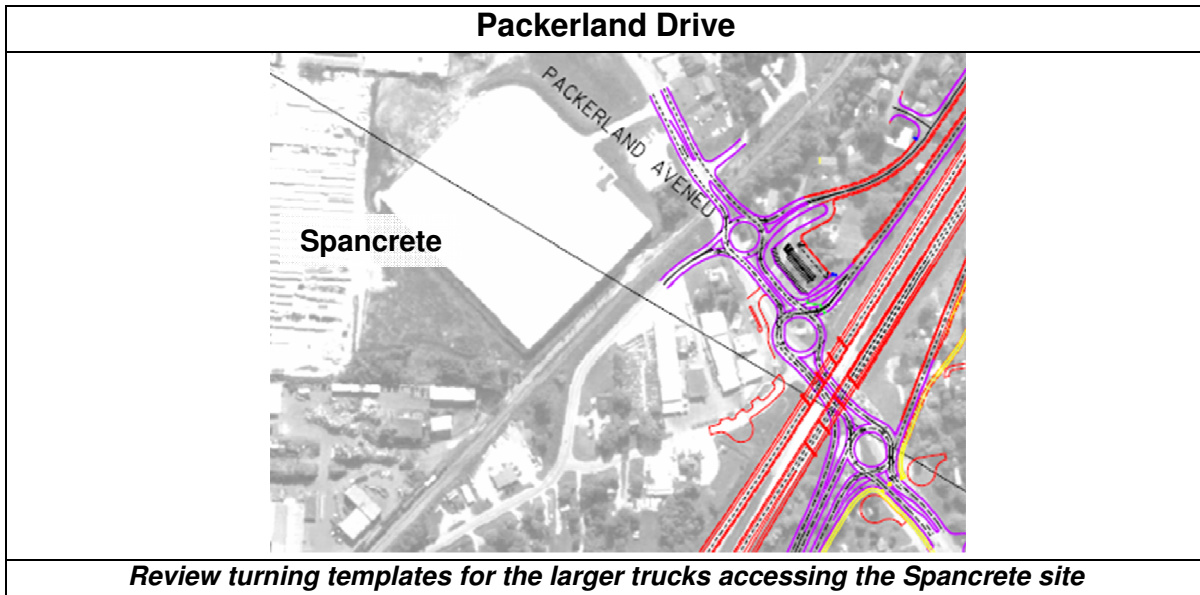
**Expected Severity:** moderate

**Risk Rating:** C (moderate risk level)

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**Suggestions:**

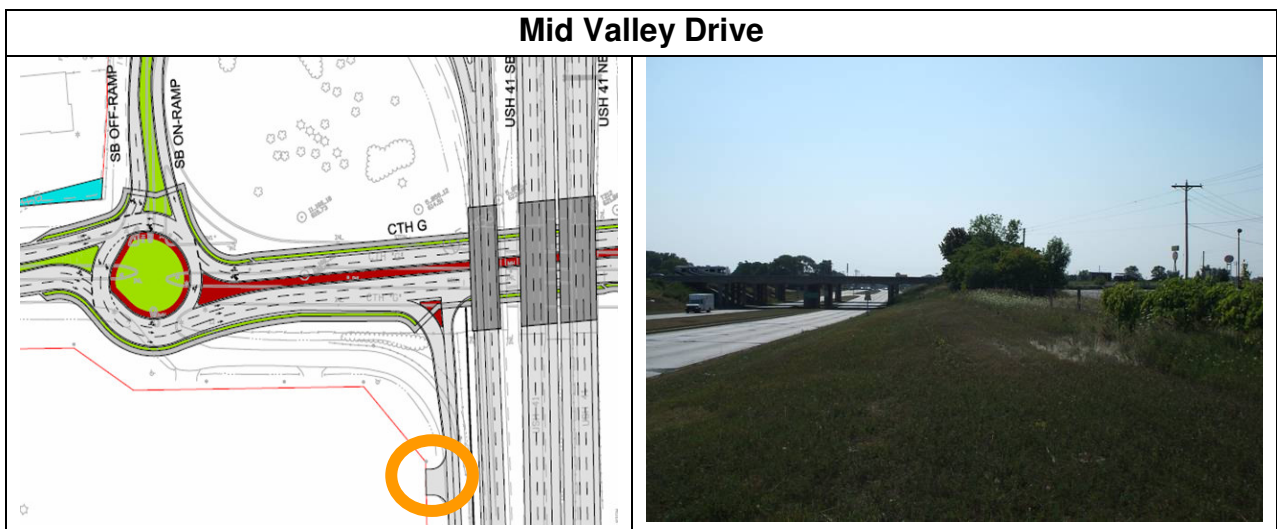
- Review Design Vehicle:* A design vehicle of WB 67 was used to determine the radius of the roundabout. Larger trucks such as the WB 100 from Spancrete may not be able to return to the distribution center if need be. A review of the design vehicle is suggested for all of the locations nearby to distribution centers and industrial areas to determine if larger trucks are able to travel through the roundabouts.
- Review Turning Templates:* Spancrete may utilize trucks larger than a WB 67 that have a larger turning radius than the typical design vehicle used. It is suggested that a review of turning templates at Packerland Drive be completed to determine whether the radii needed for a Spancrete truck to return back to the distribution center with the load. This is suggested for all of the locations nearby to distribution centers and industrial areas to determine if larger trucks are able to travel through the roundabouts.



## 5.6 Safety Issue 6: Access Management

### Safety Issue 6(a): Mid Valley Drive south of CTH G

**Safety Issue 6(a) Description:** A new intersection between Mid Valley Road and CTH G is proposed. As a result the access to the gas station on Mid Valley Drive is being relocated. As a result, the proposed location may have some sight distance restrictions caused by the vertical alignment at the Mid Valley Road and CTH G intersection. Furthermore, drivers turning on to Mid Valley Road from CTH G may not be expecting vehicles to be entering the roadway due to the vertical sight distance restrictions.



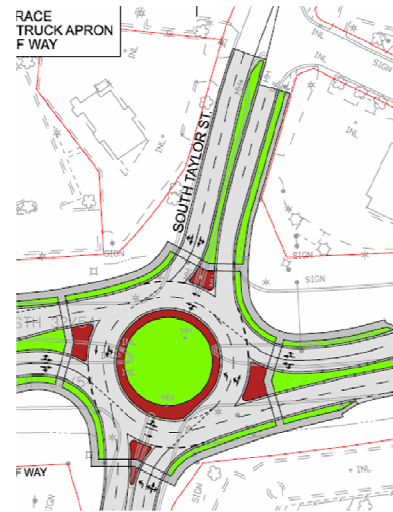
Suggested location of driveway	Vertical alignment
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**Suggestions:**

1. *Relocate Driveway:* Relocate driveway further to the south. This will allow for a more gradual vertical curve on the Mid Valley Road approach CTH G.
2. *Review Vertical Alignment:* Review the vertical alignment of the road to determine the best placement for the driveway to allow trucks to reach allowable speeds.

**Safety Issue 6(b): Taylor north of STH 54 (Mason Street)**

**Safety Issue 6(b) Description:** The median is extended just beyond the Circuit City driveway on Taylor Street north of Mason not allowing for left-turns. This may cause drivers to make U-turns around the median to turn into the driveway which may result in secondary rear-end collisions.



**Suggestions:**

*Left-Turn Lanes at Major Driveways:* Shorten the length of the median to allow direct left-turns into the Circuit city driveway. This would result in the decrease of conflicts with vehicles making U-turns.

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**Expected Crash Types:** intersection collisions

**Expected Frequency:** occasional

**Expected Severity:** moderate

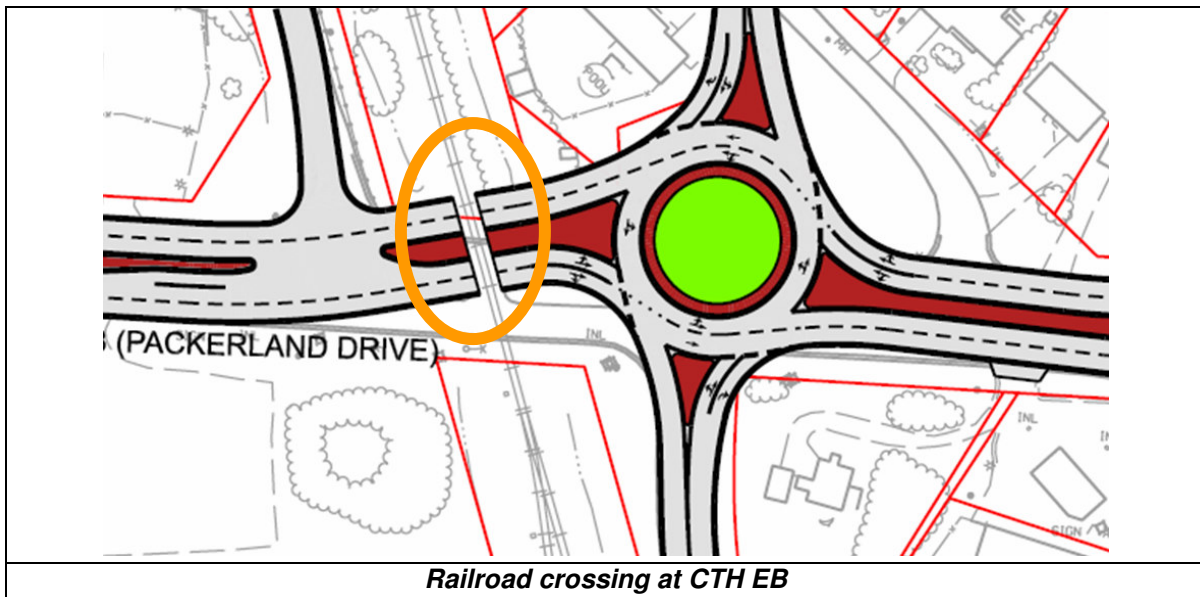
**Risk Rating:** C (moderate risk level)

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## 5.7 Safety Issue 7: Railroad Crossing at CTH EB

### Safety Issue 7: Close proximity of railroad track to roundabout

**Safety Issue 7 Description:** A railroad track is located on CTH EB approximately 150 feet west of Ulmer Road. Drivers may not be aware of train when exiting the roundabout, due to the close proximity of railroad track to the roundabout. Collisions with a train may result in severe injury or a fatality. Major delays and secondary rear end collisions may occur due to train crossing.



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**Expected Crash Types:** train collisions

**Expected Frequency:** rare

**Expected Severity:** extreme

**Risk Rating:** C (moderate risk level)

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**Suggestions:**

Changeable Message Signs: It is suggested that changeable message signs be installed on the roundabout entrances to inform vehicles that a train is approaching.

**Suggestions:**

1. *Pursue Track Relocation:* Track relocation would be the ideal improvement to improve roundabout operations. Relocation of the track would reduce delays near the roundabout and decrease collisions.
2. *Active Warning Signs:* If the track is not relocated, active warning signs to warn drivers of a train will alert drivers to slow down and stop while exiting and entering the roundabout.
3. *Gates:* Gates will prevent drivers from driving on the track while a train is passing thru. A gate will also decrease the possibility of a train collision to occur.
4. *Changeable Message Signs:* It is suggested that changeable message signs be installed on the roundabout entrances to inform vehicles that a train is approaching.









- Road Safety Engineering
- Transportation Planning
- Traffic Operations
- Transit and Sustainability
- Community and School Safety
- Asset Management