Report for

Bowling Green and Warren County Metropolitan Planning Organization

US 31W Bypass Traffic Analysis

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ABBREVIATIONS

ADT	average daily traffic
BG-WC MPO	Bowling Green–Warren County Metropolitan Planning Organization
CMF	crash modification factors
FHWA	Federal Highway Administration
GIS	geographic information system
HCM	Highway Capacity Manual
KYTC	Kentucky Transportation Cabinet
LOS	Level of Service
MEV	million entering vehicles
PHF	peak hour factor
RRFB	rectangular rapid flashing beacons
SIDRA	SIDRA 7 software
Strand	Strand Associates, Inc.®
Synchro	Synchro 10/SimTraffic 10 software
TWLTL	two-way left-turn lane
v/c	volume-to-capacity ratio
VMT	vehicle miles traveled
vpd	vehicles per day

OVERVIEW

The existing US 31W Bypass corridor between University Drive and Lehman Avenue is classified as an Urban Minor Arterial with 2019 average daily traffic (ADT) volumes of 16,090 vehicles per day (vpd) on the west end of the corridor and 18,203 vpd on the east end of the corridor (see Figure 1). The US 31W Bypass was built in the late 1940s as a narrow four-lane corridor located on the edge of the urban boundary at that time. Because the corridor was undeveloped with low projected volumes, little consideration was given to accommodating the heavy left-turn volumes that would eventually follow. Over time the Bypass has become a heavily developed commercial corridor with a high density of entrances and approaches, and the current roadway exhibits very poor access control. The number of entrances and approaches generate frequent left-turn movements from the interior through lane, which reduces roadway capacity and increases crashes. Furthermore, the high frequency of access points creates additional safety concerns for bicycles and pedestrians along the route. To that end, the Bowling Green and Warren County Metropolitan Planning Organization (BG-WC MPO) and partnering agencies seek to improve safety and mobility for all roadway users along the Bypass corridor.

The dense development with businesses and parking located very close to the existing right-of-way makes widening the existing four-lane road to a five-lane facility with a two-way left-turn lane (TWLTL) cost-prohibitive. Because of these constraints, the implementation of a road diet may offer a low-cost alternative to accommodate frequent left turns and also improve bike and pedestrian safety. Therefore, the BG-WC MPO collaborated with the City-County Planning Commission, the City of Bowling Green, and the Kentucky Transportation Cabinet (KYTC) to commission a study that would determine the feasibility of implementing a road diet as an economical solution to improve safety and mobility for all users. The proposed road diet on the US 31W Bypass would convert the existing four-lane road into a three-lane facility with a TWLTL and investigate additional bike and ped improvements, including the feasibility of adding dedicated bike lanes. Funding for this study was provided by BG-WC MPO discretionary funds and the City of Bowling Green.

Figure 1 US 31W Bypass Corridor

Strand Associates, Inc.® (Strand) performed an intersection traffic analysis that considered existing conditions, future conditions without intersection or corridor improvements, and future conditions with the road diet to evaluate intersection capacity and operations. The intersections that were evaluated as part of the analysis include US 31W Bypass and University Drive, US 31W Bypass and Chestnut Street, US 31W Bypass and Cabell Drive, US 31W Bypass and Broadway Avenue, US 31W Bypass and 10th Avenue, and US 31W Bypass and Lehman Avenue. The analysis is based on existing signal timings and turning movement counts completed on October 19, 2017, and September 19, 2019.

DATA COLLECTION

The existing conditions analysis included collecting signal timing data, geographical information system (GIS) data, crash data, and intersection turning movement counts. KYTC District 3 provided existing signal timing data for the traffic models.

A. Turning Movement Counts

Strand completed six-hour vehicular turning movement counts for the peak hours at the following intersections:

- US 31W Bypass and University Drive
- US 31W Bypass and Chestnut Drive
- US 31W Bypass and Cabell Drive
- US 31W Bypass and Broadway Avenue
- US 31W Bypass and 10th Avenue
- US 31W Bypass and Lehman Avenue

The Lehman Avenue count was conducted on October 19, 2017 and the remaining turning movement counts were conducted on September 19, 2019. Figure 2 shows the turning movement count locations. The AM peak hour occurs between 7:15 A.M. and 8:15 A.M. except at the US 31 Bypass and Lehman Avenue intersection where the peak occurs between 7:30 A.M. and 8:30 A.M. The peak-hour factors (PHF) for the AM peak are between 0.84 and 0.92. The PM peak hour occurs between 4:30 P.M. and 5:30 P.M. except at the US 31 Bypass and Lehman Avenue intersection where the peak occurs between 4:00 P.M. and 5:00 P.M. The PHFs for the PM peak are between 0.91 and 0.98. The Highway Capacity Manual (HCM) indicates a PHF below 0.92 for an urban corridor is indicative of a recognizable surge in volumes during a 15-minute period in the peak hour. The PHF exhibited during the morning commute indicates there is a noticeable peak in traffic on US 31W Bypass during a 15-minute period. The PHF for the afternoon commute indicates the surge is less noticeable and traffic volumes are more evenly distributed throughout the PM peak hour.

Figure 2 Turning Movement Count Locations

Traffic generally increased from the AM peak hour throughout the day before reaching the highest volumes during the PM peak hour. Eastbound traffic on US 31W and northbound traffic on the minor approaches were generally highest during the AM peak hour. Southbound traffic on the minor approaches was typically greater during the PM peak hour, and a more even distribution of travel direction on US 31W was observed during the PM peak hour.

Data obtained from the turning movement counts is included in Appendix A.

B. Traffic Forecast

Continued development in the Bowling Green region will lead to increased traffic volumes, typically referred to as "background traffic growth."

Traffic forecasts were developed by Strand in coordination with KYTC. KYTC used the Warren County travel demand model to provide projected 2030 traffic volume data for the US 31W Bypass corridor within the study limits. Strand reviewed the projected 2030 traffic volume data and proposed a 1.3 percent annual increase. The group also noted that historic traffic counts on this section of the US 31W Bypass show that volumes have fluctuated ±10 percent over the past 20 years and the most recent counts actually show a decline in traffic volumes. After considering this and the output from the travel demand model, the stakeholder group determined that 1.3 percent was an appropriate growth rate and would account for future growth while not overestimating future demands.

Applying the 1.3 percent growth rate to the current ADTs on the US 31W Bypass would generate a 2030 ADT of 18,300 vpd on the western portion of the corridor and 20,700 vpd. The Federal Highway Administration (FHWA) provides general guidance that indicates road diets can be successful with an ADT greater than 20,000 vpd; however, a corridor analysis should confirm there is sufficient capacity at intersections to confirm it is a good candidate. The 2019 turning movement counts were also increased for all approaches by an annual linear growth rate of 1.3 percent to project traffic volumes in the future conditions models.

INTERSECTION OPERATIONS

A. Traffic Analysis

Strand evaluated each of the following scenarios and analyzed intersection operations during the AM and PM peak hours.

1. 2019 Existing Conditions
2. 2030 Future No-Build
3. 2030 Road Diet Alternative

Existing conditions models used volumes directly from the traffic count data collected by Strand. Future scenarios used traffic count volumes projected forward using the 1.3 percent annual background growth rate. Existing and proposed motor vehicle operations were analyzed using Synchro 10/SimTraffic 10 software (Synchro). Synchro is a macroscopic program that uses equations outlined in the HCM developed by the FHWA. SimTraffic is a microsimulation program that models individual vehicles on a simulated network that represents existing or proposed street conditions. The vehicles are assigned routings based on turning movement counts at each individual intersection. Roundabouts were analyzed using SIDRA 7 software (SIDRA), another microanalytical traffic evaluation program that can analyze roundabout intersections according to HCM-defined procedures or empirical-based formulas.

Intersection operations are evaluated using collected data to provide a Level of Service (LOS). An intersection's LOS is based on average delay in seconds per vehicle for traffic entering the intersection. LOS A indicates travelers will experience minimal average delay at an intersection (less than 10 seconds). LOS F indicates the average delay is high (more than 50 seconds at an unsignalized intersection and 80 seconds at a signalized intersection or roundabout).

For signalized intersections, the overall intersection operations are reported using the HCM 6 overall intersection delay calculated in Synchro. For unsignalized intersections, the highest delay for any yielding movement is used to report the overall intersection operations to prevent the higher volume through movements with zero delay from skewing the average delay for the intersection. Table 1 shows the delay threshold for LOS at signalized and unsignalized intersections.

LOS	Signalized Intersections (average delay, seconds)	Unsignalized Intersections (average delay, seconds)
A	<10	<10
B	10 to 20	10 to 15
C	>20 to 35	>15 to 25
D	>35 to 55	>25 to 35
E	>55 to 80	>35 to 50
F	>80	>50

Table 1 LOS Thresholds

LOS E is often considered to be the limit of acceptable delay and LOS F indicates a facility on which the vehicle arrivals exceeds the capacity of the intersection. All vehicle queuing is reported as the 95th percentile queue, or the queue length that has only a 5 percent probability of being exceeded during the analysis time period.

B. 2019 Existing Conditions

The project corridor was analyzed with existing traffic volumes obtained from the turning movement counts. Table 2 displays the average intersection delay experienced by vehicles entering the intersection, as well as the intersection LOS. Detailed HCM 6 output from Synchro and SIDRA and summary tables for modeling results at each intersection and scenario are included in Appendices B, C. D. and E.

Intersection	Existing Conditions			
	AM Peak		PM Peak	
	Delay (s)	LOS	Delay (s)	LOS
US 31W Bypass and University Drive	9.0	A	9.3	A
US 31W Bypass and Chestnut Drive*	10.7	B	16.1	C
US 31W Bypass and Cabell Drive	13.7	B	18.8	B
US 31W Bypass and Broadway Avenue	79.5	E	95.7	F
US 31W Bypass and 10th Avenue**	9.8	A	9.8	A
US 31W Bypass and Lehman Avenue	20.6	C	23.4	C

*LOS refers to worst approach for unsignalized intersection.
**Left turns are restricted on US 31W Bypass at the 10th Avenue intersection.

Table 2 Existing Conditions–Intersection Delay and LOS

1. US 31W Bypass and University Drive

The existing University Drive intersection is a four-leg dual-lane roundabout that operates with all movements at LOS C or better during both peak hours. During the AM peak hour, the roundabout operates at LOS A overall with a maximum volume-to-capacity (v/c) ratio of 0.61. All movements operate at LOS A or B.

During the PM peak hour, the intersection operates at LOS A overall with the eastbound right-turn movement operating at LOS C and a 95th percentile queue of 140 feet. All other movements operate at LOS A or LOS B. Figure 3 shows the existing lane configurations at the US 31W Bypass and University Avenue intersection.

Figure 3 Existing University Drive and Chestnut Street Intersections

2. US 31W Bypass and Chestnut Street

The existing unsignalized intersection of US 31W Bypass and Chestnut Street is a three-leg intersection with a stop-controlled approach on Chestnut Street. A raised median restricts left turns, thus only allowing eastbound right-turn and westbound right-turn movements. Left-turn movements for this intersection are accommodated by the nearby roundabout at University Drive. See Figure 3 for existing lane configurations at the US 31W Bypass and Chestnut Street intersection.

The intersection operates at LOS B overall during the AM peak hour and LOS C during the PM peak hour

3. US 31W Bypass and Cabell Drive

The existing signalized intersection of US 31W Bypass and Cabell Drive is the only intersection between Lehman Avenue and University Drive that was widened to provide dedicated eastbound and westbound left-turn lanes. The intersection operates at LOS B overall during the AM and PM peak hours. See Figure 4 for existing lane configurations at the US 31W Bypass and Cabell Drive intersection.

Figure 4 Existing Cabell Drive Intersection

4. US 31W Bypass and Broadway Avenue

The signalized intersection of US 31W Bypass and Broadway Avenue has the worst operations on the corridor. This is due to relatively high traffic volumes and the split signal phases required to accommodate the high volume of left-turn movements at the intersection. Opposing traffic for left-turn movements and the lack of any dedicated left-turn lanes requires each approach be provided an exclusive green phase for all vehicle movements from that direction. This is necessary to prevent vehicles waiting to make a left turn from blocking through traffic in the shared lane. However, this also increases the overall cycle length and results in drivers having to wait for the signal to cycle through each approach before they receive the green light. This leads to a lower intersection capacity with longer delays and queue lengths than experienced with typical signal phasing. Figure 5 shows the existing intersection layout.

During the AM. peak hour, the intersection operates at LOS E overall, nearing LOS F, with a maximum v/c ratio of 1.17 on the northbound approach indicating the northbound approach is 17 percent over capacity. All approaches operate at LOS D or worse during the AM peak hour. The northbound approach operates at LOS F with a 95th percentile queue of about 475 feet. The eastbound approach operates at LOS E with a 95th percentile queue of about 330 feet. The southbound approach operates at LOS D with a 95th percentile queue of about 165 feet. The westbound approach operates at LOS D with a 95th percentile queue of about 285 feet.

Figure 5 Existing Broadway Avenue Intersection

During the PM peak hour, the intersection operates at LOS F overall with a maximum v/c of 1.19 on the northbound approach. The northbound approach operates at LOS F with a 95th percentile queue of about 430 feet. The eastbound approach operates at LOS D with a 95th percentile queue of about 265 feet. The southbound approach operates at LOS E with a 95th percentile queue of about 335 feet. The westbound approach operates at LOS F with a 95th percentile queue of about 395 feet. The high v/c ratios and average delay in both peak hours indicate this intersection is operating near or above capacity with the current layout during the peak hours.

5. US 31W Bypass and 10th Avenue

The existing signalized intersection at US 31W Bypass and 10th Avenue prohibits the eastbound left-turn and westbound left-turn movements on the US 31W Bypass and both 10th Avenue approaches are a single lane. The intersection operates at LOS A overall during the AM and PM peak hours and all movements operate at LOS A or B. Figure 6 shows the existing layout at the intersection.

Figure 6 Existing 10th Avenue Intersection

6. US 31W Bypass and Lehman Avenue

The existing conditions model for this intersection used volumes collected from a 2017 turning movement count. Modeling indicates the existing signalized intersection of US 31W Bypass and Lehman Avenue operates at LOS C overall during the AM and PM peak hours and all movements operate at LOS D or better. Figure 7 shows the existing layout at the intersection.

Figure 7 Existing Lehman Avenue Intersection

C. 2030 Future No–Build

The project corridor was also analyzed using existing intersection geometry and 2030 projected traffic volumes. The future No-Build model assumes no geometric improvements will be made to the corridor and provides a baseline for comparison to proposed alternatives. Table 3 shows the average intersection delay and LOS under future 2030 No-Build conditions. Detailed HCM output from Synchro and SIDRA, and summary tables for each intersection are included in Appendix D.

Intersection	Future No-Build Conditions			
	AM Peak		PM Peak	
	Delay (s)	LOS	Delay (s)	LOS
US 31W Bypass and University Drive	12.1	B	13.1	B
US 31W Bypass and Chestnut Drive*	11.3	B	20.0	C
US 31W Bypass and Cabell Drive	14.6	B	20.9	C
US 31W Bypass and Broadway Avenue	125.5	F	148.8	F
US 31W Bypass and 10th Avenue	10.6	B	10.6	B
US 31W Bypass and Lehman Avenue	22.2	C	26.1	C

*LOS refers to worst approach for unsignalized intersection.

Table 3 2030 No-Build Conditions–Intersection Delay and LOS

1. US 31W Bypass and University Drive

The US 31W Bypass and University Drive intersection operates at LOS B overall during the AM peak hour. All movements operate at LOS C or better.

During the PM peak hour, the intersection operates at LOS B. The eastbound shared through and right-turn lane operates at LOS D. All other movements operate at LOS C or better.

2. US 31W Bypass and Chestnut Drive

The US 31W Bypass and Chestnut Street intersection operates at LOS B overall during the AM peak hour and at LOS C overall during the PM peak hour.

3. US 31W Bypass/Cabell Drive

The US 31W Bypass and Cabell Drive intersection operates at LOS B overall during the AM peak hour. All northbound movements and the southbound left-turn operate at LOS D. All other movements operate at LOS C or better.

During the PM peak hour, the intersection operates at LOS C overall. The 95th percentile queues in the southbound through/right-turn lane reaches 225 feet. All movements operate at LOS C or better.

4. US 31W Bypass and Broadway Avenue

The US 31W Bypass and Broadway Avenue intersection operates at LOS F overall with three approaches operating with v/c ratios greater than 1.0 during the AM peak hour. The maximum v/c ratio at the intersection is 1.36 on the northbound approach during the AM peak hour. The northbound, eastbound, and westbound approaches all have v/c ratios above 1.0 indicating the projected demand exceeds capacity for the whole intersection with an overall v/c ratio of 1.06. Average intersection delay is 125.5 seconds with the average delay on the northbound approach exceeding 200 seconds.

Similar to the AM peak hour, the northbound approach operates at LOS F with a v/c ratio of 1.37 and more than 200 seconds of average delay. The southbound and westbound approaches also operate at LOS F with v/c ratios 1.11 and 1.27. The eastbound approach operates at LOS E but has a v/c ratio of 0.95. Overall, the intersection operates at LOS F with an average delay of 148.8 seconds during the PM peak hour.

5. US 31W Bypass and 10th Avenue

The US 31W Bypass and 10th Avenue intersection operates at LOS B during the AM and PM peak hours. All movements operate at LOS A or B for both peak hours.

6. US 31W Bypass and Lehmann Avenue

The US 31W Bypass and Lehmann Avenue intersection operates at LOS C overall during the AM peak hour. The southbound left-turn operates at LOS D and all other movements operate at LOS C or better.

During the PM peak hour, the intersection operates at LOS C overall. All movements operate at LOS D or better.

D. 2030 Road Diet Alternative

A road diet consists of maintaining the existing roadway footprint and replacing a through lane in each direction with a shared TWLTL. Road diets are often implemented on corridors with a high density of access points as they can provide an economical solution that addresses safety and operational concerns associated with left-turning movements. Implementing a road diet to accommodate a TWLTL in lieu of widening the US 31W Bypass reduces construction costs and eliminates the need for costly utility relocations and right-of-way acquisition. Figure 8 shows a typical three-lane road diet section, including sidewalks.

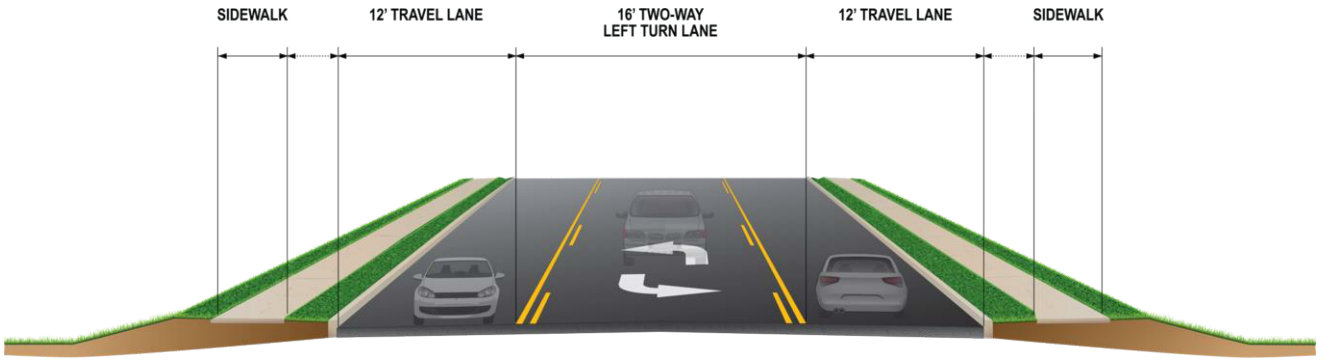


Figure 8 Three-Lane Road Diet Typical Section

E. Transitions

The proposed Road Diet alternative begins just east of the splitter island for the University Drive roundabout. This provides a relatively short distance (approximately 350 feet) for northbound traffic to merge from two lanes into one lane. However, this will be adequate because of the merge area being located downstream of the roundabout. Typically, vehicles exiting a roundabout will do so more "randomly" compared to vehicles exiting a signalized intersection. Consequently, the two northbound lanes will have an intermittent and staggered exit pattern enabling a more efficient "zipper effect" for traffic merging together. This allows the Road Diet to be implemented relatively close to the intersection while not impacting lane usage within the roundabout. As a result, the TWLTL can be added in advance of the entrance to Zaxby's drive-thru and Campus Plaza Court to mitigate the high number of crashes that occur at these locations. Figure 9 shows the conceptual layout for the transition adjacent to the roundabout.

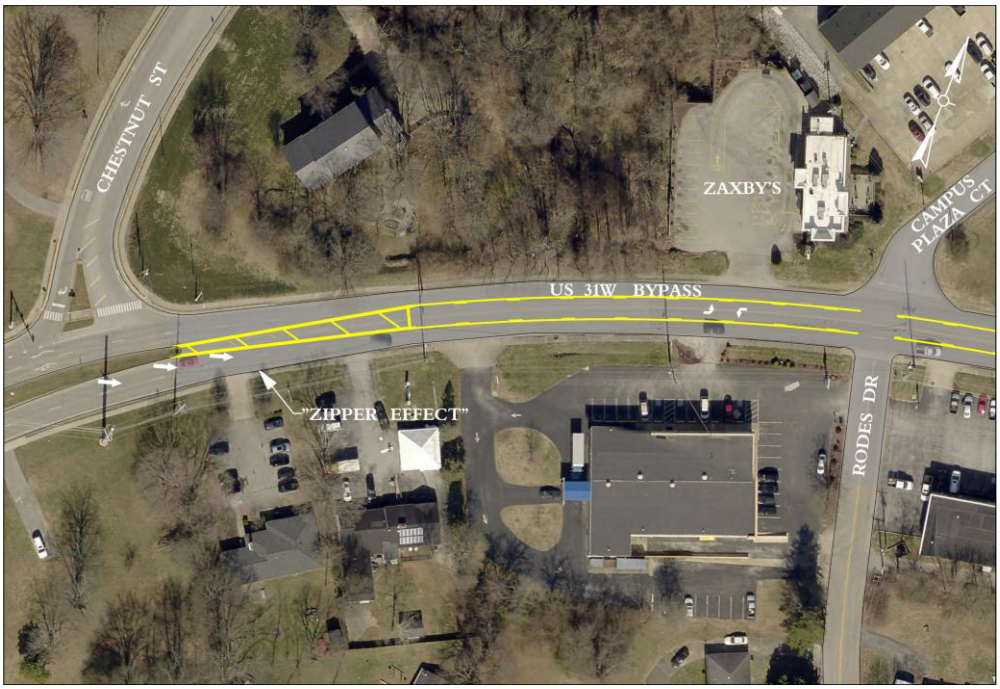


Figure 9 Conceptual Layout–Road Diet Transition at Chestnut Street

The proposed Road Diet continues east and terminates near Lain Avenue before reaching the Lehmann Avenue intersection. This will minimize impacts to lane usage that could negatively impact operations at the adjacent Fairview Avenue intersection where traffic volumes increase significantly. Unlike at the roundabout, westbound vehicles exiting the Lehman Avenue traffic signal require a longer merge area as adjacent through lanes depart the signal at the same time, making merging more difficult. Consequently, the transition into the three-lane section is located approximately 600 feet west of the Lehman Avenue intersection and more than 2,000 feet west of the Fairview Avenue intersection. Figure 10 shows a conceptual layout for the proposed westbound lane drop and eastbound left-turn lane at the transition.

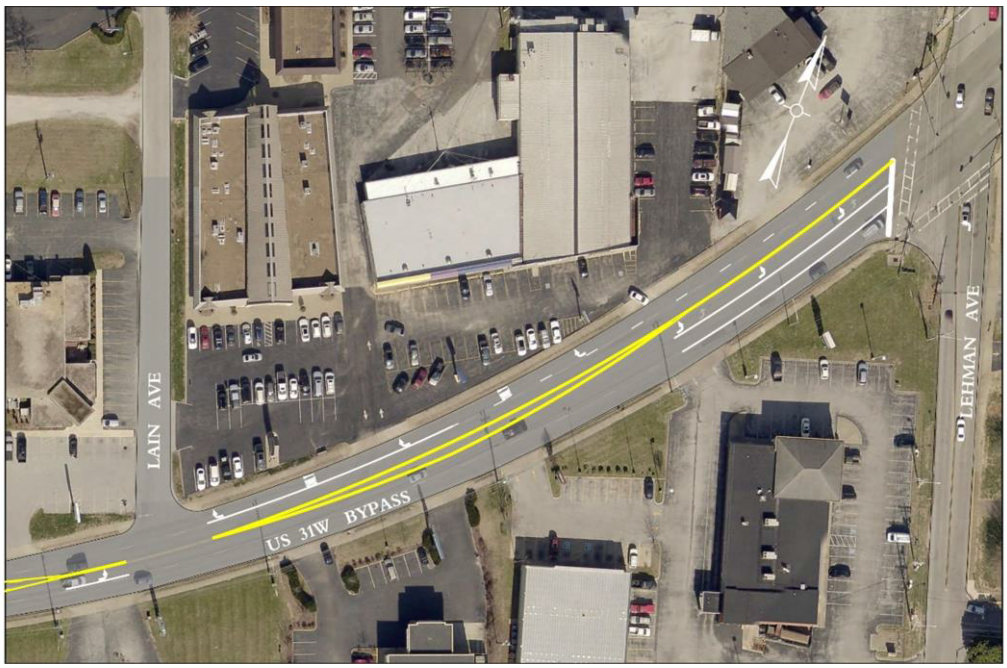


Figure 10 Conceptual Layout–Road Diet Transition at Lain Avenue

F. Operations

The project corridor was analyzed with the three-lane typical section between these transitions using traffic volumes projected for 2030. This analysis evaluated operational impacts that result from modifications made to the intersections of Cabell Drive, Broadway Avenue, and 10th Street for the Road Diet alternative. Table 4 shows the intersection delay and LOS under the 2030 Road Diet alternative. Detailed HCM output from Synchro and SIDRA, and summary tables for each intersection are included in Appendix E.

Intersection	Future Build Road Diet Alternative			
	AM Peak		PM Peak	
	Delay (s)	LOS	Delay (s)	LOS
US 31W Bypass and University Drive	12.1	B	13.1	B
US 31W Bypass and Chestnut Drive*	11.3	B	20.0	C
US 31W Bypass and Cabell Drive	16.7	B	30.2	C
US 31W Bypass and Broadway Avenue	54.7	D	66.7	E
US 31W Bypass and 10th Avenue	12.7	B	12.8	B
US 31W Bypass and Lehman Avenue	22.3	C	26.1	C

*LOS refers to worst approach for unsignalized intersection.

Table 4 2030 Road Diet Alternative–Intersection Delay and LOS

1. US 31W Bypass and University Drive

The US 31W Bypass and University Drive intersection operates at LOS B overall during the AM and PM peak hour. All movements operate at LOS D or better. These operations are identical to the future No-Build alternative as there are no changes to the intersection layout and impacts to lane usage within the intersection are not expected with the Road Diet alternative.

2. US 31W Bypass and Chestnut Drive

The US 31W Bypass and Chestnut Drive intersection operates at LOS B overall during the AM peak hour and LOS C overall during the PM peak hour. All movements operate at LOS C or better. These operations are identical to the future No-Build alternative as there are no changes to the intersection layout and impacts to lane usage within the intersection are not expected with the proposed changes.

3. US 31W Bypass and Cabell Drive

Previous widening at this intersection to add the existing dedicated eastbound and westbound left-turn lanes on the US 31W Bypass provides ample space for the proposed intersection to support dedicated right- and left-turn lanes on the eastbound and westbound approaches. The larger footprint also requires striping on the downstream end of the intersection to properly align travel lanes. Bumpouts could also be added. However, a turning movement analysis should be completed before implementation to confirm large trucks can navigate the intersection. Figure 11 shows one proposed lane configuration at the Cabell Drive intersection under the Road Diet alternative.

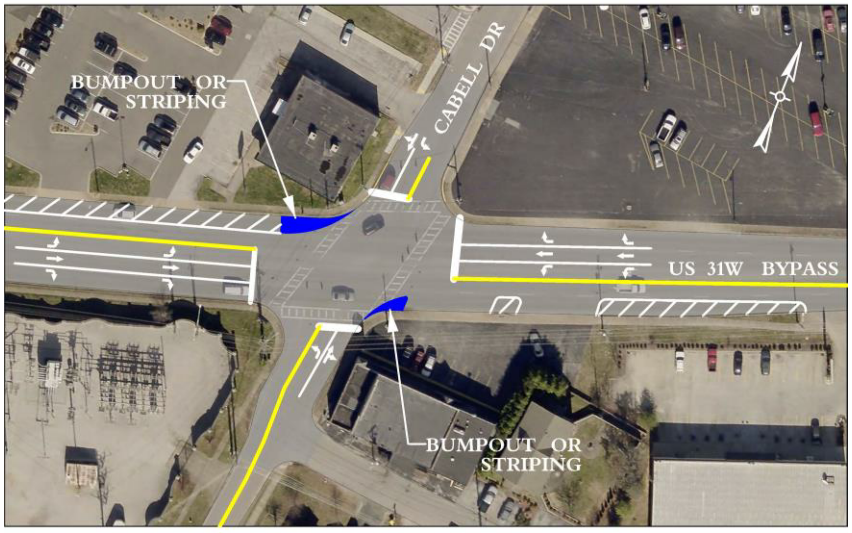


Figure 11 Cabell Drive Alt 1: Bumpouts and Right-Turn Lanes

The US 31W Bypass and Cabell Drive intersection operates at LOS B overall with a maximum v/c ratio of 0.76 for the eastbound through lane during the AM peak hour. When compared to the Future No-Build alternative, the overall average delay increased 2.1 seconds and the eastbound and westbound approaches generally experience longer delays and queue lengths. The eastbound through movement delay increases from 10.1 to 16.1 seconds, and the 95th percentile queue length increases from about 185 to 370 feet, or just past the Meredith Drive intersection. When compared to the Future No-Build alternative, the westbound through movement delay increases from 11.4 to 12.6 seconds, and the 95th percentile queue length increases from about 120 to 220 feet. The total number of vehicles in the queue and LOS for the approaches are comparable to the Future No-Build scenario. However, the queue length is nearly doubled

because the vehicles are stored in one lane rather than two. All movements operate at LOS C or better.

During the PM peak hour, the intersection operates at LOS C overall with a maximum v/c ratio of 0.89 for the westbound through-lane. Similar to the AM peak hour, there was a marginal increase in average delay (5.9 seconds) and the eastbound and westbound approaches experience longer delays and queue lengths when compared with the Future No-Build scenario. The eastbound through movement delay increases from 16.1 to 22.3 seconds, and the 95th percentile queue length increases from about 230 to 425 feet. The westbound through movement delay increases from 19.1 to 32.6 seconds, and the 95th percentile queue length increases from about 260 to 565 feet, nearly reaching the 16th Avenue intersection. While there will be a marginal decline in operations during the PM peak hour with the Road Diet alternative, delay is still within an acceptable range with all movements operating at LOS D or better.

An additional alternative was modeled for this intersection that would use a raised median on the eastbound and westbound approaches of the US 31W Bypass to restrict left turns into and out of businesses located on the Bypass. Nearly all the businesses at the intersection have additional access points on Cabell Drive, except for the development in the southeast quadrant. Restricting the left-turn movements into these developments would reduce the number of conflict points and likely improve crash rates at the intersection. Figure 12 provides a conceptual layout for this alternative.

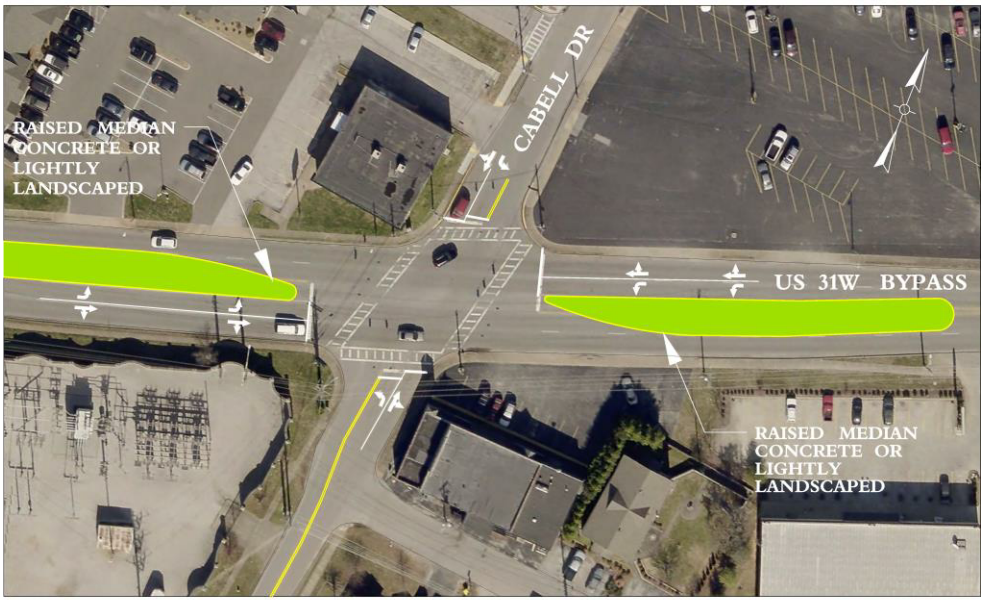


Figure 12 Cabell Drive Alt 2: Raised Median Without Right-Turn Lanes

If eastbound and westbound right-turn lanes remain with this alternative, the addition of the raised median creates a 12-foot offset between the through lanes on the US 31W Bypass and the associated receiving lanes downstream of the intersection. Therefore, the eastbound and westbound right-turn lanes were removed in the conceptual layout to avoid the need for a long taper to accommodate the 12-foot offset and to simplify the geometry at this intersection. Results from a separate traffic model, which analyzed 2030 operations without the right-turn lanes, showed the average intersection delay would increase 1.3 seconds during the AM peak hour and 3.4 seconds during the PM peak hour when compared to Alternative 1–Bumpouts with Right-Turn Lanes. Marginal increases in delays and queue lengths were seen for eastbound and westbound

movements with no noticeable changes to the northbound and southbound movements. An autoturn analysis was also completed for this alternative to establish the preliminary shape of the median. The results of this analysis confirmed the medians could not be extended into the crosswalks to provide pedestrian refuge across the US 31W Bypass.

4. US 31W Bypass and Broadway Avenue

The Road Diet alternative proposes converting all the approaches at the US 31W Bypass and Broadway Avenue intersection from a shared through-left lane and through-right lane shared to a dedicated left-turn lane and a shared through-right lane. Separating through traffic and left turns allows modifications to be made to the signal timing to replace the current split phasing with more traditional signal phasing. These modifications result in significant improvements to overall delay at the intersection.

An optional improvement would be to modify the typical section on Broadway Avenue between Indianola Street and US 31W to provide a TWLTL to Kenton Street. The typical section would then transition back into the existing roadway north of Kenton Street to preserve on-street parking spaces on Broadway Avenue between Kenton Street and Indianola Street. Figure 13 shows the proposed Broadway Avenue lane configuration.

Figure 13 Broadway Avenue Proposed Lane Configuration

During the AM peak hour, the Broadway Avenue intersection operates at LOS D overall with a maximum v/c ratio of 1.06 in the shared eastbound through/right-turn lane. The average delay for the intersection is reduced from 125.5 seconds in the Future No-Build scenario to 54.7 seconds with the Road Diet alternative. The shared eastbound through/right-turn lane operates at LOS F with a 95th percentile queue of about 895 feet. The queue is more than twice as long as the Future No-Build scenario, but the improved signal timing results in a similar amount of average delay for this movement. The southbound left-turn movement operates at LOS E with a 95th percentile queue of about 55 feet. The left turns experience more delay under this scenario, but this is offset

by the slight reduction in average delay for the southbound through and southbound right-turn movements. The westbound left-turn movement operates at LOS E with a 95th percentile queue of about 405 feet. All other movements operate at LOS D or better.

During the PM peak hour, the intersection operates at LOS E overall with a maximum v/c ratio of 1.10 for the northbound left-turn movement. The average delay for the intersection is reduced from 148.8 seconds in the Future No-Build scenario to 66.7 seconds with the Road Diet alternative. The northbound left-turn movement operates at LOS F with a 95th percentile queue of about 370 feet. The shared eastbound through/right-turn lane operate at LOS F with a 95th percentile queue of about 720 feet. The shared southbound through/right-turn lane also operates at LOS F with a 95th percentile queue of about 775 feet. The westbound left-turn lane operates at LOS F with a 95th percentile queue of about 430 feet. All other movements operate at LOS D or better. When comparing the Road Diet alternative with the No-Build alternative, the Road Diet alternative significantly reduces overall delays and v/c ratios for most movements but increases the 95th percentile queues for nearly all movements.

5. US 31W Bypass and 10th Avenue

The Road Diet alternative proposes converting the inside eastbound and westbound through lane to a left-turn lane at the US 31W Bypass and 10th Avenue intersection. Figure 14 shows the proposed lane configuration at the intersection.

Figure 14 10th Avenue Proposed Lane Configuration

Because left turns will be allowed at the intersection, the entrances on the US 31W Bypass nearest the intersection should be converted to right-in right-out to restrict left turns. All these developments have secondary entrances on 10th Avenue so left-turn movements could be routed through the signal via 10th Avenue to improve safety.

Two traffic models were analyzed for this intersection to provide a valid comparison to the Future No-Build scenario and to estimate the impact a proposed development in the southwest quadrant will have on operations. The initial model did not add in traffic volumes for the eastbound and westbound turning movements and showed a minimal increase in delays and queues when compared to the Future No-Build alternative. During the AM peak hour, the intersection operates at LOS B overall with a maximum v/c ratio of 0.80 for the shared eastbound through/right-turn movements. All movements operate at LOS A or B. During the PM peak hour, the intersection operates at LOS B overall with a maximum v/c ratio of 0.82 for the shared westbound through/right-turn movements. All movements operate at LOS C or better. Overall, the Road Diet alternative operates with less than 3 seconds of additional overall average delay when compared

to the Future No-Build alternative during the AM and PM peak hours even with the addition of the eastbound and westbound left-turn movements.

The second traffic model analyzed the intersection with the trips generated by the proposed development added to the intersection. Because left turns from the US 31W Bypass are currently restricted at this intersection, the original traffic counts did not record an eastbound or westbound left-turn movement. Therefore, traffic volumes were generated for these movements in the proposed model. Based on a discussion with project stakeholders, an eastbound left-turn volume of 40 vph for the AM and PM peak hours was established. Traffic volumes for the westbound left-turn movement were generated using trip generation rates from the Institute of Transportation Engineers Trip Generation Manual, 10th edition (Trip Generation Manual). The proposed land use, Super Convenience Mark/Gas Station (960) was considered the most appropriate based on preliminary permit applications filed for the development. The number of vehicle fueling positions used for this analysis was based on similar developments in Warren County and trips were then generated for the AM and PM peak hours based on the rates provided in the Trip Generation Manual. These calculations indicated there will be 449 additional trips during the AM peak hour and 367 total trips during the PM peak hour. These trips were then split between entering and exiting traffic and distributed based on existing traffic patterns. The traffic volumes generated with this particular land use are often conservative and require adjustments to reduce traffic volumes. These adjustments are based on final development plans that will likely include site constraints like the number of parking spaces or cashiers and checkout stations that regulate the amount of traffic into and out of the business. Modifications were not made to the generated traffic volumes in this report because development plans were not yet available.

When compared to the 2030 Road Diet model that did not include the additional trips, the overall delay increased from 12.7 seconds (LOS B) to 26.7 seconds (LOS C) during the AM peak hour. A similar increase was noted during the PM peak hour with overall delay increasing from 12.8 seconds (LOS B) to 21.9 seconds (LOS C). While this is a notable increase in delay, it should be noted that LOS C is still considered an acceptable LOS. This preliminary analysis only serves to estimate the impact a development with assumed improvements will have on the intersection. The increase in delay observed in this preliminary analysis also highlights the need to perform a more conclusive traffic analysis once development plans are created to fully understand the impact the proposed business will have on operations.

6. US 31W Bypass and Lehman Avenue

The Road Diet alternative does not propose any changes at the US 31W Bypass and Lehman Avenue intersection. The operations at the intersection are identical to the future No-Build alternative at LOS C during the AM and PM peak hours. A sensitivity analysis was performed to confirm that operations at the Lehman Avenue intersection would still be acceptable if the transition into the three-lane typical section impacted lane usage and reduced the through capacity to one lane for the eastbound through and westbound through movements. Even with a reduction in through capacity, all movements operate at a LOS D or better during both peak hours and average intersection delay is within 11 seconds of the results in the Future No-Build scenario.

Table 5 provides a summary of operations at each intersection for both the Future No-Build and Road Diet alternatives. Removal of the split phase operations at the Broadway intersection results in a significant reduction in delay even with a reduction in the number of through lanes at the intersection. All other intersections impacted by the proposed Road Diet alternative operate with no more than six additional seconds of delay. The LOS for all intersections is within an acceptable range with the proposed Road Diet alternative in place using projected 2030 traffic volumes.

Intersection	AM Peak		PM Peak	
	Future No-Build LOS (s)	Road Diet LOS (s)	Future No-Build LOS (s)	Road Diet LOS (s)
US 31W Bypass and University Drive	B (12)	B (12)	B (13)	B (13)
US 31W Bypass and Chestnut Drive*	B (11)	B (11)	C (20)	C (20)
US 31W Bypass and Cabell Drive	B (15)	B (17)	C (21)	C (27)
US 31W Bypass and Broadway Avenue	F (126)	D (55)	F (149)	E (67)
US 31W Bypass and 10th Avenue**	B (11)	B (13)	B (11)	B (13)
US 31W Bypass and Lehman Avenue	C (22)	C (22)	C (26)	C (26)

*LOS refers to worst approach for unsignalized intersection.
**Left turns are restricted in the Future No-Build alternative.

Table 5 2030 Intersection Delay and LOS Comparison of Future No-Build and Proposed Road Diet Alternative

CRASH ANALYSIS

A. Crash Data Collection

The BG-WC MPO provided data for all crashes in Warren County from 2014 to 2018. These crashes were then plotted in GIS using coordinates provided in the data to filter crashes that were located along the project corridor. Crashes along the US 31W Bypass from University Drive to Lehman Avenue were then evaluated for a 5-year period from 2014 to 2018. The corridor crash rate only considered crashes that occurred on the US 31W Bypass. Crash analysis data and calculations are included in Appendix F.

B. Crash Analysis Results

Access control was an afterthought as the US 31W corridor developed decades ago and this lack of attention resulted in a high density of entrances and roadway approaches. KYTC's current Highway Design Manual provides a recommendation for a minimum of 600 feet of spacing between access points for new construction on partially controlled roadways in urban areas. This would result in a maximum of 18 entrances per mile if the entrances were located at the same point on both sides of the road. In contrast, there are more than 100 access points per mile on US 31W between University Drive and Lehman Avenue, with each access point yielding potential conflict points between motor vehicles, pedestrians, and cyclists. Table 6 shows the corridor wide crash rate of 1,678 crashes per 100 million vehicle miles traveled (VMT) is nearly triple the statewide average of 589 crashes per 100 million VMT for an urban four-lane undivided highway, indicating there is a need for improvements that will reduce crashes. There was a total of 952 crashes from the beginning of 2014 to the end of 2018. About 65 percent of the crashes were angle or rear-end crashes, and about 17 percent were sideswipe-same direction incidents. Data shows there were zero fatalities on the corridor for this 5-year period and 57 total injury crashes. The injury crash rate of 100 crashes per 100 million VMT is also slightly above the statewide average of 90 crashes per 100 million VMT for similar roadways. Table 5 shows the corridor crash analysis summary from 2014 to 2018.

Severity	Year						US 31W Bypass Crash Rate[1]	Statewide Average Crash Rate[1,2]	Ratio (US 31W Bypass Statewide Average)
	2014	2015	2016	2017	2018	Total			
Total Crashes	149	202	196	228	177	**952**	1,678	589	2.8
Injury (KAB) Crashes	14	6	12	16	9	**57**	100	90	1.1

Notes:
[1]Segment crash rates are expressed in crashes per hundred million vehicle miles traveled.
[2]Values reported are from Analysis of Traffic Crash Data in Kentucky (2014 to 2018) for Urban Four-Lane Undivided.

Table 6 Corridor Crash Analysis Summary

Individual intersection crash rates were also analyzed at intersections where the lane configuration would be modified as a result of the proposed improvements. Crash data for each intersection included the functional area of each intersection where crashes can be attributed to the operations at the intersection. This zone of influence typically extends to the end of turn-lane storage for each leg of the intersection.

Intersection crash rates are reported as the number of crashes per million entering vehicles (MEV). Strand used volumes from the turning movement counts completed for this study to estimate ADTs at locations where KYTC had not completed a 24-hour traffic count. The calculated crash rates were then compared to an assumed regional threshold of 1.5 crashes per MEV as rates higher than this typically indicate a need for improvements. The following intersections were included in this analysis.

- US 31W Bypass and Chestnut Drive
- US 31W Bypass and Cabell Drive
- US 31W Bypass and Broadway Avenue
- US 31W Bypass and 10th Avenue

There was a total of 518 crashes at all the intersections within the study limits and all intersections exhibited a crash rate of less than 1.5 crashes per MEV. Table 7 shows the only intersection with a crash rate near the 1.5 crashes per MEV threshold is the US 31W Bypass and Cabell Drive intersection, with a crash rate of 1.46 crashes per MEV. Similar to the overall corridor crashes, incidents at this intersection primarily consisted the angle and rear-end crashes with a smaller percentage of sideswipes for vehicles traveling in the same direction. The proximity of commercial entrances to the intersection, wide commercial entrances, and intersection skew all likely contribute to the high crash rate.

Intersection Along US 31W Bypass	ADT Entering Intersection (vpd)	Total Crashes	Crash Rate per MEV
Chestnut Drive	18,010	14	0.43
Cabell Drive	18,010	50	1.46
Broadway Avenue	36,370	85	1.28
10th Avenue	23,940	47	1.08

Table 7 US 31W Bypass Intersection Crash Rate Analysis

C. Crash Rate Modification Factors

The FHWA compiled a repository of crash modification factors (CMF) to provide transportation professionals with a central source of information related to highway safety. A CMF is a multiplicative factor used to compute the expected change in crashes after implementation of a countermeasure like the addition of turn lanes or implementation of a road diet. For example, a CMF of 0.8 is expected to reduce crashes at a site by 20 percent. A CMF below 1.0 indicates a reduction in crashes while a CMF above 1.0 indicates an increase in crashes. CMFs are developed as a result of crash studies done throughout the country. CMFs can apply generally to all crash types for an individual counter measure or to a specific crash type like rear-end crashes. The following discussion outlines the potential crash reduction realized with the improvements included in the recommended alternative.

1. TWLTL CMF

Converting the US 31W Bypass from a four-lane to a three-lane cross section with a TWLTL between Lain Avenue and Chestnut Street has a CMF of 0.75, indicating a 25 percent reduction in crashes. This CMF was developed using before and after crash data from hundreds of projects where roadways were converted from four-lane to three-lane typical sections. This CMF applies to all crash types as vehicles wishing to turn left from US 31W Bypass will no longer be forced to stop in the inside through lane and vehicles turning onto the Bypass will have the option to take refuge in the TWLTL while waiting on an acceptable gap.

Several methods exist for estimating the combined effect of CMFs when multiple countermeasures are implemented together. However, caution must be used when there is overlap in the target crash type for a given set of countermeasures to prevent overestimating the crash reductions. The following analysis only considers the crash reductions associated with the road diet to provide a conservative projected crash rate along the US 31W Bypass and at specific intersections. The CMF for the road diet conversion was applied to the corridor as a whole to project crash rates after the recommended improvements are constructed (see Table 8).

Crash Segment	Length (Miles)	ADT	Counter-measure	CMF	Total Injury KAB Crashes (5 yrs)	Total Crashes (5 yrs)	Injury Crash Rate per 100 million VMT	Total Crash Rate per 100 million VMT
University Drive to Lehman Avenue	1.7	18,290	Road Diet	0.75	43	714	76	1,259
2014 to 2018 Statewide Average Crash Rate							90	589

Table 8 US 31W Bypass Projected Corridor Crash Rates with Countermeasures

BICYCLE AND PEDESTRIAN CONSIDERATIONS

A. Bicycle Considerations

Currently, cyclists use the sidewalk, which is legal per local statutes, or the roadway within the project limits. The most desirable option for bike accommodations would be to provide dedicated bike lanes adjacent to the travel lanes. FHWA states the absolute minimum width for bike lanes adjacent to the curb is 5 feet. If implemented, minimum width bike lanes would leave 30 feet of pavement to distribute to the two through lanes and the TWLTL. The minimum width for a TWLTL is 11 feet, with 14 feet or higher being preferable. Thus, using the minimum TWLTL width would only provide 9.5-foot travel lanes, which is not adequate for this roadway, especially considering cyclists would be placed adjacent to these narrow lanes. As a result, the 40-foot pavement width on the US 31W Bypass is not enough to accommodate dedicated bike lanes with the Road Diet alternative.

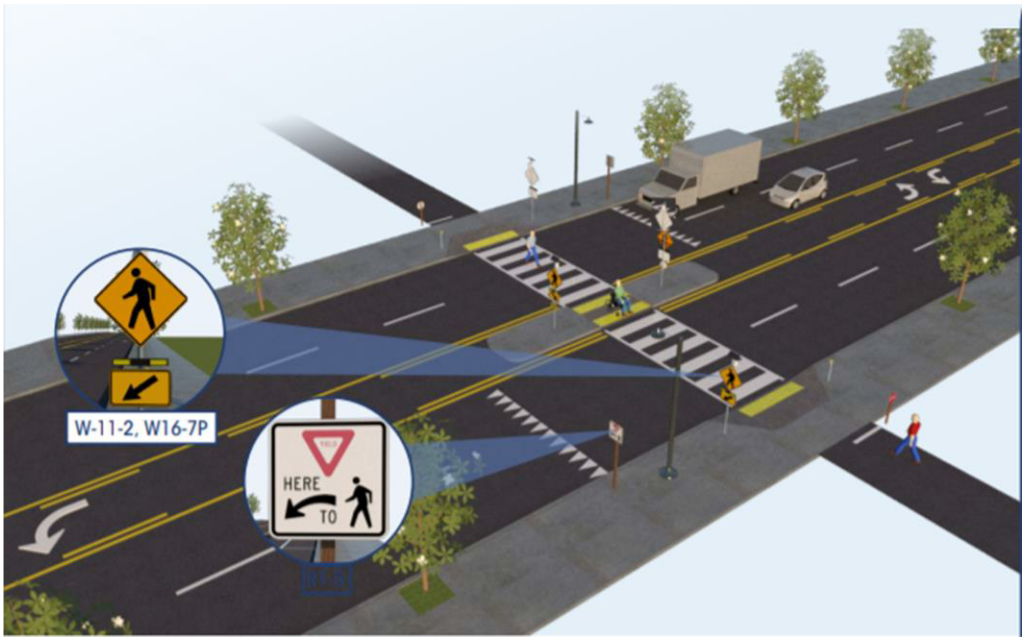
If the Bypass is reconstructed or new multimodal facilities are considered in the future, thought should be given to providing a dedicated bicycle and pedestrian facility. This would ideally consist of an 8- to 10-foot shared-use path on the east side of the US 31W Bypass to connect to the shared-use path planned from Campbell Lane to the University Drive roundabout.

B. Pedestrian Considerations

Existing sidewalks provide connectivity on both sides of the US 31W Bypass corridor. There are existing crosswalks and pedestrian signal heads at all signalized intersections, which includes Cabell Drive, Broadway Avenue, 10th Avenue, and Lehman Avenue intersections. Additionally, there is a painted crosswalk and pedestrian signs on US 31W Bypass at the unsignalized 14th Avenue intersection.

Rectangular rapid flashing beacons (RRFB) could be implemented if ongoing crash monitoring indicates a future need at the 14th Avenue crossing or if additional crossings are warranted along the corridor to accommodate pedestrian movements. RRFBs can make crosswalks and pedestrians more visible at a marked crosswalk. The City of Bowling Green has recently installed RRFBs at several locations as pedestrian activity indicated there was a need to increase visibility and provide additional warnings to drivers. Figure 14 shows an example of RRFBs from the FHWA website.

Strand also investigated the potential to reduce pedestrian exposure across the US 31W Bypass at the Cabell Drive intersection. Figure 11 shows how a combination of bumpouts and striping could be used to inexpensively improve this crossing and maintain flexibility if future demand required the roadway to revert to the current four-lane section. Traffic modeling showed the intersection footprint could be further reduced by omitting the proposed eastbound and westbound right-turn lanes and still provide an acceptable LOS. However, there were no pedestrian incidents at the intersection from 2014 to 2018 and crash history indicated improvements are needed for vehicular safety. Therefore, the recommended lane configuration at the intersection retains the right-turn lanes to mitigate issues associated with the existing intersection crash rate of 1.46 crashes per MEV.



Source: FHWA

Figure 15 RRFB Example

RECOMMENDED ALTERNATIVE

Traffic modeling for the proposed Road Diet alternative shows a three-lane section on the US 31W Bypass provides acceptable traffic operations with forecasted 2030 traffic volumes, and CMFs indicate a 25 percent reduction in crashes could be realized with implementation of this alternative. Moreover, operations at the Broadway Avenue intersection improve significantly with the three-lane typical section, providing additional intersection capacity by modifying the lane configuration and signal phasing. Overall, it is recommended the Road Diet alternative be implemented as it will reduce crashes and delay at key intersections in the project area. Moreover, this option can be constructed with a minimal investment during regular pavement resurfacing operations and the roadway is easily converted back to the existing four-lane section if future demand warrants an increase in capacity. A conceptual layout for the recommended alternative is included in Appendix G.