US 231
US 68
US 68X

INTERSECTION IMPROVEMENT STUDY

WARREN COUNTY, KY

FINAL REPORT | MAY 2022

KENTUCKY TRANSPORTATION CABINET

IN PARTNERSHIP WITH

QK4 Engineering Planning

EXECUTIVE SUMMARY

Study Background

The Kentucky Transportation Cabinet (KYTC) initiated this *US 231/US 68/US 68X Intersection Improvement Study* in Bowling Green during May 2021 to evaluate transportation options to improve safety and mobility at the US 231 (Campbell Lane and Veterans Memorial Lane)/US 68 (Russellville Road and Veterans Memorial Lane)/US 68X (Russellville Road) intersection. Over 40,000 vehicles use the intersection on any given day. The study area limits extend approximately 700 feet from the intersection center: US 68X (Russellville Road) at milepoint (MP) 0.000, US 231 (Campbell Lane) at MP 13.882, and US 68 (Russellville Road and Veterans Memorial Lane) at MP 9.334. The project location is shown in **Figure ES-1**.

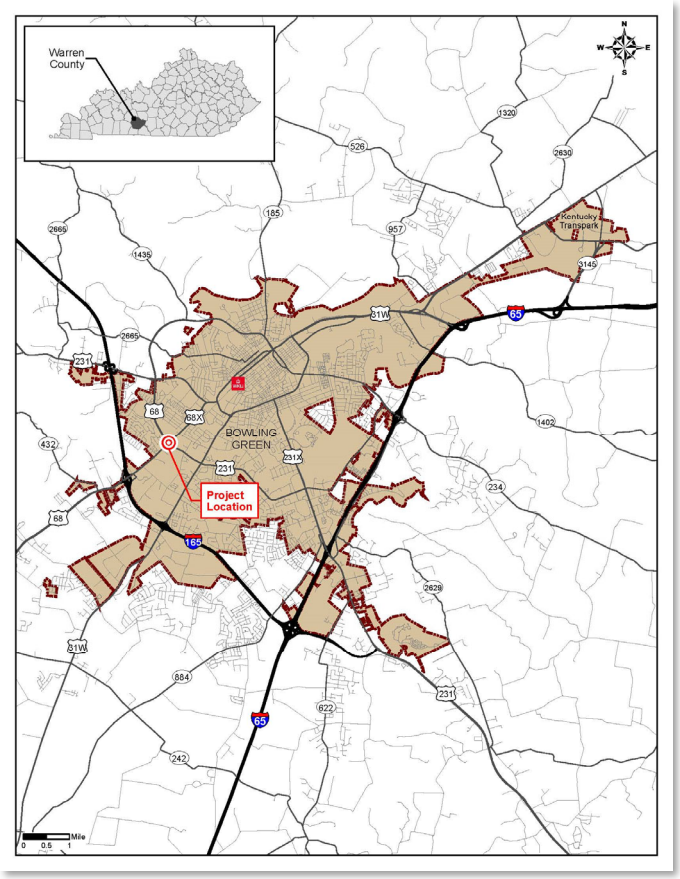

Figure ES-1: Project Location

Existing Conditions

US 68 and US 231 are classified as urban principal arterials and US 68X is an urban minor arterial. All four approaches are listed as tier 3 facilities on Kentucky's Highway Freight Network; US 68 and US 231 are on the National Highway System (NHS).

All approaches accommodate multi-lane traffic as detailed on **Figure ES-2**. Lanes are 10 feet wide on US 68X and 12 feet wide on the three other approaches. The signal operates as a semi-actuated, uncoordinated control, and follows the standard eight-phase configuration for a four-legged intersection with protected/permitted left-turn phases.

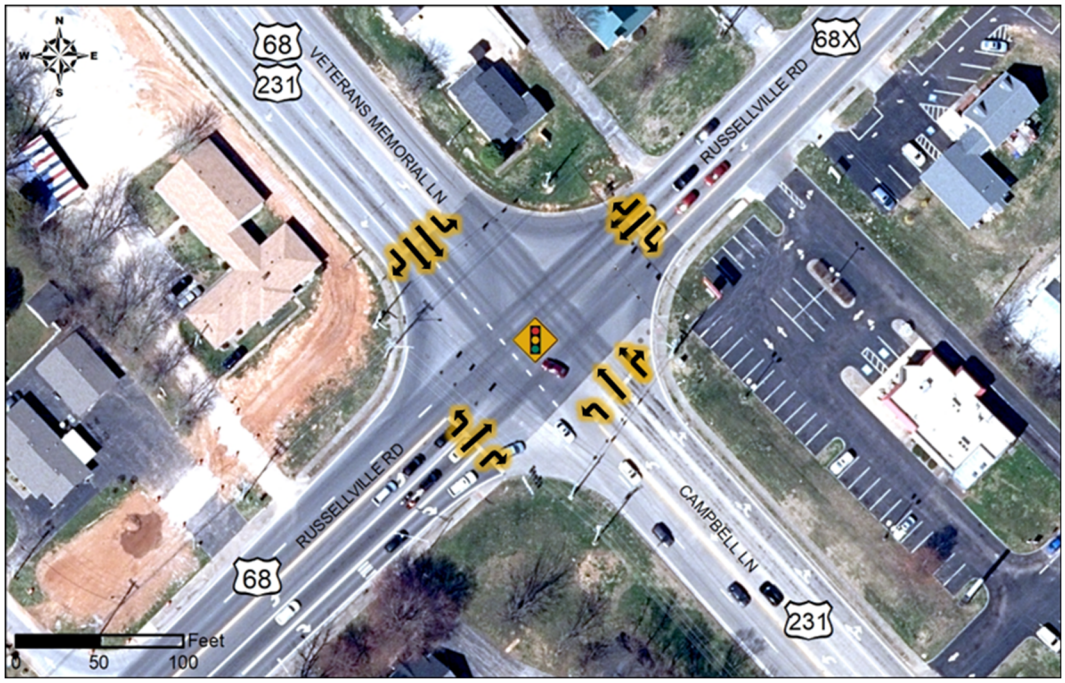

Figure ES-2: Study Intersection Configuration

Three of the four approaches are relatively straight and flat. The fourth—US 231 (Campbell Lane)—has a horizontal curve and vertial grade associated with the CSX railroad overpass about 1,000 feet east of the study intersection.

Sidewalks are present along at least one side of all intersection approaches, with pedestrian facilities in three of four quadrants but no striped crosswalks. The City of Bowling Green's 2017 *BG Moves: Multimodal Implementation Plan* identifies future greenway expansions along US 231 (Campbell Lane).

Existing and Future Traffic

Year 2021 existing traffic volumes show 40,500 cars entering the intersection during a 24-hour period, including 2,920 vehicles entering during the AM peak hour and 3,450 entering during the PM peak hour. Data show strong directional peaks in the morning: eastbound on both Russellville Road approaches and southbound on US 231. During the PM peak hour, raw volumes on each approach are higher but directional peaks are less severe. Microsimulation shows the existing intersection operates at Level of Service (LOS) D during both peak hours; left turns from each approach were congested in one or more peak hours, resulting in LOS E for these movements.

Building from existing traffic patterns, forecasts for a 2045 future analysis horizon were generated using the Bowling Green–Warren County regional travel demand model. Background socioeconomic growth assumptions in the model were adjusted to reflect the adjacent Keystone

Commons development and a new elementary school off US 68 to the south. The regional model predicted a 2.1% annual growth rate for the primary study intersection, or 61,200 entering vehicles per day in 2045. Applying hourly and directional factors, this corresponds to 4,320 vehicles entering during the AM peak hour and 5,130 entering during the PM peak hour. This degrades peak hour operations to LOS E–F; with this level of congestion, it is likely drivers would shift to other routes during the busiest periods and/or spread into other, less busy travel times.

Crash Trends

Over a four-year period from January 2017 through December 2020, 207 reported crashes were reported within the intersection vicinity, including 41 injury collisions and 166 crashes resulting in property damage only (PDO). Rear-end collisions accounted for 50% of crash types, followed by angle crashes (23%). All four approaches exhibit higher-than-expected crash rates, with a Level of Service of Safety (LOSS) rating of III or IV considering all severities. LOSS assigns ratings of I (least) through IV (most) based on how many more crashes occurred than mathematically predicted.

Environmental Setting

Natural and human environmental resources were identified from available literature and database review and a site visit. As the study area is in an urban area and largely within existing right-of-way, few environmental red flag concerns are anticipated should future project development activities occur, though additional environmental studies may be required. A geotechnical overview notes the area has an intense karst potential with underlying clay soils. A complete geotechnical investigation is recommended if the project advances, including drilling, sampling, and testing of materials.

Study Objectives

The objective of this study was to develop conceptual improvement options to address traffic flow, safety, and access at the US 231/US 68/US 68X intersection. Each improvement concept identified will address one or more of the study area's needs:

Lengthy Delays | High Mobility | Adjacent Driveways | Many Crashes | Continuing Growth | Pedestrian Safety

Improvement Concepts

A variety of improvement concepts were initially considered: additional turn lanes, a quadrant roadway system, displaced left-turn (DLT) intersection, a roundabout, and grade-separated configurations. Three Build concepts advanced for detailed study.

Build 1 (**Figure ES-3**) adds dual left-turn lanes to three of the four approaches, retiming the signal to optimize throughput. This concept improves the 2045 LOS from E–F in the No-Build to LOS D—providing the highest throughput and least delay of the options studied. Build 1 provides moderate crash savings, reducing angle crashes by about 20%, which represents about a quarter of the 207 crashes. The costs and right-of-way impacts are similar to those for the basic roundabout option (Build 3).

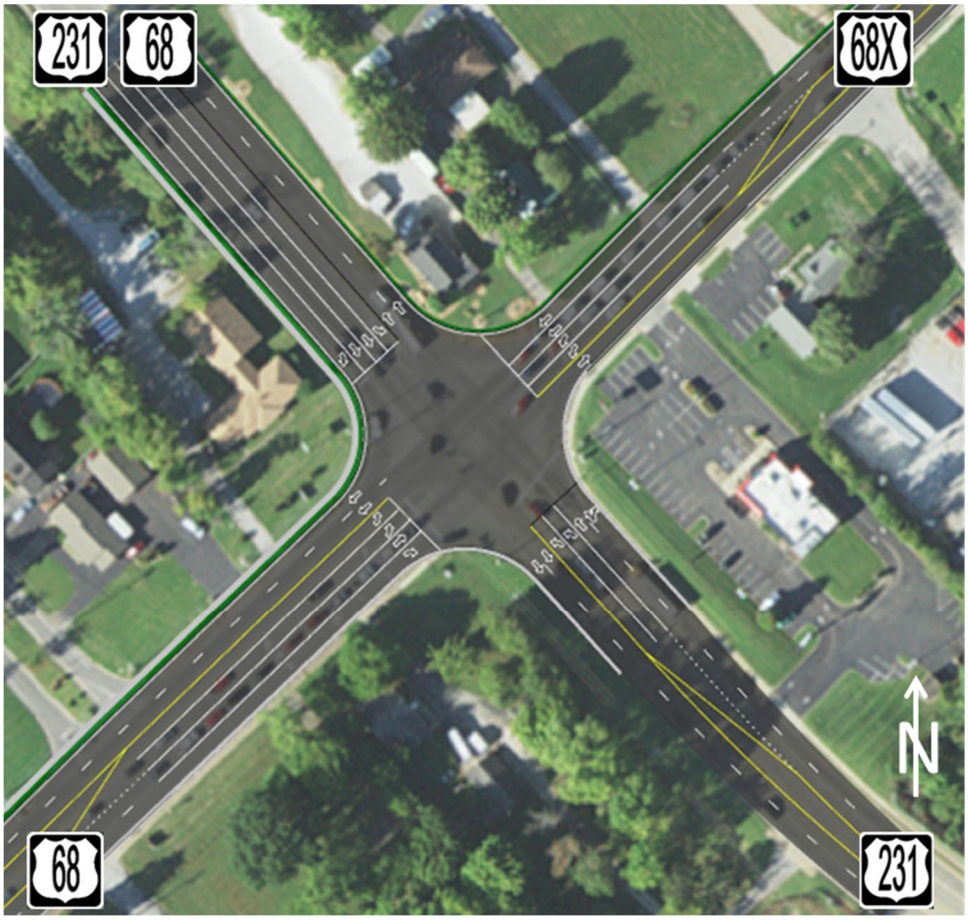

Figure ES-3: Concept Sketch for Build 1

Build 2 (**Figure ES-4**) creates a partial DLT-style intersection, which optimizes timing at the main intersection by shifting left-turning traffic on the two bypass approaches to the opposite side of the street at upstream signalized crossovers. This configuration shows 2045 peak hour traffic at LOS D–E. However, it represents a less familiar layout for drivers and adds new signals to the corridor. Since this is a more innovative layout, there is less documentation to predict how many safety benefits would result. With the highest costs and most right-of-way needed, this concept is not recommended for further consideration.

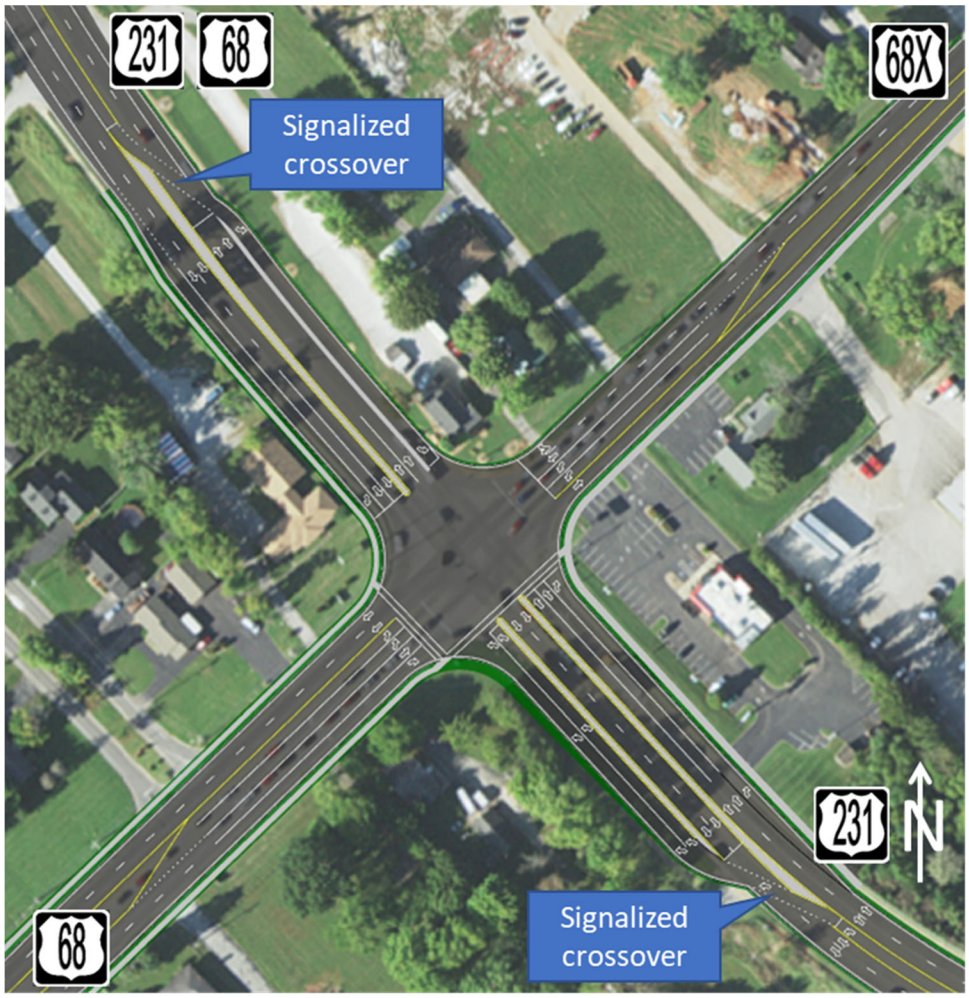

Figure ES-4: Concept Sketch for Build 2

Build 3 (**Figure ES-5** on the following page) reconstructs the intersection as a two-lane roundabout, which offers the lowest capacity of the concepts considered but could be fine-tuned in future design stages. This concept provides more than enough capacity to handle existing peak

hour turning movements and it has the best safety rating—decreasing vehicle crashes by about half and offering the safest crossing options for pedestrians with refuges in splitter islands. Costs and right-of-way impacts for the roundabout are similar to Build 1, although these do not account for future enhancements to improve throughput—e.g., adding slip lanes.

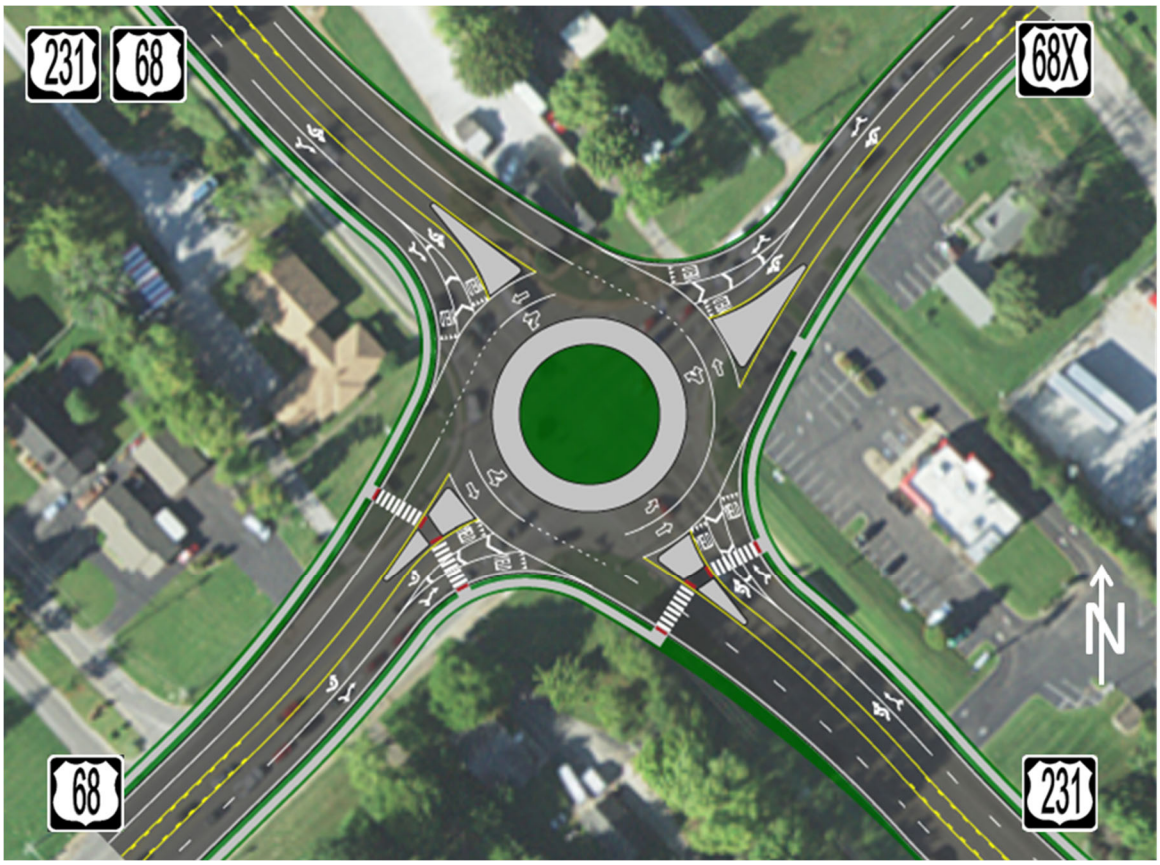

Figure ES-5: Concept Sketch for Build 3

Following technical analyses, the project team met virtually[1] with local officials and stakeholders to provide an overview of the study findings and present the three Build concepts. During the meeting, participants were polled to confirm the top three study area concerns: lengthy delays, continuing development, and high crash rates. Twelve of 14 poll respondents (86%) preferred the roundabout concept. Nine of 14 identified the displaced left style intersection as the least preferred solution.

[1] In-person gatherings were limited due to the COVID pandemic.

Project sheets (found in **Section 6.3**) provide additional details. **Table ES-1** provides a summary table of the three Build concepts considered with bold text noting the best performers in each category.

Table ES-1: Comparison of Build Concepts

Metric	Build 1: Dual Lefts	Build 2: Partial DLT	Build 3: Roundabout
2045 Traffic Operations	**Best**	Medium Less familiar and adds new signals	Least Future enhancement options
Crash Reductions	Medium $600,000 annual crash savings	Least Up to $500,000 annual crash savings	**Best** $1,700,000 annual crash savings
Pedestrian Connections	Medium	Least	**Best** Shorter crossings, steady traffic flow
Cost	**$7.2M**	$11.1M	**$7.4M**
Approx. ROW	**1.3 ac** Fewest impacts	2.6 ac	**1.5 ac**
Stakeholder Input	14% Preferred 21% Liked Least	64% Liked Least	**86% Preferred**

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ACRONYMNS LIST

ADA	Americans with Disabilities Act
BCA	Benefit-Cost Analysis
BRADD	Barren River Area Development District
CDAT	Crash Data Analysis Tool
CHAF	Continuous Highway Analysis Framework
CMF	Crash Modification Factor
DLT	Displaced Left Turn
EEC	Excess Expected Crashes
FHWA	Federal Highway Administration
HIS	Highway Information System
HSM	Highway Safety Manual
KYTC	Kentucky Transportation Cabinet
LOS	Level of Service
LOSS	Level of Service of Safety
LWCFA	Land and Water Conservation Fund Act
MP	Milepoint
mph	miles per hour
MPO	Metropolitan Planning Organization
MSAT	Mobile Source Air Toxics
MTP	Metropolitan Transportation Plan
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NHS	National Highway System
NRHP	National Register of Historic Places
NTN	National Truck Network
PDO	property damage only
SHIFT	Strategic Highway Investment Formula for Tomorrow
SPR	Statewide Planning and Research Funds
STAA	Surface Transportation Assistance Act
TED	Transportation Enterprise Database
TIP	Transportation Improvement Program
TWLTL	two-way left-turn lane
USEPA	US Environmental Protection Agency
USFWS	US Fish and Wildlife Service
UST	Underground Storage Tank
vpd	vehicles per day

1.0 INTRODUCTION

The Kentucky Transportation Cabinet (KYTC) initiated this *US 231/US 68/US 68X Intersection Improvement Study* in Bowling Green during summer 2021 to evaluate transportation options to improve safety and mobility at the US 231 (Campbell Lane and Veterans Memorial Lane)/US 68 (Russellville Road and Veterans Memorial Lane)/US 68X (Russellville Road) intersection. Over 40,000 vehicles use the intersection on any given day. Users are comprised of regional pass-though, local commuter, and heavy truck traffic. To the southwest, US 68 (Russellville Road) provides access to I-165 (former William H. Natcher Parkway), while US 68X (Russellville Road) to the northeast provides access to major traffic generators into the heart of Bowling Green. The southeast US 231 (Campbell Lane) and northwest US 68 (Veterans Memorial Lane) approaches provide access to residential subdivisions, industrial developments, and other commercial properties.

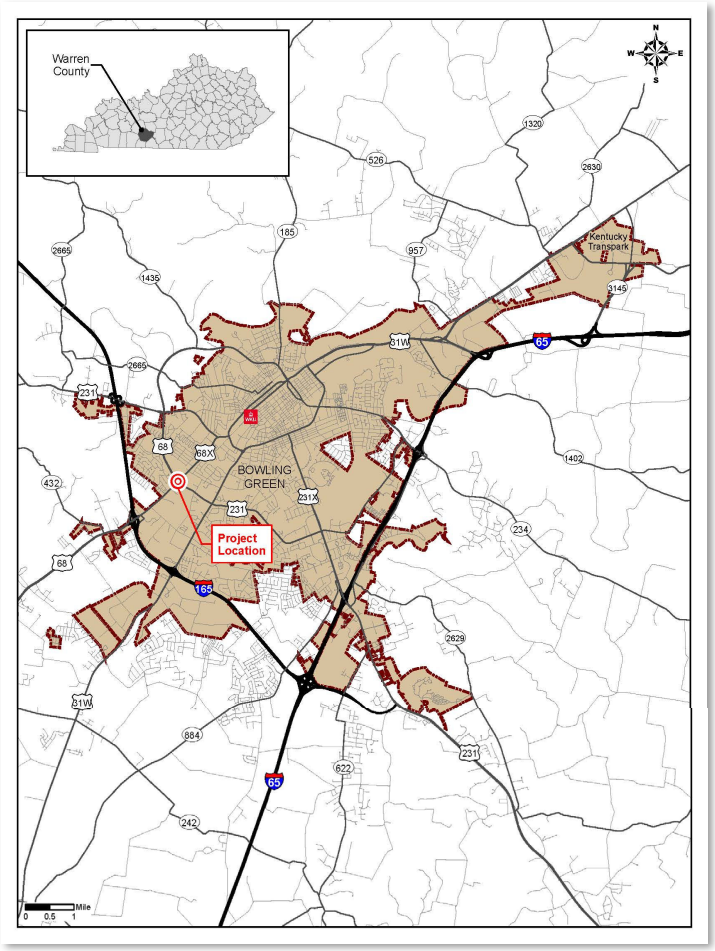


Figure 1: Bowling Green City Limits

Bowling Green (**Figure 1**) is the county seat of Warren County, Kentucky and as of 2019, its population of nearly 71,000 made it the third most populous city in the state, after Louisville and Lexington. In addition to being the home of numerous manufacturers, including General Motors, Fruit of the Loom, and Chevrolet Corvettes, it's also home to the state's second-largest public university, Western Kentucky University. Bowling Green serves as an education hub for the south-central Kentucky region and is also the region's leading medical and commercial center.

Warren County is part of the Barren River Area Development District (BRADD)[2] and Bowling Green–Warren County Metropolitan Planning Organization (MPO)[3].

Study tasks included:

- creating an inventory of existing conditions
- analyzing crash data
- forecasting existing and future traffic
- identifying red flag environmental issues
- developing Build concepts with construction cost estimates.

The study focused improvements that the KYTC and Warren County can use for further project development and implementation. Future phases are not programmed in Kentucky's *FY 2020–FY 2026 Highway Plan*.[4]

1.1 Study Area

Study area limits (**Figure 2**) extend approximately 700 feet from the intersection center: US 68X (Russellville Road) at milepoint (MP) 0.000, US 231 (Campbell Lane and Veterans Memorial Lane) at MP 13.882, and US 68 (Russellville Road and Veterans Memorial Lane) at MP 9.334. US 231 runs concurrent with US 68 on the Veterans Memorial approach.

Potential impacts to adjacent signalized intersections resulting from proposed improvements were also evaluated although they are beyond the study area limits.

[2] Area Development Districts are organizations devoted to economic planning and development in a multi-county region. BRADD serves ten counties in southcentral Kentucky.
[3] MPOs are transportation planning and policy-making bodies serving urbanized areas with populations over 50,000. They communicate and coordinate activities between local, state, and federal agencies.
[4] Online at https://transportation.ky.gov/Program-Management/Pages/2020-Highway-Plan.aspx

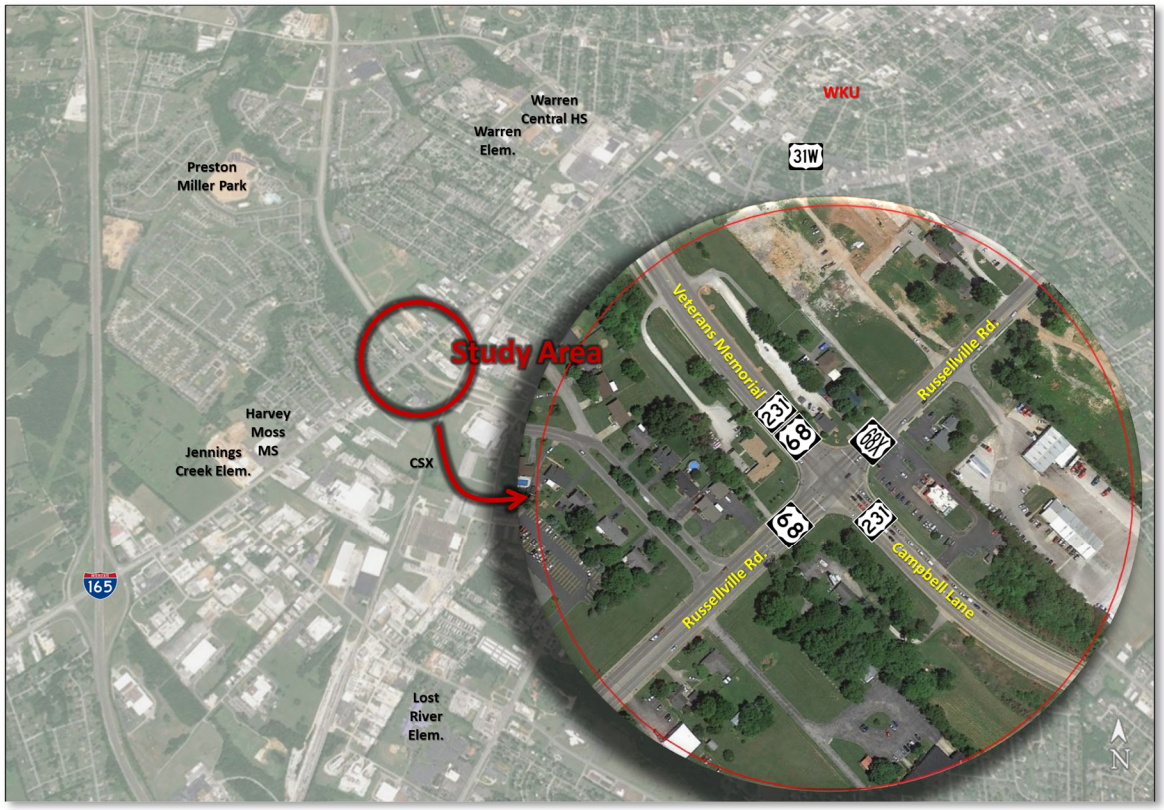


Figure 2: Study Area

1.2 Planned and Committed Projects

Figure 3 summarizes previously planned transportation projects in the vicinity. No committed projects or planned concepts for future improvements were identified for the study area. Kentucky's *FY 2020–FY 2026 Highway Plan* lists one active project in the vicinity, but outside study limits: Item No. 3-8857.00, major widening on 1.3 miles of US 31W from Campbell Lane (US 231) to University Boulevard (US 231X). The plan included right-of-way funding in the first two fiscal years. The *FY 2022–FY 2028 Highway Plan* adds funding for utility relocations in fiscal year 2024 but no other projects are identified in the immediate vicinity.

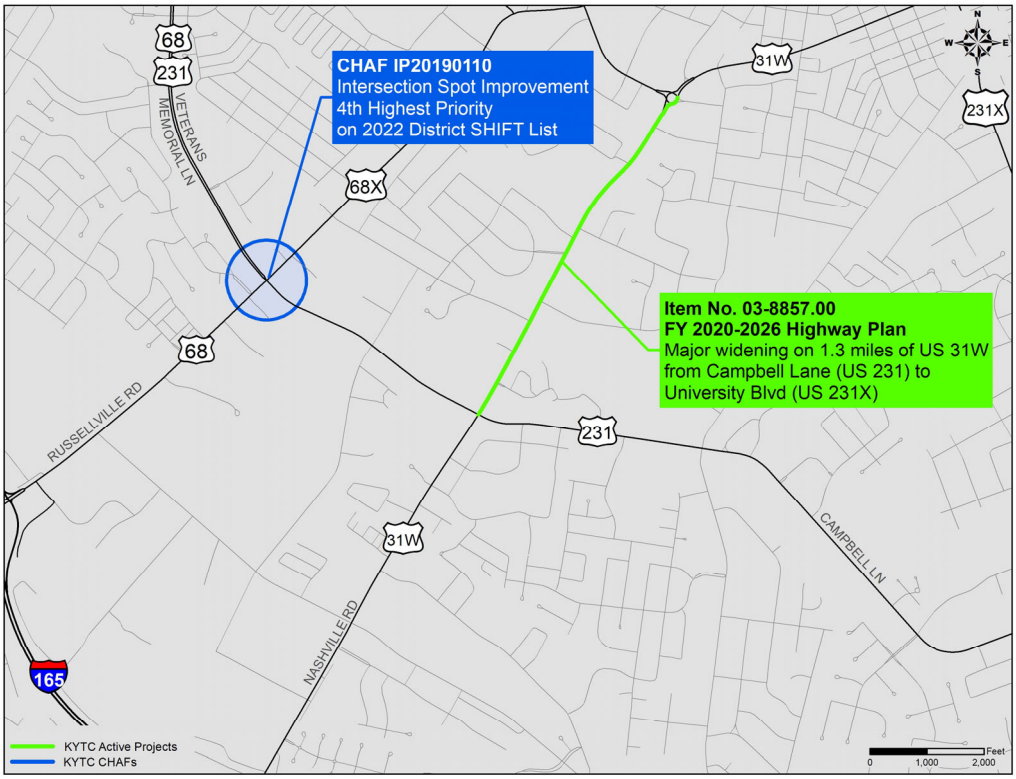


Figure 3: Summary of Planned and Committed Projects Review

CHAF[5] IP20190110, covering the study intersection, was the fourth highest district priority after boosting in the 2022 SHIFT[6] process. The same intersection is identified as a long-term priority in the *2045 Bowling Green Metropolitan Transportation Plan* (MTP)[7] with anticipated implementation before 2032.

Other recent studies in the vicinity included the following:

- Russellville Road Planning Study, 2019[8]
- BG Moves: Multimodal Implementation Plan, June 2017[9]

[5] CHAF, or Continuous Highways Analysis Framework, is an application enabling KYTC to collect, track, and analyze identified transportation needs.
[6] SHIFT, or the Strategic Highway Investment Formula for Tomorrow, is a data-driven project scoring process to compare and prioritize statewide capital improvement projects to make better use of limited transportation funds in the Commonwealth's biennial budget.
[7] Online at https://warrenpc.org/mpo/documents/
[8] Online at https://transportation.ky.gov/Planning/Pages/Planning-Studies-and-Reports.aspx
[9] Online at https://warrenpc.org/bike-ped/

- Bowling Green 2016 Bicycle Comfort Level Rating Map[10]
- Greenways Master Plan, 2014[11]

Plans for bicycle and pedestrian networks in the area are discussed further in **Section 2.3**.

2.0 EXISTING CONDITIONS

Existing transportation conditions are described in the following sections. Roadway geometry, functional classification, traffic volumes and operations, and crash history information were obtained from KYTC's Highway Information System (HIS) database, KYTC's Transportation Enterprise Database (TED), traffic counts, and field reviews.

2.1 Roadway System Designations

Functional Class. Functional Classification is the process of grouping streets and highways according to the character of travel service and access to adjacent land use they provide. This classification system is a hierarchical system of facilities that progress from lower classifications handling short, locally oriented trips to higher classifications serving longer distance travel at higher mobility levels. A roadway's classification is further designated as urban or rural based upon whether it is located within a Federal Highway Administration (FHWA) Adjusted Urban Area boundary. Functional classes with brief definitions are listed below.

Freeways & Interstates	Principal Arterials	Minor Arterials	Collectors	Local Roads
•Provide high speed, high mobility links for long distance trips.	•Serve major centers for metropolitan areas, provide a high degree of mobility, and can also provide mobility through rural areas.	•Provide service for trips of moderate length, serve geographic areas smaller than their Principal Arterial counterparts, and offer connectivity to the Principal Arterial system.	•Gather traffic from local roads and funnel them to the arterial network. Classified as either a major or minor collector, these generally serve intra-county travel and shorter trips.	•Not intended for long distance travel, except at the origin or destination end of the trip, due to their direct access to abutting land. Often designed to discourage through traffic.

[10] Online at https://www.bgky.org/policies/bicycle-friendly-community
[11] Online at https://www.warrenpc.org/wp-content/uploads/2018/04/GW_MasterPlan2014_FINAL.pdf

US 68 and US 231 are classified as urban principal arterials and US 68X is an urban minor arterial.

Truck Routes. In compliance with the Surface Transportation Assistance Act of 1982 (STAA), Kentucky established a network of highways on which commercial vehicles with increased dimensions could operate. These "STAA" vehicles include semi-trailers with 53-foot-long trailers and single-unit trucks with a total length of 45 feet. STAA routing in Kentucky corresponds to the National Truck Network (NTN), plus state-maintained highways within five miles of the NTN, 15 miles from interstate or parkway interchanges, and one mile on other public highways.

Within the study area, US 68X, US 231, and US 68 are not part of the NTN but fall within the five-mile buffer to accommodate STAA trucks. Each is also listed in Kentucky's Highway Freight Network as Tier 3 statewide regional significant facilities, providing regional access for freight to major freight generators. Each facility has a designated 80,000-pound AAA truck weight limit.

Highway Systems. US 68 and US 231 are on the National Highway System (NHS) which includes roadways important to the nation's economy, defense, and mobility. FHWA tracks a series of performance measures statewide, including pavement and bridge conditions, delay, truck travel time reliability, emissions, and more for NHS routes. Any improvements to the study intersection would have an incremental effect on these metrics.

The Kentucky State Highway System classifies state-maintained roadways by type of service and function. US 68 and US 231 are classified as state primary: long distance, high volume intrastate highways of statewide significance generally linking major urban areas. US 68X is classified as state secondary: a regionally significant highway of shorter distance, providing mobility and access to land use activity, generally serving smaller cities and county seats within a region.

Scenic Byway Systems. US 68 and US 68X are part of the US 68 Heritage Corridor scenic byway. Routes included in Kentucky's scenic byway system are considered to have roadsides or viewsheds with scenic, natural, cultural, historical, archaeological, and/or recreational value worthy of preservation, restoration, protection, and enhancement.

2.2 Roadway Geometric Characteristics

KYTC's HIS database was queried to obtain route geometric characteristics, including access control, speed limits, number of lanes and lane widths, existing lane configurations, and shoulder type and width.

Access Control. Control of access relates to a legal status limiting the types of vehicles that can use a highway, as well as a road design limiting points at which they can access it. Kentucky recognizes three types of access control for its highways:

Full Control	Partial Control	By Permit
•Highways are designed for high speed traffic flow regulated by interchanges, i.e., interstates.	•Side roads intersect the main road at grade; driveways may not connect directly to the main road so drivers must use intersecting roads to access adjacent land. Often minimum spacing thresholds between intersections are set.	•Encroachments approved at KYTC engineer's discretion based on standard engineering practices and safety criteria.

Table 1 summarizes the access control type by approach, noting the nearest access points to the study intersection.

Table 1: Access Control by Approach

Approach	Access	Nearest Access Points*
US 68X (Russellville Rd.)	By permit	Private residence driveway, 45 ft. Hardee's driveway, 100 ft.
US 231 (Campbell Ln.)	Partial control	Hardee's driveway, 250 ft.
US 68 (Russellville Rd.)	By permit	Barber College/Private residence driveways, 100 ft. Whispering Hills Blvd, 260 ft.
US 68 (Veterans Memorial Ln.)	Partial control	Cash Express/Barber College driveways, 500 ft.

** Measured from stop bar*

Speed Limits. While the traffic signal controls operations within the intersection itself, all intersection approaches have 45 mph posted speed limits.

Geometric Configuration. All approaches accommodate multi-lane traffic as detailed on **Figure 4**. The signal operates as a semi-actuated, uncoordinated control, and follows the standard eight-phase configuration for a four-legged intersection with protected/permitted left-turn phases.

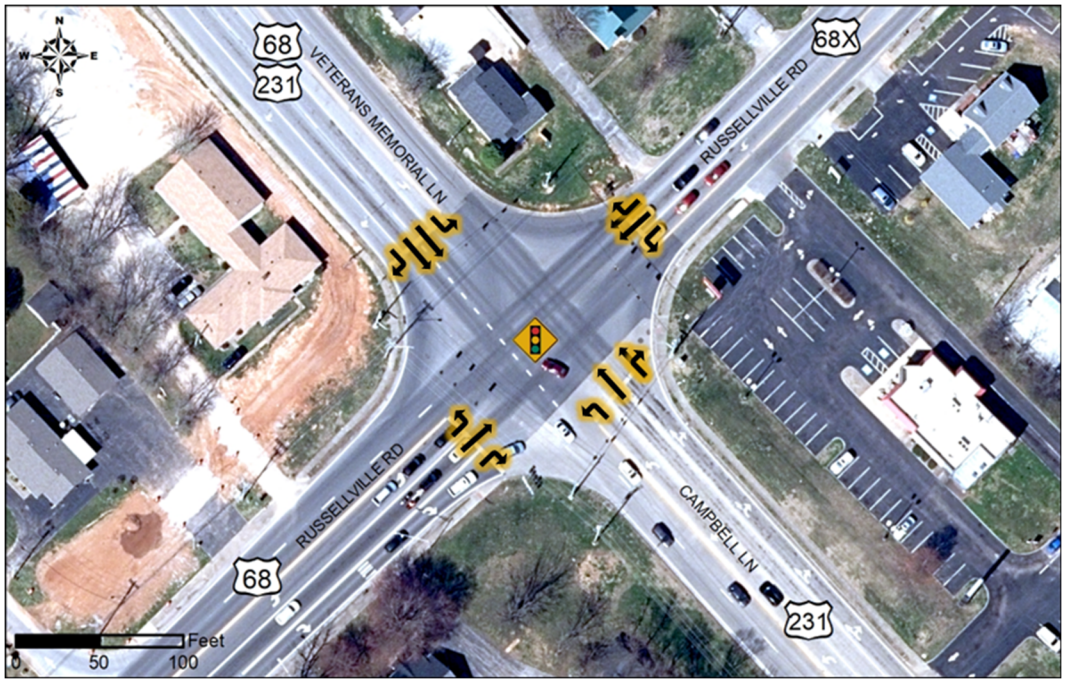


Figure 4: Lane Configurations at Intersection

- US 68X (Russellville Road) incorporates three 10-foot-wide thru lanes (two approaching the intersection plus one outbound) separated by a 12-foot-wide two-way-left-turn-lane (TWLTL) operating as a left-turn lane at the intersection. Right turns onto US 68 (Veterans Memorial Lane) share the outside thru lane.
- US 231 (Campbell Lane) is concrete while the other three approaches and interior of the intersection are asphalt. The US 231 approach includes four 12-foot-wide thru lanes (two approaching the intersection plus two outbound) separated by a 13-foot-wide TWLTL operating as a left-turn lane at the intersection. Right turns onto US 68X share the outside thru lane.
- US 68 (Veterans Memorial Lane) has four 12-foot-wide thru lanes (two approaching the intersection and two outbound) separated by an 18-foot-wide TWLTL operating as a left-only at the intersection. A separate right-turn lane onto US 68 (Russellville Road) provides 350+ feet of storage.
- US 68 (Russellville Road) consists of four 12-foot-wide thru lanes (two approaching the intersection and two outbound) separated by a 15-foot-wide TWLTL operating as a left-turn lane at the intersection. The outer thru lane is dropped as a right-only onto US 231 approaching the intersection, as there is only one lane heading north into town on the opposing US 68X approach.

Shoulder Types and Widths. Concrete curb and gutter are present along all approaches inside the study boundary.

Horizontal and Vertical Alignment. HIS data was reviewed to identify any substandard grades or curves within the study boundary. Three of the four approaches are relatively straight and flat approaching the intersection. The fourth—US 231—has relatively steep grades (8.5%, **Figure 5**) associated with the CSX railroad overpass about 1,000 feet east of the study intersection. The 4-degree horizontal curve also limits visibility approaching the signal. In addition, District personnel noted icing concerns on this approach during inclement weather.

Figure 5: View East through Study Intersection to US 231 Grade/Curve

2.3 Pedestrian and Bicycle Facilities

Sidewalks are present along at least one side of all intersection approaches. While there are no painted crosswalks on the roadway, pedestrian amenities exist in three of four quadrants, as shown in **Figure 6**.

The 2017 *BG Moves: Multimodal Implementation Plan* notes an existing greenway along US 68 (Veterans Memorial Lane) and identifies future greenway expansions in the vicinity, including along US 231 (Campbell Lane), listed as a low priority project.

Figure 6: Existing Pedestrian Facilities

2.4 2021 Traffic Volumes and Operations

Available existing traffic volumes for the study area roadways, including truck percentages, K-factors[12], and directional distributions were reviewed based on recent KYTC counts. Year 2021 segment volumes were calculated based on appropriate historical trends, adjusting pre-2020 volumes to create a consistent 2021 dataset while minimizing influence of the COVID pandemic on observed traffic volumes.

Further, eight turning movement counts were collected during August 2021 to observe current traffic flows and operational characteristics. Miovision video capture technology recorded traffic volumes, vehicle classification (i.e., motorcycles, cars, buses, single unit trucks, and articulated trucks), and queue lengths at the study intersection during 7 AM to 7 PM.

[12] K-factor is defined as the proportion of annual average daily traffic occurring in the design hour.

Table 2 compares pre-COVID count data for each of the four approaches, KYTC's most recent (2020) counts, and the 2021 12-hour counts factored up to represent a 24-hour period. Additional traffic information is in the *Traffic Forecast Report* in **Appendix A.**

Table 2: Existing Traffic Versus Historic Trends

Approach	Pre-2020 Count	2020 Count	2021 Existing*
US 68X Russellville Road	17,400 11% trucks	-	16,900 4.5% trucks
US 231 Campbell Lane	23,800	20,000 5% trucks	22,100 2.5% trucks
US 68 Russellville Road	23,400	20,700 7% trucks	24,500 3.1% trucks
US 68 Veterans Memorial Lane	19,600	16,300 5% trucks	17,500 3.7% trucks

**Truck percentage based on 12-hour count data*

Existing turning movements for the AM and PM (in parentheses) peak hours are shown in **Figure 7**. Data show strong directional peaks in the morning eastbound on both Russellville Road approaches and southbound on US 231. During the PM peak hour, raw volumes on each approach are higher but directional peaks are less severe.

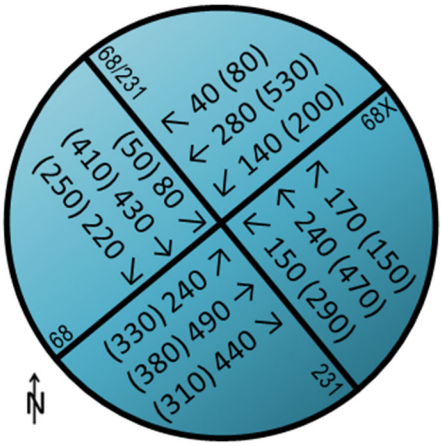


Figure 7: 2021 AM (PM) Peak Volumes

2.4.1 Traffic Operations

Several metrics exist to measure traffic operations, such as Level of Service (LOS), delay, and queue lengths at intersections. LOS is a qualitative measure describing traffic conditions, graded on an A to F scale. LOS A is associated with free flow conditions, high freedom to maneuver, and little or no delay. LOS E represents conditions at or near capacity. At LOS F, traffic conditions are oversaturated and beyond capacity, with low travel speeds, little or no freedom to maneuver, and high delays. As a rule of thumb, LOS D or better is acceptable in urban areas.

For this study, Vissim microsimulation software was used to model corridor operations. While any model has limitations—particularly in over-capacity congested conditions—the model represents the best tool available to approximate current and future traffic scenarios. To calibrate the model, analysts collected information regarding existing traffic conditions: signal timing plans, queue lengths, operating speeds, etc. In addition to illustrating existing needs within the study area, the microsimulation model forms a baseline to test how proposed infrastructure improvements would affect traffic operations.

Summarized in **Table 3**, analyses showed the overall intersection performed at LOS D in both AM and PM peak hours. Left-turning movements on each approach were congested in one or more peak hours, resulting in LOS E movements.

Table 3: 2021 AM (PM) Level of Service by Movement

Approach	Overall LOS	Left	Thru	Right
US 68X Russellville Road	D (D)	E (E)	D (D)	C (D)
US 231 Campbell Lane		D (E)	C (D)	C (C)
US 68 Russellville Road		D (E)	D (D)	B (A)
US 68 Veterans Memorial Lane		E (D)	D (E)	A (A)

Additional microsimulation modeling using Synchro software[13] for the next signalized intersection on each approach: US 68/Woodmont Avenue to the southwest, US 231/Industrial Drive to the southeast, US 68X/Emmett Avenue to the northeast, and US 68/Tomblinson Way to the northwest. Each of these four intersections operates at LOS C or better during both peak hours.

2.5 Crash History

Historical crash data retrieved from KYTC's Transportation Enterprise Database (TED) warehouse were evaluated for a four-year period (January 2017 through December 2020). Crashes by location, severity, and manner of collision are shown in **Figure 8**. While traffic patterns in 2020 were somewhat atypical, the total number of crashes was in line with other analysis years, representing 23% of the dataset. A table of corresponding crash data is included as **Appendix B**.

During this timeframe, 207 total crashes occurred within the intersection vicinity, including 41 injury collisions and 166 crashes resulting in property damage only (PDO). No fatalities were reported during the study period. Injury crashes accounted for 20% and were subdivided by "KABCO"[14] severity classifications: overall, 5 were serious, 13 minor, and 23 possible injury crashes. Rear-end collisions accounted for 50% of crash types, followed by angle (23%) and sideswipe-same direction crashes (12%).

[13] Synchro provides signal optimization tools not available within Vissim. It is also less complex, providing a more cost-effective model to analyze a larger geographic area.
[14] The KABCO scale corresponds to the severity of the injuries as assessed by law enforcement responding to investigate the scene. K = Fatal, A = Serious Injury, B = Minor Injury, C = Possible Injury, and O = Property Damage Only.

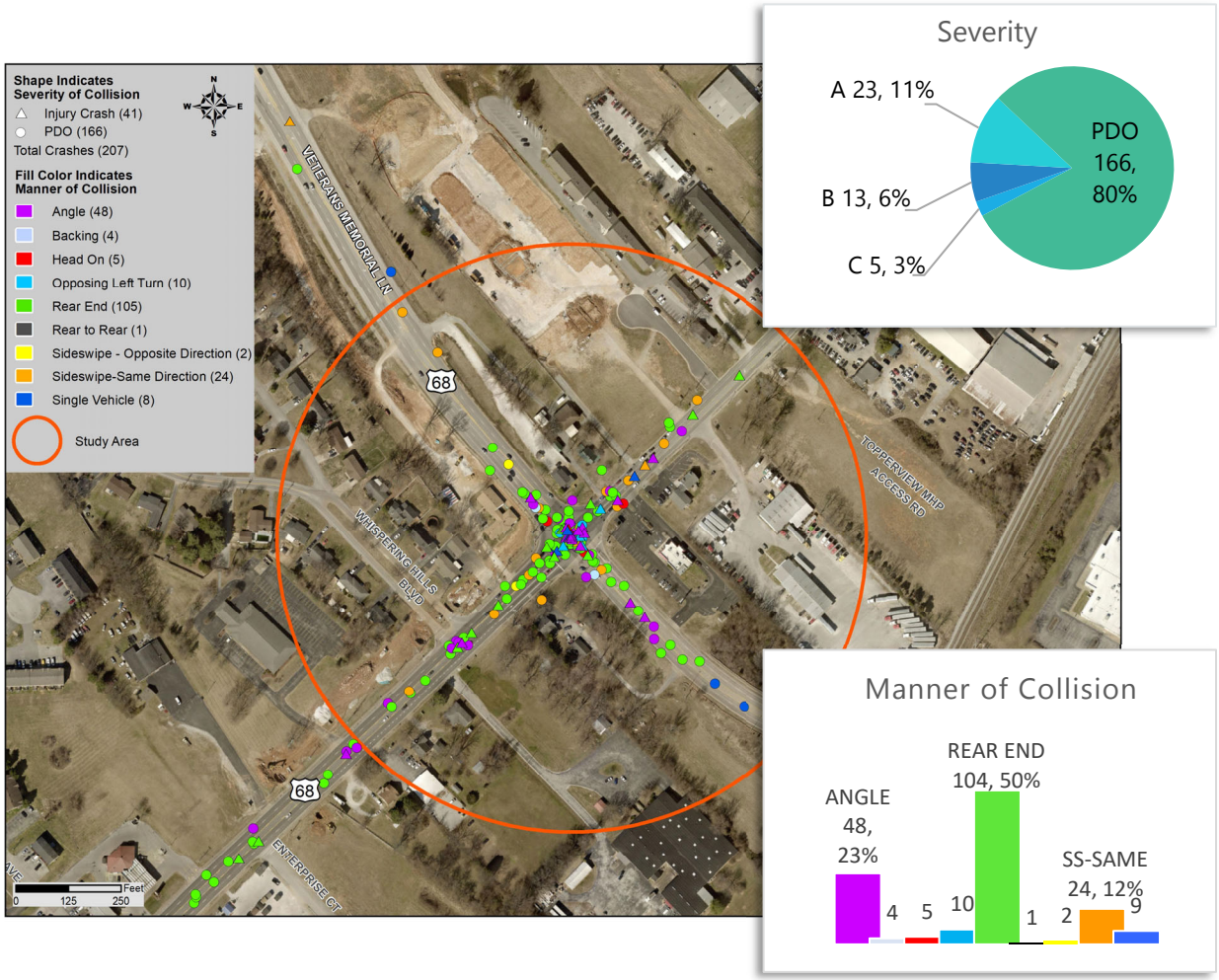


Figure 8: Intersection Crashes by Severity and Manner of Collision

2.5.1 Crashes by Intersection Approach

Of the 207 crashes, 79 (38%) occurred along US 68X, 44 (21%) along US 231, 49 (24%) along US 68 (Russellville Road), and 35 (17%) along US 68 (Veterans Memorial Lane). **Table 4** and **Table 5** summarize the severity and manner of collision distributions for each approach.

Table 4: Crash Distribution by Severity

			Injury							
	Total Crashes		A-Serious		B-Minor		C-Possible		PDO	
US 231/US 68/US 68X	207		5	3%	13	6%	23	11%	166	80%
US 68X Russellville Road	79	38%	3	4%	6	8%	11	14%	59	75%
US 231 Campbell Lane	44	21%	1	2%	4	9%	5	11%	34	78%
US 68 Russellville Road	49	24%	–	–	3	6%	3	6%	43	88%
US 68 Veterans Memorial Lane	35	17%	1	3%	–	–	4	11%	30	86%

Table 5: Distribution of Crashes by Manner

	Total	Rear End		Angle		Sideswipe Same		Opposing Left Turn		Single Veh.		Head On		Backing		Sideswipe Opposite		Rear to Rear	
US 231/US 68/US 68X	207	104	51%	48	23%	24	12%	10	5%	9	4%	5	2%	4	2%	2	1%	1	0%
US 68X Russellville Rd.	79	41	51%	14	18%	12	15%	7	9%	2	3%	2	3%		0%		0%	1	1%
US 231 Campbell Ln.	44	17	38%	14	32%	3	7%	3	7%	4	9%	2	5%	1	2%		0%		0%
US 68 Russellville Rd.	49	26	53%	14	29%	5	10%		0%	3	6%		0%		0%	1	2%		0%
US 68 Vets Memorial Ln.	35	20	57%	6	17%	4	11%		0%		0%	1	3%	3	9%	1	3%		0%

Other Crash Trends. Further crash analyses were conducted to identify crash trends.

- Non-motorized users. Two crashes with bicyclists were reported during the study period: one serious injury crash on US 68X and one minor injury crash on US 68 (Russellville Road). In both cases, the cyclist was changing lanes to make a left turn and did not see the approaching motorist.
- Travel direction. Motorists traveling toward the center of the intersection accounted for 64% of all crashes on US 68 (Russellville Road). All other approaches exhibited more evenly distributed crash distributions related to travel direction.
- Cited crash causes. Crash data for each approach were examined to identify commonalities among collisions. Notable causes cited in crash reports were:
    - Signals: For the intersection, the responding officer cited the signal as a contributing factor for 67% of 207 crashes.
    - Left Turns: Overall, 17% of 207 crashes involved a motorist turning left. None of these occurred on the US 68 (Veterans Memorial Lane) approach.
    - Wet Road: Overall, 17% of 207 crashes occurred in wet conditions.
    - Nighttime: For the intersection, 21% of 207 crashes occurred after dark. Overhead lights are mounted in three of the four intersection quadrants. The US 231 approach represents a disproportionately high number of nighttime crashes: 15 of 44 (34%).

2.5.2 Statistical Crash Analyses

A statistical methodology based on the *Highway Safety Manual* (HSM) enables analysts to evaluate safety needs. The Crash Data Analysis Tool (CDAT) was employed to determine Excess

Expected Crashes (EEC) and Level of Service of Safety (LOSS) for the intersection as well as each approach.

EEC values are based on a crash prediction model estimating the number of crashes expected on an average roadway segment of a given type and length. It represents the number of excess crashes a segment is experiencing compared to other roadways of its type, adjusting for traffic volumes and a statistical correction. EEC is positive when more crashes are occurring than expected and negative when fewer crashes are occurring than expected. Higher positive values suggest the installation of safety countermeasures is warranted.

EECs are grouped into one of four categories, identified as the LOSS. Summarized graphically in **Figure 9**, LOSS categories I and II represent sites with fewer-than-anticipated crashes, while categories III and IV have more than anticipated. Because LOSS-IV sites experience such elevated crash rates—1.5 standard deviations more crashes than expected—there is a higher probability that safety countermeasures at these locations will result in larger improvements.

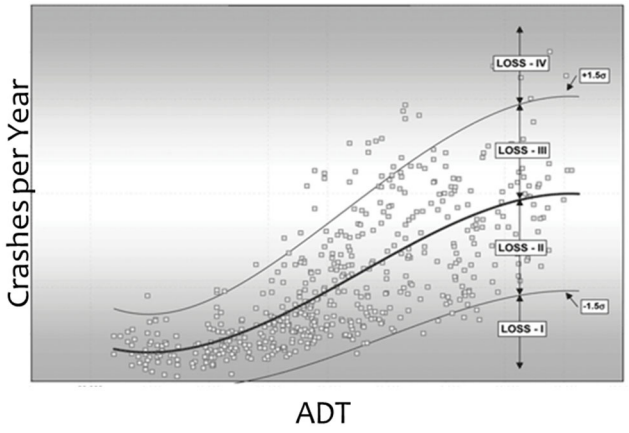


Figure 9: LOSS Categorical Thresholds

CDAT Results. Considering all crash severities based on 2015–2019 CDAT data, the study intersection and all approaches scored positive EEC values and fell into LOSS-III or LOSS-IV categories, as summarized in **Table 6**. The adjacent US 68/Whispering Hills Boulevard intersection also has a positive EEC, resulting in LOSS-III.

Table 6: EEC and LOSS Ratings

ROUTE		EEC	LOSS
US 231/US 68/US 68X Intersection		107	IV
US 68X	Russellville Road	33.2	IV
US 231	Campbell Lane	18.7	III
US 68	Russellville Road	29.8	III
US 68	Veterans Memorial Lane	18.8	IV

3.0 ENVIRONMENTAL

An environmental overview was prepared to identify resources for consideration during the development of transportation improvement concepts. Natural and human environmental resources were identified from available literature and database reviews and a site visit. As the study area is in an urban area and largely within existing right-of-way, few environmental red flags are anticipated.

The purpose of this overview was not to quantify potential environmental impacts, but instead, to identify potential environmental issues to consider during any future project development process. This information should aid the project team in making decisions to avoid, minimize, and/or plan for mitigation of potential project impacts, as appropriate. Should future projects develop following this study, additional environmental studies may be required. If there is a federal nexus (e.g., federal funds, lands, permits, etc.) on a future project, then the procedures established from the National Environmental Policy Act (NEPA) must be followed.

Water Resources. There are no aboveground water resources or wetlands, although the entire region is known for its karst terrain. The study area lies within Bowling Green, an MS4[15] community.

Land Use/Built Environment. All four adjacent parcels abutting the study area and lining both Russellville Road approaches are zoned as highway business districts.

- To the west, the Whispering Hills subdivision is accessed via Whispering Hills Boulevard and an interconnected network of adjacent neighborhood streets that provide other connections to US 68.
- To the north, a large multiuse development is under construction. Per its 2019 *Signal Warrant Study*, the site could contain 624 multi-family housing units, 10,000 square feet of office space, and retail (e.g., gas station, pharmacy, bank, and/or restaurants).
- To the east and south, an industrial area lines the CSX railroad corridor, surrounding a small apartment complex accessed off Enterprise Court.

None of the adjacent structures within the study area appear to represent unique or historic resources that would merit consideration for National Register of Historic Places (NRHP) listing.

[15] Polluted stormwater runoff is commonly transported through municipal separate storm sewer systems (MS4s), and then often discharged, untreated, into local water bodies without passing through a sewer or sewage treatment plant. The designation impacts permitting requirements.

However, should federal monies or permits be included in future projects, field survey and coordination with the Kentucky Heritage Council will be required to assess project impacts to cultural historic resources.

Section 4(f). Section 4(f) of the Department of Transportation Act of 1966 applies to federally funded projects. It is a substantive law that applies to land from publicly owned parks, recreation areas, wildlife and waterfowl refuges, and public or private historic site eligible for or listed on the NRHP. No potential Section 4(f) resources are in the study area.

Section 6(f). Section 6(f) of the Land and Water Conservation Fund Act (LWCFA) applies to both state and federally funded projects. The LWCFA provides federal grants to acquire land for outdoor recreation, protect important natural areas, and to develop or renovate outdoor recreation facilities (e.g., campgrounds, picnic areas, swimming facilities, etc.). No properties that have received LWCFA funds were identified within the study area.

Protected Species. The US Fish and Wildlife Service (USFWS) maintains a database of federally protected species—listed as endangered or threatened under the *Endangered Species Act.* There are three listed bat species, ten mussels, one crustacean, and one flowering plant that have the potential to occur per USFWS records. The monarch butterfly is also under consideration for official listing.

Listing status for all species are shown in **Table 7**. All of Warren County is designated as critical habitat for Indiana bats.

Table 7: Listed Threatened and Endangered Species

Group	Name	Scientific Name	Status
Mammals	Gray Bat	*Myotis grisescens*	Endangered
Mammals	Indiana Bat	*Myotis sodalis*	Endangered
Mammals	Northern Long-eared Bat	*Myotis septentrionalis*	Threatened
Mussels	Clubshell	*Pleurobema clava*	Endangered
Mussels	Fanshell	*Cyprogenia stegaria*	Endangered
Mussels	Pink Mucket Pearlymussel	*Lampsilis abrupta*	Endangered
Mussels	Purple Cat's Paw	*Epioblasma obliquata obliquata*	Endangered
Mussels	Rabbitsfoot	*Quadrula cylindrica cylindrica*	Threatened
Mussels	Ring Pink	*Ibivarua retysa*	Endangered
Mussels	Rough Pigtoe	*Pleurobema plenum*	Endangered
Mussels	Sheepnose	*Plethobasus cyphyus*	Endangered
Mussels	Snuffbox	*Epioblasma triquetra*	Endangered
Mussels	Spectaclecase	*Cumberlandia monodonta*	Endangered
Insects	Monarch Butterfly	*Danaus plexippus*	Candidate

Group	Name	Scientific Name	Status
Crustaceans	Kentucky Cave Shrimp	*Palaemonias ganteri*	Endangered
Flowering Plants	Prices Potato-bean	*Apios priceana*	Threatened

A habitat assessment should be completed in the early stages of project development for future project(s) to assess potential project impact to threatened and endangered species. Projects that occur within an area of known bat habitat will require project-specific evaluation to assess appropriate minimization/mitigation measures. For other federally listed species, specific ecological surveys may be required for projects that have the potential to impact habitat. Coordination with the USFWS Kentucky Field Office will be necessary to determine the need for future project-specific surveys.

Hazardous Materials Considerations. Readily available records from the US Environmental Protection Agency (USEPA) were compiled to illustrate the range of monitored sites within the study area. Beyond construction permits, there are no known monitored sites within the study area limits. One underground storage tank (UST) is located north of the intersection, associated with ABF Freight Systems, but has been closed.

Air Quality Considerations. USEPA has established National Ambient Air Quality Standards (NAAQs) for six criteria pollutants: ozone, lead, nitrogen dioxide, sulfur dioxide, carbon monoxide, and particulate matter ($PM_{2.5}$ and PM_{10}). Warren County is in attainment for all criteria pollutants.

Because the study area is located within an MPO, any federally funded transportation projects should be included in the Bowling Green–Warren County MPO transportation improvement program (TIP) and statewide TIP to ensure air quality conformity requirements are satisfied. Future federal projects may need to analyze potential Mobile Source Air Toxics (MSAT) impacts based on the project type. FHWA has developed a tiered approach for three categories to analyze MSATs in NEPA documents, depending on specific project circumstances. The three tiers and associated level of analysis are no potential/exempt projects requiring no analysis, low potential requiring a qualitative analysis, and higher potential requiring quantitative analysis.

Noise Considerations. There are noise sensitive receptors in the vicinity of potential future improvements. Noise sensitive receptors include all outdoor areas of frequent human use such as residential areas, parks, cemeteries, hospitals, churches, schools, and some commercial properties with exterior use. Site specific traffic noise impact analyses may be required in future project development activities. State funded projects do not require a traffic noise impact analysis, unless directed by the legislature. However, federally funded projects that add capacity or shift traffic closer to sensitive receptors do require the consideration of traffic noise impacts.

3.1 Geotechnical

KYTC Geotechnical Branch prepared a *Geotechnical Overview Report* to help identify geotechnical concerns that may affect potential project designs. A summary of those findings is provided here, with the full report in **Appendix C**.

- The study area is within the Pennyroyal Physiographic Region, characterized by soluble limestones known to form karst features. Within the St. Genevieve formation, the area is rated as having an intense karst potential with multiple mapped sinkholes in the vicinity. Special treatment of sinkholes will be required, which often involves capping or use for drainage.
- Underlying soils are typically clays with low to medium/high plasticity.
- There are no mapped faults within the study area; no issues due to bedrock structural condition are expected. Landslides are not expected to be a concern.
- There are no active mines or quarries, water wells, oil/gas wells, or ponds in the study area.

Per the overview, a complete geotechnical investigation including drilling, sampling, and testing of materials will be needed to anticipate and plan for any special treatment of issues encountered. This may include the taking of pavement cores where directed by the project team. Analyses of rock core and soil sample testing should be compiled.

4.0 FUTURE CONDITIONS AND NEEDS

Once existing conditions were assessed and known/potential environmental constraints identified, the project team launched the next study phase: projecting future traffic volumes and defining study area needs from which initial improvement concepts were identified. Future No-Build traffic operations, defined study goals, and initial improvement concepts are discussed in the following subsections.

4.1 2045 No-Build Traffic

Building from existing traffic patterns (**Section 2.4**), forecasts for a 2045 future analysis horizon were generated using the Bowling Green–Warren County regional travel demand model. As discussed in the *Traffic Forecast Report* (**Appendix A**), background socioeconomic growth assumptions in the model were adjusted to reflect the Keystone Commons development and the Jennings Creek Elementary School, which opened in fall 2018. No existing or committed transportation projects in the vicinity were adjusted within the model network. The regional model

predicted annual growth rates ranging from 1.4% to 3.6%, combined to represent a 2.1% annual growth rate overall for the primary study intersection.

Because the predicted 2.1% is an aggressive growth rate, analysts reviewed recent studies in the vicinity to compare growth rate assumptions. Both KYTC's 2019 *Russellville Road (US 68X and 231X) Planning Study* and 2020 *Kentucky and Adams Street (US 68X) Improvement Study*[16] assumed a 1.5% annual growth rate. The 2019 *Keystone Commons Signal Warrant Study* also assumed a 1.5% annual growth rate, but this did not include the 9,000 new weekday trips projected to access the development. Furthermore, population projections published by the Kentucky State Data Center show the county population increasing by 38% between 2020 and 2040, equating to approximately 1.8% per year. Due to the additional Keystone Commons trip generation volumes and predicted population growth, analysts deemed the 2.1% annual growth appropriate to represent a conservative, worst-case view of potential 2045 traffic volumes.

Using the 2.1% annual growth, **Table 8** compares forecast 2045 No-Build daily traffic volumes to the 2021 Existing scenario.

Table 8: 2045 No-Build Daily Traffic Volumes

Approach	2021 Existing	2045 No-Build
US 68X Russellville Road	16,900	25,500
US 231 Campbell Lane	22,100	33,400
US 68 Russellville Road	24,500	37,000
US 68 Veterans Memorial Lane	17,500	26,400

AM and PM peak hour turn movements at the main study intersection are shown in **Figure 10** with PM in parentheses.

2045 No-Build Traffic Operations. The Vissim model was updated to reflect traffic operations assuming current intersection geometry with optimized signal timing plans. As shown in **Table 9**, this degrades operations to LOS E in the AM peak and puts the intersection over capacity (LOS F) in the PM peak. All turn movements operate at LOS E or F during one or both peak hours.

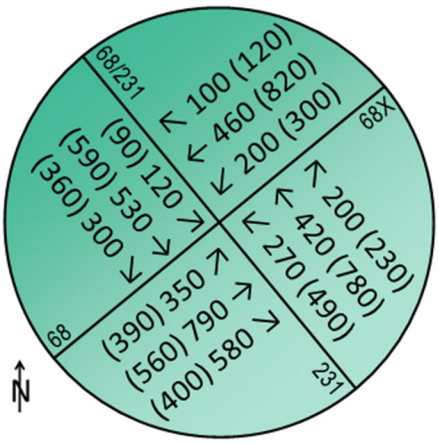


Figure 10: 2045 AM (PM) Peak Traffic

[16] Both reports available online at https://transportation.ky.gov/Planning/Pages/Planning-Studies-and-Reports.aspx

With this level of projected congestion, drivers would likely shift to other routes during the busiest travel periods and/or spread into other, less busy travel times.

Table 9: 2045 No-Build AM (PM) Level of Service by Movement

Approach	Overall LOS	Left	Thru	Right
US 68X Russellville Road	E (F)	E (F)	D (E)	D (E)
US 231 Campbell Lane		E (F)	D (F)	D (F)
US 68 Russellville Road		D (E)	F (F)	E (D)
US 68 Veterans Memorial Lane		E (F)	E (F)	B (E)

No-Build microsimulation modeling using Synchro software for adjacent signalized intersections showed each generally operates at LOS D or better during both peak hours. There are two exceptions: US 231/Industrial Drive (signalized) operates at LOS E in the PM peak and the Whispering Hills Boulevard stop-controlled approach to US 68 operates at LOS F in the PM peak.

4.2 Study Goals and Objectives

The objective of this study was to develop conceptual improvement options to address traffic flow, safety, and access at the US 231/US 68/US 68X intersection.

Each improvement concept identified should address one or more of the study area's needs described in **Chapter 2.0**:

High traffic volumes contribute to lengthy delays at the intersection. With 2,920 vehicles entering during the AM peak hour and 3,450 entering vehicles during the PM peak hour, the intersection currently operates at LOS D in both peaks.

All four approaches are US highways and classified as arterials, suggesting a high degree of mobility is appropriate.

Lengthy peak hour queues restrict visibility and block access to/from adjacent driveways and cross streets.

High crash trends indicate safety concerns. A total 207 crashes were reported over the four-year analysis period (2017–2020), including 41 injury crashes. Crashes were mainly rear ends (43%) and angle collisions (23%).

Ongoing and continued development in the vicinity is expected to increase traffic volumes, exacerbating current mobility and safety concerns.

Pedestrian and bicyclist safety is a growing concern; two reported collisions involved cyclists during the four-year analysis period. Sidewalks and greenways serve the area, and there are long-range plans to increase pedestrian facilities in the vicinity. The intersection provides ADA-compliant ramps and actuated pedestrian flashers in some quadrants but lacks striped crosswalks.

4.3 Initial Improvement Concepts

Five preliminary improvement concepts were initially considered to ease intersection congestion. In each case, lane configurations/widths and sidewalk connections are assumed to match the existing layout of each approach. As illustrated in **Section 2.4.1**, **Table 3,** left-turn movements currently experience the most delay within the intersection.

Conventional Left-Turn Lanes. This concept adds dual left-turn lanes on both Russellville Road approaches and US 231. As US 68X only has a single travel lane leading away from the intersection, dual lefts on US 68 (Veterans Memorial Lane) are not feasible without larger-scale corridor widening. Adding dual left-turn lanes increases capacity for this movement within the existing signal phasing plan.

Quadrant Roadway System. A quadrant roadway system (**Figure 11**) adds an extra connection in one quadrant to eliminate all left turns at the main intersection, simplifying signal timing/phasing. Left-turning vehicles are routed to the new quadrant roadway link; and only thru and right turns remain at the main intersection. KYTC District 6 recently constructed a quadrant roadway along US 42 in Florence, Kentucky.

A Quadrant Roadway System is likely to result in larger property impacts and costs than would other concepts considered.

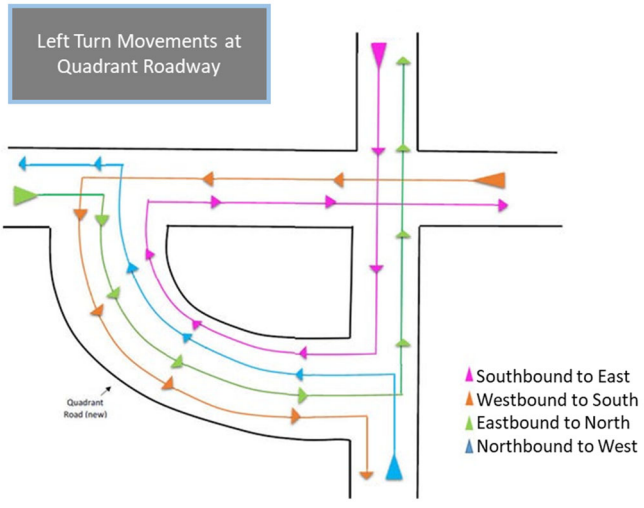


Figure 11: Quadrant Roadway Diagram

Displaced Left-Turn (DLT) Intersection. A more innovative intersection layout, the partial displaced left-turn (DLT) intersection shifts left-turn movements to the far side of the roadway, allowing them to run concurrently with thru traffic to simplify signal timing/phasing. **Figure 12** provides a visual summary of the layout's operation.

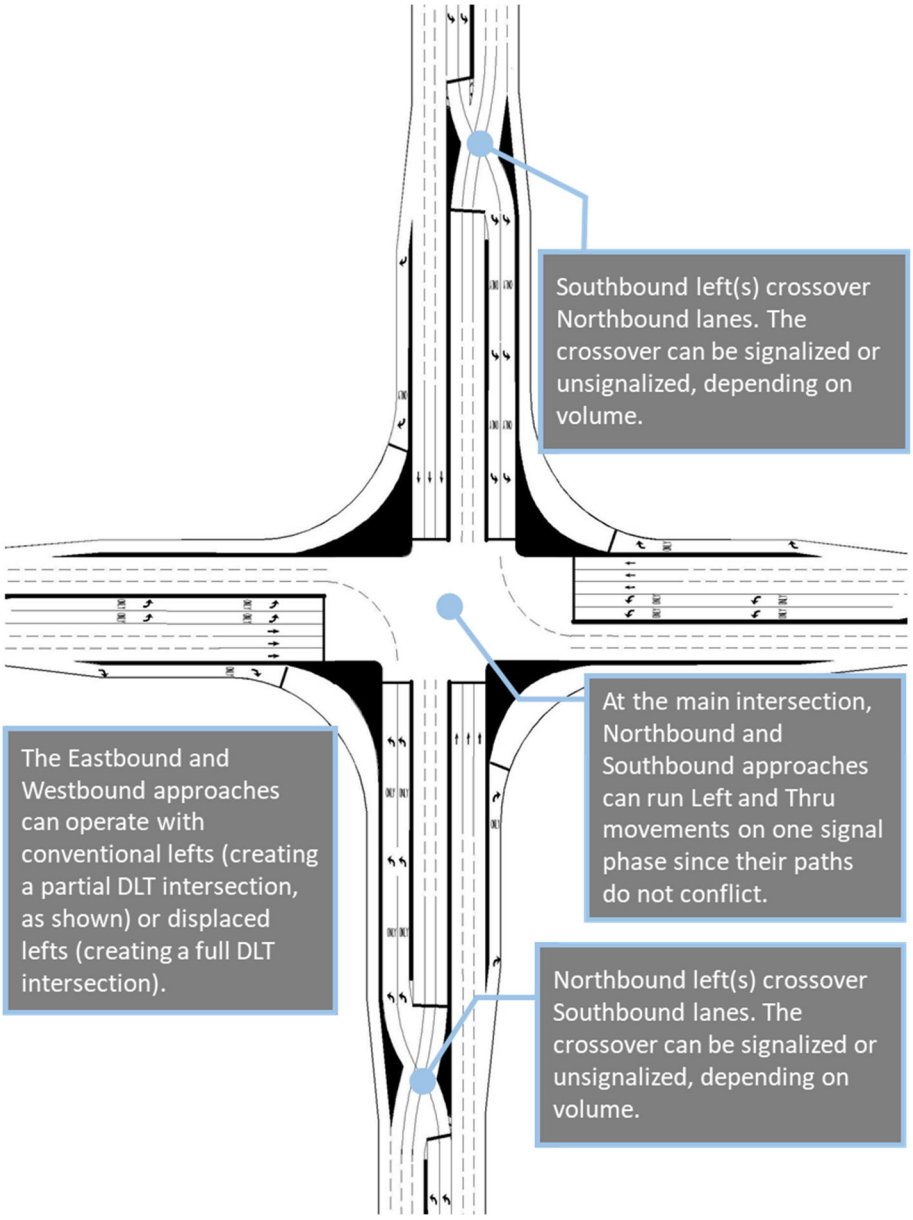


Figure 12: Partial DLT Diagram

Several DLT intersections have been constructed in the US, with the nearest to Kentucky located in Miamisburg, Ohio (near Dayton) at the OH 741/Austin Boulevard intersection. FHWA recommends the left crossovers be placed at least 300–500 feet from the main intersection to

accommodate queues; any existing access points between the crossovers would be eliminated or converted to right-in/right-out movements.

DLT lanes were considered along the bypass approaches (US 68 and US 231) to route left-turning traffic to the opposite side of the highway so these thru and left-turn movements can share the same signal phasing. DLT lanes along Russellville Road were not considered as they would have substantial impacts to access points near the study intersection.

Roundabout. Replacing the existing four-leg intersection with a dual lane roundabout was considered to improve safety and reduce delay. Roundabouts have proven safety benefits for both drivers and pedestrians; however, future traffic operations could be a concern owing to lower capacity than some other configurations. The estimated 2045 volumes (**Figure 10**) exceed recommended daily capacities shown in **Table 10**.

Table 10: KYTC Guidance for Planning-Level Roundabout Capacities[17]

Volume	Single Lane	Double Lane	Triple Lane
Peak Hour (vehicles/hour)	<2,000	2,000-4,000	4,000-7,000
Daily (vehicles/day)	<20,000	20,000-40,000	40,000-70,000

Grade-Separated Layouts. A series of grade-separated configurations would elevate one of the arterial highways with one or more ramp-like connections to provide access between levels. This configuration type will result in larger property impacts and costs than other concepts considered.

4.4 First Project Team Meeting

The project team included KYTC District 3, Central Office, BRADD, and consultant personnel. Coordination efforts were essential for identifying areas of concern and potential improvement opportunities. Meeting summaries are in **Appendix D**, arranged chronologically.

The project team met virtually October 22, 2021, to review existing conditions information—presented throughout **Chapter 2.0**—and discuss preliminary concepts to advance for further analysis. Ongoing and planned developments potentially influencing future traffic patterns were discussed.

Initial improvement concepts described in **Section 4.3** were presented. The quadrant roadway system and grade-separated options were dismissed, citing feasibility concerns based on costs and impacts. Discussion of the DLT option followed:

[17] https://transportation.ky.gov/Planning/Documents/KYTC%20Roundabout%20Feasibility%20Policy%20Markup%205%20(partial).pdf

- Any improvements should avoid impacting the railroad overpass. Shown in **Figure 13**, the existing overpass consists of five lanes: two 12-foot-wide thru lanes per direction and a 13-foot-wide TWLTL with minimal shoulders.

Figure 13: US 231 over CSX Rail lines

- Queue lengths at the intersection, sight distance limitations from the overpass to the intersection, and roadway icing are concerns. A dynamic queue warning system may be appropriate to consider.
- Driver familiarity is a consideration; a DLT intersection has not been constructed in Kentucky to date.

The project team agreed to advance the conventional left, partial DLT, and roundabout concepts for further study to ascertain operational impacts, calculate planning-level cost estimates, and determine benefits for each.

5.0 ASSESSMENT OF BUILD SCENARIOS

Three Build concepts advanced for detailed study: conventional dual lefts, a partial DLT, and a two-lane roundabout. This chapter explores traffic impacts, safety benefits, and costs.

5.1 Build Traffic

Each of the three Build concepts were coded into the No-Build microsimulation models: Vissim for the main study intersection and Synchro for a wider view of the adjacent signalized intersections. Summarized below, additional technical details are provided in **Appendix A**.

5.1.1 Conventional Lefts

This concept includes adding dual left-turn lanes for three of the four approaches—both Russellville Road approaches and US 231—and retiming the signal to optimize throughput. The concept, shown in **Figure 14**, provides the best performance for projected 2045 traffic volumes, improving peak hour operations to LOS D.

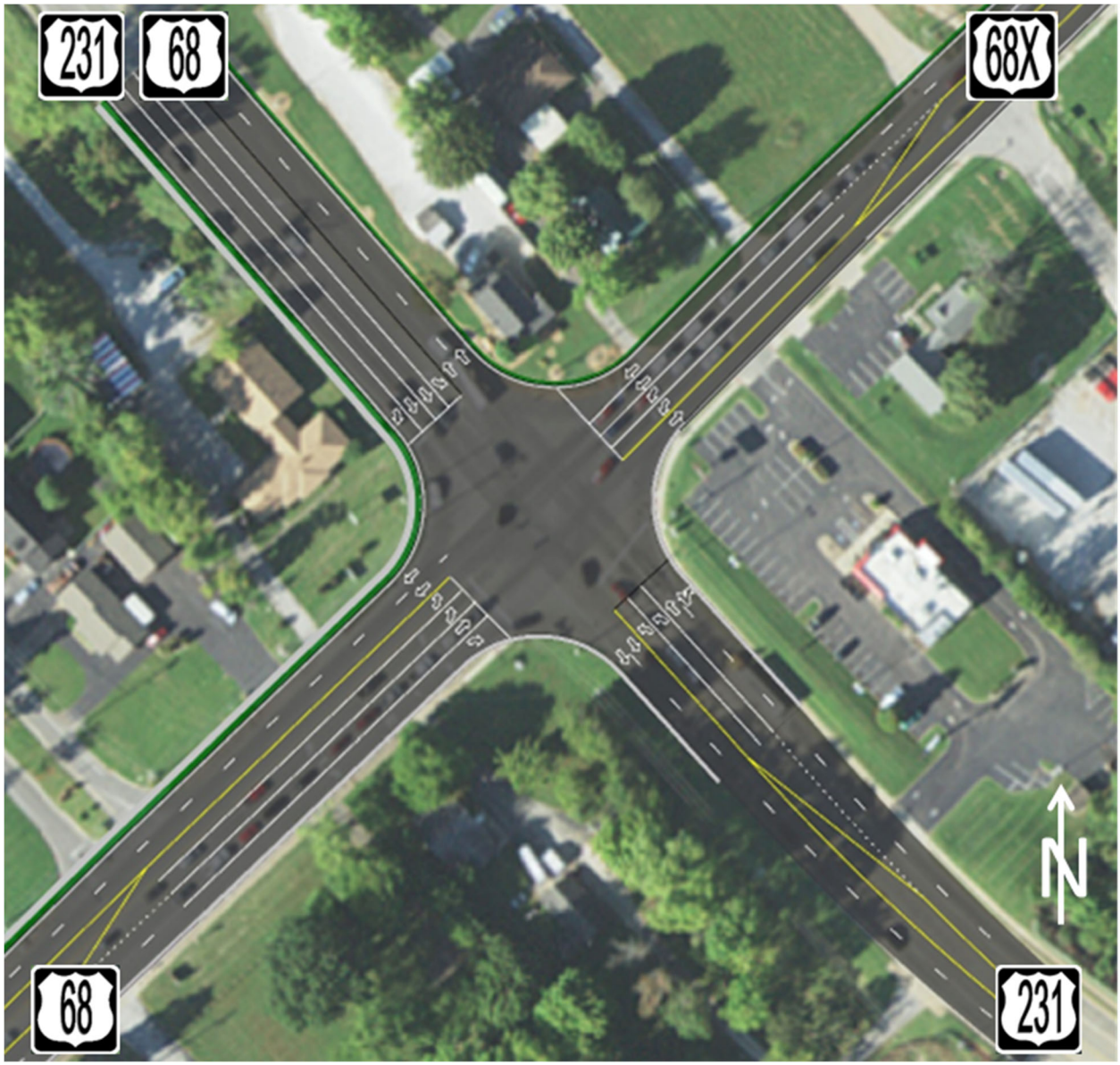


Figure 14: Conventional Dual Lefts Concept

Table 11 summarizes operational metrics by turn movement from the Vissim model. Left turns from US 68 (Veterans Memorial Lane) operate at LOS E in both peak hours; this movement remains a single left-turn lane as capacity is constrained by the single receiving lane on US 68X. The high volume of US 68 (Russellville Road) morning traffic headed north into town leads to LOS E/F for left and thru movements and lengthy queues: 1,600–1,700 feet, comparable to the No-Build scenario. For reference, existing AM queues on US 68 (Russellville Road) were nearly 1,200 feet long during August 2021 data collection efforts.

Table 11: 2045 Build AM (PM) LOS by Movement: Conventional Dual Lefts

Approach	Overall LOS	Left	Thru	Right
US 68X Russellville Road	D (D)	D (D)	C (C)	B (C)
US 231 Campbell Lane		D (D)	C (D)	C (D)
US 68 Russellville Road		F (D)	E (D)	C (B)
US 68 Veterans Memorial Lane		E (E)	D (D)	B (B)

Three nearby access points—Whispering Hills Boulevard and both Hardee's driveways—were analyzed to quantify how frequently left turns from the side street would be blocked by arterial queues. In this Build concept, each driveway is accessible over 75% of the time.

Operations at adjacent signals mimic the No-Build performance discussed in **Section 4.1**.

5.1.2 Partial DLT

Shown in **Figure 15**, the partial DLT shifts left turns from US 231 and US 68 (Veterans Memorial Lane) to cross over opposing traffic at a signalized crossover upstream from the main intersection. Signals at the main intersection and both crossovers would be coordinated to manage queue lengths.

Compared to the No-Build concept, the Partial DLT improves overall operations at the main study intersection to LOS E in the AM peak and D in the PM peak hour.

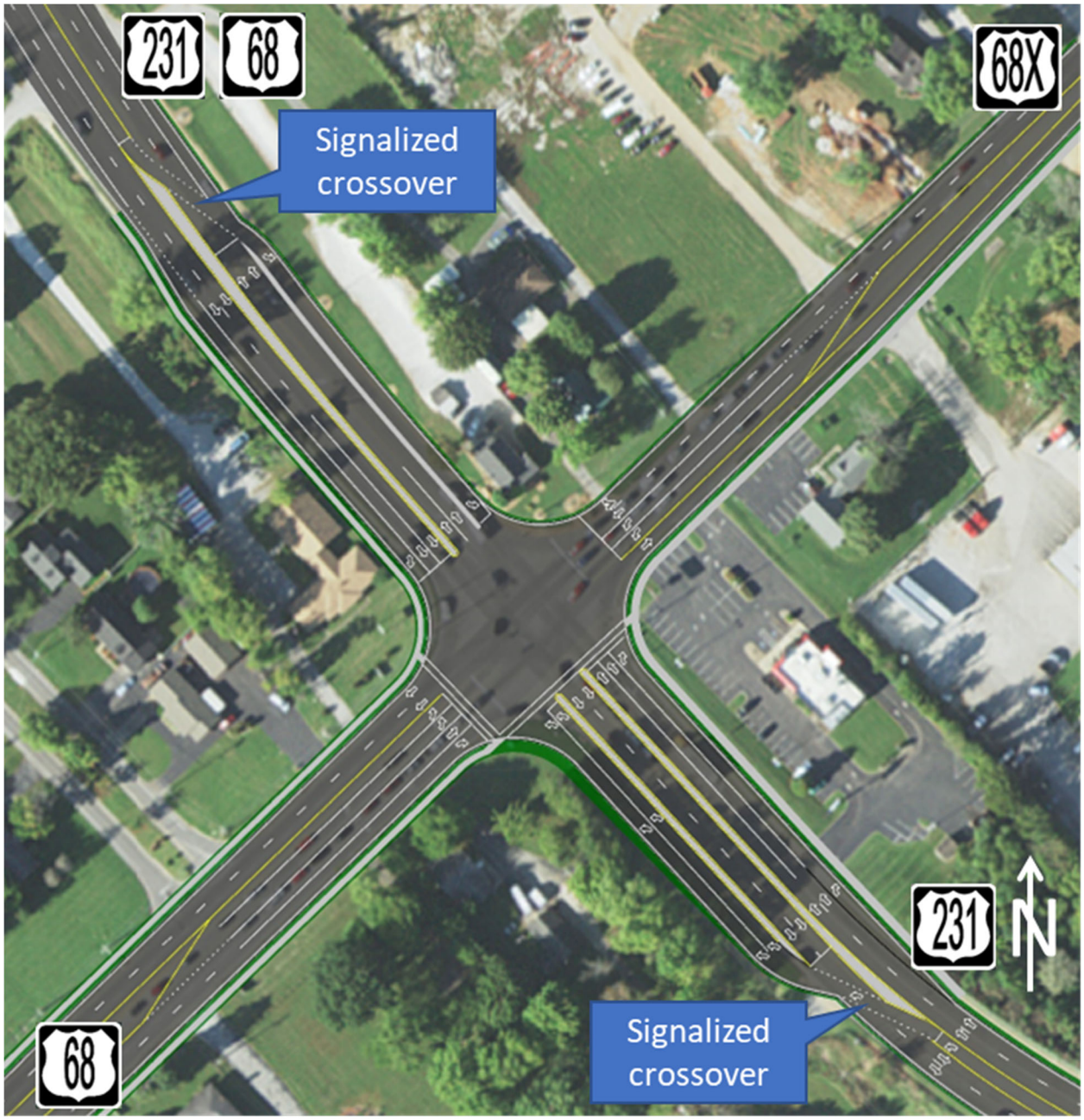


Figure 15: Partial DLT Concept

Table 12 summarizes operational metrics by turn movement. Left turns from any approach are approaching capacity in the PM peak hour. Left turns from US 68 (Russellville Road) are over capacity in the AM peak hour, operating at LOS F. Maximum queue lengths along US 68 (Russellville Road) heading into town are approaching 1,700 feet, similar to the conventional dual lefts option.

Table 12: 2045 Build AM (PM) LOS by Movement: Partial DLT

Approach	Overall LOS	Left	Thru	Right
US 68X Russellville Road	E (D)	E (E)	C (C)	D (D)
US 231 Campbell Lane		D (E)	D (D)	B (B)
US 68 Russellville Road		F (E)	E (C)	E (D)
US 68 Veterans Memorial Lane		D (E)	D (D)	B (B)

Queue lengths between the main intersection and crossovers merit consideration. Dual left-turn lanes are shown downstream of the crossovers to increase storage space. While coordinating this set of signals can help manage queues, responsibility rests with the driver to avoid blocking the crossover intersections.

Anticipated maximum queue lengths at the US 68 (Veterans Memorial Lane) crossover are around 100 feet in both peak hours. At the US 231 crossover, anticipated maximum queue lengths reach 180 feet in the AM peak and 412 feet in the PM peak—to the crest of the railroad overpass. The existing, underutilized TWLTL along US 231 could provide sufficient storage space without modifications to the structure.

As with the conventional dual left-turn lanes concept, three nearby access points—Whispering Hills Boulevard and both Hardee's driveways—were analyzed to quantify how frequently left turns from the side street would be blocked by arterial queues. Analysis results include:

- Left turns from Whispering Hills Boulevard are blocked by US 68 queues 88% of the AM peak hour, suggesting positive separation (e.g., bollards) may be warranted to discourage this maneuver. Blockage drops to 9% in the PM peak hour.
- Left turns from the Hardee's driveway onto US 68X are blocked 11% of the AM peak hour and 26% of the PM peak hour.
- The US 231/Hardee's driveway becomes a right-in/right-out with this concept, as it is downstream of the crossover.

Operations at adjacent signals mimic the No-Build performance discussed in **Section 4.1**.

5.1.3 Roundabout

Shown in **Figure 16**, the roundabout concept assumes a two-lane roundabout with a 200-foot inscribed diameter to accommodate "WB-65" semi-trucks. Congested traffic operations are predicted when applying 2045 No-Build forecast volumes. However, since significant crash reductions and improved pedestrian safety are roundabout hallmarks, further analysis was conducted.

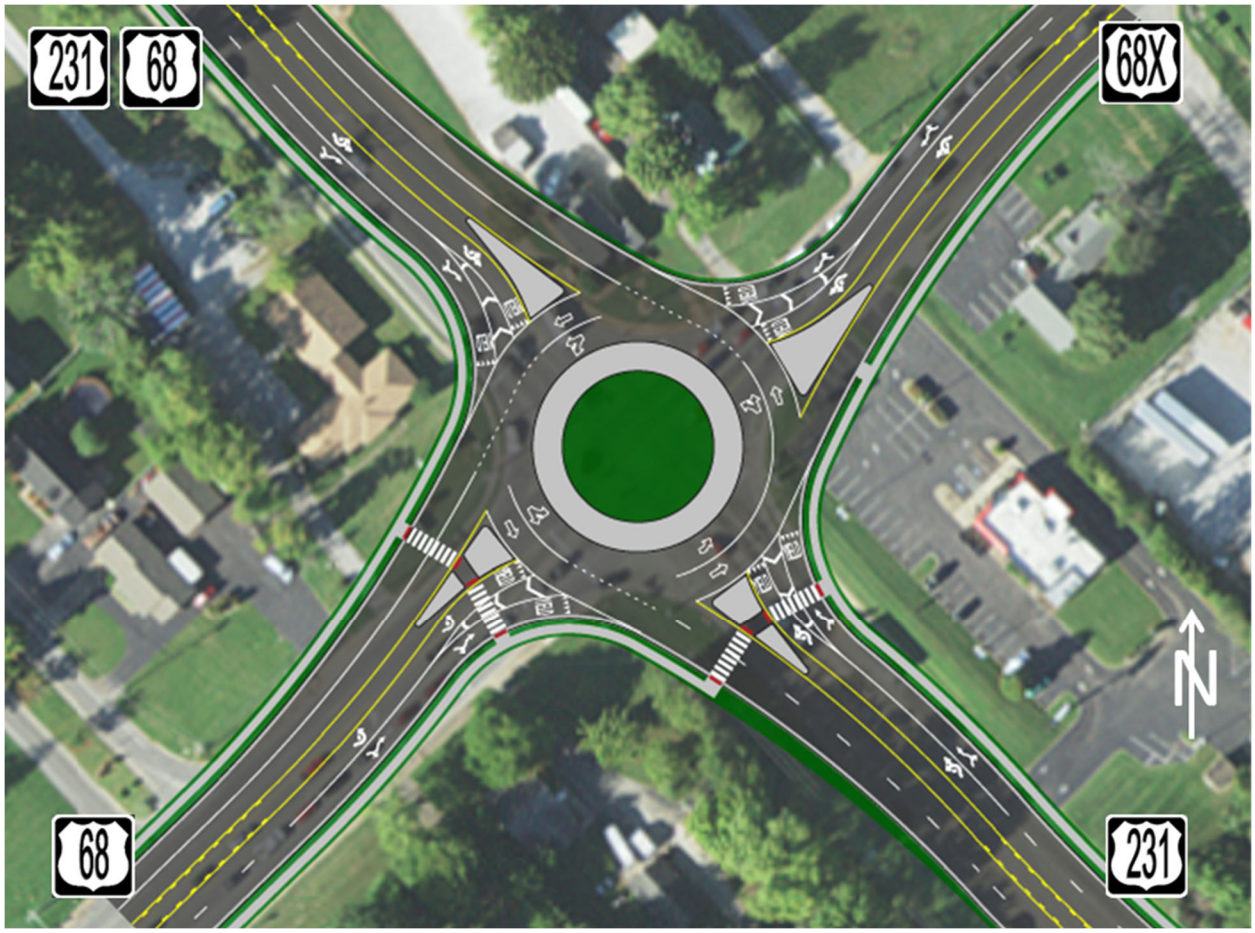


Figure 16: Roundabout Concept

A sensitivity analysis was run to determine what volumes the basic roundabout can accommodate before operations degrade. Starting with the 2021 Existing volumes, incremental growth factors were applied to the current turning movement distribution to determine critical points at which the roundabout configuration would reach LOS D, E, and F in each peak hour. Again, with this level of projected congestion, drivers would likely shift to other routes during the busiest travel periods and/or spread into other, less busy travel times.

As shown in **Table 13**, the proposed roundabout declines to LOS E once PM peak volumes grow 6% over 2021 Existing volumes, and it fails (LOS F) before reaching 9% growth.

Table 13: Roundabout Sensitivity Analysis

Roundabout LOS	AM Peak Hour		PM Peak Hour	
	VPH Increase	Entering VPH	VPH Increase	Entering VPH
Existing Volumes	--	2,914	--	3,382
LOS D	14.5%	3,337	5.5%	3,569
LOS E	23.8%	3,608	6.1%	3,588
LOS F	27.0%	3,702	8.7%	3,675

VPH = vehicles per hour

For comparison, **Table 14** presents the LOS by movement for the LOS E thresholds during the AM and PM peak periods. The US 68 (Russellville Road) approach demonstrates the worst delay in the AM peak while US 68X approach fails first in the PM peak. It is important to note that assumed growth rates in the sensitivity analysis do not correspond to the 2045 Build forecasts reflected in **Table 11** and **Table 12** for other studied concepts as the growth rate is the variable tested to determine LOS thresholds.

Table 14: AM (PM) LOS by Movement: Roundabout at LOS E Thresholds

Approach	Overall LOS	Left	Thru	Right
US 68X Russellville Road	E (E)	C (E)	C (F)	C (F)
US 231 Campbell Lane		E (E)	C (C)	A (A)
US 68 Russellville Road		F (B)	F (C)	F (C)
US 68 Veterans Memorial Lane		C (E)	B (C)	C (D)

Additional microsimulation runs suggest adding extra slip lanes for right-turning vehicles can increase throughput for the intersection. For example, adding extra right-turn lanes to both US 68 legs (see **Figure 17**)—corresponding to the highest right-turn movements—can improve operations. Adding slip lanes to the LOS F threshold case presented in **Table 13** provides the following peak hour operational benefits:

- AM peak hour increases vehicle throughput by 10% and reduces overall intersection delay from 61 seconds (LOS F) to 45 seconds (LOS E).
- PM peak hour increases vehicle throughput by 1.7% and reduces overall intersection delay from 54 seconds (LOS F) to 40 seconds (LOS E).

As in the original layout, the US 68X (Russellville Road) approach experiences the most delay; thru- and left-turn movements from this approach are predicted to operate at LOS F in both peak hours.

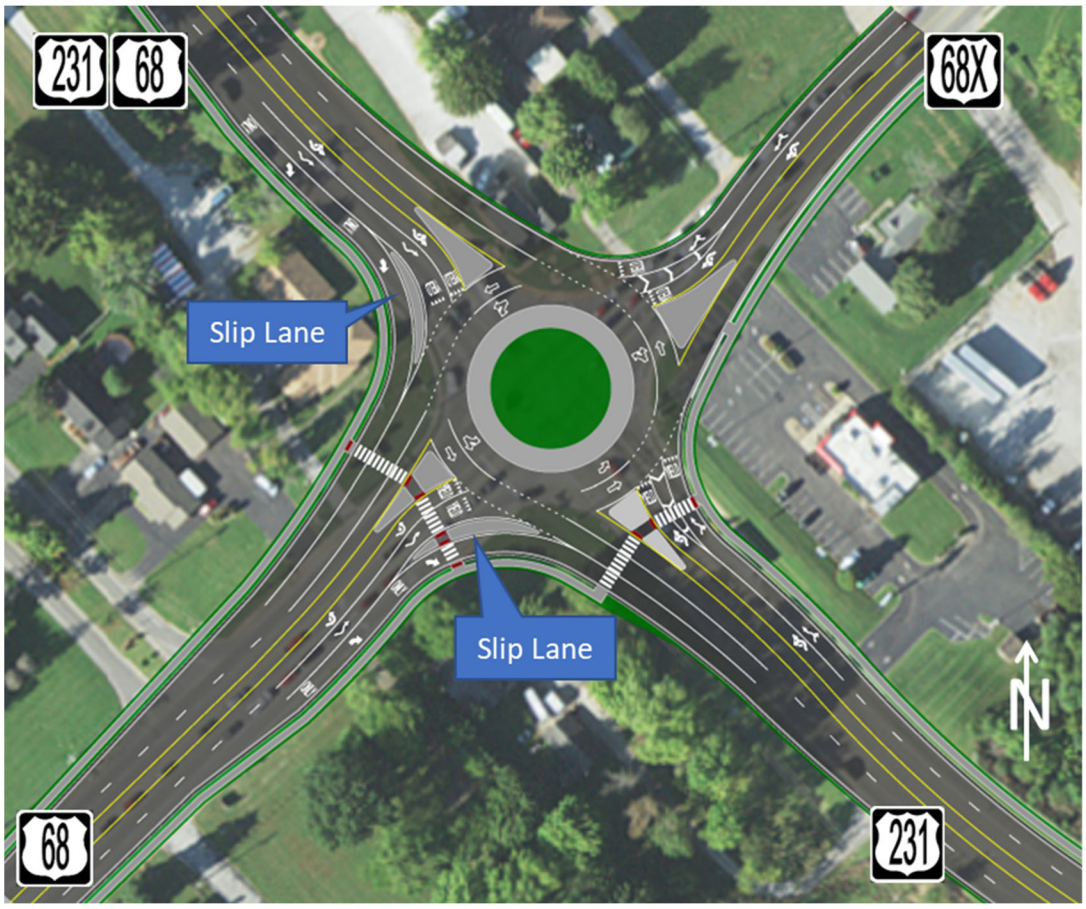


Figure 17: Potential Future Roundabout Variation with Right-Turn Lanes

5.2 Safety Benefits

In addition to traffic impacts, analysts examined potential safety benefits of each proposed Build concept. Safety benefits are based largely on research to develop crash modification factors (CMF) for the CMF Clearinghouse.[18] CMFs are used in calculations to predict future crash reductions resulting from applied countermeasures. Comprehensive crash costs per the 2020 *Kentucky Traffic Collision Facts* report[19] were applied to monetize expected safety benefits.

[18] Online at http://www.cmfclearinghouse.org/
[19] Online at https://transportation.ky.gov/HighwaySafety/Documents/2020_KY_Traffic_Collision-Facts.pdf

5.2.1 Conventional Lefts

A 2005 Florida study concluded adding dual left-turn lanes resulted in a 20% reduction in angle crashes across all severities. Applying this factor to observed crash patterns at the US 231/US 68/US 68X intersection is expected to eliminate 1.5 injury crashes and 2.4 PDO crashes annually. Applying 2020 comprehensive crash costs, this equates to nearly $600,000 in annual safety benefits.

Adding lanes increases pedestrian crossing widths on the two southern legs of the intersection. Wider roadways create more conflict points and likely requires longer pedestrian crossing phases.

5.2.2 Partial DLT

While the DLT concept is relatively new, FHWA's *Alternative Intersection/Interchanges: Information Report*[20] cites DLT crash reductions in Louisiana at 24% for all crashes or 19% for fatal and injury collisions over a two-year monitoring period. Subsequent research in Texas found crash rates increased for some movements but no other CMF was recommended.

Applying the 24% factor to the two impacted US 231/US 68/US 68X approaches shows an annual reduction of up to 0.9 injury crashes and 3.8 PDO crashes, or almost $500,000 in crash savings each year. This was considered the likely upper limit of safety benefits pending additional research as more DLTs are constructed throughout the country.

Again, adding lanes increases the crossing widths for pedestrians on the two southern legs of the intersection, creating more conflict points and likely requiring longer pedestrian crossing phases.

5.2.3 Roundabout

By eliminating left turns, roundabouts provide impressive and well-documented safety benefits. The CMF for a multi-lane roundabout estimates a 50% reduction in crashes (i.e., all types and all severities) compared to a traditional four-leg intersection. Annually, this equates to 3.3 fewer injury collisions and 12.4 fewer PDO crashes at the intersection, resulting in over $1.7 million in crash savings each year.

With lower travel speeds, designated crosswalks, and pedestrian refuges, roundabouts also provide substantial safety benefits for pedestrians as well. Refuges allow pedestrians to watch for oncoming vehicles from one travel direction at a time, simplifying crossings despite a steadier

[20] Online at https://www.fhwa.dot.gov/publications/research/safety/09060/

traffic stream. The wider roundabout variation with dedicated right-turn lanes shown in **Figure 17** may reduce pedestrian safety benefits.

5.3 Estimated Costs

Planning-level design concepts were used to estimate preliminary quantities of high-cost construction items including earthwork, pavement, and structures. Construction costs were tabulated using KYTC average unit bid prices. KYTC District 3 provided right-of-way and utility cost estimates based on conceptual model disturb limits, aerial imagery, approximate locations of existing right-of-way and property lines generated from property valuation administrator (PVA) data, and utility records. Planning-level cost estimates by phase are presented in **Table 15** with costs shown in 2021 dollars. Each construction phase estimate includes an additional 25% for contingencies.

Table 15: Cost Estimates by Phase (2021 Dollars)

Build	Total Cost	Design	Right-of-Way	Utilities	Construction
Dual Lefts	**$7.2 M**	$220,000	$1.0 M	$3.8 M	$2.2 M
Partial DLT	**$11.1 M**	$370,000	$3.0 M	$4.0 M	$3.7 M
Roundabout	**$7.4 M**	$240,000	$1.5 M	$3.3 M	$2.4 M

6.0 STUDY FINDINGS

The project team engaged with local officials and stakeholders to discuss improvement concepts, project costs, and impacts to safety and traffic operations. This chapter summarizes these efforts, providing a comparison between Build solutions.

6.1 Local Officials Briefing

The project team met virtually with local officials and stakeholders March 14, 2022, to provide an overview of study findings. A copy of the meeting summary is included in **Appendix D**. Beyond the team, 13 individuals participated. Following a review of existing conditions and the study goals, the project team presented the three Build concepts.

Participants were polled to identify the three most important study area needs. Shown in **Figure 18**, lengthy delays, continuing development, and high crash rates were top rated.

Twelve of 14 poll respondents chose the roundabout as their preferred Build concept. Nine of 14 identified the partial DLT concept as the least preferred solution.

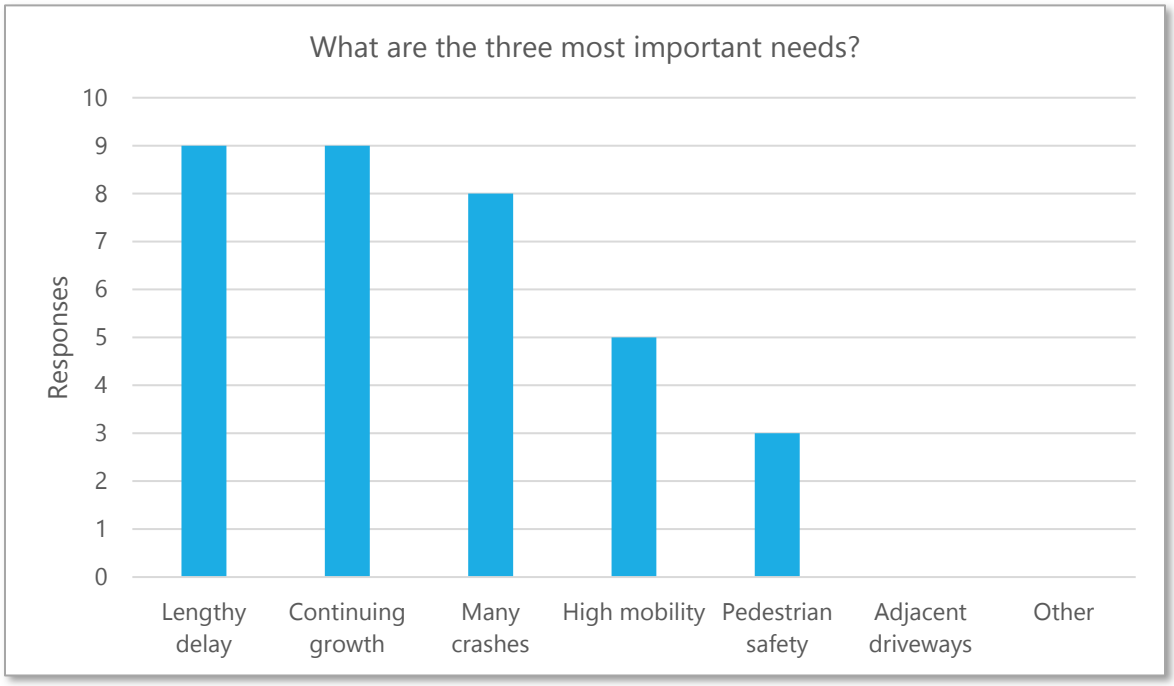


Figure 18: Stakeholder Survey Responses on Study Needs

6.2 Benefit-Cost Analysis

Comparing estimated costs (**Table 15**) and safety benefits (**Section 5.2**), safety-focused benefit-cost analyses (BCA) were computed as presented in **Table 16**. A ratio greater than one signifies the discounted present value of the safety benefits exceeds the discounted present value of the costs, suggesting the project is worthwhile solely based on its anticipated crash reductions. Ratios assume a 3% discount rate over the 20-year analysis period (2025–2045).

Table 16: Safety BCA

Build	Crashes (Fatal/Injury)	CMF ID	CMF Value	Safety BCA
Dual Lefts	52 (0/21)*	1545: Install Left-Turn Lane (Double)	0.800*	**1.45**
Partial DLT	207 (0/41)	FHWA Report 09055: Displaced Left	0.760	**0.78**
Roundabout	124 (0/26)	10098: Multi-Lane Roundabout	0.495	**4.06**

**Only applies to angle crashes*

But safety is only one component of each concept's performance. **Table 17** provides a side-by-side comparison of each Build concept. Bold entries note top performer(s) in each category: future traffic operations, crash reductions, pedestrian benefits, project costs, right-of-way needs, and stakeholder input. The conventional dual lefts and roundabout result in similar costs and right-of-way needs. The conventional dual lefts concept provides the best traffic throughput while the

roundabout provides the most safety benefits. This information is intended as a resource for future decision-makers in the transportation process.

Table 17: Performance Comparison between Build Concepts

Metric	Build 1: Dual Lefts	Build 2: Partial DLT	Build 3: Roundabout
2045 Traffic Operations	**Best**	Medium Less familiar and adds new signals	Least Future enhancement options
Crash Reductions	Medium $600,000 annual crash savings	Least Up to $500,000 annual crash savings	**Best** $1.7M annual crash savings
Pedestrian Connections	Medium	Least	**Best** Shorter crossings, steady traffic flow
Cost	**$7.2M**	$11.1M	**$7.4M**
Approx. ROW	**1.3 ac** Fewest building impacts	2.6 ac	**1.5 ac**
Stakeholder Input	14% Preferred 21% Liked Least	64% Liked Least	**86% Preferred**

6.3 Project Sheets

The partial DLT configuration is estimated to have the highest costs and largest footprint without corresponding improvements in traffic operations or safety. The concept was least preferred by local officials and stakeholders and, therefore, was eliminated from further consideration.

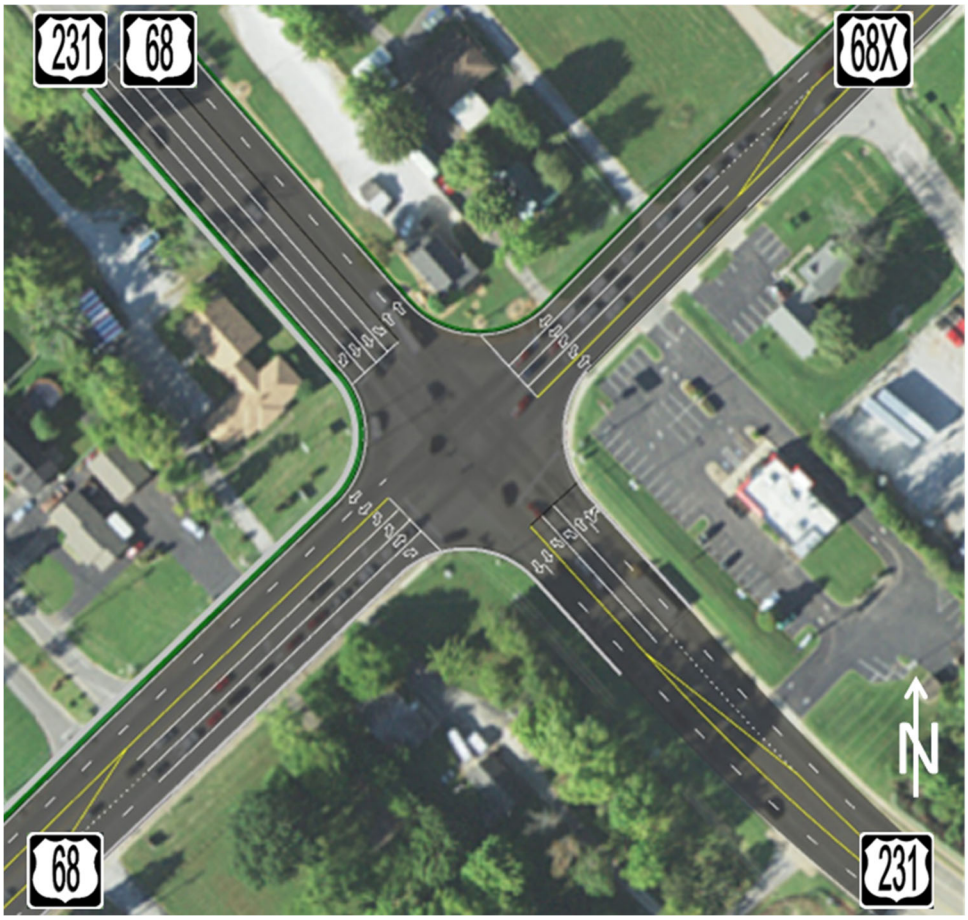
Individual information sheets for the other improvement concepts are presented on the following pages.

Dual Conventional Left-Turn Lanes		
Warren County | US 231 MP 13.882 | US 68 MP 9.334 | US 68X MP 0.000		
IMPROVEMENT DESCRIPTION: Widen to provide dual left-turn lanes on three approaches; retime signal; add painted crosswalks to match existing sidewalks; eliminate left turns to/from Whispering Hills Blvd.	Phase Estimate	(2021 $'s)
	Design	$200,000
	Right-of-Way	$1,000,000
	Utilities	$3,800,000
	Construction	$2,200,000
	Total Cost	$7,200,000

IDENTIFIED NEEDS:

2021 Existing Traffic:	40,500 vpd enter intersection; operates at LOS D in both peak hours
2045 Build Traffic:	At 2% annual growth, 61,200 vpd enter intersection; operates at LOS D in both peak hours; best capacity throughput of concepts studied
Safety:	52 angle crashes at intersection in 4 years; CMF predicts 20% reduction

CONCEPT:

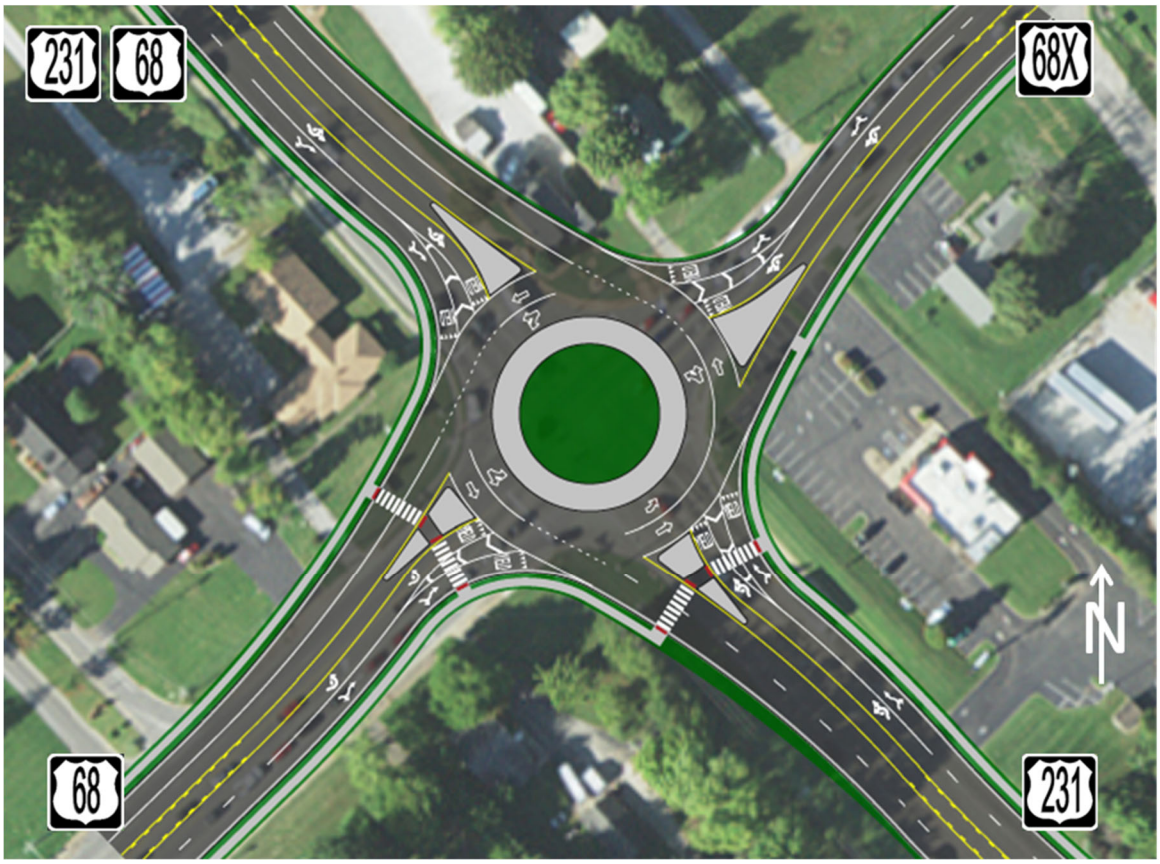


Roundabout		
Warren County | US 231 MP 13.882 | US 68 MP 9.334 | US 68X MP 0.000		
IMPROVEMENT DESCRIPTION: Reconstruct intersection as dual lane roundabout; add painted crosswalks to match existing sidewalks; eliminate left turns to/from Whispering Hills Blvd.	Phase Estimate	(2021 $'s)
	Design	$200,000
	Right-of-Way	$1,500,000
	Utilities	$3,300,000
	Construction	$2,400,000
	Total Cost	$7,400,000

IDENTIFIED NEEDS:

2021 Existing Traffic:	40,500 vpd enter intersection; operates at LOS D in both peak hours
2045 Build Traffic:	At 2% annual growth, 61,200 vpd enter intersection; basic configuration shown below can handle 8% more traffic than existing PM peak hour volume before reaching LOS F; future enhancements could maximize throughput
Safety:	124 crashes within roundabout footprint in 4 years; CMF predicts 50% reduction; best safety benefits of options studied

CONCEPT:



7.0 NEXT STEPS

For either recommended concept, the project should be considered alongside other projects in the next SHIFT prioritization cycle to secure funding for future project development activities. Once funding is identified, the next phase is Phase I Design (Preliminary Engineering), likely including environmental analyses to be eligible for federal funding. Likewise, the MPO's TIP and KYTC's Statewide TIP should be amended to reflect any future project development phases.

Further funding will be necessary to advance any improvement concept to the design phase. Coordination with local officials, key stakeholders, and the public will be critical considering the potential for impacts to adjacent properties and regional motorists.

8.0 ADDITIONAL INFORMATION

Written requests for additional information should be sent to:

KYTC Division of Planning
ATTN: Director
200 Mero Street, 4th Floor West
Frankfort, KY 40622
Phone: 502.564.7183

QK4

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