

Traffic Operations and Safety Study for the City of Belpre- 2004



Sreevatsa Nippani
Randy L. Durst
Fred L. Rader

Wood Washington Wirt Interstate Planning Commission
(An Affiliate of the Mid-Ohio Valley Regional Council),
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Executive Summary

Previous to this study, WWW prepared a Traffic Operations and Safety Study for the City of Belpre, OH in 2001. The report identified high accident locations and provided recommendations to improve performance. A similar analysis was initiated in 2004 and completed in 2005. The report documents the analysis and provides recommendations for the high accident locations to improve performance.

Various improvements were developed for the intersections with high accident frequency in the City of Belpre as a result of the recommendations identified in earlier reports. This study uses accident records from 1999-2003 and reviewed ten intersections (based upon the total number of accidents in the above-mentioned time period) in the City of Belpre. It is not an overview of all intersections in the City of Belpre.

The City of Belpre was contacted in February 2004 for information (supplementing ODOT records) about all accidents taking place between 1999-2003. Those intersections were identified which had a high frequency of accidents (number of accidents more than twenty in the specified time period). For all these intersections, traffic volume studies were conducted during peak hours in the morning (8 AM to 11 AM) and in the evening (3:00 PM to 6:00 PM). A detailed level of service analysis was conducted using the Highway Capacity Software (HCS). All the above mentioned analysis is detailed in Appendix A.

Subsequently, only five intersections were selected from among these intersections, which had the highest frequency of accidents for further analysis (in descending order of number of accidents). Traffic and turning movement counts, and intersection characteristics (i.e., geometry, driver behavior, and surrounding conditions) were collected for the identified study sample. This information was used to construct collision diagrams, intersection sketches, and graphic summaries of vehicle movements. The top five intersections with the highest accident frequency are as follows:

- a. Parkersburg Bridge and Main Street.
- b. Washington Boulevard and Walnut Street.
- c. Washington Boulevard and Lee Street.
- d. Farson Street and US-50.
- e. Main Street and US-50.

Additionally, accident reduction factors were recommended for those intersections after referring to the available literature. Accident prediction models were developed for those intersections followed by the development of counter-measures. Subsequently, accident reduction factors were recommended for those intersections after referring to the available literature.

As part of the recommendations for the future, it is advisable to use different approaches to reduce the accidents, instead of using the recommendations from the Manual of Transportation Engineering Studies. One of the approaches is to use the *Accident Reduction Factors*, in determining the efficacy of using a certain counter-measure, to mitigate a recurring safety problem at an intersection.

Another recommendation would be the development of a cross sectional database of causes and mechanisms of accidents. This database needs to be combined with the City's GIS, to enable the identification of "black-spots" and the subsequent analysis. As a result, the citizens would be able to adjust their route selection at certain times of the day.

Later, these "black spots" should be combined with the counter-measures of the previous studies, leading to the *least-cost alternatives* at each of the accident locations. As a result, the traffic safety can be considerably improved, because, there will be an opportunity for appropriate decision-making by city planners, city administration, MPO, etc, regarding the measures that need to be selected at these sites. Once this display is available on the web page of the city, it adds to the safety awareness of the city's citizens.

Chapter 1.

Introduction of the Study

The City of Belpre, Ohio is located in the Mid-Ohio Valley region along the Ohio River. The municipality is part of the Wood-Washington-Wirt (WWW) Interstate Planning Commission study area and one function of WWW is to continually study the existing transportation system to ensure that the demands (i.e., safety and level of service) created by increasing traffic volumes are adequately addressed. This study provides high accident location information and preliminary traffic analyses, which can indicate areas of further study. Descriptions of previous studies have been provided in the 2001 report [1].

This traffic operations and safety study examined accident data from January 1, 1996 to December 31, 1999 to evaluate intersections. These reports were examined to determine the total number of accidents and injuries at each intersection in the city of Belpre during the study's time period. As part of the preliminary selection process only those intersections with 13 or more accidents were kept in the study. Once the preliminary selection process had been completed the remaining fourteen intersections were ranked based on number of accidents, number of injuries, accident rates, accident severity, and Level of Service (LOS).

Traffic and turning movement counts, and intersection characteristics (i.e., geometry, driver behavior, and surrounding conditions) were collected for the identified study sample. This information was used to construct collision diagrams, intersection sketches, and graphic summaries of vehicle movements. Accident patterns and probable causes were then identified and countermeasures were recommended for each intersection.

This study was conducted by Sreevatsa Nippani, Transportation Specialist, under the supervision of Randy Durst, Transportation Study Director, WWW Interstate Planning Commission, and Fred Rader, Community Development Director, Mid-Ohio Valley Regional Council. Authors of this report acknowledge the Ohio Department of Transportation for providing the original accident data and some of the vehicle turning movement counts and previous transportation specialists for any preliminary work completed on the study.

Chapter 2.

Intersection Identification and Surveys

2.1 Selecting Study Locations

The July 2001 study prepared by WWW concluded that a majority of the accidents in the City of Belpre were intersection related; therefore, intersections were the primary focus of review for this study. Figure 1 depicts the study area and accident distributions for the City of Belpre. The Ohio Department of Highway Safety's files of City Street Traffic Accident Listings for the period of 1999-2003 were acquired and examined to identify potentially hazardous locations. Intersections with more than twenty accidents during 1999-2003 were selected for further detailed analysis. These intersections are listed below:

1. Main St., the Memorial Toll Bridge, and US 50 Eastbound Ramp
2. Washington Blvd. and Farson St.
3. Washington Blvd., Main St., and the US 50 bridge across the OH River.
4. Washington Blvd and Lee St.
5. US 50 and Farson St.
6. Washington Blvd. and Walnut St.
7. Washington Blvd. and Maple St.
8. Washington Blvd. and Putnam Howe Rd.
9. Washington Blvd. and Stone Rd.

Using the total number of accidents, the number of injuries, severity index, accident rates, and Level of Service (LOS), the intersections were ranked according to each criterion individually. Once they had been rated using each of the five categories, the ranking numbers were added and then listed in numerical order to get the final ranking of the eight most hazardous intersections.

2.2 Intersection Traffic Volumes

Average daily traffic (ADT) counts and peak hour turning movement counts were required for the final ranking process as well as the detailed analyses. Traffic counts were taken for all the intersections. Ideally, a 24-hour ADT or a peak hour count would

be desired. However, due to the time constraints of the current study, counts were taken between 8 am-11 am and 3 pm-6 pm for each location. The 6-hour counts were then adjusted using 24-hour and seasonal factors to estimate an ADT. The seasonal traffic adjustment factors were determined using a document provided by ODOT's Office of Technical Services dated March 1997.

Vehicle turning movement diagrams were produced to display the ADT volume of through traffic, left turn traffic, and right turn traffic for all intersection approaches. The turning movement data was then used to calculate accident rates, to identify possible causes of accidents, and to run the Highway Capacity Software (HCS) model.

2.3 Accident Rate

Accident records for the study area from 1996-1999 were obtained from the Ohio Department of Public Safety, Office of Technology/Information Services. The total number of accidents, number of injuries was recorded for each of the eight final intersections. This data is combined on the collision diagrams and can be used to help identify accident patterns at each intersection.

The accident rate (AR) of an intersection establishes the number of accidents per million vehicles that pass through the intersection. It is important because it allows a comparison between intersections regardless of size and volume. Accident rates were calculated for each of the 14 identified intersections using the following formula:

$$AR = [(T)(10^6)] \div [(ADT)(n)(365)]$$

where,

- T = the total number of accidents for the study period
- ADT = the average daily traffic volume (vehicles per day)
- n = the number of years studied
- 365 = the conversion from years to days

2.4 Severity Index

The accident severity compares the number of injuries at an intersection to the total number of accidents at that same intersection. Severity indices were calculated for all 9 intersections. The intersections were then ranked from 1 to 14 using both the accident rate and the severity index. These rankings, along with the statistical data, were used to prioritize the intersections for potential improvements.

2.5 Level of Service

Level of Service (LOS) is a qualitative measure describing the operational conditions within a traffic stream and it is generally described in terms of travel speed, travel time, freedom to maneuver, traffic interruptions, and driver comfort, convenience, and safety. Specifically, LOS criteria for unsignalized and signalized intersections are stated in terms of the average stopped delay per vehicle. For this study area, LOS C and above are acceptable values for intersections. The *1990 Policy on Geometric Design of Highways and Streets* describes the general operating conditions for each LOS in the following manner:

LOS	Description
A	Free flow of traffic, with low volumes and high speeds.
B	Reasonably free flow of traffic, but speeds beginning to be restricted by traffic conditions.
C	Traffic is still in the stable flow zone but most drivers are restricted in freedom to select their own speed.
D	Traffic is approaching unstable flow and drivers have little freedom to maneuver.
E	There is unstable flow. There may be short traffic stoppages.
F	Unstable flow. Stop and go traffic.

Table 1 – LOS Descriptions

WWW operations and safety studies typically use Highway Capacity Software (HCS) to calculate LOS. The *Highway Capacity Manual* recommends, when possible, using field observations to estimate LOS for unsignalized intersections and to verify conditions on signalized intersections.

2.6 Identifying Intersection Conditions

In order to identify significant intersection characteristics, a field survey was preformed for the eight most hazardous intersections. This process involved driving the locations from all approaches, observing traffic flow and walking the area to obtain notable information. The field survey provided information concerning intersection type, location, alignment, lane use and configuration, geometry, driver behavior, and surrounding conditions.

Traffic control devices, such as signs and pavement markings, were inspected to assure conformance with the *Manual on Uniform Traffic Control Devices (MUTCD)* and to note the current condition of these devices. An intersection diagram was constructed to accompany the narrative description of each intersection.

2.7 Recommending Countermeasures

The data from the accident analysis, the traffic counts/movements, and the field observations, coupled with the general guidelines from several engineering manuals, recommendations from other traffic engineers, and the author's professional opinion were used to generate probable accident causes and to recommend any countermeasures.

Minor improvements, such as warning signs or re-striping, may be implemented without further consideration; however, significant improvements like traffic signals, additional lanes, or rigid channelization should be examined more thoroughly to determine both the feasibility of the recommendation and the impacts that the countermeasure would place on the entire transportation system.

It should be noted that while the recommendations made in this document can improve safety, they may have an adverse effect on the level of service for the intersection. In the recommendations section for each intersection both factors have been considered whenever possible.

Chapter 3.

Accident Analysis

3.1 Accident Analysis Summary

Accident distributions in the study area are illustrated in Figure 1. The overall distribution of intersection accidents is presented in Table 2 and Appendix C. The nine intersections in the City of Belpre (# of accidents more than twenty for the time period 1999-2003) reported a total of four hundred and ninety three accidents during the period of 1999-2003. Two hundred and eight injuries were recorded during the same time period. From this list of nine intersections, only the top five intersections were selected which had the highest number of accidents in the descending order.

These five intersections reported a total of four hundred and ten accidents during the period of 1999-2003. Accident types consisted of 200 (49%) rear-end, 7 (1.7%) head-on, 95 (24%) right angle, 23 (5.6%) sideswipe, 3 (0.07%) animal, 14 (3.4%) fixed object, and 1 (0.025%) bicycle collisions and 6 (1.46%) of other types. The number of injuries for these intersections during the same time period was one hundred and seventy two.

3.2 Intersection Ranking Summary

Accident statistics for the ten most hazardous intersections are presented in Table 3. The intersection of SR-618 and Putnam Howe had the highest Accident Severity Index and the SR-618 and Maple street intersection had the lowest.

The highest number of accidents took place at Main Street and US-50 intersection and the least number of accidents took place at the intersection of SR-618 and Maple Street.

The Main Street and US-50 intersection had the highest frequency of injuries (163) over the 4-year study period. The Washington Boulevard and Maple Street intersection had the lowest frequency of 18 accidents, during the same time period.

Street 1	Street 2	ADT	ADT Ranking	ASI	ASI Ranking	# of Accidents	Accidents Ranking
Parkersburg Bridge	Main Street	39910	1	0.380597015	5	104	2
SR-618	Walnut	25763	3	0.372093023	6	43	5
SR-618	Lee Street	25107	4	0.462962963	3	54	3
SR-618	Maple	19668	7	0.277777778	9	18	8
SR-618	Stone	23659	6	0.285714286	8	28	6
SR-618	Farson Street	13076	9	0.533333333	2	15	9
US-50	Farson Street	26562	2	0.434782609	4	46	4
SR-618	Putnam Howe	17872	8	0.590909091	1	22	7
Main Street	US 50	23912	5	0.34375	7	163	1

Street 1	Street 2	# of Injuries	Injuries Ranking	Accident Rate	AR Ranking
Parkersburg Bridge	Main Street	51	2	229.9694859	1
SR-618	Walnut	16	4	114.3191971	4
SR-618	Lee Street	25	2	147.3146984	2
SR-618	Maple	5	9	62.68439652	9
SR-618	Stone	8	8	81.06040901	7
SR-618	Farson Street	8	7	78.57121895	8
US-50	Farson Street	20	3	118.6162536	3
SR-618	Putnam Howe	13	5	84.31341278	6
Main Street	US 50	62	1	91.66028852	5

Table 2. Accident Data and Statistics for High-Accident Intersections

Street 1	Street 2	# of Accidents	Rear-End	Head-On	Left- Turn	Right-Turn	Right-Angle
Parkersburg Bridge	Main Street	104	56	0	24	0	12
SR-618	Walnut	43	12	2	0	0	24
SR-618	Lee Street	54	24	0	0	0	24
US-50	Farson Street	46	15	1	0	0	22
Main Street	US-50	163	93	4	34	3	13

Street 1	Street 2	Side-Swipe	Pedestrian	Animal	Fixed-Object	Bicycle	Other
Parkersburg Bridge	Main Street	7	0	0	5	0	0
SR-618	Walnut	2	0	0	0	1	2
SR-618	Lee Street	5	0	0	0	0	1
US-50	Farson Street	3	0	2	0	0	3
Main Street	US-50	6	0	1	9	0	0

Table 3. Distribution of Accidents for Top Five High-Accident Intersections

Figure 1. Accident Distributions for City of Belpre

3.3 Recommendation Summary

The analysis of each intersection's accident data, vehicle turning movements and geometric conditions produced accident patterns and probable accident causes for the selected locations. Using the Manual of Transportation Engineering Studies [3], potential countermeasures were generated for each intersection to improve safety and operational efficiency. A summary of the recommendations for all of the intersections is presented in Tables 4a and 4b. The detailed analysis of each intersection contains a conclusions and recommendations section that presents possible improvements for each location.

Intersection	Traffic Control	Accident Pattern(s)	Probable Cause(s)	Possible Countermeasures
Main, M-Bridge, and US 50 EB	Actuated Signal	Rear-Ends	Slippery Pavement Surfaces Large Volumes of Vehicles Turning Poor Visibility of the Signal	Overlay/Groove Pavement Reduce Speed on Ramp Install Signal Back Plates Install Larger Signal Lenses
Washington & P-B Bridge	Pre-Timed Signal	Rear-Ends	Inadequate Signal Timing Poor Visibility of Signal	Adjust Signal Timing Install Larger Signal Lenses Install Signal Back Plates Install Warning Devices
Washington & Lee	Pre-Timed Signal	Rear-Ends Left Turns	Restricted Sight Distance Large Volume of Left Turn Traffic	Construct Left Turn Lanes on Lee Provide Left Turn Phase for Lee
US 50 and Farson	Pre-Timed Signal	Rear-Ends Left Turns Right Turns	Inadequate Signal Timing	Adjust Signal Timing
Washington & Walnut	Stop Sign	Left Turns Rear-Ends Right Angles	Drivers Unaware of Intersection Restricted Sight Distance	Install Warning Devices Install Flashing Beacon

Table 4a. Intersection Countermeasure Recommendations (Manual of Transportation Engineering Studies)

Accident Pattern	Probable Cause	Possible Counter-measures
Rear-End at Signalized Intersection	A, G, H, J, K, L, M	3, 4, 13, 15, 18, 19-22, 23, 25, 26, 12, 14, 27-32, 16, 17, 33, 34
Right-Angle at Signalized Intersection	B, E, H, K, L, N, O	2, 6, 12, 14, 15, 35, 36, 15, 16, 37, 23, 27-32, 38, 11, 17, 33, 39, 40

Where:

A-Large turn volume, **B**-Restricted Sight Distance, **E**-Excessive speed, **G**-Slippery surface, **H**-Inadequate roadway lighting, **J**-Crossing pedestrians, **K**-Poor traffic control device (TCD) visibility, **L**-Inadequate Signal Timing, **M**-Unwarranted signal, **N**-Inadequate advance intersection warning signs, **O**-Large total intersection volume.

And:

2-Add lane, **3**-Provide left-turn signal lane, **4**-Prohibit turn, **6**-Provide adequate channelization, **11**-Retime signal, **12**-Remove sight obstruction, **13**-Provide turn lane, **14**-Install or improve warning sign, **15**-Reduce speed limit, **16**-Adjust amber phase, **17**-Provide all-red phase, **18**-Increase turn radii, **19**-Overlay pavement, **20**-Provide pavement drainage, **21**-Groove pavement, **22**-Provide “slippery when wet” sign, **23**-Improve roadway lighting, **25**-Install or improve pedestrian crosswalk TCD’s, **26**-Provide pedestrian signal, **27**-Install overhead signal, **28**-Install 12-inch signal lens, **29**-Install signal visors, **30**-Install signal back-plates, **31**-Relocate signal, **32**-Add signal heads, **33**-Provide progression through a set of signalized intersections, **34**-Remove signal, **35**-Restrict parking near driveway, **36**-Provide markings to supplement signs, **37**-Install rumble strips, **38**-Install illuminated street name sign, **39**-Install multial signal controller, **40**-Install signal actuation.

Table 4b. Intersection Countermeasure Recommendations (Manual of Transportation Engineering Studies)

Chapter 4.

Detailed Analysis of Selected Intersections

4.1 Main Street, Memorial Bridge and US-50 East Bound Ramp

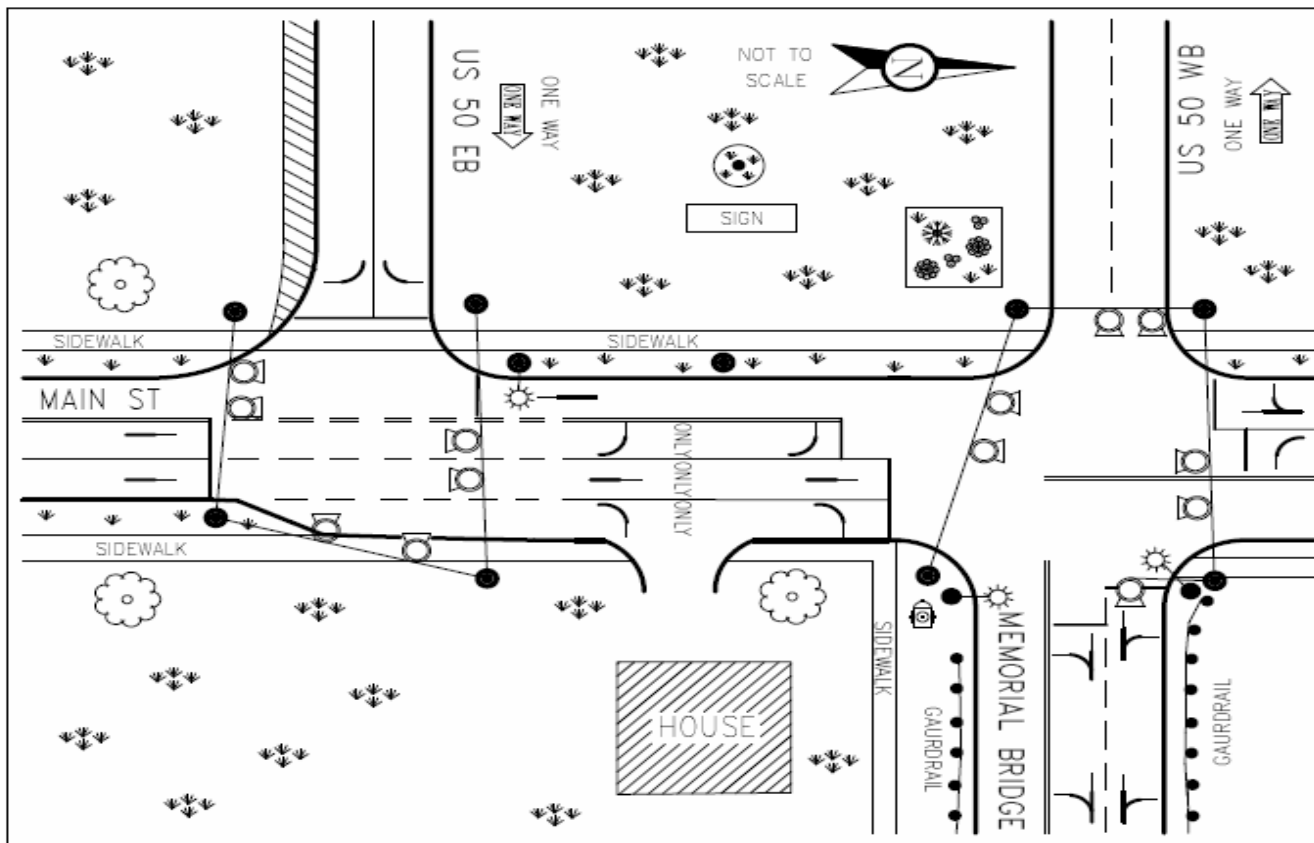
Geometric Conditions: The Main Street, Memorial Toll Bridge, and US-50 Eastbound (EB) Ramp location is actually two signalized intersections that are within 200 feet of each other. For the purposes of this study they operate as a single intersection. Main Street and US-50 are classified as other principal arterials while the Memorial Toll Bridge is classified as a principle arterial without a designated route number. US-50 constitutes the eastbound (EB) approach, the Memorial Toll Bridge constitutes the westbound (WB) approach, and Main Street the southbound (SB) and northbound (NB). Figure 2 shows the intersection diagram in question.

Traffic Volume and LOS: Figure 3 graphically illustrates the traffic movements for this intersection. The intersection was evaluated using the Highway Capacity Software (HCS) computer model, which produced the following approach delays and LOS's shown in Table 5. The overall intersection delay was 36.4 sec/veh and the intersection LOS was D.

Approach Movement	Delay (seconds/vehicle)	LOS
EB	33.2	C
WB	35	C
NB	36.7	D
SB	39	D

Table 5. Delay and LOS for Main St., Memorial Bridge. and US-50 EB Ramp.

Collision Diagram: There were a total of one hundred and sixty three accidents at this intersection. Prominently among them were, 93 rear-end accidents and 34 were left-turn accidents. Figure 4-1 and 4-2 are the collision diagrams for the above-mentioned intersection.



Reference: Traffic Operations and Safety Study for the City of Belpre (2001)

Figure 2. Intersection Diagram for Main St., Memorial Bridge, and US-50 EB Ramp

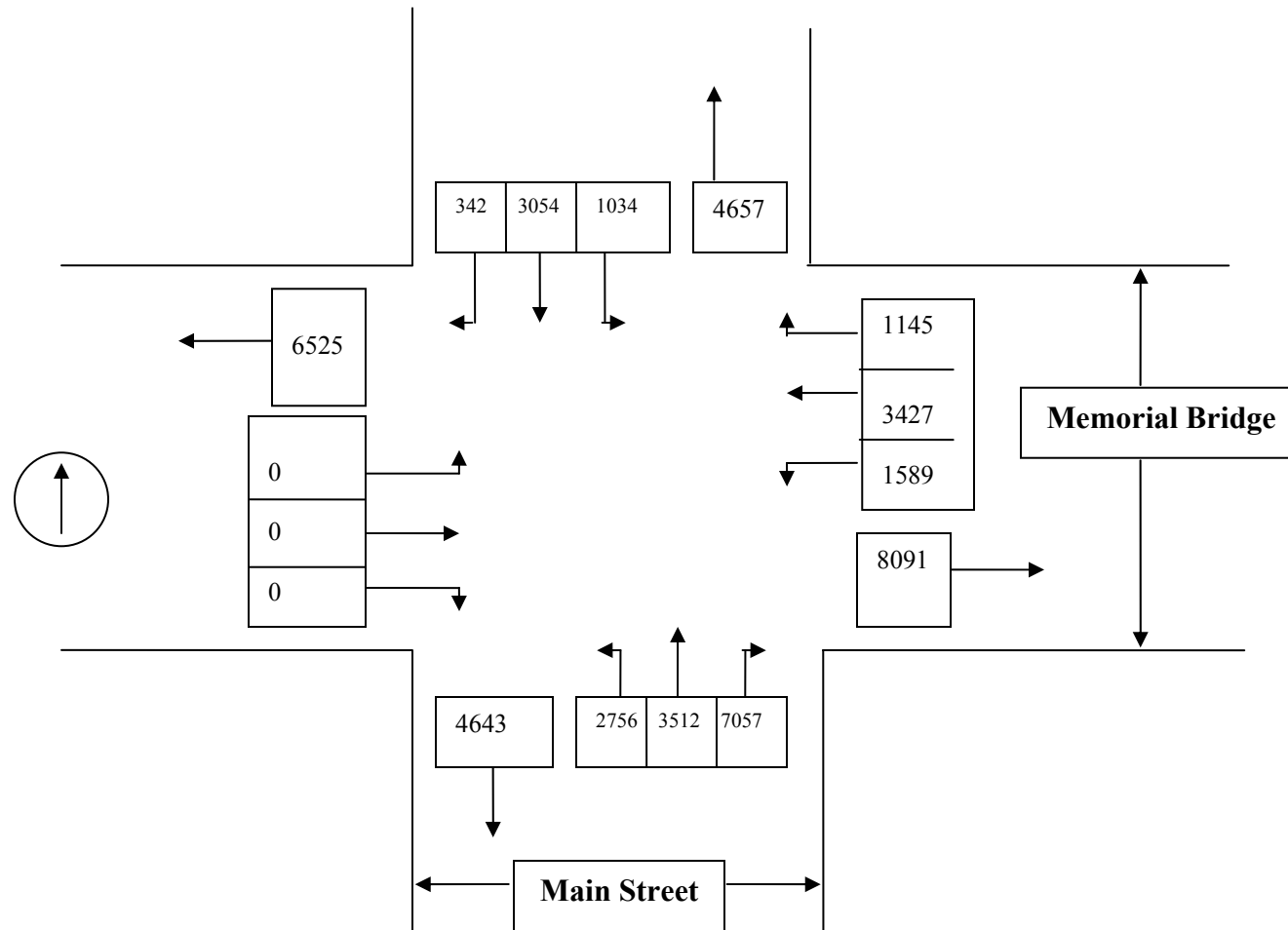


Figure 3. Turning Movement Diagram ADT along Main Street and Memorial Bridge Intersection in the City of Belpre, Ohio.

Figure 4-1. Collision Diagram for Main St., Memorial Bridge. and US-50 EB Ramp

Figure 4-2. Collision Diagram for Main St., Memorial Bridge and US-50 EB Ramp

Conclusions and Recommendations:

This intersection ranks first with respect to priority for the study group, if considered as a combination of two intersections: Memorial Bridge/ Main Street intersection, and the Main Street/ US-50 EB intersection. It's the highest with respect to the Average Daily Traffic (ADT), which is the combination of the ADT at the Memorial Bridge and Main Street intersection, and the Main Street, US-50 EB intersection.

It had the highest number of accidents (163 as a total). When compared to the previous study, the accident severity index had increased. But, the number of accidents reduced when compared to the previous study period (1995-1999). The majorities of accidents were either rear-end or right angled collisions.

There were a large number of collisions, 67 of 163 (41.1%), occurring between the two signals. Based on field observations, there is no enough storage area for vehicles intending to turn right onto Memorial Bridge. Due to the fact that right-turn on red is not allowed onto Memorial Bridge, there is a traffic back-up from the US-50 EB ramp. Due to the heavy truck traffic, the intersection had recorded about 8% of truck-related accidents. A barrier was placed there to decrease the amount of damage done to the private property located south of the ramp, due to the truck traffic.

As a result of the recommendation from the previous study, the re-construction of the eastbound ramp with an "S" curve configuration (to line it up with the Memorial Toll Bridge Approach (Appendix D)) has been programmed. This would eliminate the need for two signals and would reduce the intersection to one single signal location at the current US 50 westbound ramp, Main St., and the Memorial Toll Bridge intersection. Additionally, there would then be enough pavement to re-stripe the right turn movement with a wider radius, thereby reducing the accidents for vehicles making that turn. The right turn movement could then be controlled with either a yield sign or a stop sign.

For a list of all accident counter-measures that can be recommended for this intersection, refer to Tables 4a and 4b. Also, refer to Tables 11, 12 and 13 for the Accident Reduction Factors that can be applied to this intersection.

4.2 Washington Boulevard, Parkersburg/Belpre Bridge

Geometric Conditions: Washington Blvd., Parkersburg/Belpre Bridge is a three-leg intersection near downtown Belpre. Washington Blvd. is classified as a minor arterial and Main St. is classified as other principal arterial. Washington Blvd. runs east and west while Main St. is north-south, and the Parkersburg/Belpre Bridge runs southeast.

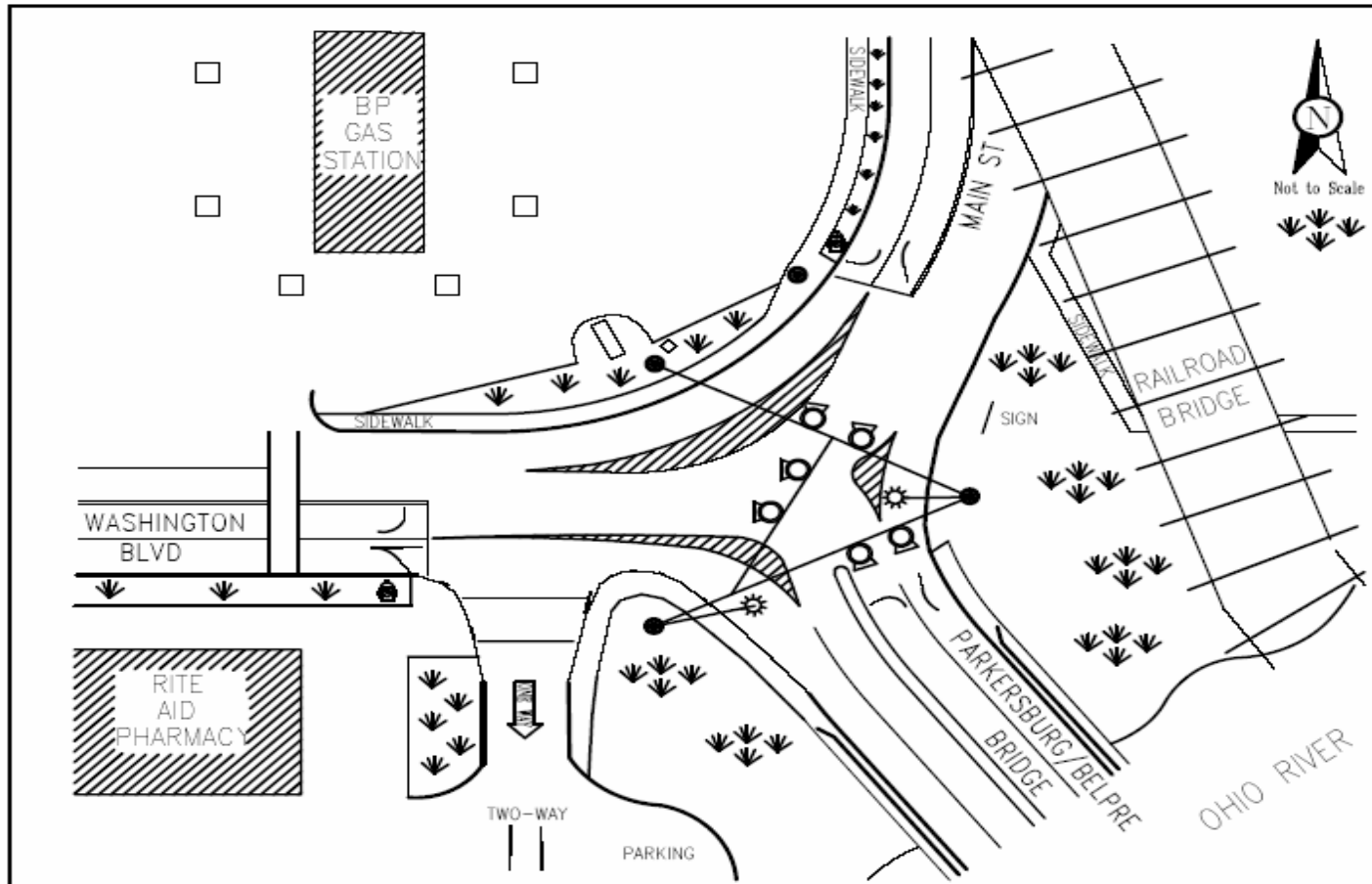
Figure 5 shows the intersection diagram in question.

Traffic Volume and LOS: Figure 6 graphically illustrates the traffic movements for this intersection. The intersection was evaluated using the Highway Capacity Software (HCS) computer model, which produced the following approach delays and LOS's shown in Table 6. The overall intersection delay was 42 sec/veh and the intersection LOS was D.

Approach Movement	Delay (seconds/vehicle)	LOS
EB	45.3	D
WB	41.7	D
NB	42.9	D
SB	43	D

Table 6. Delay and LOS for Washington Blvd., US-50, and Main Street.

Collision Diagram: There were a total of one hundred and four accidents at this intersection. Prominently among them were 58 rear-end accidents and 37 were angled accidents. Figure 7 is the collision diagram for the above-mentioned intersection.



Reference: Traffic Operations and Safety Study for the City of Belpre (2001)

Figure 5. Intersection Diagram for Washington Blvd., US-50, and Main Street

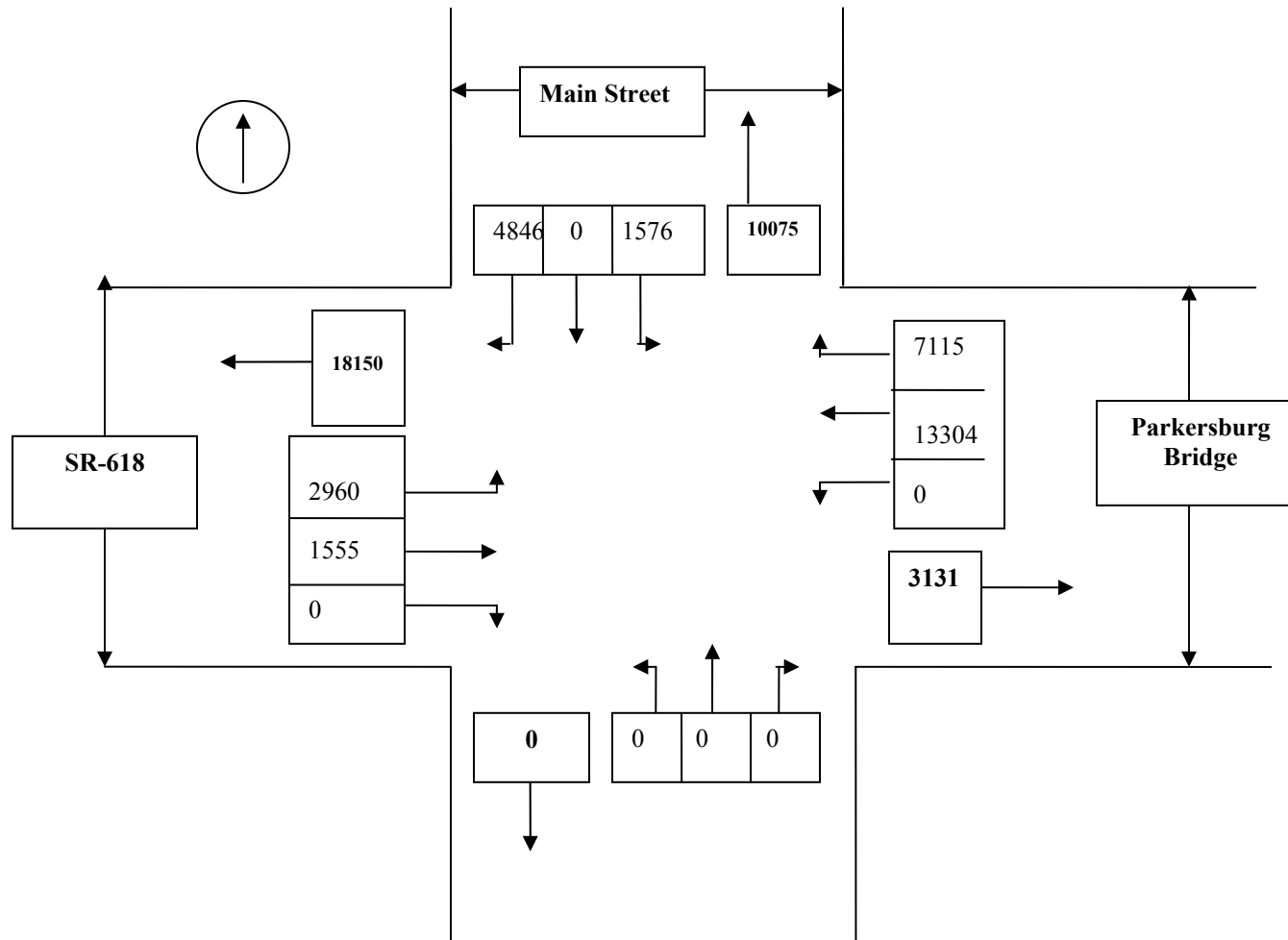


Figure 6. Turning Movement Diagram (ADT) along Belpre Bridge and Washington Boulevard Intersection in the City of Belpre, Ohio.

Figure 7-1. Collision Diagram for Washington Blvd., and Parkersburg/Belpre Bridge.

Conclusions and Recommendations:

This intersection ranks second with respect to priority for the study group. It's also the second-highest with respect to the Average Daily Traffic (ADT). It also had the second-highest number of accidents. When compared to the previous study, the accident severity index had reduced. But, the number of accidents reduced when compared to the previous study period (1995-1999). The majority of accidents were either rear-end or angled collisions.

Rear-end collisions account for the highest percentage of accidents at this intersection. Based on the data provided, it appears that inadequate signal timing and poor visibility of the traffic signals are the main causes of these accidents. Possible countermeasures include adjusting the yellow change interval, the all-red clearance interval, and/or the minimum green time, installing larger signal lenses, installing signal back plates and providing advance warning devices.

For a list of all accident counter-measures that can be recommended for this intersection, refer to Tables 4a and 4b. Also, refer to Tables 16, 17 and 18 for the Accident Reduction Factors that can be applied to this intersection.

4.3 Washington Boulevard and Lee Street

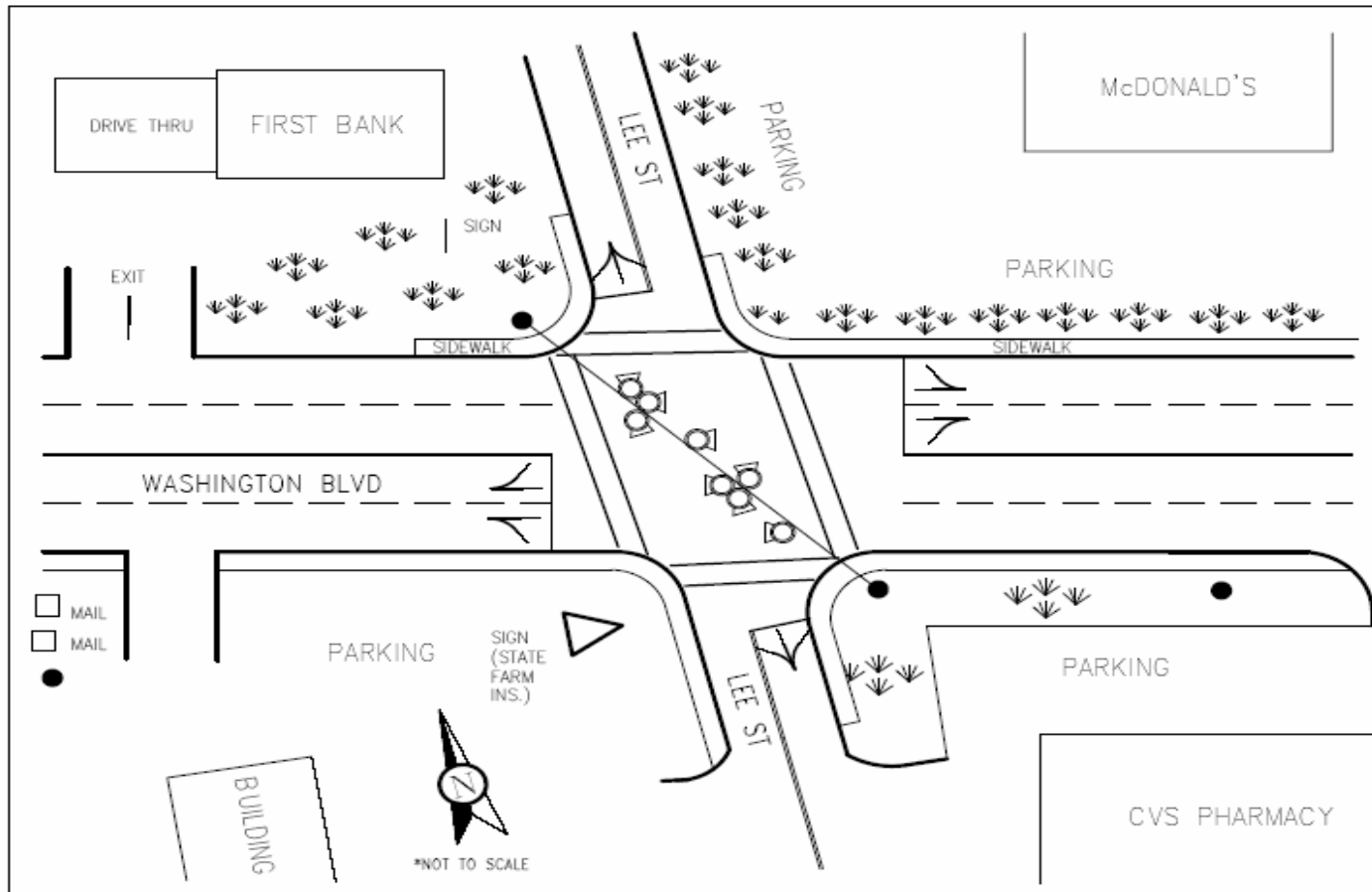
Geometric Conditions: The Washington Blvd. and Lee St. location is a four-leg intersection that intersects at an approximate seventy-five degree angle. Washington Blvd. is classified as a minor arterial and Lee St. as a local city street. Washington Blvd. is the eastbound and westbound approaches and Lee St. is the northbound and southbound approaches. Figure 8 shows the intersection diagram in question.

Traffic Volume and LOS: Figure 9 graphically illustrates the traffic movements for this intersection. The intersection was evaluated using the Highway Capacity Software (HCS) computer model, which produced the following approach delays and LOS's shown in Table 7. The overall intersection delay was 32 sec/veh and the intersection LOS was C.

Approach Movement	Delay (seconds/vehicle)	LOS
EB	32.6	C
WB	33.3	C
NB	29.8	C
SB	27.6	C

Table 7. Delay and LOS for Washington Blvd. and Lee Street.

Collision Diagram: There were a total of fifty four accidents at this intersection. Prominently among them were 24 rear-end accidents, 24 were angled accidents and five were side-swipe accidents. Figure 10 is the collision diagram for the above-mentioned intersection.



Reference: Traffic Operations and Safety Study for the City of Belpre (2001)

Figure 8. Intersection Diagram for Washington Blvd. and Lee Street.

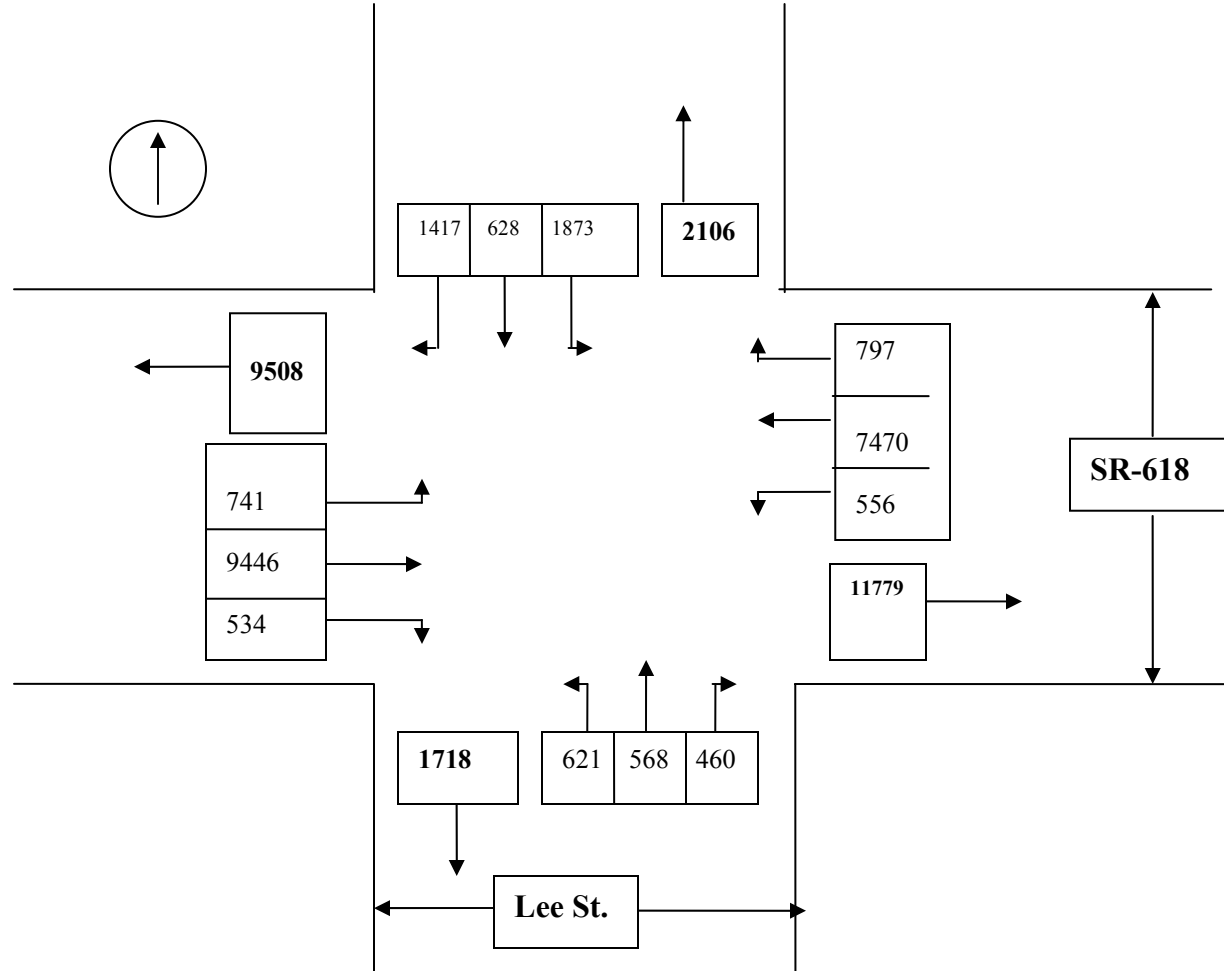


Figure 9. Turning Movement Diagram (ADT) along Lee Street and Washington Boulevard Intersection in the City of Belpre, Ohio.

Figure 10. Collision Diagram for Washington Blvd., Lee Street

Conclusions and Recommendations:

This intersection ranks second with respect to priority for the study group. It's also the fourth-highest with respect to the Average Daily Traffic (ADT). It also had the second-highest number of accidents. When compared to the previous study, the accident severity index had reduced. The number of accidents increased when compared to the previous study period (1995-1999). The majority of accidents were either rear-end or angled collisions.

Accidents at this intersection are either rear-end or left turn related. These collisions appear to be a result of restricted sight distance and a large volume of left turn traffic. A large number of vehicles turning in front of oncoming traffic due to this limited sight distance. There is also a high percentage of vehicles turning left off of Lee St. onto Washington Blvd.

The large volume of left turns contributes to both the rear-end collisions on Lee St. and the right angle collisions between vehicles on Lee St. and vehicles on Washington Blvd. A possible countermeasure would be to construct left turn lanes on both approaches of Lee St. and provide a left turn phase in the signal timing.

For a list of all accident counter-measures that can be recommended for this intersection, refer to Tables 4a and 4b. Also, refer to Tables 16, 17 and 18 for the Accident Reduction Factors that can be applied to this intersection.

4.4 US-50 and Farson Street

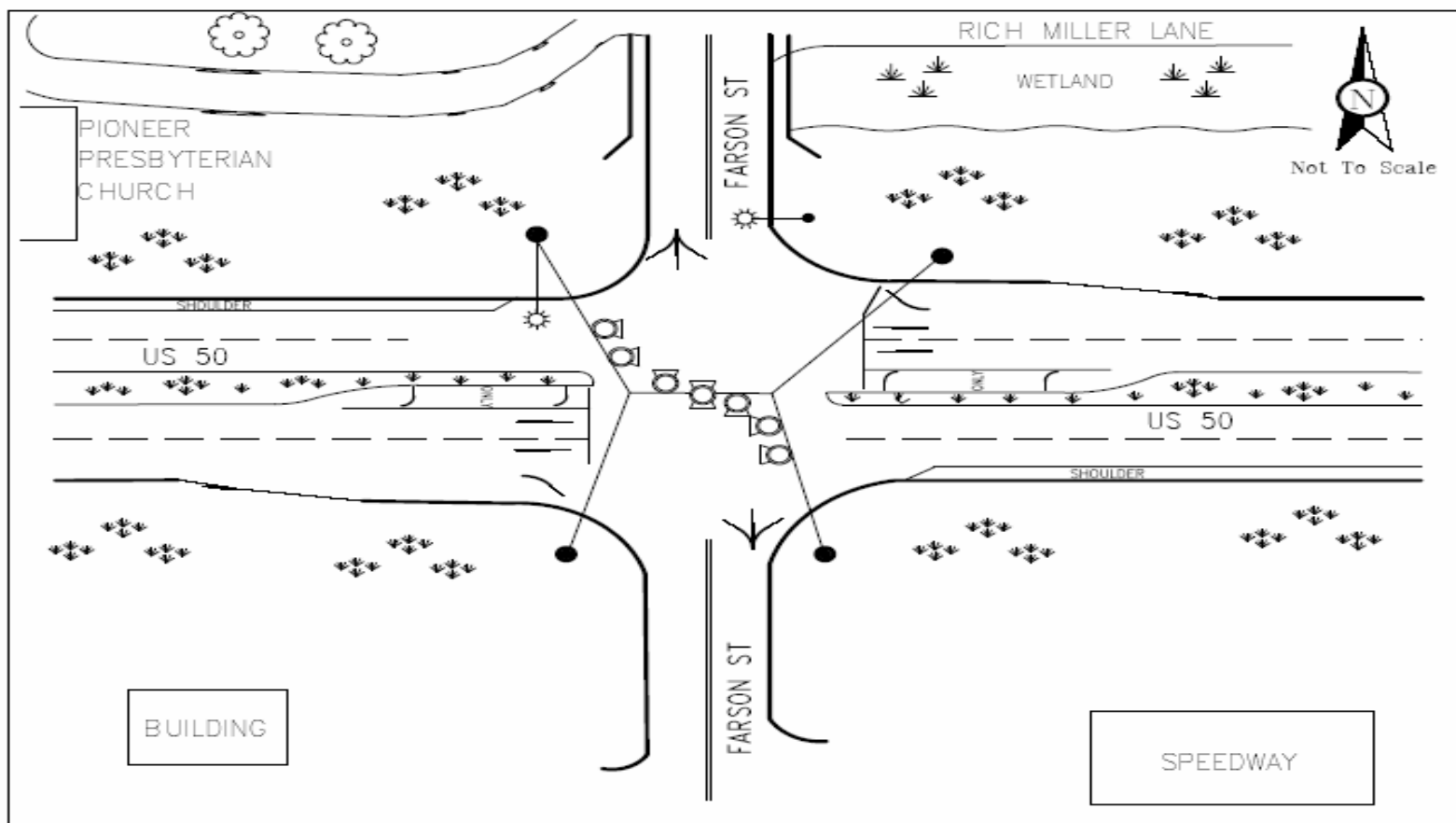
Geometric Conditions: The US 50 and Farson St. location is a four-leg or cross intersection where the legs meet at a ninety degree angle. US 50 is classified as a principal arterial and Farson St. as a major collector US 50 carries the eastbound and westbound traffic while Farson St. makes up the northbound and southbound approaches. There is an active, signal warning sign on both US 50 approaches. Figure 11 shows the intersection diagram in question.

Traffic Volume and LOS: Figure 12 graphically illustrates the traffic movements for this intersection. The intersection was evaluated using the Highway Capacity Software (HCS) computer model, which produced the following approach delays and LOS's shown in Table 8. The overall intersection delay was 47 sec/veh and the intersection LOS was D.

Approach Movement	Delay (seconds/vehicle)	LOS
EB	49.8	D
WB	45.6	D
NB	44	D
SB	47.9	D

Table 8. Delay and LOS for US-50 and Farson Street.

Collision Diagram: There were a total of forty six accidents at this intersection. Prominently among them were 15 rear-end accidents, 22 were angled accidents and five were side-swipe accidents. Figure 13 is the collision diagram for the above-mentioned intersection.



Reference: Traffic Operations and Safety Study for the City of Belpre (2001)

Figure 11. Intersection Diagram for US-50 and Farson Street.

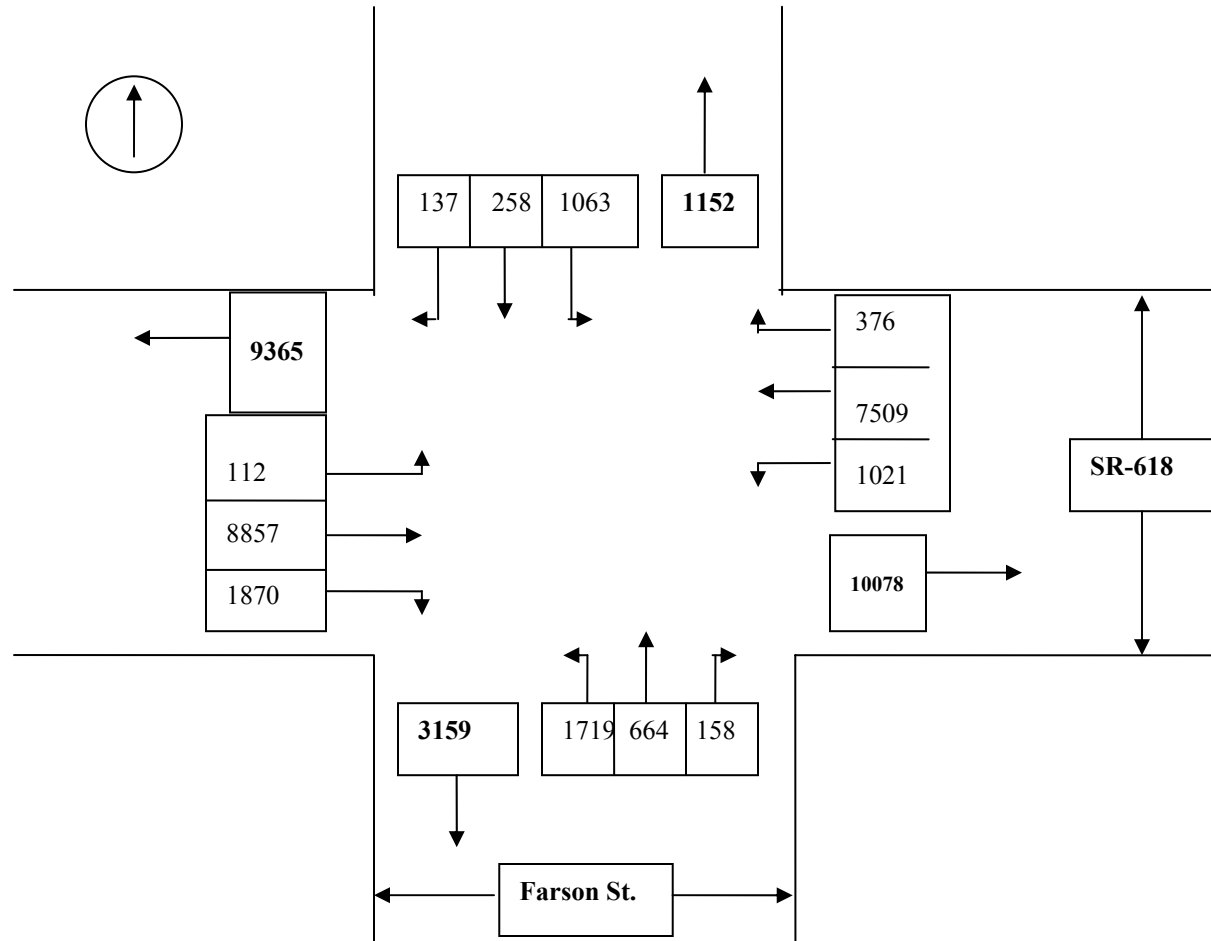


Figure 12. Turning Movement Diagram ADT along Farson Street and US-50 Intersection in the City of Belpre, Ohio.

Figure 13. Collision Diagram for US-50 and Farson Street

Conclusions and Recommendations:

This intersection ranks third with respect to priority for the study group. It's also the third-highest with respect to the Average Daily Traffic (ADT). It also had the third-highest number of accidents. When compared to the previous study, the accident severity index had increased. The number of accidents increased when compared to the previous study period (1995-1999). The majority of accidents were either rear-end or angled collisions.

This intersection has a high percentage of rear-end collisions and a fair amount of left and right turn collisions. These types of accidents could all be a result of inadequate signal timing. The yellow change interval, all-red clearance interval, and minimum green time should all be evaluated for any possible improvements. Any adjustments could also be a way to improve the LOS on the northbound and southbound approaches.

For a list of all accident counter-measures that can be recommended for this intersection, refer to Tables 4a and 4b. Also, refer to Tables 16, 17 and 18 for the Accident Reduction Factors that can be applied to this intersection.

In this respect, the recommendations from the Burgess and Niple study on US-50, and the subsequent public participation in Belpre, entitled "US 50 Corridor Traffic Study" [8] (conducted under the aegis of the Ohio Department of Transportation) need to be highlighted. The main recommendation is as follows:

1. Farson Street and Braun Road: *"A potential short-term solution for each of these intersections is to install "left turn arrows" for left turns from US 50 to Farson Street and Braun Road. The preferred solution, which is a medium to long term solution, is to realign US 50 left lanes to provide better sight distances for left turning traffic".*

4.5 Washington Boulevard and Walnut Street

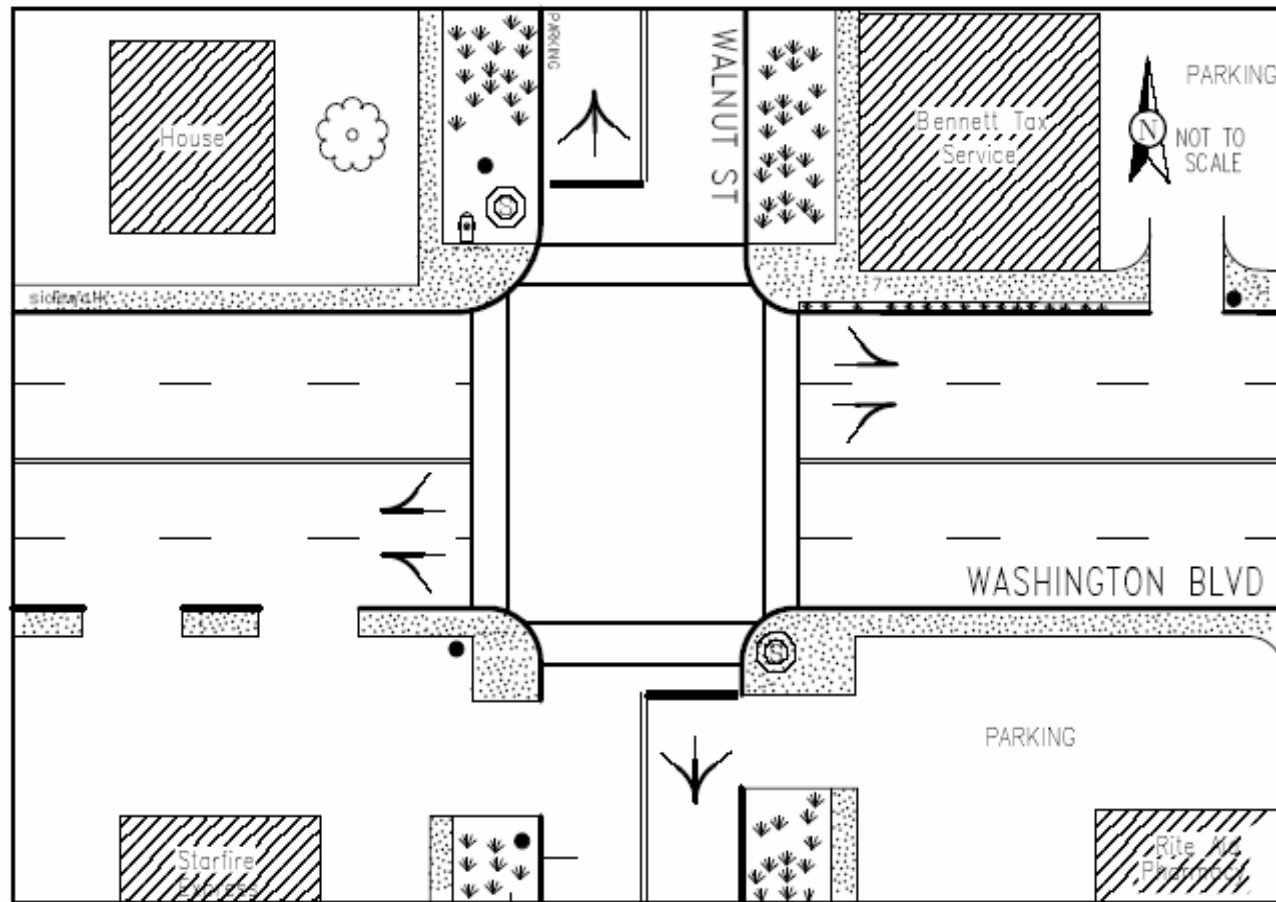
Geometric Conditions: The Washington Blvd. and Walnut St. location is a four-leg intersection with the approaches meeting at approximately a ninety degree angle. Washington Blvd. is designated as a minor arterial and Walnut St. is classified as a local city street. Figure 14 shows the intersection diagram in question.

Traffic Volume and LOS: Figure 15 graphically illustrates the traffic movements for this intersection. The intersection was evaluated using the Highway Capacity Software (HCS) computer model, which produced the following approach delays and LOS's shown in Table 9. The overall intersection delay was 32 sec/veh and the intersection LOS was C.

Approach Movement	Delay (seconds/vehicle)	LOS
EB	32.6	C
WB	34.7	C
NB	33.8	C
SB	31.06	C

Table 9. Delay and LOS for Washington Boulevard and Walnut Street.

Collision Diagram: There were a total of forty-three accidents at this intersection. Prominently among them, 12 were rear-end accidents, 24 of them were angled accidents and two were side-swipe accidents. Figure 16 is the collision diagram for the above-mentioned intersection.



Reference: Traffic Operations and Safety Study for the City of Belpre (2001)

Figure 14. Intersection Diagram for Washington Boulevard and Walnut Street.

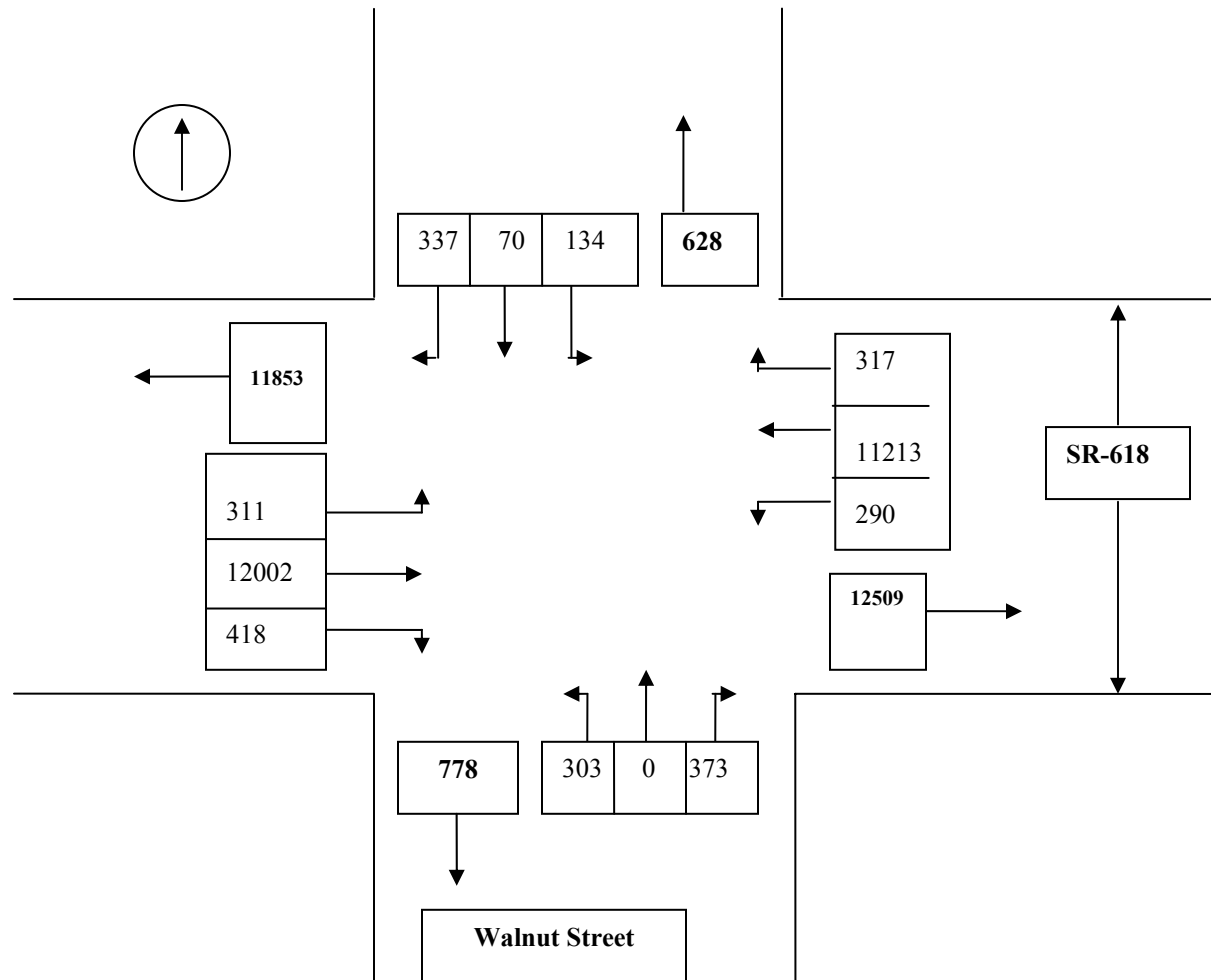


Figure 15. Turning Movement Diagram (ADT) along Walnut and Washington Boulevard Intersection in the City of Belpre, Ohio.

Figure 16. Collision Diagram for Washington Boulevard and Walnut Street

Conclusions and Recommendations:

This intersection ranks fourth with respect to priority for the study group. It's the fifth-highest with respect to the Average Daily Traffic (ADT). It also had the fourth-highest number of accidents. When compared to the previous study, the accident severity index had increased. The number of accidents also increased when compared to the previous study period (1995-1999). The majority of accidents were either rear-end or angled collisions.

The number of left turn, rear-end, and right angle collisions at this intersection suggest problems with drivers being unaware of the intersection and restricted sight distance. It is recommended that warning devices and an overhead flashing beacon be considered.

For a list of all accident counter-measures that can be recommended for this intersection, refer to Tables 4a and 4b. Also, refer to Tables 16, 17 and 18 for the Accident Reduction Factors that can be applied to this intersection.

Chapter 5.

Comparison with Previous Study and Recommendations

5.1 Comparison with the Previous Study:

When compared to the previous report (2001), it has been observed that there has been a reduction in the number of accidents for the top five intersections. While there were a total of 363 accidents for the top five locations in 2001, the corresponding number in the latest study (2004) was 338. The decrease in accidents was observed despite the increase in traffic volume. The decrease in accidents was however expected due to the countermeasures that are in place (the accident counter-measures were listed as a result of the previous safety studies), leading to the increase safety at those locations.

Out of the top eight intersections that were covered in the 2001 study, only five of them were included in this study, primarily due to the number of accidents during the study period (1999-2003). It meant that the three intersections (that were analyzed in the previous study) were not included in the current study, because of the reduction in the number of accidents on those locations for the above mentioned time period. Table 10 shows the intersection selection in comparison with the previous study.

However, the five intersections (which were common to the previous study as well as the current study) had recorded a fewer number of accidents during the time period 1999-2003, in comparison to the time period 1995-1998. This indicates that the recommendations to these five locations as part of the previous study were effective. (However, it should be noted that almost all the recommendations from the previous study, had to do with the reconfiguration of the signal timings). As a result, the accidents reduced, despite an increase in the traffic volume on those locations. The accident counter-measures for the five intersections covered in the current study, were listed in Table 4a and 4b respectively.

As part of the recommendations, it is advisable to use different approaches to reduce the accidents, instead of using the recommendations from the Manual of Transportation Engineering Studies [2]. One of the approaches is to use the *Accident*

Top Five Intersections (2001 Report)	# of Accidents (2001 Report)	Top Five Intersections (2004 Report)	# of Accidents (2004 Report)
Main Street, Memorial Bridge and US-50 EB Ramp	89	Main Street, Memorial Bridge and US-50 EB Ramp	32
Washington Blvd., US-50 and Main Street	159	Washington Boulevard, US-50 and Main Street	163
Washington Blvd. and Lee St.	47	Washington Boulevard and Lee St.	54
Farson Street and US-50	34	Farson Street and US-50	46
Washington Blvd. and Walnut St.	34	Washington Blvd. and Walnut St.	43
# of Accidents for top five locations	363	# of Accidents for top five locations	338

Table 10. Intersection Selection in Comparison with the Previous Study.

Reduction Factors, in determining the efficacy of using a certain counter-measure, to mitigate a recurring safety problem at an intersection.

5.2 Accident Reduction Factors:

Accident reduction factors (ARF's, also known as Crash Reduction Factors) provide a simple way of estimating crash reductions [3]. Many states have a set of crash reduction factors that are used for estimating the safety impacts of various types of engineering improvements, involving the areas of signing, alignment, channelization, and other traffic engineering solutions. Typically, these factors are computed using before-and-after comparisons.

However, the origins of the factors used in practice are not always clear. Factors that vary from state to state may reflect regional disparities or may indicate a need for updates. Moreover, ARF's are designed for individual improvements, yet multiple improvements usually occur when an intersection or roadway segment is being rebuilt.

It should be recognized that ARF's are a tool for quickly estimating the impact of safety improvements. Their strength is that they are relatively quick to use; their weakness is that they are based on limited data. Thus, it is desirable to develop ARFs that consider additional elements (e.g., time of day, weather, and percent of trucks). Table 16 reports the ARF's developed by the North Carolina Department of Transportation [4]. Similarly, Table 17 shows the ARF's developed by South Dakota Department of Transportation [5]. Similarly, Table 18 shows the ARF's developed by the University of Kentucky [6].

Similar factors should be developed for Washington County, Ohio, after studying the correlation between the highway improvements that were recommended (as a result of the 1996, 2001 and 2004 reports) and the reduction in the number of accidents as a result, using statistical procedures like negative binomial regression. During the course of developing these factors, it would be easy to identify the role of variables like increased seat belt use as a result of enforcement, improvements in medical technology,

safer driving due to aging of population (fewer younger people and more elderly people), etc.

5.3 Black-Spot Identification using GIS [7]:

To give a detailed demonstration of the causes and mechanisms of accidents, a cross sectional database of causes and mechanisms needs to be developed initially. Later on, this database needs to be combined with the City's GIS, to enable the identification of "black-spots" (accident prone points) and the subsequent analysis. As a result, the citizens would be able to adjust their route selection at certain times of the day.

This can also lead to the development of the *accident risk analysis models*, which take into account, several explanatory variables like traffic volume, approach speeds, type of accidents, number of lanes, number of conflict points, etc. Subsequently, this data can be used to predict the number of accidents that are likely to take place at an intersection, in future. Moreover, it would appeal to the planners and the general public, to evaluate the intersections from a risk analysis point of view, rather than the actual number of accidents.

Later, these "black spots" should be combined with the counter-measures of the previous studies, leading to the *least-cost alternatives* at each of the accident locations. As a result, the traffic safety can be considerably improved, because, there will be an opportunity for appropriate decision-making by city planners, city administration, MPO, etc, regarding the measures that need to be selected at these sites. Once this display is available on the web page of the city, it adds to the safety awareness of the city's citizens.

Improvement Type	Percentage Reduction
OVERLAY PAVEMENT:	63% Reduction of total crashes on wet pavement.
	57% Reduction of fatal and injury crashes on wet pavement.
	27% Reduction of total crashes.
	29% Reduction of fatal crashes.
	16% Reduction in injury crashes.
	32% Reduction in PDO crashes.
GROOVE PAVEMENT:	61% Reduction of fatal and injury crashes on wet pavement.
	14% Reduction of total crashes.
	12% Reduction in injury crashes.
	15% Reduction in PDO crashes.
REDUCE SPEED LIMIT:	20% Reduction in total crashes.
	35% Reduction in PDO crashes.
WARNING SIGN FOR PAVEMENT CONDITIONS:	20% Reduction in total crashes.
INSTALL MARKINGS/DELINEATION:	21% Reduction of night crashes.
	15% Reduction of total crashes.
	6% Reduction of total crashes.
	26% Reduction of total crashes.

Table 11. Accident Reduction Factors for North Carolina (Source: NCDOT)

Improvement Type	ARF's for South Dakota	ARF's for Kentucky
Install Signal with Turn Radii	54.1%	Not Available
Pavement Markings: Continuous centre turn lane	9.06%	Not Available
Pavement Markings: Left-turn turn lane	34.62%	35%
Realignment-Horizontal	100%	40%
Realignment-Horizontal and Vertical	-11.76%	50%
Reconstruction-Left Turn lane with signal phase	9.30%	Not Available
Reconstruction-continuous center turn lane	8.47%	30%
Reconstruction-Increase turning radii	100%	15%
Reconstruction-Left turn lane	30.77%	25%
Reconstruction-Realign Intersection	-14.58%	40%
Remove Fixed Object	100%	30%
Roadway Lighting	16.67%	25%
Shoulder Widening	20%	20%
Signal Upgrade	33.82%	20%
Signing	5.20%	35%
Slope Flattening of Approaches	-1.54%	NA
Traffic Signals	26.06%	25%

Table 12. Accident Reduction Factors for South Dakota (Source: South Dakota DOT)

TABLE 1. GENERAL SAFETY IMPROVEMENT CATEGORIES

- 1 - TRAFFIC SIGNS
- 2 - TRAFFIC SIGNALS
- 3 - ROADWAY DELINEATION
- 4 - LIGHTING
- 5 - CHANNELIZATION
- 6 - PAVEMENT TREATMENT
- 7 - ROADSIDE IMPROVEMENTS (APPURTENANCES/CLEAR ZONE)
- 8 - CONSTRUCTION/RECONSTRUCTION
- 9 - REGULATIONS

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY PERCENT REDUCTION			REVIEW OF LITERATURE PERCENT REDUCTION		
		NO.	RANGE	AVERAGE	NO.	RANGE	AVERAGE
TRAFFIC SIGNS	All	7	4-52	23	6	3-36	13
Warning Signs							
General	All	12	5-50	23	11	10-60	30
Curve Warning	All	16	17-55	32	11	20-55	37
	Run-off-Road	2	20-35	28			
Chevron	All	2	39-71	55	3	20-35	30
Intersection Related	All	14	25-47	36	5	15-47	32
Bridge Related	All	2	20-47	34			
Railroad Crossing	Train	5	25-40	29			
Pavement Condition	Wet Weather	2	10-25	18	1	80	80
Pedestrian (General)	Pedestrian	1	15	15			
School Zone	All	3	3-20	14			
Animal	All	2	5-10	8	1	5	5
Advisory Speed	All	2	15-36	26	2	25-36	30
Regulatory Signs							
General	All	1	15	15	2	22-23	22
2-Way Stop	All	19	12-68	39	6	12-50	36
All-Way Stop	All	16	40-73	57	10	35-73	58
Yield	All	17	25-59	45	8	20-59	45
Speed Limit	All	1	40-40	40			
Lane Use	All	2	30-30	30	1	15	15
Guide Signs							
General	All	9	7-15	14	3	14-15	15
Directional	All	2	5-14	10	3	14-50	26
Route/Street	All	1	25	25	1	20	20
Variable Message	All	9	10-40	15	2	10	10
TRAFFIC SIGNALS							
New Signal	All	28	13-68	28	20	13-45	24
	Angle				3	60-75	66
Signal Upgrade							
General	All	21	9-50	24	19	10-45	23
12-Inch Lens	All	11	10-25	12	4	10-10	10
Pretimed to Actuated	All	10	15-27	22	4	10-27	20
Backplates	All	2	15-34	24			
Optical Lenses	All	4	15-25	18	1	15	15
Remove Signal	All	3	30-100	53			
Signal Phasing	All	2	23-30	26			
Exclusive Left Turn Phase	All	15	15-80	29	4	25-43	33
	Left Turn	9	25-85	70	5	40-85	63
P/P Left Turn Phase	All	6	10-10	10	1	10	10
	Left Turn	6	40-40	40	1	40	40
Improve Timing	All	6	10-22	12	4	10-25	15
Pedestrian Phase	All	14	10-60	23	6	8-56	24
	Pedestrian	7	15-60	47	3	60-60	60

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY			REVIEW OF LITERATURE		
		NO.	PERCENT RANGE	REDUCTION AVERAGE	NO.	PERCENT RANGE	REDUCTION AVERAGE
All-Red/ Yellow	All	7	30-31	31	1	30	30
	Angle				3	20-44	32
Interconnect Signals	All	9	10-26	15	3	10-25	17
Install Flashing Beacon	All	8	20-91	38	3	10-37	23
Intersection	All	18	7-50	33	10	2-60	38
	Angle				2	45-46	46
Intersection Advance	All	11	20-42	26	3	25-30	28
General Advance	All	8	15-54	37	4	7-30	19
Railroad							
Flashing Lights	All	11	30-80	58	1	70	70
	Train	4	65-65	65	15	65-94	77
Lights and Gates	Train	11	50-100	74	11	28-87	77
Automatic Gates	Train	9	50-100	76	11	50-99	77
ROADWAY DELINEATION/ PAVEMENT MARKINGS							
General	All	4	13-13	13	6	1-6	4
Edgeline Markings	All	19	2-40	20	12	2-40	15
	Off Road	2	25-25	25	3	25-59	36
Centerline Marking	All	19	5-65	36	14	1-64	24
Wide Markings	All	2	37-60	48	1	5	5
Durable Markings	All	6	15-57	46			
No Passing Zones	All	12	30-65	42	7	30-66	48
	Passing				2	85-85	85
Crosswalks	All	2	10-10	10			
	Pedestrian	2	25-70	48			
Lane Use Arrows	All	6	30-30	30	1	30	30
Raised Pavement Markers	All	15	4-50	13	7	4-15	6
	Wet/Night	7	20-25	21	3	20-46	29
	Night	8	10-26	17	4	10-26	18
Post Delineators/ Curve	All	14	15-40	23	8	2-32	23
	Night	2	30-30	30	1	30	30
Delineators/Tangent	All	17	13-50	28	5	2-25	16
	Night	2	30-30	30	1	30	30
Flexible Delineator Post	All	1	40-40	40			
Bridge Related	All	2	15-39	27	2	15-40	28
Railroad Related	All	11	10-50	19	1	10	10
Animal Reflectors	Animal	1	25-25	25			
LIGHTING							
General	All	6	9-30	25	5	0-17	10
New Roadway	All	10	9-64	28	8	6-37	18
	Night	12	20-90	45	5	15-67	38
Upgrade Roadway	Night	2	23-61	42			
New Intersection	All	8	19-75	31	2	20-25	22
	Night	12	18-70	49	6	50-75	64

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY PERCENT REDUCTION			REVIEW OF LITERATURE PERCENT REDUCTION		
		NO.	RANGE	AVERAGE	NO.	RANGE	AVERAGE
Upgrade Intersection	All	2	25-50	38			
	Night	1	50	50	2	50-50	50
New Interchange	All	5	25-25	25	3	25-50	42
	Night	4	50-50	50	3	43-75	56
Railroad Crossing	All	9	25-50	34	2	30-62	46
	Night	5	60-60	60	6	60-65	61
Bridge	Night	7	19-62	48	5	50-50	52
Illuminate Sign	All				1	15	15
CHANNELIZATION							
General Intersection	All	15	14-50	28	10	17-60	29
Left Turn Lane	All	4	6-31	20	5	18-32	24
Signal/ No Turn Phase	All	16	15-50	22	8	15-50	21
	Left Turn				2	50-57	54
Signalized/ Turn Phase	All	13	15-50	30	9	25-50	36
	Left Turn				2	16-70	43
No Signal	All	13	19-60	41	4	15-45	28
	Rear End	3	62-93	83			
	Left Turn				1	51	51
Right Turn Lane	All	9	2-61	24	5	15-61	30
Increase Turn Lane Length	All	2	15-40	28	2	15-15	15
PAVEMENT TREATMENT							
Resurfacing	All	14	7-59	26	8	7-42	27
	Wet	7	40-42	41	3	40-54	45
Rumble Strips	All	10	18-44	29	7	2-44	25
Skid Resistant Surface	All	14	9-50	27	20	10-60	25
	Wet	7	40-70	45	5	40-55	50
Pavement Grooving	All	13	15-65	26	12	1-48	20
	Wet	10	42-75	61	5	49-75	62
Shoulder Grooving	All	2	14-50	32			
ROADSIDE IMPROVEMENTS (APPURTENANCES/CLEAR ZONE)							
Install Guardrail	All	17	0-63	22	8	0-40	20
	Fatal	6	55-100	64	3	55-90	68
	Injury	6	3-42	31	3	15-45	32
Install Median Barrier	All	10	0-65	28	13	0-75	33
	Fatal	5	60-80	64	3	45-90	65
	Injury	5	5-10	9	3	10-61	27
Upgrade Guardrail	All	11	5-15	8	10	4-30	10
	Fatal	4	9-80	51			
	Injury	5	13-60	37			
Upgraded End Treatment	All	1	10	10	6	10-75	35
Attachment to Structure	All	2	15-15	15			

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

<u>CATEGORY</u>	<u>TYPE OF ACCIDENT</u>	<u>STATE SURVEY</u>			<u>REVIEW OF LITERATURE</u>		
		<u>NO.</u>	<u>RANGE</u>	<u>AVERAGE</u>	<u>NO.</u>	<u>RANGE</u>	<u>AVERAGE</u>
Install Impact Attenuator	All	16	0-80	29	10	0-80	31
	Fatal	4	75-75	75	3	50-75	65
	Injury	4	50-50	50	3	9-50	36
Remove Fixed Objects	All	15	0-90	32	10	0-40	22
	Fatal	8	50-53	50	3	50-60	53
	Injury	8	15-28	17	3	15-20	17
	Off Road	2	55-55	55			
Relocate Fixed Objects	All	10	0-90	41	2	0-85	42
	Fatal	4	40-40	40	2	40-40	40
	Injury	4	15-15	15	2	15-15	15
	Off Road	2	55-55	55			
Flatten Side Slopes	All	11	0-46	30	10	7-46	19
	Off Road	2	46-46	46			
Convert to Breakaway	All	15	0-75	28	11	0-75	52
	Fatal	4	60-60	60	1	60	60
	Injury	4	30-30	30	1	30	30
	Off Road	2	45-45	45			
Upgrade Bridge Railing	All	8	5-50	24	8	10-45	28
	Fatal	1	75	75			
	Injury	1	75	75			
Gore Improvements	All	5	17-65	27	3	34-62	49
CONSTRUCTION/RECONSTRUCTION							
Add Median	All	10	10-70	35	8	7-30	14
Mountable	All	4	8-50	20	4	12-44	28
Non-mountable	All	11	8-50	27	8	3-15	10
Glare Shield	All	1	15	15			
Horizontal Realignment	All	20	21-80	44	6	20-60	40
	Off Road	2	50-50	50			
Curve Reconstruction	All	6	50-50	50	11	15-88	54
Vertical Realignment	All	13	21-58	41	5	15-57	40
	Off Road	2	50-50	50			
Hor. and Vert. Align.	All	6	34-80	52	13	30-50	38
Realign Intersection	All	6	30-70	41	1	50	50
Modify Superelevation	All	13	30-65	46	5	10-50	34
Sight Distance Imp.	All	13	7-40	26	1	30	30
Intersection	All	1	30	30	5	10-35	25
General	All	4	30-35	32	11	20-43	34
Widen Shoulder	All	18	5-50	19	17	8-57	20
	Off Road	2	15-15	15	1	13	13
2-4 Feet	All	2	15-32	24	2	15-16	15
Over 4 Feet	All	2	30-55	42	3	15-35	25
Pave Shoulder	All	3	10-25	18	1	20	20
	Off Road	2	15-15	15			
Shld. Stabilization/Dropoff	All	5	6-38	23	3	38-40	39

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 2. DETAILED LISTING OF SAFETY IMPROVEMENT CATEGORIES AND REPORTED REDUCTION FACTORS (CONTINUED)

CATEGORY	TYPE OF ACCIDENT	STATE SURVEY PERCENT REDUCTION			REVIEW OF LITERATURE PERCENT REDUCTION		
		NO.	RANGE	AVERAGE	NO.	RANGE	AVERAGE
Widen Pavement	All	19	5-56	26	16	7-38	22
	Off Road	2	30-30	30			
Additional Lane							
General	All	13	5-56	24	5	5-17	12
Passing/Climbing	All	9	20-30	22	7	20-50	28
Accel/Decel	All	15	10-25	12	4	10-17	13
Left Turn (at Signal)	All	17	20-45	30	3	25-30	27
	LT Rear End	2	60-90	75			
Left Turn (no Signal)	All	16	20-35	28	3	30-30	30
	LT Rear End	2	84-90	87			
Right Turn Lane	All	5	20-45	27			
Two Way Left Turn	All	21	25-45	34	10	15-50	31
Close Median Opening	All	9	30-95	49	6	29-80	52
Bridge Improvements							
Widen Bridge	All	20	23-92	49	18	23-66	43
Replace Bridge	All	17	25-62	42	12	25-70	53
Deck Repair	All				2	10-13	12
Increase Turning Radii	All	12	10-35	18	4	10-35	21
Construct Interchange	All	11	40-75	56	2	50-55	52
	Angle/RE	1	90	90			
Modify Ramp	All	7	25-45	28	1	25	25
	Off Road	2	25-25	25			
Pedestrian-Related							
Grade Separation	Pedestrian	14	60-95	90	1	95	95
Sidewalks	Pedestrian	2	60-75	68			
Truck Escape Ramp	Truck	4	18-75	36			
Brake Check Area	All	1	45	45			
Frontage Road	All	7	30-40	39	1	40	40
Drainage Imp.	All	2	10-30	20			
Animal Fencing	All	3	15-90	55			
	Animal	5	90-90	90	4	90-100	92
REGULATIONS							
Eliminate Parking	All	16	8-90	39	7	8-90	37
Angle to Parallel Parking	All				1	59	59
Prohibit Turns	All	9	40-90	46	8	25-40	35
Prohibit Turns on Red	All	3	20-25	22	1	25	25
Modify Speed Limits	All	3	20-20	20	2	20-20	20
2 way to 1 way	All	3	30-40	33			

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
1 - TRAFFIC SIGNS		
Warning Signs		
1-1	Warning Signs - General	25
1-2	Curve Warning Run-off-road Accidents	30
1-3	Intersection-Related Warning (Side road, stop ahead, etc.)	30
1-4	Railroad Crossing Train Accidents	30
1-5	Pavement Condition Surface Condition-Related Accident	20
1-6	School Zone	15
Regulatory Signs		
1-7	Stop Sign (Two-way)	35
1-8	All-Way Stop	55
1-9	Yield	45
Guide Signs		
1-10	Guide Sign - General	15
1-11	Variable Message Sign	15
2 - TRAFFIC SIGNALS		
2-1	Install Signal	25
	Angle Accidents	65

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
2-2	Signal Upgrade - General	20
2-2a	12-inch lens	10
2-2b	Backplates Right Angle Accidents	20
2-2c	Optically Programmed Signal Lenses	15
2-3	Remove Unwarranted Signal	50
Signal Phasing		
2-4	Signal Phasing - General	25
2-5	Add Exclusive Left Turn Phase Left Turn Accidents	25 70
2-6	Add Protected/Permissive Left Turn Phase Left Turn Accidents	10 40
2-7	Improve Timing	10
2-8	Add Pedestrian Phase Pedestrian Accidents	25 55
2-9	Add All-Red Interval/Increase Yellow Time Right-Angle Accidents	15 30
2-10	Interconnect Traffic Signals	15
Flashing Beacon		
2-11	Flashing Beacon - General	30
2-12	Install Flashing Beacon at Intersection	30
2-13	Intersection Advance Warning Flasher	25

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
2-14	General Advance Warning Flasher Railroad Crossings	35
2-15	Railroad Crossings - General Train Accidents	70
2-16	Flashing Lights Train Accidents	65
2-17	Flashing Lights and Automatic Gates Train Accidents	75
2-18	Automatic Gates Train Accidents	75
3 - ROADWAY DELINEATION/PAVEMENT MARKINGS		
3-1	General	15
3-2	Edgeline Markings Off Road	15 30
3-3	Centerline Markings	35
3-4	Wide Markings Night Accidents	25
3-5	No Passing Zone Passing Accidents	40
3-6	Crosswalk Pedestrian Accidents	25
3-7	Raised Pavement Markers Night Accidents Wet Night	10 20 25

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
3-8	Post Delineators Night Accidents	30
3-9	Railroad Train Accidents	15
4 - LIGHTING		
4-1	General Night Accidents	25 50
4-2	Roadway Segment Night Accidents	25 45
4-3	Intersection Night Accidents	30 50
4-4	Interchange Night Accidents	25 50
4-5	Railroad Crossing Train Accidents at Night	30 60
5 - CHANNELIZATION		
5-1	General Intersection	25
5-2	Left Turn Lane - with Signal Left Turn Related	25 45
5-3	Left Turn Lane - without Signal Left Turn Related	35 50
5-4	Right Turn Lane Right Turn Related	25 50
5-5	Increase Turn Lane Length	15

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
6 - PAVEMENT TREATMENT		
6-1	General	25
	Wet Pavement	50
6-2	Resurfacing	25
	Wet Pavement	45
6-3	Pavement Grooving	25
	Wet Pavement	60
6-4	Rumble Strips	25
6-5	Shoulder Grooving	25
7 - ROADSIDE IMPROVEMENT (APPURTENANCES/CLEAR ZONE)		
7-1	Install Guardrail	5
	Fatal Accidents	65
	Injury Accidents	40
7-2	Install Median Barrier	5
	Fatal Accidents	65
	Injury Accidents	40
7-3	General Guardrail Upgrade	5
	Fatal Accidents	50
	Injury Accidents	35
7-4	Impact Attenuator	5
	Fatal Accidents	75
	Injury Accidents	50
7-5	Remove Fixed Objects	30
	Fatal Accidents	50
	Injury Accidents	30

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
7-6	Relocate Fixed Objects	25
	Fatal Accidents	40
	Injury Accidents	25
7-7	Flatten Side Slopes	30
7-8	Convert Hardware to Breakaway	5
	Fatal Accidents	60
	Injury Accidents	30
7-9	Upgrade Bridge Railing	5
	Fatal Accidents	60
	Injury Accidents	30
7-10	Gore Improvements	25
8 - CONSTRUCTION/RECONSTRUCTION		
Realignment		
8-1	Horizontal Realignment/Curve Reconstruction	40
8-2	Vertical Realignment	40
8-3	Modify Horizontal and Vertical Realignment	50
8-4	Realign Intersection	40
8-5	Modify Superelevation	40
8-6	Sight Distance Improvement	30
Pavement Widening		
8-7	Widen Pavement	25

Table 13. Accident Reduction Factors for Kentucky

(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
8-8	Widen Shoulder	20
	4 Feet or Less	20
	Over 4 Feet	35
8-9	Shoulder Stabilization/Shoulder Dropoff	25
8-10	Pave Shoulder	15
Additional Lanes		
8-11	Add Passing/Climbing Lane	20
8-12	Add Acceleration/Deceleration Lane	10
8-13	Add Left Turn Lane	25
	Left-turn Related Accidents	50
8-14	Add Right-Turn Lane	25
	Right-turn Related Accidents	50
8-15	Add Two Way Left Turn Lane	30
Median		
8-16	Add Mountable Median	15
8-17	Add Non-mountable Median	25
Bridge		
8-18	Widen Bridge	45
8-19	Replace Bridge	45
8-20	Bridge Deck Repair	15

Table 13. Accident Reduction Factors for Kentucky**(Source: University of Kentucky)**

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
Intersection		
8-21	Increase Turning Radii	15
8-22	Sight Distance Improvements	30
Freeway		
8-23	Construct Interchange	55
8-24	Modify Entrance/Exit Ramp	25
8-25	Frontage Road	40
8-26	Glare Screen Night Accidents	15
Pedestrian		
8-27	Construct Pedestrian Grade Separation Pedestrian Accidents	90
8-28	Add Sidewalk Pedestrian Accidents	65
Other		
8-29	Drainage Improvements Wet Pavement	20 40
8-30	Install Animal Fencing Animal Related	90
9 - REGULATIONS		
9-1	Eliminate Parking Parking Related	35

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

TABLE 3. RECOMMENDED REDUCTION FACTORS (CONTINUED)

<u>TYPE OF IMPROVEMENT</u>		<u>PERCENT REDUCTION*</u>
9-2	Prohibit Turns Turning Accidents	45
9-3	Modify Speed Limits	20
9-4	Two-way to One-way Operation	30

* Refers to all accidents unless a specific accident type is noted.

Table 13. Accident Reduction Factors for Kentucky
(Source: University of Kentucky)

References:

1. Snow, Jamie [2001], "*Traffic Operations and Safety Analysis for the City of Marietta*", Wood-Washington-Wirt Interstate Planning Commission.
2. "*Ohio Manual of Uniform Traffic Control Devices for Streets and Highways*" [1999], Ohio Department of Transportation.
3. Harkey, David. [2003], "*Crash Reduction Factors for Traffic Engineering and ITS Improvements*", National Cooperative Highway Research Program - Project 17-25.
4. Voss, Linda. G. [1997], "*Accident Reduction Factors*", MOVITE.
5. "*Development of South Dakota Accident Development Factors*" [1998], Study SD 98-13, Final Report, South Dakota Department of Transportation.
6. Agent, K., Nikiforos, S., Jones, S., [2003], "*Development of Accident Reduction Factors*", University of Kentucky, Lexington.
7. Abdel-Aty, M and Radwan, A. E., [2000], "*Modeling Traffic Accident Occurrence and Involvement*", Accident Analysis and Prevention, 32: 633-642.
8. US-50 Corridor Traffic Study, Public Meeting, March 29, 2005.

Appendix A

Three-Hour Traffic Counts at Major Intersections in Belpre

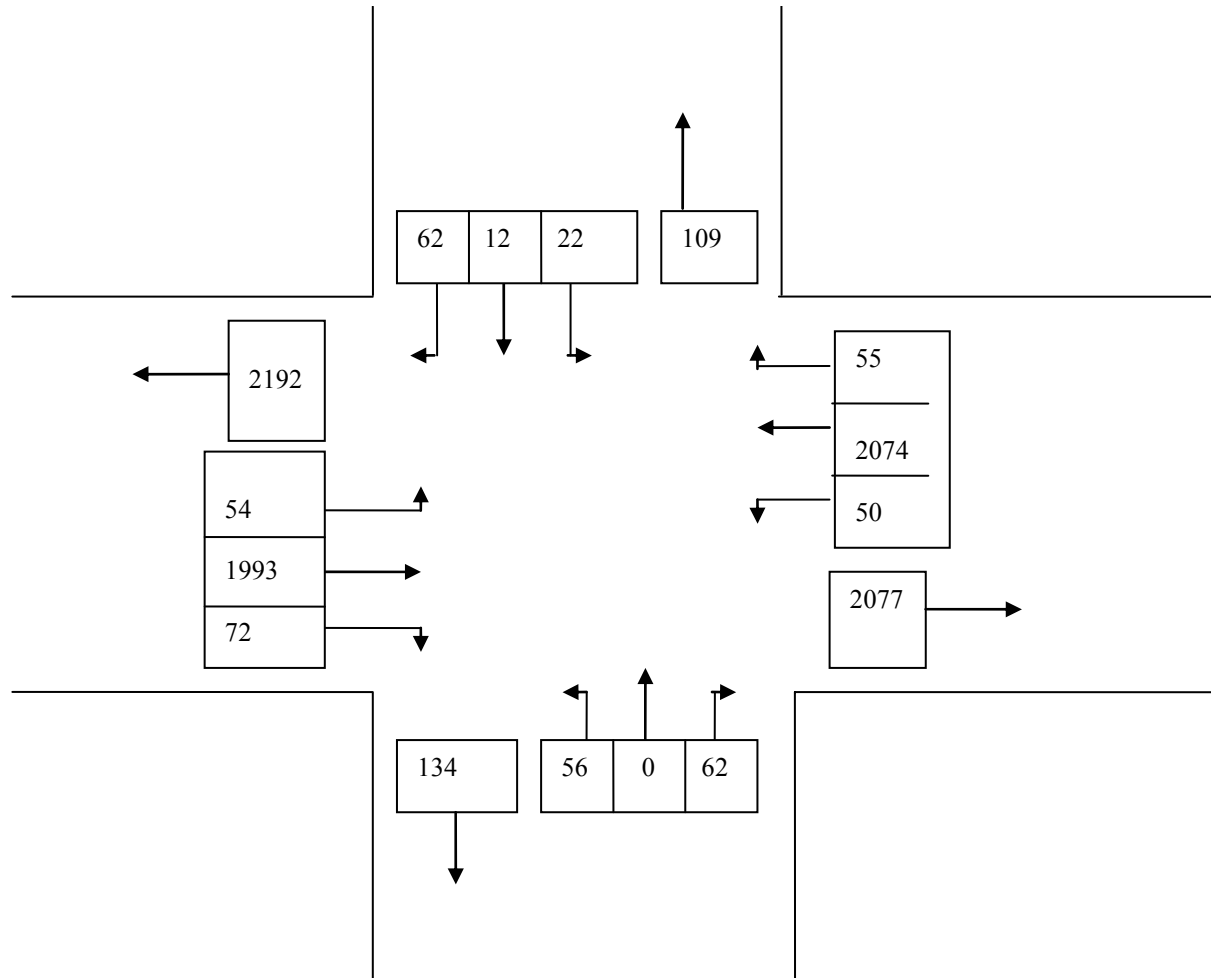


Figure 2. Three-hour Traffic count along Walnut and Washington Boulevard Intersection in the City of Belpre, Ohio.

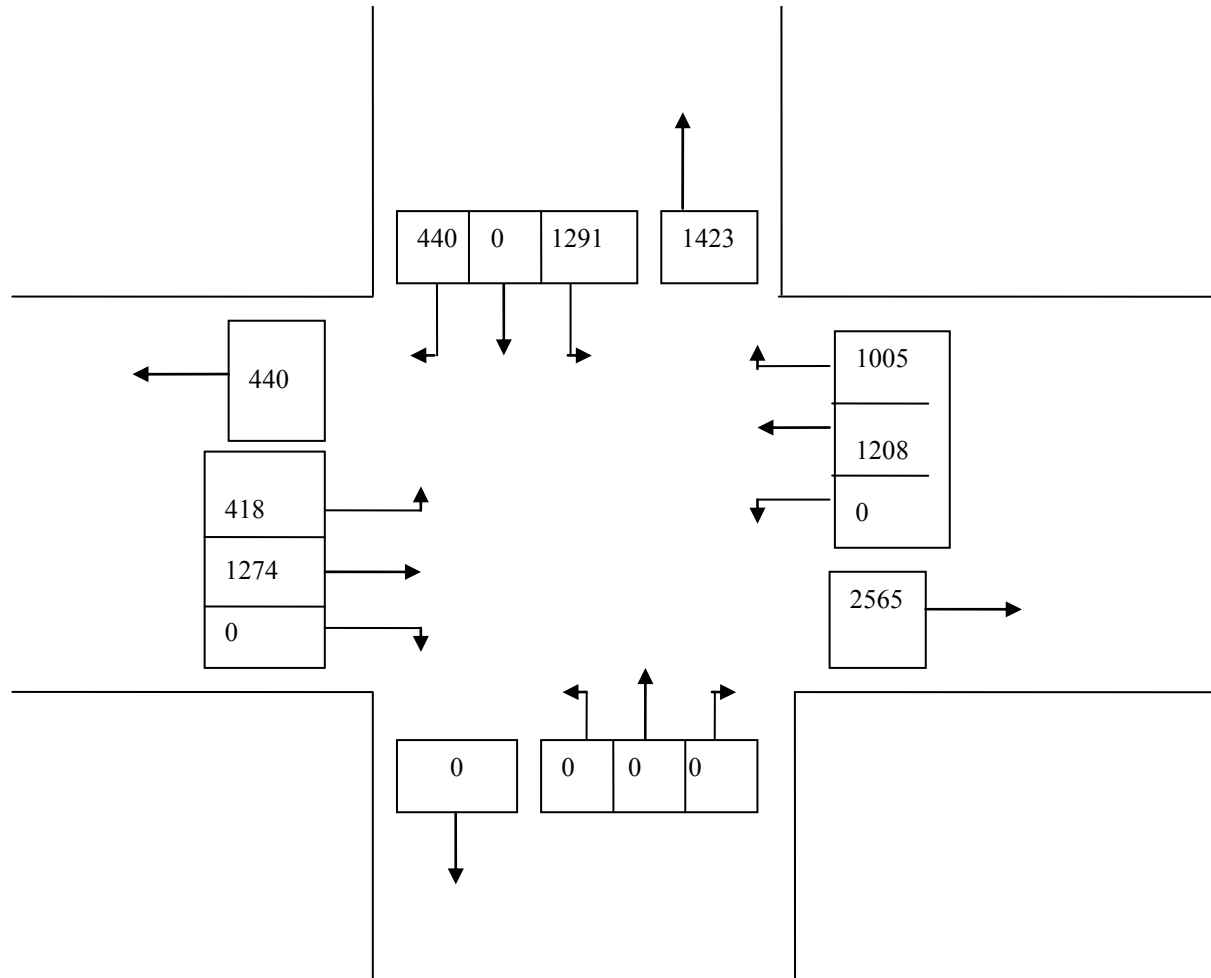


Figure 1. Three-hour Traffic count along Belpre Bridge and Washington Boulevard Intersection in the City of Belpre, Ohio.

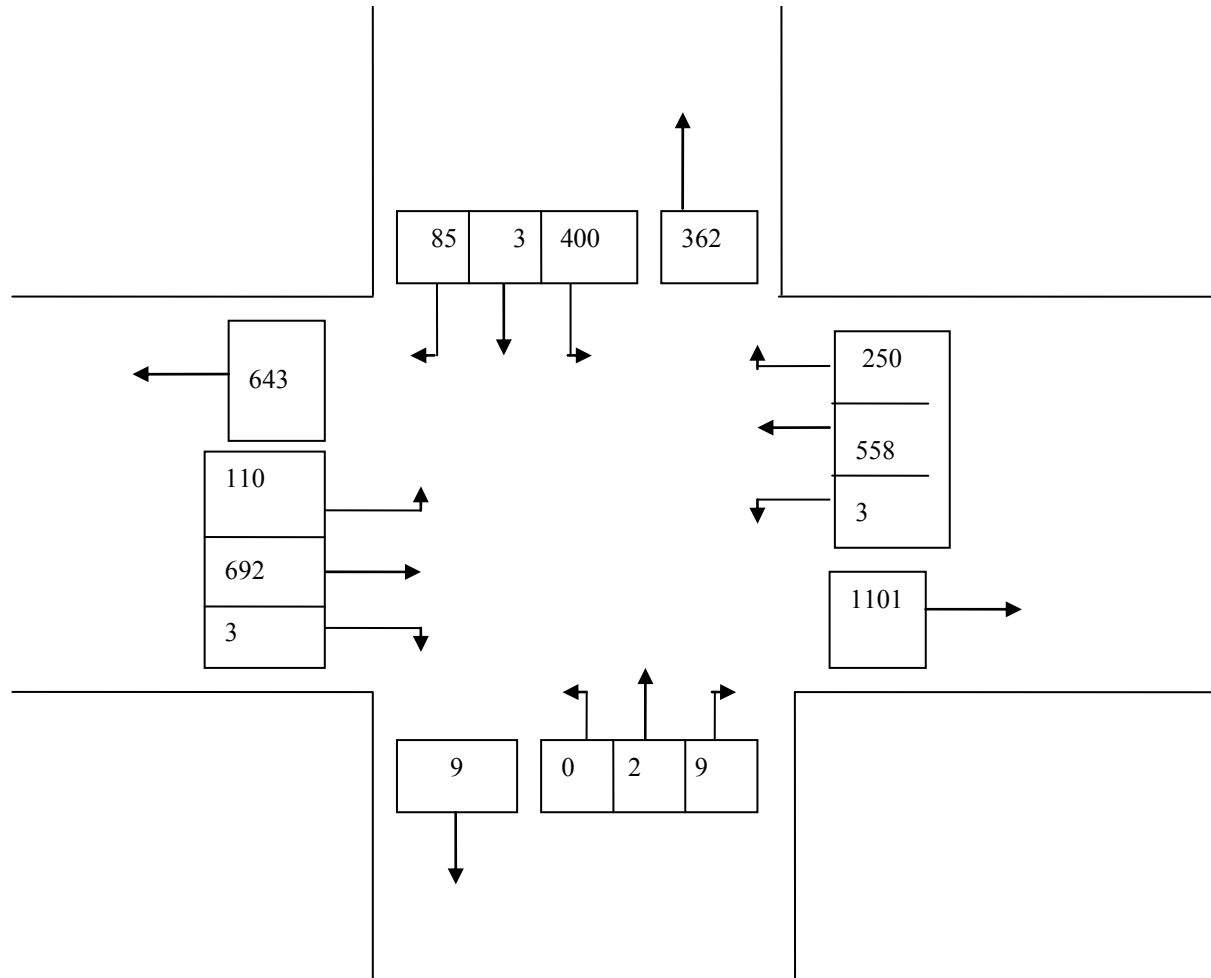


Figure 6. Three-hour Traffic count along Farson Street and Washington Boulevard Intersection in the City of Belpre, Ohio.

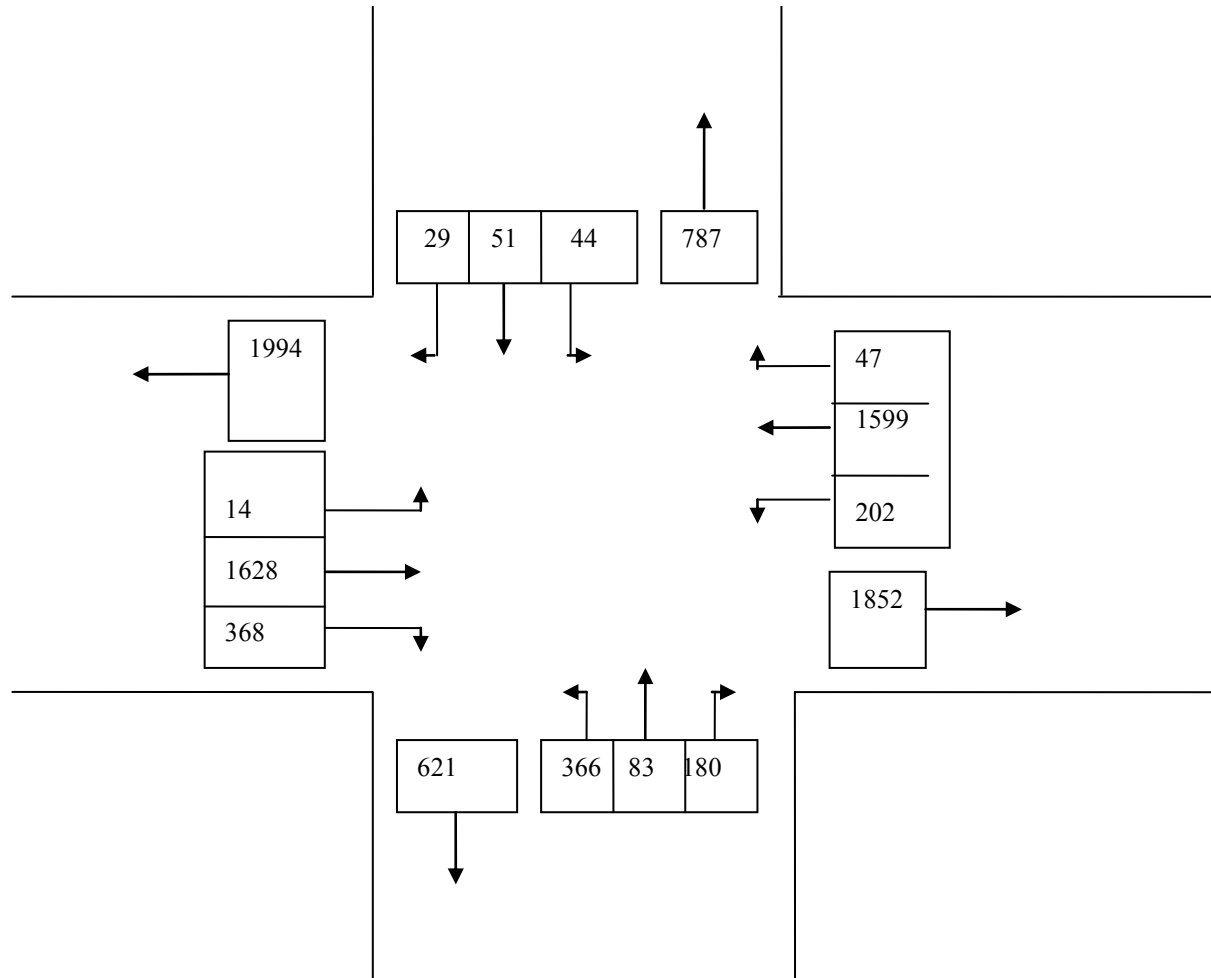


Figure 7. Three-hour Traffic count along Farson Street and US-50 Intersection in the City of Belpre, Ohio.

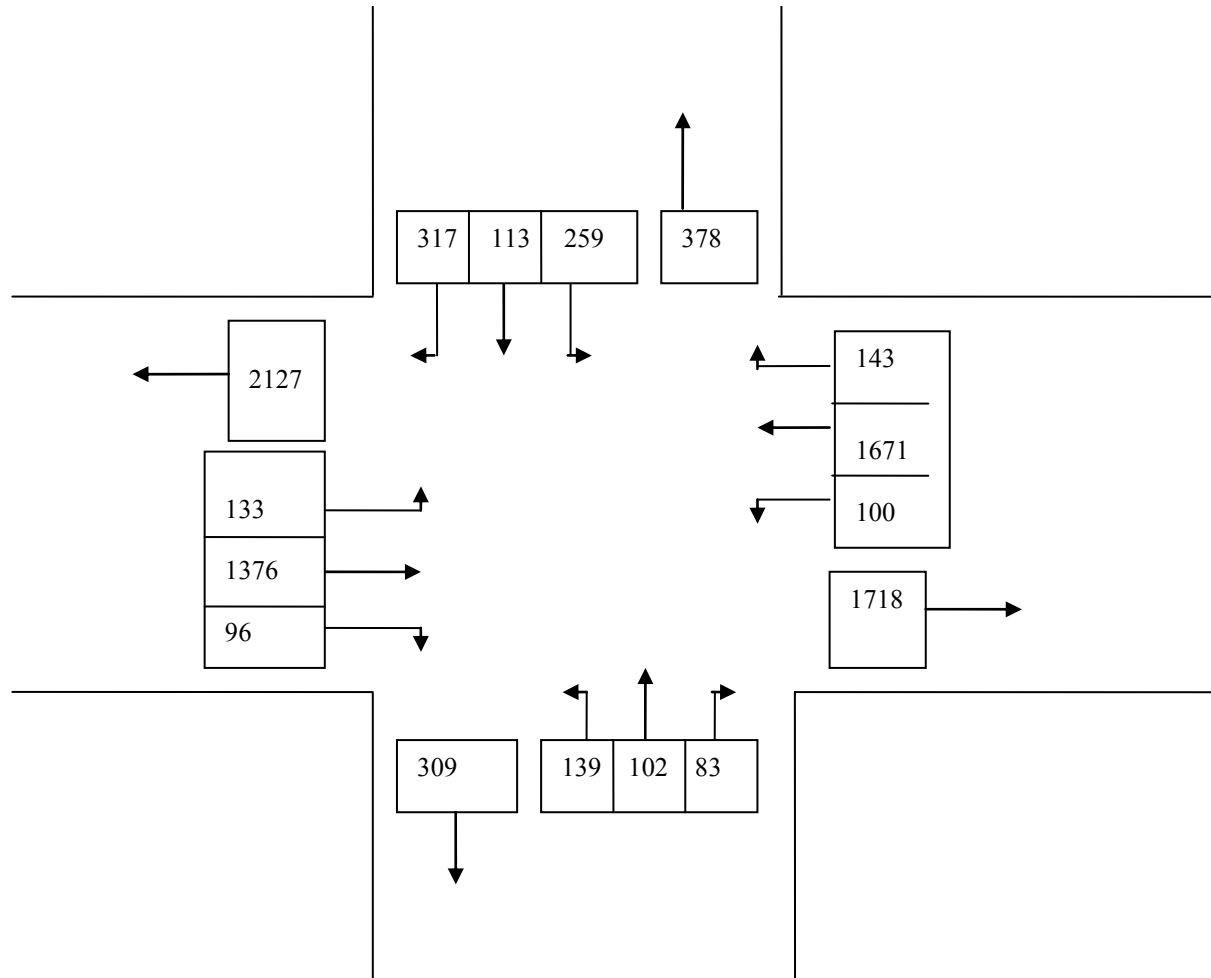


Figure 3. Three-hour Traffic count along Lee Street and Washington Boulevard Intersection in the City of Belpre, Ohio.

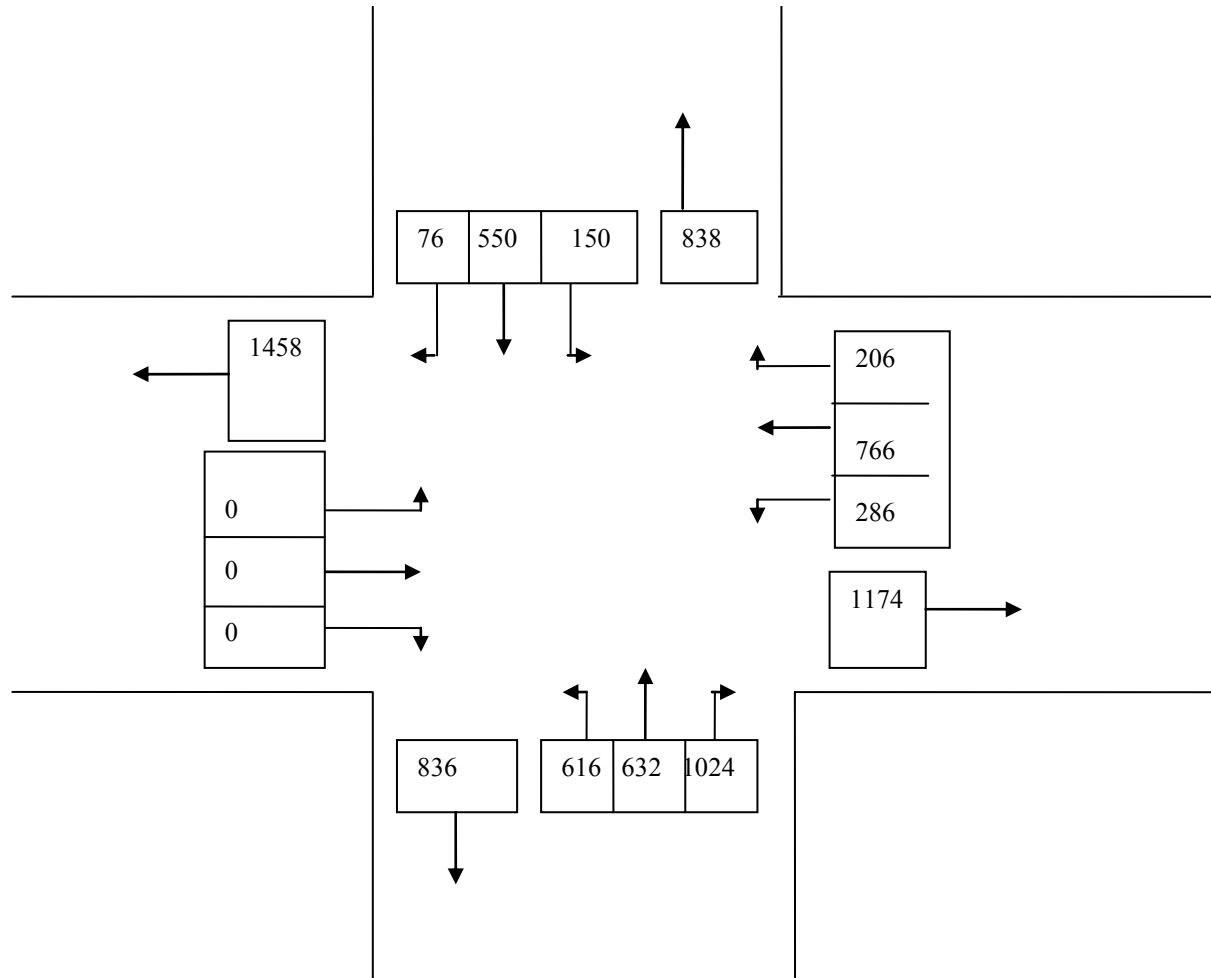


Figure 9. Three-hour Traffic count along Main Street and Memorial Bridge Intersection in the City of Belpre, Ohio.

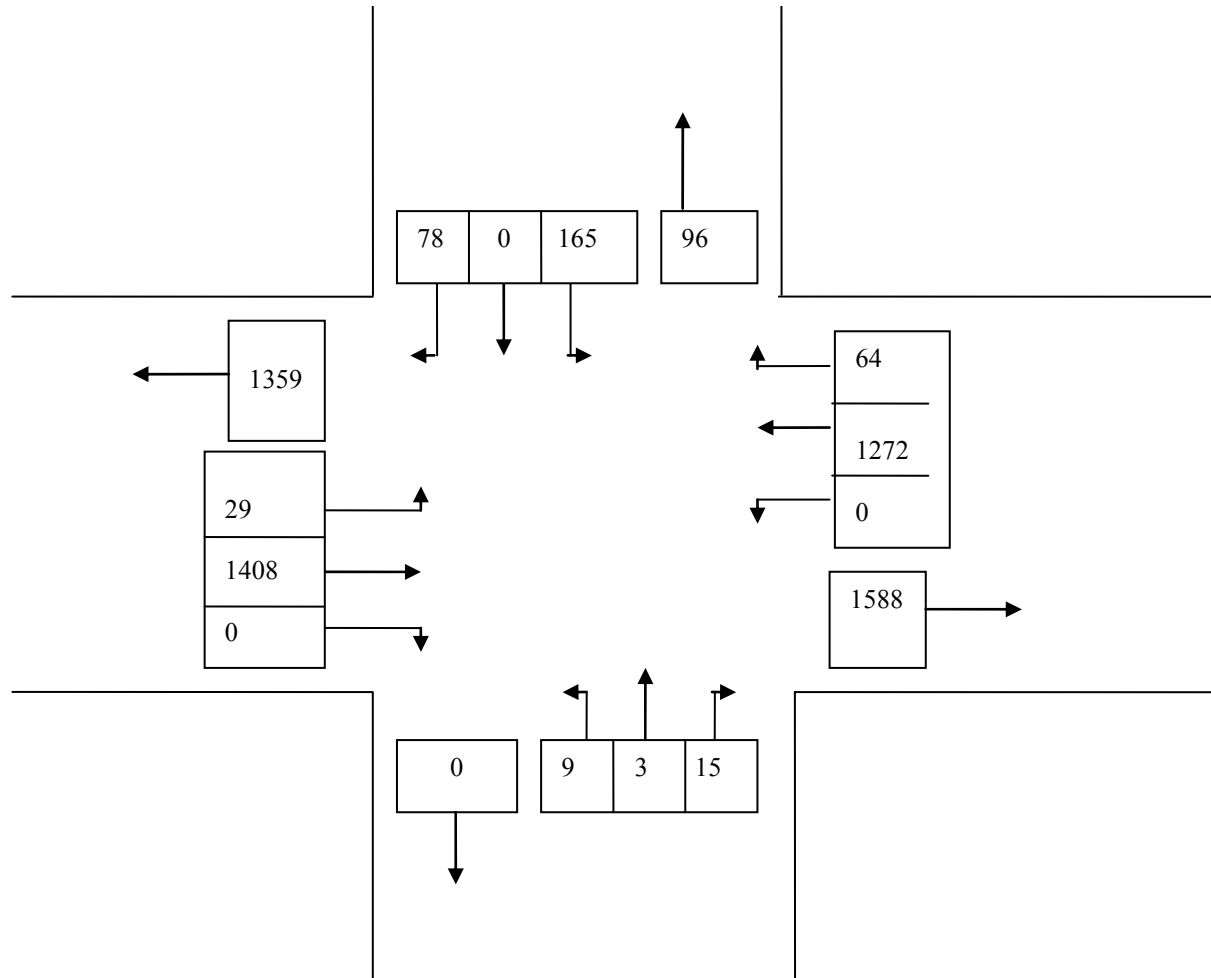


Figure 4. Three-hour Traffic count along Maple Street and Washington Boulevard Intersection in the City of Belpre, Ohio.

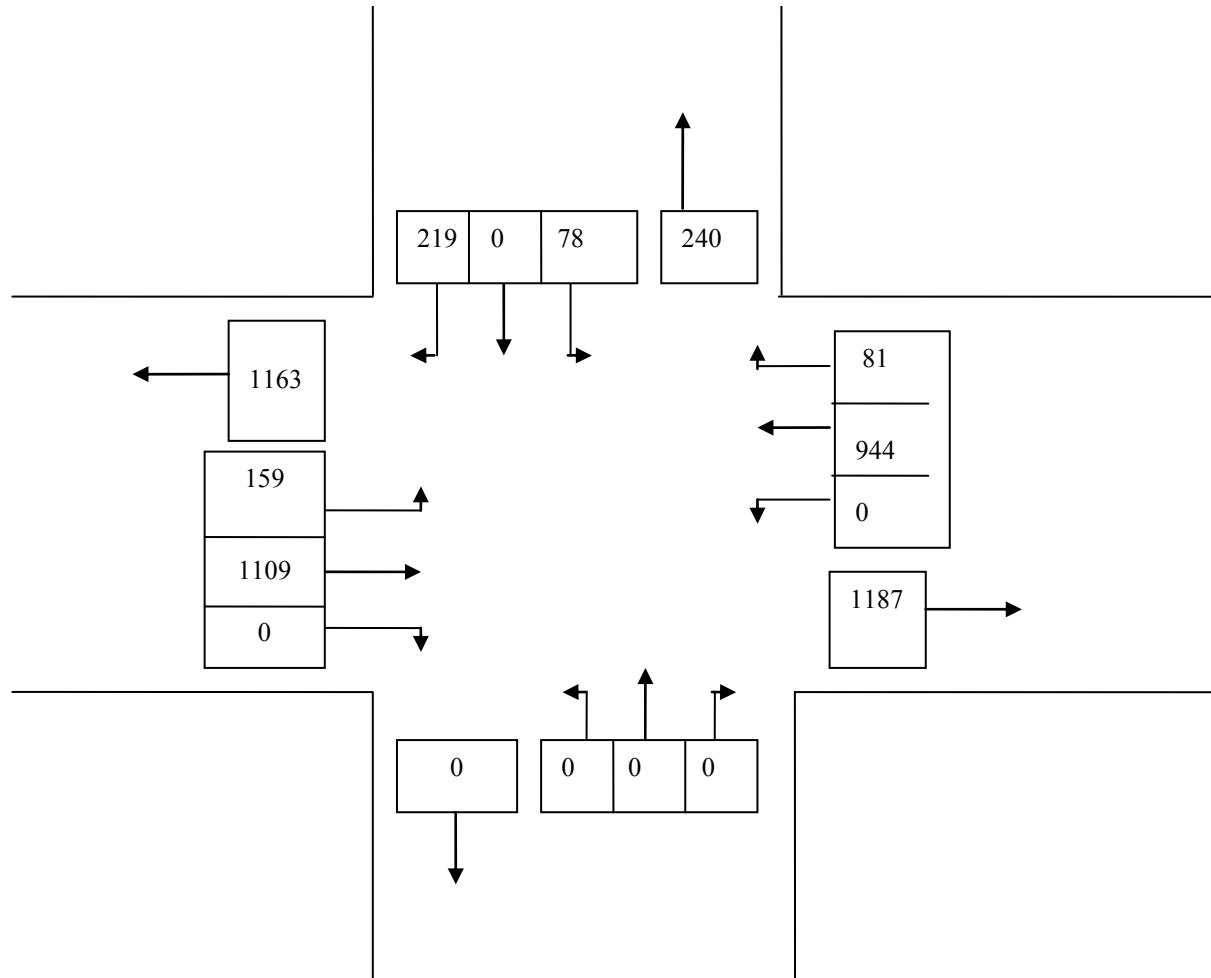


Figure 8. Three-hour Traffic count along Putnam-Howe Street and Washington Boulevard Intersection in the City of Belpre, Ohio.

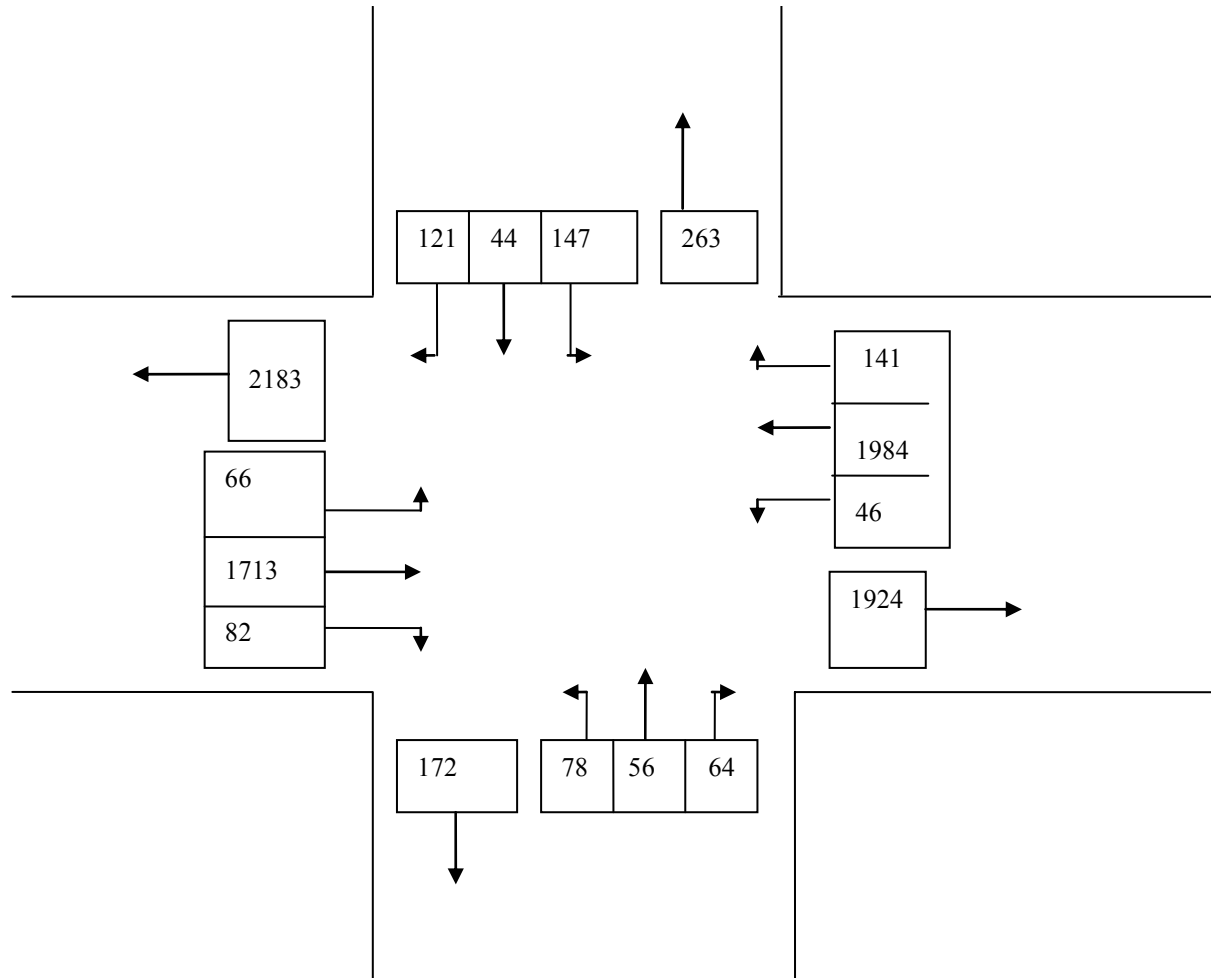


Figure 5. Three-hour Traffic count along Stone and Washington Boulevard Intersection in the City of Belpre, Ohio.

Appendix B

Belpre Intersection Analysis (Traffic Volume and Accident Information)

Street 1	Street 2	NB-3hr	SB-3hr	EB-3hr	WB-3hr	Counting Month	30 HV Seasonal Factor
Parkersburg Bridge	Main Street	1423	1208	2565	440	March	1.146
SR-618	Walnut	109	134	2077	2192	March	1.146
SR-618	Lee Street	378	309	1718	2127	March	1.1123
SR-618	Maple	96	0	1588	1359	March	1.0459
SR-618	Stone	263	172	1924	2183	April	1.0459
SR-618	Farson Street	362	9	1101	643	April	1
US-50	Farson Street	144	621	1852	1994	April	1
SR-618	Putnam Howe	240	0	1187	1163	April	1.1149
Main Street	US-50	838	836	1174	1458	April	1.1149

Street 1	Street 2	Adj NB-1hr	Adj SB-1hr	Adj EB-1hr	Adj WB-1hr
Parkersburg Bridge	Main Street	544	462	980	169
SR-618	Walnut	42	52	794	838
SR-618	Lee Street	141	115	637	789
SR-618	Maple	34	0	554	474
SR-618	Stone	92	60	671	762
SR-618	Farson Street	121	3	367	215
US-50	Farson Street	48	207	618	665
SR-618	Putnam Howe	90	0	442	433
Main Street	US-50	312	311	437	542

Table B-1. Traffic Volume-2004

Street 1	Street 2	Adj NB-24 hr	Adj SB-24 hr	Adj EB-24 hr	Adj WB-24 hr	Factor (24-hr/Peak-hr)	ADT
Parkersburg Bridge	Main Street	10075	8556	18149	3130	18.51851852	39910
SR-618	Walnut	627	777	11851	12508	14.92537313	25763
SR-618	Lee Street	2105	1717	9508	11777	14.92537313	25107
SR-618	Maple	630	0	10260	8778	18.51851852	19668
SR-618	Stone	1374	896	10015	11374	14.92537313	23659
SR-618	Farson Street	2241	56	6797	3982	18.51851852	13076
US-50	Farson Street	1152	3137	9364	10076	15.15151515	23729
SR-618	Putnam Howe	1667	0	8186	8019	18.51851852	17872
Main Street	US-50	4657	4642	6523	8090	14.92537313	23912

Table B-1. Traffic Volume-2004

Street 1	Street 2	ADT	ADT Ranking	ASI	ASI Ranking	# of Accidents	Accidents Ranking
Parkersburg Bridge	Main Street	39910	1	0.380597015	5	104	2
SR-618	Walnut	25763	3	0.372093023	6	43	5
SR-618	Lee Street	25107	4	0.462962963	3	54	3
SR-618	Maple	19668	7	0.277777778	9	18	8
SR-618	Stone	23659	6	0.285714286	8	28	6
SR-618	Farson Street	13076	9	0.533333333	2	15	9
US-50	Farson Street	26562	2	0.434782609	4	46	4
SR-618	Putnam Howe	17872	8	0.590909091	1	22	7
Main Street	US 50	23912	5	0.34375	7	163	1

Street 1	Street 2	# of Injuries	Injuries Ranking	Accident Rate	AR Ranking
Parkersburg Bridge	Main Street	51	2	229.9694859	1
SR-618	Walnut	16	4	114.3191971	4
SR-618	Lee Street	25	2	147.3146984	2
SR-618	Maple	5	9	62.68439652	9
SR-618	Stone	8	8	81.06040901	7
SR-618	Farson Street	8	7	78.57121895	8
US-50	Farson Street	20	3	118.6162536	3
SR-618	Putnam Howe	13	5	84.31341278	6
Main Street	US 50	62	1	91.66028852	5

Table B-2. Accident Tally

Street 1	Street 2	# of Accidents	Rear-End	Head-On	Left-Turn	Right-Turn	Right-Angle
Parkersburg Bridge	Main Street	104	56	0	24	0	12
SR-618	Walnut	43	12	2	0	0	24
SR-618	Lee Street	54	24	0	0	0	24
SR-618	Maple	18					
SR-618	Stone	28					
SR-618	Farson Street	15					
US-50	Farson Street	46	15	1	0	0	22
SR-618	Putnam Howe	22					
Main Street	US-50	163	93	4	34	3	13

Street 1	Street 2	Side-Swipe	Pedestrian	Animal	Fixed-Object	Bicycle	Other
US-50	Main Street	7	0	0	5	0	0
SR-618	Walnut	2	0	0	0	1	2
SR-618	Lee Street	5	0	0	0	0	1
SR-618	Maple						
SR-618	Stone						
SR-618	Farson Street						
US-50	Farson Street	3	0	2	0	0	3
SR-618	Putnam Howe						
Main Street	US-50	6	0	1	9	0	0

Table B-3. Type of Accidents

Street 1	Street 2	ADT	ADT Ranking	Adj NB-24 hr	Adj SB-24 hr	Adj WB-24 hr	Adj EB-24 hr
Parkersburg Bridge	Main Street	39910	1	10075	8556	18149	3130
SR-618	Walnut	25763	3	627	777	11851	12508
SR-618	Lee Street	25107	4	2105	1717	9508	11777
SR-618	Maple	19668	7	630	0	10260	8778
SR-618	Stone	23659	6	1374	896	10015	11374
SR-618	Farson Street	13076	9	2241	56	6797	3982
US-50	Farson Street	23729	2	1152	3137	9364	10076
SR-618	Putnam Howe	17872	8	1667	0	8186	8019
Main Street	US-50	23912	5	4657	4642	6523	8090

Street 1	Street 2	NBF(NB-S)	NBF(WB-R)	NBF(EB-L)	SBF(SB-S)	SBF(WB-L)	SBF(EB-R)
Parkersburg Bridge	Main Street	0	0.7062	0.2937	0	0	0
SR-618	Walnut	0	0.5045	0.4954	0.0895	0.3731	0.5374
SR-618	Lee Street	0.2698	0.3783	0.3519	0.3656	0.3236	0.3108
SR-618	Maple						
SR-618	Stone						
SR-618	Farson Street						
US-50	Farson Street	0.5763	0.3263	0.0974	0.082	0.3252	0.5958
SR-618	Putnam Howe						
Main Street	US-50	0.7541	0.2458	0	0.6578	0.3421	0

Table B-4. ADT Calculation

Street 1	Street 2	WBF(WB-S)	WBF(NB-L)	WBF(SB-R)	EBF(EB-S)	EBF(NB-R)	EBF(SB-L)
Parkersburg Bridge	Main Street	0.733	0	0.267	0.4966	0	0.5033
SR-618	Walnut	0.9461	0.0255	0.0284	0.9595	0.0298	0.0107
SR-618	Lee Street	0.7856	0.0653	0.149	0.802	0.039	0.159
SR-618	Maple						
SR-618	Stone						
SR-618	Farson Street						
US-50	Farson Street	0.8019	0.1835	0.0146	0.879	0.0156	0.1054
SR-618	Putnam Howe						
Main Street	US-50	0.5253	0.4224	0.0523	0	0.8722	0.1277

Street 1	Street 2	ADT(NB-S)	ADT(WB-R)	ADT(EB-L)	ADT(SB-S)	ADT(WB-L)	ADT(EB-R)
Parkersburg Bridge	Main Street	0	7115	2960	0	0	0
SR-618	Walnut	0	317	311	70	290	418
SR-618	Lee Street	568	797	741	628	556	534
SR-618	Maple						
SR-618	Stone						
SR-618	Farson Street						
US-50	Farson Street	664	376	112	258	1021	1870
SR-618	Putnam Howe						
Main Street	US-50	3512	1145	0	3054	1589	0

Table B-4. ADT Calculation

Street 1	Street 2	ADT(WB-S)	ADT(NB-L)	ADT(SB-R)	ADT(EB-S)	ADT(NB-R)	ADT(SB-L)
Parkersburg Bridge	Main Street	13304	0	4846	1555	0	1576
SR-618	Walnut	11213	303	337	12002	373	134
SR-618	Lee Street	7470	621	1417	9446	460	1873
SR-618	Maple						
SR-618	Stone						
SR-618	Farson Street						
US-50	Farson Street	7509	1719	137	8857	158	1063
SR-618	Putnam Howe						
Main Street	US-50	3427	2756	342	0	7057	1034

Table B-4. ADT Calculation

Appendix C.

Intersection Photographs



Pictures of the Belpre Bridge Intersection.



Picture of the Belpre Bridge Intersection.



Pictures of the Farson Street and US-50 Intersection.



Picture of the Farson Street and US-50 Intersection.



Pictures of the Memorial Bridge and OH SR-7 Intersection.



Picture of the Memorial Bridge and OH SR-7 Intersection.



Pictures of the OH SR-618 and Walnut Street Intersection.

Appendix D.

US-50 Re-Alignment at Memorial Bridge

