

**Indiana University-Purdue University Fort Wayne
Department of Engineering**



CE 488

Capstone Senior Design Project

Final Report

Project Title: Design of Alternative Transportation Network in Downtown Fort Wayne to Improve Traffic Flow and Circulation
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Date: April 25, 2011

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Acknowledgements

The team would like to thank a few individuals who helped make the project possible. First, we would like to thank our faculty advisor, Dr. Suleiman Ashur, for his guidance and encouragement throughout the project. Without his supervision, many details may have been overlooked and we're very thankful for his support.

Another individual we would like to thank is Shan Gunawardena, Traffic Engineer for the City of Fort Wayne. The knowledge Shan relayed to us during our CE 451 Traffic Engineering course was invaluable during this project and his assistance is greatly appreciated. Also, we would like to thank him for taking time out of his busy schedule and providing us with all our traffic counts and reviewing our alternative designs.

Finally, the group would like to thank Dan Avery, Executive Director of the Northeastern Indiana Regional Coordinating Council, for informing us how the transportation planning process works. This information helped in our decision making process and safety assessment.

Abstract

As the City of Fort Wayne continues to look for ways to stimulate financial growth, it's essential that consumers can easily access prime locations in the downtown area. One area of special interest is the parallel streets of Fairfield Avenue and Ewing Street near the newly constructed Parkview Field. With Fairfield being a one-way southbound street and Ewing being a one-way northbound street, access to potentially valuable property is limited. Therefore, the senior design team was given the task of finding an alternative design of the roadway network to better suit the community in their mission to attract new businesses to the area.

1. Section 1: Problem Statement

1.1. Problem Statement

The current network of Downtown Fort Wayne was developed to serve the needs of a major industrial zone that have since downsized or moved from the area. Specifically, one-way streets were established on Fairfield Avenue and Ewing Street between Superior Street and Baker Street to satisfy the needs of employers commuting from the northern part of Fort Wayne to the General Electric facility which employed over 10,000 people in its most prominent time. Since the relocation of the General Electric plant, the one-way roadways are no longer necessary to serve the existing and future needs of the community. The one-way traffic limits the capacity of the network and the ease at which drivers can navigate to destinations. With the addition of Parkview Field and a movement to return businesses to the Downtown region, improvements to traffic operations for vehicles, pedestrians, and bicyclist will be essential in attracting more businesses and consumers to the area.

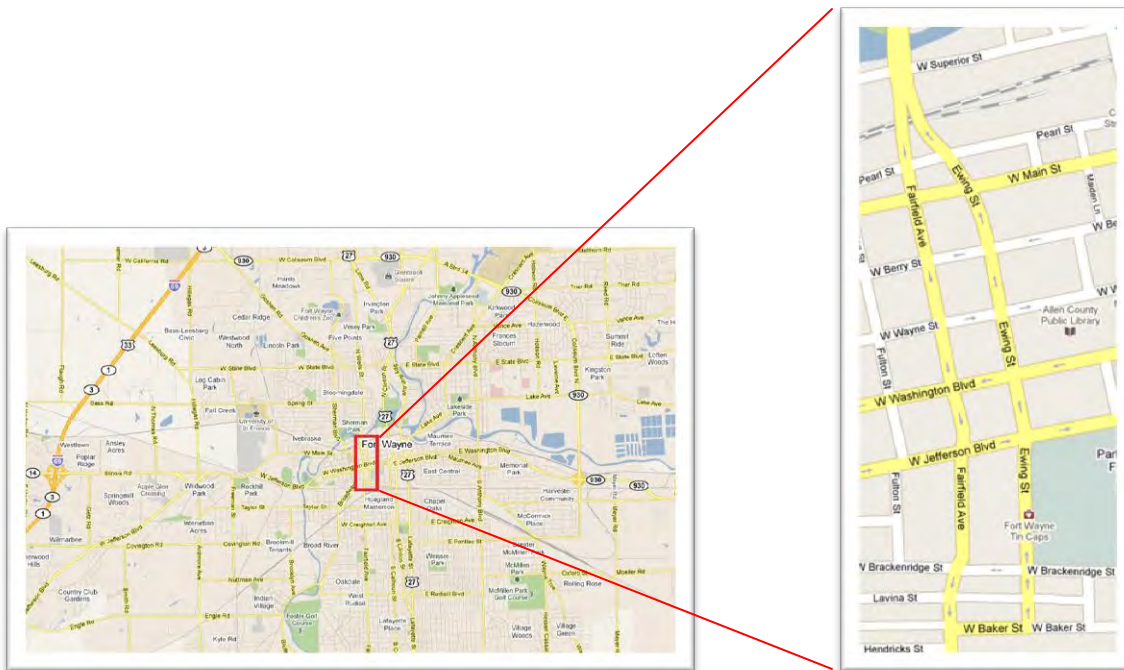


Figure 1 - Study Area

1.2. Requirements and Specifications

Various transportation alternative designs will be created to simulate and determine the most efficient traffic flow in each design. These designs must meet the requirements and specifications specified.

1.2.1. Improve Roadway Performance

A level of service of at least D must be achieved at each intersection during peak volume hours. The level of service is a common method to determine the delay, queue, and speed reduction at each intersection. The levels range from A to F, at which A is the ideal scenario and F is the worst scenario.

1.2.2. Follow Design Manuals

To ensure the project retains the federal funding it's allotted, the following new design of the roadway must adhere to the guidelines established in the following manuals.

1.2.2.1. Indiana Design Manual

The design has to meet all specifications and requirements presented in the Indiana Design Manual (IDM). The Indiana Design Manual is compiled of national design manuals developed by the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA), but also includes requirements specific to Indiana.

1.2.2.2. AASHTO Standards

The American Association of State Highway and Transportation Officials (AASHTO) is an association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. It represents all five transportation modes: air, highways, public transportation, rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national transportation system.

1.2.2.3. MUTCD Manual

The Manual on Uniform Traffic Control Devices (MUTCD) defines the standards used by road managers nationwide to install and maintain traffic control devices on all public streets, highways, bikeways, and private roads open to public traffic. The MUTCD is published by the Federal Highway Administration (FHWA).

1.2.3. Improve Safety

The safety of all vehicles and pedestrians should improve with the alterations to the roadway system.

1.2.4. Improve Accessibility

The design must be improve the ease at which motorist and pedestrians can reach a destination. The new design must also be suitable for disabled pedestrians to enter and exit the intersection safely according to the guidelines established by the Americans with Disabilities Act (ADA).

1.2.5. Improve Mobility

Mobility is a function of the travel distance and speed throughout the network. By decreasing the distance users must travel and the speed at which they're traveling in the network, the mobility of the network will be improved.

1.3. Given Parameters

The given, or fixed, parameters are those that will be the guidelines for the design of the network. The give parameters cannot be modified in any manner and will therefore dictate much of the network design.

1.3.1. Traffic Data

Traffic volume counts will be provided by the City of Fort Wayne for the study area and remain constant in all forms of analysis. From this data, a morning and afternoon peak hour can established. These peak hours can be used to ensure the network can handle traffic flow during heavy traffic periods.

1.3.2. Pedestrian Data

The pedestrian volume will remain constant throughout the analysis process. The influx of pedestrian traffic on game days at Parkview Field will be considered.

1.3.3. Crash Data

Accident reports from 2007-2009 will be provided by the City of Fort Wayne and used to determine problematic areas in the network.

1.3.4. Population Growth Rate

The growth rate of Fort Wayne will be assumed based on future outlooks for the city. For the twenty year design lifespan of a roadway, a growth factor of 2.5% will be used.

1.3.5. Speed of Traffic

Safe travel speeds have been established for the downtown area and will remain constant in the newly implemented pieces of the network.

1.4. Design Variables

As in any design, the primary purpose is to upgrade, create, or expand the existing intersection/network to satisfy the needs of the community. The design variables are the parameters that can be changed to improve the operations of the network.

1.4.1. Travel Direction

Changing the direction of travel can have a major impact on the efficiency of a roadway system. Determining whether a one-way or a two-way street arrangement provides the optimum performance will be significant.

1.4.2. Intersection Type

Numerous types of intersections have been proven in the United States. Establishing whether a signalized or unsignalized intersection is proficient will be important for each junction on the network. The use of an unsignalized roundabout will be considered at multiple locations.

1.4.3. Traffic Control Devices

Informing vehicular and pedestrian traffic of the capabilities of the facility they're traveling on is an important piece of the design. The appropriate road markings, highway signs, and traffic signals can be established using guidelines available in the Manual on Uniform Traffic Control Devices (MUTCD).

1.4.4. Number of Lanes

Providing the appropriate number of travel lanes on a roadway is essential in a roadway design. Using the provided traffic data, the number of travel lanes can be established.

1.4.5. Lane Widths

Depending on the type of traffic traveling through the system, the lane widths can have adverse effects on the system. Wider lane widths will be necessary for areas with high volumes of heavy vehicle or truck traffic.

1.5. Limitations and Constraints

The limitations and constraints of the system must also be considered in order to meet the requirements and specifications of the sponsoring company. These include anything that could inhibit the design such as right-of-way acquisition, existing geometry, funding, and public acceptance.

1.5.1. Right-of-Way

The current roadway system is very limited in expanding due to the residential and commercial development in the area. This is to help with practicality and expenses as attaining right-of-way is expensive and often difficult to attain.

1.5.2. Existing Conditions

The existing buildings and current geometry of the network will limit expansion of the roadway in many areas. As previously mentioned, acquiring right-of-way can be very expensive and timely, so working within the current boundaries of the roadways would be ideal.

1.5.3. Funding

While there is not a fixed budget for the redesign of the roadway system, it is still important to be practical in the design so that it would be feasible to implement.

1.5.4. Public Acceptance

The public must be willing to utilize the network after modifications have been made and stakeholders such as the mayor must approve of the plans.

1.6. Additional Considerations

The additional constraints that could affect the design would be those that are indicative of the present network design and governmental standards. Safety and environmental impacts in the surrounding area are a major concern and appropriate measures will be taken to ensure crashes and emissions are reduced.

1.6.1. Safety

1.6.1.1. Crash Data

Based on the crash reports from 2007-2009 provided by the City of Fort Wayne, problematic areas in the network can be identified. Once the critical intersections are identified, alternative intersection types or modified signal timings may be recommended.

1.6.1.2. ArcGIS Analysis

In order to easily identify critical intersections in the network, the database containing all the crashes in the area for a three year period must be geocoded into a more user friendly format using ArcGIS.

1.6.2. Environmental

1.6.2.1. Fuel Consumption

As fuel prices continue to rise, fuel consumption continues to be a major concern and implementing an alternative design that will reduce fuel utilization will be important in the new design.

1.6.2.2. Emissions

Global warming has been a topic of great debate recently as our ozone continues to be depleted. By creating a design that will cause vehicles to release fewer emissions, the design can help environmentalist in their effort halt global warming.

1.6.3. Impact to:

1.6.3.1. Commuting Motorist

The Downtown region employs thousands of people who rely on the network to travel to work. The alterations must accommodate them and ensure their travel time will not be increased drastically.

1.6.3.2. Parkview Field

Several major events occur at the stadium along with the baseball games each year. The final design must ensure consumers will continue to have safe and easy access to the facility.

1.6.3.3. Local Businesses

Many local commercial establishments will be affected with the changes to the network. Ultimately, the goal is to improve the ease at which vehicular and pedestrian traffic can access the locations.

1.6.3.4. Psychological

Implementing uncommon intersections types such as a roundabout may make drivers uncomfortable and repel them from the area. In order to ensure motorists continue to use the newly designed roadway, a design that satisfies local businesses and motorists must be implemented.

2. Section II: Alternative Designs

During the initiation of the Alternative design generation, many alternatives will be considered to improve mobility and accessibility, while maintaining the level of service in the network. Ultimately, the goal of the project is to improve access to prime real estate in the area and implementing two-way traffic on Fairfield Avenue and Ewing Street will be considered in each alternative design.

The existing geometry of the downtown area will restrict the number of lanes being used in each alternative, but different intersection types, traffic control devices, and lane widths will be considered to optimize the land use and maintain the level of service.

2.1. Alternative #0

In any traffic engineering project, there is always a possibility that the network should be left as it is now without any adjustments. After analyzing the performance of the network under the following Alternatives, it may be determined that the current geometry and traffic control devices work the best and it would be unnecessary to make any changes.

2.1.1. Feasibility

Since there will not be any changes to the existing network, the Alternative is very feasible and will not come with any resistance from the public or elected officials as no funding will be needed for the project.

2.1.2. Potential Problem

The Alternative will not address the issue of improving accessibility and mobility in the network. Therefore, the problems will remain an issue and most likely need to be addressed again in the near future.



Figure 2 - Alternative #0

2.2. Alternative #1

Currently, Fairfield Avenue and Ewing Street are both one-way streets with three travel lanes. The first design Alternative consists of adding northbound traffic to Fairfield Avenue, southbound traffic to Ewing Street, and adding two-way stop control at Brackenridge Street. The idea behind this design is to meet the specifications with as little change to the network as possible. In order to meet this criteria changing Ewing Street and Fairfield Avenue to two-way roads requires having one lane of traffic in each direction with a two-way center turn lane between the flows of traffic. Adding a two-way center turn lane will allow for vehicles wanting to make left hand turns to do so without slowing down the flow of traffic. It will also help for vehicles wanting to make a left hand turn onto the roadway by giving the driver a center lane to

speed up and merge onto traffic. A designated left-hand turn lane will be provided at all signalized intersections according to where they are needed.

The second change in this design would be adding a two-way stop control at Brackenridge Street/Ewing Street and Brackenridge Street/Fairfield Avenue. Currently Brackenridge Street is a two-lane one-way road westbound. The design would change the Brackenridge Street to a two-way single-lane road (one lane in both directions). The intersections where Brackenridge crosses, Fairfield and Ewing would then be design for a two-way stop control.

2.2.1. Feasibility

This design Alternative will be the least expensive of all the scenarios as it does not include the addition of a roundabout to the network system. The adjustments to the roadway design will be limited to changing the direction of traffic flow in certain lanes and changing the intersections accordingly. Without having to buy right-of-way or redesigning intersection to include roundabouts, this scenario will be the quickest, easiest, and cheapest redesign of the network system.

2.2.2. Potential Problems

A few possible drawbacks to this design Alternative are that it may not accomplish the specifications of a successful design. The idea behind roadway design is to plan for a 20 year horizon and at the moment this design may work for the current conditions, but in 20 years the network system may break down. Another drawback is that this design will likely not improve the safety at the intersection of Superior Street, Fairfield Avenue, Ewing Street, and Wells Street.



Figure 3 - Alternative #1

2.3. Alternative #2a

Again, Fairfield Avenue and Ewing Street will be converted into two way streets. Due to the three lanes approach on each arterial, the conversion of two ways would result in a designated left turn at each necessary intersection. This means that there would be only one lane for each through approach. In addition, with the designated left turns, the signal timing plans will need to be modified to protective and permissive at the intersection of Fairfield Avenue and Main Street and Ewing Street and Main Street. While at the other intersections, the signal plans can be changed to best optimize the flow at each intersection. The traffic control at each intersection will be unchanged except at Superior Street and Wells Street.

Also on Brackenridge, the whole roadway would be converted from a one way to a two way. This will help the flow to and from Parkview Field. In addition, with the future businesses

located near the Parkview Field, the two ways will help attract more buyers to the area. With the two way stops at Fairfield Avenue and Brackenridge and Ewing Street and Brackenridge, this intersection may be congested during game nights.

The only intersection that will be modified is at Superior Street and Wells Street. The suggested change is to convert this intersection to a one lane roundabout. This will help the flow of vehicles because of the constant movement. Also cost to maintain a roundabout is drastically cheaper than a traffic control. The amounts of death and injury are greatly lower than at a traffic control due to the reduction of speed. The minimum size of a single lane roundabout is about 100' while the entry width is usually 18'. The amount of vehicles a single lane roundabout can handle is roughly 25,000 vehicles per day. A one lane roundabout would mean before each roundabout approach, the lanes must merge into a single lane. Therefore, there will be a single exit and approach lane at the roundabout. A pedestrian walkway will be constructed due to the high volume of pedestrians in the area. This crosswalk should be located 1-2 car lengths behind the yield line of the roundabout. To comply with the Americans with Disabilities Act (ADA), rectangular rapid flash beacons (RRFB) can be implemented to help disable pedestrians to cross the roundabout.

2.3.1. Feasibility

The conversion of Brackenridge into two way traffic can be implemented easily. The alley way, currently on Brackenridge, will be sufficiently enough to create two lanes. In addition, the maintenance cost of a roundabout compared to a traffic signal will be less costly therefore overtime the roundabout will be more economically favorable.

2.3.2. Potential Problems

With the two way stops at Fairfield Avenue and Brackenridge and Ewing Street and Brackenridge, this intersection may be congested during game nights. In addition to the space requirement, the pedestrian distance to cross the two lane roundabout has increased greatly compared to a one lane roundabout and a traffic signal. Lastly, majority of drivers' knowledge on how to enter, exit, and operate in a roundabout is at a minimum.



Figure 4 - Alternative #2a

2.4. Alternative #2b

It begins with the conversion of Fairfield Avenue and Ewing Street, both being one ways, into two way streets. The location of Fairfield Avenue and Ewing Street can be seen in Figure 4. Due to the 3 lanes approach on each arterial, the conversion of two ways would result in a designated left turn at each necessary intersection. This means that there would be only one lane for through approach. In addition, with the designated left turns, the signal timing plans will needed to be modified to protective and permissive at the intersection of Fairfield Avenue and Main Street and Ewing Street and Main Street. While at the other intersections, the signal plans can be changed to best optimize the flow at each intersection. The traffic control at each intersection will be unchanged except at Superior Street and Wells Street.

Also on Brackenridge, the whole roadway would be converted from a one way to a two way. This will help the flow to and from Parkview Field. In addition, with the future businesses located near the Parkview Field, the two ways will help attract more buyers to the area. With the two way stops at Fairfield Avenue and Brackenridge and Ewing Street and Brackenridge, this intersection may be congested during game nights.

The only intersection that will be modified is at Superior Street and Wells Street. The suggested change is to convert this intersection to a two lane roundabout. This will greatly help the flow of vehicles because of the constant movement. Also cost to maintain a roundabout is drastically cheaper than a traffic control. The amounts of death and injury are greatly lower than at a traffic control due to the reduction of speed. The minimum size of a two lane roundabout is about 220 feet while the entry width is still the same at 18 feet. The amount of vehicles a two lane roundabout can handle is roughly 45,000 vehicles per day. The two lane roundabout will have a faster flow but the confusion for inexperienced drivers could be risky. Therefore, DMV should implement sections on how to enter and exit a roundabout. A pedestrian walkway will be constructed due to the high volume of pedestrians in the area. This crosswalk should be located 1-2 car lengths behind the yield line of the roundabout. To comply with the Americans with Disabilities Act, rectangular rapid flash beacons (RRFB) can be implemented to help disable pedestrians to cross the roundabout. A two lane roundabout will be much more difficult for pedestrians to cross due to the additional lane.

2.4.1. Feasibility

The conversion of Brackenridge into two way traffic can be implemented easily. The alley way, currently on Brackenridge, will be sufficiently enough to create two lanes. In addition, the maintenance cost of a roundabout compared to a traffic signal will be less costly therefore overtime the roundabout will be more economically favorable.

2.4.2. Potential Problems

With the two way stops at Fairfield Avenue and Brackenridge and Ewing Street and Brackenridge, this intersection may be congested during game nights. Also, the intersection at the roundabout requires even more space for a two lane roundabout than a traffic signal. In addition to the space requirement, the pedestrian distance to cross the two lane roundabout has increased greatly compared to a one lane roundabout and a traffic signal. Lastly, majority of drivers' knowledge on how to enter, exit, and operate in a roundabout is at a minimum.



Figure 5 - Alternative #2b

2.5. Alternative #3a

The third Alternative will again include implementing two-way traffic on Fairfield Avenue and Ewing Street. Along with the changes to Fairfield and Ewing, a one-lane roundabout will also be placed at Superior and Brackenridge. As previously mentioned, one-lane roundabout typically handle 25,000 vehicles per day without any major problems. Both the Superior and Ewing intersection and Fairfield and Brackenridge intersection will experience changes in traffic flow due to the implementation of two-traffic on Fairfield and Ewing and the roundabout could alleviate some of delay experienced by road users at those junctions. While current traffic does not exceed 25,000 vehicles per day, future expectations may cause traffic volumes to surpass that value.

Along with the other changes, Main Street will be converted to three lanes with one through lane in each direction and a dedicated left turn at Fairfield Avenue and Ewing Street. Also to accommodate smaller side streets and alleys, a two-way center left turn lane will be used on the road.

2.5.1. Feasibility

Implementing two-way traffic on Fairfield Avenue and Ewing Street will be a fairly simple task. By re-striping the pavement marking and making a few adjustments to the traffic signal timings, that portion of the project would be completed in a very short time period. This Alternative may be more costly than the previous alternatives due to the construction of two roundabouts and right-of-way acquisition at each of the intersections. Where money is spent on the roundabout construction, it can be saved by not installing traffic control devices and not having to maintain those devices each year.

2.5.2. Potential Problems

Acquiring the right-of-way to build the roundabouts may be very costly and take several years and owners are unwilling to part with their property. Another difficult portion of the Alternative will be maintaining traffic flow during the construction of the two roundabouts. Although many studies claim roundabouts can be completely constructed and operating within sixty days and one side of the roundabout can be open during construction, it will still cause congestion and longer delay than many of the local people are accustomed to.



Figure 6 - Alternative #3a

2.6. Alternative #3b

Similarly to Alternative #3a, two-way traffic will be introduced on Fairfield and Ewing, a one-lane roundabout will be placed at Brackenridge, and Main Street will be converted to three lanes, while a two-way roundabout is being utilized at Superior. The two-way roundabout will only be needed if projected traffic volumes in the 20 year horizon exceed 25,000 vehicles per day.

2.6.1. Feasibility

Again, the Alternative will be costly and take the most time to implement due to the construction of two roundabouts.

2.6.2. Problem

Due to the larger roundabout being constructed at Superior Street, even more right-of-way will need to be attained, costing more money and potentially irritating local property owners.



Figure 7 - Alternative #3b

3. Section III: A Summary of the Evaluation of Different Alternative Designs

After generating several Alternatives, each design was evaluated to determine the best alternative. Each alternative was evaluated based on level of service, accessibility, mobility, cost, safety, and public acceptance.

3.1. Alternative #0

- Do not make any changes to the network.

3.1.1. Advantages

- a) No Cost
- b) Easy for Public to Accept

3.1.2. Disadvantages

- a) Will Not Address Current and Future Issues

3.2. Alternative #1

- Two-Way on Fairfield, Ewing, and Brackenridge
- Added Two-Way Turn Lane
- Change Lane Configuration on Main Street
- Dedicated Left-Hand Turns at All Signalized Intersections

3.2.1. Advantages

- a) Least Expensive of All Design Alternatives
- b) No Need to Purchase Right-of-Way
- c) Shortest Construction Time
- d) Increased Accessibility to Parkview Field
- e) Increased Accessibility to Future Businesses
- f) Increased Mobility Through Network
- g) Simple to Implement Design
- h) Easy for Public to Adjust to

3.2.2. Disadvantages

- a) May Not Meet Specifications and Requirements
- b) Potential to Fail in 20 Year Horizon
- c) Will Not Improve Safety at Critical Intersections

3.3. Alternative #2a

- Two-Way on Fairfield, Ewing, and Brackenridge
- Added Two-Way Turn Lane
- Changed Lane Configuration on Main Street
- Dedicated Left-Hand Turns at All Signalized Intersections
- Single Lane Roundabout Added to Intersection of Superior, Fairfield, and Ewing

3.3.1. Advantages

- a) Intersection of Superior, Fairfield, and Ewing Street
- b) Improved Safety
- c) Improved Traffic Flow
- d) Increased Accessibility to Parkview Field
- e) Increased Accessibility to Future Businesses
- f) Increased Mobility Through Network
- g) Less Fuel Consumption and Emissions

3.3.2. Disadvantages

- a) Possible Congestion on Brackenridge Intersections
- b) Small Amount of Right-of-Way Must Be Acquired
- c) Majority of Drivers Are Unfamiliar With Roundabout Operations
- d) Single Lane Roundabout May Not Have Sufficient Capacity for Future

3.4. Alternative #2b

- Two-Way on Fairfield, Ewing, and Brackenridge
- Added Two-Way Turn Lane
- Change Lane Configuration on Main Street
- Dedicated Left-Hand Turns at All Signalized Intersections
- Two Lane Roundabout Added to Intersection of Superior, Fairfield, and Ewing

3.4.1. Advantages

- a) Intersection of Superior, Fairfield, and Ewing Street
- b) Improved Safety for Vehicles
- c) Improved Traffic Flow (Over Single Lane Roundabout)
- d) Two Lane Roundabout Can Handle 45,000 vehicles per day
- e) Increased Accessibility to Parkview Field
- f) Increased Accessibility to Future Businesses
- g) Increased Mobility Through Network

- h) Less Fuel Consumption and Emissions

3.4.2. Disadvantages

- a) Possible Congestion on Brackenridge Intersections
- b) More Right-of-Way Must Be Acquired
- c) May Anger Public
- d) Pedestrian Distance to Cross Traffic Increased
- e) Majority of Drivers Are Unfamiliar With Roundabout Operations

3.5. Alternative #3a

- Two-Way on Fairfield, Ewing, and Brackenridge
- Added Two-Way Turn Lane
- Changed Lane Configuration on Main Street
- Dedicated Left-Hand Turns at All Signalized Intersections
- Single Lane Roundabout Added at Intersection of Superior, Fairfield, and Ewing
- Single Lane Roundabout Added at Intersection of Brackenridge and Fairfield

3.5.1. Advantages

- a) Intersection of Superior, Fairfield, and Ewing Street and Roundabout at Brackenridge and Fairfield
- b) Improved Safety
- c) Improved Traffic Flow
- d) Improved Traffic Flow on Game Nights
- e) Increased Accessibility to Parkview Field
- f) Increased Accessibility to Future Businesses
- g) Increased Mobility Through Network
- h) Less Fuel Consumption and Emissions

3.5.2. Disadvantages

- a) Right-of-Way Must Be Acquired
- b) Expensive
- c) Majority of Drivers Are Unfamiliar With Roundabout Operations
- d) Single Lane Roundabout May Not Have Sufficient Capacity for Future

3.6. Alternative #3b

- Two-Way on Fairfield, Ewing, and Brackenridge
- Added Two-Way Turn Lane
- Change Lane Configuration on Main Street
- Dedicated Left-Hand Turns at All Signalized Intersections
- Two Lane Roundabout Added at Intersection of Superior, Fairfield, and Ewing
- Single Lane Roundabout Added at Intersection of Brackenridge and Fairfield

3.6.1. Advantages

- a) Roundabout at Superior, Fairfield, and Ewing Street and Roundabout at Brackenridge and Fairfield
- b) Improved Safety
- c) Improved Traffic Flow
- d) Two Lane Roundabout Can Handle 45,000 vehicles per day
- e) Improved Traffic Flow on Game Nights
- f) Increased Accessibility to Parkview Field
- g) Increased Accessibility to Future Businesses
- h) Increased Mobility Through Network
- i) Less Fuel Consumption and Emissions

3.6.2. Disadvantages

- a) Most Right-of-Way Must Be Acquired
- b) May Anger Public
- c) Most Expensive of All Design Alternatives
- d) Time of Construction: Approximately 90 Days
- e) Pedestrian Distance to Cross Traffic Increased
- f) Majority of Drivers Are Unfamiliar With Roundabout Operations

3.7. Decision Matrix

In order to determine the best design, several major criteria were analyzed in each of the alternatives and placed into a decision matrix. The criteria included: level of service, accessibility, mobility, cost, safety, environmental impact, and public acceptance. Each criteria was weighted based its ability to address the problem with a 1 through 5 rating system (1 = very bad, 2 = bad, 3 = average, 4 = good, 5 = very good) and weighted against the importance of each criteria.

The importance of each criterion was based on analysis completed with Synchro, calculations according to the Highway Capacity Manual, and past experiences from others making similar changes to their networks. The estimated importance of each criterion are shown below along with completed decision matrix in Table 1.

- Level of Service (20%)
- Accessibility (15%)
- Mobility (15%)
- Cost (10%)
- Safety (25%)
- Environmental Impact (10%)
- Public Acceptance (5%)

Table 1 - Decision Matrix

Alternative	0		1		2a		2b		3a		3b	
Level of Service	1	0.2	2	0.2	4	0.2	4	0.2	3	0.2	5	0.2
Accessibility	1	0.15	2	0.15	4	0.15	4	0.15	4	0.15	4	0.15
Mobility	1	0.15	3	0.15	3	0.15	4	0.15	3	0.15	4	0.15
Cost	5	0.1	4	0.1	3	0.1	1	0.1	2	0.1	1	0.1
Safety	2	0.25	2	0.25	4	0.25	4	0.25	4	0.25	4	0.25
Environmental Impact	2	0.1	2	0.1	4	0.1	4	0.1	4	0.1	4	0.1
Public Acceptance	5	0.05	5	0.05	4	0.05	2	0.05	4	0.05	2	0.05
Total Rating	2.0		2.5		3.8		3.6		3.5		3.8	

The decision matrix proves implementing minor changes such as adjustments to the traffic signal timing and major changes such as a roundabout at the intersection of Superior Street and Wells Street greatly improve the performance of the network. After evaluating the alternatives, Alternative #2a and #3b were equal in the total rating. Based on the additional cost associated with constructing another roundabout and acquiring more right-of-way in Alternative #3a, Alternative #2a was chosen as the optimum design.

4. Section IV: Detailed Design of the Selected Alternative

4.1. Network Analysis

In order to analyze the effects of the changes proposed for the network, several software packages were utilized. For modeling traffic scenarios, Synchro and SIDRA were used, while AutoCAD Civil 3D was utilized to create the geometric design of the network.

4.1.1. Synchro

Trafficware Synchro 7 was used to design the necessary network for the 20 year horizon. Synchro has many useful features such as multiple bitmaps for backgrounds, lane alignment through intersections, detailed detector settings, level of service analysis, and many more. These tools were applied to the design the five conceptual designs. Once all of the necessary values are inputted and the design is finalized, the option to optimize the network or separate intersections is considered. Optimizing the network will find the most efficient cycle length, for the whole network, and distribute the timing accordingly to approach volume counts. Figure 8 shows a typical intersection model in Synchro.



Figure 8 – Modeling with Synchro 7

After inputting the appropriate alterations for each of the alternatives, Synchro has the ability to generate a report detailing key performance measures in the network. A complete Synchro generated report can be seen in Appendix 8.1. While Synchro

analyzes many different items, seven primary entries were selected to verify the best alternative. The key elements selected to evaluate the alternatives were: total delay, stops per vehicle, fuel economy, average speedway, carbon monoxide emissions, and performance index. Table 2 displays the results for the main arterials traversing northbound and southbound through the network. By examining these results, the alternative which allows motorist to travel completely through the network most efficiently can be determined. The total results reveal Alternative #3b scoring the best overall in these performance areas. By summing the results of the two roadway results, the chosen design, Alternative #2a scored with second base overall, based solely on these performance measures.

Table 2 – Main Arterials Analysis based on Synchro Analysis

Alternative	Ewing Street					Fairfield Avenue				
	1	2a	2b	3a	3b	1	2a	2b	3a	3b
Total Delay (sec/veh)	28	10	11	9	9	26	19	20	34	10
Stops/Vehicle	0.53	0.5	0.55	0.54	0.49	0.38	0.49	0.56	0.6	0.57
Fuel Economy (mpg)	6.7	9.9	9.4	9.7	10.2	7.9	8.6	8.1	5.7	10.2
Average Speed (mph)	8	15	14	15	16	9	11	10	6	14
CO Emissions (kg)	2.31	1.56	1.65	1.47	1.39	6.84	6.28	6.73	7.75	4.85
Performance Index	25.7	11.4	12.5	10.6	9.8	74.2	58.6	64.1	92.2	36.6
Rank	5	3	4	2	1	4	2	3	5	1

While determining the most efficient alternative for traversing completing north or sound through the entire network, equally important is how efficient road users can travel through all roads in the network, including those individuals traveling eastbound and westbound. Table 3 exhibits the results of the seven primary performance criterions. The complete network analysis again shows Alternative #3a with the highest ranking and Alternative #2a graded as the second highest.

Table 3 - Synchro Analysis on Complete Network

Network Totals					
Alternative	1	2a	2b	3a	3b
Total Delay (sec/veh)	32	24	24	38	13
Stops/Vehicle	0.54	0.58	0.61	0.59	0.56
Fuel Economy (mpg)	8.2	9.6	9	5.8	8.9
Average Speed (mph)	9	12	11	6	13
CO Emissions (kg)	27.69	25.6	25.35	25.28	15.74
Performance Index	286.1	225.4	231.8	305.9	127
Rank	5	2	3	4	1

In order to verify there were not any major conflicts, the networks were monitored using the software associated with Synchro, called SimTraffic. SimTraffic simulates traffic on the roads and allows users to visualize how the network will respond to alterations. In addition to helping visualize the changes, SimTraffic also notifies the user of any potential problems that may be encountered. Specifically, when signal timings may need adjusted to allow adequate time for pedestrians to cross the intersection, or when a lagging phase may be more appropriate for a certain phase. An example of SimTraffic is shown in Figure 9.

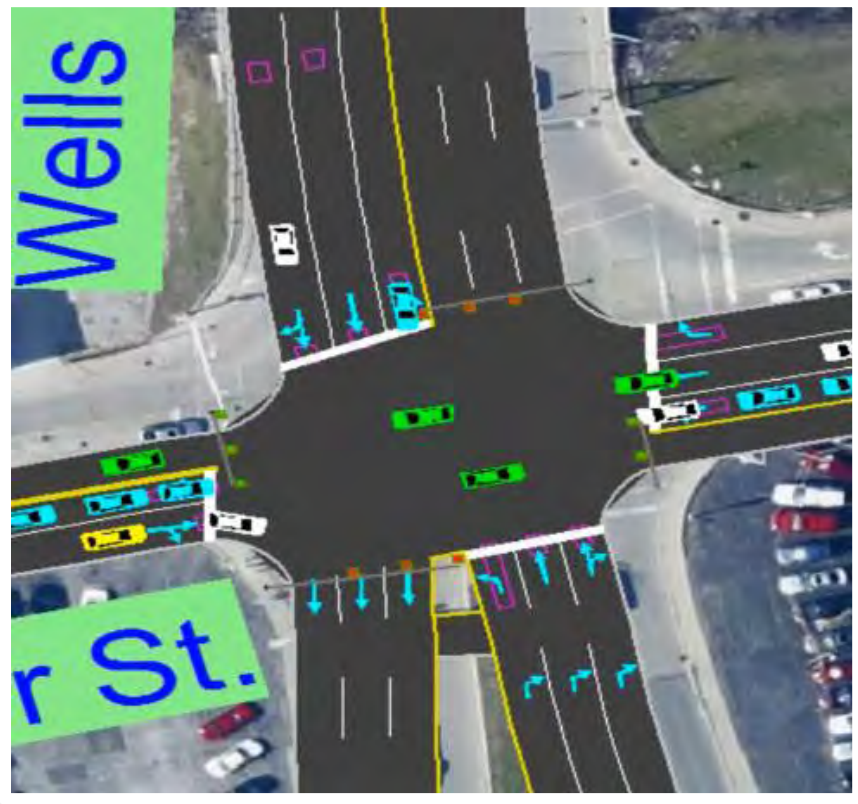


Figure 9 - SimTraffic Simulation

4.1.2. SIDRA

While Synchro is one of the premier macroscopic modeling programs for traditional intersections, when modeling a roundabout, Synchro has very limited capabilities. Therefore, SIDRA became the chosen program to model the proposed roundabout at the intersection on Wells Street and Superior Street. SIDRA has been in development for

over thirty years and includes fully updated analysis based on the most recent version of the Highway Capacity Manual.

The first step in modeling a roundabout in SIDRA is laying out the geometry of the roadways. Once the geometric features are established, other parameters such as the expected traffic volumes during the peak hours can be applied to the model. Figure 10 displays roundabout model generated with SIDRA. The current configuration of Wells Street and Superior Street allowed for four lanes to be used on the north, west, and east sides of the roundabout with major additions to the roadway. Also, the current three lane configuration of Fairfield Avenue and Ewing Street was retained in the network.

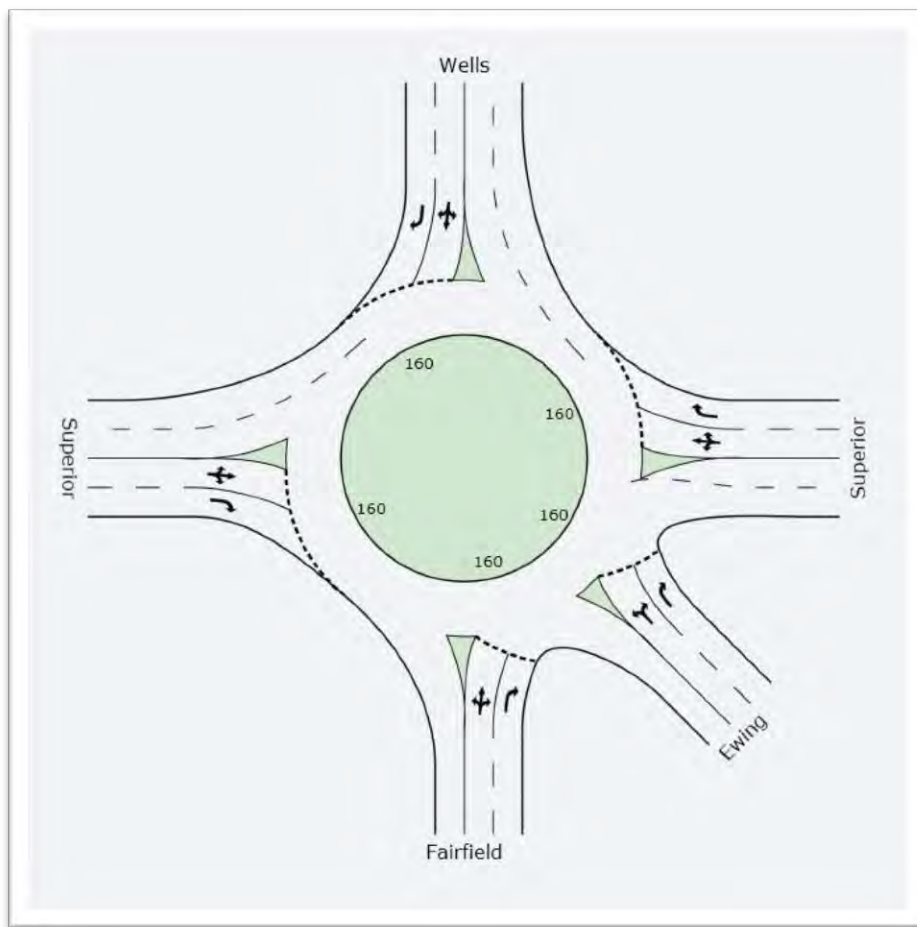


Figure 10 - Roundabout Modeling using SIDRA

After finalizing the geometric features of the roundabout and entering the projected traffic volumes, SIDRA was able to determine the expected delay for each approach

during the peak hours. Four out of the five approach delays were under the project goal of 55 seconds. The SIDRA analysis confirmed a one lane roundabout with dedicated right hand turn lanes at three of the approaches would be sufficient for this particular intersection. The results of the SIDRA analysis are shown in Figure 11.

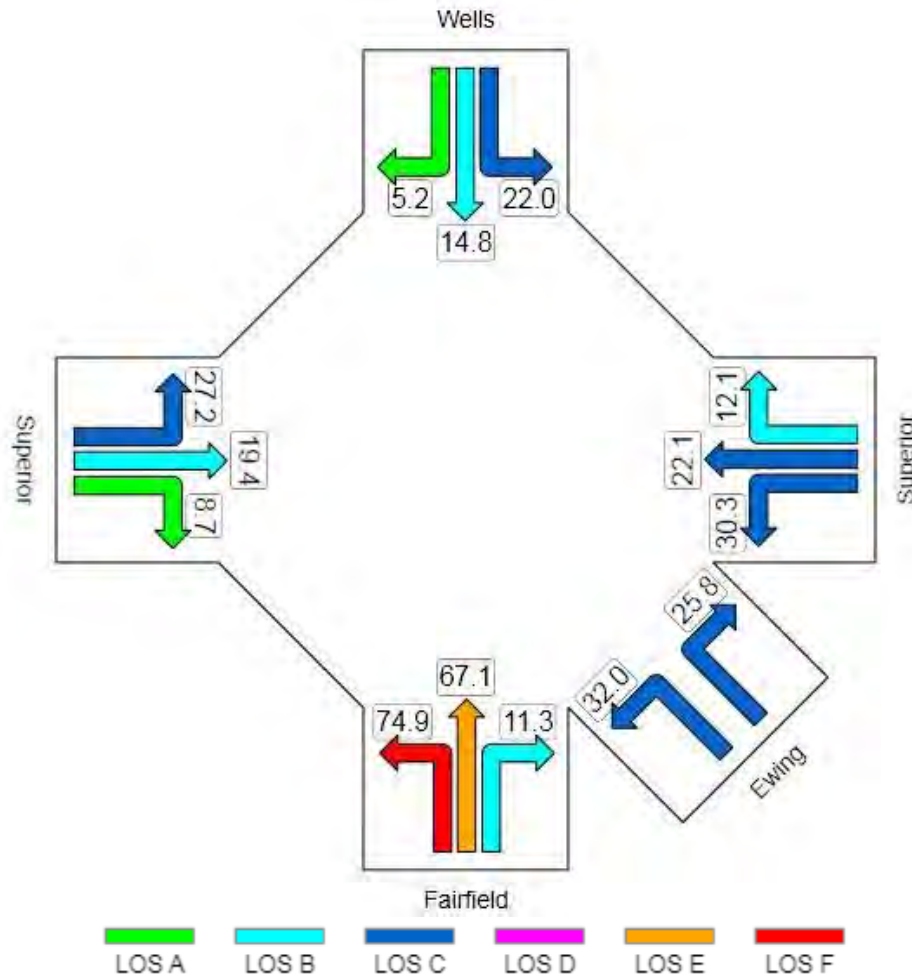


Figure 11 - Roundabout Approach Delays based on SIDRA Analysis

4.1.3. ArcGIS

After each reported crash, police officers enter information into a form which is compiled into a statewide database. Using the database for the Fort Wayne area, problematic intersections in the network were identified. Each crash record in the database contains: latitude and longitude, vehicles involved, injuries, deaths, weather conditions, estimated damage, and several other factors which may have contributed to the accident.

Using the software program ArcGIS, the crashes were geocoded, displaying them in the aerial photo shown in Figure 12. Once the crashes were visible on the map, potentially problematic intersections were identified using the Identify tool. By selecting each individual point on the map, all the crashes that occurred at that particular point are displayed.



Figure 12 - Geocoded Crash Data

When zoomed into a particular intersection such as Superior Street and Wells Street shown in Figure 13, it appears only four crashes occurred in a three year period, but actually over twenty accidents ensued in this particular intersection. As previously mentioned, many accidents are represented by each point on the map, and the Identify tool must be used to detect all the the crashes.

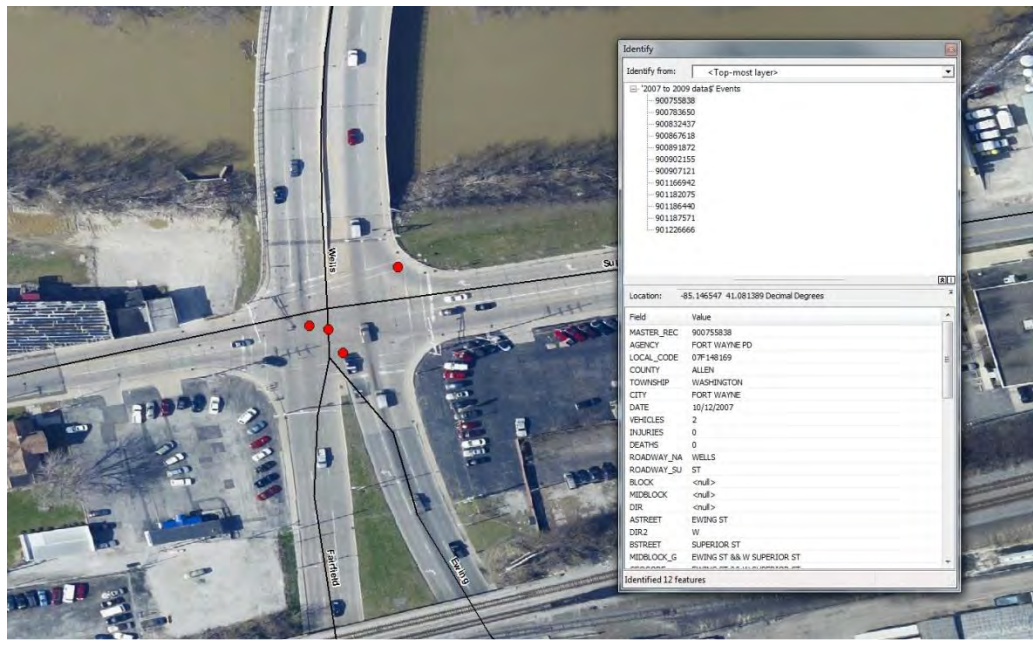


Figure 13 - Geocoded Crash Data at Superior Street & Wells Street

After analyzing the geocoded crashes, it became apparent the intersections with the highest crash rates were Superior Street and Wells Street, Fairfield Avenue and Main Street, and Ewing Street and Main Street. In order to determine the extent of the problem at each intersection, the following data was retrieved from the crash database: vehicles involved, number of individuals injured, deaths, and estimated damage. Tables 2-4 display the values corresponding to those particular intersections in each of the three years recorded in the database.

Table 4 - Crash Analysis at Fairfield Avenue & Main Street

Fairfield Avenue & Main Street					
Year	Crashes	Vehicles Involved	# Injured	Deaths	Estimated Damage
2007	18	36	7	0	\$130,000.00
2008	12	25	9	0	\$130,000.00
2009	11	23	3	0	\$52,750.00
Total	41	84	19	0	\$312,750.00

Table 5 - Crash Analysis at Ewing Street & Main Street

Ewing Street & Main Street					
Year	Crashes	Vehicles Involved	# Injured	Deaths	Estimated Damage
2007	13	25	2	0	\$106,750.00
2008	8	21	2	0	\$80,000.00
2009	15	30	1	0	\$120,750.00
Total	36	76	5	0	\$307,500.00

Table 6 - Crash Analysis at Superior Street & Wells Street

Superior Street & Wells Street					
Year	Crashes	Vehicles Involved	# Injured	Deaths	Estimated Damage
2007	8	16	5	0	\$50,750.00
2008	5	9	1	0	\$20,000.00
2009	8	17	1	0	\$58,250.00
Total	23	42	7	0	\$129,000.00

From the compiled data for the three problematic intersections, it became apparent the most accidents with greatest numbers injuries were occurring on Main Street. Both intersections in the network on Main Street tallied over \$300,000 in damages, which indicated a possible configuration change. In order to justify any changes, accidents per million entering vehicles (RMEV) was calculated with the equation shown below. Typically, RMEV values less than 2.0 are acceptable and do not require any alterations. The total RMEV for each of the three intersections is shown in Table 7.

$$RMEV = \frac{\text{Crashes Per Year}}{\text{Approach ADT} * 365} * 10^6$$

Table 7 - Crash Frequency Analysis

Intersection	Crashes Per Year	ADT	RMEV
Superior Street & Wells Street	7.67	33700.00	0.62
Main Street & Ewing Street	12.00	22587.50	1.46
Main Street & Fairfield Avenue	13.67	21337.50	1.75

The RMEV values for the three intersections fell below the critical value of 2.0, indicating a major change was not necessary. Even though there were not major issues with the intersections on Main Street were approaching a dangerous level. Therefore, the current four-lane design on Main Street will be converted to a three-lane design with a dedicated left turn in each direction. The left turn movements will also be given a protected left turn providing a safer movement for those users.

4.2. Detailed Plans

4.2.1. Geometric Design

AutoCAD Civil 3D is a powerful and efficient software program for civil engineers because it simplifies certain tasks that normal AutoCAD cannot, such as making alignments and creating intersections. This project took advantage of AutoCAD Civil 3D's features of creating alignments and designing a single lane roundabout based on AASHTO standards. The first step in creating the roundabout involved using a pre-existing tutorial file that already had a surface layer for which the roundabout may be constructed on. Then an alignment for each roadway at the intersection was created using the AutoCAD's built in AASHTO standards with a $\pm 2\%$ super elevation for drainage. From this point it is possible to use AutoCAD's "create roundabout" feature.

By following the AutoCAD's tutorial, the intersection was created (see Geometric Design, Details for input data), though it had a few flaws. The approach lane on E. Superior Street was not created, but AutoCAD had a built in feature to allow for adding additional approach lanes. The next part was to determine how to handle the exiting number of lanes at each approach of the roundabout in order to be efficient and help with vehicular delay. It was decided that the option to add right turn slip lane would be the best choice. AutoCAD Civil 3D again provides necessary tools to add turn slip lanes. Following the tutorial and using basic AutoCAD tools for modification such as offset, copy, delete, and so on, turn slip lanes were added to W. Superior, E. Superior, Wells, and Ewing Street. A right turn slip lane was not added to Fairfield as this would need the addition of another lane and would likely not benefit that approach. Wells Street was converted from a 6-lane approach to a 4-lane approach in order to work effectively with the single lane roundabout.

The last section of the design is placing the signage in the correct location. AutoCAD Civil 3D provides a set of default signs that are to be used with recommended distances. These signs follow the MUTCD and IDM requirements. Some of the signs on the drawing, such as the pedestrians cross walk and the yield signs, exist in AutoCAD Civil 3D by default, but have been modified in order to follow the requirements of this project.

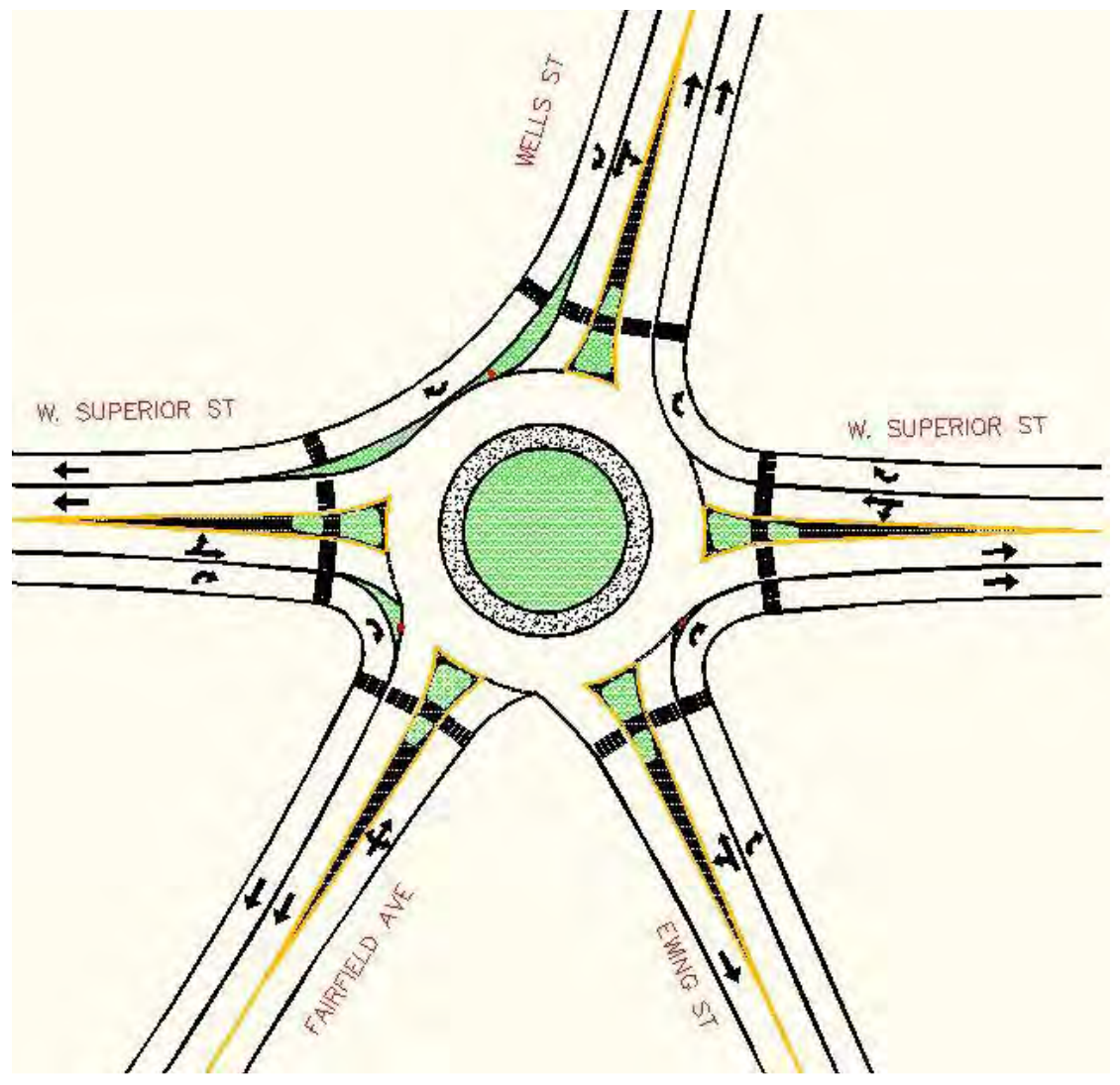


Figure 14 - General Layout of AutoCAD Design

4.2.2. Roundabout Definitions

- 1) Approach Design Speed - The design speed of the roadway leading into the roundabout.
- 2) Bypass Lane - A lane that separates right-turn movements from the roundabout-circulating traffic.
- 3) Central Island - The area of the roundabout inside the circulatory roadway including the truck apron.
- 4) Central-Island Diameter - The diameter of the central island, including the truck apron.
- 5) Circulatory Lane - A lane used by vehicles circulating in the roundabout.
- 6) Circulatory Roadway - The travel lanes adjacent to the central island and outside the truck apron, including the entire circumference of the circle.
- 7) Circulatory-Roadway Width - The width between the outer edge of the inscribed diameter at the curb face of this roadway and the central island curb face. It is typically 1 to 1.2 times the width of the widest entry width. It does not include the width of a traversable apron, which is defined to be part of the central island. The circulatory roadway width defines the roadway width, curb face to curb face, for vehicle circulation around the central island.
- 8) Conflict Point - A point where traffic streams cross, merge, or diverge.
- 9) Deflection - The change in the path of a vehicle imposed by the geometric features of a roundabout, resulting in a slowing of vehicles.
- 10) Entry Angle - The angle between the entry roadway and the circulating roadway, measured at the yield line.
- 11) Entry Lane - The lane or set of lanes for traffic approaching the roundabout.
- 12) Entry Radius - The radius of curvature of the outside curb face at the exit.
- 13) Entry Width - The width of the roadway where it enters the roundabout. It is measured perpendicularly from the outside curb face to the inside curb face at the splitter-island point nearest the inscribed circle.
- 14) Exit Lane - The lane or set of lanes for traffic leaving the roundabout.
- 15) Exit Radius - The radius of curvature of the outside curb at the exit.
- 16) Exit Width - This defines the width of the exit where it meets the inscribed circle. It is measured perpendicularly from the right curb-face edge of the exit to the intersection point of the left curb-face edge and the inscribed circle.
- 17) Fastest Path - The shortest possible route that a single vehicle can travel through a roundabout in the absence of other traffic, and ignoring all lane markings. The fastest path determines the fastest possible entering, exiting, and circulating speeds within a roundabout.
- 18) Flare Length - The distance over which the approach roadway widens to the entry width, if such flaring is present.

- 19) Half Width, V - The width of the existing approach roadway before it starts to widen, if flaring is present.
- 20) Inscribed Circle - The outer edge of the circulatory roadway.
- 21) Inscribed-Circle Diameter - The outside diameter of the inscribed circle measured from face of curb to face of curb.
- 22) Landscaping Buffer - Often provided to separate vehicular and pedestrian traffic and to encourage pedestrians to cross only at the designated crossing locations. A landscaping buffer can also improve the aesthetics of the intersection.
- 23) Natural Vehicle Path - The path that a driver will navigate a vehicle given the layout of the intersection and the ultimate destination.
- 24) Path Overlap - This occurs where the natural path of a vehicle traveling through a roundabout overlaps the path of an adjacent vehicle.
- 25) Pedestrian Crossing - This is typically located about 10 ft before the yield line and is usually a painted crosswalk. A pedestrian crossing allows a pedestrian to cross in one direction of vehicle travel at a time and provides median refuge in the splitter island.
- 26) Roundabout - A circular at-grade intersection with yield control of all entering traffic, channelized approaches with raised splitter islands, counterclockwise circulation, and appropriate geometric curvature.
- 27) Splitter Island - The raised island at each two-way leg between entering and exiting vehicles, designed primarily to control entry and exit speeds by providing deflection. It also prevents wrong-way movements and provides pedestrian refuge.
- 28) Truck Apron - The paved portion of the central island located adjacent to the circulating roadway. It is defined by a sloping curb on the outside and helps accommodate large trucks.
- 29) Yield-at-Entry - The requirement that vehicles on all entry lanes must yield to vehicles within the circulatory roadway.
- 30) Yield Line - A pavement marking used to mark the point of entry from an approach into the circulatory roadway and is marked along the inscribed circle.

4.2.3. Geometric Components

The geometric design of a roundabout is much different than that of a traditional intersection. Safety is still the main focus as always, but the way in which safety is obtained is drastically different. To obtain this safety in roundabouts, the most critical design aspect is to determine the appropriate vehicular speed through the roundabout. In order to determine the best speed in a roundabout one must find the fastest path allowed by the geometry of the roundabout. This speed will be determined by the alignment of

the roundabout and also the smallest radius (usually inscribed circle) within the fastest allowable path.

According to the FHWA, the roundabout is optimally located when the centerlines of all approach legs pass through the center of the inscribed circle. If this is not possible, a slight offset to the left of the inscribed circle is acceptable.

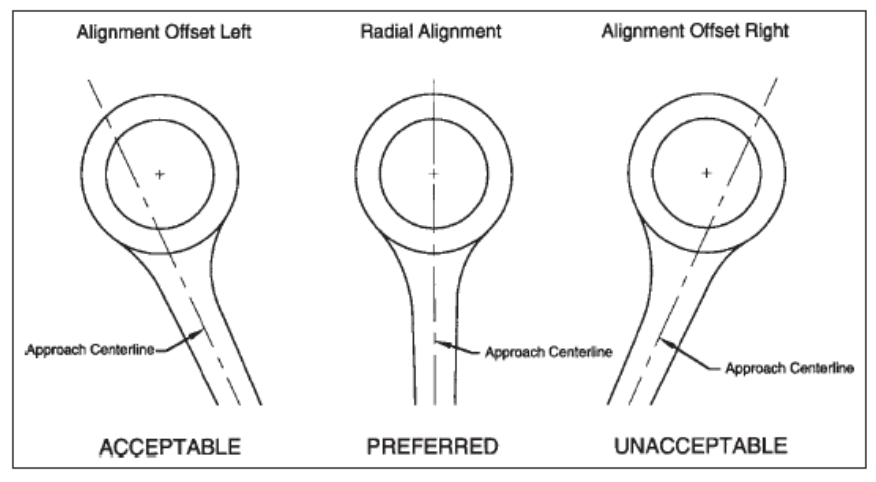


Figure 15 - Acceptable, Preferred, and Unacceptable Alignments

The purpose of these alignments is to slow the entry and exit of vehicles entering and leaving the roundabout. To sharp of a tangential entry (as seen in Figure 14) will not slow a vehicle down enough to allow safe passage to other vehicles and pedestrians. If possible, it would be preferred that all entries are equally spaces apart (i.e. 3 entries 120 degrees apart, 4 entries 90 degrees apart). The design chosen for this project will be difficult to have all legs entering in the preferred radial alignment since there are five incoming approaches. Four of the five legs will have radial alignment with Wells Street being the only leg with a slight right offset alignment. This configuration is acceptable as the island diameter will be large enough to counteract this alignment problem, forcing vehicles to slow down to a safe speed.

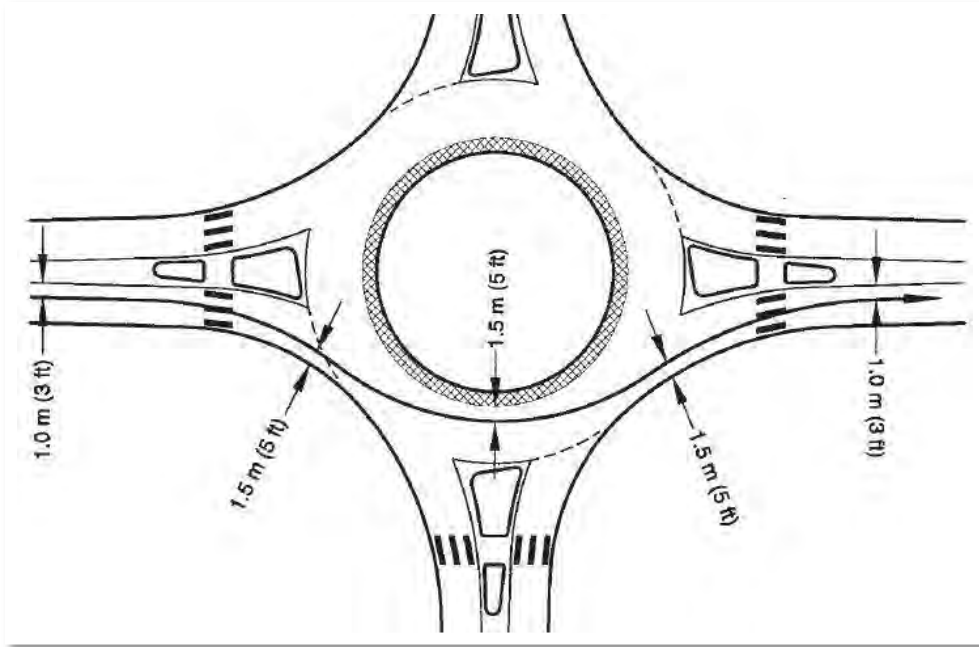


Figure 16 - Fastest Path for Single Lane Urban Roundabout

The next step is to calculate the design speed using the equation given by the Federal Highway Administration:

$$V = \sqrt{15 * R * (e + f)}$$

where, V= velocity, R = smallest radius of through path, e = super elevation, f = side friction factor.

The super elevation is usually assumed to be +0.02 and -0.02 for entry and exit curves respectively. According to the Indiana design guide the roundabout speed is determined by the fastest path allowed by the geometry of the roundabout. This is the smoothest, flattest path possible for a single vehicle, in the absence of other traffic and ignoring all lane markings, traversing through the entry, around the central island, and out the exit. Thus, the fastest path and design speed was found after inputting the given alignments and dimensions of the roundabout using AutoCAD Civil 3D. Figure 16 shows fastest path for which the design velocity will be found given an arbitrary roundabout.

The first area to look at of the geometric elements in a roundabout is the inscribed circle diameter. The inscribed circle diameter is determined by many different design objectives and often times the designer must experiment with different diameters in order to find the optimal size. The FHWA actually supplies a range of given inscribed circle diameters based on whether the location of the roundabout is urban or rural, single lane or

double lane. Table 8 shows the recommended inscribed circle diameter range for a roundabout depending on the number of circulatory lanes and location.

Table 8 - Recommended Values for Inscribed Circle Diameter Given by the FHWA

Site Category	Typical Design Vehicles	Inscribed Circle Diameter Range (ft)
Mini-Roundabout	Single-Unit Truck	45-80
Urban Compact	Single-Unit Truck/Bus	80-100
Urban Single Lane	WB-15 (WB-50)	100-130
Urban Double Lane	WB-15 (WB-50)	150-180
Rural Single Lane	WB-20 (WB-67)	115-130
Rural Double Lane	WB-15 (WB-50)	180-200

The design vehicle is the largest vehicle the roundabout is expected to handle safely. For example, a WB-50 would be a semi-truck with a 50 foot trailer attached. After using SIDRA and Synchro it was determined that a single lane urban roundabout would be the best choice for the given network. The roundabout design at the intersection of Wells and Superior will be expected to handle vehicles as large as WB-67. Since the single lane roundabout will need to be designed to handle a slightly larger vehicle, the inscribed circular diameter chosen was 130 feet in order to handle the larger vehicle while taking up as little right-of-way as possible. This inscribed circle will include the lane width, truck apron, and the center island. The lane width needs to have necessary space in order to accommodate for the design vehicle, in this case a WB-65. According to the FHWA roundabout guide, the lane width should be at least as wide as the maximum entry width (up to 120% of the maximum entry width). Therefore, the lane width was chosen to be equal to the maximum entry width of the roundabout design, 20 feet. The truck apron is a raised portion on pavement on the outer edge of the central island. Note: the truck apron is technically part of the central island, but for design parameters it was chosen to explain them as separate entities. This portion of pavement acts as an extra lane for large vehicles by allowing the back wheels of the truck to ride up on the truck apron so the truck can complete its turn easily and safely. The raised section of pavement will discourage smaller vehicles from using this truck apron. It is recommended that the truck apron be between 3 and 13 feet. For this design, a truck apron of 10 feet was chosen. The last section of the inscribed circle is the central island. The central island is in most inner part of the roundabout and should always be raised from the ground so that drivers will be able to easily recognize. The central island plays a vital role in determining how much vehicles will be deflected as they travel through the roundabout. This portion will encompass the remaining space inside the inscribed circle diameter, 70 feet.

The next step added the addition of a turn slip lane for right turning movements only. This was done in order to conform better to the existing roadway conditions and improve delay times without adding a second lane to the roundabout. The only approach that did

not receive a right turn slip lane was Fairfield Street since the existing three-lane geometry of the roadway would not allow this addition. The next part of the design will be to determine the entry and exit widths.

Entry widths play a vital role in the capacity and safety of a roundabout. Entry widths need to be kept at a minimum to maximize safety (slowing vehicles down) while also being able to achieve the necessary capacity demand. According to the INDOT design guide, entry widths are to be measured perpendicularly from the outside curb face to the inside curb face at the splitter island point nearest to the inscribed circle. Entry widths are preferred to be narrow in order to increase safety; however, a WB-65 vehicle will require an 18 to 22 ft entry width. By increasing the entry width or flare length, the capacity of the roundabout will greatly increase. For this design, an entry width of 20-21 feet was chosen in order to balance the need for capacity and safety while also being able to support a WB-65 trailer. Exit widths need to be at least the same size as the circulatory width, 20 feet. In order to determine the radii of the entry and exit curves, AutoCAD Civil 3D was used. AutoCAD allowed each entry and exit curve to be optimally designed using the existing alignments and AutoCAD's built in AASHTO Design Standards. The entry curve controls, in part, the amount of deflection imposed on vehicles entering the roundabout, thus decreasing or increasing the speed of the vehicle. The FHWA recommends the entry radii to be between 33 to 98 feet for a single lane urban roundabout.

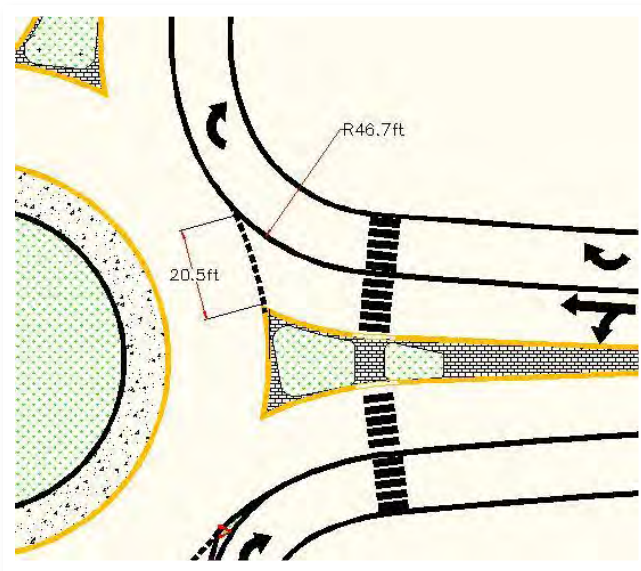


Figure 17 - Example of Entry Width and Entry Radii

Exits usually have larger radii to help minimize congestion of those vehicles exiting while at the same time making sure the radius is small enough to maintain low speeds for pedestrians who may be crossing. Like the entry radii, AutoCAD determined the best radii for the existing alignment of the roadway for the exit radii. According to the FHWA design guide, exit radii should be no less than 50 feet unless the intersection has a lot of pedestrian activity. In that case the exit radii may be as low as 33 to 39 feet. For this design AutoCAD chose the best radii for the exit on each leg based on the given alignments and the chosen inscribed circle diameter. Figure 18 below shows the exit radii on East Superior Street.

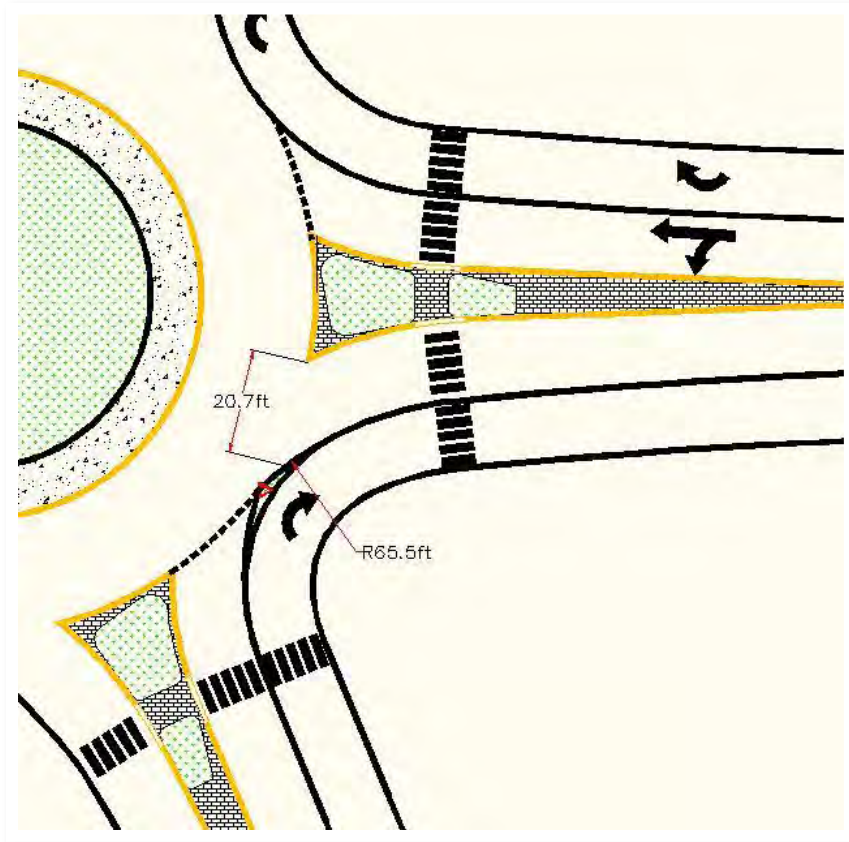


Figure 18 - Description of Exit Radii

The effective flare length for an approach may be from 15 feet to as long as 330 feet, see Figure 18. According to the INDOT design guide, after the effective flare length exceeds 330 feet, its impact on capacity will become minimal. Using AutoCAD, it was determined that the best flare length for the given roadway alignment would be around 140 feet for each leg.

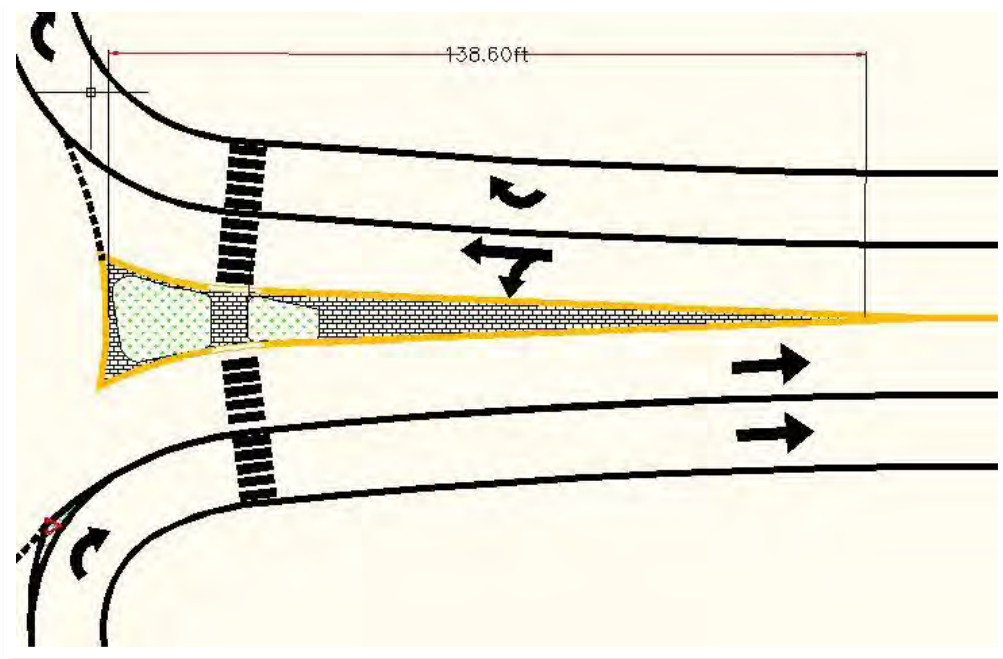


Figure 19 - Dimensions of General Flare Length

The next section to be considered is for pedestrians and the splitter islands. Pedestrian safety and pedestrian convenience is very important in the design of roundabout where pedestrians are present. At the intersection of Superior Street and Wells Street there will be a steady amount of pedestrian traffic, so this was taken into account in the design of the roundabout. In order to account for pedestrian convenience and pedestrian safety it is important to make the crosswalks as close to the intersection as possible without putting the pedestrian in danger. The reason for this is that pedestrians will normally find the quickest path and if the crosswalk is inconvenient the pedestrian may look for a shorter path and put themselves and vehicles in danger. One way to help keep the pedestrian crosswalk close to the intersection, while keep the pedestrian safe, is to have a splitter island that is easily accessible. The splitter island actually has multiple functions. It not only makes a safe haven for pedestrians crossing traffic, but also helps guide traffic into the roundabout and separate opposing flows of traffic. The splitter island can also be used as a place for mounting signs. According the FHWA design guide, the pedestrian refuge space provided by the splitter island should be a minimum width of 6 feet in order to adequately provide shelter for persons pushing a stroller or using a bicycle. The design manual also states that the pedestrian crossing should be located 20-25 feet away from the yield line.

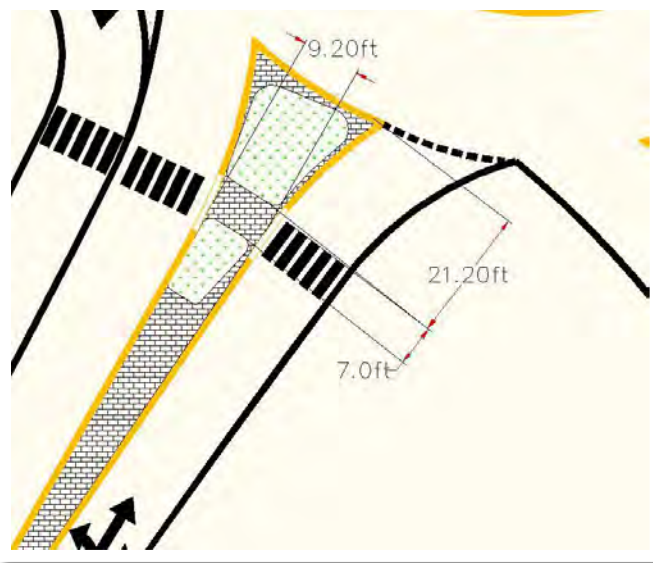


Figure 20 - Dimensions of Splitter Island

4.2.4. Other Changes to Existing Roadway

The following section will discuss changes that were made to the existing roadway with regards to the chosen design alternative. This design alternative includes changing Fairfield, Ewing, & Brackenridge Street to 2-way streets as opposed to the current 1-way conditions. There will also be a 2-way turn lane added to the center lane on Fairfield and Ewing Street. Lastly, the lane configuration on Main Street will also be changed from a 4-lane 2-way road to a 3-lane 2-way road with dedicated right hand turns. Because there will be no change to the actual roadway geometry the ease of converting the 1-way roads to 2-way with a 2-way center turn lane will be fairly easy since Fairfield and Ewing currently have three lanes in one direction. This means that using the current roadway it will be possible to change the 1-way traffic to 2-way traffic with a center turn lane by changing the striping on the road, as well as the addition of signal lights and changing the signal timings. This striping will of course follow the guidelines specified in the MUTCD. The lane widths will stay at the current lane widths of 12ft.

Brackenridge Street is currently a single lane 1-way road with public parking on both sides of the street. The southern parking lots will be kept while the northern parking lots will be converted into a driving lane in order to make Brackenridge a 2-way street. Brackenridge will also keep the lane widths at 12ft in order to keep the existing geometry. The only addition to the changes made at Brackenridge will be a stop sign at the intersection of Brackenridge and Fairfield in accordance to the MUTCD.

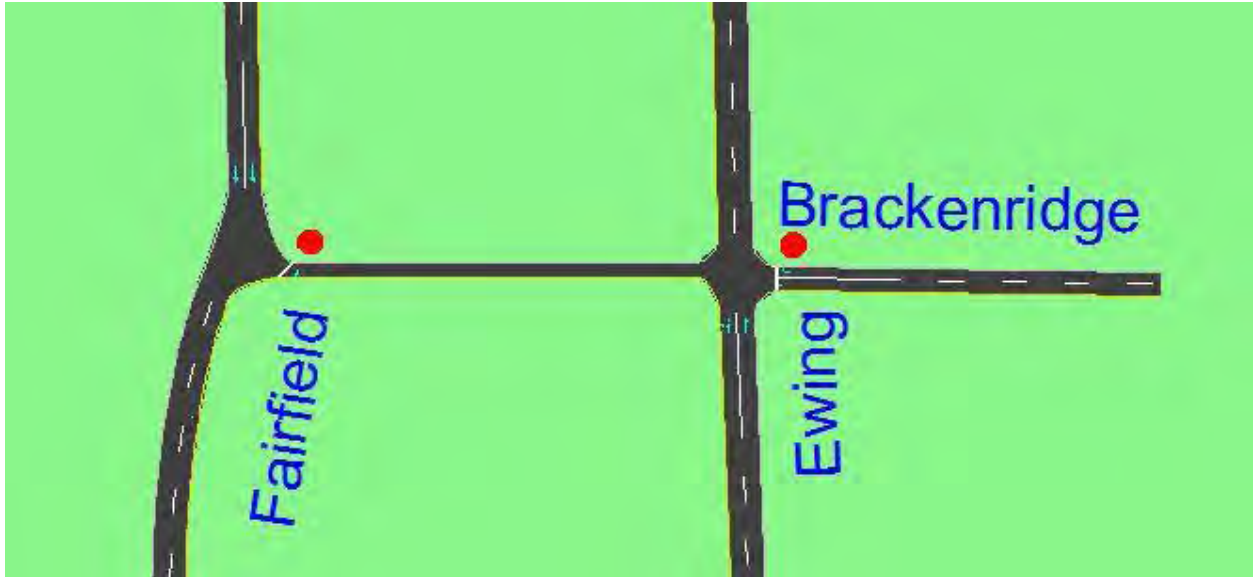


Figure 21 - Current Geometric Conditions on Brackenridge Street

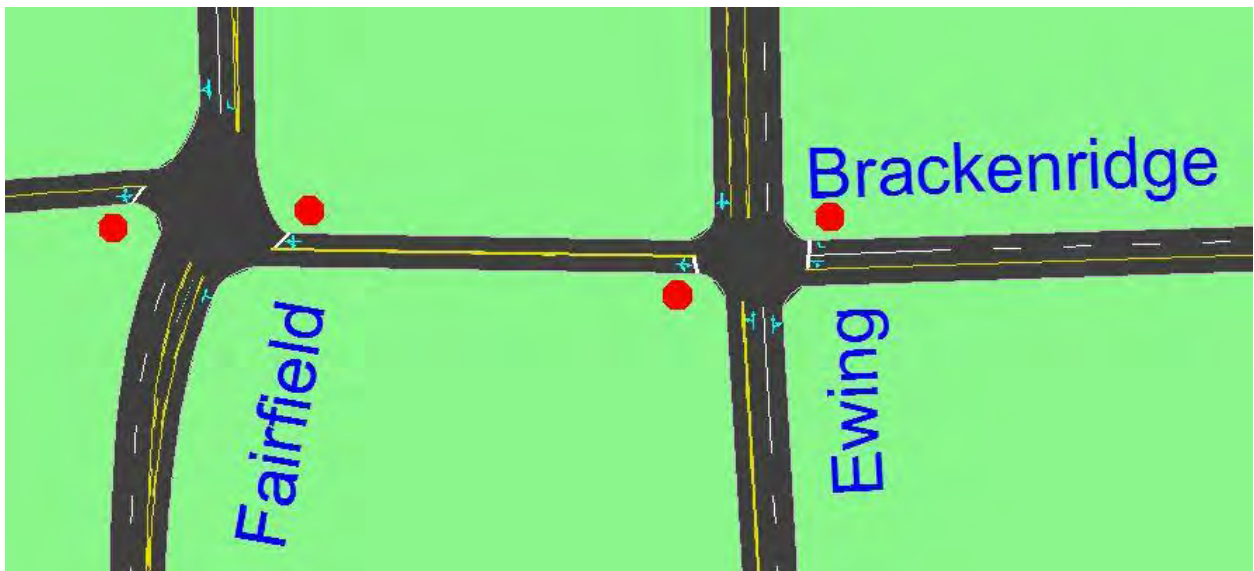


Figure 22 - Future Geometric Conditions on Brackenridge Street

Concerning the changes made to the signalized intersections on Fairfield and Ewing Street, there will be a dedicated left hand turn installed at all approaches as well as new signal lights for the new approaches. The dedicated left hand turns will also be 12ft in order to stay with the geometric constraints. Since the lane configurations and traffic volumes will be changing, the signal timings will also be changing. Using Synchro,

optimized signal timings were obtained and may be found in the appendix for more details.

The changes made to Main Street will also follow a similar concept as the changes made on Fairfield, Ewing, and Brackenridge. In order to improve safety and traffic delay, it has been found that changing Main Street to a 3-lane 2-way road with dedicated right hand turns would be the best option. The lane configurations will be changed by changing the paint markings and signals to coincide with the new lane configuration in accordance with the MUTCD. The three lanes will stay at the standard width of 12ft. This will add extra space on the edges of Main Street since there will be one less lane. The extra space may be turned into more parking spaces, extra sidewalk room, or even a bicycle lane. Currently, it has not been fully determined what to do with this extra space. Having a meeting with the public and surrounding businesses is likely the best option for determining the most important social use of the extra lane space.



Figure 23 - Current Geometric Conditions on Main Street and Fairfield



Figure 24 - Future Geometric Conditions on Main Street and Fairfield

5. Section V: Cost Analysis/Estimation

5.1. Construction

Based on past experience, roundabout construction typically last less than twelve weeks. During construction of the roundabout, any one roadway will not be completely closed for any more than a four week period. One side of the roundabout will be constructed during an approximate four week period, and traffic will be redirected to opposite of the intersection. Once one side the roundabout is complete, traffic will then be rerouted to the completed side of the roundabout.

Along with the construction of the roundabout, alterations must be made to the north and southbound roads of Fairfield Avenue and Ewing Street. Those modifications include: removing and replacing roadway markings, adding additional signage, and adding and adjusting traffic signal.

5.2. Cost Estimation

To estimate the cost of the materials for the project, the current unit prices utilized by the Indiana Department of Transportation were taken into account. The total material list and costs are shown in Table 9.

Not included in the cost estimation are the engineering, right-of-way, and labor cost. These items could add substantial value to the project, but were not considered in our cost estimate.

Table 9 – Materials Costs

Item	Unit	Quantity	Unit Cost(\$)	Cost (\$)
Asphalt	TON	2718.09	\$130.00	\$353,351.70
Concrete	CYS	249.37	\$130.00	\$32,418.10
Sidewalk Concrete, 6 in.	SYS	144	\$43.04	\$6,197.76
Signs	Each	27	\$22.75	\$614.25
Sign Post, Tubular	LFT	182	\$57.50	\$10,465.00
Loop Detector	Each	10	\$900.00	\$9,000.00
Traffic Signal Head, 3 Face, 12 in. Red, Amber Arrow, Green Arrow	Each	10	\$670.60	\$6,706.00
Fiber Optic Cable, In Conduit	LFT	750	\$3.00	\$2,250.00
Mast Arm, 15 ft.	Each	10	\$518.75	\$5,187.50
Light Standard	Each	4	\$879.26	\$3,517.04
Light Pole, 42 ft. E.M.H., 15 ft. Mast Arm	Each	4	\$1,458.70	\$5,834.80
Lighting Foundation, Concrete, High Mast Tower	Each	4	\$4,585.00	\$18,340.00
Pavement Message Markings, Preformed Plastic, Arrow	LFT	144	\$195.00	\$28,080.00
Transverse Marking, Thermoplastic, Crosswalk, 8 in.	LFT	616	\$1.23	\$757.68
Line, Thermoplastic, Broken, White, 4 in.	LFT	750	\$0.32	\$240.00
Line, Thermoplastic, Solid, White, 4 in.	LFT	1000	\$0.28	\$280.00
Pavement Message Markings, Thermoplastic, Word (Yield)	Each	5	\$110.00	\$550.00
Line, Thermoplastic, Broken, Yellow, 4 in.	LFT	19538	\$0.22	\$4,298.36
Line, Thermoplastic, Solid, Yellow, 4 in.	LFT	24739	\$0.27	\$6,679.53
Transverse Marking, Thermoplastic, Stop Line, 24, in.	LFT	112	\$4.22	\$472.64
Pavement Message Markings, Thermoplastic, Word (Only)	Each	23	\$75.38	\$1,733.74
Pavement Message Markings, Thermoplastic, Word (Stop)	Each	8	\$67.00	\$536.00
Total				\$465,722.00

- CYS: cubic yards
- LFT: linear foot
- SYS: square yards

6. Conclusion

For the downtown roadway network of Fairfield Avenue and Ewing Street bounded by Superior Street on the north and Baker Street on the south, several modifications will aid the City of Fort Wayne in improving mobility to key areas in the downtown region and accessibility through the network.

Keeping level of service, accessibility, mobility, cost, safety, environmental impact, and public acceptance in mind, some of the modifications include the implementation of:

- Two-Way Travel on Fairfield Avenue, Ewing Street, and Brackenridge Street
- Two-way left turn lanes on Fairfield Avenue and Ewing Street
- Converting Main Street from four lanes to a three lanes with dedicated left turn lanes
- Dedicated left-hand turns at all signalized intersections
- A single lane roundabout at the intersection of Superior Street, Fairfield Avenue, and Ewing Street

By making these adjustments to the network, the downtown area will become more attractive to developers and businesses owners, while maintaining satisfactory vehicular flow and circulation for the 20-year horizon.

7. References

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8. Appendix

8.1. Sample Synchro Network Analysis for Alternative #2a.

Detailed Measures of Effectiveness

3/22/2011

1: Superior St. & Fairfield Ave.

Direction	EB	WB	NB	SB	NW	All
Volume (vph)	715	450	627	682	154	2628
Control Delay / Veh (s/v)	0	0	0	0	0	0
Queue Delay / Veh (s/v)	0	0	0	0	0	0
Total Delay / Veh (s/v)	0	0	0	0	0	0
Total Delay (hr)	0	0	0	0	0	0
Stops / Veh	1.00	1.00	1.00	1.00	1.00	1.00
Stops (#)	715	450	627	682	154	2628
Average Speed (mph)	30	30	30	30	30	30
Total Travel Time (hr)	6	5	2	5	1	18
Distance Traveled (mi)	171	137	67	159	17	551
Fuel Consumed (gal)	11	8	6	10	2	37
Fuel Economy (mpg)	15.6	16.9	10.8	15.4	10.8	14.8
CO Emissions (kg)	0.77	0.57	0.44	0.72	0.11	2.60
NOx Emissions (kg)	0.15	0.11	0.08	0.14	0.02	0.51
VOC Emissions (kg)	0.18	0.13	0.10	0.17	0.02	0.60
Unserviced Vehicles (#)	0	0	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0	0	0

2: Pearl St. & Fairfield Ave.

Direction	EB	WB	NB	SB	All
Volume (vph)	49	49	627	563	1288
Control Delay / Veh (s/v)	17	17	0	0	2
Queue Delay / Veh (s/v)	0	0	0	0	0
Total Delay / Veh (s/v)	17	17	0	0	2
Total Delay (hr)	0	0	0	0	1
Stops / Veh	1.00	1.00	0.07	0.04	0.13
Stops (#)	49	49	45	22	165
Average Speed (mph)	15	7	28	30	25
Total Travel Time (hr)	0	0	1	2	4
Distance Traveled (mi)	7	2	25	60	94
Fuel Consumed (gal)	1	1	1	3	5
Fuel Economy (mpg)	NA	NA	18.9	23.0	18.1
CO Emissions (kg)	0.05	0.04	0.09	0.18	0.36
NOx Emissions (kg)	0.01	0.01	0.02	0.04	0.07
VOC Emissions (kg)	0.01	0.01	0.02	0.04	0.08
Unserviced Vehicles (#)	0	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

3: Pearl St. & Ewing St.

Direction	EB	WB	SE	NW	All
Volume (vph)	49	49	283	182	563
Control Delay / Veh (s/v)	12	12	2	1	3
Queue Delay / Veh (s/v)	0	0	0	0	0
Total Delay / Veh (s/v)	12	12	2	1	3
Total Delay (hr)	0	0	0	0	0
Stops / Veh	1.00	1.00	0.33	0.19	0.40
Stops (#)	49	49	93	34	225
Average Speed (mph)	9	21	27	26	23
Total Travel Time (hr)	0	1	1	0	2
Distance Traveled (mi)	2	11	31	9	52
Fuel Consumed (gal)	0	1	2	1	4
Fuel Economy (mpg)	NA	NA	16.4	NA	13.9
CO Emissions (kg)	0.03	0.06	0.13	0.04	0.26
NOx Emissions (kg)	0.01	0.01	0.03	0.01	0.05
VOC Emissions (kg)	0.01	0.01	0.03	0.01	0.06
Unserviced Vehicles (#)	0	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0	0

4: Main St. & Fairfield Ave.

Direction	EB	WB	NB	SB	All
Volume (vph)	793	731	548	563	2635
Control Delay / Veh (s/v)	67	31	83	75	62
Queue Delay / Veh (s/v)	0	10	0	0	3
Total Delay / Veh (s/v)	67	42	83	75	65
Total Delay (hr)	15	8	13	12	48
Stops / Veh	0.78	0.59	0.82	0.83	0.74
Stops (#)	615	428	450	466	1959
Average Speed (mph)	10	4	3	2	6
Total Travel Time (hr)	22	10	14	12	59
Distance Traveled (mi)	230	44	41	22	337
Fuel Consumed (gal)	24	10	13	12	60
Fuel Economy (mpg)	9.7	4.2	3.0	1.8	5.7
CO Emissions (kg)	1.66	0.72	0.94	0.84	4.16
NOx Emissions (kg)	0.32	0.14	0.18	0.16	0.81
VOC Emissions (kg)	0.38	0.17	0.22	0.20	0.96
Unserviced Vehicles (#)	37	0	39	17	93
Vehicles in dilemma zone (#)	0	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

5: Main St. & Ewing St.

Direction	EB	WB	NB	SB	All
Volume (vph)	650	743	182	188	1763
Control Delay / Veh (s/v)	2	18	17	28	13
Queue Delay / Veh (s/v)	2	0	0	0	1
Total Delay / Veh (s/v)	4	18	17	28	14
Total Delay (hr)	1	4	1	1	7
Stops / Veh	0.14	0.70	0.52	0.79	0.48
Stops (#)	89	519	95	149	852
Average Speed (mph)	20	19	10	5	16
Total Travel Time (hr)	2	10	1	2	15
Distance Traveled (mi)	39	185	13	9	246
Fuel Consumed (gal)	3	13	2	2	20
Fuel Economy (mpg)	15.1	13.9	7.9	4.0	12.4
CO Emissions (kg)	0.18	0.93	0.12	0.16	1.38
NOx Emissions (kg)	0.04	0.18	0.02	0.03	0.27
VOC Emissions (kg)	0.04	0.21	0.03	0.04	0.32
Unserviced Vehicles (#)	0	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0	0

6: Berry St. & Fairfield Ave.

Direction	WB	NB	SB	All
Volume (vph)	576	426	586	1588
Control Delay / Veh (s/v)	22	7	6	12
Queue Delay / Veh (s/v)	0	0	2	1
Total Delay / Veh (s/v)	22	7	8	13
Total Delay (hr)	3	1	1	6
Stops / Veh	0.76	0.35	0.27	0.47
Stops (#)	436	149	160	745
Average Speed (mph)	8	16	16	12
Total Travel Time (hr)	5	2	3	9
Distance Traveled (mi)	37	29	44	109
Fuel Consumed (gal)	6	3	4	13
Fuel Economy (mpg)	5.7	10.9	12.1	8.6
CO Emissions (kg)	0.45	0.19	0.25	0.89
NOx Emissions (kg)	0.09	0.04	0.05	0.17
VOC Emissions (kg)	0.10	0.04	0.06	0.21
Unserviced Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

7: Berry St. & Ewing St.

Direction	WB	NB	SB	All
Volume (vph)	581	141	194	916
Control Delay / Veh (s/v)	15	21	7	14
Queue Delay / Veh (s/v)	0	0	0	0
Total Delay / Veh (s/v)	15	21	7	14
Total Delay (hr)	2	1	0	4
Stops / Veh	0.62	0.71	0.20	0.54
Stops (#)	358	100	39	497
Average Speed (mph)	21	9	17	19
Total Travel Time (hr)	8	1	1	10
Distance Traveled (mi)	156	10	14	179
Fuel Consumed (gal)	10	2	1	13
Fuel Economy (mpg)	15.3	6.3	13.2	14.1
CO Emissions (kg)	0.71	0.11	0.08	0.89
NOx Emissions (kg)	0.14	0.02	0.01	0.17
VOC Emissions (kg)	0.16	0.03	0.02	0.21
Unserviced Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

8: Wayne St. & Fairfield Ave.

Direction	EB	NB	SB	All
Volume (vph)	435	376	650	1461
Control Delay / Veh (s/v)	34	4	6	14
Queue Delay / Veh (s/v)	0	0	1	0
Total Delay / Veh (s/v)	34	4	7	14
Total Delay (hr)	4	0	1	6
Stops / Veh	0.87	0.23	0.31	0.46
Stops (#)	380	88	201	669
Average Speed (mph)	14	21	16	15
Total Travel Time (hr)	8	1	3	12
Distance Traveled (mi)	105	26	44	175
Fuel Consumed (gal)	9	2	4	15
Fuel Economy (mpg)	11.1	14.2	11.5	11.6
CO Emissions (kg)	0.66	0.13	0.27	1.06
NOx Emissions (kg)	0.13	0.03	0.05	0.21
VOC Emissions (kg)	0.15	0.03	0.06	0.25
Unserviced Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

9: Wayne St. & Ewing St.

Direction	EB	NB	SB	All
Volume (vph)	347	126	217	690
Control Delay / Veh (s/v)	5	7	6	6
Queue Delay / Veh (s/v)	0	0	0	0
Total Delay / Veh (s/v)	5	7	6	6
Total Delay (hr)	0	0	0	1
Stops / Veh	0.16	0.25	0.52	0.29
Stops (#)	55	32	112	199
Average Speed (mph)	19	17	17	18
Total Travel Time (hr)	1	1	1	3
Distance Traveled (mi)	22	9	15	46
Fuel Consumed (gal)	2	1	2	4
Fuel Economy (mpg)	14.3	NA	10.0	12.2
CO Emissions (kg)	0.11	0.05	0.11	0.26
NOx Emissions (kg)	0.02	0.01	0.02	0.05
VOC Emissions (kg)	0.03	0.01	0.02	0.06
Unserved Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

23: Washington Blvd & Fairfield Ave.

Direction	WB	NB	SB	All
Volume (vph)	2516	371	630	3517
Control Delay / Veh (s/v)	81	66	39	72
Queue Delay / Veh (s/v)	2	0	1	2
Total Delay / Veh (s/v)	83	66	41	74
Total Delay (hr)	58	7	7	72
Stops / Veh	0.79	0.63	0.62	0.74
Stops (#)	1991	234	390	2615
Average Speed (mph)	3	3	5	3
Total Travel Time (hr)	63	8	9	80
Distance Traveled (mi)	162	24	44	230
Fuel Consumed (gal)	60	7	9	77
Fuel Economy (mpg)	2.7	3.3	4.8	3.0
CO Emissions (kg)	4.20	0.51	0.64	5.35
NOx Emissions (kg)	0.82	0.10	0.12	1.04
VOC Emissions (kg)	0.97	0.12	0.15	1.24
Unserved Vehicles (#)	291	24	0	315
Vehicles in dilemma zone (#)	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

24: Washington Blvd & Ewing St.

Direction	WB	NB	SB	All
Volume (vph)	2236	125	210	2571
Control Delay / Veh (s/v)	12	14	11	12
Queue Delay / Veh (s/v)	2	0	0	1
Total Delay / Veh (s/v)	13	14	11	13
Total Delay (hr)	8	0	1	9
Stops / Veh	0.63	0.48	0.37	0.60
Stops (#)	1412	60	78	1550
Average Speed (mph)	19	11	13	19
Total Travel Time (hr)	23	1	1	25
Distance Traveled (mi)	441	8	15	464
Fuel Consumed (gal)	32	1	1	35
Fuel Economy (mpg)	13.8	8.0	9.7	13.4
CO Emissions (kg)	2.24	0.07	0.10	2.42
NOx Emissions (kg)	0.44	0.01	0.02	0.47
VOC Emissions (kg)	0.52	0.02	0.02	0.56
Unserved Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

27: Jefferson Blvd & Fairfield Ave.

Direction	EB	NB	SB	All
Volume (vph)	2174	288	614	3076
Control Delay / Veh (s/v)	30	20	16	26
Queue Delay / Veh (s/v)	0	0	1	0
Total Delay / Veh (s/v)	30	20	16	26
Total Delay (hr)	18	2	3	22
Stops / Veh	0.86	0.70	0.57	0.79
Stops (#)	1876	203	348	2427
Average Speed (mph)	15	13	10	15
Total Travel Time (hr)	37	3	4	44
Distance Traveled (mi)	565	37	39	642
Fuel Consumed (gal)	47	4	6	56
Fuel Economy (mpg)	12.1	9.6	7.0	11.4
CO Emissions (kg)	3.27	0.27	0.39	3.93
NOx Emissions (kg)	0.64	0.05	0.08	0.76
VOC Emissions (kg)	0.76	0.06	0.09	0.91
Unserved Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

28: Jefferson Blvd & Ewing St.

Direction	EB	NB	SB	All
Volume (vph)	2214	125	205	2544
Control Delay / Veh (s/v)	3	26	16	5
Queue Delay / Veh (s/v)	0	0	0	0
Total Delay / Veh (s/v)	3	26	16	5
Total Delay (hr)	2	1	1	3
Stops / Veh	0.15	0.76	0.40	0.20
Stops (#)	332	95	81	508
Average Speed (mph)	23	13	10	19
Total Travel Time (hr)	7	2	1	10
Distance Traveled (mi)	152	19	13	184
Fuel Consumed (gal)	9	2	2	13
Fuel Economy (mpg)	16.3	9.7	8.1	14.2
CO Emissions (kg)	0.65	0.14	0.12	0.90
NOx Emissions (kg)	0.13	0.03	0.02	0.18
VOC Emissions (kg)	0.15	0.03	0.03	0.21
Unserviced Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

29: Brackenridge & Fairfield Ave.

Direction	EB	WB	NB	SB	All
Volume (vph)	36	103	209	417	765
Control Delay / Veh (s/v)	12	11	0	0	2
Queue Delay / Veh (s/v)	0	0	0	0	0
Total Delay / Veh (s/v)	12	11	0	0	2
Total Delay (hr)	0	0	0	0	0
Stops / Veh	1.00	1.00	0.00	0.05	0.21
Stops (#)	36	103	0	19	158
Average Speed (mph)	14	13	30	30	26
Total Travel Time (hr)	0	1	1	2	3
Distance Traveled (mi)	3	7	16	53	80
Fuel Consumed (gal)	0	1	1	2	4
Fuel Economy (mpg)	NA	6.6	NA	23.0	17.8
CO Emissions (kg)	0.03	0.08	0.05	0.16	0.31
NOx Emissions (kg)	0.01	0.01	0.01	0.03	0.06
VOC Emissions (kg)	0.01	0.02	0.01	0.04	0.07
Unserviced Vehicles (#)	0	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0	0

Detailed Measures of Effectiveness

3/22/2011

30: Brackenridge & Ewing St.

Direction	EB	WB	NB	SB	All
Volume (vph)	36	173	112	155	476
Control Delay / Veh (s/v)	11	11	1	1	5
Queue Delay / Veh (s/v)	0	0	0	0	0
Total Delay / Veh (s/v)	11	11	1	1	5
Total Delay (hr)	0	1	0	0	1
Stops / Veh	1.00	1.00	0.14	0.12	0.51
Stops (#)	36	173	16	19	244
Average Speed (mph)	13	18	27	29	22
Total Travel Time (hr)	0	1	0	1	3
Distance Traveled (mi)	3	24	7	24	57
Fuel Consumed (gal)	0	2	0	1	4
Fuel Economy (mpg)	NA	10.1	NA	21.6	13.5
CO Emissions (kg)	0.03	0.16	0.03	0.08	0.29
NOx Emissions (kg)	0.01	0.03	0.01	0.01	0.06
VOC Emissions (kg)	0.01	0.04	0.01	0.02	0.07
Unserved Vehicles (#)	0	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0	0

31: Baker St & Fairfield Ave.

Direction	NB	SB	All
Volume (vph)	233	418	651
Control Delay / Veh (s/v)	0	0	0
Queue Delay / Veh (s/v)	0	0	0
Total Delay / Veh (s/v)	0	0	0
Total Delay (hr)	0	0	0
Stops / Veh	1.00	0.00	0.36
Stops (#)	233	0	233
Average Speed (mph)	30	30	30
Total Travel Time (hr)	0	1	1
Distance Traveled (mi)	12	32	44
Fuel Consumed (gal)	2	1	3
Fuel Economy (mpg)	6.8	24.3	14.2
CO Emissions (kg)	0.12	0.09	0.22
NOx Emissions (kg)	0.02	0.02	0.04
VOC Emissions (kg)	0.03	0.02	0.05
Unserved Vehicles (#)	0	0	0
Vehicles in dilemma zone (#)	0	0	0

Detailed Measures of Effectiveness

3/22/2011

32: Baker St & Ewing St.

Direction	EB	WB	SB	All
Volume (vph)	176	75	156	407
Control Delay / Veh (s/v)	13	9	7	10
Queue Delay / Veh (s/v)	0	0	0	0
Total Delay / Veh (s/v)	13	9	7	10
Total Delay (hr)	1	0	0	1
Stops / Veh	0.49	0.49	1.49	0.88
Stops (#)	87	37	233	357
Average Speed (mph)	13	20	15	15
Total Travel Time (hr)	1	1	1	2
Distance Traveled (mi)	15	11	10	35
Fuel Consumed (gal)	2	1	2	4
Fuel Economy (mpg)	9.4	NA	5.0	8.2
CO Emissions (kg)	0.11	0.05	0.13	0.30
NOx Emissions (kg)	0.02	0.01	0.03	0.06
VOC Emissions (kg)	0.03	0.01	0.03	0.07
Unserviced Vehicles (#)	0	0	0	0
Vehicles in dilemma zone (#)	0	0	0	0

Ewing St.

Direction	NB	SB	All
Control Delay / Veh (s/v)	10	9	10
Queue Delay / Veh (s/v)	0	0	0
Total Delay / Veh (s/v)	10	9	10
Total Delay (hr)	3	4	8
Stops / Veh	0.51	0.50	0.50
Stops (#)	586	804	1390
Average Speed (mph)	14	15	15
Total Travel Time (hr)	6	9	15
Distance Traveled (mi)	91	130	221
Fuel Consumed (gal)	9	13	22
Fuel Economy (mpg)	9.7	10.1	9.9
CO Emissions (kg)	0.66	0.90	1.56
NOx Emissions (kg)	0.13	0.17	0.30
VOC Emissions (kg)	0.15	0.21	0.36
Unserviced Vehicles (#)	0	0	0
Vehicles in dilemma zone (#)	0	0	0
Performance Index	5.0	6.4	11.4

Detailed Measures of Effectiveness

3/22/2011

Fairfield Ave.

Direction	NB	SB	All
Control Delay / Veh (s/v)	22	16	19
Queue Delay / Veh (s/v)	0	1	0
Total Delay / Veh (s/v)	22	17	19
Total Delay (hr)	22	24	47
Stops / Veh	0.55	0.45	0.49
Stops (#)	2029	2288	4317
Average Speed (mph)	9	12	11
Total Travel Time (hr)	32	41	72
Distance Traveled (mi)	276	497	773
Fuel Consumed (gal)	39	51	90
Fuel Economy (mpg)	7.1	9.8	8.6
CO Emissions (kg)	2.73	3.55	6.28
NOx Emissions (kg)	0.53	0.69	1.22
VOC Emissions (kg)	0.63	0.82	1.46
Unserved Vehicles (#)	63	17	80
Vehicles in dilemma zone (#)	0	0	0
Performance Index	28.0	30.5	58.6

Network Totals

Number of Intersections	17
Control Delay / Veh (s/v)	23
Queue Delay / Veh (s/v)	1
Total Delay / Veh (s/v)	24
Total Delay (hr)	181
Stops / Veh	0.58
Stops (#)	16031
Average Speed (mph)	12
Total Travel Time (hr)	298
Distance Traveled (mi)	3524
Fuel Consumed (gal)	366
Fuel Economy (mpg)	9.6
CO Emissions (kg)	25.60
NOx Emissions (kg)	4.98
VOC Emissions (kg)	5.93
Unserved Vehicles (#)	408
Vehicles in dilemma zone (#)	0
Performance Index	225.4

8.2. SIDRA Roundabout Analysis

INTERSECTION SUMMARY

Superior Street & Wells Street
Roundabout

Intersection Performance - Hourly Values		
Performance Measure	Vehicles	Persons
Demand Flows (Total)	2857 veh/h	3428 pers/h
Percent Heavy Vehicles	2.0 %	
Degree of Saturation	1.393	
Practical Spare Capacity	-39.0 %	
Effective Intersection Capacity	2051 veh/h	
Control Delay (Total)	68.41 veh-h/h	82.09 pers-h/h
Control Delay (Average)	86.2 sec	86.2 sec
Control Delay (Worst Lane)	216.2 sec	
Control Delay (Worst Movement)	216.2 sec	216.2 sec
Geometric Delay (Average)	2.6 sec	
Stop-Line Delay (Average)	86.2 sec	
Intersection Level of Service (LOS)	LOS F	
95% Back of Queue - Vehicles (Worst Lane)	61.8 veh	
95% Back of Queue - Distance (Worst Lane)	1569.4 ft	
Total Effective Stops	6364 veh/h	7637 pers/h
Effective Stop Rate	2.23 per veh	2.23 per pers
Proportion Queued	0.91	0.91
Performance Index	187.6	187.6
Travel Distance (Total)	1031.8 veh-mi/h	1238.2 pers-mi/h
Travel Distance (Average)	1907 ft	1907 ft
Travel Time (Total)	105.0 veh-h/h	126.0 pers-h/h
Travel Time (Average)	132.3 sec	132.3 sec
Travel Speed	9.8 mph	9.8 mph
Cost (Total)	1538.96 \$/h	1538.96 \$/h
Fuel Consumption (Total)	74.3 gal/h	
Carbon Dioxide (Total)	703.7 kg/h	
Hydrocarbons (Total)	1.323 kg/h	
Carbon Monoxide (Total)	41.61 kg/h	
NOx (Total)	1.203 kg/h	

Level of Service (LOS) Method: Delay & v/c (HCM 2010).

Roundabout LOS Method: Same as Sign Control.

Intersection LOS value for Vehicles is based on average delay for all vehicle movements.

Roundabout Capacity Model: US HCM 2010.

HCM Delay Model used.



Intersection Performance - Annual Values		
Performance Measure	Vehicles	Persons
Demand Flows (Total)	1,371,130 veh/y	1,645,357 pers/y
Delay	32,835 veh-h/y	39,402 pers-h/y
Effective Stops	3,054,723 veh/y	3,665,667 pers/y
Travel Distance	495,274 veh-mi/y	594,329 pers-mi/y
Travel Time	50,382 veh-h/y	60,458 pers-h/y
Cost	738,700\$/y	738,700\$/y
Fuel Consumption	35,665 gal/y	
Carbon Dioxide	337,788 kg/y	
Hydrocarbons	635 kg/y	
Carbon Monoxide	19,975 kg/y	
NOx	577 kg/y	

LANE SUMMARY

Superior Street & Wells Street
Roundabout

Lane Use and Performance																
	Demand Flows				HV	Cap.	Deg. Satn	Lane Util.	Average Delay	Level of Service	95% Back of Queue		Lane Length	SL Type	Cap. Adj.	Prob. Block.
	L	T	R	Total							Vehicles	Distance				
	veh/h	veh/h	veh/h	veh/h	%	veh/h	v/c	%	sec		veh	ft	ft		%	%
South: Fairfield																
Lane 1	133	464	0	597	2.0	428	1.393	100	216.2	LOS F	61.8	1569.4	1600	-	0.0	4.4
Lane 2	0	0	86	86	2.0	428	0.200	14 ⁵	11.5	LOS B	0.7	16.7	1600	-	0.0	0.0
Approach	133	464	86	683	2.0		1.393		190.4	LOS F	61.8	1569.4				
South East: Ewing																
Lane 1	46	0	38	84	2.0	343	0.244	100	15.1	LOS C	0.8	20.0	1600	-	0.0	0.0
Lane 2	0	0	84	84	2.0	343	0.244	100	15.1	LOS C	0.8	20.0	1600	-	0.0	0.0
Approach	46	0	122	167	2.0		0.244		15.1	LOS C	0.8	20.0				
East: Superior																
Lane 1	93	290	0	384	2.0	479	0.802	100	35.5	LOS E	5.9	148.7	1600	-	0.0	0.0
Lane 2	0	0	104	104	2.0	479	0.218	27 ⁵	10.7	LOS B	0.7	18.7	1600	-	0.0	0.0
Approach	93	290	104	488	2.0		0.802		30.2	LOS D	5.9	148.7				
North: Wells																
Lane 1	318	379	0	698	2.0	649	1.076	100	82.1	LOS F	31.8	807.9	1600	-	0.0	0.0
Lane 2	0	0	43	43	2.0	649	0.067	6 ⁵	6.3	LOS A	0.2	5.6	1600	-	0.0	0.0
Approach	318	379	43	741	2.0		1.076		77.6	LOS F	31.8	807.9				
West: Superior																
Lane 1	259	267	0	526	2.0	519	1.014	100	71.3	LOS F	18.0	456.1	1600	-	0.0	0.0
Lane 2	0	0	251	251	2.0	519	0.484	100	15.7	LOS C	2.2	56.5	1600	-	0.0	0.0
Approach	259	267	251	777	2.0		1.014		53.4	LOS F	18.0	456.1				
Intersection				2857	2.0		1.393		86.2	LOS F	61.8	1569.4				

Level of Service (LOS) Method: Delay & v/c (HCM 2010).

Roundabout LOS Method: Same as Sign Control.

Lane LOS values are based on average delay and v/c ratio (degree of saturation) per lane.

LOS F will result if v/c > irrespective of lane delay value (does not apply for approaches and intersection).

Intersection and Approach LOS values are based on average delay for all lanes (v/c not used as specified in HCM 2010).

Roundabout Capacity Model: US HCM 2010.

HCM Delay Model used.

Processed: Friday, April 22, 2011 12:12:34 PM
SIDRA INTERSECTION 5.1.3.1990

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