COMPARATIVE ANALYSIS OF DIVERGING DIAMOND INTERCHANGE AND PARTIAL CLOVERLEAF INTERCHANGE USING MICRO-SIMULATION MODELING"

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By:

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Outline

- Introduction
- □ Literature Review
- Methodology
- Results
- □ Conclusion/Future Research

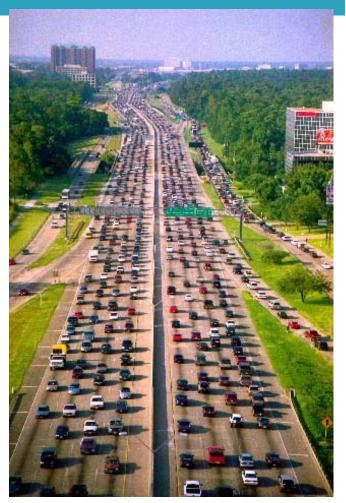
- Motivation
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- Research Objective **OEs**
- **Gpapetoic Freetunge** *
- **Traffic Volume Scenarios** •••
- **Signal Plans/Optimization** * Model
- **Microsimulation Models** *



Motivation

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- **•** Mobility in the U.S. is considered a necessity
- The effectiveness of the transportation
 system is a vital constituent of people's daily
 lives
- Transportation planners and traffic
 engineers are facing the challenge of
 mitigating congestion
- Alleviating delays and improving safety for motor vehicles and pedestrians are primary motives



Source: mobility.tamu.edu

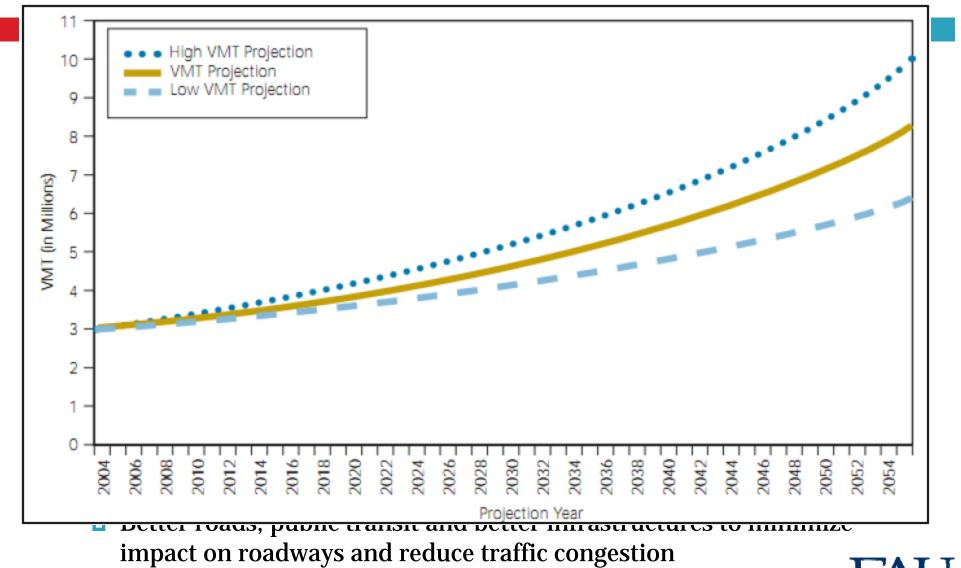


Motivation

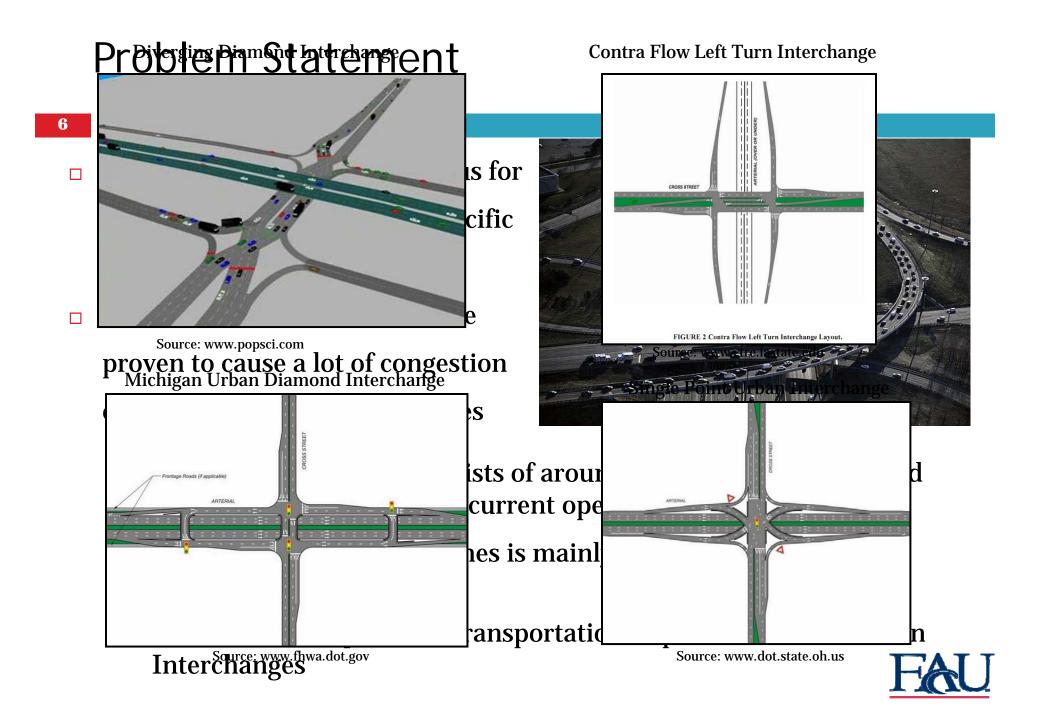
- The United States has always been a very competitive nation in the global economy
 - The system of highways, bridges, public transportation and railroads on which the nation depends have been the main cause
- The development of the Interstate System allowed the U.S. economy in the last half of the 20th century to nourish and grow in size and productivity
- Nowadays, the capacity and the performance of the current Interstate Highway System is too congested
 - Reduction in the ability to sustain the increased productivity the United States will need to compete in the global economy



Problem Statement







Problem Statement

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- The main goal of any well designed interchange is to sustaining
- An interchange is a system of interconnecting roads in conjunction with one or more grade separations that provide movement of traffic between two or more roadways (AASHTO Greenbook)
 - Interchanges can be considered in two categories:
 - System interchanges (freeway-freeway)
 - Service interchanges (freeway -surface street)
 - The type of configuration used at a particular site is determined by:
 - The number of intersection legs, expected volumes of through and turning movements, topography, designer's initiative, etc.



Research Objective

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Determine from an operational and safety aspect if the DDI design operates better at different traffic flow conditions

Source: Guidelines for preliminary selection of the optimum interchange type for a specific location



Literature Review



Diverging Diamond Interchange

- Chlewicki (2003) "New Interchange and Intersection Designs: The Synchronized Split-Phasing Intersection and the Diverging Diamond Interchange"
 - **Introduces a new design "Diverging Diamond Interchange"**
 - The main goal was to better accommodate left turn movements and potentially eliminate a phase in the cycle for the signals
 - The researched showed great potential for the design but further research is recommended
- Bared et. al. (2005) "Design and Operational Performance of Double Crossover Intersection and Diverging Diamond Interchange"
 - **DDI** is compared with the results of conventional diamond interchange
 - For higher traffic volumes the DDI had better performance and for lower and medium volumes the performances of DDI and conventional intersection were similar
 - Cycle length of 70 sec is optimal for lower to medium flows, and a cycle length of 100 sec gives best results for higher flows



Diverging Diamond Interchange con't

- Speth (2007) "A Comparison Analysis of Diverging Diamond Interchange Operations"
 - Discusses the operational benefits of the DDI in comparison to a diamond and a Single Point Urban Interchange (SPUI)
 - **DDI** outperforms the Diamond and the SPUI under all scenarios
 - Future Research: Compare the diverging diamond interchange concept to other interchange configurations, including partial clover and diamond interchanges



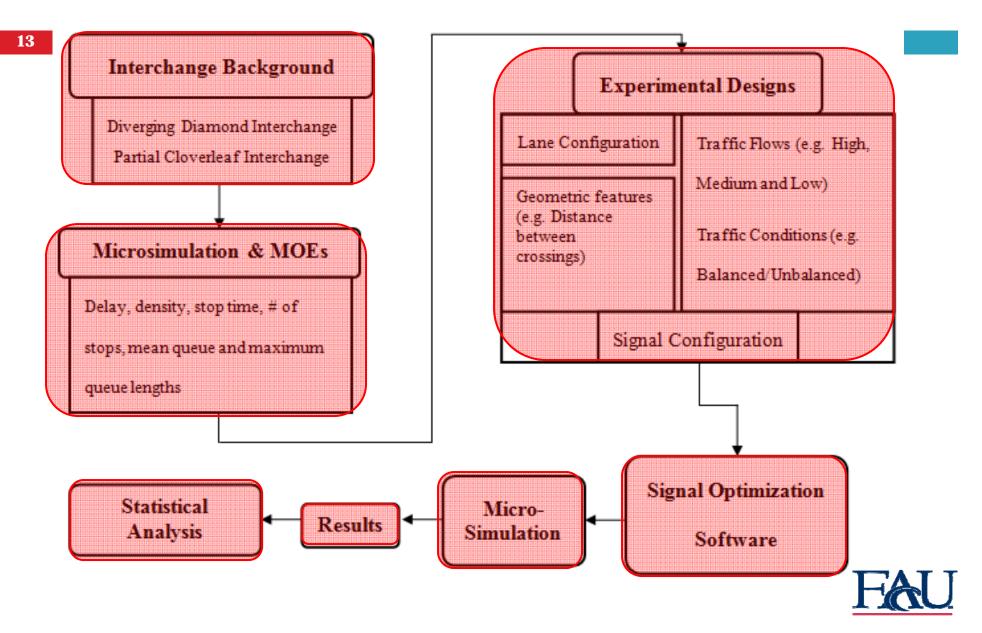
Partial Cloverleaf

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- Milan et. al. (1999) "Comparison of Partial and Full Cloverleaf Interchange Operations Using the CORSIM Microsimulation Model"
 - The partial cloverleaf design accommodates more traffic than the full cloverleaf configuration and also improves the ability to control off-ramp and arterial traffic flows
 - Increase average travel speeds and reduce delay and queuing, and increase the total number of vehicles served in nearly all cases
- Zhang et. al. (2010) "Signal Control of Dual T-Intersections and Partial Cloverleaf Interchanges with One Controller"
 - This paper provides a study on the possibility of controlling two adjacent Tintersections and partial cloverleaf interchanges with one controller
 - Results showed that in the controlling of two adjacent T-intersections, one controller can be used, and the selection of different phasing scheme can yield to different progression performances



Methodology





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Experi

Lane Configuration

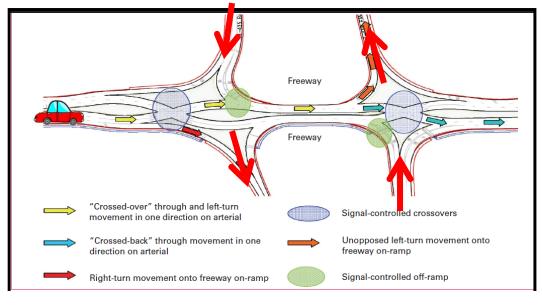
ental Design

Traffic Flows (e.g. High Medium and Low)

Source: Google Earth



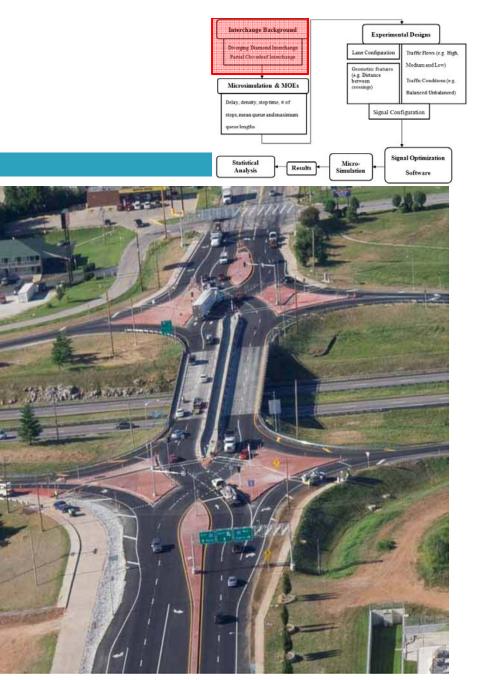
- The DDI is a new interchange design that has gained recognition as a viable interchange design that can improve traffic flow and reduce congestion
- The freeway is connected to the cross street by two on-ramps and two off-ramps in a manner similar to a conventional diamond interchange
- Through and left-turn traffic on the crossroad maneuver differently as the traffic crosses to the opposite side between the ramp terminals
 - Accommodate higher left-turn movements and eliminates a phase in the signal cycle





DDI

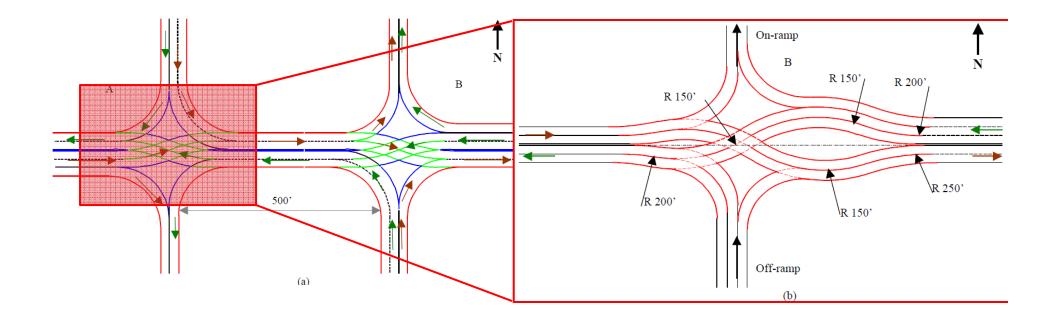
- There are 7 known existing applications of DDI interchanges
 - Missouri
 - Utah
 - Tennessee
 - Kentucky
- The first one in the United States opened to traffic on June 22, 2009, in Springfield, MO



Source: Missouri Department of Transportation



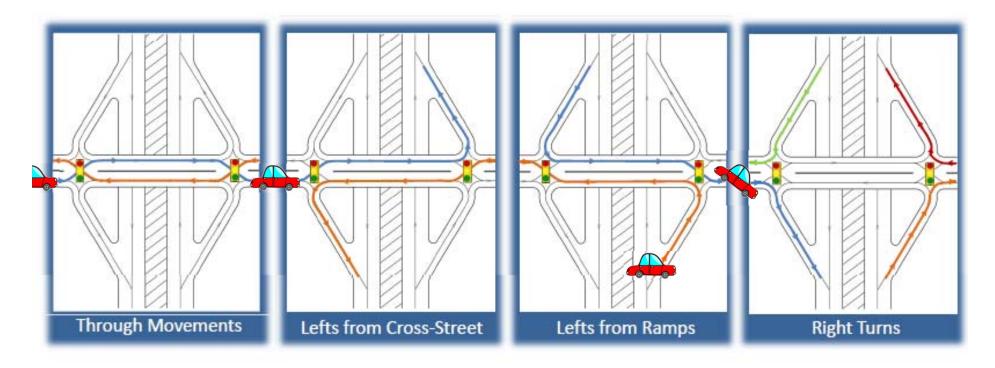




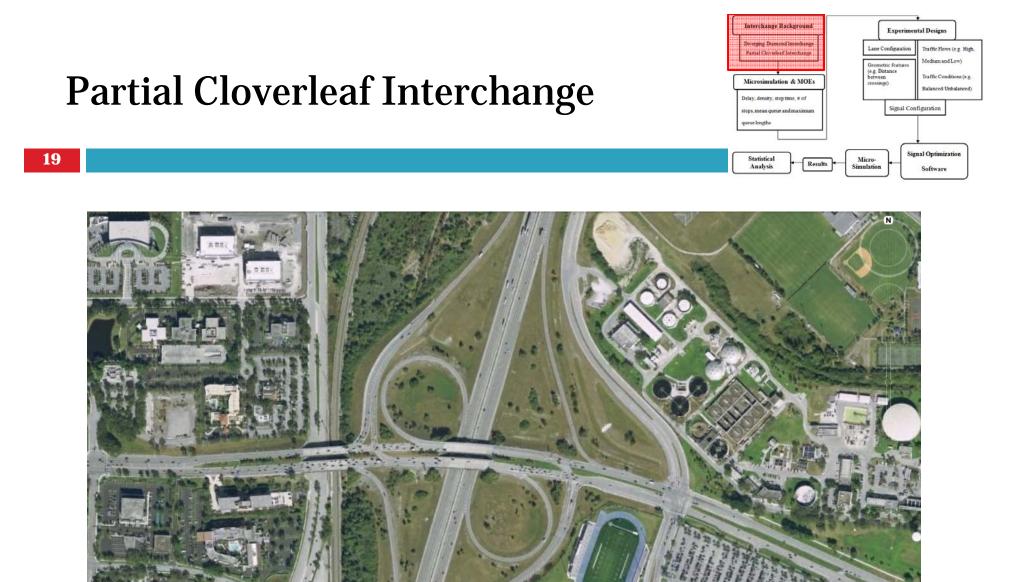




Traffic Movements







I-95 and Glades Rd, in Boca Raton, Florida

Source: Google Earth

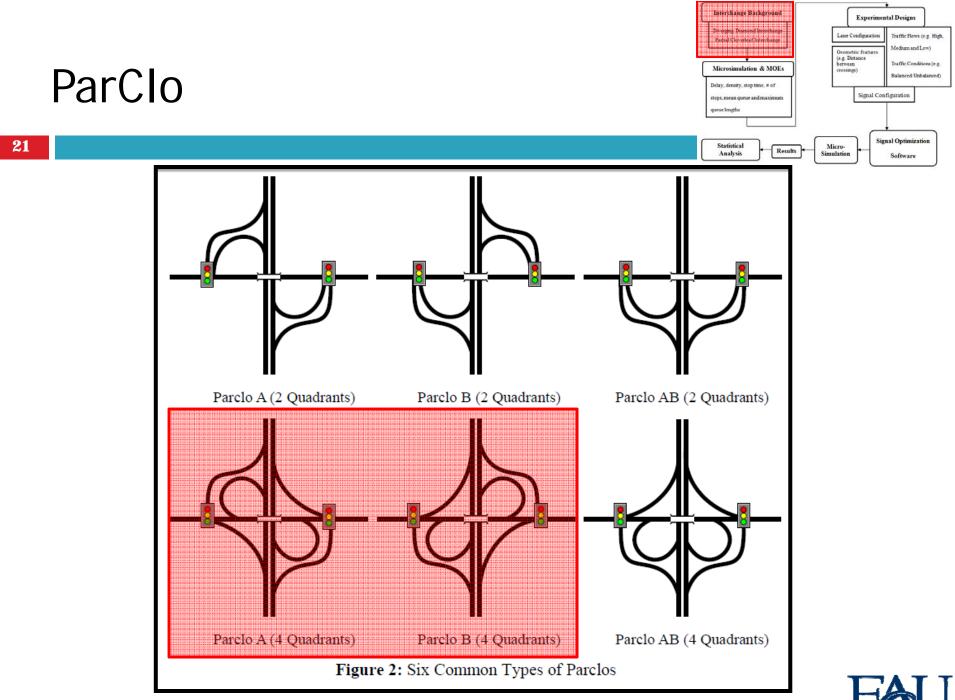


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- Also known as "ParClo" is a modification of a full cloverleaf interchange
- Developed by the Ontario Ministry of Transportation as a replacement for the cloverleaf on 400-Series Highways
 - Removal of dangerous weaving patterns which allowed for more acceleration and deceleration space on the freeway
 - Allows for a high left turn movement
- Partial cloverleaf is now well received as one of the most popular freeway to arterial interchange designs in North America
- **Ramp separation between 600-1000 ft**

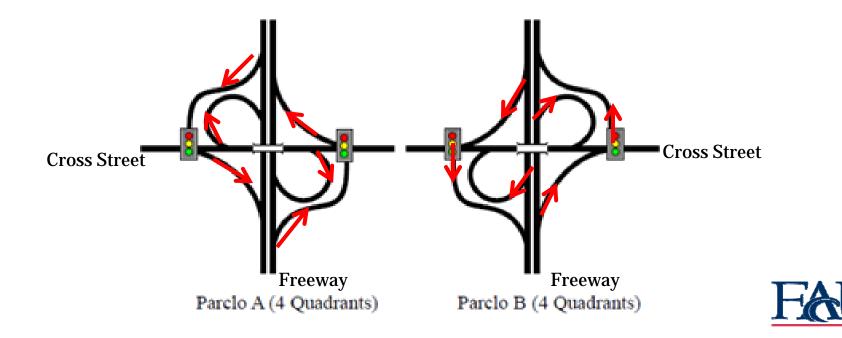




Source: Signal Control of Dual T-intersections and partial cloverleaf interchanges with one controller



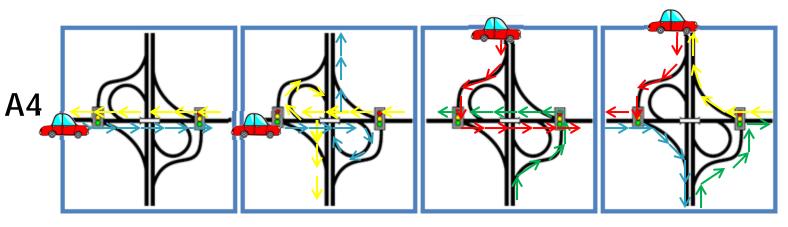
- In a ParClo A4, the freeway is connected to the arterial cross street by four on ramp and two off ramps
- In a ParClo B4, the freeway is connected to the arterial cross street by two on ramps and four off ramp





Traffic Movements

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Through Movements Lefts from Cross-Street Lefts from Ramps Right turns

Lefts from Cross-Street

Lefts from Ramps

Right turns

Micro-simulation

- □ Xiao et al., 2005
 - Compared Vissim and Aimsun using qualitative and quantitative criteria
 - Both simulators are reasonably accurate and selection of the best option is highly subjective

□ AIMSUN 6.0

- Simulation software tool which is able to model and reproduce the traffic conditions of any traffic network
- Presents its output as a real time visual display
- It enables a wide range of network geometries to be dealt with
- It can also model incidents and conflicting maneuvers
- The behavior of every single vehicle is continuously modeled throughout the simulation period
- □ Computer: Intel[®] Core[™] i5 CPU 3.20 GHZ, 4.00 GB of RAM

interchange Background

Diverging Diamond Interchang

dicrosimulation & MOE

Analysi

Partial Cloverleaf Intercha

Experimental Designs

Signal Configuration

Signal Optimization

Software

Traffic Flows (e.g. Hig

Traffic Conditions (e)

Salanced Unbalance

Medium and Lov

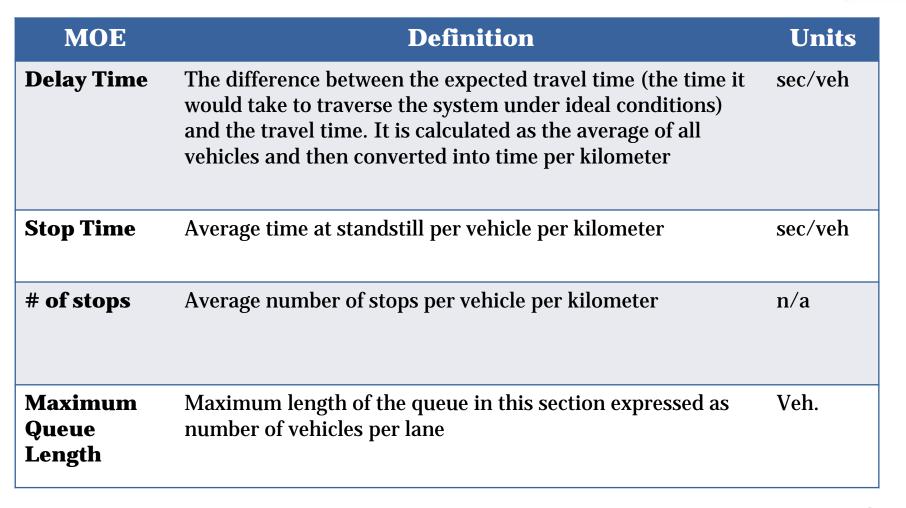
Lane Configuration

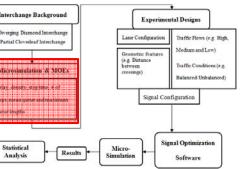
Geometric feature (e.g. Distance

Micro

Results

Measures of Effectiveness (MOEs)



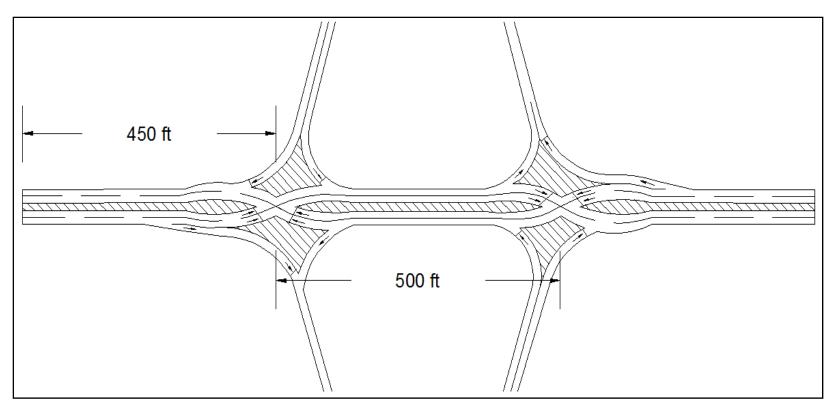




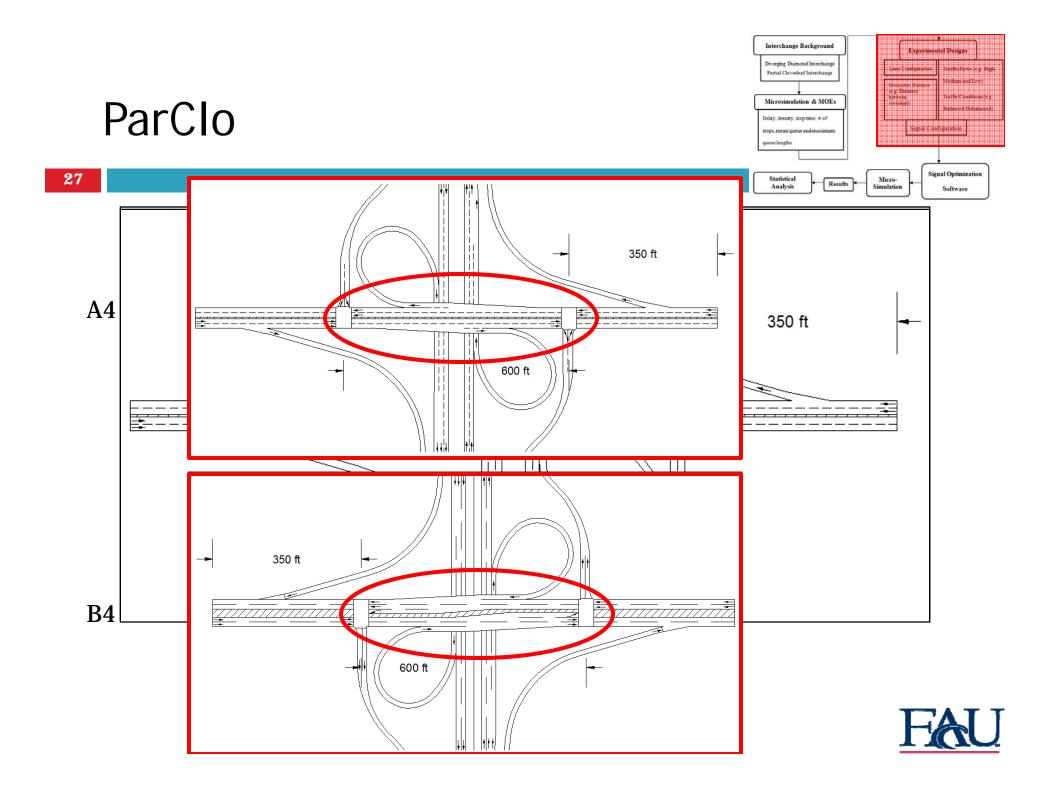
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 Geometry of the interchanges will be based on the geometry from the DDI that opened in 2009 in Springfield





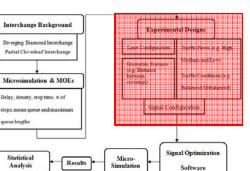




- The traffic volume nows that will be
 - High 3: 6,100 veh/hr
 - High 2: 5,600 veh/hr
 - High 1: 5,100 veh/hr
 - Medium: 3,200 veh/hr
 - Low: 1,700 veh/hr
- **Each of the scenarios will further be divided into:**
 - Balanced Conditions "Opposing movements (e.g. northbound and southbound through) in each phase have the same traffic volume"
 - Unbalanced Condition "One opposing direction has double the flow as the other direction"



Traffic Volume Scenarios



arue lengths

Statistical Analysis

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| a | Cross | Freeway | | | |
|-----------|-------------------|------------|----------------------|--|--|
| Scenarios | Through Movements | Left Turns | Left Turns off-ramps | | |
| 1 | Balanced | Balanced | Balanced | | |
| 2 | Balanced | Balanced | Unbalanced | | |
| 3 | Balanced | Unbalanced | Balanced | | |
| 4 | Balanced | Unbalanced | Unbalanced | | |
| 5 | Unbalanced | Balanced | Balanced | | |
| 6.1* | Unbalanced | Balanced | Unbalanced | | |
| 6.2^ | Unbalanced | Balanced | Unbalanced | | |
| 7 | Unbalanced | Unbalanced | Balanced | | |
| 8.1* | Unbalanced | Unbalanced | Unbalanced | | |
| 8.2^ | Unbalanced | Unbalanced | Unbalanced | | |

*Heavier through volume opposes the heavier left-turn volume

^Heavier through volume opposes the lighter left-turn volume



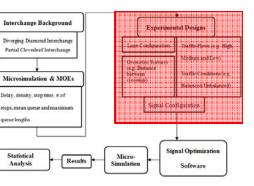
Traffic Volume Scenarios

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Example:

High 3: 6,100 vph

| Traffic | Eastbound Bound | | | Westbound Bound | | | Southbound off-ramp | | Northbound off-ramp | | Total | |
|-----------|-----------------|------|------|-----------------|------|------|------------------------|------|------------------------|------|--------|--|
| Scenarios | Right | Thru | Left | Right | Thru | Left | Right | Left | Right | Left | volume | |
| 1 | 550 | 850 | 450 | 550 | 850 | 450 | 450 | 750 | 450 | 750 | 6100 | |
| 2 | 550 | 850 | 450 | 550 | 850 | 450 | 600 | 1000 | 300 | 500 | 6100 | |
| 3 | 550 | 850 | 300 | 550 | 850 | 600 | 450 | 750 | 450 | 750 | 6100 | |
| 4 | 550 | 850 | 300 | 550 | 850 | 600 | 600 | 1000 | 300 | 500 | 6100 | |
| 5 | 550 | 567 | 450 | 550 | 1133 | 450 | 450 | 750 | 450 | 750 | 6100 | |
| 6.1 | 550 | 567 | 450 | 550 | 1133 | 450 | 600 | 1000 | 300 | 500 | 6100 | |
| 6.2 | 550 | 567 | 450 | 550 | 1133 | 450 | 300 | 500 | 600 | 1000 | 6100 | |
| 7 | 550 | 567 | 300 | 550 | 1133 | 600 | 450 | 750 | 450 | 750 | 6100 | |
| 8.1 | 550 | 567 | 300 | 550 | 1133 | 600 | 600 | 1000 | 300 | 500 | 6100 | |
| 8.2 | 550 | 567 | 300 | 550 | 1133 | 600 | 300 | 500 | 600 | 1000 | 6100 | |







- The traffic signals were coded as pre-timed to reduce the variability in results that can occur when simulating semi or fully actuated signal control
- Synchro 7 was used to develop an optimum timing plan for each scenario
 - Synchro is a macroscopic analysis and optimization software application

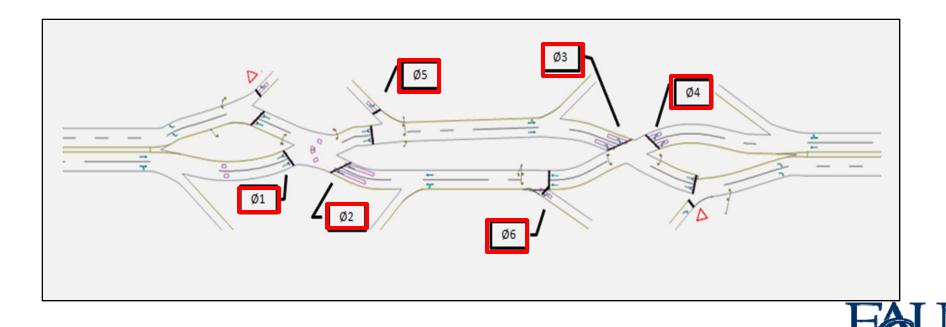


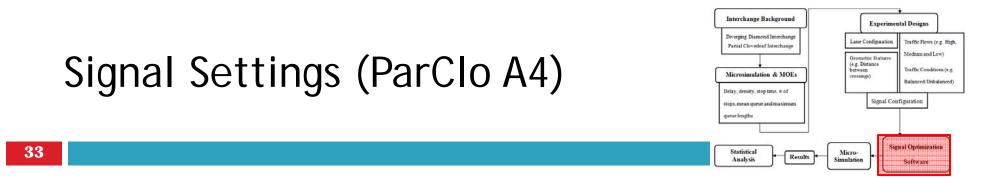
Synchro 7 can optimize cycle lengths, splits and offsets, eliminating the need to try multiple timing plans



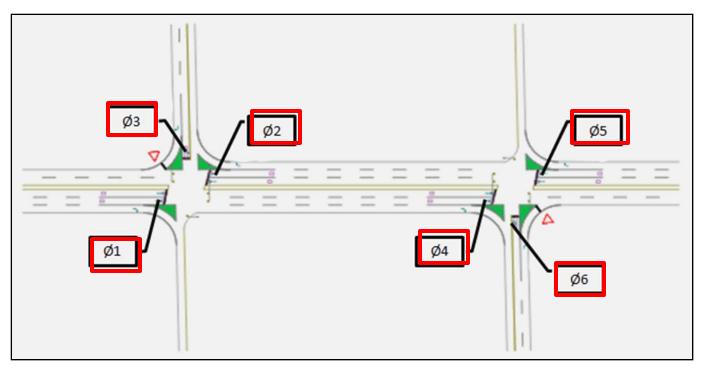


- **DDI** controlled by a two phase operation
- The first phase of the interchange is controlled by phases Ø1, Ø3 and Ø6 and the second phase is controlled by phases Ø2, Ø4 and Ø5

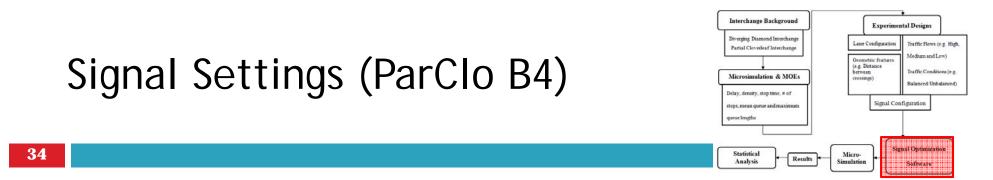




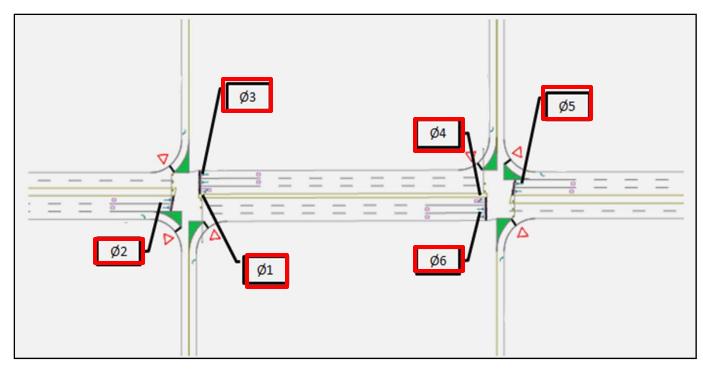
- ParClo A4 controlled by a two phase operation
- The first phase of the interchange is controlled by phases Ø1, Ø2, Ø4 and Ø5 and the second phase is controlled by phases Ø3 and Ø6







- ParClo B4 controlled by a two phase operation
- The first phase of the interchange is controlled by phases Ø2, Ø3, Ø5 and Ø6 and the second phase is controlled by phases Ø1, Ø3, Ø4 and Ø6



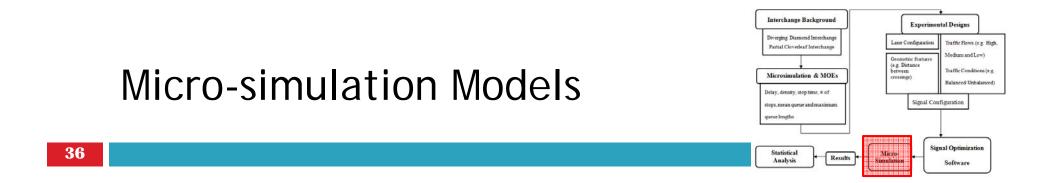


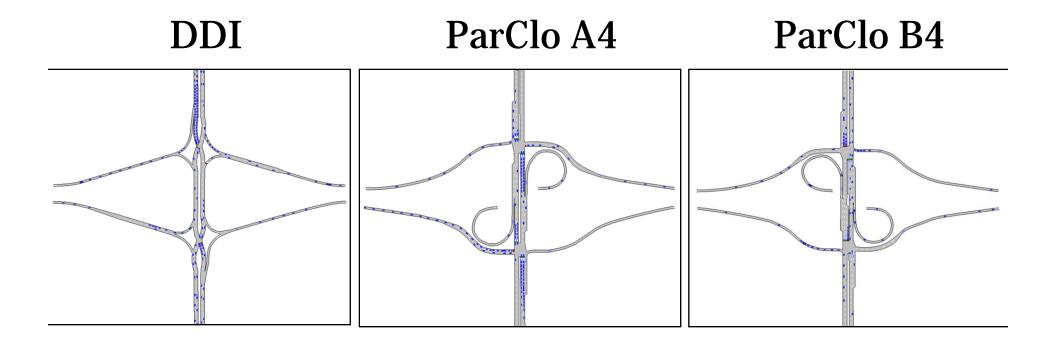


Optimum Cycle lengths for a) DDI with 4 thru lanes b)
 DDI with 6 thru lanes c) ParClo A4 d) ParClo B4

| a |) |] | b) | (| c) | d) | |
|----------------|---------------|----------------|---------------|----------------|---------------|----------------|----------------|
| Traffic Volume | Optimum Cycle | Traffic Volume | Optimum Cycle | Traffic Volume | Optimum Cycle | Traffic Volume | Optimum Volume |
| Scenario | Length (sec) | Scenario | Length (sec) | Scenario | Length (sec) | Scenario | Scenarios |
| High 3 | 100-130 sec | High 3 | 60-80 sec | High 3 | 90-150 sec | High 3 | 55-60 sec |
| High 2 | 90-110 sec | High 2 | 60-80 sec | High 2 | 90-130 sec | High 2 | 50-60 sec |
| High 1 | 75-100 sec | High 1 | 55-70 sec | High 1 | 80-110 sec | High 1 | 45-55 sec |
| Medium | 50-55 sec | Medium | 50 sec | Medium | 40-55 sec | Medium | 40 sec |
| Low | 50 sec | Low | 50 sec | Low | 40 sec | Low | 40 sec |

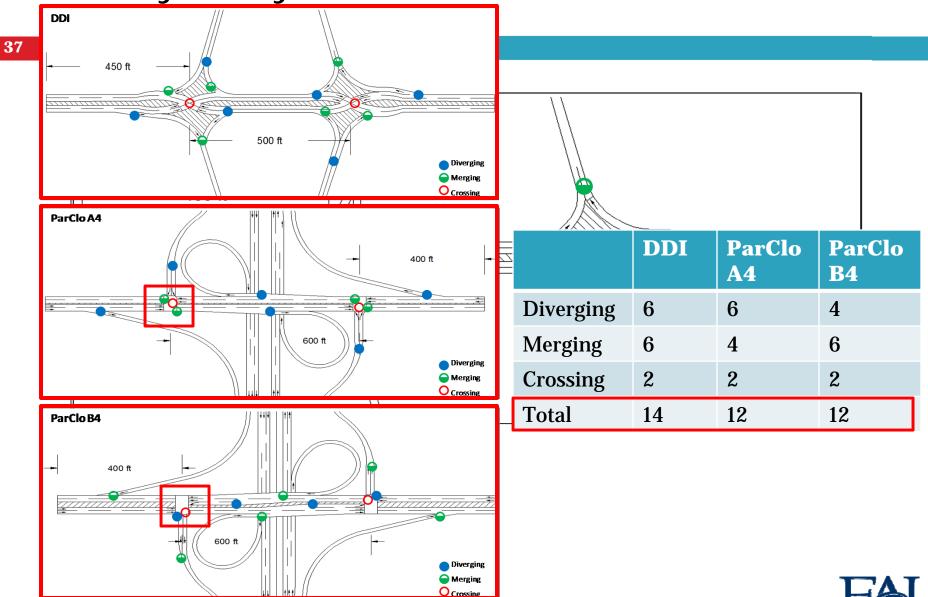




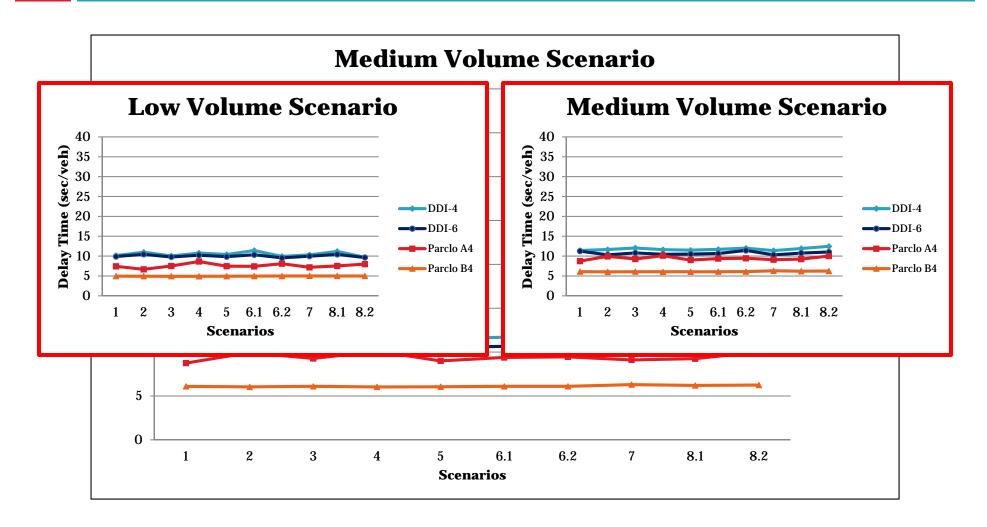




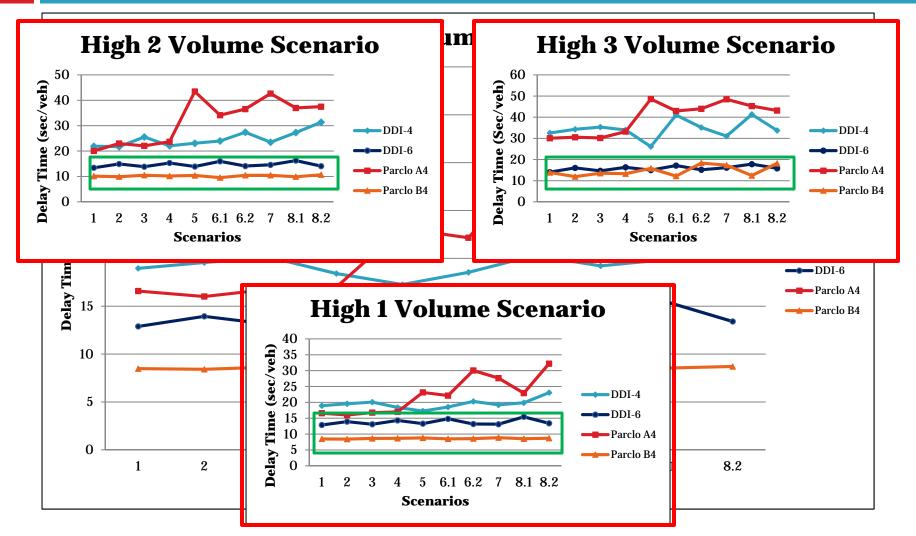
Safety Analysis: Conflict Points



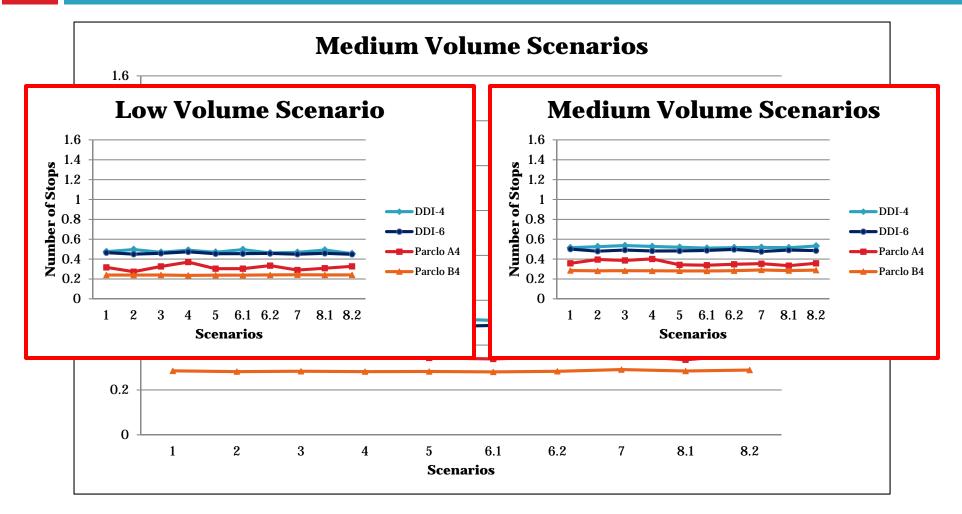
Results for Delay Time (sec/veh)



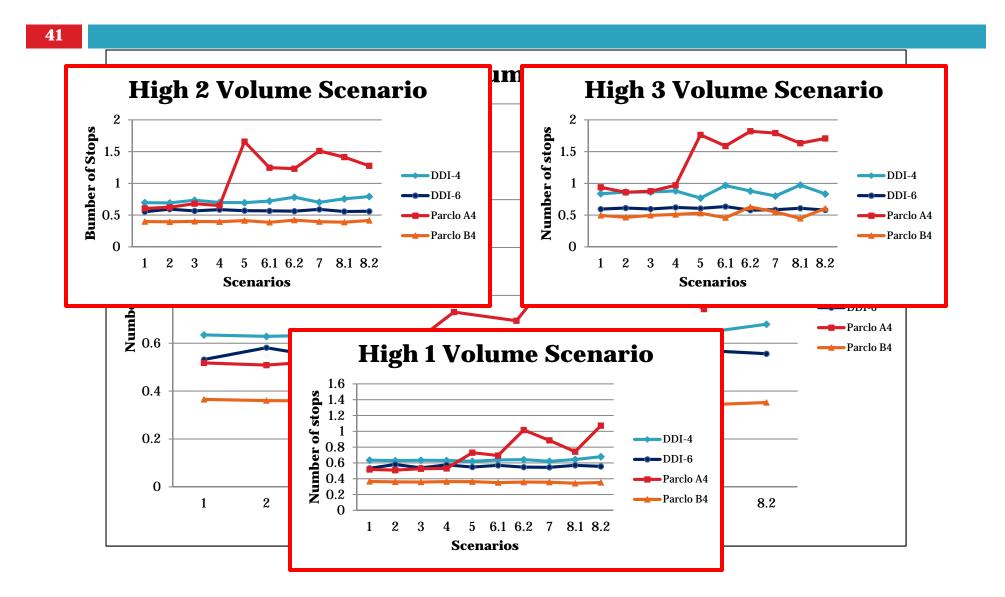
Results for Delay Time (sec/veh)



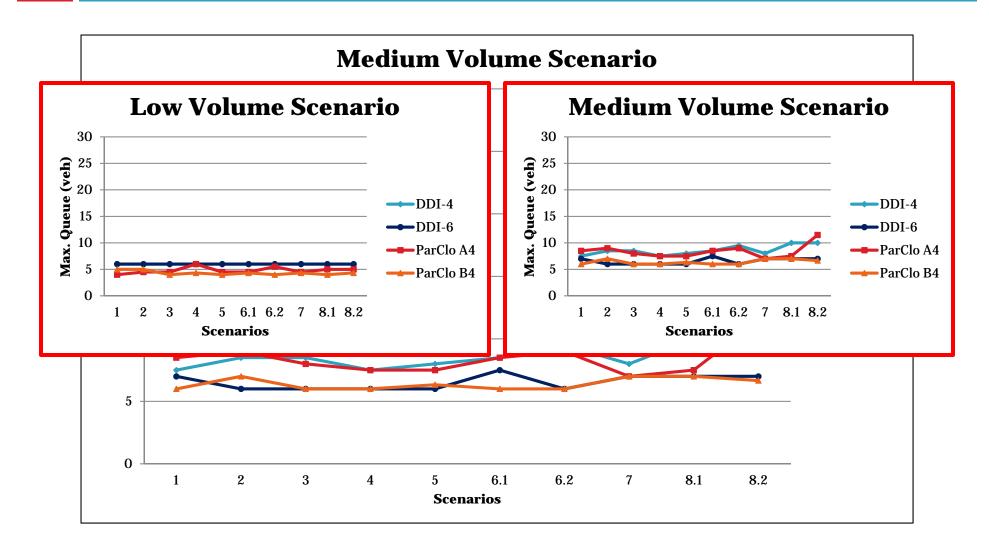
Results for Number of Stops



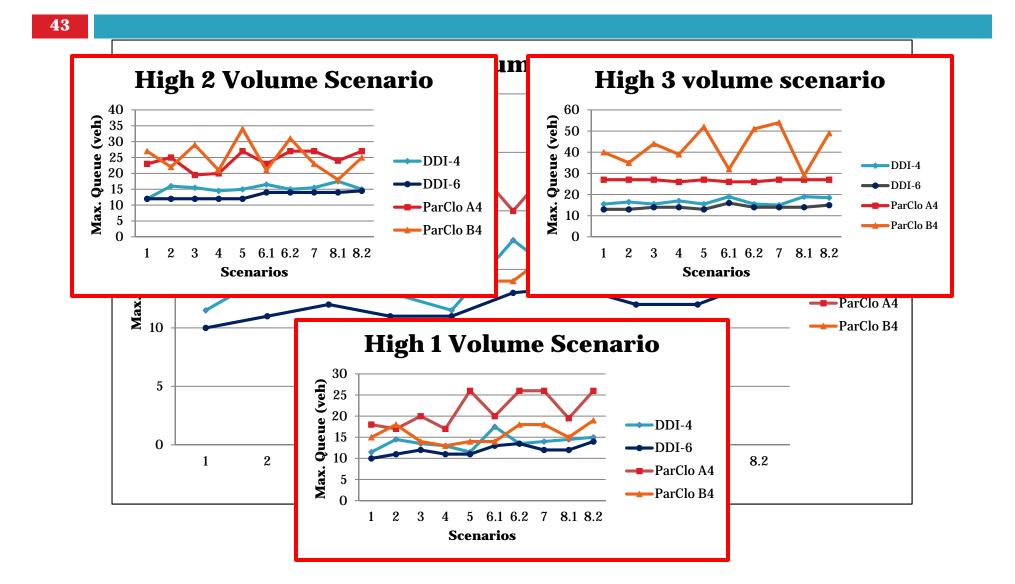
Results for Number of Stops



Results for Maximum Queue (veh)



Results for Maximum Queue (veh)



Conclusion

- This research compared the operational performance The Diverging Diamond Interchange (DDI) and Partial Cloverleaf (ParClo)
- The operations and geometry of interchanges modeled was shown
- Average Delay time, Average Stop Time, Average Number of Stops and Maximum Queue were used to compare the designs
- Cycle length were optimized using Synchro 7 for each design

Conclusion

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- In terms of safety, the DDI designs had two more conflict points but they were all spread compared to the ParClo designs
- For low and medium volumes the performance of all the interchanges was similar
- **The DDI-6 showed promise for higher volumes**
- The DDI-4 compared to the ParClo A4 had better results at high volumes when unbalanced conditions were predominant
- The DDIs had a much better performance in terms of maximum queue

Future Research

- A wider range of geometry (dual-left turn lanes, etc.) should be analyzed in situations approaching capacity
- The effect of pedestrians and bicycles should be examined to evaluate the operations of the interchange configurations
- Environmental impact associated with the implementation of the interchanges should be conducted
- A cost-benefit analysis of the DDI vs. ParClo Interchanges is recommended
- Performance of an statistical analysis and Safety Analysis is recommended



 Gilbert Chlewicki, President and CEO of Advanced Transportation Solutions, LLC
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 Advisor and Supervisory Committee Members
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