Signal Control Strategies for Interchanges and Unconventional Intersections

Zong Z. Tian, Ph.D., P.E.
Center for Advanced Transportation Education and Research (CATER)
University of Nevada, Reno

http://unr.edu/homepage/zongt/
About Reno and UNR
About Reno and UNR
About Reno and UNR
Outline

- Signal timing basics
  - NEMA phase/ring/barrier concept
  - An exercise

- Signal control at interchanges and unconventional intersections
  - Interchanges: SPUI – Single point urban interchange; Diamond interchange; Partial cloverleaf; Diverging diamond interchange
  - Unconventional intersections: Median U-turn; Bowtie; Super-Street; Continuous-flow.
Class Objectives

- Familiarize with basic technical terms related to signal control
- Familiarize with some common interchange types and unconventional signalized intersections
Signal Timing Terminologies

- Basic signal terms
  - Cycle and cycle length
  - Interval
    - Change interval (yellow)
    - Clearance interval (all-red)
    - Green interval
    - Red interval
  - Phase = Green + Yellow + All-red
    (*A signal phase is associated with a particular traffic movement)
Traffic Movements
One-way Streets

Side Street

EB

Main Street

N
Traffic Movements
One-way Streets

Side Street

Main Street

EB

N
Traffic Movements
One-way Streets

EB

Side Street

N

Main Street
Traffic Movements
One-way Streets

EB

Side Street

Main Street

N
Traffic Movements
One-way Streets

Side Street

Main Street

EB

N
Traffic Movements
One-way Streets

Side Street

EB

Main Street

N
Two-Phase Operation
Controlled Movements

Side Street
SB

EB

NB

WB
Main Street

N
Conflicting Movements

Side Street
SB

EB

NB

Main Street
WB

N
8-Phase Quad Left Control (NEMA)

Side Street
- SB (φ8 φ3)

Main Street
- EB (φ1 φ6)
  - WB (φ2 φ5)
- NB (φ7 φ4)
Phase, Ring and Barrier Structure

Barrier

Ring 1

Ring 2

Main Street

Side Street

Cycle Length

N

Barrier
Overlap Phase

Overlap – more than one phase for controlling one movement

A = φ4 + φ5
For the intersection shown below, determine (1) how many signal phases are needed, assuming left-turns are protected; (2) provide a feasible phasing scheme (give a number for each phase) following the NEMA phase/ring/barrier structure.
Solution 1

\[ \phi_8 \phi_3 \]

\[ \phi_2 \]

\[ \phi_4 \]
Westbound right-turn can be controlled by overlap phase A.
What about the two marked with the question mark? Can they be controlled with overlap phases?
Signalized Interchange Types

- Diamond Interchange (>70%)
- Partial Cloverleaf
- Single-point Urban Interchange (SPUI)
- Diverging Diamond Interchange
Unique Characteristics at Signalized Interchanges

- Involve two (2) signals (except for SPUI)
- Limited movements at each signal
- Traffic movements are related at the two signals
- Close spacing
- Usually more efficient with one controller
SPUI – Single Point Urban Interchange
SPUI – Single Point Urban Interchange

SPUI Video
Diamond Interchange

- Tight Diamond (<400 ft)
- Compressed (400~800 ft)
- Conventional (>800 ft)
Signal Phases at a Diamond Interchange
Signal Phases at a Diamond Interchange

A = \phi_1 + \phi_2

B = \phi_5 + \phi_6
BASIC 3-PHASE
BASIC 3-PHASE
BASIC 3-PHASE
BASIC 3-PHASE
UNR STUDY
UNR STUDY

Before

McCarran

After
Parclo – Partial Cloverleaf

Parclo A (2 Quadrants)  Parclo B (2 Quadrants)  Parclo AB (2 Quadrants)

Parclo A (4 Quadrants)  Parclo B (4 Quadrants)  Parclo AB (4 Quadrants)
Studied Intersections at Parclo Interchanges
DDI – Diverging Diamond Interchange
DDI

DDI Video - Animation

DDI Video - Illustration

DDI videos under …Research/PictureVideo
Base DDI Signal Phasing
Enhanced DDI Signal Phasing
Moana Ln/US 580 in Reno
Phasing Scheme 1

\[
\begin{align*}
\phi_1 + \phi_4 &+ \phi_6 \\
\phi_4 &+ \phi_2 + \phi_3 \\
\phi_1 + \phi_6 + \phi_4 &+ \phi_3 \\
\phi_2 &+ N
\end{align*}
\]
Phasing Scheme 2

\[ \phi_4 + \phi_5 + \phi_6 + \phi_2 + \phi_4 + \phi_6 + \phi_3 + \phi_1 + \phi_2 + \phi_7 + \phi_3 + \phi_1 \]
Phase/Ring/Barrier

Ring Barrier

Ring 1

Ring 2

Maximum Call

Minimum Call

Cycle

\( \phi_1 \) \( \phi_2 \) \( \phi_4 \) \( \phi_3 \)

\( \phi_5 \) \( \phi_6 \) \( \phi_7 \) \( \phi_8 \)
VISSIM Hardware-in-the-Loop
Unconventional Signalized Intersections

- Median U-turn
- Bowtie intersections
- Continuous-flow intersections
- Super-street intersections
Primary Objectives

- Minimize or eliminate conflicting points
- Minimize number of signal phases, particularly the LT phases
Median U-Turn

“Michigan Left”
Median U-Turn

Major Street Movements

Minor Street Movements
Bowtie Intersection
Bowtie Intersection
Superstreet Intersection
Continuous Flow Intersection

Fairview and Eagle
Continuous Flow Intersection

Parcels Impacted
Parcel Area Impacted
17
2.68 ac.

Construction Costs
Right-of-Way Costs
Total
$10.7 m
$1.0 m
$11.7 m

Incremental Costs
User Benefits
$6.4 m
$71.2 m

Benefit/Cost Ratio
11.1

Scenario | LOS | Delay (sec/veh)
---------|-----|----------------
2030+ no-build | F | 214.7
2030+ improvement | D | 40.7

Volume Information
PM Peak Hour (2007)
PM Peak Hour (2030)
Hourly Capacity
2005 ADT
2030 ADT
Capacity

6,500 PM Pk Hour
9,500 PM Pk Hour
12,500 Cap.
Continuous Flow Intersection

Phase 1: Lefts "crossover" while E-W throughs are running

Phase 2: Lefts are free go at the same time that N-S throughs go

Bangerter & 3500 S.
West Valley City, Utah
Summary

- Discussed the basic principles of signal control at intersections and interchanges
- Covered some special types of interchanges/intersections
- Discussed the operational efficiency and safety aspects of such interchanges/intersections