

# NEW SIGNALIZED INTERSECTION METHODOLOGY

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 TRANSPORTATION RESEARCH BOARD



## Housekeeping

2

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3

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- Completion of course evaluation
- Passage of assessment

These requirements must be met to earn 1.5 PDH/.2 IACET CEU

At the conclusion of the course you will receive an email with directions to the [online course evaluation and quiz](#).

## Instructor

4

- James A. Bonneson, P.E., Ph.D.
  - Senior Research Engineer
  - Texas Transportation Institute
  - College Station, Texas, USA




## Introductory Session

5

- Overview and Background
  - Instructor
  - Briefing series overview
  - Objectives and scope
  - Background
  - Presentation overview

## Briefing Series Overview

6

- HCM 2010 Overview – April 12
- New Active Traffic Mgmt. Chapter – April 14
- Unsignalized Intersections – April 26
- Multi-modal Urban Streets – April 28
- New Signalized Intersections – May 17 
- Multi-modal Urban Streets: Auto Mode – May 19
- Alternative Tools: Micro simulation models – June 21
- New Freeway Weaving Methodology – June 23
- Enhancements to the Freeway Facilities – July 19
- Enhanced Planning Methods – July 21

## Objectives and Scope

7

- Learning Objectives
  - Learn about new capabilities of the signalized intersections methodology
  - Understand how the methodology can be used to evaluate intersection operation
- Scope of Presentation
  - HCM 2010
  - Signalized intersections
    - Automobile methodology

## Background

8

- Research Leading to HCM 2010
  - 35 references in Signalized Intersections chapter
  - Messer and Fambro. "Critical Lane Analysis for Intersection Design." *TRR 644*, 1977.
  - Akcelik. *ARRB Report 123 - Traffic Signals: Capacity and Timing Analysis*, 1981.
  - Reilly, et al. *Signalized Intersection Capacity Method*, NCHRP Project 3-28(2), JHK & Associates, 1983.

## Background

9

- Research Leading to HCM 2010
  - Prassas and Roess. "Left-Turn Adjustment for Permitted Turns from Shared Lane Groups." *TRR 1398*, 1993.
  - Fambro, Roupail, Sloup, Daniels, Li, Anwar, and Engelbrecht. *Highway Capacity Manual Revisions of Chapters 9 and 11*. Report FHWA-RD-96-088, 1996.
  - Courage, Fambro, Akcelik, Lin, Anwar, Vilorio. *Capacity Analysis of Traffic-Actuated Intersections*, NCHRP Project 3-48, 1996.

## Background

10

- Research Leading to HCM 2010
  - NCHRP Project 3-79, *Measuring and Predicting the Performance of Automobile Traffic on Urban Streets* (2007)
  - NCHRP Project 3-70, *Multimodal Level of Service Analysis for Urban Streets* (2008)
  - NCHRP Project 3-92, *Production of the Year 2010 Highway Capacity Manual* (2010)
- Reports Available At:
  - <http://www.hcm2010.org/>

## Presentation Overview

11

- Session 1 – Content and Structure
- Session 2 – Methodology Basics
- Session 3 – New Capabilities

## Questions

12

- Format for Questions
  - Enter questions/comments in the Question Pod.
  - After each session, I will spend about five minutes addressing as many as possible

## Presentation Overview

13

- Session 1 – Content and Structure
- Session 2 – Methodology Basics
- Session 3 – New Capabilities

## Session 1

14

- Content and Structure
  - Background
  - HCQSC vision for chapter
  - HCM 2010 organization
  - Chapter outline

## Background

15

- HCM 2000 Signalized Intersections
  - ▣ Chapter 10 – Urban Streets Concepts
    - Terminology and variables
    - Required inputs and default values
    - 19 pages
  - ▣ Chapter 16 – Signalized Intersections
    - Influence of upstream signal based on arrival type
    - Requires phase duration as an input
    - Auto performance
    - Worksheet description
    - 161 pages

## HCQSC Vision for HCM 2010

16

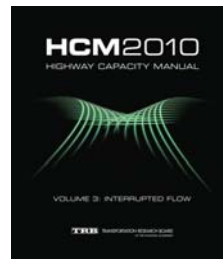
- Multi-Modal Evaluation
  - ▣ Incorporate pedestrian and bicycle methodologies
- Improve Procedures
  - ▣ Add procedure for actuated phase duration
  - ▣ Improve delay and queue length procedures
- Manual Worksheet Description not Required
  - ▣ Computational intensity of some calculations more than can be worked with worksheet
  - ▣ Working with software developers to implement



## HCM 2010 Organization

17

- Volume 1 - Concepts
- Volume 2 – Uninterrupted Flow
- Volume 3 – Interrupted Flow
- Volume 4 – Applications Guide
  - <http://www.hcm2010.org/>



## HCM 2010 Organization

18

- Volume 1 - Concepts
- Volume 2 – Uninterrupted Flow
- Volume 3 – Interrupted Flow
  - Chapter 18: Signalized Intersections
- Volume 4 – Applications Guide
  - Chapter 31: Signalized Intersections: Supplemental



## Chapter 18

19

- Signalized Intersections
  - Introduction
    - Level of service criteria
    - Required input data
    - Scope and limitations
  - Methodology
    - Automobile mode (refers to Chapter 31 for some details )
    - Pedestrian mode
    - Bicycle mode
  - Applications
    - Default values
  - Example Problems
- 107 pages

## Chapter 31

20

- Signalized Intersections: Supplemental
  - Traffic Signal Concepts
  - Capacity and Phase Duration
  - Queue Accumulation Polygon
  - Queue Storage Ratio
  - Quick Estimation Method
  - Field Measurement Techniques
    - Control delay; Saturation flow rate
  - Computational Engine Documentation
- 124 pages

## Questions?

21

- Content and Structure
  - Background
  - HCQSC vision for chapter
  - HCM 2010 organization
  - Chapter outline
  
- Questions on Content or Structure?
  - Enter questions/comments in the Question Pod.

## Presentation Overview

22

- Session 1 – Content and Structure
- Session 2 – Methodology Basics
- Session 3 – New Capabilities

## Session 2

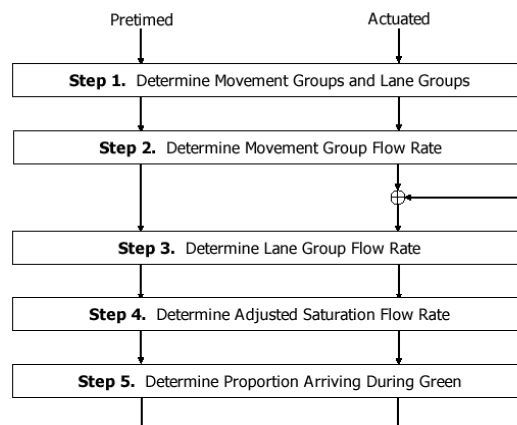
23

- Methodology Basics
  - Calculation framework
  - New terms
  - New concepts
  - New input data
  - Performance measures

## Calculation Framework

24

- Ten Steps
  - Determine groups
  - Movement group flow
  - Lane group flow
  - Saturation flow
  - Arrivals on green

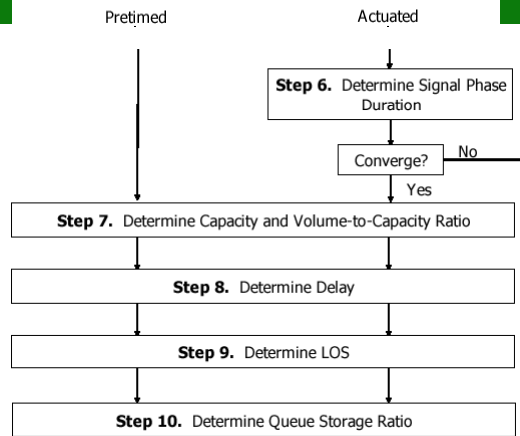


## Calculation Framework

25

### □ Ten Steps

- Phase duration
- Capacity
- Delay
- LOS
- Queue length



## New Terms














26

- Movement Group
  - A turn movement in an exclusive lane is a group
  - All remaining lanes are one group
- Lane Group
  - A turn movement in an exclusive lane is a group
  - Any shared lane is a group
  - All remaining lanes are one group
- Difference Between Group Types
  - Apparent for mix of shared and exclusive lanes

## New Terms

27

- Movement Group
  - Useful for describing needed input data
- Lane Group
  - Used as basis for analysis

Number of Lanes	Movements by Lanes	Movement Groups (MG)	Lane Groups (LG)
1	Left, thru., & right: 	MG 1: 	LG 1: 
5	Exclusive left:  Exclusive left:  Through:  Through:  Thru. & right: 	MG 1:  MG 2: 	LG 1:  LG 2:  LG 3: 

## New Concepts

28

- Peak Hour Factor (PHF)
  - Converts peak hour to peak 15-min flow rate
- HCM 2010 uses “Intersection” PHF
  - PHF is based on total entering volume during common 15-min period
  - Each movement has same value of PHF
- HCM 2000 used “Movement” PHFs
  - Each movement can have unique value of PHF
  - Approach tended to overestimate flow during the common 15-min peak period

## New Concepts

29

- Level of Service Criteria (LOS)
  - No change in threshold values
  - V/C ratio now used (with delay) for lane group LOS

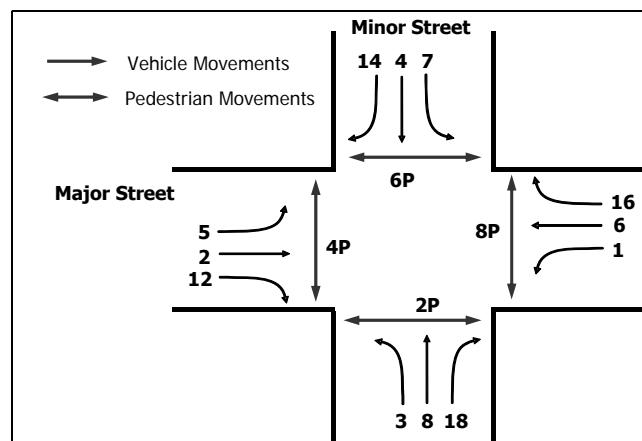
Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio <sup>a</sup>	
	≤1.0	>1.0
≤10	A	F
>10–20	B	F
>20–35	C	F
>35–55	D	F
>55–80	E	F
>80	F	F

Note: <sup>a</sup> For approach-based and intersectionwide assessments, LOS is defined solely by control delay.

## New Concepts

30

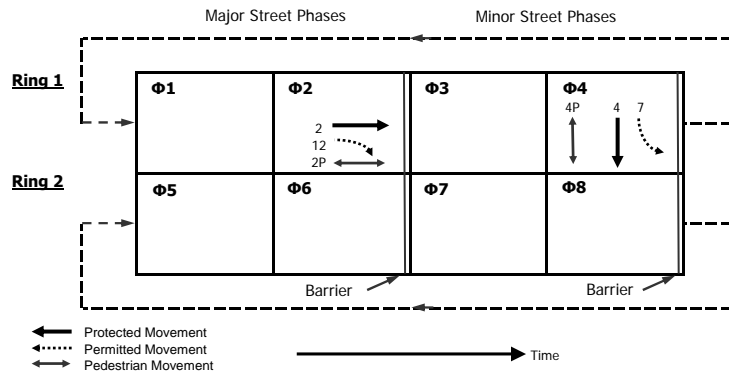
- Movement Numbers



# New Concepts

## 31 Dual-Ring Structure

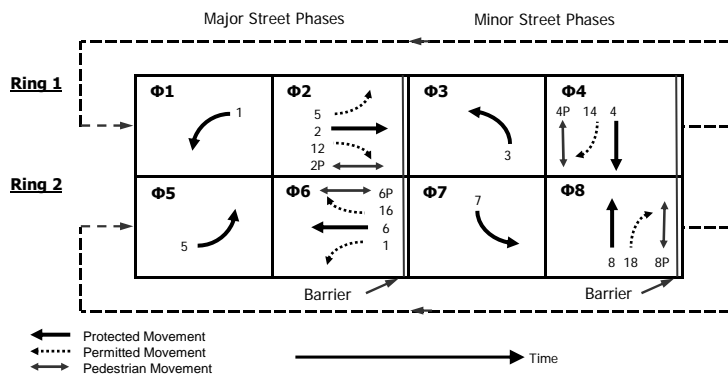
- Ring defines sequence of conflicting movements
- Barrier separates movements on each street
- Example sequence for two one-way streets



# New Concepts

## 32 Dual-Ring Structure

- Example sequence for leading left-turn phases
  - Left-turn phase times first, then opposing through phase

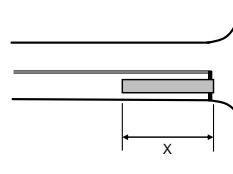




## New Input Data

33

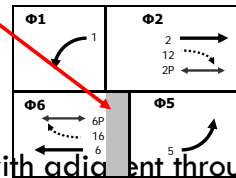
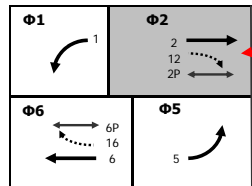
- Traffic
  - Approach speed
- Controller Settings
  - Passage time (vehicle interval, unit extension)
  - Maximum green
  - Minimum green
  - Walk + pedestrian. clear
  - Recall (min, max, ped)
- Detector Design
  - Detector length



## New Input Data

34

- PPLT w/Flashing Yellow (Dallas Phasing)
  - Permissive left period is concurrent with conflicting through phase
- Traditional PPLT
  - Permissive left period is concurrent with adjacent through phase (less green arrow)



Permissive period



## New Input Data

35

- HCM 2000 Input
  - Average phase duration for actuated control
  - No longer an input for HCM 2010
- Replicating Pretimed Control
  - Set maximum green to desired duration
  - Set Recall to “max”

## Performance Measures

36

- Measures in HCM 2010
  - Control delay
  - Volume-to-capacity ratio
  - Queue storage ratio
    - Ratio of back-of-queue to available storage
    - Ratio > 1.0 indicates queue spillover
  - Probability of phase termination by max out



## Questions?

37

- Methodology Basics
  - Calculation framework
  - New terms
  - New concepts
  - New input data
  - Performance measures
- Questions on Methodology Basics?
  - Enter questions/comments in the Question Pod.

## Presentation Overview

38

- Session 1 – Content and Structure
- Session 2 – Methodology Basics
- Session 3 – New Capabilities

## Session 3

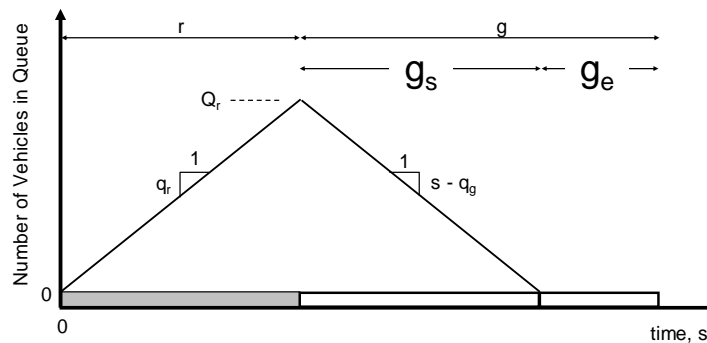
39

- New Capabilities
  - Actuated phase duration
  - Uniform delay
  - Queue length
  - Evaluation possibilities

## Actuated Phase Duration

40

- Procedure Overview
  - Compute queue service time ( $g_s$ )
  - Compute green extension time ( $g_e$ )
  - Example: exclusive lane, through movement



## Actuated Phase Duration

41

### □ Procedure Overview

- Process is iterative
- Choose a starting value, compute other variables, find convergence
- Green = f(queue service time, green extension)
  - Queue service time = f(lane vol., sat. flow rate, cycle)
  - Cycle length = f(green)
  - Green extension = f(green, queue service time, cycle)
  - Sat. flow rate for lefts = f(green)
  - Lane volume = f(sat. flow rate)

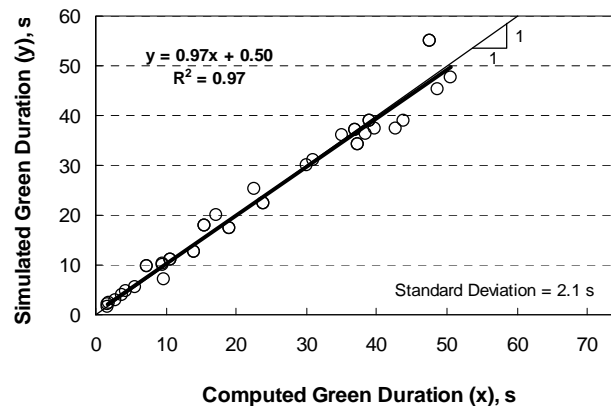


## Actuated Phase Duration

42

### □ Calibration

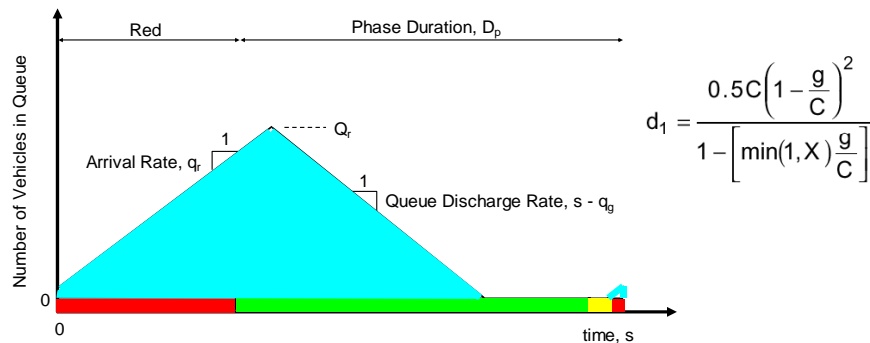
- Simulation data
- Data point – one-hour average for one phase



# Uniform Delay

43

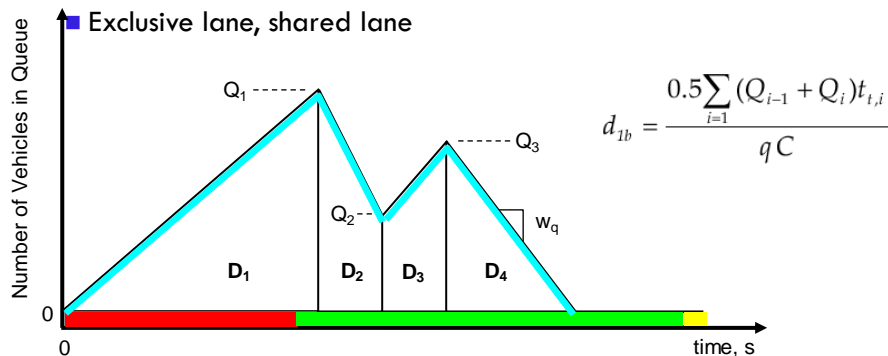
- HCM 2000 Procedure for Estimating Delay
  - Equation based on area of triangle
  - Works well for protected movements in an exclusive lane (or lanes)



# Uniform Delay

44

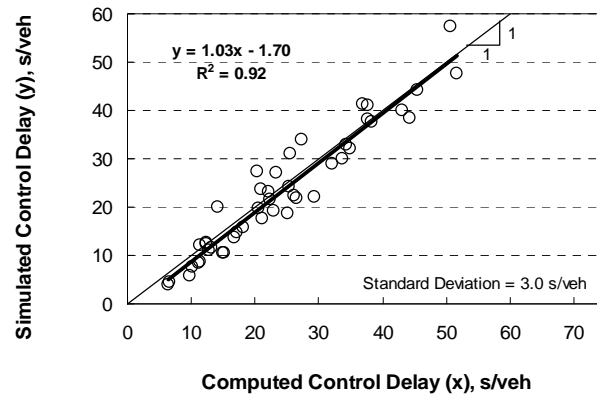
- 2010 HCM Procedure for Estimating Delay
  - Computes delay as area of queue polygon
  - Works for all movements and lane assignments
    - Permitted, protected, protected-permitted
    - Exclusive lane, shared lane



## Uniform Delay

### 45 Calibration

- Simulation data
- Data point – one-hour average for one phase



## Queue Length

46

- Back-of-Queue
  - Maximum backward extent of queued vehicles during a typical cycle
  - When back-of-queue reached, not likely to be more than one vehicle stopped
- Queued Vehicle
  - Vehicle that fully stops because of signal
- Full Stop
  - Vehicle slows to zero (or crawl speed) because of change from green to red

## Queue Length

47

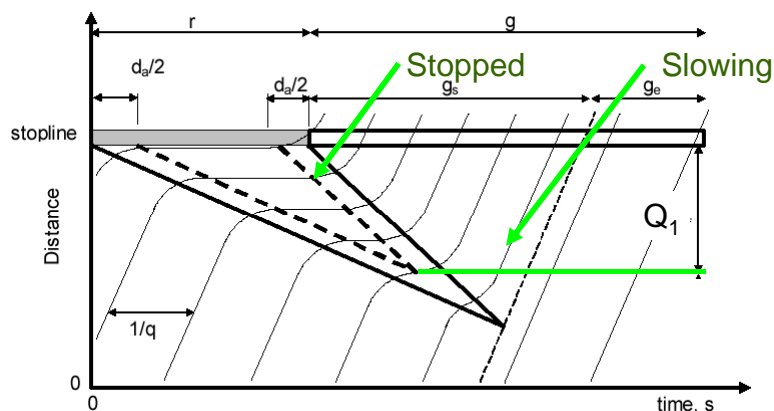
- Components of Back-of-Queue,  $Q$ 
  - $Q = Q_1 + Q_2 + Q_3$
  - First term ( $Q_1$ )
    - Queue due to signal cycle
  - Second term ( $Q_2$ )
    - Queue due to cycle failure (random overflow)
    - Queue due to oversaturation
  - Third term ( $Q_3$ )
    - Queue due to initial queue at start of analysis period

## Queue Length

48

### First Term Back-of-Queue

- HCM 2010 is based on stopped vehicles
- HCM 2000 is based on slowing + stopped vehicles





## Queue Length

49

- New Capabilities
  - Focus on fully stopped vehicles
  - Models for predicting all three terms refined
  - Percentile queue length equation refined

## Evaluation Possibilities

50

- Possible Scenarios
  - Impact of flashing yellow prot.-perm. left-turn
  - Impact of providing protected right-turn phase
  - Impact of changes to various actuated controller settings
    - Maximum green
    - Passage time
    - Phase recall (ped., min., max)
  - Impact of signal operation on ped. or bicyclist

## Software Availability

51

- HCS 2010 (McTrans)
  - HCS+ users with active support subscriptions will receive HCS 2010 automatically by mail
- VISUM 11.5 (PTV)
  - May 2011 service pack will include HCM 2010 method for pretimed signalized intersections
- TEAPAC Complete 2010 (Strong Concepts)

## Questions?

52

- New Capabilities
  - Actuated phase duration
  - Uniform delay
  - Queue length
  - Evaluation possibilities
- Questions on New Capabilities?
  - Enter questions/comments in the Question Pod.

## Closure

53

- Forthcoming Briefings
  - Multi-modal Urban Streets: Auto Mode – May 19
  - New Material on the Use of Alternative Tools – June 21
  - New Freeway Weaving Methodology – June 23
  - Enhancements to the Freeway Facilities – July 19
  - Enhanced Planning Methods & Application of Generalized Service Volume Tables – July 21
- Thanks for your time!

## Thank You

54

Please provide your feedback. A link to an online Web briefing evaluation will follow in an e-mail to Web briefing registrants. Please distribute this email to participants at your site. The evaluation will close in one week.

Questions/Comments  
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