

NEW SIGNALIZED INTERSECTION METHODOLOGY

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 TRANSPORTATION RESEARCH BOARD



Housekeeping

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Instructor

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




Introductory Session

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

Briefing Series Overview

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- 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

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- 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

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- 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

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- 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

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- 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

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

Session 1

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- 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

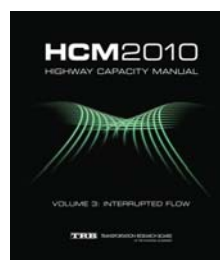
16

- 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

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



HCM 2010 Organization

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- 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

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- 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?

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- 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

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

Session 2

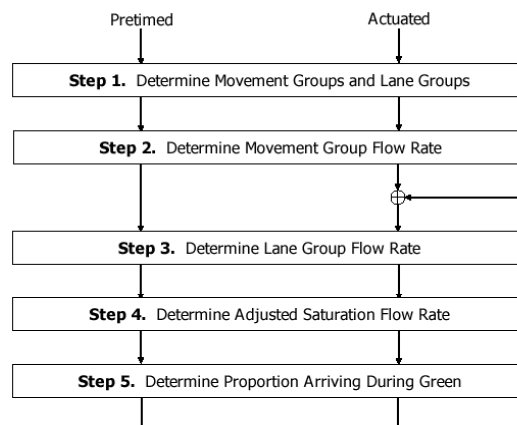
23

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

Calculation Framework

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

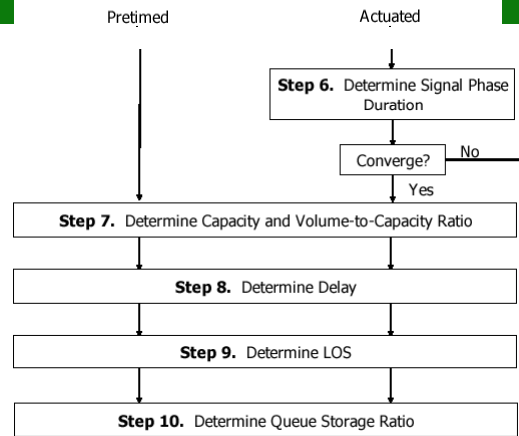


Calculation Framework

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

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- 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

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

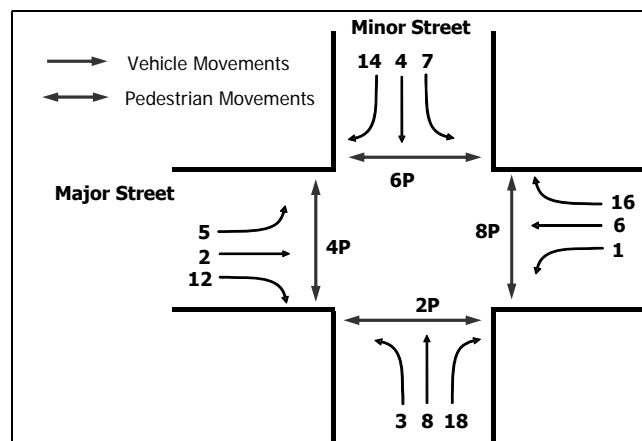
Control Delay (s/veh)	LOS by Volume-to-Capacity Ratio ^a	
	≤1.0	>1.0
≤10	A	F
>10–20	B	F
>20–35	C	F
>35–55	D	F
>55–80	E	F
>80	F	F

Note: ^a For approach-based and intersectionwide assessments, LOS is defined solely by control delay.

New Concepts

30

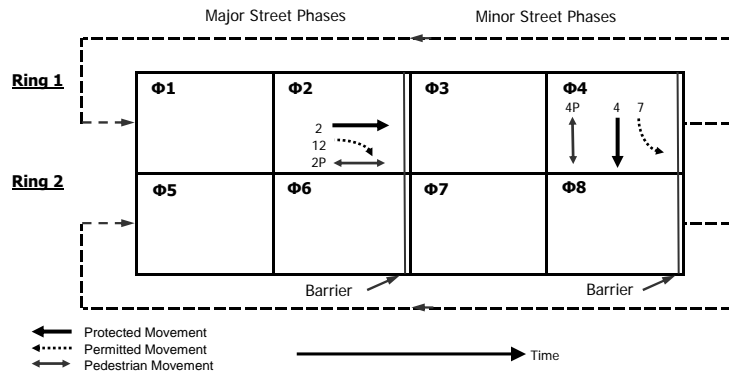
- Movement Numbers



New Concepts

31 Dual-Ring Structure

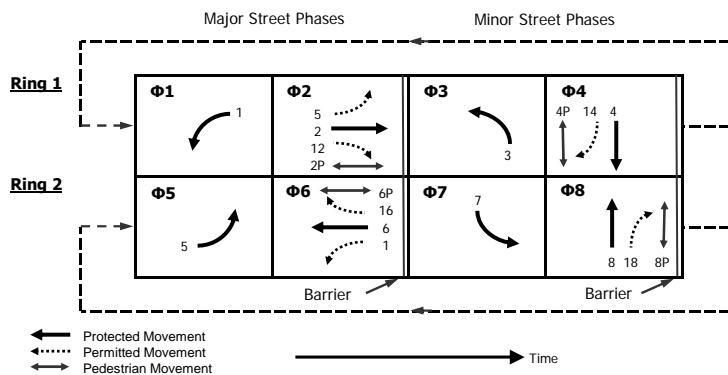
- Ring defines sequence of conflicting movements
- Barrier separates movements on each street
- Example sequence for two one-way streets



New Concepts

32 Dual-Ring Structure

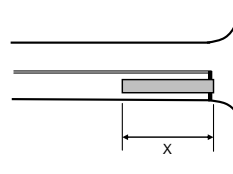
- Example sequence for leading left-turn phases
 - Left-turn phase times first, then opposing through phase



New Input Data

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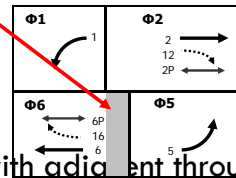
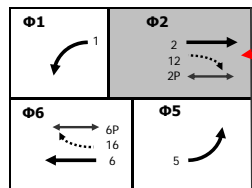
- Traffic
 - Approach speed
- Controller Settings
 - Passage time (vehicle interval, unit extension)
 - Maximum green
 - Minimum green
 - Walk + pedestrian. clear
 - Recall (min, max, ped)
- Detector Design
 - Detector length



New Input Data

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- 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)



New Input Data

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- 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

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

Session 3

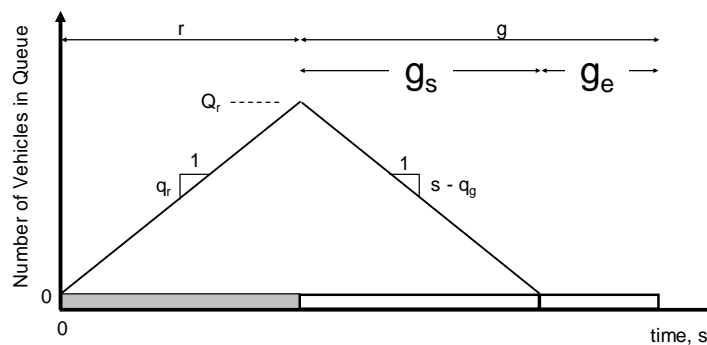
39

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

Actuated Phase Duration

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



Actuated Phase Duration

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□ 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)

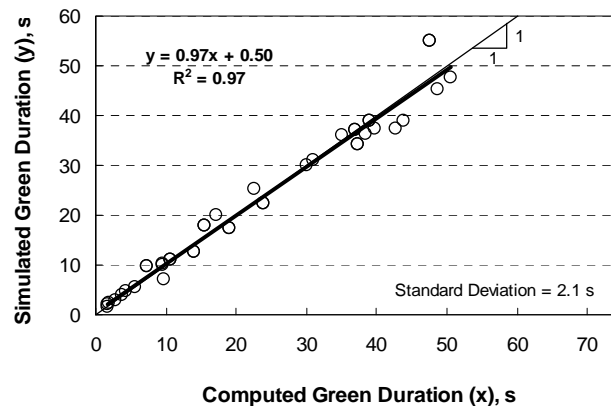


Actuated Phase Duration

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□ Calibration

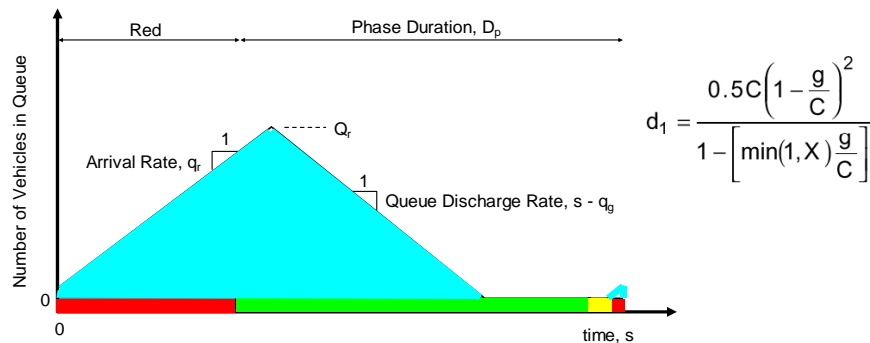
- Simulation data
- Data point – one-hour average for one phase



Uniform Delay

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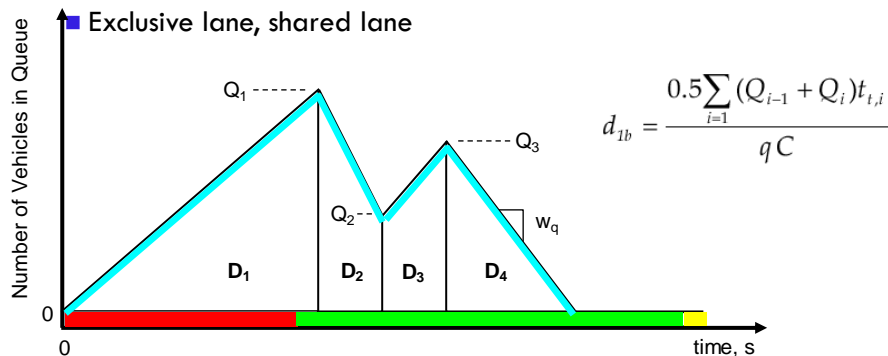
- HCM 2000 Procedure for Estimating Delay
 - Equation based on area of triangle
 - Works well for protected movements in an exclusive lane (or lanes)



Uniform Delay

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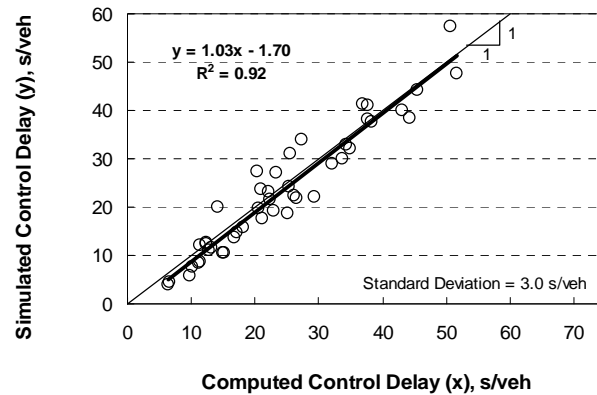
- 2010 HCM Procedure for Estimating Delay
 - Computes delay as area of queue polygon
 - Works for all movements and lane assignments
 - Permitted, protected, protected-permitted
 - Exclusive lane, shared lane



Uniform Delay

45 Calibration

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



Queue Length

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- 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

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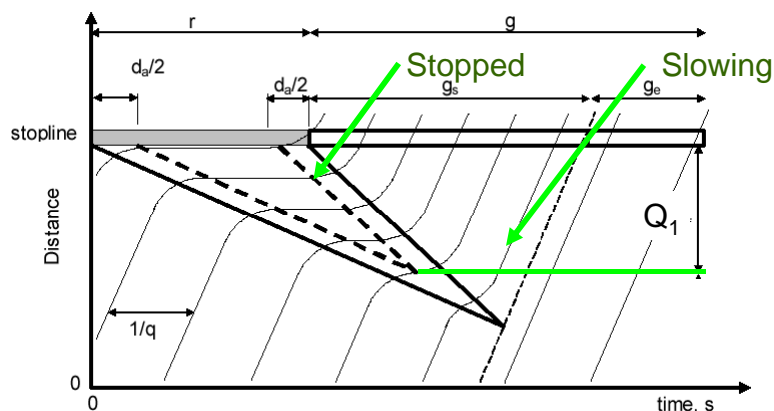
- Components of Back-of-Queue, Q
 - $Q = Q_1 + Q_2 + Q_3$
 - First term (Q_1)
 - Queue due to signal cycle
 - Second term (Q_2)
 - Queue due to cycle failure (random overflow)
 - Queue due to oversaturation
 - Third term (Q_3)
 - Queue due to initial queue at start of analysis period

Queue Length

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First Term Back-of-Queue

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



Queue Length

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

Evaluation Possibilities

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- 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

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- 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?

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

Closure

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- 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

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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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