Weather-Responsive Signal Timing: Practical Guidelines

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Overview

- Background
- Research Significance
- Study Design
- Results
- Recommended Guidelines
- Future Research

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Background

- **Signal Timing: Main Design Parameters**
- **Adverse Weather Effect**
  - **Approach Speed**
  - **Tire-Pavement Traction (friction)**
  - **Acceleration (Start-Up Lost Time)**
  - **Saturation Headway**
- **Retiming Plan**
  - **Potential Improvement in Safety & Performance**

Significance

- Adverse Weather: Commonplace in Many States during Winter Season
- Adverse Weather Conditions
  - Heavy Rain
  - Snow
  - Ice
  - Slush
  - Etc.
- Driving Conditions
  - *Very Bad!! Safety & Performance Compromised*

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Study Design

- Operational Analysis
  - Set-Up
    - Normal - Optimized
    - Adverse Weather- Not Optimized >> Impacts
    - Adverse Weather- Optimized >> Benefits
  - Analytical Techniques
    - Optimization: SYNCHRO
    - Simulation: SimTraffic
  - Measure of Performance
    - Average Travel Time (min / km)

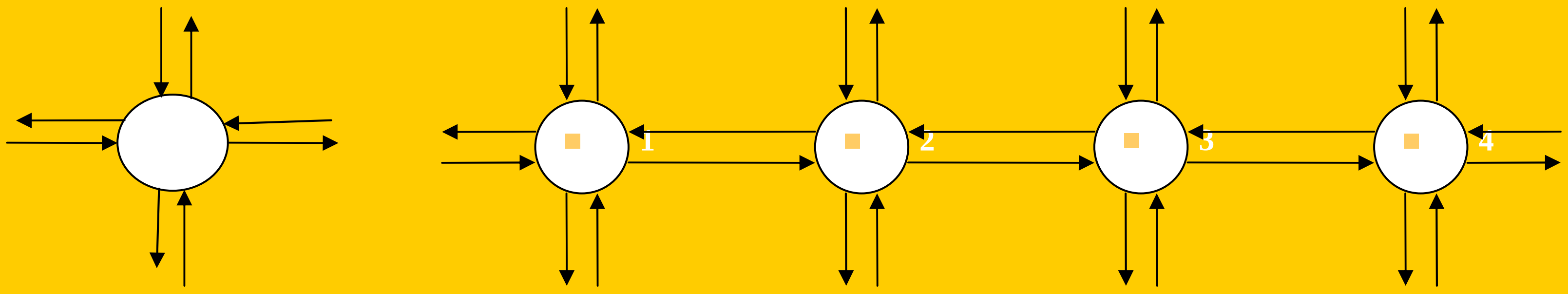
Study Design

- Operational Analysis (Continued)
  - Scenarios Investigated
    - Urban vs. Suburban
    - Isolated Intersections vs. Coordinated Corridors
    - Heavy, Moderate & Low Traffic Levels
- Safety Analysis
  - Safety indicators
    - Adequacy of Amber/All-Red Interval
    - Presence of Dilemma Zone
  - Analytical Technique
    - Spreadsheet Analysis
  - Variables
    - Approach Speed
    - Tire-Pavement Traction (frictional factor)

Experimental Design

- **Study Variables**
  - **Approach Speed-** Uninhibited speed of traffic, Decreases
  - **Start-up Lost Time-** Accounts for longer headways of first few vehicles in queue, Increases
  - **Saturation Flow-** Max # of vehicles per lane that can be discharged during one hour of green, Decreases
  - **Frictional Factor-** Traction Between Tire and Pavement. (Only used in Safety Analysis)
- **Parametric Analysis**
  - Multivariate Experimentation

Isolated & Coordinated Signals



Link-node representation of isolated and coordinated signalized intersections

Design of Parametric Analysis

Parameter	Speed Reduction (%)	Start-up Lost Time Incr. (%)	Saturation Flow Decrease (%)
Range	0 - 50	0 - 60	0 - 25
Levels	0	0	0
	10	10	5
	20	20	10
	30	30	15
	40	40	20
	50	50	25
	-------------------	60	----------------
Default Value	20	20	10

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Results – Operational Analysis

Average Benefits from Re-Optimizing

		Urban Area		Suburban Area	
		Isolated	**Coordinated Corridor**	**Isolated**	**Coordinated Corridor**
Approach Speed Reduction	Heavy Traffic	8.16	25.82	8.53	4.71
	Moderate Traffic	4.93	19.56	7.14	3.50
	Light Traffic	8.57	7.45	5.90	3.50
	Overall Average	*7.22*	*17.61*	*7.19*	*3.90*
Start-up Lost Time Increase	Heavy Traffic	12.51	36.72	8.95	9.56
	Moderate Traffic	8.94	19.74	12.62	3.09
	Light Traffic	8.98	7.67	6.20	2.34
	Overall Average	*10.14*	*21.38*	*9.26*	*4.99*
Saturation Flow Reduction	Heavy Traffic	8.76	34.46	8.96	8.67
	Moderate Traffic	18.95	7.87	9.36	4.53
	Light Traffic	7.53	7.43	6.41	2.79
	Overall Average	*11.75*	*16.59*	*8.24*	*5.33*

Results - Safety Analysis

Required Change & Clearance Interval

			Speed					
			80	**72**	**64**	**56**	**48**	**40**
Dry	Coefficient of Friction	**0.7**	5.22	5.18	5.17	5.20	5.30	5.50
Favorable Weather ↑		**0.65**	5.34	5.29	5.27	5.29	5.37	5.56
		0.6	5.48	5.42	5.38	5.39	5.46	5.64
		0.55	5.66	5.57	5.52	5.51	5.56	5.72
		0.5	5.86	5.76	5.68	5.65	5.69	5.83
		0.45	6.11	5.98	5.88	5.83	5.84	5.95
		0.4	6.43	6.27	6.14	6.05	6.03	6.11
		0.35	6.83	6.63	6.46	6.33	6.27	6.31
Design (wet)		**0.3**	7.37	7.12	6.89	6.71	6.59	6.58
Adverse Weather ↓		**0.25**	8.13	7.80	7.50	7.24	7.05	6.96
		0.2	9.26	8.82	8.40	8.03	7.73	7.53
		0.15	11.15	10.52	9.91	9.35	8.86	8.47
		0.1	14.93	13.92	12.93	12.00	11.13	10.36
		0.05	26.26	24.11	22.00	19.93	17.92	16.02

Summary of Findings

- Adverse Weather Causes Serious Impacts
- Benefits of Optimization Vary
  - Area Setting
  - Mode of Operation
- Urban Corridors: Most Significant Benefits (> 18%)
- Urban Isolated Intersections: Less Than 10% Improvement
- Suburban Isolated: 8% Average Benefit

Summary of Findings

- Suburban Coordinated Corridors: Less than 5% Savings in Travel Time
- Greater Impacts ➔ Greater Benefits
- Adequacy of Change / Clearance Interval is Often Compromised in Adverse Weather

Recommended Guidelines

		Speed Reduction (%)	Urban		Suburban	
			Isolated	Coordinated Corridor	Isolated	Coordinated Corridor
Dry	0 %	0	8.48* (21.47)**	15.54 (23.30)	6.52 (15.51)	6.97 (7.50)
Wet Wet & Snowing	10 % 13 %	10	9.54 (25.36)	15.00 (29.77)	6.33 (18.16)	5.14 (11.39)
Wet & Slushy	22 %	20	6.27 (29.04)	17.12 (39.43)	9.38 (26.28)	5.47 (19.57)
Slushy in Wheels' Path	30 %	30	5.79 (36.82)	18.21 (48.14)	8.05 (34.25)	4.18 (30.43)
Snowing & Packed	42 %	40	6.00 (49.21)	21.20 (69.61)	7.17 (44.74)	0.377 (44.44)
	50 %	50	7.23 (67.79)	18.60 (86.62)	5.67 (61.04)	1.27 (66.72)

* Upper value indicates percent savings in travel time as a result of signal retiming (benefit)

** Lower value (in parentheses) indicates percent increase in travel time under inclement weather (impact)

Future Research

- Effect of Impaired Visibility
- Economic Feasibility of Weather Responsive Control

Thank You

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