

A Framework for Evaluating Incident Management Strategies on Freeways

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Introduction

- *What is a highway incident*

Any non-recurring event that causes reduction of roadway capacity.



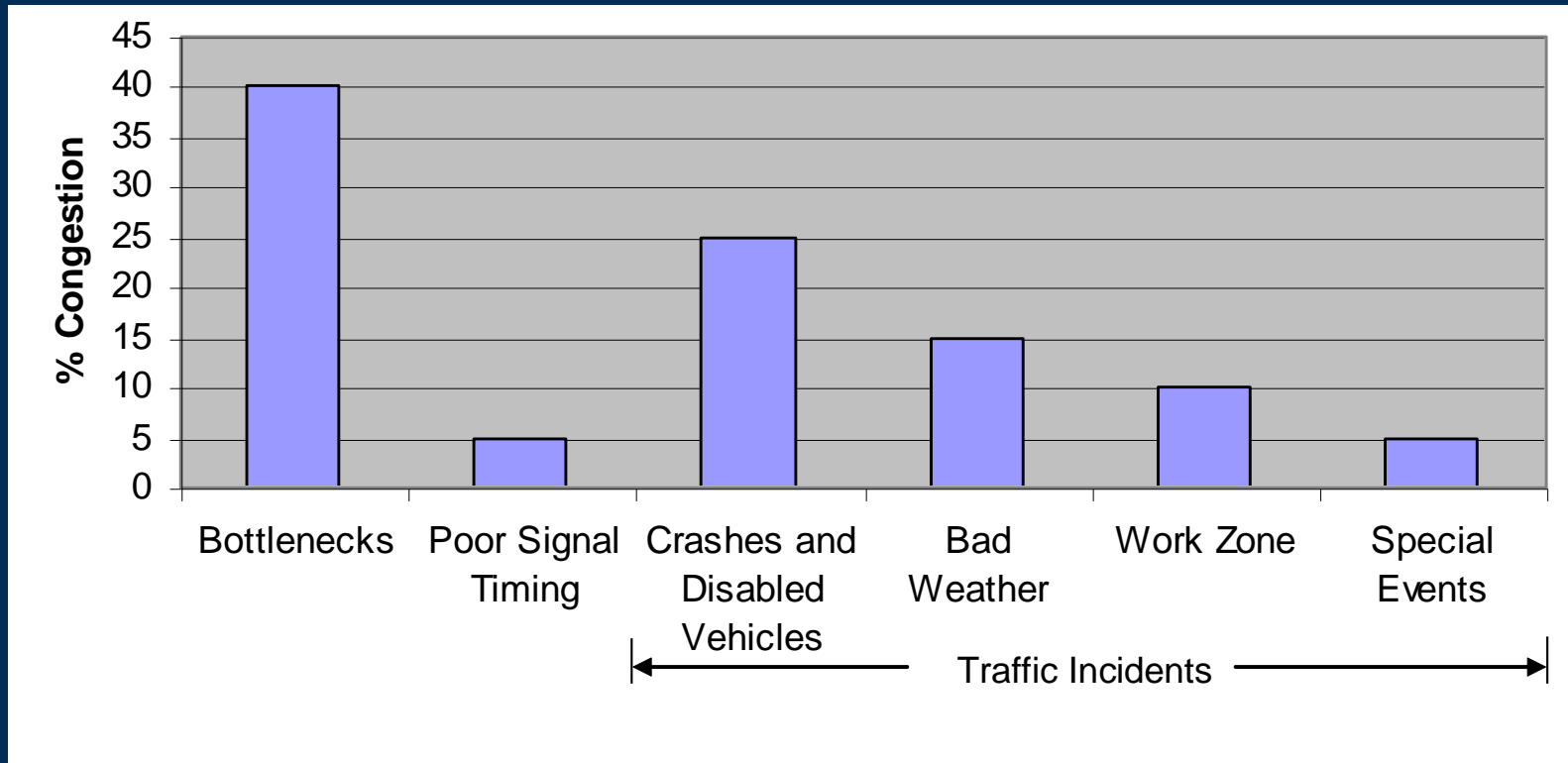
Examples of Highway Incidents

Reduction in capacity caused by events:

- predefined
- random



Sources of Congestion



Case Study: Three-lane gulf freeway, Texas



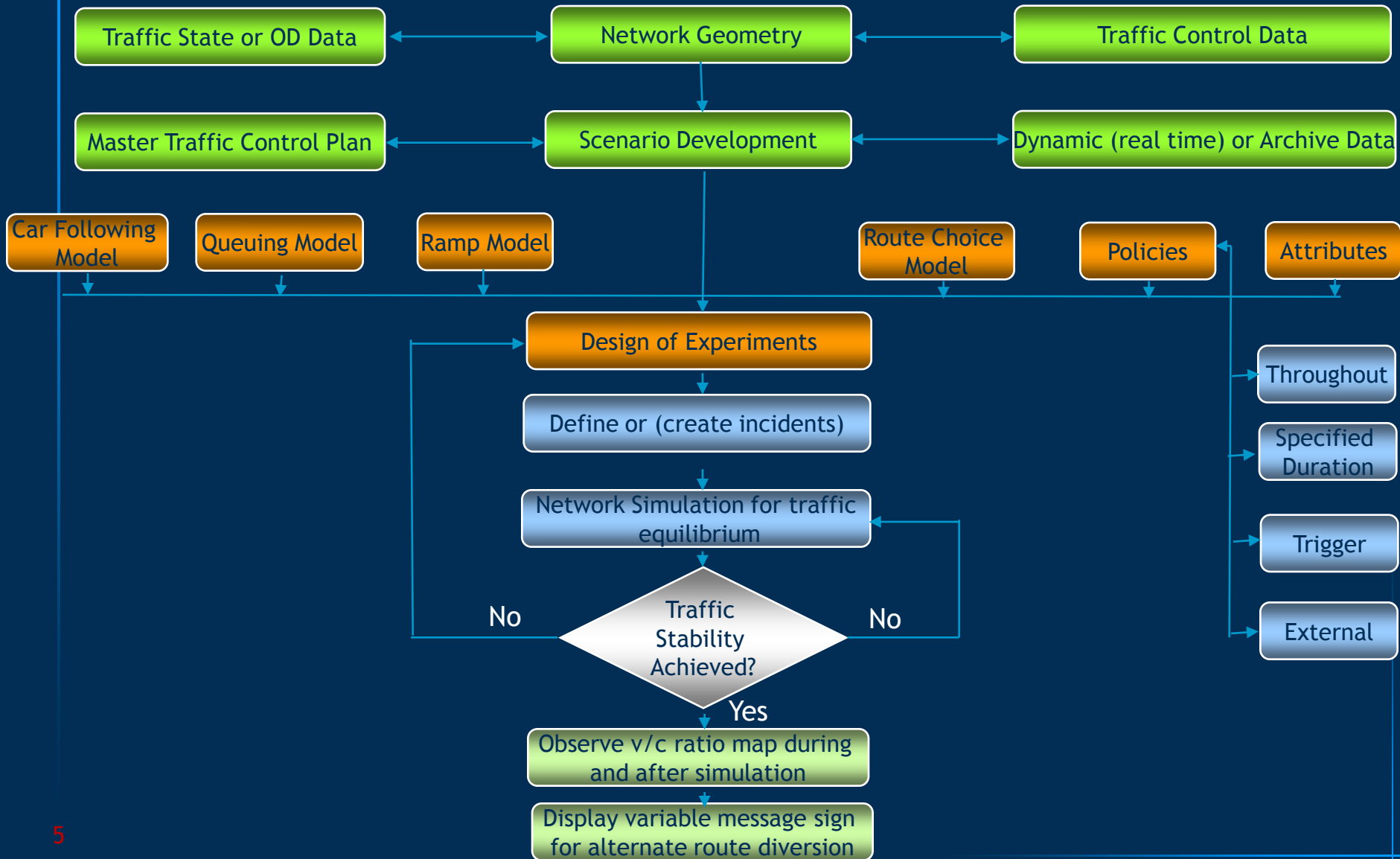
Problem Statement

- Incident and reduction in capacity

Incident Type	Capacity Reduction (%)
Normal Flow	-
Stall (One Lane Blocked)	48
Non-injury accident (one lane blocked)	50
Accident (two lanes blocked)	79
Accident on Shoulder	26

Case Study: Three-lane gulf freeway, Texas

Methodology





Data Inputs

- Traffic State or O/D matrix
- Lane Configuration
- Roadway Type
- Position of detectors
- Variable Message Sign
- Capacity
- Speed limit
- Signal groups, phases
- Modes of traffic
- Public transportation plan



Simulation Options and Results

- Tracking of individual vehicle
- Selection of a section of network / traversal matrix
- Display v/c ratio.
- Shortest path method
- Tracking of in / out vehicles
- Time of day analysis
- Public transit assignment with mixed traffic

Calibration Measures

Goodness-of-fit Measures	Formulae	Desirable
RMSE (Measures Overall % Error)	$\sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{x_i - y_i}{y_i} \right)^2}$	Close to 0
Correlation Coefficient: r (Measures Linear Association)	$\frac{1}{n-1} \sum_{i=1}^n \frac{(x_i - \bar{x})(y_i - \bar{y})}{\sigma_x \sigma_y}$	Close to 1
Theil's Inequality Coefficient: Ui (Disproportionate Weight of Large Errors)	$\frac{\sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - y_i)^2}}{\sqrt{\frac{1}{n} \sum_{i=1}^n y_i^2} + \sqrt{\frac{1}{n} \sum_{i=1}^n x_i^2}}$	Close to 0
Theil's Component-Us: (Measure of Variance Proportion)	$\frac{n(\bar{y} - \bar{x})^2}{\sum_{i=1}^n (y_i - x_i)^2}$	Close to 0
Theil's Component-Uc:: Measure of Covariance Proportion	$\frac{2(1-r)n\sigma_y\sigma_x}{\sum_{i=1}^n (y_i - x_i)^2}$	Close to 1
Theil's Component-Um: (Measure of Bias Proportion)	$\frac{n(\sigma_y - \sigma_x)^2}{\sum_{i=1}^n (y_i - x_i)^2}$	Close to 0



Network Components

- Links

- Freeways
- Arterials
- On/Off Ramps

- Nodes

- Intersections
- Stop signs
- Roundabouts

- Centroids

Center of activity for each zone

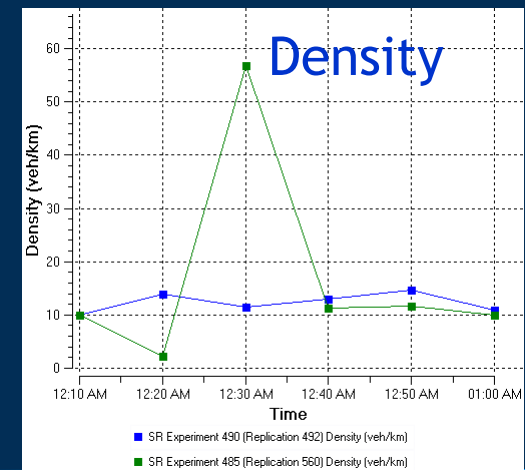
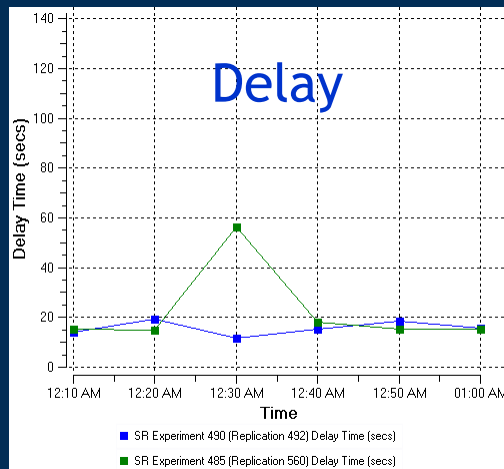
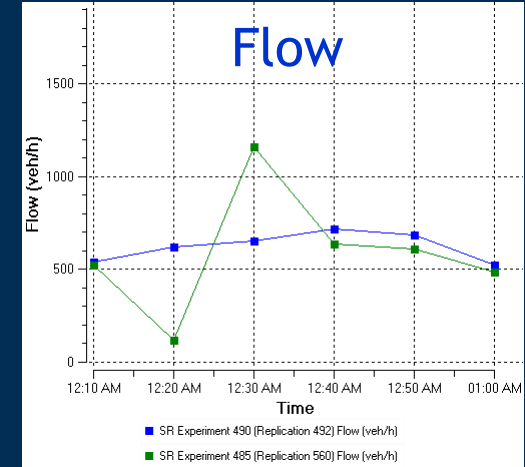
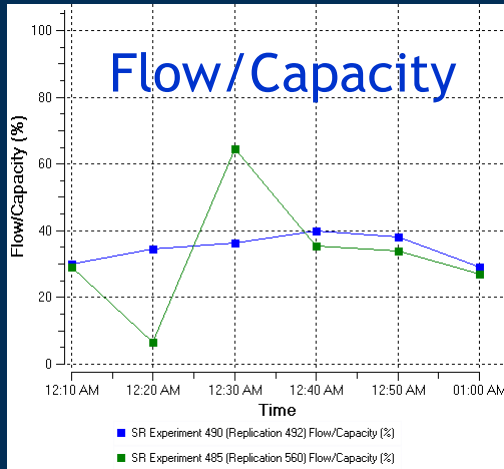
- Sections

Part or a link depending upon geometry/operational characteristics

Incident Observation and Output (With and Without)

Incident created at 12:10 hrs

— Without Incident
— With Incident



VMS Display during an incident for route guidance

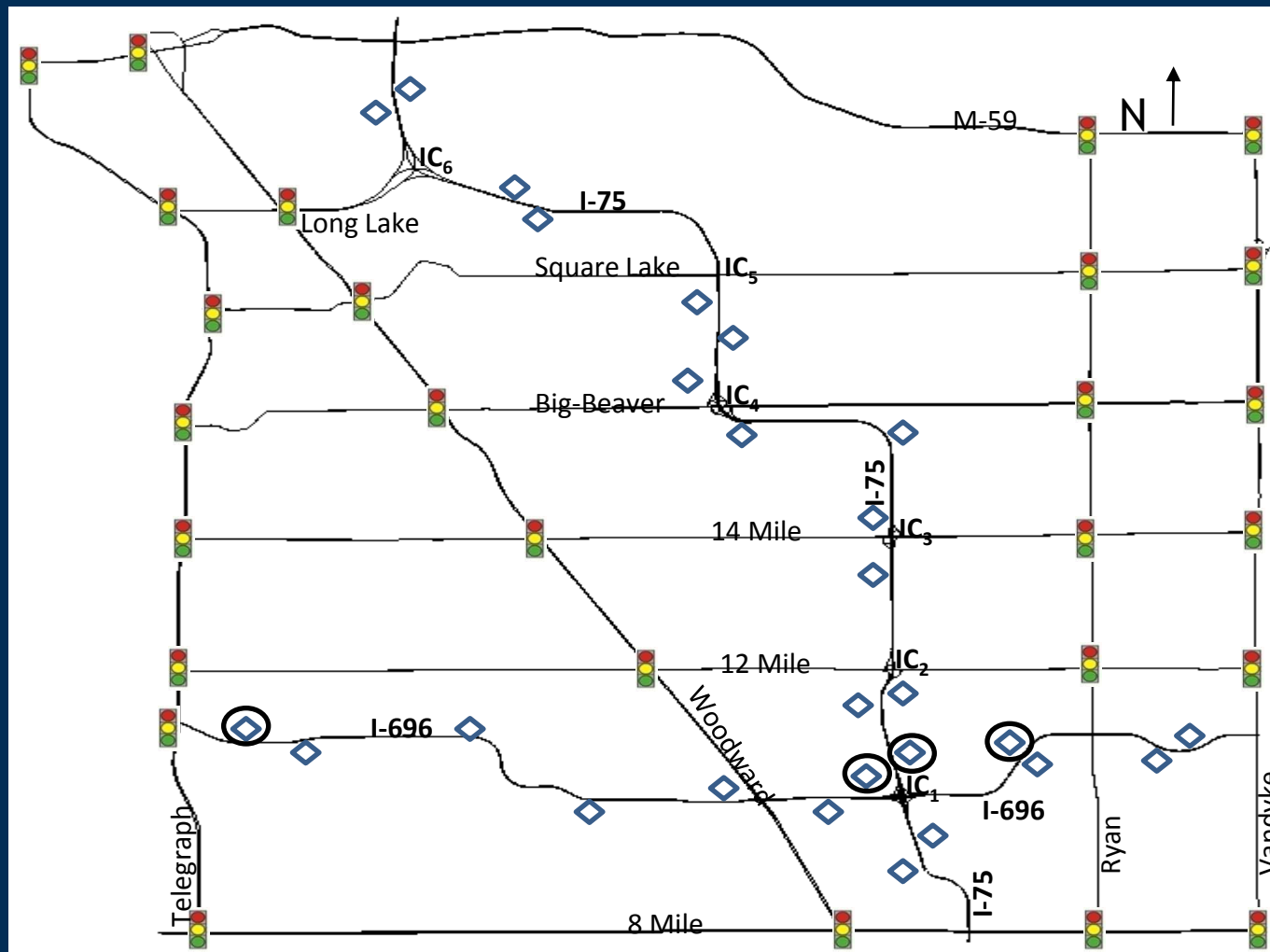







Model Application

- **Lane closure:** where a single or multiple lanes are closed for a given section.
- **Section incident:** where a section of lane(s) is blocked due to a traffic crash, disabled vehicles or any other specific reasons.
- **Forced turning:** where vehicles are forced to turn from its original path because of a complete road closure.
- **Congestion:** where the volume to capacity ratio is more than 0.9 in at least one link of the network

Detroit Area Network



-  : Signalized Intersection
-  : Sensor Location on Freeway
- IC : Interchange
-  : Sensor used for Calibration



Network Details

Highway Name	Highway Class	# of Lanes per direction	Posted Speed Limit (mph)	Approximate Length (miles)
I-75	Freeway	3*	70	18.97
I-696	Freeway	3*	70	14.48
Telegraph	Major Arterial	3	40	15.16
Woodward	Major Arterial	4	40	16.05
Ryan	Major Arterial	2	30	12.38
Van Dyke	Major Arterial	3	40	12.58
M59	Arterial	3	40	15.88
8 Mile	Arterial	4	45	13.57
12 Mile	Arterial	2	40	13.32
14 Mile	Arterial	2	40	13.27
Big Beaver	Arterial	3	40	7.90

Calibration Results

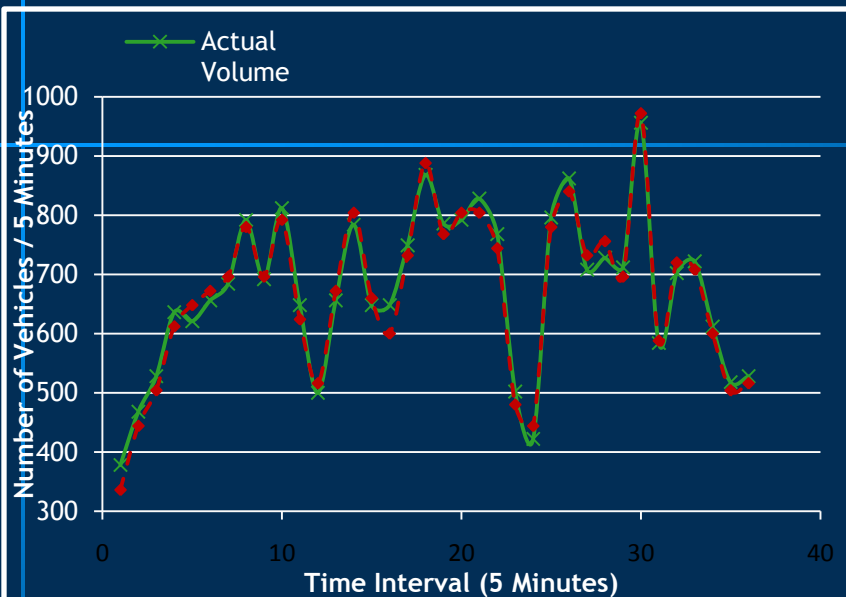


FIGURE 4(a) Actual and Simulated Volume on I-75 South and I-696

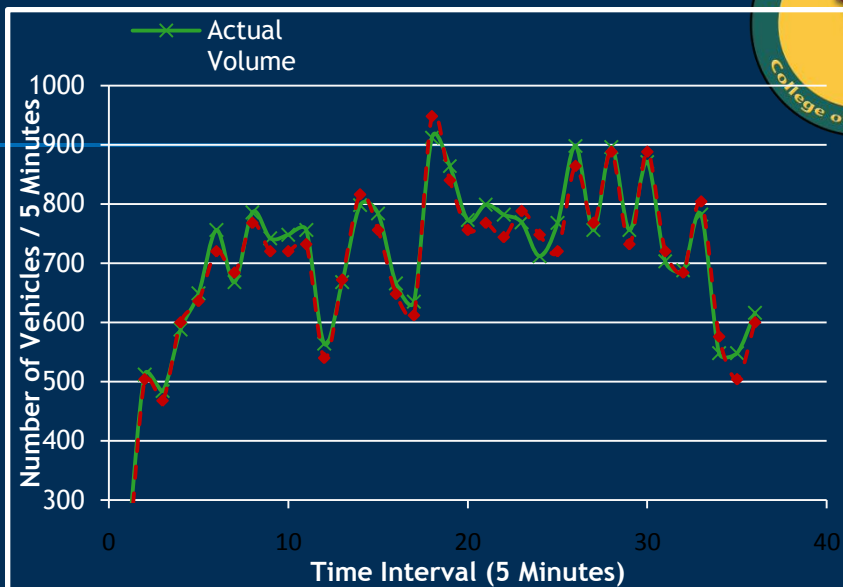


FIGURE 4(b) Actual and Simulated Volume on I-75 North and I-696

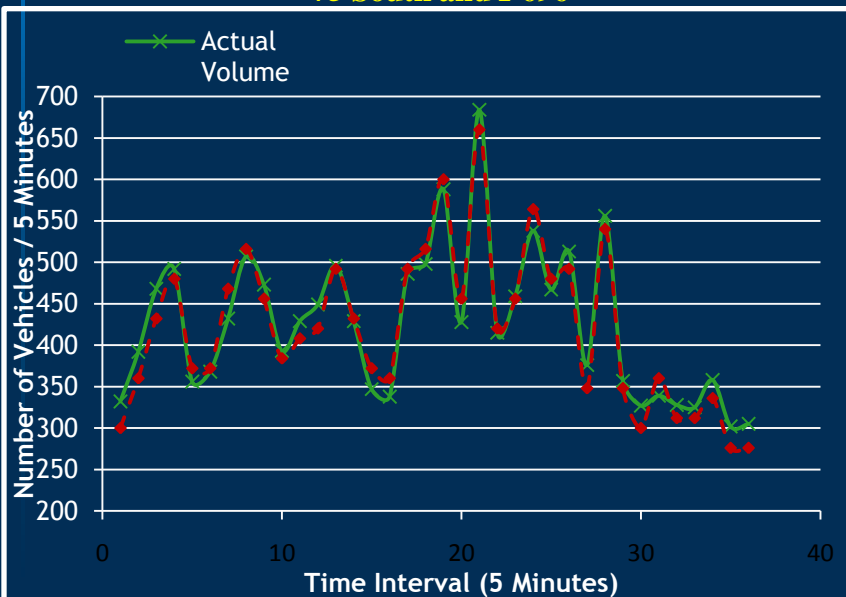


FIGURE 4(c) Actual and Simulated Volume I-696 at East and North I-75

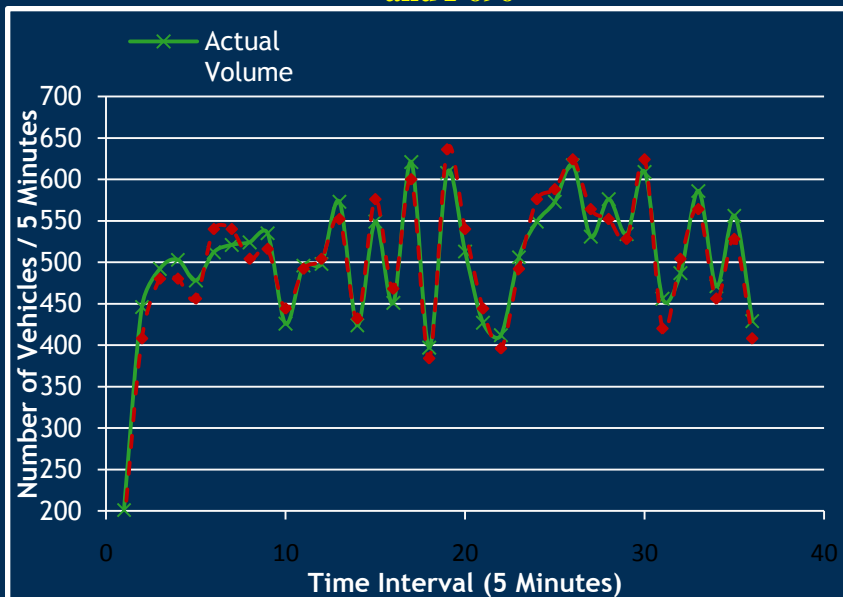


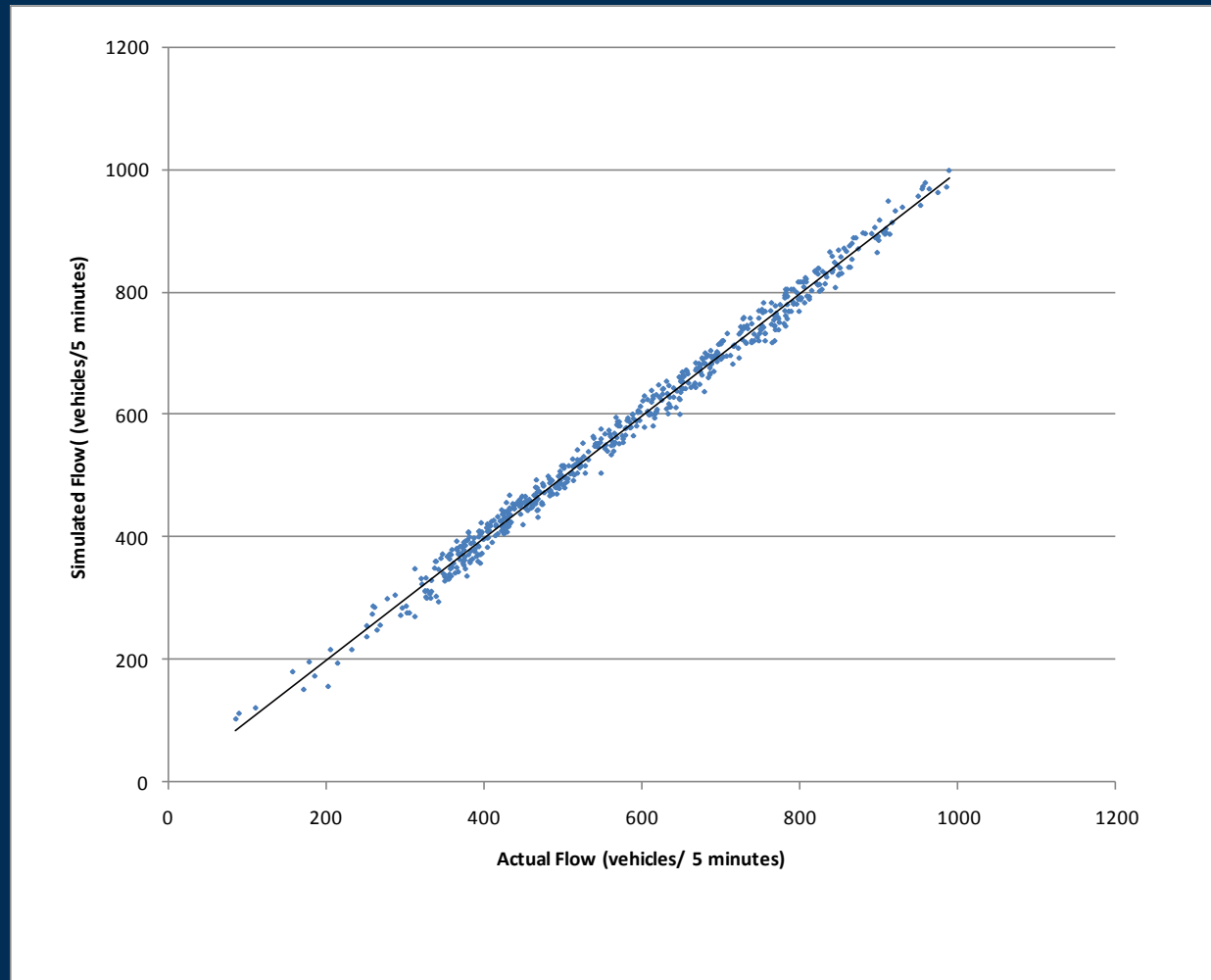
FIGURE 4(d) Actual and Simulated Volume on I-696 near Telegraph



Calibration Results

Location	Root Mean Square Error (RMSE) % Error	Correlation Coefficient (r)	Theil's Weight of Large Errors (U _i)	Theil's Variance Proportion (U _s)	Theil's Covariance Proportion (U _c)	Theil's Bias Proportion (U _m)
I-75 at I-696	0.036	0.988	0.015	0.053	0.928	0.045
I-75 at 14 Mile	0.054	0.988	0.018	0.002	0.873	0.014
I-696 at Telegraph	0.053	0.975	0.024	0.046	0.922	0.058
I-696 at Telegraph	0.044	0.97	0.020	0.089	0.915	0.013
I-75 Corridor	0.001	0.995	0.013	0.000	0.987	0.014

Model Fit





Incident Type and Policy

Serial Number	IMS	Policy	Simulation Duration for Case Study (min)
1	Lane Closure	Throughout	s
2	Section Incident	Specified Duration	0.5s, and 0.75s
3	Forced Turning	Specified Duration	0.5s, 0.75s and s
4	Congestion	Throughout	s

Note: s: Simulation Period in minutes



Micro-simulation Results

- No-Incident: Represents the base condition
- Unguided: Represents incident condition but no IMS is deployed
- Guided: Represents a situation where an appropriate IMS has been deployed after the incident



Experimental Design Location

Type	Date	Time	Notation	Location in the Network
Lane Closure	2/20/2006	9:00 AM - 10 AM	L1	On I75North at 14 Mile Rd
	3/24/2006	7:00 AM-8:00 AM	L2	On I75North at 14 Mile Rd
	6/02/2006	7:00 AM-8:00 AM	L3	On I75North at 12 Mile Rd
	6/09/2006	9:00 AM-10:00 AM	L4	On I75North between 12 Mile Rd and I696
	6/04/2007	1:00PM-2:00PM	L5	On I75North between 14 Mile and 12 Mile Rd
Section Incident and Forced Turning	6/21/2006	10: 00 AM-11:00 AM	S1	On I75North at Big
	8/27/2006	12: 00 PM-1:00 PM	S2	On I75North between 14 Mile and 12 Mile Rd
	5/2/2007	7: 00 AM-8:00 AM	S3	On I75North at 14 mile Rd
	6/22/2007	10: 00 AM-11:00 AM	S4	On I75North between 14 Mile and 12 Mile Rd
	10/11/2007	7: 00 AM-8:00 AM	S5	On I75North approaching 12 Mile Rd
Congestion	6/2/2006	4:00 PM - 5.00 PM	C1	On I75South to the west of 12 Mile Rd
	6/21/2006	5.00 PM - 6.00 PM	C2	On I75North to the west of I696
	5/2/2007	4:00 PM - 5.00 PM	C3	On I75South to the west of I696
	6/22/2007	2.00 PM - 3.00 PM	C4	On I75South to the west of 14 Mile Rd
	6/10/2008	5.00 PM - 6.00 PM	C5	On I75North to the west of I696

Travel Time Results for Lane Closure (sec/mi/vehicle)



Measure	Notation	No Incident	1 Lane Closed			2 Lanes Closed			All Lanes Closed		
			Unguided	Guided	% Improvemt	Unguided	Guided	% Improvemt.	Unguided	Guided	% Improvem t.
Travel Time	L1	70.65	77.26	58.23	24.64	80.92	63.46	21.57	85.66	50.02	41.60
	L2	72.84	76.64	59.34	22.57	80.48	64.65	19.67	87.08	49.61	43.03
	L3	77.33	81.05	61.19	24.50	86.68	68.17	21.35	92.24	54.34	41.10
	L4	77.44	82.83	62.93	24.03	88.35	69.07	21.82	93.76	56.20	40.05
	L5	78.05	80.63	62.30	22.73	86.85	69.14	20.40	92.31	53.34	42.22
Delay	L1	14.83	17.97	13.16	26.77	20.61	15.70	23.81	23.73	11.84	50.10
	L2	15.98	19.89	14.42	27.51	22.43	16.99	24.25	25.74	13.05	49.31
	L3	16.23	21.80	14.93	31.51	24.65	17.49	29.05	27.58	14.24	48.37
	L4	16.43	21.37	15.27	28.54	24.26	17.75	26.86	27.92	13.95	50.03
	L5	17.28	23.78	16.41	30.99	25.87	18.78	27.43	29.78	15.41	48.24

Travel Time Results for Section Incident (sec/mi/vehicle)



Measure	Notation	No Incident	30 minutes						45 minutes					
			1 Lane Closed			2 Lanes Closed			1 Lane Closed			2 Lanes Closed		
			Un-guided	Guided	% Improvement	Un-guided	Guided	% Improvement	Un-guided	Guided	% Improvement	Un-guided	Guided	% Improvement
Travel Time	S1	75.75	79.42	62.8	20.93	81.43	65.62	19.42	80.48	64.57	19.77	82.56	67.4	18.36
	S2	75.48	80.4	60.03	25.34	81.98	62.3	24	80.71	61.01	24.4	83.3	64.7	22.33
	S3	77.26	80.5	60.37	25	82.49	63.02	23.6	81.62	61.72	24.38	83.52	64.94	22.25
	S4	69.96	74.03	59.66	19.41	76.14	62.4	18.05	75.48	61.54	18.46	77.22	64.31	16.71
	S5	77.62	83.56	63.91	23.51	85.53	66.53	22.22	84.46	65.16	22.84	86.92	68.48	21.21
Delay	S1	17.2	19.28	15.16	21.37	21.16	16.85	20.38	20.51	15.96	22.2	22.22	17.78	19.99
	S2	16.67	19	15.3	19.48	20.85	16.93	18.83	20.16	16.14	19.95	21.85	18.09	17.23
	S3	18.84	20.71	16.62	19.74	22.38	18.28	18.33	21.77	17.68	18.77	23.43	19.6	16.35
	S4	14.11	16.78	13.31	20.71	18.41	14.95	18.79	17.73	14.34	19.15	19.36	16.04	17.12
	S5	20.88	22.64	18.09	20.11	24.33	19.84	18.45	23.67	19.23	18.76	25.34	20.93	17.4

Travel Time Results for Forced Turning (sec/mi/vehicle)



Measure	Notation	No Incident	30 minutes			45 minutes			60 minutes		
			All Lanes Closed			All Lanes Closed			All Lanes Closed		
			Unguided	Guided	% Improvement	Unguided	Guided	% Improvement	Unguided	Guided	% Improvement
Travel Time	S1	76.78	83.17	61.17	26.45	86.39	59.39	31.25	89.67	52.39	41.58
	S2	76.96	83.62	57.78	30.9	86.85	55.86	35.68	90.09	49.81	44.7
	S3	78.74	84.38	58.13	31.1	87.98	55.53	36.89	91.25	49.06	46.24
	S4	71.86	78.44	56.93	27.43	81.99	55.29	32.57	85.23	48.62	42.95
	S5	79.31	87.19	62.22	28.64	90.72	60.35	33.47	94.06	53.39	43.24
Delay	S1	18.13	23.56	13.52	42.62	26.79	14.77	44.86	29.75	13.23	55.54
	S2	18.91	25.25	13.63	46.02	28.59	15.12	47.1	31.79	13.37	57.95
	S3	20.76	24.59	14.98	39.07	27.82	16.35	41.24	30.68	14.71	52.07
	S4	15.46	20.1	11.68	41.87	21.75	13.1	39.79	24.76	11.44	53.8
	S5	21.61	26.53	16.43	38.08	29.59	17.84	39.7	32.55	15.96	50.96

Travel Time and Delay Data for Congestion (sec/mi/vehicle)



Measure	Notation	Unguided	Guided	% Improvement
TT	C1	98.81	65.62	33.59
	C2	96.11	63.04	34.4
	C3	96.44	63.62	34.03
	C4	92.69	60.55	34.68
	C5	85.92	57.12	33.52
Delay	C1	35.61	17.96	49.57
	C2	36.86	19.84	46.18
	C3	36.57	19.42	46.9
	C4	29.17	15.04	48.43
	C5	21.22	11.31	46.7

Queue Length for Unguided and Guided Scenarios for Lane Closure Strategy (L3)

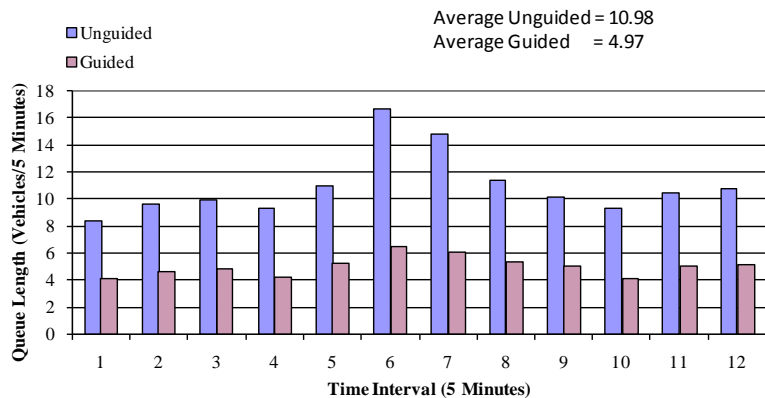


FIGURE 6(a) Queue Length for “Unguided” and “Guided” Scenarios on I-75 South and I-696

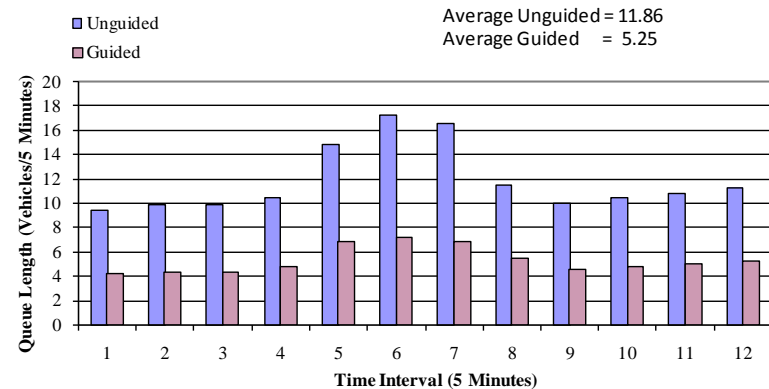


FIGURE 6(b) Queue Length for “Unguided” and “Guided” Scenarios on I-75 North and I-696

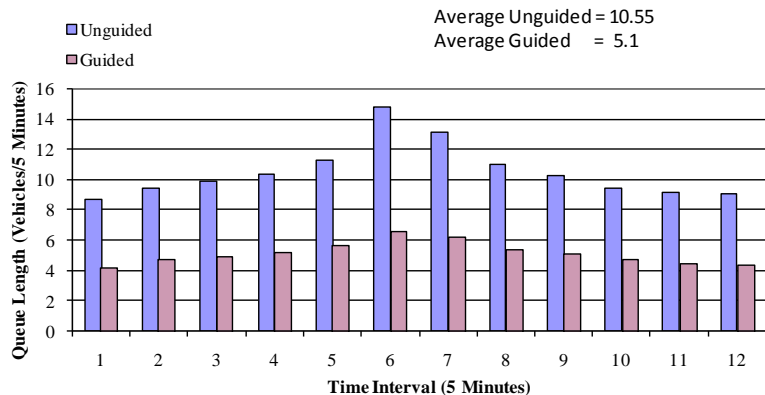


FIGURE 6(c) Queue Length for “Unguided” and “Guided” Scenarios on I-696 at East and North I-75

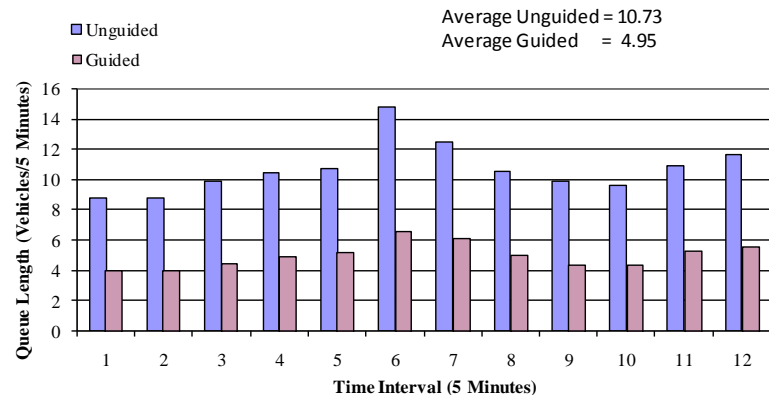


FIGURE 6(d) Queue Length for “Unguided” and “Guided” Scenarios on I-696 near Telegraph



Conclusion

- Combination of freeways and arterials are considered for the network
- Policies and strategies are developed to address IMS's
- The framework presented is conceptually sound and robust
- Model calibration with two sets of data and comparison between observed and modeled data
- Model application to test IMS's, shows that the model output is sensitive to the operational changes
- When motorists are guided during incidents, network level performance data (i.e. travel time, delay, and queue length) improved significantly compared to the "unguided" conditions.



Future Scope of Work

- Larger I-75 network
- Comparison of Micro, Meso, and Macro simulation performance
- Application of the model in seven county area in Michigan

THANK YOU

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