

## **INTEGRATED CONTROL STRATEGIES FOR SURFACE STREET AND FREEWAY SYSTEMS**

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Zong Z. Tian  
Associate Transportation Researcher  
Texas Transportation Institute  
The Texas A&M University System  
E-mail: [z-tian@tamu.edu](mailto:z-tian@tamu.edu)

Kevin Balke  
Center Director, Translink<sup>®</sup>  
Texas Transportation Institute  
The Texas A&M University System

Roelof Engelbrecht  
Associate Transportation Researcher  
Texas Transportation Institute  
The Texas A&M University System

Larry Rilett, Ph.D., P.E.  
Associate Professor  
Department of Civil Engineering  
Texas A&M University

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## **INTEGRATED CONTROL STRATEGIES FOR SURFACE STREET DIAMOND INTERCHANGE AND FREEWAY RAMP METERING**

*Zong Tian, Kevin Balke, Roelof Engelbrecht, Larry Rilett*

### **Abstract**

Freeway ramp metering often exists in the vicinity of a signal controlled diamond interchange, where the surface street system and the freeway system intersect. Even though both systems are controlled by traffic signals, they primarily operate independently one another. This paper presents a study on integrated operations of surface street system and freeway system using VISSIM, a microscopic simulation model. A traffic network consisting of a surface street and a freeway segment was constructed in VISSIM. The surface street and freeway are connected through a diamond interchange with on-ramps and off-ramps. The objective of the study was to develop an integrated control algorithm for both the diamond interchange signal and the ramp-metering signal. The proposed control algorithm, including an adaptive diamond interchange control and a traffic-responsive ramp-metering control were programmed using VISSIM's Vehicle Actuated Programming (VAP), which serves as an external control function for the simulation model. Preliminary tests of the proposed control algorithm indicated improved operations for both the surface street system and the freeway system. Significant improvements on traffic operations were achieved when compared to non-adaptive diamond control and static ramp-metering control. Although similar performance measures were found (with the particular scenarios evaluated) with no-metering control, with the existing traffic-responsive ramp-metering control, and with the proposed traffic-responsive ramp-metering control, the proposed control algorithm has more flexibility and may be adapted over a broader range of traffic flow conditions.

**Key Words:** Integrated Control, Diamond Interchange, Ramp Metering, Simulation

## **Introduction**

Signalized interchanges and ramp metering are major components of the interface between the surface street system and the freeway system. The ramp-metering signal is the only active component of the freeway surveillance and control system that links to the surface street system. Although interchange signal control and ramp metering are both driven by signal controllers, the two facilities have been primarily treated as separate control components. The fact that the facilities are not integrated often results in inefficient operations on both systems. While the concept of integrated operations of surface street signal system and freeway ramp metering system had appeared in the early 1970's as part of the corridor control plan, integrated operations have primarily remained a relatively strategic view. Actual integration of the two systems is often not pursued for a number of reasons – the least of which is the jurisdictional control of the two systems and often competing objectives. As urban congestion continues to grow and easing congestion has become a common goal for all the transportation organizations, the importance of collaboration among transportation agencies has been recognized in order to achieve the optimal operations for the entire transportation system. Therefore, understanding the relationship between surface street and freeway operations is critical to the success on integrated operations of the two systems. Different traffic flow characteristics and management strategies for the two systems present a significant challenge to the integration process. The purpose of this study is to explore, using microscopic traffic simulation as a tool, the concepts and implementation strategies of integrated operations between surface-street and freeway system. Current practice, including related research and field implementation projects, is reviewed first. A traffic network constructed using VISSIM [1], a microscopic simulation model is then presented, where various control strategies featuring traffic-responsive ramp metering and adaptive interchange signal timing algorithms were implemented. Finally, the simulated performance measures of the system are presented based on various traffic flow and control scenarios.

## **Current Practice and Research**

Freeway on-ramps basically operate in one of the following three modes: no metering or

no control, static metering, and dynamic or traffic-responsive metering. No metering has no control of the traffic entering the freeway, therefore, it is not considered as part of the freeway management strategy. Static ramp metering uses metering rates determined off-line based on historical volume data, and the ramp metering rates can only be changed on a time-of-day basis. Such a metering strategy lacks the ability to react to temporary traffic variations on the freeway. Some advanced signal controllers have implemented traffic-responsive features for ramp metering. When operating under traffic-responsive mode, some pre-determined ramp-metering rates could be implemented based on the mainline traffic conditions and the ramp queue conditions [2]. Traffic-responsive ramp metering is often part of an integrated ramp metering system, where the objective is to optimize the system-wide freeway flow.

The following aspects reflect the lack of integrated operations between the surface street signals and the ramp-metering signals. All current ramp-metering strategies primarily focus on managing traffic operations from the perspective of optimizing freeway traffic flow. As a result, queue backup often exists on freeway on-ramps and eventually affects the operations of signalized intersections. Since the freeway system has no knowledge of this problem, ramp metering would continue regardless of the negative impact on the surface street. One of the solutions of preventing queue spillback is to use queue detectors at freeway on-ramp locations. A presence loop detector is often placed at the upstream end of the on-ramp. Ramp queue buildup is sensed with this detector. When queue spillback is detected, the metering rate is increased or the metering may turn off to discharge the excessive queues regardless of the negative impact on the freeway flow. Queue detectors are also used at off-ramp locations to prevent queue spillback onto the freeway. At such off-ramp locations, a queue detector is often placed at the upstream end of the off-ramp. When queue on the off-ramp backs up to the freeway, the queue detector cause preemption to the interchange signal to discharge the queue. Although the action eliminates queue spillback onto freeway, it often disrupts normal signal operations on the surface street, especially when the signals are coordinated. There are typical examples of lack of integrated operations between surface street system and freeway system.

Integrating the surface street signal and the ramp-metering signal may achieve improved operations for both the surface street system and freeway system. A good example for such an integrated operation is the ramp access control. Access to an on-ramp could be limited by reducing the capacity of the signalized intersection, which could be achieved by increasing all red clearance intervals in the signal cycle, or reducing the green time for the signal phases that control the traffic movements feeding the ramp. Where major flows feeding the on-ramp gain access via a yield or stop sign, signaling such movements may be necessary to provide a positive means of control.

Since 1993, the Federal Highway Administration (FHWA) initiated a number of major researches and field implementation projects on integrated control systems. The study conducted at Turner-Fairbank Highway Research Center [3] is probably the first major study on this subject toward practical applications. The study explored integration strategies and tactics for possible field implementation. A similar research was also conducted by Pooran and Lieu [4]. The microscopic simulation model INTRAS [5] was used in both research projects to evaluate the effectiveness of the various strategies. Between 1994 and 2000, FHWA sponsored two major field implementation projects: Integrated Corridor Traffic Management (ICTM) [6], and Field Operational Test (FOT) [7]. Both projects aimed at evaluating the effectiveness of coordinated operational strategies for surface street system and freeway system. The first project, located in the Twin Cities in Minnesota, is an 8-mile section of the I-494 transportation corridor, consisting of the I-494 freeway, four parallel arterial streets, and seven perpendicular arterial streets crossing five jurisdictions. The Sydney Coordinated Adaptive Traffic System (SCATS) was used to provide adaptive traffic control technology for both freeway metered ramps and arterial traffic signals. The entire project covered a time span of almost five years (from 1994 to 1999). The second project is located in the City of Irvine, California. The project was initiated in 1994, and an evaluation report was prepared based on the progress by the spring of 1999. The system was still not fully functioning at the time of the report. Two control systems were deployed in the FOT projects: System-Wide-Adaptive Ramp Metering (SWARM) for freeway ramp metering, and Optimized Polices for Adaptive Control (OPAC) for the arterial signal systems.

Research and field implementation projects [3-7] performed to date revealed several deficiencies including software functionality, hardware communications, and incompatible data sets for performance evaluations. This latter problem occurred because the before and after studies occurred over a long period during which the traffic patterns changed substantially. Although the value of using simulation model was recognized for conducting research on this topic, testing of the strategies was primarily constrained by the limitations of the INTRAS software used in previous studies [3,4]. As indicated by the researchers at the Turner-Fairbank Highway Research Center, the close interaction between the ramp metering signal and the surface signal cannot be modeled on a real-time basis. Advanced traffic-responsive ramp metering requires sophisticated modeling features to reflect the stochastic nature of traffic flow. Not only is the ramp metering affected by the lane imbalances on freeways, the capacity itself is also not constant at freeway segment due to variations on traffic composition, speed and density.

This study used Vehicle Actuated Programming (VAP), one of the unique modeling features of VISSIM, where user defined signal control algorithms can be implemented in the simulation model. In addition to the advanced modeling features on signal control, VAP also provides features such as incident detection and dynamic routing for system monitoring and management purposes.

### **Integration Strategies**

The study conducted at the Turner Fairbank Highway Research Center [3] provided an excellent documentation on possible coordination strategies and control tactics. Four types of coordination strategies and sixteen types of control tactics were identified. A brief description of the strategies and tactics related to our study is provided below.

- **Local Coordinated Strategy** – To be used when the freeway traffic demands do not require integrated ramp control. The focus is on the local conditions at each individual interchange and requires a close and responsive interaction between the ramp meter controller and traffic signal controller.

- Diversion Strategy – To be used when non-recurring incidents occur, requiring diversion of traffic and special signal timing and ramp metering to handle the diverted traffic.
- Off-Ramp Priority Tactic – To handle the diverted traffic from freeway due to an incident or recurring congestion. Adjustment on the green split of the traffic signal that handles the off-ramp traffic is required.
- On-Ramp Priority Tactic – To maximize flow onto the freeway such as by removing ramp metering. It is used when an incident occurs immediately upstream of the on-ramp, where freeway traffic is diverted from the upstream off-ramp through the interchange and back via on-ramp.
- Inhibit Metering Tactic – Similar to on-ramp priority, ramp meter is turned off during periods of temporary congestion on the on-ramp.

The study described in this paper focused on a rather small-scale network, which includes a diamond interchange and a freeway segment where a ramp metering exists in the close vicinity of the diamond interchange. An integrated control algorithm, which includes an adaptive diamond control and a proposed traffic-responsive ramp metering, was implemented and tested in VISSIM. The control algorithm was designed to operate under both normal traffic conditions and non-recurrent incident conditions.

## **Study Approach**

### ***System Description***

Figure 1 shows the system network configuration used in this study, and Table 1 provides descriptions of each segment of the network, following similar definitions as the Highway Capacity Manual (HCM) [8]. An Origin-Destination (OD) matrix was developed and used for the simulation tests in this study, referencing the values provided in Table 1.

The network consists of a surface street (East-West) that connects to the freeway (North-South) through a diamond interchange. A ramp meter is located on the southbound on-ramp (5-6). A single traffic signal controller controls the operations of the diamond interchange with the phasing scheme (TTI 4-phase) shown in Figure 2. This phasing scheme is used at most closely spacing diamond interchanges to eliminate vehicle stopping within the interchange. Capacity values shown in Table 1 for each segment were estimated based on the deterministic models of the HCM. These values only serve as guidelines for model calibration purpose and for developing traffic patterns and demands to be implemented in the simulation model. The dynamic modeling process does not rely on these values, because capacity is an emergent property of the simulation model.

### ***Model Development***

An integrated control algorithm has two components: the diamond interchange control and the ramp control. Implementation of the integrated control algorithms relies on the placement of several detectors at various key locations. Information obtained from these detectors serves as the major inputs for the control algorithms. Besides the presence and passage detectors typically used at interchange or ramp locations for normal actuated control (not shown in the figure), three special detectors are placed at the locations shown in Figure 3. An incident detector is placed approximately 200 meters downstream of the first off-ramp to detect freeway incidents. During a simulated incident, the outermost lane will be closed, resulting in reduced capacity on the freeway. Under normal conditions, the diamond interchange operates in a fully-actuated control mode, with designated timing parameters such as minimum green times, maximum green times, passage times, yellow and red intervals. During an incident occurrence (the diamond interchange signal receives such information from the incident detector), it was assumed that ten percent of the southbound freeway traffic will be diverted to the off-ramp, passing through the interchange, and re-entering the freeway using the downstream on-ramp. The maximum green times are automatically adjusted for each phase of the diamond interchange. For example, in the tests performed the maximum green for phase 4 (off-ramp) was increased

from 35 to 60 seconds during an incident to accommodate the increased demand. Once the incident is resolved, the timing parameters are automatically changed back to the original settings. Such an adaptive control concept can also be applied to coordinated signal systems, where adjustments will be made to the phase splits.

A queue detector is placed at the upstream end of the on-ramp to detect queue spillback conditions. An occupancy detector is located immediately upstream of the merging location on the outmost lane to detect the traffic conditions on freeway. The occupancy data from these detectors are used to determine whether the ramp should be metered, and what metering rate should be applied. Such a dynamic ramp-metering algorithm incorporates both the conditions and operations on both the surface street and freeway systems. The dynamic ramp-metering algorithm is illustrated in Figure 4. The algorithm adopts two freeway occupancy threshold values: a lower threshold ( $O_1$ ) and a higher threshold ( $O_2$ ). Three ramp-metering scenarios can be resulted: No Metering, Low Rate, and High Rate. By implementing different occupancy threshold values, different ramp metering strategies can be obtained. For example, higher values on  $O_1$  and  $O_2$  (e.g., 0.20 and 0.60) would result in a more aggressive metering strategy where a high metering rate is allowed even though the freeway already operates at high volumes. Similarly, a conservative metering strategy can be achieved by implementing lower occupancy threshold values (e.g., 0.10 and 0.50).

Testing the effectiveness of the control algorithm must be based on a set of traffic demand/volume conditions. One of the major objectives of this study is to test whether various ramp-metering algorithms (including traffic-responsive metering) can be implemented and tested using the advanced modeling features in VISSIM. The effectiveness of the proposed integrated control algorithm during incident conditions is of special interest. Since such kind of data is difficult to obtain from the field, the analysis conducted in this study is purely simulation based. Therefore, an origin/destination matrix was manually created. Table 2 illustrates the origin/destination patterns to be used in the simulation. The values of each origin/destination patterns were determined so that the congestion and diversion strategies can be adequately assessed. For example, the O-D

pattern would result in the southbound freeway traffic demand close to the HCM two-lane capacity (during incidents). Traffic demands on the east-west surface street were kept under 60% of the capacities. Such a traffic demand level would likely result in temporary congestion on the freeway during incident occurrences, while the surface street is under capacity, which would provide higher flexibility for the diamond interchange signals during the adaptive control operations.

### ***Modeling Results***

A total of eight control scenarios were simulated based on the combination of the diamond interchange control and the ramp control. Two types of controls at the diamond interchange were considered, which include a non-adaptive (N) signal control mode and an adaptive (A) signal control mode. Four types of ramp controls were considered at the on-ramp: no metering (N), static metering (S), existing traffic-responsive metering (E), and the proposed traffic-responsive metering (P). The proposed ramp-metering algorithm as shown in Figure 4 was used where the two threshold values  $O_1$  and  $O_2$  were set at 0.10 and 0.50. Calibration of these values may be necessary for field implementation to achieve a certain objective. For example, for the same traffic condition, different occupancy values may be obtained depending on the type of detection technology. Applying higher threshold values in the algorithm will result in a more aggressive ramp-metering strategy (less restrictive to the ramp traffic). The low metering rate was set at 510 vph (2 second green, 5 second red), and the high metering rate was set at 720 vph (2 second green, 3 second red). It is noted that the traffic-responsive metering algorithm described in Figure 4 can actually result in cases where the metering is turned off (i.e., no-metering) depending on the mainline occupancy and ramp queue conditions. The static metering strategy used a constant metering rate of 720 vph (2 second green, 3 second red). The existing traffic-responsive ramp-metering algorithm was modeled using similar metering rates as the proposed algorithm, however, ramp-metering is turned off whenever a queue is detected on the ramp. The eight control scenarios include:

- Adaptive Interchange/Static Ramp Metering (AS)
- Adaptive Interchange/Existing Responsive Metering (AE)

- Adaptive Interchange/Proposed Responsive Ramp Metering (AP)
- Adaptive Interchange/No Ramp Metering (AN)
- Non-Adaptive Interchange/Static Ramp Metering (NS)
- Non-Adaptive Interchange/ Existing Responsive Metering (NE)
- Non-Adaptive Interchange/Proposed Responsive Ramp Metering (NP)
- Non-Adaptive Interchange/No Ramp Metering (NN)

Two incident occurrences of ten minutes duration were simulated in each scenario. A total of 40 multiple simulation runs with different random seeds were carried out for each study scenario to minimize the error on the performance measure estimates. The performance measure from simulation was focused on the average delay for the major traffic flow patterns in the system as described in Table 3. In this study, the southbound direction is the primary focus, where the integrated control strategies were implemented. The primary traffic flows affected by the control strategies include the southbound freeway traffic, the diverted freeway traffic, the southbound freeway to surface street traffic, the surface street to southbound freeway traffic, and the surface street traffic passing through the diamond interchange. Table 3 lists the delay measurement segments defined in VISSIM for these major traffic flows. The delay for each traffic flow pattern is the weighted average of the delays in the associated segments.

Table 4 is a summary of the delay results from simulation. The results are summarized for each major traffic flow with different control scenarios. The results are also presented in Figures 5 and 6. Two-sample t-tests can be performed based on the results given in Table 4 to determine whether statistical difference exists between two scenarios. It is noted that the delays for the southbound freeway traffic do not count the diverted traffic in the table and the figures.

Based on the results shown in Table 4, Figures 5 and 6, a summary of the major findings is given below:

- In most cases, the adaptive signal control at the diamond interchange resulted in less delay to the affected major traffic flows as compared to the non-adaptive signal control.
- The ramp-metering strategies have demonstrated significant impact on the diverted traffic and the surface-street-to-freeway traffic. The control scenarios with static ramp metering resulted in significantly higher delays to these two traffic flows compared to other control scenarios.
- All the other control scenarios (no metering, existing traffic-responsive metering, and proposed traffic-responsive metering) seem to yield similar results for the particular cases analyzed in this study. For example, with the adaptive control at the diamond interchange, the no-metering strategy resulted in the least delays to the diverted traffic (e.g., 38.1 sec/veh) and the surface-street-to-freeway traffic (31.9 sec/veh), but it resulted in slightly higher delays on the freeway traffic (72.0 sec/veh). Similar results were also found for the existing traffic-responsive ramp metering control. Such results are mainly due to the increased reserve capacity on the freeway resulted from upstream incidents. Nevertheless, the results from simulation seem reasonable.

### **Summary and Conclusions**

The paper presents a study on integrated operations of surface street and freeway systems using the VISSIM micro-simulation model. Integrated control algorithms were implemented in the simulation model using the advanced modeling features on signal control and incident management. The effectiveness of various control strategies was evaluated based on the performance measures from the simulation model. The following conclusions can be made based on the results of this study:

- Integrated control strategies for surface street and freeway systems are successfully implemented and evaluated using the advanced modeling features provided by VISSIM. The VAP function provided by VISSIM allows users to develop and test

various control algorithms, especially in modeling dynamic signal control and system management strategies such as incident management. Use of simulation models would also significantly reduce the frustration and fine-tuning effort associated with direct field implementation process.

- The results from the study indicate that by applying integrated control strategies, improved traffic operations can be achieved on both surface street and freeway systems. The algorithms implemented in the model on traffic-responsive ramp metering and adaptive diamond interchange signal control produced effective system operations during freeway incident occurrences.
- For the particular cases analyzed in this study where incidents and traffic diversion scenarios were assumed, similar performance measures were found ramp controls with no-metering, with existing traffic-responsive metering, and with the proposed traffic-responsive metering. With freeway incidents and traffic diversion, the existing traffic-responsive metering and no-metering controls can work just as good as the proposed traffic-responsive ramp - metering control due to the increased reserve capacity on freeway resulted from upstream incidents. However, the proposed traffic-responsive ramp-metering algorithm provides more flexibility in providing optimal system operations under any traffic flow conditions.

Further study is currently underway to include an expanded network with parallel arterial streets and to test integration strategies on a broader range.

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**FIGURE 2** Signal Phasing (TTI - 4 Phase) for the Diamond Interchange

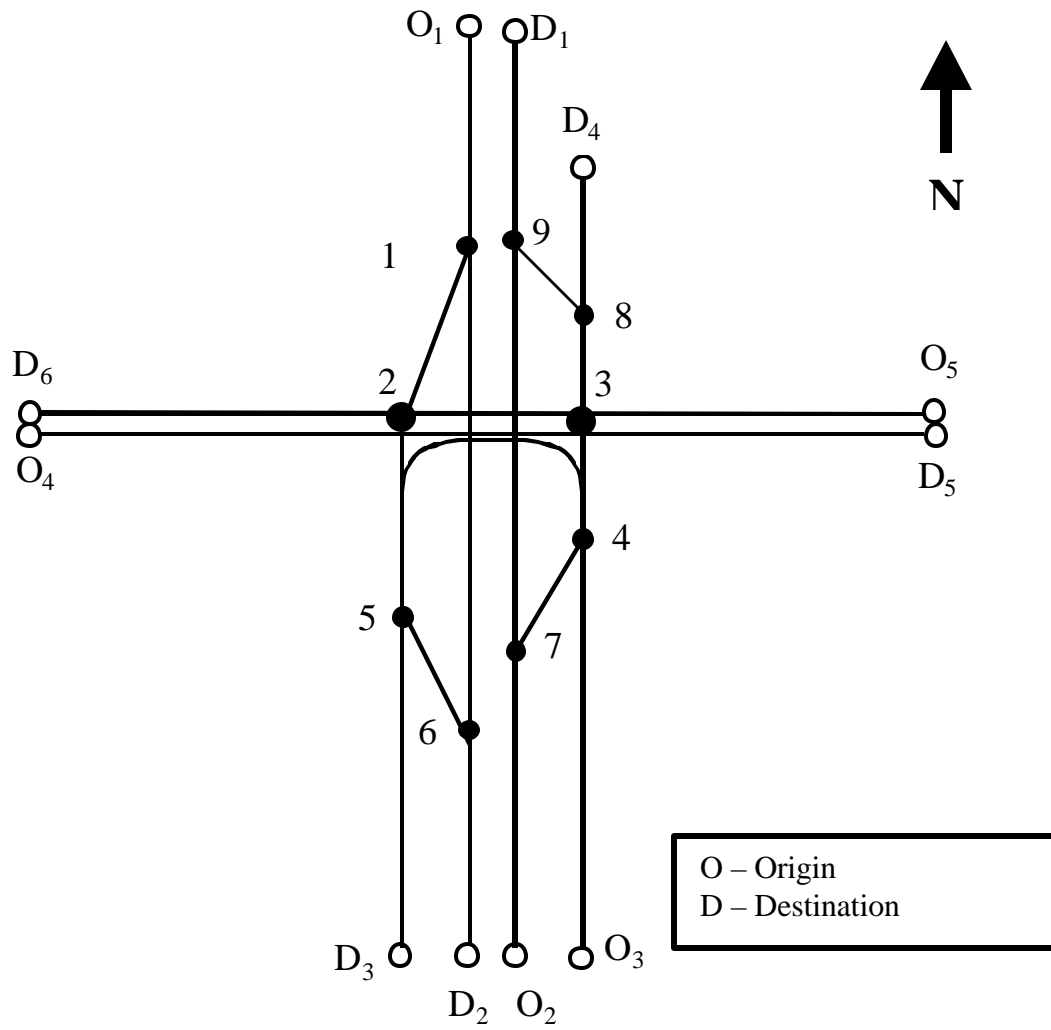
**FIGURE 3** Simulation Network and Detector Locations

**FIGURE 4** Illustration of the Proposed Traffic-Responsive Ramp Metering

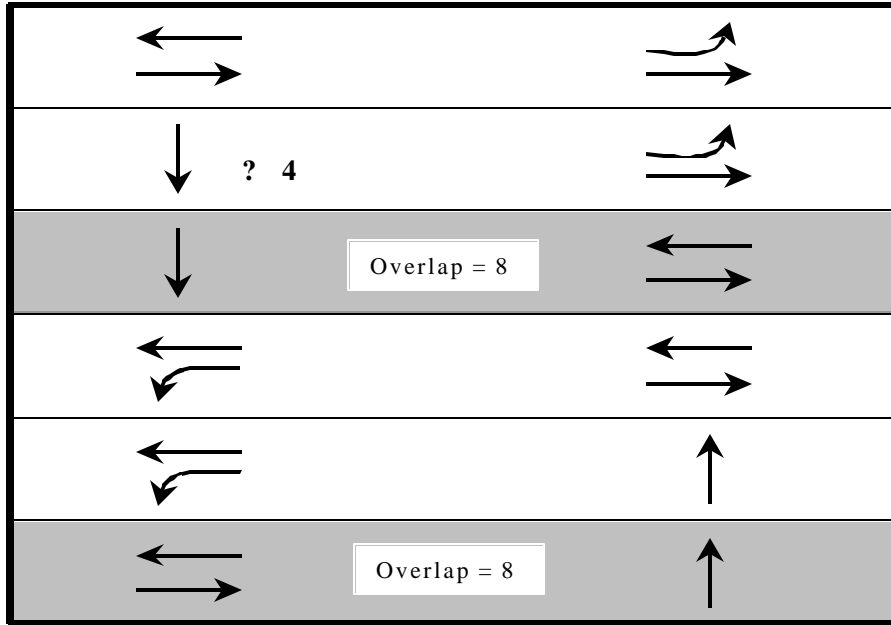
**Algorithm**

**FIGURE 5** Delay Results for the Southbound Freeway and the Diverted Traffic

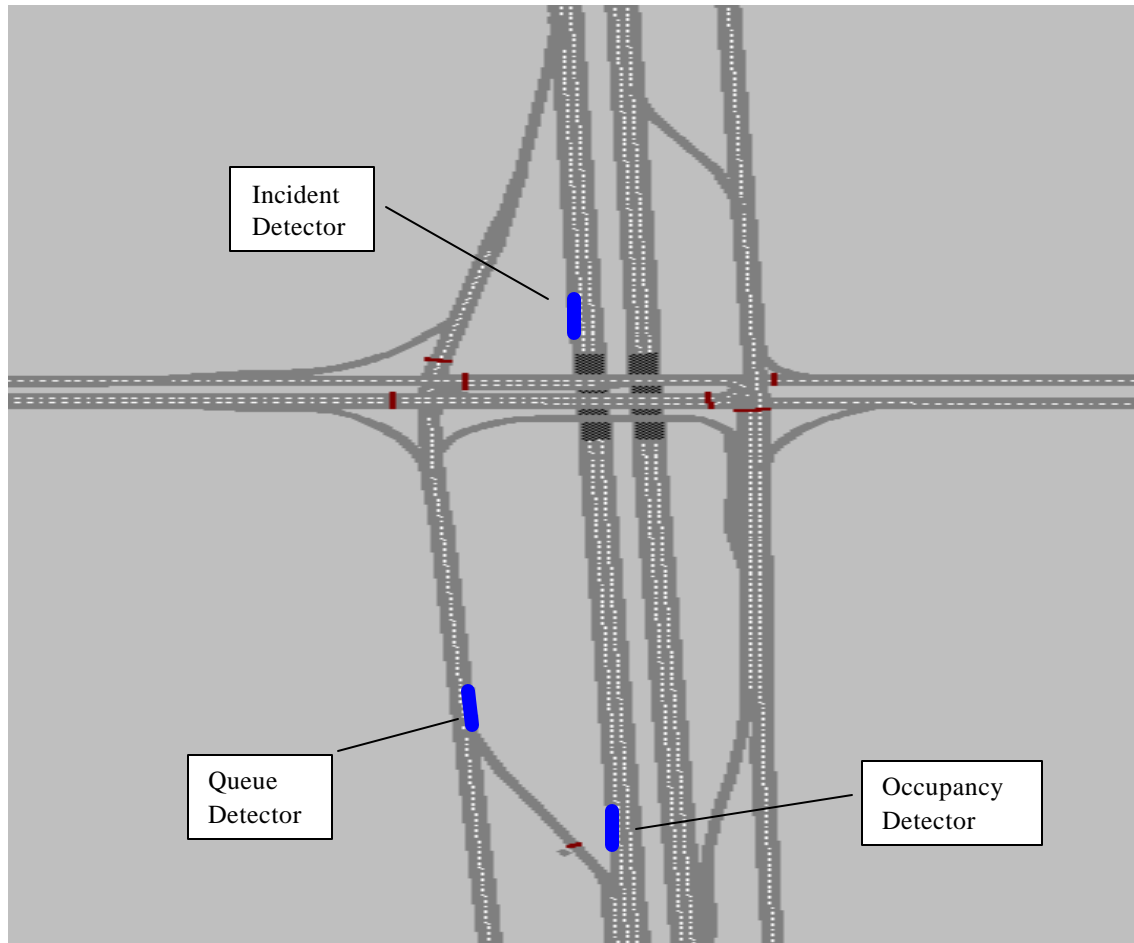
**FIGURE 6** Delay Results for Surface Street Traffic



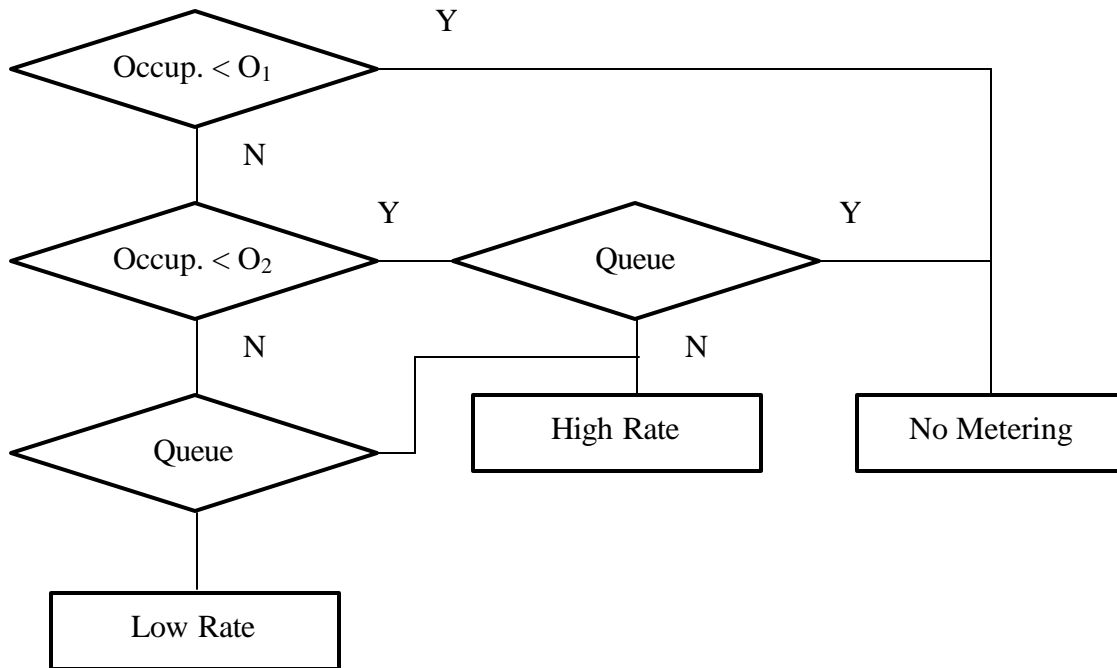
**FIGURE 1** System Configuration



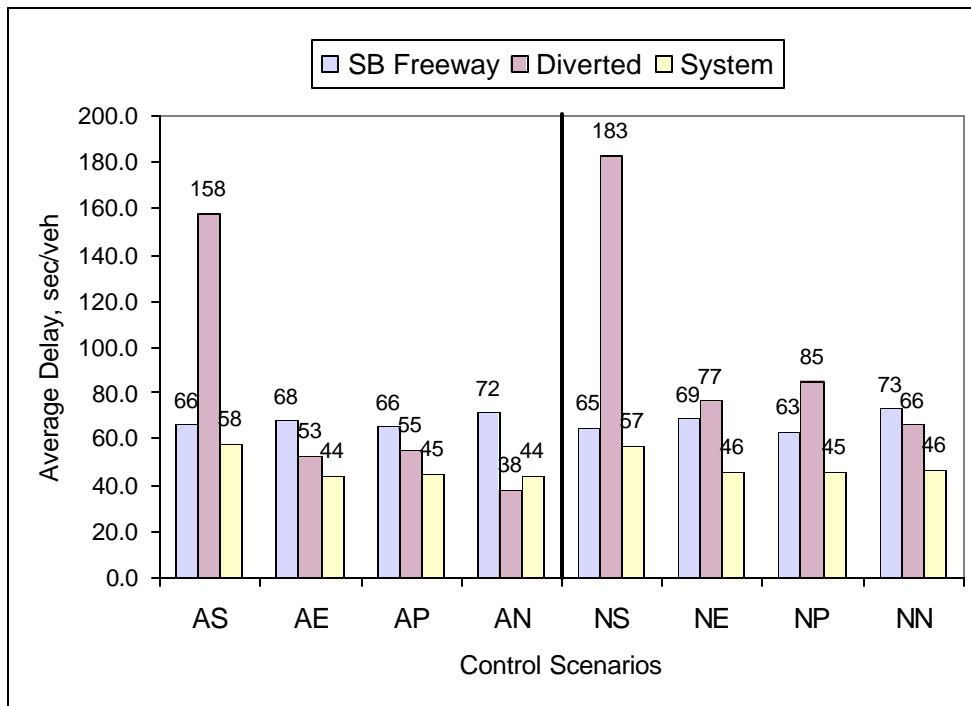
**FIGURE 2** Signal Phasing (TTI - 4 Phase) for the Diamond Interchange



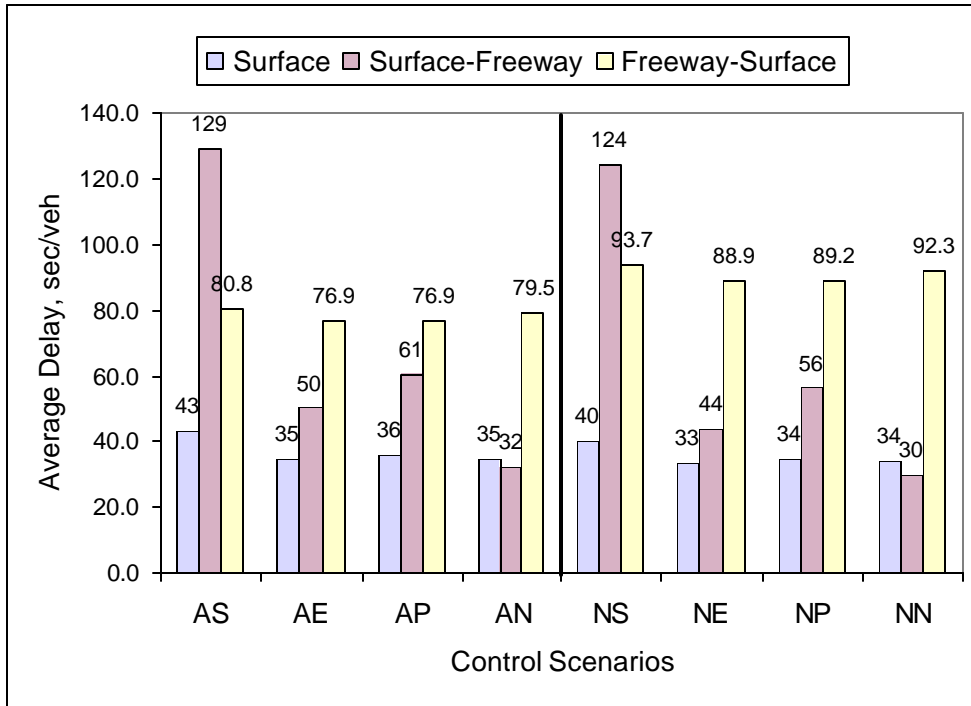
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**FIGURE 4** Illustration of the Proposed Traffic-Responsive Ramp Metering Algorithm



**FIGURE 5** Delay Results for the Southbound Freeway and the Diverted Traffic



**FIGURE 6 Delay Results for Surface Street Traffic**

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**TABLE 1**  
**Description of Network Segments**

Segments		Facility Type	Segment Type	Chapter Reference	Length (meters)	Through Lanes	Capacity (vph)
A-Node	B-Node						
O <sub>1</sub>	1	Freeway	Diverge	25	220	3	6600
1	6	Freeway	Basic	23	599	3	6600
6	D <sub>2</sub>	Freeway	Merge	25	299	3	6600
O <sub>2</sub>	7	Freeway	Diverge	25	299	3	6600
7	9	Freeway	Basic	23	625	3	6600
9	D1	Freeway	Merge	25	250	3	6600
1	2	Off-ramp	Interchange	26	235	1	1800
5	6	On-ramp	-	25	69	1	1800
7	4	Off-ramp	-	25	149	1	1000
8	9	On-ramp	-	25	69	1	1800
O <sub>4</sub>	2	Arterial	Class III	15	400	3	2100
2	D <sub>6</sub>	Arterial	Class III	15	400	2	3400
2	5	Arterial	Class III	15	250	2	3400
5	D <sub>3</sub>	Arterial	Class III	15	369	2	3400
O <sub>3</sub>	4	Arterial	Class III	15	325	2	3400
4	3	Arterial	Class III	15	220	3	2100
3	8	Arterial	Class III	15	134	2	1400
8	D <sub>4</sub>	Arterial	Class III	15	224	2	3400
3	D <sub>5</sub>	Arterial	Class III	15	299	2	3400
O <sub>5</sub>	3	Arterial	Class III	15	299	2	1400
2	3	Arterial	Class III	15	114	3	2100
3	2	Arterial	Class III	15	114	2	1400

**TABLE 2**  
**Manipulated Origin/Destination Data, vph**

<b>Origin/Destination</b>	<b><i>D</i><sub>1</sub></b>	<b><i>D</i><sub>2</sub></b>	<b><i>D</i><sub>3</sub></b>	<b><i>D</i><sub>4</sub></b>	<b><i>D</i><sub>5</sub></b>	<b><i>D</i><sub>6</sub></b>	<b><i>Total</i></b>
<b><i>O</i><sub>1</sub></b>	-	4760	280	-	280	280	5600
<b><i>O</i><sub>2</sub></b>	2400	-	150	150	150	150	3000
<b><i>O</i><sub>3</sub></b>	180	120	30	-	120	150	600
<b><i>O</i><sub>4</sub></b>	360	360	120	-	360	-	1200
<b><i>O</i><sub>5</sub></b>	240	240	-	40	-	280	800
<b><i>Total</i></b>	3180	5480	580	190	910	860	11200

*Note:* *O*<sub>1</sub> – Origin of SB Freeway; *O*<sub>2</sub> – Origin of NB Freeway; *O*<sub>3</sub> – Origin of NB Frontage Road; *D*<sub>1</sub> – Destination of SB Freeway; *D*<sub>2</sub> – Destination of NB Freeway; *D*<sub>3</sub> – Destination of SB Frontage Road; *OD*<sub>1</sub> – West End Surface Street; *OD*<sub>2</sub> – East End Surface Street

**TABLE 3**  
**Delay Measurement Segments in VISSIM**

<b>Major Traffic Flows</b>	<b>Delay Measurement Segments</b>
<i>SB Freeway</i>	O <sub>1</sub> - D <sub>2</sub>
<i>Freeway Diverted</i>	1 - 6
<i>Surface Street</i>	O <sub>4</sub> -D <sub>5</sub> , O <sub>4</sub> -D <sub>4</sub> , O <sub>4</sub> -D <sub>3</sub> , O <sub>5</sub> -D <sub>6</sub> , O <sub>5</sub> -D <sub>4</sub> , O <sub>5</sub> -D <sub>3</sub> , O <sub>3</sub> -D <sub>5</sub> , O <sub>3</sub> -D <sub>6</sub> , O <sub>3</sub> -D <sub>4</sub> , O <sub>3</sub> -D <sub>3</sub>
<i>Surface Street to SB Freeway</i>	O <sub>4</sub> -D <sub>2</sub> , O <sub>5</sub> -D <sub>2</sub> , O <sub>3</sub> -D <sub>2</sub> ,
<i>SB Freeway to Surface Street</i>	O <sub>1</sub> -D <sub>6</sub> , O <sub>1</sub> -D <sub>6</sub> , O <sub>1</sub> -D <sub>3</sub> , O <sub>1</sub> -D <sub>4</sub>

\* Note: Refer to Figure 1 for delay measurement locations

**TABLE 4**  
**Delay Results from Simulation**

<b>Control Scenarios</b>	<b>Major Traffic Flows</b>					
	<i>Freeway</i>	<i>Diverted</i>	<i>Surface Street</i>	<i>Surface-SB Freeway</i>	<i>SB Freeway-Surface</i>	<i>System</i>
<i>Adaptive - Static (AS)</i>	66.2 /13.2	157.7 /31.1	42.8 /8.0	129.1 /39.7	80.8 /8.3	57.9 /11.8
<i>Adaptive - Existing (AE)</i>	67.9 /8.7	52.6 /9.2	34.7 /1.7	50.3 /8.5	76.9 /4.5	44.2 /3.9
<i>Adaptive - Conservative (AP)</i>	65.8 /6.6	55.4 /17.3	35.6 /1.7	60.7 /23.4	76.9 /4.4	44.6 /3.9
<i>Adaptive - No Meter (AN)</i>	72.0 /10.1	38.1 /3.4	34.7 /1.9	31.9 /3.0	79.5 /7.3	44.0 /4.0
<i>Non-Adaptive - Static (NS)</i>	64.5 /12.9	182.7 /31.4	40.3 /5.3	124.3 /34.5	93.7 /11.6	57.0 /8.9
<i>Non-Adaptive - Existing (NE)</i>	68.7 /9.4	76.6 /8.3	33.5 /1.2	43.8 /4.5	88.9 /8.6	45.7 /3.6
<i>Non-Adaptive - Conservative (NP)</i>	63.1 /6.0	85.1 /20.2	34.4 /2.3	56.3 /21.4	89.2 /8.1	45.3 /4.1
<i>Non-Adaptive - No Meter (NN)</i>	73.0 /13.2	66.4 /8.4	33.9 /1.5	30.0 /2.2	92.3 /11.2	46.1 /5.3

\* Note: \*\*/\*\* - Average Delay (sec/veh)/Standard Deviation (sec/veh)