Advanced Traveler Information System for Guiding Route Choice to Ocean City, Maryland

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A real-time advanced traveler information system for traffic heading to Ocean City, Maryland, is presented. It can provide dynamic route choice guidance for en route travelers, offer web-based historical data for pretrip tourists, and perform real-time traffic monitoring as well as emergency evacuation for responsible agencies with its 40 detectors. The proposed system is designed to contend with most critical issues associated with real-time operations, including automated detection of incidents, reliable estimation of missing data, and continuous updates of historical databases. Implementation results demonstrate that the travel time information displayed by the proposed system has been well received by drivers and is viewed as the primary resource for choice of routes to Ocean City. The evolution of traffic volumes on alternative routes during congested periods reveals that the travel time information from variable message signs not only provides guidance to drivers but also leads to better use of roadway capacity and results in more throughputs for the same period of operation.

Travel time information is one of the essential components for an advanced traveler information system (ATIS), which has the potential to provide dynamic route guidance for travelers, increase the reliability of road networks, and alleviate congestion and its negative environmental and social effects (*1*). A successful ATIS not only can provide reliable travel time information to travelers but also can distribute condensed traffic volume and affect recurrent travel patterns.

This study presents a real-time ATIS for traffic heading to Ocean City, which is a popular tourist destination on Maryland's Eastern Shore. The population in the summer peak season may reach 150,000 to 300,000 people, compared with 7,000 to 25,000 during the off-peak season (*2*). This large traveler population can lead to serious congestion on the major eastbound roads, especially during summer weekends and holidays. As shown in Figure 1, travelers heading to Ocean City can take either of two routes: US-50, a two-lane arterial with intersections controlled by signals, or MD-90, a largely one-lane expressway with one signalized intersection near Ocean City (*3*). A variable message sign (VMS) is located before the split of the network to provide time-dependent travel times for these two alternative routes and is updated at 5-min intervals. Hence, travelers could use reliable travel time information to adjust their route choice and to avoid congestion.

Development of a real-time ATIS is receiving increasing attention from both researchers and practitioners. Liu et al. (*3*), Kwon and Coifman (*4*), Rice and Van Swet (*5*), and Chen et al. (*6*) developed simulation-based online travel time prediction systems to contend with most critical issues associated with real-time operations. Real-world travel time systems have been implemented in the United States. For example, TranStar in Houston, Texas, and the travel time system in Chicago, Illinois, post the average travel time of completed trips for commuters (*7*). Georgia Navigator software has been used in several states to display the travel time computed by current average speeds collected on each link, including in Atlanta and Macon, Georgia, Portland, Oregon, and Nashville, Tennessee (*7*). Another well-known example is California's freeway performance measurement system developed at the University of California, Berkeley, which collects and analyzes real-time freeway traffic data and generates freeway travel time as one of the comprehensive performance measures (*8, 9*). A recent study at the University of Maryland indicated that its automated real-time travel time prediction system (ARAMPS) can provide reliable travel time information in real-time operations with sparsely located sensors under different congestion levels (*10*).

Unlike most existing systems that provide travel time information for only one route, this study presents a recently developed ATIS system that can predict travel times on the two alternative routes concurrently for traffic into Ocean City. This ATIS system is expected to help drivers make proper route choices and to make the best use of existing roadway capacity.

SYSTEM KEY FEATURES

To ensure effective and efficient implementation, the proposed ATIS system for Ocean City contains the following key functions.

Dynamic Route Choice Guidance for En Route Travelers

Distinct from most previous studies, the proposed real-time ATIS can display time-dependent travel times for two alternate roads to the same destination, that is, a two-lane arterial of 12.4 mi on US-50 and a one-lane freeway of 12.9 mi on MD-90, as shown in Figure 2*a*. More important, by using predicted travel times, the proposed ATIS system could dynamically guide travelers to switch to a less-congested route (Figure 2*b*). With such information, the proposed system offers the potential for control center operators to distribute heavy traffic volume between two available routes and to best use

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FIGURE 1 Study network.

roadway capacity, especially for heavily congested conditions during peak seasons.

Web-Based Pretrip Planner for Tourists

To help tourists adjust their departure times to avoid possible congestion, the proposed system features a web-based pretrip planner, which offers the following critical information:

- Real-time predicted travel times (Figure 3*a*),
- Current status and data of the 40 detectors in East Shore region (Figure 3*b*),
- Current speed and volume maps in the target network (Figures 3*c* and 3*d*),
- Historical data of the 40 detectors in East Shore region (Figure 3*e*), and
- Historical travel times at different days and departure times archived in the system (Figure 3*f*).

Real-Time Traffic Monitoring and Emergency Evacuation for Transportation Authorities

In addition to providing real-time route choice information for recurrent traffic conditions, the proposed system has an embedded real-time traffic monitoring feature to help system operators deal with emergent events, such as traffic incidents and hurricanes.

To prevent the system from yielding unrealistic travel times due to incidents, the single-station automated incident detection algorithm and the dual-variable automated incident detection algorithm have been combined in the proposed system to reliably detect any incurred incident in real time (Figure 4).

Furthermore, under the threat of a coming hurricane, current and historical population information about the Ocean City region computed from the entry–exit volumes of Detector 1, Detector 129, and Detector 130 (Figure 5) will be used as the basis for evacuation planning. By comparing the real-time traffic conditions observed from the proposed system with the traffic conditions simulated in the predefined candidate evacuation plans, system operators can make necessary adjustments to the implemented evacuation plans, considering potential bottlenecks identified from the proposed ATIS system.

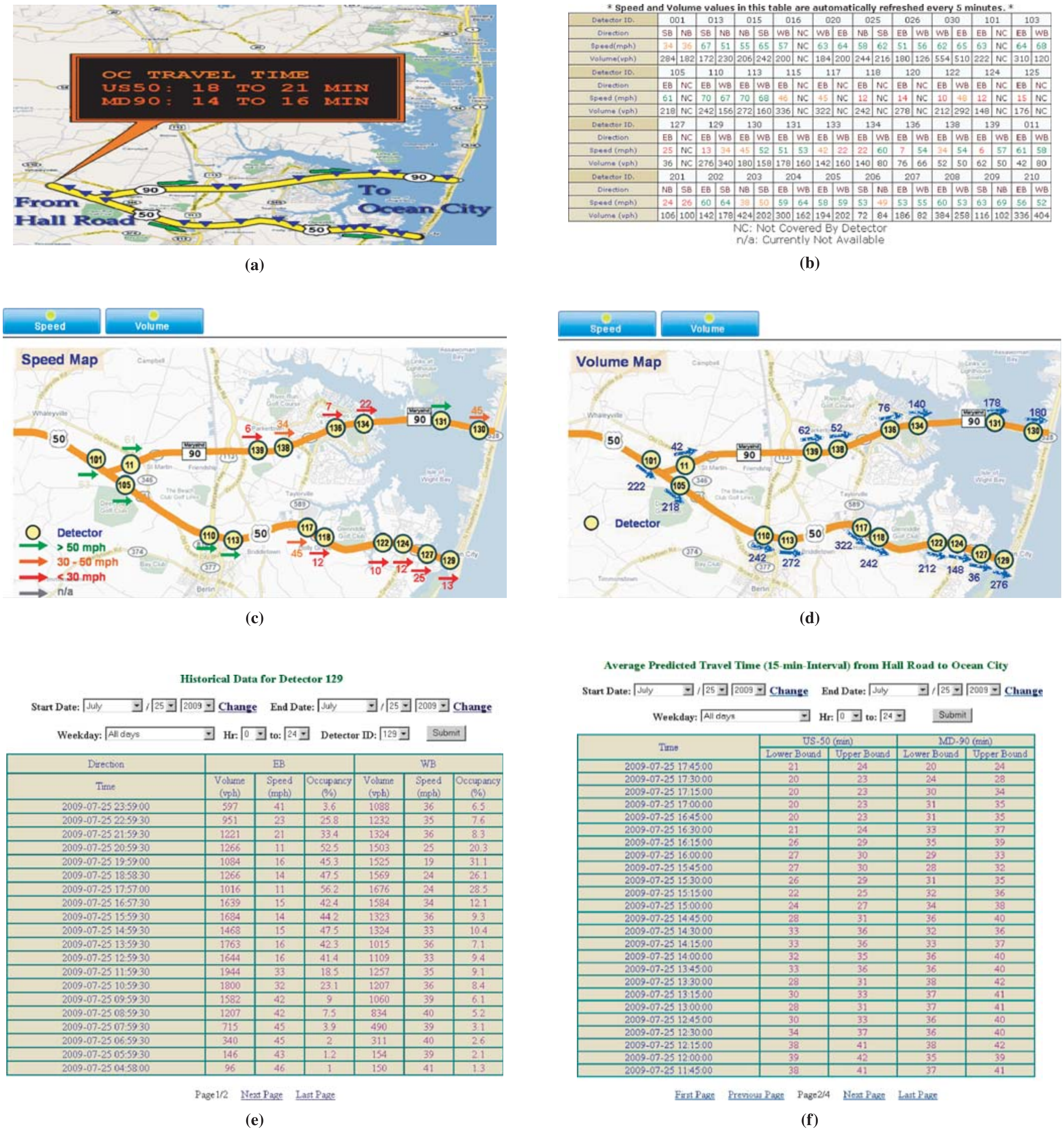
SYSTEM DESIGN

Principal Functions of System Modules

Figure 6 presents the framework of the proposed ATIS system. The system consists mainly of three layers: data collection layer, logical layer, and application layer.

(a) (b)

FIGURE 2 Real-time route choice information on VMS: (*a*) travel time information and (*b*) route choice guidance.



Detector ID.	001		013		015		016		020		025		026		030		101		103	
Direction	SB	NB	SB	NB	NB	SB	WB	NC	WB	EB	NB	SB	EB	WB	WB	EB	EB	NC	EB	WB
Speed(mph)	34	36	67	51	55	65	57	NC	63	64	58	62	51	56	62	65	63	NC	64	68
Volume(vph)	284	182	172	230	206	242	200	NC	184	200	244	216	180	126	554	510	222	NC	310	120
Detector ID.	105		110		113		115		117		118		120		122		124		125	
Direction	EB	NC	EB	WB	EB	WB	EB	NC	EB	NC	EB	NC	EB	NC	EB	WB	EB	NC	EB	NC
Speed (mph)	61	NC	70	67	70	68	46	NC	45	NC	12	NC	14	NC	10	48	12	NC	15	NC
Volume (vph)	218	NC	242	156	272	160	336	NC	322	NC	242	NC	278	NC	212	292	148	NC	176	NC
Detector ID.	127		129		130		131		133		134		136		138		139		011	
Direction	EB	NC	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB
Speed (mph)	25	NC	13	34	45	52	51	53	42	22	22	60	7	54	34	54	6	57	61	58
Volume (vph)	36	NC	276	340	180	158	178	160	142	160	140	80	76	66	52	50	62	50	42	80
Detector ID.	201		202		203		204		205		206		207		208		209		210	
Direction	NB	SB	EB	SB	NB	SB	EB	WB	EB	WB	SB	NB	EB	WB	EB	WB	SB	NB	EB	WB
Speed (mph)	24	26	60	64	38	50	59	64	58	59	53	49	53	55	60	53	63	69	56	52
Volume (vph)	106	100	142	178	424	202	300	162	194	202	72	84	186	82	384	258	116	102	336	404

Direction	EB			WB		
Time	Volume (vph)	Speed (mph)	Occupancy (%)	Volume (vph)	Speed (mph)	Occupancy (%)
2009-07-25 23:59:00	597	41	3.6	1088	36	6.5
2009-07-25 22:59:30	951	23	25.8	1232	35	7.6
2009-07-25 21:59:30	1221	21	33.4	1324	36	8.3
2009-07-25 20:59:30	1266	11	52.5	1503	25	20.3
2009-07-25 19:59:00	1084	16	45.3	1525	19	31.1
2009-07-25 18:58:30	1266	14	47.5	1569	24	26.1
2009-07-25 17:57:00	1016	11	56.2	1676	24	28.5
2009-07-25 16:57:30	1639	15	42.4	1584	34	12.1
2009-07-25 15:59:30	1684	14	44.2	1323	36	9.3
2009-07-25 14:59:30	1468	15	47.5	1324	33	10.4
2009-07-25 13:59:30	1763	16	42.3	1015	36	7.1
2009-07-25 12:59:30	1644	16	41.4	1109	33	9.4
2009-07-25 11:59:30	1944	33	18.5	1257	35	9.1
2009-07-25 10:59:30	1800	32	23.1	1207	36	8.4
2009-07-25 09:59:30	1582	42	9	1060	39	6.1
2009-07-25 08:59:30	1207	42	7.5	834	40	5.2
2009-07-25 07:59:30	715	45	3.9	490	39	3.1
2009-07-25 06:59:30	340	45	2	311	40	2.6
2009-07-25 05:59:30	146	43	1.2	154	39	2.1
2009-07-25 04:58:00	96	46	1	150	41	1.3

Time	US-50 (min)		MD-90 (min)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
2009-07-25 17:45:00	21	24	20	24
2009-07-25 17:30:00	20	23	24	28
2009-07-25 17:15:00	20	23	30	34
2009-07-25 17:00:00	20	23	31	35
2009-07-25 16:45:00	20	23	31	35
2009-07-25 16:30:00	21	24	33	37
2009-07-25 16:15:00	26	29	35	39
2009-07-25 16:00:00	27	30	29	33
2009-07-25 15:45:00	27	30	28	32
2009-07-25 15:30:00	26	29	31	35
2009-07-25 15:15:00	22	25	32	36
2009-07-25 15:00:00	24	27	34	38
2009-07-25 14:45:00	28	31	36	40
2009-07-25 14:30:00	33	36	32	36
2009-07-25 14:15:00	33	36	33	37
2009-07-25 14:00:00	32	35	36	40
2009-07-25 13:45:00	33	36	36	40
2009-07-25 13:30:00	28	31	38	42
2009-07-25 13:15:00	30	33	37	41
2009-07-25 13:00:00	28	31	37	41
2009-07-25 12:45:00	30	33	36	40
2009-07-25 12:30:00	34	37	36	40
2009-07-25 12:15:00	38	41	38	42
2009-07-25 12:00:00	39	42	35	39
2009-07-25 11:45:00	38	41	37	41

FIGURE 3 Snapshots from website for tourists: (*a*) real-time predicted travel time, (*b*) current detector data, (*c*) current speed map, (*d*) current volume map, (*e*) historical detector data, and (*f*) historical travel times.

The data collection layer functions to collect, store, and provide required data for the logical layer, which includes the following three modules:

- The surveillance module obtains volume, speed, and occupancy data from roadside radar detectors and outputs those raw data into the integrated database on a daily basis.
- The database module provides basic input information to both online and offline models for travel time estimation and prediction and includes two parts: historical data archiving and real-time detector data collection.
- The missing-data estimation module is designed to deal with the missing or delayed data that frequently occurs because of detector malfunctions or communication problems. A set of specially

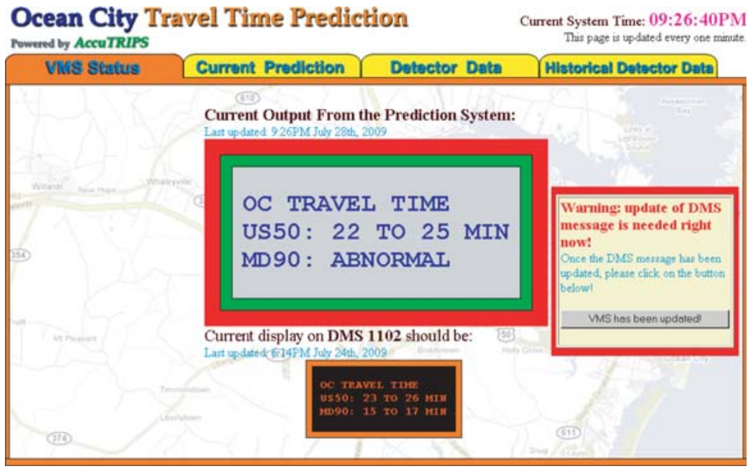


FIGURE 4 Alarm system for incident detection.

designed algorithms is embedded in this module to fit the hybrid model structure used in the travel time prediction and to evaluate the reliability of the estimated missing data (*11*).

As the core of the proposed system, the logical layer contains three major functional modules:

- The travel time estimation module estimates travel times from the detector data and updates the historical travel time database if no direct measurement of the travel time is available in the system database. Considering the differences between freeways and arterials, the research team has developed two sets of hybrid models that integrate a customized clustered linear regression model with an enhanced trajectory-based model to capture the impact of various geometric features and different traffic patterns on the dynamics of travel times. A detailed discussion of these key models in this module can be found elsewhere (*12, 13*).
- The main function of the travel time prediction module is to predict travel times based on the real-time detector data and historical information in the database. A hybrid model structure that consists of a multitopology neural network model with a rule-based clustering function and a *k*-nearest neighbor model has been developed to ensure prediction accuracy. The core algorithms of this module have been discussed elsewhere (*10, 14*).
- Two automated incident detection algorithms have been embedded in the third module, where the single-station detection algorithm is used to detect incidents close to the detector station at either end of a link and the dual-station detection algorithm is designed to identify incidents that are far from either detector (*15*). The combination of these two algorithms has been successfully tested with the incident data obtained from the ARAMPS system and the CHART program in Maryland (*10*).

FIGURE 5 Detector distributions on Eastern Shore for evacuation purposes.

The application layer is designed to output the following three types of information for system users and operators:

- VMS message, to display the predicted travel time and to provide dynamic route choice information to travelers when they arrive at the origin of the target network;
- Tourist-oriented website, to provide both current and historical travel time information to help potential travelers better plan their departure time before their trip; and
- Operator-oriented website, to alarm system operators if one or more incidents have incurred in the network.

Note that the proposed system features a module-based structure that allows system operators to conveniently continue model updating if more data are available for the day-to-day operations. For instance, to provide required data for system operations, all supporting modules and functional modules are integrated seamlessly with each other through the carefully designed data exchange mechanism. However, each individual module is relatively independent in its input and output needs, which offers the flexibility for further system expansion or enhancement.

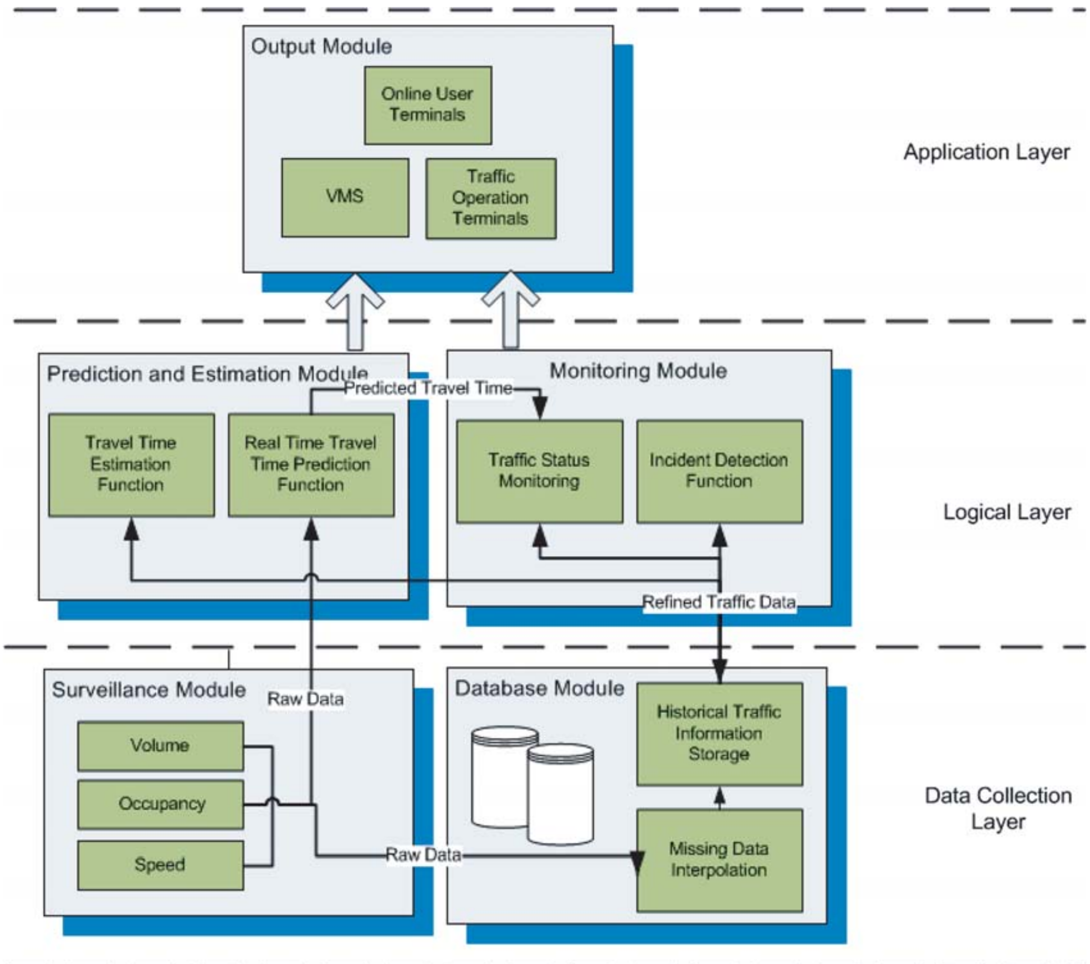


FIGURE 6 System framework.

Development of System Operational Flowcharts

The proposed ATIS system for route choice contains the model training phase and the real-time operation phase. The main tasks in the model training phase are to build the historical database and to train the model parameters (*10*). This paper focuses on the real-time operational phase. Figure 7 shows the phases operational flowchart.

- Step 1. Acquire data. At time interval *t,* the system will receive real-time data from all detectors and then store them in the traffic database.
- Step 2. Detect incident. The proposed travel time prediction system will first use its incident detection module to scan incoming traffic data. If one or more incidents are detected, the system will alarm the control center and stop the predictions for the routes affected by detected incidents at the current time interval.
- Step 3. Estimate missing data. The missing-data estimation module will perform a test on the routes experiencing no incidents and evaluate whether any required input data are missing. If the missing-data estimation module detects that two or more consecutive detectors are broken down on one of the routes, it will notify the system to stop the prediction of travel times on this route.
- Step 4. Predict travel time. The prediction module predicts travel times for the routes that do not experience any traffic anomaly.
- Step 5. Display route choice information on the VMS and the website. There are three different options for displaying the route choice information based on the results obtained from the prediction module: (*a*) display Major Delays on US-50 (or MD-90) if the predicted travel time on one of these two routes exceeds 60 min at the current time interval; (*b*) display Major Delays on One Route, Use the Other Route to OC if the travel time difference between US-50 and MD-90 is more than 20 min at the current time interval; (*c*) display the predicted travel times on both US-50 and MD-90 at the current time interval so travelers can make their preferred route choice decisions.
- Step 6. Update the database of historical travel times. The travel time estimation module will use the most recent detector data available to estimate the travel times of completed trips. The information of the most recently completed trips will be available immediately for use by the travel time prediction module in the next time interval, which is 1 min, and it can be varied in response to user needs.

SYSTEM APPLICATION

This section presents some results of the developed ATIS for Ocean City, Maryland, with respect to the following three aspects:

- Accuracy in providing travel time information,
- Effectiveness in dynamic route choice guidance, and

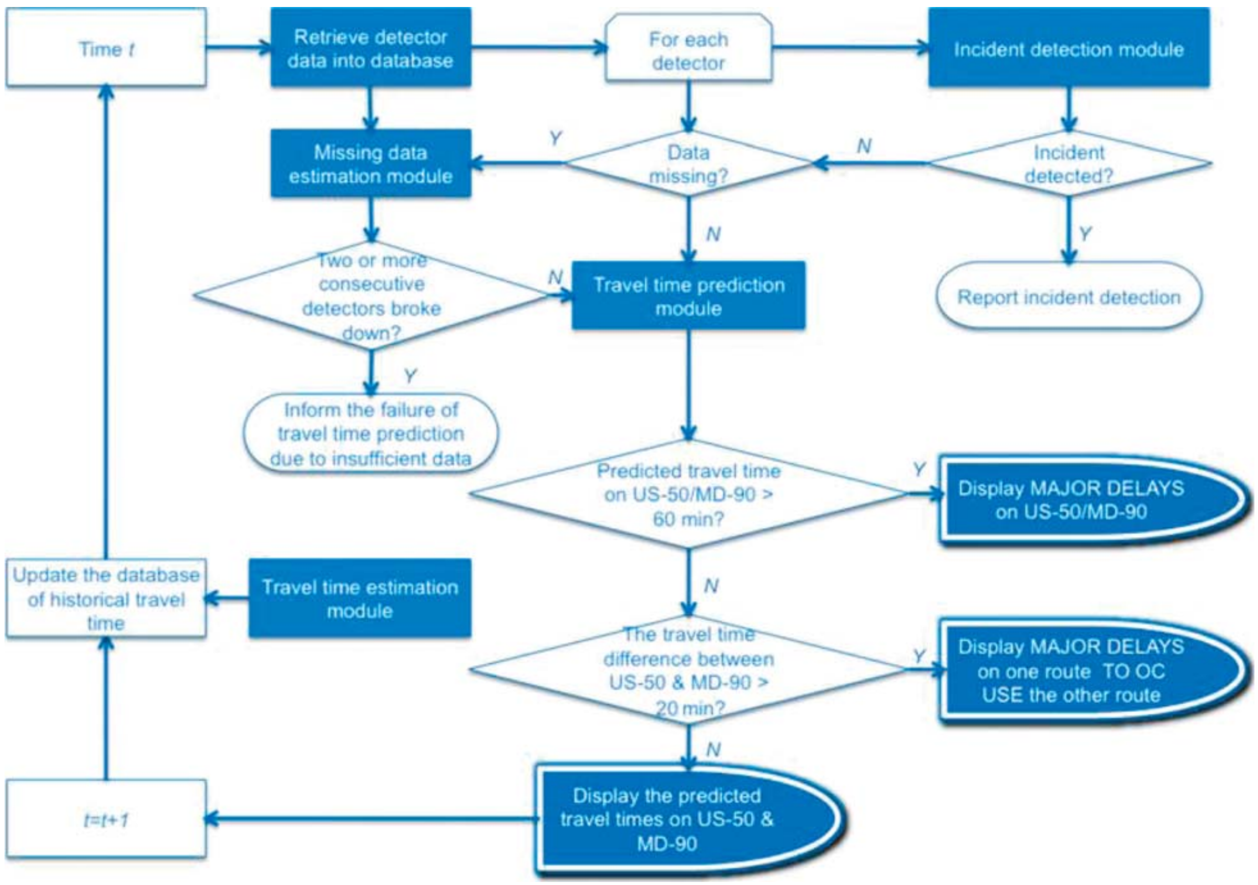


FIGURE 7 System operational flowchart in real-time operation.

• Efficiency in relieving congestion and increasing system throughput.

Accuracy in Providing Travel Time Information

Comparisons between the predicted and actual travel times with field surveys are reported in Tables 1 and 2 under different congestion levels based on the average absolute error (AAE) and the relative average absolute error (RAAE). The following results can be seen:

• The proposed system has demonstrated its ability to predict travel times for both freeways and arterials with an average relative absolute error of less than 8% that is generally viewed as acceptable to travelers.

• The travel times predicted for MD-90 are more reliable than those predicted for US-50. This is probably because of interrupted traffic flows in the urban environment.

Effectiveness in Dynamic Route Choice Guidance

Implementation of the ATIS for Ocean City offers a field lab where the research team can investigate the following issues: (*a*) how such a system will affect drivers' behavior, (*b*) how drivers may adapt and learn to use route choice information, and (*c*) how changes in driver behavior will ultimately affect the distribution of traffic volume in the network. Some preliminary results on these issues follow.

TABLE 1 Performance Evaluation: US-50

	Travel Time Range (s)		
	≤1,500	1,500~2,400	2,400~3,600
Sample size	8	19	16
Maximum travel time (s)	1,488	2,357	3,590
Average travel time (s)	1,326	2,011	3,321
Average absolute error (s)	91.1	133.5	249.2
Average relative error (%)	6.89	6.84	7.77

TABLE 2 Performance Evaluation: MD-90

	Travel Time Range (s)		
	≤1,200	1,200~2,100	2,100~3,600
Sample size	6	16	11
Maximum travel time (s)	1,194	2,074	3,588
Average travel time (s)	899	1,716	3,033
Average absolute error (s)	59.7	98.5	205.5
Average relative error (%)	6.53	5.99	6.79

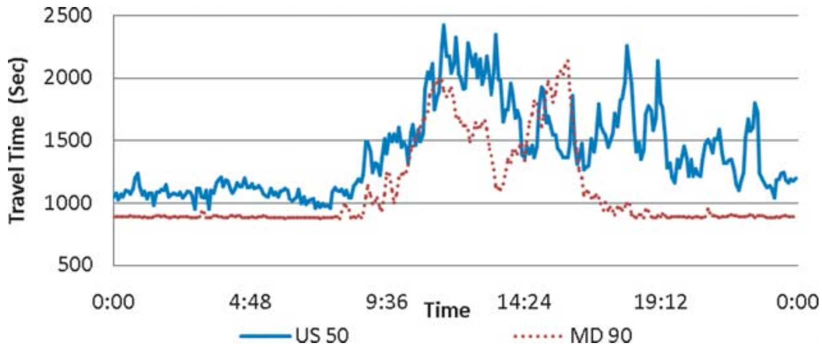


FIGURE 8 Travel time distributions without VMS, July 11, 2009.

Traveler Route Choice Preferences in VMS-Off Scenario

Figures 8 and 9 illustrate the distribution of travel times and traffic volumes on US-50 and MD-90 on a typical peak-season weekend day. These figures show that without the ATIS, travelers habitually prefer US-50, which often has longer travel times, to MD-90. This is probably because US-50 has more traveling lanes and offers easy access to the major resorts in Ocean City.

Evolution of Traffic Volume Distribution Under VMS

To investigate the impact of displayed travel times on travelers' route choice behavior, the study collected the evolution of traffic volume distribution (in 5-min increments) and corresponding travel times on US-50 and MD-90. The comparison results are illustrated in Figure 10. During the off-peak hours (Figure 10*a*), travel times on US-50 and MD-90 displayed at the VMS are relatively stable and exhibit no significant impact on travelers' route choice preferences, as reflected in the low variation of volume differences between the two routes (five to 30 vehicles per 5 min). In contrast, during the peak hours, the impact of VMS information on travelers' route choice patterns is significant. The evolution patterns in Figure 10*b* show that traffic volumes on US-50 exhibit a cyclic trend, alternating between low and high in response to the travel time differences between US-50 and MD-90 (Figure 11). However, if the difference in travel time between US-50 and MD-90 is less than 2 min, traveler route choice is not affected by the VMS.

Impact of Route Guidance System on Network Traffic Patterns

To evaluate the effectiveness of the developed route guidance system for balancing traffic conditions between the two routes, the study compared the time-varying travel times and traffic volumes between US-50 and MD-90 based on similar traffic demand levels in the following six scenarios:

Scenario 1. Weekday peak hours,
Scenario 2. Weekday off-peak hours,
Scenario 3. Weekend peak hours,
Scenario 4. Weekend off-peak hours,
Scenario 5. Holiday peak hours, and
Scenario 6. Holiday off-peak hours.

Four types of performance index are used for comparison:

- Mean ratio of travel time (US-50 versus MD-90)—mean TT ratio,
- Variance of travel time ratio (US-50 versus MD-90)—var TT ratio,
- Mean ratio of volume (US-50 versus MD-90)—mean V ratio, and
- Variance of volume ratio (US-50 versus MD-90)—var V ratio.

Tables 3 and 4 and Figure 12 summarize the comparison results and evolution of traffic volume with and without the VMS. The following conclusions can be made from the summarized statistics:

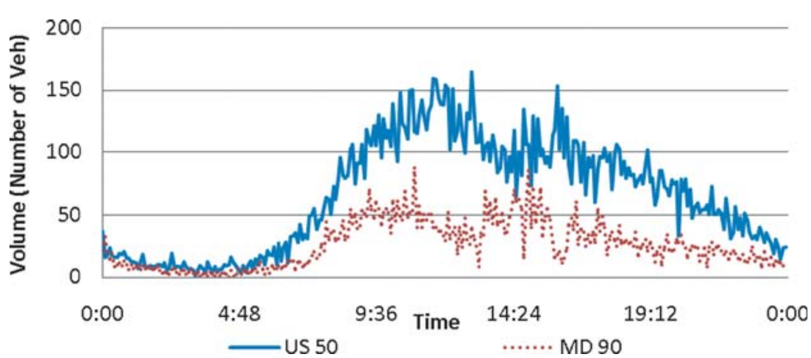


FIGURE 9 Traffic volume distributions without VMS, July 11, 2009.

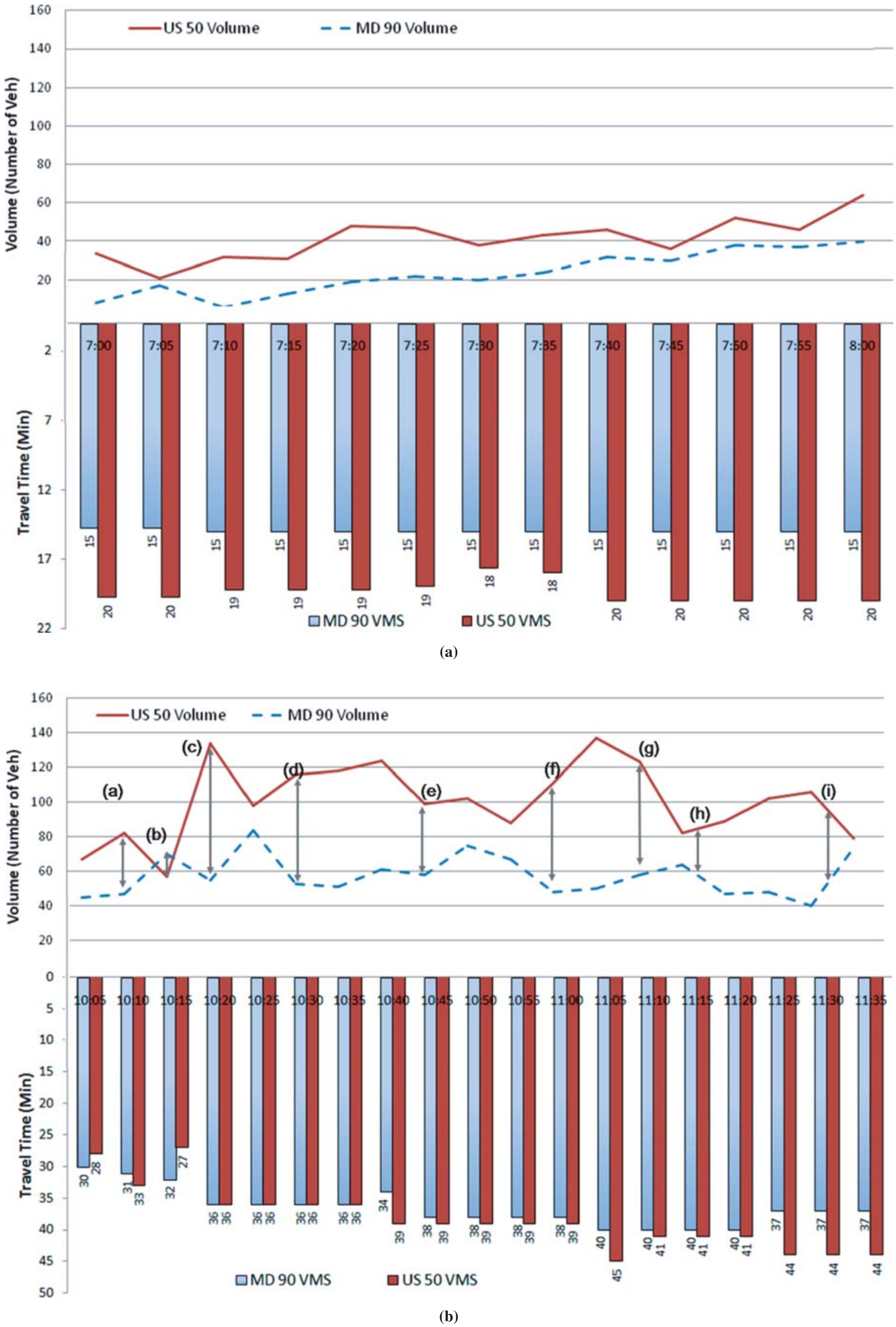


FIGURE 10 Evolution of traffic volume distributions under effect of VMS: (*a*) off-peak hours and (*b*) peak hours.

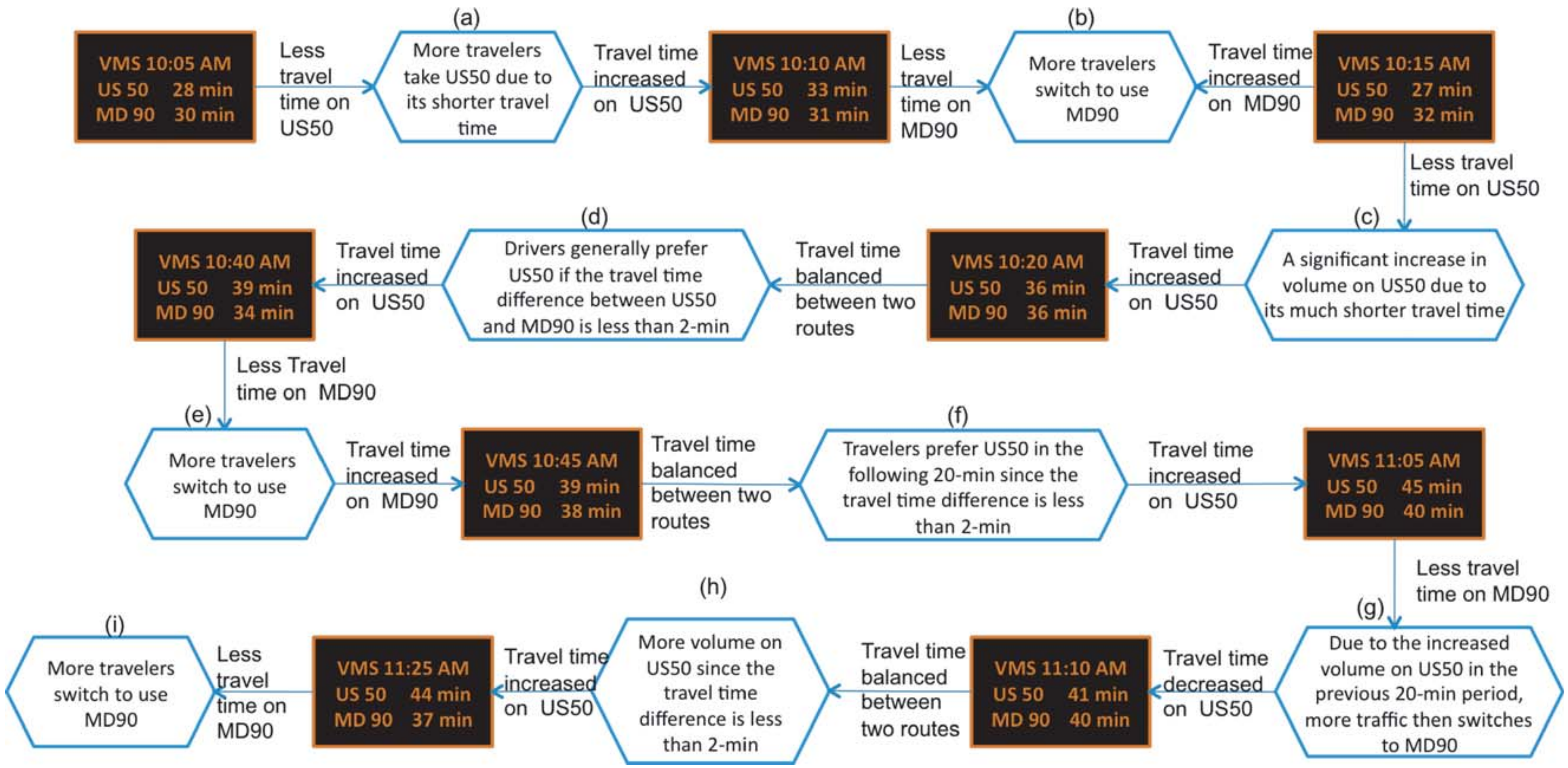


FIGURE 11 Traffic volume evolution patterns under effect of VMS.

TABLE 3 Comparison of Travel Time Ratios and Traffic Volume Ratios: Off-Peak Hours

	Weekday	Weekend	Holiday
VMS_{on}			
Mean (TT ratio)	1.28	1.20	1.13
Var (TT ratio)	0.005	0.003	0.015
Mean (V ratio)	2.23	2.81	3.32
Var (V ratio)	0.90	2.79	4.47
VMS_{off}			
Mean (TT ratio)	1.31	1.17	1.42
Var (TT ratio)	0.007	0.003	0.097
Mean (V ratio)	2.67	2.69	4.33
Var (V ratio)	0.40	1.02	4.95

TABLE 4 Comparisons of Travel Time Ratios and Traffic Volume Ratios: Peak Hours

	Weekday	Weekend	Holiday
VMS_{on}			
Mean (TT ratio)	1.56	1.06	1.20
Var (TT ratio)	0.009	0.007	0.032
Mean (V ratio)	2.00	2.00	1.52
Var (V ratio)	0.37	0.48	0.17
VMS_{off}			
Mean (TT ratio)	1.52	1.20	1.59
Var (TT ratio)	0.011	0.021	0.026
Mean (V ratio)	2.86	3.66	3.09
Var (V ratio)	0.64	1.02	0.43

• On weekdays, implementation of the route guidance system appears to encourage more travelers to use MD-90 (indicated by the reduced volume ratio between US-50 and MD-90: 2.67→ 2.23 for off-peak hours and 2.86→ 2.00 for peak hours). However, there are no significant changes in travel time patterns between these two routes, as indicated by the similar travel time ratios with and without VMS (1.28 versus 1.31 for off-peak hours and 1.56 versus 1.52 for peak hours). This is probably because MD-90 has sufficient capacity to accommodate those switching traffic volume without incurring a significant increase in travel time.

• On weekends and holidays, there is a significant imbalance of traffic conditions between the two routes, because tourists prefer US-50 when traveling to Ocean City if there is no route guidance information (e.g., on holidays, the travel time ratios between US-50

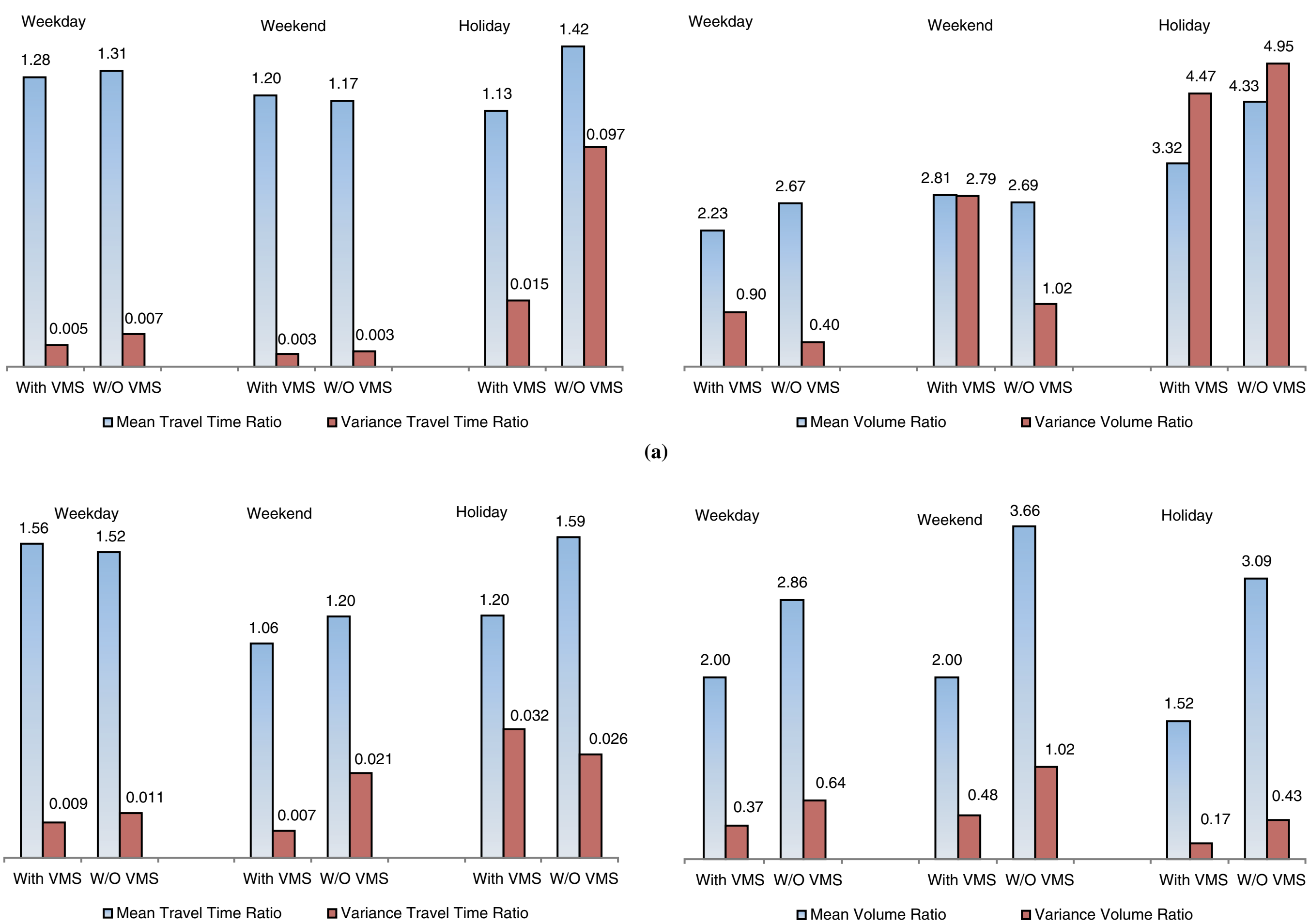


FIGURE 12 Comparisons of travel time ratios and traffic volume ratios, with VMS versus without VMS: (*a*) off-peak hours and (*b*) peak hours.

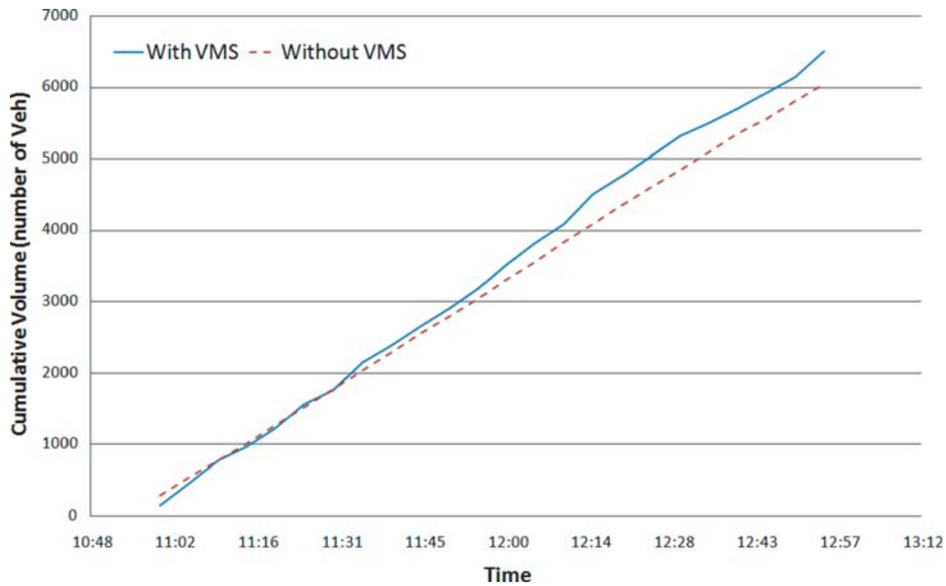


FIGURE 13 Time-varying system throughputs to Ocean City, with VMS and without VMS.

and MD-90 are 1.42 and 1.59 for off-peak hours and peak hours, and the traffic demand ratios between US-50 and MD-90 are 4.33 and 3.09 for off-peak hours and peak hours, respectively). However, after implementation of the route guidance system, the travel time ratios between US-50 and MD-90 drop from 1.42 to 1.13 for the off-peak hours and from 1.59 to 1.20 for the peak hours. The traffic volume ratios between US-50 and MD-90 drop from 4.33 to 3.32 during the off-peak hours and from 3.09 to 1.52 during the peak hours, reflecting the effectiveness of the system, which leads to better use of the roadway capacity of both routes.

Efficiency in Relieving Congestion and Increasing System Throughputs

To further investigate the effectiveness of the developed ATIS system for alleviating traffic congestion and increasing system throughputs, the study compared time-varying system throughputs between those with and without VMS scenarios under very similar traffic demand levels during peak hours. The time-dependent entry–exit volumes from Detectors 129 and 130, located at the ends of US-50 and MD-90, respectively, were used as the basis for calculating cumulative system throughputs. As illustrated in Figure 13, implementation of the developed ATIS system can yield significantly positive effects by increasing overall system throughputs within a 2-h period (6,492 vehicles with VMS versus 6,037 vehicles without VMS). This effect is probably due to the ability of the proposed system to evenly distribute condensed traffic volumes along the two routes, thus using existing roadway capacity more efficiently.

CONCLUSIONS AND POTENTIAL EXTENSIONS

This paper presented a real-time ATIS for drivers heading to Ocean City, Maryland. The proposed system with its embedded prediction algorithms, roadside detectors, and monitoring website allows system operators from the Maryland State Highway Administration to display predicted travel time via VMS for en route drivers and to provide historical traffic information from the website for pretrip travelers. The implementation results demonstrate that the displayed travel time information has been well received by drivers and is viewed as the primary source for information on choice of routes to Ocean City (*16*). The evolution of traffic volumes on both routes during congested periods reveals that the travel time information from VMS not only provides guidance to drivers but also leads to better use of roadway capacity and results in more throughputs over the same periods of operations.

The proposed ATIS system presented in this paper can (*a*) provide reliable travel time information under different congestion levels with an average relative absolute error of less than 8%, which is generally viewed as acceptable to travelers; (*b*) yield positive effects on drivers' route choice behavior, especially for heavily congested conditions during peak seasons; and (*c*) help travelers make proper route choices and best use existing roadway capacity.

Much remains to be done before the proposed ATIS system can be fully utilized in a variety of real-world scenarios, especially on such critical issues as extending travel time prediction under nonrecurrent congestion and development of an empirical statistical model to predict driver responses to the travel time information displayed in the proposed system. In addition, per the results obtained from the empirical statistical model, a real-time route guidance model can be further developed to improve overall system efficiency and to better use existing roadway capacity.

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