Extended Abstract

Traffic diversion in response to incident detection on coastal urban roads

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1. INTRODUCTION

This study focuses on real-time incident detection on coastal urban roads and on traffic diversion benefits. The main objective is to detect real-time incidents on a busy coastal road in a city center, leading to the port. Following incident detection, road users are to be informed through Variable Message Sign (VMS). Port users are expected to benefit from incident detection and coastal road users' diversion since they can reach port on time. Coastal road users will be diverted to alternative routes to reach their destinations avoiding port traffic delays. A real time incident detection algorithm was parameterized for urban roads and Intelligent Transportation Systems (ITS) data were analyzed. We simulated congestion and accident conditions on a coastal road segment in Patras and traffic diversion rates, estimating diversion benefits based on site data and performance indices.

2. LITERATURE REVIEW

Automatic incident detection algorithms were initially developed in the 1970s. Most detection algorithms were developed for motorways and few are transferable to arterials. Less effort has been devoted to automatic detection for arterials and urban road networks [1, 2]. From the literature, 40-45% of drivers would change their route if they were warned on time on an important traffic problem downstream [3]. In Greece, when traffic was interrupted owing to an incident on a road in Athens, 40% of the drivers chose an alternative route responding to Variable Message Sign [4].

3. PROPOSED INCIDENT DETECTION ALGORITHM

For real-time incident detection we used the following tests [5]:

$$T = \frac{\hat{O}_i(t) - \hat{O}_{i+1}(t)}{\max\{\hat{O}_i(t-M), \hat{O}_{i+1}(t-M)\}} \geq T_1 \quad \mathbf{(1)}$$

$$T' = \frac{\left[\hat{O}_i(t) - \hat{O}_{i+1}(t)\right] - \left[\hat{O}_i(t-M) - \hat{O}_{i+1}(t-M)\right]}{\max\{\hat{O}_i(t-M), \hat{O}_{i+1}(t-M)\}} \geq T_2 \quad \mathbf{(2)}$$

Regarding test 1 (Eq. 1), each time a new occupancy value becomes available, two smoothed occupancy values are calculated for each detector, denoted by $\hat{O}_i(t)$ for the current and $\hat{O}_i(t-M)$ for the past period. In a way similar to the Minnesota algorithm [5], the algorithm examines the current spatial occupancy difference to detect congestion between stations i and $i+1$. The above difference is normalized by the maximum of $\hat{O}_i(t-M)$ and $\hat{O}_{i+1}(t-M)$ to reflect changes relative to previous traffic conditions and is compared to test threshold T_1. The choice of M in the above transformation followed practical considerations, when t is the current time.

If test 1 is true, test 2 employs the temporal change of the spatial occupancy difference to decide whether the congestion has resulted from an incident (e.g. accident). The variable used for the incident test is normalized and compared to incident test threshold, T_2. After an incident is signaled, test 1 is employed at consecutive time intervals to indicate whether the incident is still in effect. The alarm is terminated at the first time interval at which test 1 fails.

These tests were first developed for motorways. In our case, the calculation of the smoothed occupancy values was modified in order to adapt to urban roads needs. The proposed detection logic is as follows. The two stations record time occupancy values every 20 seconds, and the algorithm calculates the smoothed time occupancy (average value of the time occupancy values), for each station, every 60 seconds. Each smoothed time occupancy value is used only once for test 1 calculation. If over two consecutive times test 1 is true, "congestion" alert is activated and test 2 is triggered. Test 2 is applied for the current period t and the past period in which congestion was detected $(t-2*M)$. If over two consecutive times test 2 is true, then "accident" alert is activated and a message warning regarding an incident downstream of the road segment should be displayed in the VMS. In order to calculate thresholds T_1 and T_2 we used traffic simulation software to create congestion and accident conditions in the road section under study, based on current and past data.

4. CASE STUDY

The case study was a section of Othonos-Amalias Avenue, which is the main coastal road of the city of Patras. Othonos-Amalias Avenue is heavily used by vehicles leaving the city or arriving at the port of Patras, and by those preferring not to cross the city center. Machine vision systems have been installed at the start and end points of the road section during project "Guideport" [6], which had been developed to address the needs of ports in Greece and Italy. Prior to algorithm implementation, we extracted data from these two machine vision systems.

5. ALGORITHM VERIFICATION

For calculating (Eq. 1, Eq. 2) thresholds T_1 and T_2, and analyzing vehicle diversion benefits, we estimated the value of critical flow in our road section in the case of a) congestion conditions and b) accident conditions. We tested a range of input flow values for the two scenarios using Aimsun traffic simulation software and site data. During simulation passenger vehicles were 94.60% of the total flow, and the rest 5.40% were heavy vehicles and buses. The fuel type of 75% of passenger vehicles was petrol, while the fuel type of 25% and all heavy vehicles/buses was diesel. Criteria to estimate the input critical flow value was that no vehicle should remain on the same traffic light for more than one period,

and that there should be no bottleneck on crossing roads. Thus, the critical flow value in the road segment was estimated to be 2,200 vehicles/hour during congestion conditions and 1,800 vehicles/hour in case of an accident. After several tests, the value of T_1 is equal to 0.467 and T_2 is equal to 0.543.
We implemented the proposed algorithm over a 2-month period, generating more than 85,000 values for test 1 and checking more than 42,500 "no congestion" or "congestion" alerts. "Congestion" alerts were mostly related to peak hours, such as 11:00 to 12:30, 13:30 to 15:00 and 17:30 to 19:30. Ground truth confirmed congestion in these time intervals. Although test 2 was triggered any time "congestion" alert was activated, only two times test 2 was true for two consecutive time intervals. The algorithm was verified for these two cases since an accident occurred both times, based on data collected by the Police.

6. TRAFFIC DIVERSION RESULTS

Port users' benefits from incident detection and traffic diversion are presented in Table 1. Results include the values of performance indicators for different passenger vehicle-diversion rates.

Table 1 - Results of vehicle diversion recommendations after incident detection.

Vehicle Diversion (%)	**Travel Time (sec)**	**Fuel Consumption (L)**	**CO_2 Emissions (kg)**	**Time Headway (sec)**	**Level of Service**
0	130,8	1121	1,743	2,15	E
25	116,3	582	1,036	3,39	A
30	117,6	578	1,004	3,43	A
35	117,1	559	1,010	3,47	A
40	117,8	531	939	3,60	A
45	117,2	506	935	3,63	A

Travel time is reduced by 11% and fuel consumption by 50% when passenger vehicle diversion is applied. CO_2 emissions are significantly reduced, and Level of Service is A for all vehicle diversion scenarios. Time headway increased by more than 1 sec. in any diversion scenario. Certain indicators exhibit small fluctuations at high diversion rates, and this is due to operating randomness of the simulation software.

7. CONCLUDING REMARKS

The results derived from the implementation of the proposed incident detection algorithm on a busy coastal road in the city center of Patras are encouraging. The information regarding a detected incident can be valorized by displaying the corresponding warning message on an upstream Variable Message Sign. The proposed algorithm can be applied at urban or/and coastal road segments, when time occupancy data are available from at least two traffic stations, installed at the start and end of the road segment.

In case of an incident, several traffic diversion rates were studied. The benefits from traffic diversion for road users travelling to the port were profound. Even for the minimum traffic diversion rate of 25%, all performance indicators were substantially improved indicating potential benefits for road users.

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