Abridgment

Vehicle Platoon Parameters: Methodology for Traffic Control

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An underwater tunnel for vehicles often becomes a restricted facility creating congestion if demand exceeds capacity in one or more of its sections. These sections become bottlenecks from which slow-moving queues (platoons) emanate, especially during the peak period. Not only do these high concentration areas decrease velocities, but they also reduce the average flow rate.

It has been found on some facilities, however, that bottleneck situations can be alleviated by traffic controls (1). The usual problem has been to decide which control strategy (type of system or plan of operation or both) will achieve optimum operation through a system with one or more restricted points.

In 1971 the Department of Civil Engineering of the University of Maryland initiated a three-phase study of traffic flow in the Baltimore Harbor Tunnel (2, 3). During phases 1 and 2, it was observed that as traffic increased vehicles tended to form platoons regardless of the control alternatives tested. However, the degree, length, and frequency of platoon formation did vary with each alternative. These observations suggested that a methodology utilizing platoon flow characteristics might be developed to evaluate the control alternatives and to determine the best control strategy (2). This paper, undertaken as part of phase 3, evaluates traffic flow in terms of these characteristics.

LITERATURE REVIEW

Studies of the effects of traffic behavior in platoons on traffic flow have not been conclusive except to show that platoon behavior is a major concern in the application of traffic flow theory. One of the first traffic studies involving platoon behavior was conducted on the Pasadena Freeway by Forbes (4) in 1951. Forbes reported that platoon behavior was not adequately described by the behavior of the overall traffic stream. In 1959, the Port of New York Authority (5) conducted a series of experiments to evaluate platoon behavior and measure road capacity in the south tube of the Holland Tunnel. In another analysis of the Holland Tunnel data, Greenberg and Daou (6) observed the tendency of vehicles to have a higher flow rate when they follow a gap in the traffic stream.

In Greenshields' study (7), the minimum spacing distribution is random and extends from about 9 to 61 m (30 to 200 ft). Evidently there are few, if any, spacings below 9 m. Beyond gaps of 61 m there is another random distribution different from that below 61 m. This may be interpreted to mean that under 61 m the distribution varies according to the reaction-perception time of the driver and his judgment of what constitutes a safe distance. Beyond 61 m, spacing may be judged according to the chance placement of the vehicles within the system.

This leads to a simple criterion for platoon definition: Use a minimum spacing of 61 m to separate successive platoons and to separate platoons and noninteracting vehicles (one-vehicle platoons) (1, 2, 3, 8).

STUDY APPROACH

The Baltimore Harbor Tunnel consists of two tunnel tubes, each with two traffic lanes 3 m (10 ft) wide with no shoulders. The Baltimore Harbor Tunnel Thruway regulations specifically prohibit lane changing within the tunnel, and trucks are restricted to the right lane, used also by passenger vehicles. The left lane is nearly 100 percent passenger vehicles. This unbalanced demand caused many shock waves in the left lane.

This research concerns the evaluation of control alternatives with respect to increased flow, and we therefore decided to concentrate on the left lane.

Initial data collection for the research project began in February 1973. Data were collected only on days when the pavement was dry and demand was sufficiently high to cause traffic flow problems. Included in these data were peak-period flows (3:30 to 6:30 p.m.) on Tuesday, Thursday, and Friday (February 13, 15, and 16 respectively) and Tuesday (March 13). This produced a total of 12 h of traffic characteristics for the uncontrolled situation.

Greenshields' criterion was applied to the individual vehicle flow data, which were obtained via a computer program that identified a platoon leader as a vehicle having a space headway between it and the vehicle in front of it greater than 61 m. A vehicle is defined as a single vehicle platoon if its space headway and that of the following vehicle are both greater than 61 m. This single vehicle was not considered an interacting vehicle and was not utilized in this analysis. The following basic values were obtained from each platoon: number of vehicles, average vehicle velocity defined as platoon velocity, and average space headway of the vehicles within the platoon.

After many delays a pretimed metering system was installed in October 1973, and we began data collection in December. Two traffic signal heads with 30-cm (12-in) signal lenses were installed adjacent to the northbound lanes, one for each lane, upstream of the tunnel entrance. Based on subjective analysis (3), cycle lengths of 120, 160, 180, and 240 s were chosen. For example, the 120-s cycle consisted of a 7.2-s red, 3.6-s amber, and 109.2-s green.

We included seven vehicle detection stations in each lane, each station consisting of two photocell detectors slightly over 4.1 m (13.5 ft) apart and capable of sensing many flow characteristics. Time headway, space headway, and velocities are obtainable, and individual vehicles may be identified and traced through the tunnel. Further details of this data collection system, data storage and manipulation, and derivation of the traffic flow characteristics are discussed by Carter and Palaniswamy (2).

DATA ANALYSIS AND RESULTS

A simple method of evaluating the control alternative is to inspect the average platoon velocities (APV) of each control alternative. Figure 1 shows profiles of platoon velocity change from stations 1 to 3 to 5. Station 1 is approximately at the tunnel entrance (downhill); station 3 is approximately at the midpoint of the level section;

and station 5 is at the beginning of the uphill section. It is evident that the no-control alternatives tend to be high in stations 1 [17 m/s (55 ft/s)] and 3 [18 m/s (60 ft/s)] but drop below the 120-s alternative [17 m/s (55 ft/s)] at station 5 [less than 17 m/s (55 ft/s)].

At station 5, the APV of the 240-s alternative [9 m/s (29 ft/s)] is only 60 percent of the next highest alternative, the 160-s alternative [15 m/s (48 ft/s)]. There is only a 1.7-m/s (5.6-ft/s) difference between the remaining 4 alternatives at station 5; only the no-control alternative has an APV lower than that at station 1 (as is also the case for the 240-s alternative).

Figure 1. Platoon velocity profiles.

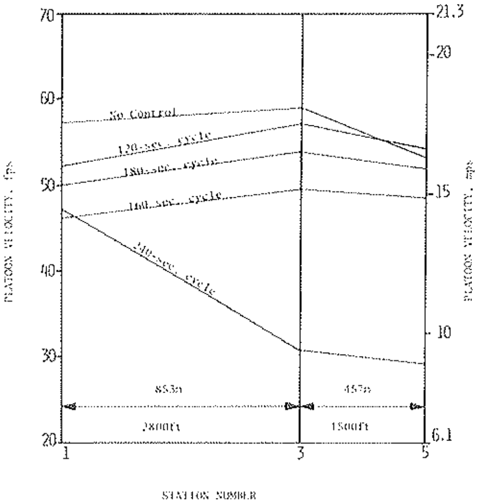


Table 1. Platoon concentration and average number of vehicles.

Velocity Increment (m/s)	Control Alternative							
	No Control		120 s		160 s		180 s	
	PC[a]	AVP[b]	PC	AVP	PC	AVP	PC	AVP
0 to 6	46.83	3[c]	—	—	—	—	—	—
6 to 8	73.03	74[c]	—	—	—	—	78.67	83[c]
8 to 9	71.61	123	72.68	123	72.79	228	70.66	137
9 to 11	63.02	73	65.70	83	66.82	242	65.37	141
11 to 12	55.30	32	60.74	47	58.50	55	59.94	43
12 to 14	50.01	16	57.68	34	61.15	37	50.83	22
14 to 15	43.75	8	52.19	18	54.47	18	53.17	19
15 to 17	48.42	9	48.07	13	50.04	12	48.12	12
17 to 18	44.56	8	46.50	9	44.97	9	44.87	8
18 to 20	46.13	9	41.44	6	41.08	6	42.86	6
20 to 21	40.73	5	38.82	5	37.91	5	38.04	4

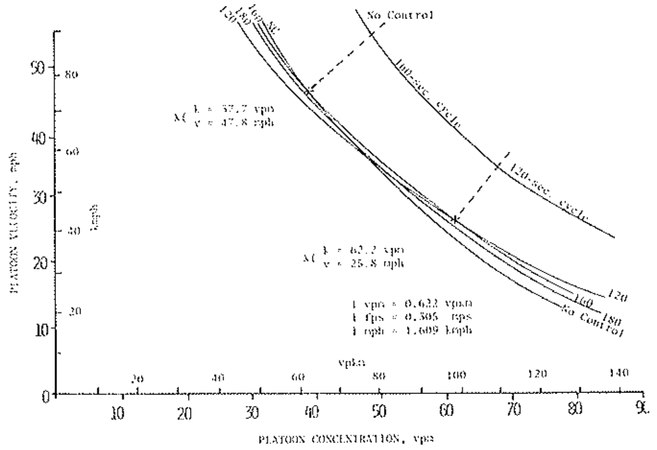
Note: 1 m/s = 3.28 ft/s.

[a] Platoon concentration.

[b] Average number of vehicles per platoon.

[c] Less than six platoons in sample.

Figure 2. Platoon velocity versus platoon concentration analysis.



Since the 240-s alternative obviously had the worst APV, no further analysis was made. This poor showing of the 240-s alternative agrees with earlier research at the Baltimore Harbor Tunnel (3). Further evaluation should be primarily concerned with the station 5 bottleneck, because any improvement at this point will benefit flow upstream from the bottleneck.

Concentration is defined as the number of vehicles in a given length of roadway. In the case of a platoon, concentration (PC) may be thought of as the average number of vehicles within the platoon (AVP), separated by an average space headway plus the platoon definition, that is, the total distance from the front of the first vehicle to the rear of the last vehicle plus the platoon criterion, in this case Greenshields' 61 m.

Table 1 shows PC and AVP obtained at station 5 for each control alternative. Values for velocities greater than 21 m/s (70 ft/s) were not obtained because the system would be operating over the maximum posted velocity [22 m/s (73 ft/s)].

The PC values for control alternatives vary slightly at velocities below 11 m/s (35 ft/s). The maximum difference between the values for each control alternative is approximately 2.5 vehicles/km (4 vehicles/mile). It is interesting to note that although the PC values do not show any significant differences at velocities below 11 m/s there are significant differences in the AVP. At the 9 to 11 m/s (25 to 30 ft/s) increment, the AVP value for the 160-s alternative is almost double that of the other alternatives, almost twice that of the 180-s alternative, and almost three times that of the 120-s and no-control alternatives.

Within the velocity range of 11 to 17 m/s (35 to 55 ft/s), except for the no-control alternative, there is not much difference in the AVP among the control alternatives. The AVP for the no-control is almost half of those for the other alternatives. Above 17 m/s (55 ft/s), the AVP for all control alternatives is approximately the same.

The relationship between concentration and velocity is essential to understanding and evaluating how well a system is operating. To investigate the platoon concentration and platoon velocity relationship, a least squares fit of the data was attempted by using Greenberg's exponential model. The results for each control alternative at station 5 are plotted in Figure 2. The optimum platoon velocities are high, 17 m/s (56 ft/s), while the optimum platoon concentrations (k_n) lie within the range of 22 to 28 vehicles/km (35 to 45 vehicles/mile). The jam concentration (k_j), in the case of platoons, may be regarded as the maximum platoon concentration the control alternative can handle without traffic coming to a complete standstill (flow = 0).

From Figure 2, one can see where each control alternative is dominant by finding the highest points of intersection of the curves. It was found that the 120-s, the 160-s, and the no-control alternatives are dominant. The results form the basis for a control strategy utilizing platoon concentration and velocities. An optimum control policy can be utilized for on-line computer control for a facility such as the Baltimore Harbor Tunnel.

FINDINGS

A basic framework for the evaluation of traffic control alternatives has been formulated in this research. The conclusions we drew were that

1. The platoon parameters (APV, PC, and distribution of platoon vehicles) provide a simple and effective

methodology for the evaluation of control alternatives;

2. The parameter APV established that the no-control, 120-s, 160-s, and 180-s alternatives yielded high and almost constant platoon velocities through the tunnel; and

3. The platoon flow values established that in some PC and velocity ranges one alternative predominated.

A control policy utilizing the no-control, the 120-s, and the 160-s alternatives was proposed.

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Abridgment

Comparison of Two Types of Left-Turn Channelization

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As traffic volumes increase, turn controls at intersections can eliminate or reduce conflicts, decrease accident hazard, reduce delay, and increase intersection capacity. One of the most useful left-turn controls is a separate lane, called slot, reservoir, pocket, or bay.

In Tempe, Arizona, separate left-turn lanes have been installed at almost every major intersection with an adequate street width. The function of the left-turn bays is to guide vehicles out of the way of through traffic and to prevent rear-end collisions.

A typical left-turn channelization is shown in the Manual on Uniform Traffic Control Devices (MUTCD) (1) with the recommended design of letter markings and arrows applicable to lane-use control. This is the type A marking adopted by the Tempe Traffic Engineering Department (Figure 1).

Another type of marking, type B, not illustrated or recommended by the MUTCD but used in other cities, is shown in Figure 2. Two solid yellow lines in the form of parallel reverse curves are used in the type B marking to identify the path a left-turning vehicle should follow; the type A example shows only an open entry space for access to the left-turn lane.

PURPOSE OF THE STUDY

The purpose of this study was to investigate driver performance at selected sites under types A and B left-turn markings and to determine which type produced better driver performance. After the data for type A markings had been collected, the markings were changed to type B at each location by the Tempe Traffic Engineering Department.

PROCEDURES

Intersections Studied

Of the 12 type A intersections indicated by the Tempe traffic engineer, 4 were selected for this study. Two were chosen for observing the turning movement from an arterial to a collector street (AC I and AC II) and 2 from an arterial to an arterial street (AA I and AA II). Only 1 approach on each intersection was observed in this study. The last 2 intersections have many left turns into areas surrounded by commercial and cultural activities; the first 2 have less volume and lead to residential areas.