An Analysis of the Travel Conditions on the U. S. 52 Bypass in Lafayette, Indiana

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INTRODUCTION

In recent years vehicular travel has increased at a tremendous rate. The construction of new highways and the improvement of existing facilities have failed to keep pace with the growth of motor-vehicle travel. The problem is especially acute in urban areas, where major arterial highways lack needed capacity for handling the large movements of intracity travel. Many urban roads were constructed decades ago, when the present status of vehicular travel was inconceivable. Inadequate planning and improvement of these facilities have resulted in congestion and delays which are costly and irritable to road users.

Limited-access freeways are being constructed in large urban areas to accommodate the major flows of through and intracity travel. Existing arterial highways continue to play an important role in the movement of traffic, however, and they serve as collectors and distributors for the new expressways. Through sound traffic engineering techniques, the improvement of these arterial facilities is necessary for the efficient and safe functioning of the complete transportation system of an urban area. With a large expenditure of funds for the construction of new roads, the continuing renovation of the present highways has been largely neglected.

The purpose of this research investigation was a detailed analysis of travel speeds and delays on a congested arterial highway located in an urban area. (5)* The facility selected for study was the U. S. 52 Bypass in Lafayette, Indiana. The specific objectives of this traffic engineering evaluation were the following:

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* Numbers in parentheses refer to items in the bibliography.

1. Determine the significant variables which influence travel speeds and delays;
2. Develop equations using these significant variables to predict travel speeds and delays; and
3. Make recommendations of traffic engineering techniques to improve the movement of traffic on this bypass facility.

Travel time studies have been performed for various purposes, all of which are related to the evaluation of the level of service afforded by a highway section. Because the driver often considers total travel time in reaching his destination as the criterion for selecting a certain route, travel time is given consideration in the evaluation of a highway system. (2)

PROCEDURE

The U.S. 52 Bypass in Lafayette, Indiana, serves a variety of traffic functions which include:

1. Through traffic between Indianapolis, Chicago, and intermediate points;
2. Terminal traffic from throughout Tippecanoe County to Lafayette, an industrial center and the county seat, and to Purdue University in adjoining West Lafayette; and
3. Local traffic to commercial and industrial establishments abutting the bypass.

To permit the proper evaluation of travel conditions, the bypass was divided into 18 homogeneous study sections by considering highway geometry, speed limits, roadside development, and locations of traffic signals. These sections are shown on the map in Figure 1. Signalized intersections were separated from the other sections of this route. These intersections, which were categorized as "interrupted flow," represented a special condition where traffic was required to stop for the red-signal indication. A distance of 500 ft on each side of the intersection center was established to define the zone of influence of the traffic signal. The remaining sections of the two-lane bypass were designated and analyzed as "uninterrupted flow."

The selection of the variables to be included in this study was dependent on an examination of those items included in previous investigations and on the availability and ease of collecting data. These variables were descriptive of roadway geometry, roadside development, traffic conditions, and traffic signals.

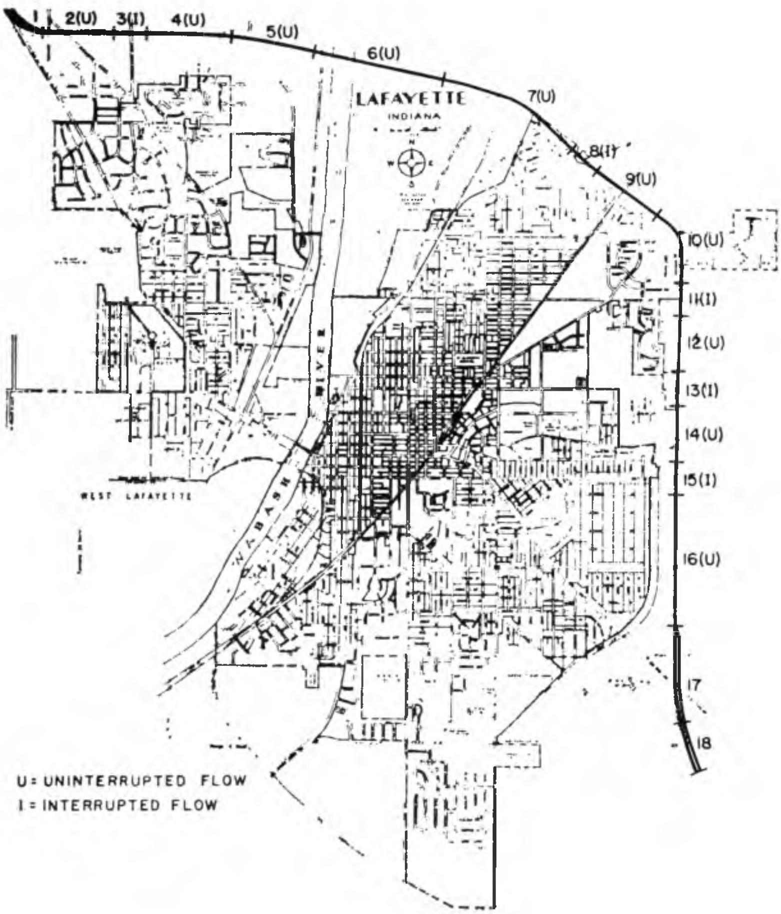

Fig. 1. Test sections of U. S. 52 Bypass.

Data Collection

Many variables in the analyses of uninterrupted and interrupted flows described various physical characteristics of the study locations, and these values remained constant for each test section. The exceptions were those variables associated with volumes, commercial vehicles, time periods, days of the week, travel speeds, and delays. An inventory of the physical characteristics for the bypass was made from construction plans and aerial photographs. In some cases, actual measurements were performed in the field.

Travel times were measured by the average-car technique. This method was especially appropriate, because the heavy traffic volumes permitted few opportunities for passing maneuvers. The driver operated the test car at a speed which, in his opinion, was representative of the average speed of the traffic stream. During periods when the test car was not influenced by other vehicles, the driver observed the speed limits. Travel times at the section boundaries were recorded with a stop watch by an observer in the car. Whenever the vehicle was forced to stop, the duration of this stop was measured with a second stop watch.

Forty runs were made in each direction to assure a good estimate of the mean travel speed for each section. (1, 4) This procedure provided a sample size of 800 observations for the ten sections representing uninterrupted flow. Five sections provided a sample size of 400 observations for the analysis of interrupted flow.

All test car runs were made over the entire length of the bypass. The data collections were made on weekdays, in daylight between the hours of 8 a.m. and 6 p.m., and during clear and dry weather conditions. To insure a variation in traffic volumes, trips were made during peak and off-peak hours.

Analysis of Data

Before the statistical analyses were performed, the data were processed and summarized to facilitate the various calculations. In addition, travel times were converted to travel speeds, which were averaged for each test section.

The travel delay for each run at signalized intersections was computed as follows:

$$1.\quad D_1 = T - \left[\frac{L\,(3600)}{0.5\,(\overline{S}_B + \overline{S}_A)} \right]$$

where D_1 = travel delay, sec,
T = travel time, sec,
L = length of section, miles,
S_B = average overall travel speed of adjacent section before intersection, mph, and
S_A = average overall travel speed of adjacent section after intersection, mph.

The term in the brackets in Equation 1 was considered as the hypothetical travel time if the intersection had not existed. In a few cases where the computed delay was a negative value, these delays were assumed to be zero.

The average delay per vehicle for each signalized intersection was again calculated by a theoretical method which depends on the red interval of the cycle, the average arrival headways in the traffic stream, and the starting performance of the queue. This method is fully described in the textbook, *Traffic Engineering.* (3)

Multiple linear regression equations were developed to predict mean travel speeds and delays from the significant study variables. A "buildup" regression routine was used to determine the various functional relationships.

RESULTS

To develop the general levels of travel conditoins presently existing on the U.S. 52 Bypass in Lafayette, Indiana, mean travel speeds and delays were computed for the study sections. These relative delays are indicated in Figure 2 by the comparison of running speed with overall speed for each location. Travel delays were evidenced in those sections in which the running speed exceeded the overall speed.

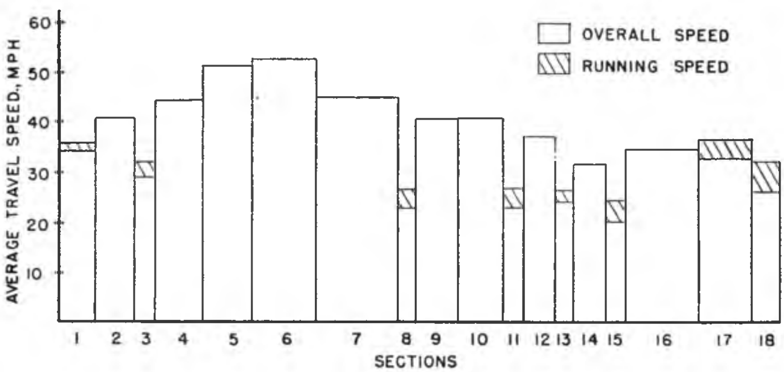

Fig. 2. Average travel speeds for sections.

Uninterrupted Flow

A total of 38 variables was observed to describe the travel conditions of uninterrupted flow. The following multiple linear regression equation was selected as the most valid functional relationship for the estimation of overall travel speed:

2. $S_1 = 68.60 - 0.4541X_1 - 0.1775X_2 - 0.1007X_3 - 0.0150X_4 - 0.0301X_5$

where S_1 = mean travel speed, mph,

X_1 = intersecting streets on both sides, number per mile,

X_2 = commercial establishments on both sides, number per mile,

X_3 = portion of section length where passing was not permitted, percent,
X_4 = practical capacity, vph, and
X_5 = total traffic volume, veh per 15 min.

The measure of correlation was expressed by a multiple correlation coefficient of 0.704. The variables of intersection streets, commercial establishments, no-passing zones, practical capacity, and total volume were all negatively related to travel speed and accounted for 50 percent of the total variation in overall travel speeds for the uninterrupted flow sections of the bypass.

A considerable portion of the unexplained variation in overall travel speeds was probably caused by individual driver behavior. Variations were evident in the driving habits of vehicle operators as the test-car driver attempted to relate his speed to the average speed of the traffic stream.

Interrupted Flow

The analysis of interrupted flow followed the same pattern as the investigation of uninterrupted flow. Delays observed from the actual travel times agreed quite closely with the theoretical delays computed for each signalized intersection. The travel conditions through the intersectional areas were initially described by 41 variables.

Multiple linear regression equations were derived to estimate travel speeds and delays for interrupted flow t hrough the intersection locations as functions of the significant study variables. The mean speed relationship has the following form:

3. $S_2 = 28.595 - 0.4165X_6 - 0.2118X_7 - 0.0120X_8 - 0.0170 X_9 + 29.4800X_{10}$

where S_2 = mean travel speed, mph,
X_6 = average algebraic grade of approach, percent,
X_7 = cycle length of traffic signal, sec,
X_8 = traffic volume approaching the intersection in the direction of travel, vehicles per 15 min,
X_9 = total traffic volume entering the intersection on all four approaches, vehicles per 15 min, and
X_{10} = green time to cycle length ratio.

The degree of linear correlation was indicated by a multiple correlation coefficient of 0.368. The five significant variables accounted for only 14 percent of the variation in travel speeds. The variables of approach grade, cycle length, approach volume, and total intersection volume were negatively related to speed, and the green time to cycle length ratio was positively associated with travel speed.

The following multiple linear regression equation for travel delay was evolved:

$$4.\quad D_2 = 11.951 + 0.2299X_7 + 0.0135X_8 + 0.0168X_9 - 35.7935X_{10} + 0.0052X_{11}$$

where D_2 = mean travel delay, sec,
X_7 = cycle length of traffic signal, sec,
X_8 = traffic volume approaching the intersection in the direction of travel, vehicles per 15 min,
X_9 = total traffic volume entering the intersection on all four approaches, vehicles per 15 min,
X_{10} = green time to cycle length ratio, and
X_{11} = length of approach to special turning lane, ft.

The correlation coefficient of 0.326 measured the degree of the functional relationship for the variables. Approximately 11 percent of the variability in delay was explained by the independent variables. Positive relationships with delay were reflected in cycle length, approach volume, total intersection volume, and length of turning lane. The remaining variable of green time to cycle length ratio had a negative relationship with travel delay.

The multiple correlation coefficients of these two regression equations were lower for the analysis of the interrupted flow than that for the uninterrupted flow. Overall travel speeds and delays at signalized intersections depended greatly on whether or not the vehicle was required to stop. This condition of chance was not accounted for in the analysis. In addition, some variables which were significant in the final models exhibited little variation among the study intersections.

Suggested Improvements

The results of the analyses of uninterrupted and interrupted flow were applied for the recommendation of traffic engineering improvements to minimize delays on the U.S. 52 Bypass in Lafayette, Indiana. The major delays to the traffic stream occurred at the signalized intersections. The significant reasons for these delays were largely associated with the design of the signal timings and the approach volumes. Reductions in speed for the uninterrupted flow portions of the bypass were mainly influenced by the degree of commercial development, the number of access points, and traffic volume.

These findings formed the basis of suggestions for reducing delays on the bypass. Proposed short-range improvements include the limitation and designation of access points, the improvement of the geometric design of signalized intersections, and the critical evaluation of the signal-cycle phases. A long-range recommendation is the reconstruction of the bypass as a four-lane, divided highway to provide the proper highway and intersection capacities.

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