Analysis of Delay and User Costs at Unwarranted Four-Way Stop Sign Controlled Intersections

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ABSTRACT

A study was conducted to examine the operational characteristics of traffic controls at low-volume, low-speed intersections with unwarranted four-way stop sign control. The research involved the collection of traffic volume and delay data at eight selected four-way stop sign controlled intersections in three cities in northwestern South Carolina. These data and various unit delay values and unit cost factors were used to quantitate the delays and road user costs experienced by motorists at these intersections. The delay and road user costs that would result from two-way stop sign control at the intersections were estimated based on field data collected at similar intersections and compared with the delay and road user costs associated with four-way stop sign control. This comparison of delay and road user costs showed that four-way stop sign control at the eight intersections selected for study caused 26,430 hr of additional delay and $296,610 in additional road user costs annually. Four-way stop sign control produced an average of 3,300 hr of additional delay per intersection and $37,080 per intersection in additional road user costs annually. Therefore, it was concluded that unless an accident problem susceptible to correction by four-way stop sign control exists, the unwarranted use of four-way stop sign control results in unnecessary delay and road user costs to the driving public and that the intersection traffic control should be changed to two-way stop sign control. Also, traffic engineers should resist efforts by the public to have four-way stop sign control installed at intersections where it is not warranted.

PURPOSE AND OBJECTIVES

The purpose of the study reported here was to evaluate certain operational characteristics of traffic at four-way stop sign controlled intersections that did not meet accepted minimum warrants for the installation of four-way stop sign control. To fulfill this purpose, the specific objectives were (a) to collect traffic volume and delay data at selected four-way stop sign and two-way stop sign controlled intersections, (b) to quantify delay and road user costs at the selected four-way stop sign controlled intersections, (c) to estimate the delay and road user costs associated with two-way stop sign control at the selected four-way stop sign controlled intersections, and (d) to present information on the comparison of delay and road user costs at intersections with different forms of intersection traffic control.

DATA COLLECTION

The primary criterion for selecting the four-way stop sign controlled intersections for this study was the failure of an intersection to meet the minimum warrants for multiway stop sign control (1). The eight four-way stop sign controlled intersections selected for study were located in Anderson and Oconee counties in northwestern South Carolina. Three intersections were located in the Oconee County town of Seneca that had a 1980 population of 7,436. Three intersections were located in Walhalla, the county seat of Oconee County, that had a 1980 population of 3,977. Two intersections were located inside the corporate limits of Anderson, a city that had a 1980 population of 27,965.

Data were collected on traffic volume and vehicle
Byrd and Stafford

delay characteristics at each intersection during weekdays so the data would represent typical traffic conditions. The two components of intersection delay measured were stopped-time delay and the delay associated with speed change cycles. The procedures followed in conducting the stopped-time delay studies were those described in the Manual of Traffic Engineering Studies (2); these procedures represent a widely adopted method of obtaining information on stopped-time delay. This method involved the Counts of vehicles stopped at an intersection approach at successive time intervals.

Speed change cycle delay, which is defined as the additional time required to decelerate from a specific approach speed and then accelerate back to the initial approach speed above the time required to travel through the intersection at the initial approach speed, was computed for each intersection approach. In this analysis all vehicles approaching a four-way stop sign controlled intersection were assumed to be traveling at the speed limit and then came to a complete stop. The unit values of delay used in the analysis of the speed change cycle delay were obtained from Winfrey's Economic Analysis for Highways (3). The speed change cycle delay was combined with the stopped-time delay to obtain total intersection delays.

The operational restrictions imposed by intersection traffic control devices create additional road user costs for motorists. It has long been recognized that traffic congestion and the associated delay are not only inconvenient but add to the cost of transporting goods and passengers. A highway improvement that reduces congestion and delay can result in a significant reduction in road user costs. Therefore, quantifying road user costs is an important part of a study of intersection traffic control. The two types of costs considered in this study were those associated with the operation of the vehicle and the value of motorists' time. Vehicle operating costs are defined as those direct road user costs that result from the operation of a vehicle. Because all vehicles must stop at four-way stop sign controlled intersections, the vehicle operating costs calculated were those resulting from vehicles decelerating from the initial speed to a stop and accelerating back to the initial speed plus vehicle idling costs while stopped. This study used the widely accepted methods provided in the AASHTO "Red Book" (4) for quantifying vehicle operating costs.

The AASHTO methods involved the application of cost factors to the traffic volume and delay data collected at each four-way stop sign controlled intersection. AASHTO provided cost factors that represented 1975 conditions and price levels. Before applying these cost factors, they were updated to March 1982 conditions and price levels using procedures recommended in the Red Book (4). These procedures are based on the consumer and wholesale price indexes published by the U.S. Bureau of Labor Statistics.

The daily volume of vehicles passing through each intersection was multiplied by the appropriate updated AASHTO cost factor to obtain the speed change cycle costs generated at an intersection. Because of the low percentages of single-unit and tractor-semitrailer trucks in the traffic stream at the intersections involved in the study, the daily speed change cycle costs at the intersections resulted primarily from passenger vehicle speed change cycles.

Idling costs are incurred when a vehicle is stopped at an intersection. The amount of cost is dependent on the vehicle type and the length of time the vehicle is stopped. To calculate the daily vehicle idling cost at an intersection, the unit values of idling cost recommended in the Red Book (4) were updated and used. Each unit cost value per idling hour was multiplied by the daily stopped-time delay to obtain the daily idling costs at an intersection.

This study also placed a value on the time associated with traveling through an intersection by multiplying unit values of time by the amount of time consumed and by a vehicle occupancy factor. The unit values of time used were $3.00 per traveler hour for the occupants of passenger vehicles and $6.00 per traveler hour for the occupants of single-unit and combination tractor-semitrailer trucks. All passenger vehicles were considered to have an average occupancy of 1.6 adults per vehicle and all trucks were considered to have an average occupancy of 1.2 adults per vehicle. The total road user costs at each four-way stop sign controlled intersection were calculated by combining the vehicle operating cost from speed change cycles and vehicle idling with the time cost.

IMPACT OF TWO-WAY STOP SIGN CONTROL
The delay and road user costs associated with four-way stop sign control were compared with the delay and road user costs resulting from two-way stop sign control. Estimation of the delay and road user costs that would result if the four-way stop sign controlled intersections if they were controlled by two-way stop signs required the collection of additional delay data at two-way stop sign controlled intersections. The additional delay data were analyzed to obtain numerical values of the stopped-time delay per vehicle and the frequency and magnitude of all speed change cycles associated with two-way stop sign control. The selection of intersections where the additional delay data were collected was done on the basis of similarity of traffic volumes, approach speeds, turning movements, traffic stream characteristics, and abutting land uses at the intersection and at a particular four-way stop sign controlled intersection examined previously. Each intersection was located as close as possible to a particular four-way stop sign controlled intersection to take advantage of similarities in traffic characteristics and environmental conditions in a given area. Four two-way stop sign controlled intersections were selected for analysis. Two four-way stop sign controlled intersections had a highway in common with one of these two-way stop sign controlled intersections.

The stopped-time delay that was measured at the two-way stop sign controlled intersections was used to estimate the stopped-time delay that would result if the four-way stop sign controlled intersections were controlled by two-way stop signs. The stopped-time delay per vehicle on the minor approaches was determined for each two-way stop sign controlled intersection and these values were applied to the traffic volume on the minor approaches of the four-way stop sign controlled intersections.

The frequencies and magnitudes of the speed change cycles that occurred at the two-way stop sign controlled intersections were applied to the traffic volumes on the four-way stop sign controlled intersections to estimate the speed change cycle delay that would result if the four-way stop sign controlled intersections were controlled by two-way stop signs.

The analysis of the economic impact of two-way stop sign control at the four-way stop sign controlled intersections focused on road user costs. These road user costs consisted of the vehicle operating costs from speed change cycles and vehicle...
idling plus the time cost to vehicle occupants. The
methods and procedures used to calculate the road
user cost that would result from two-way stop sign
control were the same as those described previously
for four-way stop sign control. A more detailed
description of the study techniques employed, the
methods used for computing total intersection delay
and road user costs, and the results obtained from
the study has been presented by Byrd (2).

SUMMARY AND CONCLUSIONS

This study investigated the operational characteris-
tics of selected unwarranted four-way stop sign
controlled intersections. Field data were collected
on traffic volume and delay characteristics at eight
intersections currently operating with four-way stop
sign control in northwestern South Carolina. Stopped-
time delay studies were conducted on all of the
approaches to the intersections. The traffic volume
and delay data were then used in conjunction with
unit delay and cost factors obtained from previous
research to quantify delay and road user costs at
each intersection.

The annual delay at the eight four-way stop sign
controlled intersections was calculated to be 42,660
hr or 5,330 hr per intersection. Sixty-eight percent
of this delay resulted from speed change cycles and
the remaining 32 percent was stopped-time delay. The
annual road user cost that resulted at all eight
four-way stop sign controlled intersections was
$477,960 or $59,750 per intersection. Fifty-four
percent of this cost resulted from vehicle operating
costs during the speed change cycles. Time costs
represented 44 percent and vehicle idling costs
accounted for the remaining 2 percent of the road
user costs.

To estimate the magnitude of the possible bene-
fits of two-way stop sign control at the eight four-
way stop sign controlled intersections that did not
meet the minimum traffic volume warrant of the Man-
ual on Uniform Traffic Control Devices (1), inter-
sections with comparable traffic characteristics and
currently operating under two-way stop sign control
were analyzed. Using the data obtained at these
intersections, the delay and road user costs that
would result from two-way stop sign control at the
four-way stop sign controlled intersections were
estimated. These estimates were then compared with
the delays and road user costs that existed with
four-way stop sign control to determine the impact
that two-way stop sign control would have on the
delay and road user costs at these intersections.
These comparative analyses showed that the installa-
tion of two-way stop sign control would reduce
intersection delay and intersection road user costs 62
percent.

Unwarranted four-way stop sign control at the
eight intersections selected for study, assuming 100
percent driver obedience of stop signs, caused
26,430 hr of additional delay and $296,610 in addi-
tional road user costs annually. Neglecting dif-
fferences in traffic volumes at the intersections,
unwarranted four-way stop sign control caused an
average of 3,300 hr of additional delay per inter-
section and $27,000 per intersection in additional
road user costs annually.

This study was conducted on low-volume, low-speed
intersections with unwarranted four-way stop sign
control in northwestern South Carolina. In the
context of this study, low-volume intersections were
considered to be intersections with fewer than 8,000
vehicles per day on all approaches. Low-speed in-
tersections were considered to be intersections with
approach speed limits of 35 mph or less. The fol-
lowing conclusions, which were derived from this
study, may apply to intersections similar to the
ones investigated but not to all intersections with
four-way stop sign control.

1. The unwarranted use of four-way stop sign
control causes motorists to experience substantial
amounts of additional and unnecessary delay and road
user costs.

2. The installation of two-way stop sign control
at an intersection operating with unwarranted four-
way stop sign control can produce significant delay
reductions and road user cost savings.

3. The total delay to the minor highway traffic
at unwarranted four-way stop sign controlled inter-
sections would not be significantly changed by the
installation of two-way stop sign control.

The effectiveness of four-way stop sign control
as a safety measure is dependent on individual in-
tersection characteristics. If an intersection is
operating with unwarranted four-way stop sign con-
trol that is not a needed safety measure, the driv-
ing public is forced to pay unnecessary road user
costs and suffer delay. In addition, it has been
established previously that the use of unwarranted
four-way stop sign control results in increased fuel
consumption and vehicle emissions. Therefore, this
study concluded that unwarranted four-way stop sign
control at low-volume, low-speed intersections
should be changed to two-way stop sign control when
highway safety will not be seriously compromised.
Also, traffic engineers should use the information
on additional delay and road user costs associated
with four-way stop sign controlled intersections to
resist the efforts of the public to have four-way
stop sign control installed at intersections where
it is not warranted.

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