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Abridgment

Potential Impact of Speed Reduction at Freeway Lane Closures: A Simulation Study

ZOLTAN A. NEMETH and AJAY K. RATHI

ABSTRACT

The objective of this study was to evaluate the potential impact of reduced speed limits at temporary freeway lane closures at work zones at arbitrarily assumed levels of compliance. Although some transportation engineers prefer to reduce speeds at work zones to protect the working crew, others are hesitant to introduce such a disturbance to the traffic flow. The study approach involved simulation experimentation, using FREESIM, a microscopic, stochastic model. A fractional factorial design was developed for the analysis of three independent variables: two-lane volumes (800, 1,200, 1,500 and 1,800 vehicles per hour); speed limits (55, 50, and 45 mph); and assumed compliance with speed limit (33, 66, and 100 percent). The number of uncomfortable decelerations and the variance of the speed distribution were selected as the dependent variables. These two variables were offered as a measure of the internal friction created by the merging of two-lane traffic into a single lane. It was hypothesized that this internal friction is increased by the introduction of lower speed limits. The results of this simulation study indicate that compliance with reduced speed limits will have no significant impact on the number of uncomfortable decelerations but will reduce variance in speed distribution. These results, therefore, do not support the assumption that effective speed reduction at work zones would create a potentially hazardous disturbance in the flow of traffic.

Freeway lane closures at work zones require properly developed traffic control plans to minimize the disturbance of the traffic flow and provide for the safety of both drivers and working crew. The introduction of reduced speed zones is a somewhat controversial aspect of traffic control. Although, at least intuitively, reduced speed implies greater safety especially for the working crew, it introduces a disturbance that may well have a negative impact on the safety of the traffic flow.

The objective of this computer simulation study was to evaluate the potential safety impacts of speed zones at freeway lane closures at different levels of assumed compliance. The specific configuration selected for analysis was the closure of the median (left or passing) lane on two-lane, rural freeway sections.

It is generally recognized that posted speed limits are not necessarily effective in reducing mean speeds, although there are means by which the effectiveness can be improved. This study, however, was concerned only with the impact of the reduced speed limits at specified levels of compliance on the stability of traffic flow.

SIMULATION MODEL

FREESIM is a microscopic, stochastic simulation model. The model logic is based on a rational description of the behavior of drivers in a lane closure situation. The vehicles are advanced in the system using the classical car-following approach. The model simulates lane changing as well as overtaking. The simulation program is written in SIMSCRIPT II.5 programming language (1).

Verification of the simulation model included operational testing of the simulation dynamics

algorithms (i.e., car following and lane changing) and sensitivity analysis of measures of effectiveness to the exogenous (input) variables.

Validation of the simulation model was accomplished by the comparison of simulated time-headway, speed, and merging distributions with four sets of actual observations obtained from three different rural freeway lane closure sites (2). Also, the simulation model outputs on overall speed, flow, throughput, and lane-changing frequencies were compared with some well-known empirical data from the literature.

The input requirements for implementing reduced speed zoning are the reduced speed limit parameters (i.e., legibility and perception-reaction time) for the speed limit sign and the proportion of drivers that complies with it.

DESIGN OF SIMULATION EXPERIMENTS

A fractional factorial design was developed for the analysis of three independent variables: speed limit, specified compliance with the speed limit, and two-lane approach volume. Compliance levels of 0.33, 0.66, and 1.00 were used for each of the two reduced speed limits implemented: 50 and 45 mph. Four levels of two-lane approach volumes (vehicles per hour) were used: 800, 1,200, 1,500, and 1,800. A total of 140 simulation runs were made: five "replications" of each of the 28 combination of factor levels.

Because the objective of this study was to evaluate the safety impacts of speed zoning, two safety-related measures of performance were selected:

1. The number of uncomfortable decelerations per vehicle-hour (UNCOM.DECEL) and
2. The variance of speed distribution in the open lane at the beginning of the transition zone (i.e., taper).

UNCOM.DECEL is perhaps the best representation of driver response to unexpected, potentially unsafe conditions. An uncomfortable deceleration is defined as one that exceeds by more than 2 ft/sec^2 what is normally considered the comfortable deceleration rate for vehicular traffic at a given speed [see Table 2.7 of The Transportation and Traffic Engineering Handbook (3)].

FINDINGS

The average UNCOM.DECEL and the variance of speed at a transition zone in the open lane, for each combination of factor levels, are given in Tables 1 and 2, respectively. The impacts of reduced speed zoning on uncomfortable decelerations and on variance of speed are discussed separately.

Uncomfortable Decelerations

The base condition is represented by the 55 mph speed limit condition. In this case, each driver has a desired speed assigned from one of two normal distributions (means: 52.8 mph inner lane, 57.2 mph passing lane) intended to represent near free flow conditions.

It is quite clear that the UNCOM.DECEL increases rapidly as volumes approach single lane capacity. The question is: will compliance with a reduced speed limit compound the problem or will it offset it?

Compared to the base case, some reduction in the UNCOM.DECEL is observed in most cells in Table 1. Note, however, that changes due to compliance with reduced speed limits are insignificant in comparison to changes due to variation in volume.

Overall, reduced speed limits have a mostly positive but negligible, in magnitude, impact on uncomfortable decelerations.

TABLE 1 Average Number of Uncomfortable Decelerations per Vehicle-Hour

Speed Limit (mph)	Compliance (%)	Volume (vph) 800	1,200	1,500	1,800
55		0.0465	0.1130	0.2784	0.6989
50	33	0.0485	0.0947	0.2187	0.6767
	66	0.0525	0.0990	0.2808	0.6767
	100	0.0550	0.0937	0.3037	0.8416
45	33	0.0550	0.0847	0.2221	0.5453
	66	0.0465	0.1063	0.2597	0.6544
	100	0.0470	0.0837	0.2795	0.5844

TABLE 2 Variance of Speed (miles^2/hr^2) at the Beginning of the Transition Zone in the Open Lane

Speed Limit (mph)	Compliance (%)	Volume (vph) 800	1,200	1,500	1,800
55		33.69	44.41	80.19	102.11
50	33	21.35	38.43	62.00	97.07
	66	17.90	26.43	81.89	107.45
	100	9.80	22.26	84.49	112.35
45	33	26.37	32.47	53.90	83.12
	66	18.05	25.19	56.59	81.63
	100	10.14	20.07	64.83	84.70

Variance of Speed Distribution

The variance of speed distribution at the taper is suggested as another measure of disturbance created by the forced merge of two-lane traffic into a single lane. To facilitate the interpretation of the results of the simulation study, the mean speeds are also presented (Table 3). In the base case situation (at 55 mph speed limit), the mean speeds drop by about 10 mph as volumes increase from 800 to 1,800 vehicles per hour (vph). This is not unexpected as practically all the approaching vehicles will be traveling in the open lane at the beginning of the taper, having completed the necessary merging maneuvers. Because mean speeds are near or below 50 mph, compliance with a posted 50 mph speed limit would have little impact on mean speeds, especially at higher volumes. The data presented in Table 3 confirm this expectation. The reduction in speed variance is also limited to the lower volume ranges (Table 2).

Compliance with a 45 mph speed limit, however,

TABLE 3 Mean Speed (mph) at the Beginning of the Transition Zone in the Open Lane

Speed Limit (mph)	Compliance (%)	Volume (vph) 800	1,200	1,500	1,800
55		51.13	49.03	45.66	41.59
50	33	50.33	48.70	46.06	41.88
	66	49.68	48.67	45.26	41.63
	100	49.43	48.46	45.11	41.34
45	33	48.62	47.20	44.20	40.43
	66	45.60	44.68	42.25	39.37
	100	44.59	44.10	41.20	39.06

would result in both lower mean speeds and lower speed variances. The reduction in speed variance due to compliance with the 45 mph speed limit can offset or reduce considerably the impact of increased volumes. For example, at 1,800 vph, the speed variance at 45 mph is only slightly higher (83.12, 81.63, 84.70) than the 55 mph speed variance at 1,500 vph (80.19).

DISCUSSION OF RESULTS

There are two opposing interests in effect at work zones involving freeway lane closures. The protection of the working crew appears to require speed reduction to minimize the potential impact of cars accidentally crashing into the working zone. The obvious interest of the driving population is to pass by working zones without delay or disturbance.

This study was undertaken to test the hypothesis that the introduction of speed reduction will increase the disturbance created in the traffic flow by the lane closure. The simulation study, however, did not generate any evidence to support this assumption.

Compliance with either the 50 mph or the 45 mph speed limit had negligible impact on uncomfortable decelerations.

Compliance with the 50 mph speed limit resulted in a small reduction in the variance of speed reduction at lower volume ranges. At higher volume ranges, the changes were largely negligible. It was noted that at higher volumes the mean speeds were considerably lower than 50 mph even before the introduction of speed control. Both mean speed and variance of speed distribution were found to be strongly volume dependent.

Compliance with the 45 mph speed limit, however, offset at least partly the increase in speed variance created by increased volume levels.

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