A Critique of Tignor and Warren's "Driver Speed Behavior on U.S. Streets and Highways"

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Summary

The paper "Driver Speed Behavior on U.S. Streets and Highways," by the Federal Highway Administration's (FHWA's) Samuel Tignor and Davey Warren, erroneously concludes that raising speed limits by up to 15 mph has little or no effect on travel speeds, and that speed limits should be set in the 70-90th percentile range (Tignor and Warren, 1990). These conclusions are contrary to the findings of numerous other studies that show that speeds increase when speed limits are raised. Moreover, the studies used by Tignor and Warren to support their claims have not been released by the FHWA, preventing proper peer review of the research. Evidence available from unpublished copies of the research reports shows that the conclusions arrived at by Tignor and Warren are unwarranted.

Tignor and Warren's paper could promote public policy and traffic engineering actions that are likely to result in more crashes and crash deaths. The paper and its suggestions regarding raising speed limits do a dangerous disservice to traffic engineering and highway safety.

Background

In their paper, Tignor and Warren draw the following conclusions:

- "Raising the speed limit by various amounts up to 15 mph has little or no effect on speeds over a broad range of road types and speed levels."
- "There is no evidence in our studies that raising the speed limit to 65 on rural interstate freeways led to an increase in speeds off the freeway."
- "The accident involvement rates on streets and highways in urban areas was highest for the slowest 5 percent of traffic, lowest for traffic in the 30 to 95 percentile range and increased for the fastest 5 percent of traffic."
- "Speed limits should be set in the 70 to 90 percentile range or roughly 5 to 10 mph above the average speed to correctly reflect maximum safe speed."

Tignor is chief of FHWA's information and behavioral systems division (formerly the traffic safety research division) and Warren is a FHWA traffic engineer who worked in Tignor's division when the paper was written. The paper was based on research conducted by two contractors for the FHWA.

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Although the paper contains a disclaimer stating that it is the opinions of the authors and not necessarily those of the FHWA that are presented, proponents of higher speed limits have cited this paper as representative of FHWA's position on speed limits. These proponents use the paper to justify claims that higher speed limits will not result in either increased speeds or more crashes, and that it is the slower vehicles that cause most crashes. However, Tignor and Warren's paper, written while the research was still under way, only summarized "preliminary results" of the two FHWA contracts, and references documenting their research and findings are not cited. Although their paper was published in September 1990, documents relating to the research cited have not been released publicly; however, three unpublished contractors' reports and a published summary report were obtained and reviewed.

One of the unpublished reports, entitled, "Assessment of Current Speed Zoning Criteria" (Harkey, Davis, Robertson, and Stewart, 1989), was completed in January 1989 and a substantially different version of the same report was completed in June 1989. A summary of this work was published under the same title by Harkey, Robertson, and Davis (1991). In this study, speed and crash data were collected and analyzed to determine speed characteristics and the lowest point of crash risk. The other study, entitled "Effects of Raising and Lowering Speed Limits," which is being conducted by Martin R. Parker and Associates (MPA), apparently has not been completed (as of October 1991). This study is intended to determine the effects of raising and lowering speed limits on driving behavior and crashes. A draft report documenting data collection and analysis in just one of 23 states that were to be studied was provided to FHWA in March 1991 (MPA, 1991). However, this paper contains a disclaimer that "the discussion, data, figures, and presentation given in this draft are for illustrative purposes only and do not reflect the contents of the draft final report."

The unwillingness of Tignor and Warren to release the reports and data associated with the research described in their paper has prevented proper peer review and has made it difficult to evaluate their methodology and findings. However, based on a review of the documents obtained, it is evident that Tignor and Warren have incorrectly described the research and that the conclusions presented in their paper are unsubstantiated, erroneous, and based on poorly designed and improperly executed research.

Speed Limits and Speeds

Tignor and Warren's contention that raising, or lowering, speed limits by various amounts up to 15 mph had little or no effect on travel speeds appears to be based on the MPA study. Tignor and Warren report that free-flow speeds defined by a 4 second headway were measured for 24-hour

periods at 102 sites in 23 states both before and one year after the speed limit at each site was raised or lowered. Data were collected during similar periods at 102 sites on apparently similar roads where speed limits were unchanged. These sites were supposed to represent a full range of speed limits and road types, including a few freeways where speeds were raised from 55 mph to 65 mph. Tignor and Warren illustrate data from 45 sites where speed limits were raised and 57 sites where speed limits were lowered.

However, the claim that raising speed limits had no influence on speeds cannot be substantiated with the available information. The MPA March 1991 draft report identifies 13 control sites where speeds were not changed and 13 two-lane roads (one urban and 12 rural) in Ohio where speeds were *lowered.* Eleven of the 13 experimental sites had 55 mph speed limits. None were on interstates or freeways. No data from sites where speed limits were *raised* were presented.

The study reports that after speed limits were lowered, mean speeds of all vehicles increased slightly at six sites, decreased slightly at five sites, and were unchanged at two sites. Similar findings are reported for 85th percentile speeds. There were reportedly no changes at the control sites, although these sites were quite dissimilar to the experimental ones (e.g., four of the experimental sites had traffic signals but none of the control sites did). However, the extent to which the speeds of just the free-flow vehicles -- the ones most likely to be influenced by speed limit changes -- were influenced remains unknown. It should also be noted that mean and 85th percentile speeds are not sufficiently sensitive measures to gauge changes in speed distributions. If studies of sites where speed limits were increased were done using these methods, the results would be inadequate. Measures such as the proportions of free-flow vehicles that exceed various speed thresholds (e.g., 55, 60, or 65 mph) are far more sensitive measures of the influence of speed limit changes, but these were not reported.

The claim that travel speeds are uninfluenced by changes in speed limits is also contradicted by numerous studies on the effects of both raising and lowering speed limits. Following the enactment of the 55 mph maximum speed limit in 1974, rural interstate average speeds declined from 65 mph in 1973 to 57.6 mph in 1974, increasing only slightly to 59.1 mph by 1983; the accompanying reduction in the highway death rate was far larger than could be expected due to reduced travel or other factors (National Research Council, 1984). Raising speed limits has been found to increase both speeds and crashes. For example, soon after New Mexico raised the speed limit on its rural interstates in April 1987, speeds began a long-term upward trend in that state. In 1988, speeds on Virginia's rural interstates increased immediately after the speed limit was raised to 65 mph and continued a gradual rise, while speeds on similar roads in Maryland, which retained a 55 mph limit, did not change

(Freedman and Esterlitz, 1990). In addition, speeds have been shown to continue to increase to a greater extent in states adopting a 65 mph speed limit than in states that kept the speed limit at 55 mph (Freedman and Williams, 1991). National Highway Traffic Safety Administration (NHTSA) research has substantiated this result in all of the many other states they examined, and research by NHTSA, the Insurance Institute for Highway Safety, and others has shown that the increased speeds result in increased highway deaths (NHTSA, 1990; Baum, Wells, and Lund, 1991; Godwin, 1990; Wagenaar, Streff, and Schultz, 1990; McKnight and Klein, 1990).

Further, Tignor and Warren ignored the FHWA sponsored research by Harkey et al. that showed speeds do increase above the speed limit even when the speed limit is based on engineering studies using the 85th percentile based travel speed. Harkey et al. report that from 60.1 to 77.5 percent of free-flow vehicles exceeded the 85th percentile based speed limits. By definition only 15 percent should have exceeded the speed limit if, as Tignor and Warren claim, the 85th percentile speed did not change.

Speeds Off the 65 mph Rural Interstates

Tignor and Warren's claim that raising the speed limit to 65 mph on rural interstates has not led to increased speeds off the freeways is not substantiated by the contractors' reports. The MPA report gives no freeway data, and Tignor and Warren report data from only one rural interstate, one intersecting non-interstate, and two unrelated roads. Data from a sample of one roadway pair is not adequate to support such a claim. Research by others on speed adaptation has demonstrated that speeds on arterial roads that intersect freeways are influenced upward by the drivers' adaptation to higher speeds on the freeways. Schmidt and Tiffin (1969) found that initial exposure to high speed driving caused drivers to upwardly distort their speeds when asked to change to a lower speed. In an observational study, Mathews (1978) found that vehicles on a four-lane divided highway that intersected a freeway and that were exposed to 60 mph freeway speeds exceeded by about 4 mph the velocity of vehicles on the same four-lane arterial but not previously exposed to the freeway speeds. Casey and Lund (1988) found that speeds of vehicles adapted to driving on three rural freeways with a speed limit of 55 mph were higher than the speeds of vehicles not adapted to freeway driving on intersecting arterials at measurement points that were 1.0 to 2.5 miles from the freeway-arterial intersection.

Crash Involvement Rates

Tignor and Warren contend that crash involvement rates in urban areas were lowest for traffic in the 30th to 95th percentile speed range and highest for both the slowest and fastest 5 percent of traffic on urban streets. This conclusion is based on the Harkey et al. study and is purported to be consistent with work by Solomon (1964) and Cirillo (1968). However, these earlier studies suffer from the same limitations as the current reports -- they rely on pre-crash speeds reported by the involved drivers. It is known that such self-reported data are unreliable (White and Nelson, 1990). Thus the analysis overestimates the involvement of slower drivers and underestimates the involvement of faster drivers.

The statistical and methodological foundations on which the Harkey et al. study were based are extremely weak, and Tignor and Warren incorrectly describe the methodology that was used. For example, they report the crash rate versus speed relationship for *urban* roads, yet Harkey et al. stated that the data could not be used to distinguish between urban and rural crash rates because of sampling inconsistencies that yielded urban sites that appeared to be more rural and vice versa. Tignor and Warren state that the Harkey et al. sites were randomly selected from FHWA's Highway Performance Monitoring System (HPMS), a nationwide system of highway segments for which traffic speed, volume, and other information are routinely gathered. The selection process was supposed to follow a stratified clustered sampling plan to represent urban, small-urban, and built-up rural areas on low and moderate speed roads in four states, but the site selection plan was completely compromised.

Rather than choosing a random sample of states that represented the diversity of U.S. travel characteristics, a convenience sample of just four states (Delaware, North Carolina, Colorado, and Arizona) was selected based on their ability to supply speed and crash data. These states did not in any way constitute a representative sample. Only two states (North Carolina and Colorado) ultimately provided crash data that included pre-crash speed estimates although Tignor and Warren say that four states' data were used. The random selection of sites was again compromised because Harkey et al. discarded short roadway segments and replaced them with longer HPMS segments. Harkey et al. also lengthened the HPMS segments that were chosen to capture more crash data but failed to report on how the potentially greater traffic volume in these lengthened segments was handled. Traffic volume was used to compute vehicle miles of travel (VMT) in each segment. VMT was, in turn, used as the exposure measure to calculate crash rates, thus errors in VMT would affect crash rates.

In addition, Tignor and Warren failed to report that Harkey et al. excluded both rear-end and angle crashes from their analysis of multiple vehicle crashes. Harkey et al. state, without justification,

that such crashes could not have occurred in free-flow traffic. The inclusion of rear-end and angle crashes could greatly alter the findings. The authors also failed to report that 55 mph, weekend, alcohol-related, and intersection crashes were excluded. Further, they show than Harkey et al. reported crash rates indicating that the highest relative involvement rate for single-vehicle crashes was for those vehicles traveling at less than the 5th percentile travel speed. Obviously, high crash rates for pre-crash speeds of less than the 5th percentile are not realistic and indicate pre-crash speeds were significantly underestimated in the Harkey et al. crash data. This also suggests that some of the involved vehicles were not free-flowing but may have been slowing or stopping. Finally, Harkey et al. reported that crash rates for 25 mph speed zones were consistently much higher than for any other zone. However, this was primarily due to one 25 mph multi-lane site that had 291 crashes in a segment only 0.7 miles long. It is doubtful that the 25 mph speed limit at this site had anything to do with its crash frequency, but it is much more likely that other site characteristics such as road geometry and land use were associated with these crashes. It is absurd to believe that if the speed limit were higher at this site crashes would be reduced.

Setting Speed Limits

Tignor and Warren claim that speed limits should be set in the 70th to 90th percentile range, or roughly 5 to 10 mph above the average speed, to correctly reflect the maximum safe speed. Their claim is based on the notion that current speed limits coincide with the 30th percentile speed, as reflected in the Harkey et al. travel speed data, and that this is close to the lower bound of safe travel speed. This conclusion, which appears to be based on the Harkey et al. data showing that crash risk is lowest for vehicles traveling at speeds between the 30th and 90th percentile, depends upon inaccurately reported pre-crash speeds, arbitrarily limited crash types, and a compromised sampling plan. Tignor and Warren also claim that enforcement should allow an additional 5 mph tolerance above the 70-90th percentile based speed limit so that drivers who are clearly at risk would be targeted. However, numerous studies of speeds on rural interstate highways have shown that mean and 85th percentile speeds increased when speed limits were raised to 65 mph, and they have continued to increase. The 85th percentile is not a stationary speed, but rather one that increases when speed limits are raised. Thus, if speed limits are raised to meet the current 85th percentile speed, a new, higher 85th percentile will soon appear. It is not appropriate to repeatedly raise speed limits. Finally, when speed limits are based on an 85th or 90th percentile there is absolutely no room for an additional 5 mph tolerance before enforcement action should be taken.

Part of Harkey et al.'s research task was to determine a relationship between speed and other roadway characteristics using regression analyses. Tignor and Warren failed to report relevant details of the research involving the various regression analyses. They report partial results of Harkey et al.'s regression modeling stating that "the factors that had the most influence on speeds were number of access points and commercial development." Harkey et al. performed regression analyses in an attempt to establish the relationship between certain environmental factors and speed to develop a model for specifying speed limits. However, these attempts were replete with model specification and other methodological errors. For example, posted speed limit was not included as a variable in the model although by itself it may have accounted for most of the variance. Among Harkey et al.'s preliminary findings, which were not reported by Tignor, presumably because they make no sense, were that as roadways become wider, lower speed limits should be specified and that severe curvature sites require specifying higher speed limits. In some cases, the sample size was close to the number of variables in the model, negating the model's usefulness.

The contractor warned Tignor against reporting the modeling results, stating, "... examination of variables in combination was virtually meaningless because of the small sample. This fact combined with the very large between site variability resulted in regression models ... that lack validity and have little practical application." They further warn, "while commercial development and driveway access appeared to best explain the variance in travel speeds, the relatively small number of sites precluded definitive conclusions." In spite of these warnings, Tignor and Warren reported the results.

Unsubstantiated and Erroneous Claims

In summary, the paper by Tignor and Warren presents a plethora of unsubstantiated and erroneous claims that are based on poorly designed and improperly executed research. The contractors even disclaim their methodology and conclusions, with Harkey et al. writing:

> "... the findings and results of this study to date are inadequate to support definitive criteria and procedures for establishing speed limits..." (p.38)
>
> "The potential for an inadequate data base was clearly recognized at the beginning of the study." (p.38)
>
> "Regression models for mean and 85th percentile speeds lack validity and have little practical application." (p.37)

> "The only piece missing [in this study] is a database sufficient in scope and size to address the basic research questions with statistically credible confidence." (p.39)
>
> MPA writes "... the data, figures, and presentation ... are for illustrative purposes only and do not reflect the contents of the draft final report." (preface)

Tignor and Warren's refusal to provide details of the research prevents proper review by peers in the scientific community. The claims made by Tignor and Warren are contrary to the findings of FHWA's own research and other research on speeds and the relationship between speeds and crashes. Their paper could promote public policy decisions and traffic engineering actions that are likely to result in more crashes and crash deaths.

It is irresponsible to present such a paper, especially in a forum in which the authors' status as FHWA officials lends undeserved credibility to the conclusions, and where the claims may be acted upon by highway administrators who are pressured by those who wish to see speed limits raised and enforcement decreased. The conclusions of the paper should be disavowed by the FHWA.

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