Lessons Learned from 45+ Years of Traffic Engineering Research

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Abstract

In the late 1960s, highway and traffic engineering community concerns were directed at efforts to improve street and roadway capacity and safety. In the years since then, "hot" topics changed with legislative initiatives and funding opportunities. Traffic research has also evolved as the tools for data collection have improved and the techniques for data analysis have advanced dramatically. This paper will document the experience of one university faculty researcher from the very real, practical problems of the 1960s to the more theoretical problems facing today's professionals. Specific topics will include accommodating large commercial vehicles, alcohol-involved crashes, construction zone crashes, elderly drivers, geometric design criteria, overturning crashes, pedestrian safety, rail-highway grade crossing safety, roadside hazards, traffic control on low-volume roads, traffic flow rates, vehicle speeds and limits, and wide edgelines.

Background

The author's career in transportation began informally in June 1961 when I worked my first of four summers for the Oregon Highway Department. It continued more formally in the Fall 1966 when I began my studies for an MS degree in engineering at the University of Washington (UW); that was also when I joined ITE as a Student Member. Following my 1969 graduation from UW with a PhD in Civil Engineering, I became an academic, where the guiding principle for success was, and continues to be, publish or perish. And the primary accepted mechanism for publishing articles in technical journals is to conduct research, lots of it done by graduate students. Reflecting back on my years in academia, I have learned a number of lessons that might be of interest to others in the profession. I hope to share some of those through this paper and presentation.

The Beginning

Like many professionals in transportation engineering, my introduction to research came in graduate school; I studied two-way left-turn lanes (twltls) for my MS thesis. In 1967, this treatment was a *Western thing* and not well accepted elsewhere; as the Feds said at the time, *you're going to have vehicles traveling in both directions sharing a center lane??* The research involved assessing the safety of twltls and determining how well this relatively new device was accepted by motorists and adjacent property owners/businesses. The research found that there were safety benefits on streets and highways with speed limits ranging from 30 to 55 mph. But the lesson learned is that those receiving a graduate engineering education don't have any skill in developing a survey instrument.

I was exceptionally fortunate in my PhD dissertation research to study the road user benefits *after* the I-5 freeway had been completed through Seattle, replacing US 99, the former primary route. The research involved assessing the travel time, fuel consumption, and safety benefits of I-5. The field work utilized five test vehicles: a compact sedan, a standard four-door sedan, a pickup truck, a single-unit truck with dual rear tires and a diesel tractor-trailer unit. The test routes in the 1962 (*Before*) study were Eastlake north of the CBD, Aurora - East Marginal Way (old US 99), 2nd and 4th Avenues through the CBD, and 23rd Avenue. These routes, plus I-5, were used in the 1968 (*After*) study. Checkpoints were established at intervals along each route. During the numerous test vehicle runs, travel time and delay were measured with separate analog stopwatches. Fuel consumption in the passenger vehicles was measured with a model FM 200 fuel meter while burette boards were used in the trucks. The study found that user benefits due to travel time savings greatly exceeded the fuel saving benefits. Due to higher unit cost of time and greater freeway time savings for commercial vehicles, they enjoy a disproportionate share of these benefits. Freeway accident rates are much lower than those on arterials, although property damage costs are higher on the freeway. The primary lessons learned from this study are that it's easy to misread analog stopwatches, travel time studies (at that time) were labor intensive, and riding as a passenger while operating and monitoring a burette fuel board is inherently dangerous.

The next study in 1972-73 involved field data collection and analysis to evaluate the effectiveness and desirability of Maryland's differential truck speed limit. At the time, the highest truck speed limit on Interstate, US and state highways in Maryland was 60 mph, while the passenger vehicle speed limit varied by roadway to 60, 65, or 70 mph. Radar spot speed studies were conducted at 55 sections, some with two-directional studies, resulting in a total of 84 directional studies. Speed data were classified by vehicle type; crash data were collected for each study section and classified by vehicle type. Truck compliance with the speed limits averaged 73 percent when the limit was the same (60/60) for both trucks and cars, but only 51 percent when there was a differential 60/70 limit; the comparable figures for cars at these sites were 40 and 62 percent, respectively. The study was unable to find a safety benefit associated with Maryland's differential truck speed limit and therefore recommended that the state temporarily raise the truck speed limit on two well-designed sections of rural Interstate to 70 mph. This recommendation was not implemented because months later, the Federal Government imposed a nationwide 55 mph speed limit. The primary lesson learned from this study was that average measured speeds doesn't provide any information about the speed of crash-involved vehicles. A secondary lesson learned was that motorist compliance with the 55 mph limit on its first day was 100 percent.

A 1974 study employed field and photolog studies to examine the sites of fixed object collisions on 168 miles of state and US highways in Maryland. The study routes were chosen due to their high incidence of fixed object crashes. The principle problems identified in the study were narrow right-of-ways (often 30 to 40 feet), objects on the outside of horizontal curves, proximate lateral locations of objects, outdated designs (notably guardrail and drainage facilities), and poor treatment of bridge terminals and sideslopes. The primary lesson learned from this study was that roadside safety improvements recommended by the AASHO "Yellow Book" and incorporated on new freeways were rarely found on non-Interstate highways.

Another 1974 study sought to evaluate alternative signing for real-time traffic diversion. At the time, there were four major routes (I-95, US 1, US 29, and the Baltimore-Washington Parkway) between the Baltimore, MD and Washington DC. The Maryland State Highway Administration was interested in the type of message that would be most likely to encourage motorists to leave a congested route and take an alternate route. The field portion of the study involved the distribution of a survey instrument to motorists on I-95 near its intersection with I-495. One questionnaire included five signs that with the wording FREEWAY CONDITION, a color coded message of Normal or Congested, and then five alternative reasons: Accident Ahead, Delay Time x minutes, Next y miles, SPEED zz MPH, and Use Alternate Route ABC Avenue. The survey also solicited demographic information, including years of driving experience and annual miles driven. The most popular sign was the one showing the length of congestion, followed by the suggestion of an alternate route. The variable speed limit sign was judged the worst. The results varied somewhat with driving experience. The primary lesson learned from this study was that it is not a good idea to distribute a questionnaire on a freeway.

A subsequent study sponsored by the Insurance Institute for Highway Safety (IIHS) conducted field studies at the sites of all 151 fatal overturning crashes in New Mexico for the year ending July 31, 1979. At the time, overturning crashes accounted for 21 percent of nationwide highway fatalities, but in Montana, New Mexico, and Wyoming they accounted for over 40 percent. Studies were also conducted at *comparison sites* located 1.00 mile upstream from the crash site. The sites were located in the field through data provided on the investigating officers' reports; sites were typically visited by a three-member crew four to eight weeks after the crashes. Measurements were made of curvature, superelevation and gradient; roadside spot objects were enumerated; elongated objects, road and shoulder widths, roadside slopes and pavement friction were measured. The primary lessons learned were that crash sites were characterized by sharper curvature and curves to the left, steeper downgrades and greater embankment depths than the nearby *comparison sites*. Secondary lessons were that statewide studies of this type are expensive and labor-intensive and that field crews need special training to work in the roadway.

A simplistic but expensive solution to the problems identified in the previous study would be to suggest that states reconstruct sharp horizontal curves and steep downgrades. Recognizing that highway agencies have limited budgets, the IIHS funded subsequent studies to identify low-cost but effective treatments used by the states to ameliorate run-off-the-road crashes, and then to test some of these treatments in the field. The study found that a majority of survey respondents used chevrons, standard and specialized signing, and raised pavement markings, although they only had faith in the effectiveness of the chevrons. Speed reduction was thought to be the best surrogate to assess the effectiveness of run-off-the-road countermeasures. A primary lesson learned from this study is that some DOTs will not respond to survey instruments. A followup field study found some unexpected consequences of installing chevrons on horizontal curves. For example, nighttime speeds on horizontal curves increased after the installation of chevrons, presumably because of higher driver confidence in the roadway alignment.

The next study examined New Mexico traffic crashes involving impact with guardrail, selected fixed objects or overturning on the roadside. The objective of the study was to determine if the New Mexico State Highway Department (NMSHD) should prioritize the placement of guardrail at sites where it was warranted, or improve or replace existing guardrail that did not meet modern standards. The field data collection procedures were similar to those used in the study of overturning crash sites. The primary lesson learned in this study was that average crash severity was significantly higher at fixed object and overturning crash sites that lacked guardrail, suggesting that new guardrail installation should be a top priority.

In 1982, New Mexico had 845 public rail-highway grade crossings. During that year, field studies were conducted at 57 of these crossings where one or more accidents had occurred during the previous 30-month period. In general, the sites had good geometric and operational conditions. Of the sites studied, 35 percent had active traffic control devices installed after the accident. The study also documented numerous errors in the Federal Railroad Administration (FRA) grade crossing inventory. The primary lesson learned in this study was that the NMSHTD had achieved an acceptable level of safety at rail-highway grade crossings, thus allowing the state to spend federal monies earmarked for rail-highway grade crossing improvements on other approved safety projects. A secondary lesson learned was that no mid-level railroad engineers have first or middle names, just initials.

In a 1984, a small study was conducted using New Mexico's computerized accident record system and data from the Office of Medical Investigator to assess engineering factors in Alcohol-involved traffic accidents. At the time of the study, national statistics indicated that intoxicated drivers and pedestrians accounted for approximately 50% of all fatal highway accidents. For the five-year period 1979-83, New Mexico had approximately 245,000 reported accidents; of these, 2528 (1.03%) were classified as fatal, resulting in 2915 fatalities. These accidents involved a total of 4105 drivers and pedestrians, of which 21.2% had been drinking (HBD) drunk, 11.3% HBD impaired, 9.6% HBD sobriety unknown, and 57.9% not drinking/unknown. Contingency analyses were used in an effort to determine if there was a difference in highway engineering factors based on driver and pedestrian severity. For pedestrian accidents, the only factors that were over represented were darkness and rural areas. For single vehicle, non-pedestrian accidents, darkness and instate motorists were over represented. Horizontal curves were more common in intoxicated driver accidents. The primary lesson from this study is that virtually all engineering treatments that help sober drivers will help intoxicated drivers. A secondary lesson from was that police officers did a poor job of correctly identifying road user sobriety.

The popular news media reported in 1983 that 8-inch wide edgelines caused drivers to assume a more central position in their lane and reduced both centerline and edgeline encroachments, with a supposed benefit being a reduction in run-off-the-road accidents. In an effort to determine if this was a real benefit, the NMSHD agreed to test some wide edgelines. The critical rate technique was used to identify sections of rural road with high rates of single vehicle run-off-the-road accidents on the state's Federal-Aid Primary (FAP) and Secondary (FAS) systems. A computer analysis identified 61 hazardous sections on the FAP and 89 on the FAS. Because these were too many to paint with an unproven treatment, 19 sections (10 on the FAP and 9 on the FAS) were selected and painted with wide edgelines in June 1984; the remaining sections were retained as *comparison* sites. The study collected run-off-the-road crashes for an 18-month after period. The combined accident rate for the sections treated with an 8-inch edgeline decreased 10 percent, from 1.59/mvm to 1.43/mvm. However, the accident rate at the *comparison* sites dropped from 1.59/mvm to 1.34/mvm, a decrease of 16%. The primary lesson learned from this study is not to believe the claims of product manufacturers, in this case a supplier of glass beads.

Another study attempted to examine crashes in construction work zones that began sometime between January 1983 and December 1985. The NMSHD identified 355 candidate projects; this set was subsequently shortened by eliminating minor projects (e.g., costing less than $100,000, stockpiling, traffic signal installation, etc.). The modified list included 168 major construction projects on rural state highways. A search of the 1983-85 computerized accident records found 261 accidents that were coded to indicate that the site was a construction zone; surprisingly only 18 occurred at the sites and times of the 160 projects in the data set. Because the aforementioned elegant method wasn't working, the researchers used a brute force method - for each construction project, all crashes between the beginning and ending mileposts and between the start and completion dates of the construction, but not during the winter or other suspensions were identified. In addition, for projects with durations less than one year, the computer identified the accidents on these sections during the identical period of the prior year. The 114 latter sites proved to be of greatest interest. They had 499 accidents in the *before* period and 631 accidents *during* construction. Overall, there was a 26% increase in accidents during construction: 33% on Interstate highways, 25% on the FAS and 17% on the FAP. Contingency table analysis concluded that construction site crashes were over represented in clear weather and on dry pavement. To a lesser extent, the following factors were over represented *during* construction: “following to close,” “improper lane change,” multiple-vehicle crashes, rear end impacts, and large trucks.

On April 2, 1987, only hours after the US Congress overrode President Reagan’s veto of the Surface Transportation Act, New Mexico’s Governor and Chief Highway Administrator installed a 65 mph speed limit sign on I-25 south of Santa Fe. That night, the event was a lead story on the CBS Evening News. Within days, this paper’s author was contacted by the IIHS, and two weeks later, spot speed studies of free-flowing vehicles were initiated at both rural and urban sites on I-25 and I-40 near Albuquerque. Directional sample sizes at all sites were 512 vehicles, which permitted meaningful statistical analyses. Field studies continued at these sites six times a year through 1990, then three times a year until April 1995. Studies were performed again in 1996-97, when New Mexico’s rural speed limit was raised to 75 mph outside of major cities. During the period that the rural Interstate speed limit was 65 mph, the percent of vehicles exceeding 70 mph rose from 7% in April 1987 to 32% in April 1995. A primary lesson learned in this study was that speeds on rural Interstate highways creep up over time, and jump when the posted speed limit changes. A secondary lesson learned is that speeds measured at automated speed data collection sites understate the true speed of free-flowing vehicles.

A 1988-89 study sought to establish a relationship between hourly traffic volume and hourly accident rates on New Mexico highways. The databases for this project consisted of traffic volumes at 44 rural permanent count stations and accidents for the three year period 1985-87 for the five miles on either side of the count stations. Peak travel occurs in the hours 4-5 and 5-6 pm, both with 7.4% of the ADT. There is no discernable morning peak; rather, hourly travel increases from 7 am through the late afternoon. The hours beginning at 2, 3, and 4 am each accounted for about 0.9% of the daily travel. The ten-mile section length is long enough to ensure a meaningful number of accidents while maintaining homogeneous geometric design. During the study period, the sites had 2006 accidents. Another essential data set necessary for this project is one that includes those factors needed to calculated highway capacity. Roadway sections at the study sites included two-lane roads, a couple of four-lane divided roads, and four-lane freeways; all have 12-foot lanes and clear roadsides. A major factor affecting capacity is the combination of terrain and traffic composition; these parameters were available at most sites. The peak hour for accidents is 6 pm (6.3%), followed by 7 am and 5 pm (5.6% each). The least share of accidents occur at 4 am (2.7%). The overall accident rate at the study sites was 0.7 acc/mvm, but the peak was 3.2/mvm at 2 am. For all the hours 11 pm to 5 am, accident rates were more than twice the daily average. The primary lesson learned in this study is that a relationship could not be established between accident rate and v/c ratio. A secondary lesson is that hourly accident rates decrease dramatically as hourly traffic volumes increase.

A 1990 project sought to establish justifiable guidelines for the installation of intersection beacons and hazard identification beacons. Following the standard review of the technical literature, a survey of traffic engineers in the states west of the Mississippi river was conducted to identify additional guidance not available in the technical literature. Most states relied on the minimal guidance provided by the Manual on Uniform Traffic Control Devices, but three states (California, Minnesota and Missouri) provide more detailed guidance in their traffic manuals. These states recommended considering speed, sight distance, crash experience and roadway parameters. Nebraska and Washington provided reports on before-and-after studies at intersection beacon installation sites; they showed accident reductions in the range 20-30%, specifically right-angle and nighttime accidents. The field portion of this study involved visits to the sites of all beacon installations on New Mexico's rural state highways. The researchers worked with the six district offices and the NMSHD central office in Santa Fe to identify beacon sites; however, the database was incomplete and numerous additional *unknown* beacons were discovered during the field study. The installation dates for most older beacons were unknown, making before-and-after studies impossible for all but the most recent installations. Although beacons were used throughout the state, they were concentrated in the southeast quadrant, adjacent to Texas, where they are ubiquitous. A primary lesson learned from this study is that New Mexico needs to maintain better record systems to be able to do its job. A secondary lesson from this study is that the actual accident reduction from the installation of a beacon is somewhere between small and nonexistent.

In hindsight, one of the most interesting research projects over the past 45 years didn't require any of the extensive field work of some of the previous projects - rather, it was exclusively a computer-based study. The 1990 Labor Day Edition of *USA Today* began a three-part series on states with high highway fatality rates; New Mexico, and in particular its Interstate highways, didn't fare well in these articles. Using 1988-89 FARS data and FHWA travel data, *USA Today* concluded: "You are more likely to die on the highways of New Mexico than in any other state in the USA. And if you do die in an accident, chances are someone was drinking." Not what the NMSHD or the local Chambers of Commerce would want to hear. The story detailed how, of 1345 counties with Interstate highways, New Mexico's San Miguel had the nation's second highest Interstate fatality rate, and seven other New Mexico counties made the list of the top 100. An unfunded study was undertaken with the purpose of checking the validity of *USA Today's* findings. New Mexico's three Interstate highways (I-10, I-25, and I-40) traverse 21 of the state's 33 counties. Using the state's computerized accident record system and Interstate segment daily traffic volumes, rates were calculated for each county; among the 8 in *USA Today's* story, four were within 8% of the article's figures, while four were substantially higher or lower. Furthermore, the results of USA Today's analysis provided little help with identifying problem counties. The annual Interstate highway fatalities in the 8 NM counties decreased from 60 to 45 in the following three years, while in the 13 remaining counties, annual fatalities increased from 43 to 53. The primary lesson learned from this study is to be wary of technical calculations done by persons not familiar with the data.

The Las Vegas ITE Technical Committee has specified a limit of six pages for papers. Consequently, it is not possible to cite all the projects I've worked on or the lessons learned. Some of these include studies of speeds on horizontal curves, crash characteristics of elderly motorists, speed limits on low-volume rural roads, accommodating pedestrians in work zones, techniques for controlling speeds in work zones, traffic flow-rates in single constrained lanes, early AASHO design standards, and expected costs of accidents by impact type. Likewise, there wasn't room to cite references to the studies included in this paper. For the interested reader, these references are easily identified on pages 3-4 at the author's web site http://www.unm.edu/~jerome/resume.htm .