# *TRANSPORTATION RESEARCH DIGEST*

*JUNE 2009*

ARIZONA TRANSPORTATION INSTITUTE

***e-mail*** ***jsemmens@cox.net***

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# TRANSPORTATION RESEARCH DIGEST
## ARIZONA TRANSPORTATION INSTITUTE

***e-mail*** jsemmens@cox.net

*JUNE 2009*

TO: TRANSPORTATION PROFESSIONALS, MANAGERS, & POLICY MAKERS

FROM: ARIZONA TRANSPORTATION INSTITUTE

The volume of information on transportation issues, policies, technologies, and related topics is huge. Not even the most well-read professional can keep up with everything that might be useful to know. The *Transportation Research Digest* series is designed to expedite the transmission of information by condensing and summarizing significant documents. Busy professionals or managers may quickly obtain the gist of new developments and determine whether they need to see the full document.

The *Transportation Research Digest* is not meant to present definitive resolutions of scientific or policy controversies, but contributions to the pursuit of knowledge and the debate of issues. The intent is to be comprehensive rather than conclusive on the multitude of issues and topics of concern to those working in the field of transportation. Readers are encouraged to obtain the original document summarized in the *Transportation Research Digest* and subject the content to their own judgment.

Transportation professionals who would like to recommend documents to be summarized or submit summaries to be considered for inclusion in this publication are invited to do so. To recommend a document please send a copy (or information indicating how a copy can be obtained) of the research report to be summarized. To be considered, the report must meet the following requirements: (1) it is transportation related, (2) it is no more than two years old, (3) there is enough information in the report to warrant a two page summary. To write a summary, insure that the document being summarized meets the above requirements. The summary should be submitted in an electronic format. This summary should be in the 500 to 800 word range and may include tables and/or simple graphics—all of which must fit within the *Transportation Research Digest's* two-page format. Submissions are subject to editing for clarity and length. We do not guarantee that all submissions will be published.

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*Transportation Research Digests* from December 1995 to November 2003 are available on request.

A "Topic" code in the Table of Contents will help readers more quickly identify items of interest. The topic codes are explained in the table below.

| Code | Topic | Code | Topic |
|---|---|---|---|
| ADM | Administration | PLAN | Planning |
| AIRP | Airports | PRIV | Privatization |
| AVIA | Aviation | RAIL | Railroads |
| BIKE | Bicycles | RDSD | Roadside |
| CON | Construction | ROW | Right-of-Way |
| ECON | Economics | SAFE | Safety |
| ENV | Environment | STR | Structures |
| FIN | Finance | TECH | Technology |
| INOV | Innovations | TOLL | Toll Roads |
| MAIN | Maintenance | TRAN | Transit |
| MISC | Miscellaneous | TRF | Traffic |
| MVD | Motor Vehicle Dept | TRK | Trucking |
| PAVE | Pavement | VEH | Vehicles |

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Thank you.

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***Correcting the Pervasive Inequities in Gas Tax Spending Should Be a Reauthorization Priority*** by Ronald Utt (Heritage Foundation, 214 Massachusetts Ave NE, Washington DC 20002-4999; ph 202.546.4400; http://www.heritage.org/Research/SmartGrowth/bg2269.cfm) (May 2009)

**Highlights**

- Although less than 2% of all surface passengers use some form of transit, transit receives about 20% of the federal transportation spending.
- The regional distribution of transit spending is far more inequitable than the distribution of highway spending.
- We could achieve interstate equity without a tax increase by allowing each state to keep the 18.3-cents-per-gallon federal fuel tax revenues collected within its borders.

The federal highway program, trust fund, and reauthorization process actually fund two different transportation programs: highways and transit. Transit includes buses, commuter rail, trolley cars, and metro systems. Although less than 2 percent of all surface passengers and less than 5 percent of commuters use some form of transit, transit receives about 20 percent of the federal transportation spending authorized by the highway bill. In 2007, $10.5 billion was spent on 15 separate transit programs, while $41.5 billion was spent on all highway programs, although some of this money was diverted to transit, hiking trails, and bicycle paths.

Most federal and state transit spending is paid by motorists through federal and state fuel taxes. The federal fuel tax is currently 18.3 cents per gallon, 2.87 cents of which goes into the "transit account" within the highway trust fund. Another approximately $2 billion in annual federal transit spending is funded by general revenues. In turn, these dedicated revenues are allocated to the states according to a formula (and earmarks).

The regional distribution of transit spending is far more inequitable than the distribution of highway spending. In 2007, 36 states were donors to the transit program, and their return shares were substantially lower than what donor states typically experience with the highway program. While the worst return ratio under the highway program was just 83.8 percent, return ratios of less than 40 percent are common with the transit program, and South Carolina and Nebraska fared the worst with returns below 20 percent.

Most transit funding winners were also highway winners, notably Alaska, Connecticut, the District of Columbia, Massachusetts, Rhode Island, Pennsylvania, and New York. Indeed, New York received 23.1 percent of all federal transit spending in 2007. As with the highway program, the transit program transfers billions of dollars of income from motorists in the South and the Midwest to a small number of transit riders concentrated in the wealthier Northeast and the Mid-Atlantic states and a few major urban areas in Illinois and on the West Coast.

If Congress were willing to abandon the current system's underlying assumption that Washington knows best, it could achieve interstate equity without another taxpayer bailout or tax increase by allowing each state to keep the 18.3-cents-per-gallon federal fuel tax revenues collected within its borders to spend on the transportation priorities of its own choosing. Legislation to enact such a plan was introduced in the Senate during the 110th Congress. The bill would have phased out the federal highway program incrementally over five years while transferring taxing and spending responsibilities to each state.

Despite the simplicity of the solution, many Members of Congress oppose it because it would require them to surrender the spending power to provide substantial rewards to privileged and influential constituencies through earmarks and new programs that divert trust fund money to non-transportation purposes. Nonetheless, the donor states are sufficiently numerous to force a meaningful resolution of the issue.

Given that Congress may be reluctant to abandon a federal program that provides Members with so many earmarking opportunities, an alternative would be to keep the program in its current form but allow states to opt out of it in return for agreeing to meet certain performance standards that would include maintaining and enhancing their segments of the interstate highway system. Beyond that, opt-out states would be free to pursue transportation objectives in the best interest of their citizens, while states that chose to stay in the program would continue to benefit from guidance provided by USDOT and Congress.

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***e-mail*** jsemmens@cox.net

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***Identifying and Quantifying Rates of State Motor Fuel Tax Evasion,*** *NCHRP Report 623* by Mark Weimar, *et al*. (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_623.pdf) (2008)

**Highlights**
- This report covers the process of developing a methodological framework to examine and reliably quantify state motor fuel tax evasion rates.
- There are three approaches outlined in to estimate error, omission, and evasion (EOE): (1) audit and inspection, (2) tracking, and (3) statistical analyses of sales.

This report covers the process of developing a methodological framework to examine and reliably quantify state motor fuel tax evasion rates. Chapter 1 critically assesses physical, administrative, and enforcement characteristics of state practices and identifies how these characteristics have traditionally correlated with certain types of evasion. Chapter 2 compiles and summarizes the results of interviews completed with state motor fuel tax administrators and other relevant organizations including oil industry representatives and federal fuel tax authorities and explores key issues identified during the interview process including: evasion techniques, fuel tracking, point of taxation, state fuel tax collection and enforcement procedures, coordination and uniformity among states, and issues related to motor carriers. Chapter 3 describes various models and approaches that have been used to quantify fuel tax evasion in the past, and discusses the strengths and weaknesses of each approach. Chapter 4 provides a review of the data available for these types of analyses. Chapter 5 presents a detailed methodology for estimating state motor fuel tax evasion using readily available data and documents the data required to perform each estimation procedure. Chapter 6 presents conclusions and recommended methods for disseminating the outcome of the project.

This report highlights state-by-state variation in the data quality and quantity available, considering some of the following factors:
- Varied motor fuel tracking systems,
- Differing data on aspects of audits and inspections (i.e., some states have considerable data and some do not),
- Differing characteristics that lead to evasion (i.e., some states have Native American reservations and/or on-road diesel programs while others do not),
- Level of fuel tax compliance and enforcement in a state, and
- Varied requirements regarding access to existing (but restricted) data.

There are three approaches outlined in Chapter 5 to estimate error, omission, and evasion (EOE): audit and inspection, tracking, and statistical analyses of sales approaches. Various approaches could be used to examine audit and inspections data, including statistical sampling, and regression techniques such as ordinary least squares (OLS), Tobit, and logit analysis.

The second approach, tracking, uses tracking systems to follow fuel from terminals to taxpayer and calculate the difference of fuel supplied to taxes paid.

The third and final approach is recommended for estimating evasion losses due to the presence of Native American retail outlets. The approach recommended compares the amount of gallons in question and calculates a percent of the total fuel consumption for that state that is associated with the nonpayment of taxes. If more variables and associated data are available, more sophisticated techniques can be used to calculate the amount of taxes forgone. Chapter 2 identifies nine evasion methods and provides recommended approaches for estimating EOE associated with each evasion method. Chapter 5 also presents a decision tree to assist states in conducting analysis of EOE and provides detailed data collection recommendations.

In addition, Chapter 5 includes a list of data needed to undertake estimation of EOE. Chapter 6 presents study conclusions and concepts for disseminating the outcome of this research project. Chapter 6 proposes a two-step process to disseminating the outcomes of the project. The first step would include developing a website that included the report.

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***e-mail*** jsemmens@cox.net

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***Sustainable Mobility in American Cities*** by Shirley Ybarra and Samuel Staley (Reason Foundation, 3415 S. Sepulveda Blvd. Suite 400 Los Angeles, CA 90034; ph (310) 391-2245; http://www.reason.org/news/show/1003139.html) (Sep 8, 2008)

**Highlights**
- Strategies that focus on reducing automobile use are not sustainable in an economic or an environmental sense.
- The automobile dominates because it provides flexibility and adaptability.
- Transit cannot provide the back bone of a transportation network because our economic, social, and cultural needs are too diverse and dynamic.
- Road pricing will be the key policy reform needed to meet transportation needs.

Too often, policy recommendations adopting a sustainability label implicitly accept a static policy making environment and focus on redistributing existing resources rather than thinking about how the stock of resources might be improved. Increased mobility leads to greater economic productivity, allowing us to use existing resources more effectively and efficiently. Moreover, technology and innovation can easily make what now seems like a very scarce and limited resource obsolete within a generation.

From an economic perspective, efforts to push travelers and commuters into public transit inevitably have one of two effects. First, it lengthens commute and travel times, reducing productivity and compromising the ability of our cities compete to globally. Second, strategies that explicitly attempt to limit automobile based travel force people (and businesses) into higher densities. While higher densities often include a much higher cost of living and lower mobility.

Importantly, fixed-route alternatives are less likely to meet the mobility needs of a globally-competitive, 21st century city. Notably, global cities such as London and Paris still rely on the automobile for most travel in their urban areas. The automobile dominates because it provides flexibility and adaptability, two crucial features of a dynamic, competitive services based economy. A fixed-route transit-centric approach, as London is finding out, will increase travel times and ultimately degrade mobility for every one. Lowering mobility degrades both equity, by limiting access to jobs and products for workers and consumers, and economy by reducing productivity and efficiency.

If automobile-based travel is the core of a contemporary, flexible urban transportation network, we must thoroughly rethink the way this system is managed. Congestion is rising at dramatic rates. In the U.S., 12 metropolitan areas will have levels of congestion equivalent to, or exceeding, current-day Los Angeles unless policies are changed dramatically. Transportation policy must add capacity to allow supply to meet demand, but the new capacity as to be the right capacity, in the right place, at the right time. It also has to be managed efficiently.

Ultimately, road pricing will be the key policy reform needed to meet these transportation needs and ensure our transportation networks maximize mobility in a sustainable way. Road pricing in the U.S. is being introduced in the form of HOT (High-Occupancy Toll) Lanes. HOT lanes are reserved for buses and other high occupancy vehicles, but are also open to single occupant vehicles upon payment of a toll. The number of cars using the reserved lanes is controlled through the use of variable pricing (via electronic toll collection) to maintain free flowing traffic at all times even during rush hours. While occupancy rates vary in carpool lanes -- some permit high-occupancy vehicle (HOV) rates of 2 or HOV-3 to ride free while others are free only to super-high-occupancy vehicles such as van pools and buses.

When properly planned and executed, HOT lanes can be combined into a HOT Network of interconnected roadways that allow congestion-free travel throughout the region. There are currently no HOT networks in operation, but a number of metro areas include them in their long range transportation plans. Moreover, many of these HOT Networks can be self-funding if designed properly.

HOT lanes benefit not only those on the HOT lanes, but transit as well. For motorists, free-flowing HOT lanes give everyone an option of "congestion insurance" as an alternative to gridlock when drivers decide it is most important: to pick the kids up from daycare, make it to their soccer game or catch a flight. Variable pricing allows roadway managers to change the price to ensure sustainable congestion-free travel over the long term while also creating a sustainable flow of revenues to maintain and improve the facilities. By using pricing to discourage certain folks from traveling during peak hours, HOT lanes actually increase mobility. Orange County's experience is that the HOT lanes represent one third of the highway's lane miles, but carry over half of the traffic during the rush hour.

HOT lanes benefit transit riders as well. Because HOT lanes are free flowing and operating at high speeds even during rush hours, they can provide reliable guideways for express bus service. With value pricing keeping HOT lanes free-flowing, HOT lanes become the virtual equivalent of dedicated busways.

HOT lanes with variable pricing have become widely accepted as sustainable congestion relief technology in the U.S. The concept is supported by environmental groups, local business associations and politicians of all persuasions. Implementing variable-pricing is a top priority of the U.S. Department of Transportation.

In conclusion, sustainable mobility means a lot of things to a lot of people. But, in the end, we need to focus on the ultimate purpose of a transportation system and network: improving mobility for people, businesses, services, and goods. We also need to be sensitive to the demands of high-end, services based economies that are adding significant value in the global economy. Most of all, we need to ensure we don't let naïve ideas about current resource use trap us into adopting policies that technology and innovation will solve on their own. Policymakers have bold new tools; most notably road pricing that will provide both the incentives and the financial wherewithal to make increasingly mobile urban areas sustainable environmentally, socially, and economically. Policies that compromise mobility are not sustainable in the long run.

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***e-mail*** jsemmens@cox.net

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***High-Speed Rail Plans Should Be Called Moderate-Speed Rail*** by Robert Poole (Reason Foundation, 3415 S. Sepulveda Blvd. Suite 400 Los Angeles, CA 90034; ph (310) 391-2245; http://www.reason.org/news/show/1007490.html) (May 5, 2009)

**Highlights**

- Putting huge sums into projects whose benefits are far less than their costs will make the country poorer.

On April 16th, President Obama touted his administration's plan to put $13 billion in federal funding into high-speed rail corridors around the country, holding out the promise of reduced travel times, less congestion, reduced emissions, and of course the creation of jobs. Many people in the public-private partnership infrastructure community have been cheered by this new program, seeing the potential for making money while improving U.S. transportation.

In the United States, "high-speed rail" means anything in excess of 110 mph. The only U.S. train that goes (briefly) faster than that is Amtrak's Acela service on the Northeast Corridor route; all other current Amtrak lines have a top speed of 79 mph. Nearly all of the 10 corridor proposals in contention for a piece of the federal $13 billion are planning upgrades of existing passenger service to get to 110 mph.

As unambitious as those projects may sound, they are more than capable of absorbing most or all of the $13 billion. These corridors serve a mix of freight and passenger trains, with the former tending to be very long and operating at speeds that seldom exceed 60 mph. To enable 110 mph passenger trains to operate on these tracks will require major upgrades to signaling systems and the addition of passing sidings. And if priority is given to an expanded number of passenger trains, that means the freight trains will spend even more time than they do now stopped on mile-long (or longer) sidings.

The conflict between freight and passenger service is one of the little-noticed problems with what really should be called "moderate-speed rail." You can optimize a rail network for freight or for passenger service, but not for both. The current US rail network is optimized for freight, and as a result, rail's share of US freight ton-miles is about 40%. By contrast, Europe's network is optimized for passenger trains, and as a result, rail's share of freight ton-miles is only 10-15%. Consequently, the carbon-intensity of goods movement is about 25% higher in Europe than in the USA.

True high-speed rail (HSR) is represented by the bullet trains in Japan, France, Spain, and Germany, with speeds of 150-200 mph. Those relatively few routes are built, out of necessity, on exclusive rights of way—with wider curves, shallower grades, and full grade separation. That makes their cost much higher than the moderate-speed rail featured in the Obama plan. A table in a recent Government Accountability Office report on the subject shows the construction cost of recent overseas HSR lines, in 2008 dollars. Except for an outlier in Japan that cost $143 million/mile, they averaged $51 million per mile to construct (i.e., these figures do not include the vehicles). Thus, the $13 billion in federal aid promise by President Obama would build less than 300-miles of HSR.

Despite various claims to the contrary, the Government Accountability Office found: "In each of the countries we visited, the central government paid the up-front construction costs of their country's high-speed rail lines, and did so with no expectation that its investment would be recouped through ticket revenues."

Thus, claims about "profits" that appear in the media refer only to operating profits—and even those appear to occur on only some of these lines. In the U.K., for instance, *The Economist* reports that in 2007 the British government subsidized the operating costs of UK rail operators to the tune of $6.6 billion. The new HSR line that opened in Taiwan in 2007 lost $1.5 billion in its first year of operation. University of Paris transport economist Remy Prud'Homme estimates that overall, passenger rail service in the European Union receive about $100 billion in subsidies each year.

The only one of the 10 U.S. corridors with an actual HSR (as opposed to moderate-speed) plan in place is California. The California High-Speed Rail Authority (CHSRA) expects to raise about one-third of the capital cost of this very ambitious project from private investors. Anyone interested in considering such an investment should go to the Reason Foundation website and download the "due diligence" report that was released last September. Researchers Wendell Cox and Joseph Vranich review the reasonableness of CHSRA's numbers—the construction costs (significantly under-stated), ridership (completely unbelievable, by comparison either with the far denser Northeast Corridor or overseas systems), travel times, mode share, etc. Of particular note is the CHSRA's now-abandoned claim that the rail system would reduce $CO_2$ emissions sufficient to meet about 1.5% of the state's goal. And the cost per ton of achieving even that miniscule change would range from a low of $1,949 to a high of $10,302. The widely accepted benchmark for cost-effective $CO_2$ reduction is $50/ton.

One of the first lessons of Economics 101 is that because resources are always limited, if you spend $300 billion on X, it's not available to spend on Y. Putting huge sums into projects whose benefits are far less than their costs is not a recipe for prosperity, but for the opposite: making the country poorer.

None of Amtrak's current low- or moderate-speed routes even covers operating and maintenance costs from passenger fares, any profit potential from design-build-operate contracts looks highly speculative. There might be potential in some cases to adapt the model used by the state of Victoria, Australia, under which tram and commuter rail services in Melbourne are being operated and upgraded under medium-term contracts for which bidders competed on the basis of which firm proposed less operating subsidy while meeting a set of performance metrics.

That's a far cry from the vision of a new era of bullet trains developed with substantial private investment in their multi-billion-dollar capital costs, with a return on investment derived from passenger fares. That will remain a fantasy.

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***e-mail*** jsemmens@cox.net

*JUNE 2009*

***Clear Zone – A Synthesis of Practice and an Evaluation of the Benefits of Meeting the 10 ft Clear Zone Goal on Urban Streets*** by Thomas H. Maze, Christian Sax, Neal Hawkins, Center for Transportation Research and Education, Iowa State University, 2711 South Loop Drive, Suite 4700, Ames, IA 50010-8664 (Iowa Highway Research Board, Iowa Department of Transportation, 800 Lincoln Way, Ames, IA 50010; http://www.ctre.iastate.edu/reports/clear_zone_report.pdf; phone: 515-239-1101) (Nov 2008)

**Highlights**

- There is very little benefit from increasing the fixed object setback to more than 5 ft from the face of the curb.

In urban communities, there is limited right-of-way available to establish a safe, clear run-out zone. On roadway projects, the clear zone recommended by the administering jurisdiction is sometimes not implemented or defined because of the presence of established buildings, trees, or other fixed objects that would be too difficult or costly to remove.

To address this issue, the research presented in this report was conducted in two phases. The first phase involved a synthesis of clear zone practices, which included a literature review and a survey of the practices in jurisdictions with developmental and historical patterns similar to those of Iowa. The second phase was to investigate the benefits of an established 10 ft clear zone, which involved collecting and examining data from recommended urban corridors in Iowa that met and did not meet the 10 ft clear zone goal.

The synthesis of practice developed in the first phase of this research indicates that the 20 state agencies surveyed followed an array of urban clear zone guidance. Some states followed the minimum operational setback recommended by AASHTO, while other states have created their own guidance, which is currently being followed by design engineers. Some states went as far as to ignore the presence of the curb and to require the use of the AASHTO-recommended setback distances for non-curbed roads.

The descriptive analysis conducted in the second phase of this research investigated the effects of clear zones and effectively updated the analysis, which is believed to have been the impetus for the 10 ft minimum setback requirement in Iowa. The findings of this phase of the research are as follows:

- It was found that the minimum, average, and 15th percentile setback distances do not have a statistically significant relation to fixed object crashes at the 90% confidence interval.
- Within 45 m of an intersection, roadways were found to have a statistically significant increase in the number of fixed object crashes at the 90% confidence interval.
- A consistent fixed object offset helps reduce the number of fixed object crashes.
- A weak relationship was found between the number of fixed object crashes and the posted speed limit on the roadway.
- There is no significant relationship between the density of fixed objects and the number of fixed object crashes.
- When minimizing the number of fixed object crashes is a primary goal, a 5 ft clear zone is the most effective setback

distance. Of the 53 predictors described in section 5.8 of this report, 43 indicated a highly linear relationship between setback distance and the number of fixed object crashes within 5 ft of the pavement edge.

- When minimizing the cost of fixed object crashes is a primary goal, a 3 ft clear zone is the most effective setback distance. Of the 44 predictors described in section 5.9 of this • In the incremental cost analysis, the greatest benefits accrued when the setback distance was increased to 3 ft and to 5 ft from the curb. On roadways with higher speeds or with a higher ADT, increasing the setback did not result in large cost savings.

The policy question that can be addressed as a result of this research is, What is the optimal fixed object setback on urban curbed roads? This research has shown that there is a natural break in the fixed object crash frequency at a fixed object setback of 5 ft. There is also a natural break in the fixed object crash cost at a fixed object setback of 3 ft. Therefore, there is very little benefit of increasing the fixed object setback to more than 5 ft from the face of the curb.

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***e-mail*** jsemmens@cox.net

*JUNE 2009*

***An Evaluation of Engineering Treatments and Pedestrian and Motorist Behavior on Major Arterials in Washington State*** by Katherine D. Davis, Mark E. Hallenbeck, Washington State Transportation Center, University of Washington, Box 354802, University District Building, 1107 NE 45th Street, Suite 535, Seattle, Washington 98105-7370 (Research Office, Washington State Department of Transportation, Transportation Building, MS 47372, Olympia, Washington 98504-7372; Project Manager: Kathy Lindquist, 360-705-7976) (Sep 2008)

**Highlights**

The purpose of this study was to gain further insight into pedestrian and motorist behavior and the efficacy of various engineering treatments designed to improve pedestrian safety on arterials. It hoped to answer two questions:

- What causes motorists to yield to pedestrians?
- What causes conflicts between motorists and pedestrians?

As described in the findings, vehicle yielding is directly influenced by the visibility of the crossing. Pedestrian crossings with signs, crosswalk markings, flashers, and/or signals seem to have higher yielding rates than those without these features. There is often so much visual clutter on these roadways that pedestrians blend easily into the background if strong signals are not sent to motorists.

The causes of conflicts are much more varied: ignorance of or noncompliance with the law (by motorists or pedestrians), inattention, vehicles following too closely, impatience, anxiety when attempting to catch a bus, use or non-use of pedestrian facilities, placement of features in the built environment, and more. Most of these issues can be addressed with engineering, education, and/or enforcement. Unfortunately, all of these solutions require funding, which is currently in short supply.

**Recommendations**

Improvements to pedestrian safety must compete with new roads, road maintenance and reconstruction, and a host of other priorities for funding. Therefore, only the most promising treatments should be carried forward through design and implementation, and lower cost improvements should be considered first.

**Costs and Benefits**

Education and enforcement: although these methods were not used at any of the study sites, they are often included in pedestrian safety projects. The costs of education and awareness campaigns can vary significantly, depending upon the media used and the frequency of use (i.e., radio, television, posters, bus advertising, etc., and how many commercial spots are purchased, posters printed, and more). As an example, a 2002 Washington, D.C., campaign cost about $300,000 and utilized radio, bus advertising (on transit vehicles and shelters, and inside the buses themselves), posters, mailing inserts, and stickers. Researchers were able to show that awareness of the campaign and its issues increased after the campaign concluded.

Enforcement of crosswalks and motorist yielding behavior is typically done as an overtime function of a city police department or a county sheriff's department. This would cost approximately $40 per hour per officer. No effectiveness statistics are available.

Crosswalk markings: Cost estimates range from $400 for a standard (transverse) pattern painted crosswalk to approximately $1500 for a thermoplastic continental crosswalk marking (all based on a seven-lane roadway cross-section). The accompanying signage may cost from $200 to $300 per sign (including installation). At the Spanaway site, motorist yielding behavior increased by 5% to 35% when crosswalk markings were present.

Stop bars: Costs range from about $120 for a painted stop line to about $300 for a thermoplastic stop line. At the Airway Heights site, the stop bars appeared to increase the pedestrians' sense of security by creating more separation between them and the approaching vehicles. This resulted in a significant reduction in pedestrian running behavior. It appeared that the stop bars may have decreased the number and severity of shielding conflicts that were observed at that site.

Raised medians: The cost for the type of raised median used at the Spanaway site is approximately $5,000. The median did seem to increase pedestrians' feelings of security while waiting in the center lane.

Overhead illumination: The cost, per pole for overhead illumination is approximately $5,000 to $15,000. Because of a lack of pedestrian crossings made during dark hours in this study, the effects of overhead lighting on vehicle yielding and pedestrian-motorist conflicts could not be examined.

Sidewalk, curb, and gutter: Costs for this treatment would be about $10,000 per 300 linear feet, plus $1,500 per curb ramp. Although these improvements were not explicitly studied in this project, the treatment would serve to grade-separate pedestrians and vehicles, as well as better define driveways and intersections, which could reduce conflicts.

Flashers (actuated): Costs would be $5,000 per crossing with sign-mounted flashers only, and $15,000 to $20,000 per crossing with in-pavement flashers and sign-mounted flashers. Motorist yielding rates at the Airway Heights site were very high—almost 90%—when both sign-mounted and in-pavement flashers were present. This rate dropped slightly (to about 70% compliance) when the in-pavement lights began to fail, but the sign-mounted lights were still fully functional. (Yielding rates at unmarked, mid-block crossings in Kent and Shoreline were 18 percent and 25 percent, respectively.)

Signals: Costs range from $40,000 to $200,000 per signal, depending upon the complexity of the intersection. At the Spokane sites, vehicle yielding was 14% to 28% higher at Rowan Avenue (with permissive left turns) than at the unsignalized Lacrosse Avenue intersection. Motorist yielding at Wellesley Avenue (with protected left turns) was 40% to 52% higher than at Lacrosse Avenue. Pedestrian and motorist delay will increase with the addition of a traffic signal and turning conflicts will be higher, but most other conflicts (pedestrian and vehicle evasive action, running behavior, and center lane waits) will be dramatically less. Protected left turns lower these rates further than signals that allow permissive left turns.

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## ARIZONA TRANSPORTATION INSTITUTE
***e-mail*** jsemmens@cox.net

*JUNE 2009*

***Statewide Crash Analysis and Forecasting*** by Paul P. Jovanis, Jonathan Aguero and Kun-Feng Wu, Thomas D. Larson Pennsylvania Transportation Institute, Pennsylvania State University, 201 Transportation Research Building, University Park, PA 16802-4710 (Pennsylvania Department of Transportation, Bureau of Planning and Research, Commonwealth Keystone Building, 400 North Street, 6 Floor, Harrisburg, PA 17120-0064; ftp://ftp.dot.state.pa.us/public/pdf/BPR_PDF_FILES/Documents/Research/Complete%20Projects/Reducing%20Fatalities/Statewide%20Crash%20Analysis%20and%20Forecasting.pdf) (Nov 2008)

**Highlights**
- A "Sites with Promise" list can be used to identify those road segments that have an elevated risk of a crash and also offer the greatest potential for safety improvement.
- Penn State researchers developed a model that simultaneously estimated the expected crash frequency for each of five levels of outcome severity.

There is a need for the development of safety analysis tools to enable the Pennsylvania Department of Transportation (PennDOT) to better assess the safety performance of road segments in the Commonwealth. The objective of this project was to conduct analyses of existing PennDOT data to provide PennDOT with tools to better manage road safety, reducing fatalities, injuries, and property damage losses in the Commonwealth. A particular objective was to conduct studies that would produce products of use in PennDOT's *Crash Data Analysis and Retrieval Tool* (C-DART).

*Identifying Sites with Promise*

One critical task in the project was the identification of "Sites With Promise" (i.e., SWiPs). A SWiP is a road segment with a crash risk above the mean for comparable segments (those from one of six road classes considered in this research: urban and rural two-lane highways, urban and rural multilane highways, and urban and rural freeways and expressways).Jdentification of SWiPs included use of segment length and annual average daily traffic (AADT) as predictors.

A list of SWiPs has been provided to PennDOT for potential inclusion in C-DART. The list includes the PennDOT designation for the link (using county, route, and segment numbering) along with the mean and standard deviation of the excess risk. The list is in rank order with the highest-risk segment listed first. This list can be used to identify those road segments that have an elevated risk of a crash and also offer the greatest potential for safety improvement. This potential for improvement arises because the site has an expected crash frequency that is substantially higher than comparable road segments, controlling for AADT and segment length. The difference in expected crashes indicates that the site is "less safe" than comparable sites, presumably because of some site, driver, or other characteristics; this poorer safety is an indication that there are likely positive actions that can be taken to improve safety. A safety analyst at PennDOT can use this list of SWiPs to identify high-risk locations in a given district and then use the other analysis capabilities of C-DART to explore differences between the SWiPs and other sites in the comparison group.

Such identifications should assist PennDOT in identifying and investing truly high-risk sites.

*Level of Outcome Severity*

An additional challenge in safety management is to find a way to adequately consider level of crash severity in the analysis. Crash frequencies are often treated as a whole, combining crashes of different severities of outcome (as described above). Alternatively, safety analysts may arbitrarily choose outcome levels for inclusion in a study (e.g., fatal and injury crashes only). Penn State researchers developed a sophisticated statistical model that simultaneously estimated the expected crash frequency for each of five levels of outcome severity ranging from fatal to property damage only. Further, the method explicitly considered the correlation between crashes of different severity levels. The more sophisticated model reduced the standard deviation of the crash frequency estimates on the order of 20 percent overall and 40 percent or more for fatal and major injury crashes. This improved precision allows PennDOT safety analysts to be much more confident of the estimates of the mean of each crash outcome. Lists of the most severe outcome road segments have been provided to PennDOT in county, route, segment format for inclusion in C-DART for studies that require specific consideration of crash outcome. One interesting outcome of the analysis is that fatal and serious injury crashes showed a high correlation, while they were only slightly correlated to moderate, low severity and property damage only outcomes. This supports the concept of PennDOT combining fatal and serious injury crashes together in safety studies.

*Type of Collision and Demographic Factors*

To further illustrate the utility of the Penn State approach, separate analyses were conducted of two specific crash types: single vehicle run-off-road and multiple vehicle head-on and sideswipe crashes. Using a procedure similar to those described above, the team identified SWiPs for each crash type. These have also been provided to PennDOT for use by safety staff interested in these severe outcome crash types.

The Penn State team added census records to link level data in the Harrisburg and Clearfield PennDOT districts. Models were estimated seeking to capture the effect of factors such as area income and driver age on crash risk. A list of sites was not a required outcome, but the final models are included in Appendix C of this report.

*Summary*

The analyses conducted and models produced in this research should enhance PennDOT’s ability to conduct safety analyses, particularly those using C-DART. The list of SWiPs contains a rank ordering of road segments offering the greatest potential for safety improvement. The model containing crash severity levels should give PennDOT additional confidence when combining fatal and severe injury crashes in needed analyses. Lastly, the models including census data have explored the feasibility of using that approach to safety modeling (although additional testing is needed).

TRANSPORTATION RESEARCH DIGEST
ARIZONA TRANSPORTATION INSTITUTE
*e-mail* jsemmens@cox.net

*JUNE 2009*

***Traffic Safety Evaluation of Nighttime and Daytime Work Zones,*** *NCHRP Report 627* by Gerald L. Ullman, *et al*. (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_627.pdf) (2008)

**Highlights**
- Overall, working at night does not result in a significantly greater crash risk.

This project was initiated to objectively determine and document how nighttime and daytime work zones affect traffic safety. More and more, agencies are doing roadway work on high-volume facilities at night to reduce adverse traffic impacts and complaints by the public that typically occur when the same work is being done during the day. Nighttime travel is commonly characterized by lower traffic volumes, a higher percentage of truck traffic, higher operating speeds, reduced visibility, and higher concentrations of drowsy and impaired drivers. Arguments exist on both sides of the question as to whether working at night is more or less safe than working during the day.

A two-pronged investigation was adopted for this research project. The first prong utilized the New York State Department of Transportation (NYSDOT) Work Zone Accident database. The second prong of the research effort was the collection and analysis of crash experiences of work zones performed in California, North Carolina, Ohio, and Washington.

Overall, working at night does not result in a significantly greater crash risk for an individual motorist traveling through the work zone than does working during the day. In addition, traffic crashes that occur in nighttime work zones were not necessarily more severe than those that occur in similar daytime work zones. The implications of these findings are that work activities that require temporary lane closures have substantially lower total safety impacts to the motoring public if the work is done at night. The lower traffic volumes present at night result in a much lower number of crashes occurring over a work operation of a given duration.

Although the increased risk of a crash is similar, differences do exist in the types of crashes that occur at nighttime and daytime work zones. Traffic crashes involving workers, construction vehicles or equipment, and construction materials and debris (both intrusion and non-intrusion crashes) comprise a greater percentage of crashes at night than during the day. Although the relative percentage of these crashes was higher at night, it should be noted that they were only a small proportion of the total work zone crashes experienced in either time period.

Strategies that appeared to offer the greatest potential for crash cost reduction included the following items:

- Practices to reduce the number and duration of work zones required,
- Use of full directional roadway closures via median crossovers or detours onto adjacent frontage roads,
- Use of time-related contract provisions to reduce construction duration,
- Movement of appropriate work activities (i.e., those that require temporary lane closures) to nighttime hours,
- Use of demand management programs to reduce volumes through work zones,

- Use of enhanced traffic law enforcement.

Strategies that appeared to offer a moderate work zone crash reduction potential included the following:

- Design of adequate future work zone capacity into highways,
- Use of full roadway closures that require traffic detours onto adjacent surface streets,
- Use of intelligent transportation system (ITS) strategies to reduce congestion and improve safety,
- Improvement of work zone traffic control device visibility,
- Efforts to reduce flaggers' exposure to traffic, and
- Efforts to reduce workspace intrusions and their consequences – primarily at long-term, high-volume work zones.

Although these strategies appear capable of having positive impacts on work zone safety, determining the extent to which they meet these expectations can only be determined objectively through the improved collection and use of work zone crash data. Highway agencies have access to their state crash reporting databases and can usually develop some fairly basic metrics such as total work zone fatalities or injuries. Beyond that, however, the data are generally not sufficient to be useful for many of the potential applications. Although no work zone crash data system currently in use fully addresses the needs of effective work zone safety management, it appears that such a system can be developed by combining the desirable features of the Model Minimum Uniform Crash Criteria (MMUCC) guidelines that have been developed nationally with an agency construction accident reporting program similar in concept to the one now in use in NYSDOT. However, revisions and improvements to both of these are considered essential to achieving the goal of providing comprehensive, timely, and consistent data for crashes, construction accidents, and other harmful events in and related to highway work zones. In addition to enhancing the actual crash data being collected, the collection of exposure data at work zones is particularly needed to improve process-level work zone crash analysis.

# TRANSPORTATION RESEARCH DIGEST

## ARIZONA TRANSPORTATION INSTITUTE

***e-mail*** jsemmens@cox.net

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***Cost-Effective Performance Measures for Travel Time Delay, Variation, and Reliability,*** *NCHRP Report 618* by Cambridge Systematics, *et al*. (Transportation Research Board, 500 Fifth Street, NW, Washington, DC 20001; (202) 334-3213; http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_618.pdf) (2008)

**Highlights**

- This guidebook presents a framework and cost-effective methods to estimate, predict, measure, and report travel time, delay, and reliability performance data.

This guidebook presents and assesses performance measures currently believed to be most appropriate for estimating and reporting travel time, delay, and reliability from a perspective that system users and decision makers will find most understandable and relevant to their experience and information needs. This guidebook also presents various data collection methods, analysis approaches, and applications that most effectively support transportation planning and decision making for capital and operational investments and for quality of service monitoring and evaluation. Methods are presented in a manner to be useful for application in a range of settings and complexity, but are not intended to support real-time applications of travel-time data such as Traveler Information programs.

The paragraphs below provide a detailed overview of each of the chapters in the guidebook.

1. *Introduction*. This chapter describes the purpose and scope of the guidebook, intended users, and the audience, those who must eventually understand the results and make or influence decisions based on those results. Included is a discussion of travel time, delay, and reliability in transportation systems, and intended applications for the guidebook. Necessary definitions and nomenclature with enough background and history to establish the foundation and continuity of this guidebook is provided.

This introductory chapter contains several key sections:

- Why Measure Travel-Time Performance? The rationale and sales pitch for the use of travel-time-based measures in planning and decision-making. Discuss the various aspects of measurement, such as trip-based versus vehicle-based measures, relevance to freight movements, and how the guidebook will address modes other than autos on freeways and highways.
- How to use the guidebook. A description of the information contained here, the organization of the information, and a recommended approach to using the guidebook.
- Limitations of the guidebook. A few key caveats regarding uses for which the manual is not intended (e.g., traveler information or public relations programs).
- Measuring Mobility and Reliability. An overview of the key steps involved in using travel-time-based measures to define and predict system performance, and how to approach the use of such measures in a planning situation.

2. *Selecting Performance Measures*. What should influence the selection of

measures for a given application; relative importance and sequence of agency goals and objectives in determining appropriate measures. We provide a checklist of considerations for measure selection, a quick reference guide to selected measures, and detailed discussion and derivation of the most useful measures that define mobility (in terms of travel time and delay) and reliability (in terms of variability in travel time).

3. *Data Collection and Processing*. This chapter provides guidance on the development of a data collection and sampling strategy for measuring travel time in the field and for managing data quality. It describes how to compute the mean and variance of travel time and delay. It also describes how to compute the basic components of reliability metrics.

4. *Before/After Studies*. This chapter describes how to solve special issues involved in evaluating the effectiveness (in the field) of measures to reduce travel time, delay, and variability.

5. *Identification of Deficiencies*. This chapter describes how to identify travel time, delay, and reliability deficiencies from field data and distinguish actual deficiencies from random variation in the field data. A diagnosis chart is included to assist in identifying the root causes of travel time, delay, and reliability deficiencies.

6. *Forecast/Estimate Travel Time*. This chapter provides procedures for estimating travel time, delay, and reliability from travel volumes. This information is presented to allow prediction of future conditions where a travel model is used to generate future demand volumes, and to accommodate the many agencies that currently do not have continuous data collection processes on the system or facilities they wish to measure.

7. *Alternatives Analysis*. This chapter provides guidance on the generation and evaluation of alternative improvements for reducing travel time, delay, and variability.

8. *Using Travel-Time Data in Planning and Decision Making*. This chapter provides guidance and examples of effective methods for presenting the results of travel time, delay, and reliability performance analysis or forecasts. This chapter also describes the specific steps for using quantitative travel-time performance data to support decisions about transportation investments, using six typical planning applications to illustrate the process for developing and incorporating information into the planning process.

**Limitations**

The primary intended use of this guidebook is to support planning and decision making for transportation system investments, including capital projects and operational strategies. The level of precision of the methods is consistent with the precision and accuracy of data typically collected or generated to support planning activities; for example, periodic data collection and use of computer-based forecasting models to estimate future demand for potential system improvements. The procedures here are intended to support a higher-level screening and analysis process to identify needs and deficiencies and to evaluate potential solutions for meeting needs or correcting deficiencies.

# TRANSPORTATION RESEARCH DIGEST
## ARIZONA TRANSPORTATION INSTITUTE
***e-mail*** jsemmens@cox.net

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***Roadway Network Productivity Assessment: System-Wide Analysis Under Variant Travel Demand*** by Noblis, Inc., 3150 Fairview Park Drive, Falls Church, Virginia 22042 (Federal Highway Administration, 1200 New Jersey Avenue, SE, Washington, DC 20590; ph 202-366-0660; http://www.ops.fhwa.dot.gov/publications/fhwahop09019/fhwahop09019.pdf) (Nov 2008)

**Highlights**
- Freeways are more productive when not overtaxed by excessive traffic volume.

Since 2002, Noblis has processed travel time and traffic volume data from urban freeway systems to calculate three key network performance measures (hours of congestion, travel time index, and planning time index) to provide a national snapshot of urban mobility on a monthly basis. This national snapshot is reported as a part of the Urban Congestion Report (UCR) effort in a series of graphical dashboards illustrating congestion trends and factors that contribute to congestion: weather, work zones, incidents and variations in travel demand.

In collecting, assuring quality control, and analyzing these data, Noblis has developed a large repository of traffic volume and speed data for more than twenty U.S. cities and metropolitan areas. In 2007, this data repository was used to quantitatively analyze the key components of traffic congestion for the Chicago metropolitan area. One element of this analysis examined area-wide aggregations of vehicle miles traveled (VMT) at five-minute periods on weekdays. These VMT data were correlated with average network speed over the same five minute intervals. In this congested network, the relationship between system-level aggregated VMT and speed suggested that an overall system maximum productivity could be observed when average network speeds operated in a relatively narrow range. Based on the results of that study, FHWA tasked Noblis to conduct additional research on the characterization of system-level productivity under a range of estimated travel demand and network speed conditions.

The analysis documented in this report examines the hypothesis that total freeway system peak period productivity is higher in moderate travel demand conditions than in excessive travel demand conditions. The Noblis analysis addressed the hypothesis using two approaches:

1. A micro-level study examining interactions between individual bottlenecks on the urban roadway network that characterizes travel demand and productivity relationships on the "edges" of congestion evolving throughout the day; and
2. A macro-level study using aggregated measures for the entire urban roadway network system to examine changes in system-wide productivity measures for various travel demand conditions.

Noblis conducted these studies using archived UCR speed and traffic volume data for roadway networks in Los Angeles and Chicago metropolitan areas. This report summarizes the macrolevel study of aggregate system productivity in UCR networks from Los Angeles and Chicago.

**Conclusions**

Results from the analysis support the study hypothesis, with a single important caveat. When system productivity is defined using measures like delay or quality-weighted VMT, then it is clear that higher productivity is linked with conditions that best match overall system demand with system carrying capacity. The quality-weighted productivity ratio (QPR) measure appears to be the best single measure in this study to illustrate this concept. The QPR drops as low as 0.2 when travel demand is far lower than system carrying capacity, as in at 6 AM in Chicago on Labor Day. It also drops to as low as 0.3 when excessive demand has caused broad network congestion as at 8 AM in Los Angeles on September 10, 2007. High QPR values can be found during the AM peak on Columbus Day or in the latter portions of the Labor Day PM peak period when networks are loaded close to some level where a large volume of vehicles can be accommodated without significant breakdown.

The caveat from the study is that the hypothesis is less well supported when measures of productivity that are indifferent to quality of travel are considered. For example, Total VMT (regardless of speed) does not indicate a significant difference between Columbus Day and September 10, 2007 in any peak period or when the entire day is considered. Our observations of these measures indicate that there is a self-regulating component to a connected, but open system like a freeway network. In a closed system, a link-level bottleneck may develop and cause a reduction in volume that can be observed downstream. In an open system, with many access points, additional volume can fill downstream of the bottleneck with little apparent loss of productivity. Queued vehicles held upstream of a bottleneck are converted into increased volume (and productivity) downstream of the bottleneck.

One analogy that may be helpful when considering productivity measures is the consideration of two factories, each of which produces 100 widgets per day. The first factory has a reject rate for its widgets of 50% while the other has a reject rate of 1%. By simply comparing the number of widgets produced (100 vs. 100), we may not be fairly representing one kind of higher productivity realized by the second factory (50 vs. 99).

The QPR and other measures provide a new and potentially insightful way of considering the productivity of a large complex system like a freeway network. Maximum uncongested VMT appears to be a useful measure in characterizing overall system resilience and carrying capacity. Either measure could be used to systematically identify productivity losses associated with incidents, work zone activity, weather or other impacts if these other data were combined with the concurrent speed and traffic count data.