

# ***TRANSPORTATION RESEARCH DIGEST***

*MAY 2008*

ARIZONA TRANSPORTATION INSTITUTE

*e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)*

The contents of the *Transportation Research Digest* reflect the views of the authors who are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the Institute

# ***TRANSPORTATION RESEARCH DIGEST***

## ***ARIZONA TRANSPORTATION INSTITUTE***

*e-mail* [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

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.

If you would like to obtain the full report upon which a *Transportation Research Digest* summary is based you have several options. Check your local university library. You may want to contact the publisher using the contact information appearing in the *Transportation Research Digest*. Some of the documents are free for the asking. Others can be purchased.

There is a database listing of all the previously published *Transportation Research Digests* that we have on file (back to 1984). Copies of the list or of portions of the list selected by topic or mode can be provided on request. You may also access the database via the internet at

*Transportation Research Digests* from December 1995 to November 2003 are available at <http://www.dot.state.az.us/ABOUT/atrc/Publications/DocRev/TRDtest.htm>

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.

<u>Code</u>	<u>Topic</u>	<u>Code</u>	<u>Topic</u>
ADM	Administration	PLAN	Planning
AIRP	Airports	PRIV	Privatization
AVIA	Aviation	RAIL	Railroads
BIKE	Bicycles	RDSO	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

Requests or inquiries may be made via e-mail ([jsemmens@cox.net](mailto:jsemmens@cox.net)).

Thank you.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

### **TABLE OF CONTENTS**

<b><u>Topic</u></b>	<b><u>Title</u></b>	<b><u>Pages</u></b>
FIN/ funding	<b><i>Challenges and Investment Options for the Nation's Infrastructure</i></b> (United States Government Accountability Office, 441 G Street NW, Room LM, Washington, D.C. 20548; Patricia Dalton at (202) 512-2834 or <a href="mailto:daltonp@gao.gov">daltonp@gao.gov</a> ; <a href="http://www.gao.gov/new.items/d08763t.pdf">http://www.gao.gov/new.items/d08763t.pdf</a> ) (May 2008). A variety of taxes and user fees, such as tolling, can be used to help fund infrastructure projects.	7-8
MAIN/ pavement markers	<b><i>Evaluation of Wet-Weather and Contrast Pavement Marking Applications</i></b> by Paul J. Carlson, Jeffrey D. Miles, Adam M. Pike, and Eun Sug Park, Texas Transportation Institute, Texas A&M University System, College Station, Texas 77843-3135 (Texas Department of Transportation, Research and Technology Implementation Office P.O. Box 5080, Austin, Texas 78763-5080; 979.845.1734; <a href="http://tti.tamu.edu">http://tti.tamu.edu</a> ) (Aug 2007). The most cost-effective system is spray applied thermoplastic with supplemental RRPMs.	9-10
PAVE/ concrete	<b><i>Corrosion Resistant Alloys for Reinforced Concrete</i></b> by William H. Hartt, Rodney G. Powers, Diane K. Lysogorski, Virginie Liroux & Y. Paul Virmani (Office of Infrastructure Research and Development, Federal Highway Administration, 6300 Georgetown Pike, McLean, VA 22101-2296; (202) 493-3022) (July 2007) Time-to-corrosion of the different reinforcements in concrete increased in direct proportion to the chloride threshold that was determined by accelerated testing.	11-12
PAVE/ recycled	<b><i>Evaluation of Recycled Portland Cement Concrete Pavements for Base Course and Gravel Cushion Material</i></b> by L. Allen Cooley, Jr., Jimmy Brumfield, Jonathan Easterling and Prithvi S. Kandhal, Bums Cooley Dennis, Inc. 278 Commerce Drive Ridgeland, MS 39157 (South Dakota Department of Transportation, Office of Research, 700 East Broadway Avenue, Pierre. SD 57501-2586) (Jun 2007) Recycled Portland cement concrete pavements are a viable option for use in gravel cushion and aggregate base course construction.	13-14
PLAN/ FIN	<b><i>More Roads to Travel: A Path to Transportation Solutions in Arizona</i></b> by Byron Schlmoach (Goldwater Institute, 500 East Coronado Road, Phoenix, Arizona 85004; Phone: (602) 462-5000; <a href="http://www.goldwaterinstitute.org/common/img/tranbw.pdf">http://www.goldwaterinstitute.org/common/img/tranbw.pdf</a> ) (Apr 30, 2008) Responses to the state's traffic problems must reflect the reality that people prefer the flexibility and autonomy provided by cars.	15-16

RAIL/ TRF	<b><i>Non-Vital Advance Rail Preemption of Signalized Intersections Near Highway-Rail Grade Crossings</i></b> by Leonard G. Ruback, Kevin Balke, and Roelof Engelbrecht, Texas Transportation Institute, Texas A&M University System, College Station, Texas 77843-3135 (Texas Department of Transportation, Research and Technology Implementation Office P.O. Box 5080, Austin, Texas 78763-5080; 979.845.1734; <a href="http://tti.tamu.edu">http://tti.tamu.edu</a> ) (Sep 2007) A significantly higher degree of accuracy is obtained from the radar-based train detection system.	17-18
SAFE/ concrete barriers	<b><i>Traffic Control Design For Portable Concrete Barriers</i></b> by M.B.C Ulker, M. S. Rahman, A. Mirmiran, R. Zheng, Department of Civil Engineering, North Carolina State University, Campus Box 7908, Raleigh, NC 27695-7908 (NC Department of Transportation, Research and Analysis Group, 104 Fayetteville Street, Raleigh, NC 27601) (APR 2006) Two types of barriers were evaluated: (1) New Jersey barriers and (2) Oregon Tall-F barriers.	19-20
STR/ concrete slab bridges	<b><i>Improved Load Rating of Reinforced Concrete Slab Bridges</i></b> by David V. Jauregui, Alicia Licon-Lozano, and Kundan Kulkarni, Mew Mexico State University, Department of Civil Engineering, Box 30001, MSC 3CE, Las Cruces, NM 88003-8001 (NMDOT Research Bureau, 7500B Pan American Freeway NE, PO Box 94690, Albuquerque, NM 87199-4690) (Sep 2007) An AASHTO load rating analysis of Bridge 7270 was performed.	21-22
TRAN/ ENV	<b><i>Does Rail Transit Save Energy or Reduce Greenhouse Gas Emissions?</i></b> by Randal O'Toole (Cato Institute, 1000 Massachusetts Avenue, N.W., Washington D.C. 20001-5403; Phone (202) 842-0200: <a href="http://www.cato.org/pubs/pas/pa-615.pdf">http://www.cato.org/pubs/pas/pa-615.pdf</a> ) (April 14, 2008) Most rail transit lines use more energy per passenger mile than the average passenger automobile.	23-24
TRAN/ perform	<b><i>Performance-Based Budgeting for North Carolina Public Transportation</i></b> by Thomas J. Cook, Judson J. Lawrie, Institute for Transportation Research and Education North Carolina State University, Centennial Campus, Box 8601, Raleigh, NC 27695-8601 (North Carolina Department of Transportation Research and Analysis Group, 1 South Wilmington Street, Raleigh, North Carolina 27601) (Jun 2007) Few transit systems use formal performance-based budgeting.	25-26

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

*Challenges and Investment Options for the Nation's Infrastructure* (United States Government Accountability Office, 441 G Street NW, Room LM, Washington, D.C. 20548; Patricia Dalton at (202) 512-2834 or daltonp@gao.gov; <http://www.gao.gov/new.items/d08763t.pdf>) (May 2008)

### **Highlights**

- The nation's transportation infrastructure includes 4 million miles of roads, 117,000 miles of rail, 600,000 bridges, 26,000 miles of commercially navigable waterways, 11,000 miles of transit lines, 500 train stations, 300 ports, 19,000 airports.
- Demand has outpaced the capacity of our nation's surface transportation and aviation systems.
- A variety of taxes and user fees, such as tolling, can be used to help fund infrastructure projects.

Physical infrastructure is critical to the nation's economy and affects the daily life of virtually all Americans—from facilitating the movement of goods and people within and beyond U.S. borders to providing clean drinking water. However, this infrastructure—including aviation, highway, transit, rail, water, and dam infrastructure—is under strain. Estimates to repair, replace, or upgrade aging infrastructure as well as expand capacity to meet increased demand top hundreds of billions of dollars. Calls for increased investment in infrastructure come at a time when traditional funding for infrastructure projects is increasingly strained, and the federal government's fiscal outlook is worse than many may understand.

This testimony discusses (1) challenges associated with the nation's surface transportation, aviation, water, and dam infrastructure, and the principles GAO has identified to help guide efforts to address these

challenges and (2) existing and proposed options to fund investments in the nation's infrastructure. This statement is primarily based on a body of work GAO has completed for the Congress over the last several years. To supplement this existing work, GAO also interviewed Department of Transportation officials to obtain up-to-date information on the status of the Highway Trust Fund and various funding and financing options and reviewed published literature to obtain information on dam infrastructure issues.

The nation faces a host of serious infrastructure challenges. Demand has outpaced the capacity of our nation's surface transportation and aviation systems, resulting in decreased performance and reliability. Given these types of challenges and the federal government's fiscal outlook, it is clear that the federal government cannot continue with business as usual. Rather, a fundamental reexamination of government programs, policies, and activities is needed. Through prior analyses of existing programs, GAO identified a number of principles that could guide a reexamination of federal infrastructure programs. These principles include

- creating well-defined goals based on identified areas of national interest,
- establishing and clearly defining the federal role in achieving each goal,
- incorporating performance and accountability into funding decisions,
- employing the best tools and approaches to emphasize return on investment, and

- ensuring fiscal sustainability.

Various options are available to fund infrastructure investments. These options include altering existing or introducing new funding approaches and employing various financing mechanisms, such as bonds and loans. For example, a variety of taxes and user fees, such as tolling, can be used to help fund infrastructure projects. In addition, some have suggested including an infrastructure component in a future economic stimulus bill, which could provide a one-time infusion of funds for infrastructure projects. Each of these options has different merits and challenges, and

choosing among them will likely involve trade-offs among different policy goals. Furthermore, the suitability of the various options depends on the level of federal involvement or control that policymakers desire. However, as GAO has reported, when infrastructure investment decisions are made based on sound evaluations, these options can lead to an appropriate blend of public and private funds to match public and private costs and benefits. To help policymakers make explicit decisions about how much overall federal spending should be devoted to investment, GAO has previously proposed establishing an investment component within the unified budget.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

*Evaluation of Wet-Weather and Contrast Pavement Marking Applications* by Paul J. Carlson, Jeffrey D. Miles, Adam M. Pike, and Eun Sug Park, Texas Transportation Institute, Texas A&M University System, College Station, Texas 77843-3135 (Texas Department of Transportation, Research and Technology Implementation Office P.O. Box 5080, Austin, Texas 78763-5080; 979.845.1734; <http://tti.tamu.edu>) (Aug 2007)

### **Highlights**

- Raised retroreflective pavement markers (RRPMs) have the longest wet-night detection distance.
- The most cost-effective system is spray applied thermoplastic with supplemental RRPMs.

### *Findings from the Visibility Study*

Rain conditions are an infrequent nighttime occurrence, as a rain event occurs during less than 1% of the total nighttime hours.

Dry retroreflective measurements have a strong correlation with detection distance (0.85 to 0.75). Wet retroreflective measurements have a weaker correlation with detection distance (0.70 to 0.40). Dry retroreflectivity measurements cannot be used to estimate or predict wet retroreflectivity measurements.

Generally, retroreflectivity measurements decrease as the wetting rate is increased.

Not all wetting techniques are equal. Many variables impact the results including but not limited to the following: cross slope at measurement location, water flow rate, wind, droplet size, droplet density, uniformity of water sprayed, and interference with the instrument measuring window. This makes it difficult to compare continuous wetting retroreflectivity measurements made with different setups or in different conditions.

It was shown that as the rate of continuous wetting increases, so do the correlation levels associated with detection distance. The findings produced herein also showed weaker correlations than those previously reported. The researchers attribute this to the fact that a broad range of materials were used in this study, which had not been the case previously.

There was no continuous wetting rate that provided retroreflectivity measurements that resulted in significantly higher correlation rates than other continuous wetting rates (compared to detection distances). The strength of the correlations was not improved even when the continuous wetting rate to measure retroreflectivity and the rainfall rate used to measure detection distance were the same.

Raised retroreflective pavement markers (RRPMs) have the longest wet-night detection distance of any other marking tested. The average detection distance of the RRPMs was over 550 ft, which was over 200 ft longer than the longest average detection distance for any of the other markings tested.

Besides RRPMs, a newly available tape from 3M provided the longest wet-night detection distances under both the low and high rainfall rates (206 ft and 187 ft, respectively). In comparison, thermoplastic with Type III beads performed reasonably well within the group of non-structured markings. The detection distances measured under both the low and high rainfall rates were 183 ft and 155

ft, respectively. The benefit of the larger Type III bead was revealed when thermoplastic with Type II beads resulted in some of the substantially shorter detection distances (171 ft and 128 ft, respectively). The impact of heavier rain and small beads was again revealed by the Phase II results--the 128 ft detection distance for thermoplastic and Type II beads under the higher rainfall rate was the shortest detection distance of all markings studied in Phase II.

Various rumble stripe designs consisting of different spacings (12 inches and 24 inches on center) and different bead types (Type II and Type III) were compared versus their flat line counterparts. It was found that rumble stripes appear to improve wet-night performance when Type II beads are used. However, when Type III beads are used there is no apparent benefit in terms of maximum detection distance.

No conclusive benefits were found when the marking width was increased to 6-inch over the standard 4-inch width. The results of five pairs of markings were tested under dry and wet conditions. In addition, an interaction between research participants and wider lines was also explored, but to no avail.

#### *Findings from the Cost-Effectiveness Study*

Generally, thermoplastic pavement markings do not perform as well on Portland cement concrete (PCC) surfaces as they do on asphalt surfaces. Polyurea may be a viable alternative as it has displayed better performance on concrete, but costs twice as much. Tape products are another option that

should be considered for PCC surfaces but may be cost prohibitive.

Tape products are expensive but have several advantages: they can perform well in high traffic situations on PCC surfaces, they can provide greater visibility than other markings in both wet and dry conditions, they typically are warranted by the manufacturer, and they can be purchased as a contrast marking.

When considering wet and dry visibility, the most cost-effective system is spray applied thermoplastic with supplemental RRPMs.

#### *Findings from the Contrast Marking Study*

Contrast marking usage is increasing in the United States, 22% of states in 2002 versus 64% in 2006. In TxDOT districts, 64% say they currently use contrast markings, and 79% say they plan to use them in the future.

Contrast marking usage seems to be increasing on PCC surfaces, but has not been used much on faded asphalt surfaces.

Contrast marking tape was the most common material used even though it is the most expensive. The bordered design was the most commonly used design. This design was found to be unique to tape products and is applied to the roadway the same way standard tape is. The lead and lag designs were also common due to being easier to implement and maintain than some of the other designs.

Public feedback indicated a driver preference for bordered contrast marking.

# TRANSPORTATION RESEARCH DIGEST

## ARIZONA TRANSPORTATION INSTITUTE

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

*Corrosion Resistant Alloys for Reinforced Concrete* by William H. Hartt, Rodney G. Powers, Diane K. Lysogorski, Virginie Liroux & Y. Paul Virmani (Office of Infrastructure Research and Development, Federal Highway Administration, 6300 Georgetown Pike, McLean, VA 22101-2296; (202) 493-3022) (July 2007)

### Highlights

- The ranking (best to worst) was: 316 > Stelax >> 2201 > MMFX-II<sup>TM</sup> > 3Cr12 > Black Bar, except for the macro-cell slab specimens where the 3Cr12 exhibited longer times-to-corrosion than either 2201 or MMFX-II<sup>TM</sup>.
- Time-to-corrosion of the different reinforcements in concrete increased in direct proportion to the chloride threshold that was determined by accelerated testing.

Both short-term laboratory experiments in simulated pore solutions and long-term exposure of concrete specimens reinforced with corrosion resistant rebars exposed to chlorides were performed. The reinforcements included UNS-S31603 (Type 316L stainless steel (SS)), UNS-31803 (Type 2205 SS), ASTM A055-98 (Type 2201LDX SS), UNS-S41003 (Type 3Cr12 SS), ASTM A615, Grade 75 (MMFX-II<sup>TM</sup>), two 316 SS clad steels (Stelax and SMI), and ASTM A615 (black bar).

### Conclusions

For Accelerated Screening Test-1 (AST-1), which involved measurement of polarization resistance and weight loss of bars exposed to repetitive 1.75 hours wet--4.25 hours dry cycles in synthetic pore solution with chlorides for a total of 84 days, 316L SS solid bars performed best and black bars the worst. Corrosion rate for the other bars was intermediate and shared a common scatter band. Performance of the clad bars was mixed in that data for some specimens

without intentional clad defects approached that of the solid 316L SS, whereas with clad defects polarization resistance approached that of the black bars.

Accelerated Screening Test-2A (AST-2A) involved exposure of specimens that were potentiostatically polarized to +100 mV<sub>SCE</sub> in synthetic pore water to which chlorides were incrementally added. Corrosion initiation was defined as having occurred when current density reached 10  $\mu\text{A}/\text{cm}^2$ . For bars that became active, the average critical Cl<sup>-</sup> concentration for corrosion, [Cl<sub>th</sub><sup>-</sup>], was 0.25 weight percent (w/o) Cl<sup>-</sup> (black bar), 0.47 w/o Cl<sup>-</sup> (3Cr12), 0.87 w/o Cl<sup>-</sup> (MMFX-II<sup>TM</sup>), and 1.06 w/o Cl<sup>-</sup> (2201). By comparison of the presently determined [Cl<sub>th</sub><sup>-</sup>] values with those from the literature that were acquired using pore water expression from specimens for which companion chloride thresholds in concrete, C<sub>T</sub>, were available, C<sub>T</sub> of black bar was projected as 0.54 w/o, for 3Cr12 0.80 w/o, for MMFX-II<sup>TM</sup> 1.10 w/o, and 2201 1.30 w/o (cement weight basis). A comparison between the AST-1 and AST-2A data indicated that rebars with a polarization resistance greater than  $6 \times 10^4 \text{ ohm} \cdot \text{m}^2$  had a [Cl<sub>th</sub><sup>-</sup>] greater than 5 w/o, whereas below this [Cl<sub>th</sub><sup>-</sup>] was about 1 w/o or less. It was unclear if the [Cl<sub>th</sub><sup>-</sup>] could be predicted from the Pitting Resistance Equivalent Number (PREN).

Three types of reinforced concrete specimens, simulated deck slabs, three bar columns, and macro-cell slabs, have been under either continuous or cyclic wet-dry ponding

with a NaCl solution for over 600 days. Similar to the accelerated tests, the best corrosion resistance was exhibited by the 316L reinforcement (both solid and clad); however, no 2205 SS bars have been tested in concrete. For bars with poor or intermediate performance in the accelerated tests (black bar, 3Cr12, MMFX-II<sup>TM</sup>, and 2201), time-to-corrosion in concrete increased in proportion to  $[Cl_{th}]$  as determined in the accelerated AST -2A tests. The ranking (best to worst) was: 316 > Stelax >> 2201 > MMFX-II<sup>TM</sup> > 3Cr12 > Black Bar, except for the macro-cell slab specimens where the 3CR12 exhibited longer times-to-corrosion than either 2201 or MMFX-II<sup>TM</sup>. This may have been because these bars were wire brushed; however, if this is the explanation,

then wire brushing the pickled 3Cr12 resulted in greater corrosion resistance enhancement than wire brushing the as-rolled 2201 or MMFX-II<sup>TM</sup>.

In general, time-to-corrosion of the different reinforcements in concrete increased in direct proportion to the chloride threshold that was determined by accelerated testing (AST-2A).

Additional data are still being collected for the concrete specimens with various types of reinforcement that remain under test. Final analysis based on non-destructive data and observed condition of dissected specimens may change the ranking which will be documented in the final report.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

*Evaluation of Recycled Portland Cement Concrete Pavements for Base Course and Gravel Cushion Material* by L. Allen Cooley, Jr., Jimmy Brumfield, Jonathan Easterling and Prithvi S. Kandhal, Bums Cooley Dennis, Inc. 278 Commerce Drive Ridgeland, MS 39157 (South Dakota Department of Transportation, Office of Research, 700 East Broadway Avenue, Pierre. SD 57501-2586) (Jun 2007)

### **Highlights**

- Recycled Portland cement concrete pavements are a viable option for use in gravel cushion and aggregate base course construction.

The objectives of this research included the following:

- Determine if recycled Portland cement concrete pavements should be used as a base course or gravel cushion.
- Develop materials guidelines and specifications for construction of pavements using recycled concrete for base course or gravel cushion.
- Develop laboratory and field material testing requirements for recycled pavements.

### **Conclusions**

Recycled Portland cement concrete pavements are a viable option for use in gravel cushion and aggregate base course construction.

Because the SDDOT specifies and constructs gravel cushion and aggregate base course layers to be relatively impermeable, leachates or precipitates should pose no problems. Alkali-Silica reactivity is not considered a potential problem in gravel cushion or aggregate base course layers; however, it is unclear if some new deicing materials could affect the potential for alkali-silica reactivity problems in the future.

There is a concern about sulfate attack in thick layers of gravel cushion or aggregate base course. The critical thickness is not known.

Results from the Micro-Deval test were not found to be related to durability as defined by the lack of strong relationships with other durability tests.

The sodium sulfate soundness test had a strong relationship with results from the Los Angeles Abrasion and Impact test and the combined New York Freeze/Thaw and Micro-Deval test. Results of the sodium sulfate test are considered an indicator of durability. There is a potential that the sulfates contained in the sodium sulfate solution during soundness testing can attack the cement mortar within the recycled concrete aggregate resulting in artificially higher loss values. In these instances, the New York Freeze/Thaw test can be used as a surrogate test for the sodium sulfate soundness test.

The Los Angeles Abrasion and Impact test had a strong relationship with the sodium sulfate soundness and New York Freeze/Thaw test. Results from the Los Angeles Abrasion and Impact test are considered related to durability.

Results from the Atterberg limit testing, namely the liquid limit and plasticity index, identified potentially harmful fine materials added to RCA materials. Results of Atterberg limit testing is considered related to durability.

Strong and stable gravel cushion and aggregate base course layers can be attributed to the gradation, angularity and cleanliness of the RCA materials. Current gradation requirements contained within SDDOT specifications for gravel cushion and aggregate base course are applicable.

Recycled Portland cement concrete pavements have a relatively high level of water absorption. This relatively high level of water absorption could potentially make the proper compaction of gravel cushion and aggregate base course layers variable.

### **Recommendations**

Recycled Portland cement concrete pavements should be allowed within gravel cushion and aggregate base course layers.

Only recycled Portland cement concrete pavements owned by the Department should be allowed on new Department projects.

Recycled concrete aggregates crushed from Department owned pavements can be blended with conventional aggregates.

The cleanliness of recycled concrete aggregates should be specified. It is recommended that the Department maintain the requirements of a maximum liquid limit of 25 and maximum plasticity index of 6.

In order to minimize any potential effects of sulfate attack on recycled concrete aggregate layers, the Department should test nearby sub grade soils and surface water for sulfates. ASTM C1580, Standard Test Method for Water Soluble Sulfate in Soil, and ASTM D516, Standard Test Method for Sulfate Ion in Water, should be used.

The sodium sulfate soundness test should be used to evaluate the durability of potential recycled concrete aggregates for gravel cushion and aggregate base course. A maximum value of 15% is recommended.

The "Resistance of Coarse Aggregates to Degradation by Freeze/Thaw" should be utilized if the results of the sodium sulfate soundness test is greater than 30%. A maximum value of 15% for this freeze/thaw test is recommended.

The Los Angeles Abrasion test is recommended to evaluate the toughness and durability of recycled concrete aggregates. A maximum percent loss of 40% is recommended.

No changes are recommended to the current gradation requirements for gravel cushion or aggregate base course.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

*More Roads to Travel: A Path to Transportation Solutions in Arizona* by Byron Schmoach (Goldwater Institute, 500 East Coronado Road, Phoenix, Arizona 85004; Phone: (602) 462-5000; <http://www.goldwaterinstitute.org/common/img/tranbw.pdf>) (Apr 30, 2008)

### **Recommended Options**

- Build more roads.
- Use tolls to equitably & efficiently finance roads.
- Privatize transit.
- Stop requiring the AzDOT to purchase state land.
- Establish performance measures with accountability.
- Synchronize traffic signals.
- Build grade separations.
- Convert streets to one-way.
- Implement smart road technology.
- Adopt truck lane restrictions.
- Get rid of HOV lanes.

Arizona has a transportation problem. The average Phoenix commuter spends some 38 hours a year stuck in traffic, and one in Tucson spends an average 42 hours. Overall, traffic congestion costs Arizonans at least \$2 billion annually in lost time and wasted fuel. The state must take action on a number of fronts to ensure that transportation problems do not damage Arizona's economy and quality of life.

*Create a new transportation funding mechanism – toll roads.* Arizona should actively pursue a toll road policy, which would make it possible to build needed roads now, rather than decades from now. A toll road in San Diego only 10 miles long will allow many commuters to shorten their drives by 20 minutes, allowing many to have dinner with their families for the first time in years.

*Build more roads.* The state desperately needs an east-west alternative to I-10, bypassing Phoenix and Tucson, and could have such a road sooner if toll financing were used. Other construction recommendations are discussed in the report.

*Consider tolls or congestion pricing to reduce traffic at peak hours.* Fully half of the people on the roads at peak times are not commuting to work and could be encouraged to travel at a different time with toll incentives.

*Minimize expensive, inflexible mass transit and legalize flexible, private mass transit.* Phoenix isn't dense or centralized enough to be a good candidate for mass transit. Many countries have private systems using small vans and buses to transport riders on very flexible schedules and routes. Arizona should legalize this approach.

*Amend Arizona's constitution so that the Arizona Department of Transportation can avoid having to purchase state land.* Currently, it is illegal for the Arizona State Land Department to turn property over to any state agency for any purpose. AzDOT must buy the land, with proceeds going to public schools. Requiring the state to buy land from itself often makes building new roads cost-prohibitive.

*Implement known techniques to improve traffic flow.* These include signal synchronization, building grade separations, converting streets to one-way, and adopting restrictions on truck lanes. "Smart" road technology, such as dynamic signage, can help. The effectiveness of High Occupancy Vehicle

(HOV) versus general-purpose lanes should be evaluated.

Arizona's traffic is bad and getting worse. The costs of congestion are enormous. Arizona needs transportation solutions now. The state must act quickly to get more pavement on the ground and to revamp how roads are financed.

There is no magic bullet. Too often, policymakers promise more than they can ever possibly deliver, or the latest fad is promoted as an easy solution. Real solutions involve new ways of thinking. Many of the solutions offered above are new to Arizona, but they have been tried elsewhere throughout the world and are solving real transportation problems right now.

Responses to the state's traffic problems must reflect the reality that people prefer the flexibility and autonomy provided by cars.

Efforts at social engineering and expensive transportation fads should be avoided.

Market forces have a role to play. They can help stimulate investment and manage demand. Arizona drivers—indeed, drivers everywhere—seldom take into account the real costs of the commute decisions they make. Potential problem-solvers in the private sector need incentives to bring their potential solutions forward.

Economic development is good, and traffic is an inescapable byproduct. Increased traffic is not the problem, but unrealistic responses to traffic cause problems. Everybody can win if human ingenuity is fully harnessed and market incentives are allowed to work.

To improve transportation, policymakers should embrace a variety of approaches that harness market forces and the personal preferences of Arizonans.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

*Non-Vital Advance Rail Preemption of Signalized Intersections Near Highway-Rail Grade Crossings* by Leonard G. Ruback, Kevin Balke, and Roelof Engelbrecht, Texas Transportation Institute, Texas A&M University System, College Station, Texas 77843-3135 (Texas Department of Transportation, Research and Technology Implementation Office P.O. Box 5080, Austin, Texas 78763-5080; 979.845.1734; <http://tti.tamu.edu>) (Sep 2007)

### **Highlights**

- A significantly higher degree of accuracy is obtained from the radar-based train detection system.
- Neither type of NVAP strategy caused a significant change in the average queue lengths on the intersection approaches.

This research project experimented with the concept of non-vital advance preemption (NVAP). The NVAP would be a potential safety enhancement overlay for active grade crossings near signalized intersections. These intersections receive a preempt signal from the railroad which alerts the traffic signal controller to the impending arrival of a train and more specifically to the closure of the roadway by a lowered crossing gate. The intersection has to ensure vehicles and pedestrians are treated safely during the transition from intersection normal operation to operation in advance of a train. A simultaneous preemption from the railroad equipment provides a minimum of 20 seconds advance notice of the arrival of the train and simultaneous notification of the activation of the lights and gates. The solution grants the traffic controller a minimum amount of time to safely manage vehicles and pedestrians. Railroad-supplied advance preemption provides more time, but the costs are high and may not be fully warranted by the specifics of the intersection. The NVAP system is envisioned to provide a similar advance warning like the advance preempt, but at a

much lower cost and with equipment deployed solely on public right of way. The extra notification time supplied by the NVAP system could be used to better manage pedestrians by trying to ensure a minimum pedestrian phase (NVAP Type 1) or by eliminating it altogether in advance of a train (NVAP Type 2).

The research investigated two methods for train detection. The first method utilized microwave radar installed upstream and downstream of the target intersection where the NVAP will be used. The solution reused products from past TxDOT-sponsored research although the products are not “off the shelf” items. The second option was to use preemption signals from other intersections in a corridor to track to the progress of the train. This option was attractive because it required no extra equipment installed along the right of way; instead, it leveraged the value of current intersection investments.

Train arrival estimates are the central element on which the NVAP system operates. These estimates need to be as accurate as possible. Data gathered from the College Station radar system and the Alice preemption system testing clearly show the value of using a technique which can track and update (radar) itself over a simpler find and project solution (preemption).

The radar-based system clearly produced more reliable predictions. The system was able to predict the arrival of between 60% to 80% (approximately) of the trains within five

seconds of actual using radar sensors placed more than 3500 feet away. The probability extends to as much as 96% for an interval of 10 seconds around the expected. The standard deviation for the radar system was consistently lower than the preemption system. In all but the close intersection case at Cameron with a standard deviation of 8.8 seconds, the radar system standard deviation is better than half that of the preemption solution.

The preemption only option does not compare well. Probabilities compare only if the distances between locations are short, as would be expected. As distances increase, the reliability suffers greatly as shown by the quickly increasing standard deviation. Looking at the 140-second mean case, the site was located approximately 3000 feet away from the target intersection. Using this case to compare to the radar option (radars were more than 3500 feet away), the value of the radar solution is easily seen. The radar system, at worst case, was able to post a 59% probability of predicting the arrival within 5 seconds of the expected while the preemption system was only able to yield at 25% probability.

The research shows that a significantly higher degree of accuracy is obtained from the radar-based train detection system. This solution should be used for NVAP strategies that are sensitive to prediction variation. In the case of NVAP Type 1, very long dwell times can occur in the track clearance phase which results in lower operational efficiency at the location. The preemption-based solution may be reasonable for detection situations where a much lower degree of accuracy is required. For example, the scheme may be appropriate for a project which takes a more macroscopic perspective on corridor operations. In this case the important aspects might be that a train is approaching an intersection and will arrive within a time period of 60 seconds. Precise

decisions are not made using the train data, but rather the data are used as more general information describing the situation in the corridor.

In terms of enhancing pedestrian safety at signalized intersections, the research found that both the NVAP Type 1 and NVAP Type 2 strategies were able to reduce the number of times that the pedestrian clearance interval had to be truncated compared to when simultaneous preemption was used at the test intersections. NVAP Type 1, which uses a second preemption to ensure that a full pedestrian clearance interval is provided in advance of the normal preemption sequence, provided adequate pedestrian clearance in almost every observed train event, but resulted in increased vehicle delays at the intersection. NVAP Type 2 strategy, which uses Pedestrian Omits (a feature available in most NEMA type controllers) to skip the pedestrian phase altogether, resulted in fewer truncations of the pedestrian walk interval. Using the NVAP Type 1 strategy also resulted in a 30-percent reduction in the number of times that the vehicle green interval had to be truncated during the preemption sequencing.

In terms of intersection operations, the NVAP Type 1 strategy caused the average intersection delay to increase approximately 13% compared to when the other strategies were used at the test intersections. NVAP Type 2 showed no appreciable increase in vehicle delays; however, one disadvantage of this strategy was the long time delay between activations of pedestrian walk intervals which could cause pedestrians at intersections to feel like they have been skipped and potentially cross when a "DON'T WALK" indication is active at the intersection. Neither type of NVAP strategy caused a significant change in the average queue lengths on the intersection approaches.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

**Traffic Control Design For Portable Concrete Barriers** by M.B.C Ulker, M. S. Rahman, A. Mirmiran, R. Zheng, Department of Civil Engineering, North Carolina State University, Campus Box 7908, Raleigh, NC 27695-7908 (NC Department of Transportation, Research and Analysis Group, 104 Fayetteville Street, Raleigh, NC 27601) (APR 2006)

### **Highlights**

- The problems of vehicular impact on barriers are investigated.
- Two types of barriers were evaluated: (1) New Jersey barriers and (2) Oregon Tall-F barriers.

In this study the problem of vehicular impact on barriers are investigated. The two available crash tests are modeled and impact response simulated through a finite element based program, ANSYS/LS-DYNA. On the basis of the insight gained through these detailed numerical analyses and calibration of essential model parameters, a simpler program, MSC Working Model, is used to perform a comprehensive study of the barriers' response under vehicular impact. This leads to the development of a set of design curves for assessing the barrier displacement and related design variables.

The finite element based modeling and simulation was found to be a very useful tool to study the impact problem under consideration. In addition, the finite element software, ANSYS/LS-DYNA, is found to be an effective too; with adequate capabilities and useful features. Some basic benchmark problems were solved analytically and numerically. The comparison of the results showed a good agreement. Then, with a sense of confidence in ANSYS/LS DYNA, the researchers moved to the actual modeling and simulation of the two crash tests. As far as the maximum displacements of the barrier segments are

concerned, for both of the crash simulations, results obtained from finite element study agreed well with the crash tests. Besides, overall behavior of the vehicles and the barriers during the simulations for both of the crash .models compared reasonably well with those from the crash tests. Also, from additional studies of the simulation of two crash tests, it was found that the concrete barriers can be treated as rigid bodies. This provided the justification to use the simpler program of MSC Working Model for further analyses and the development of design curves.

The design curves here are developed on the basis of a detailed study of collision between vehicle and the barriers and therefore these are recommended to replace the existing empirical method currently used by NCDOT.

It is very important to note that the conditions used for developing the design charts and tables and the following summary results need to be the same as those in the crash tests that were used to calibrate the models in this study. For example, wet or dry condition of the pavement may have a significant effect on the deflections. Moreover, the design charts and tables and the following summary results are based on the vehicle type used in the crash tests, and could be quite different for heavier vehicles.

*New Jersey barriers on asphalt pavements:*

- a) For speeds less than 45 mph, with only one lane of traffic, the barrier is not expected to deflect more than 2.5 ft. For

roadways with more than one lane of traffic, the barrier could deflect as much as 3.5 ft.

b) For speeds between 45 and 65 mph, with only one lane of traffic, the barrier is not expected to deflect more than 3 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 4 ft.

c) For speeds greater than 65 mph or conditions different from the crash tests used for calibration of the model, or for a more precise deflection calculation, one may directly consult with the design charts and tables.

*New Jersey barriers on concrete pavements:*

a) For speeds less than 45 mph, with only one lane of traffic, the barrier is not expected to deflect more than 1.75 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 2.5 ft.

b) For speeds between 45 and 65 mph, with only one lane of traffic, the barrier is not expected to deflect more than 2 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 3 ft.

c) For speeds greater than 65 mph or conditions different from the crash tests used for calibration of the model, or for a more precise deflection calculation, one may directly consult with the design charts and tables.

*Oregon Tall-F barriers on asphalt pavements:*

a) For speeds less than 45 mph, with only one lane of traffic, the barrier is not

expected to deflect more than 1.5 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 2.25 ft.

b) For speeds between 45 and 65 mph, with only one lane of traffic, the barrier is not expected to deflect more than 1.75 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 2.5 ft.

c) For speeds greater than 65 mph or conditions different from the crash tests used for calibration of the model, or for a more precise deflection calculation, one may directly consult with the design charts and tables.

*Oregon Tall-F barriers on concrete pavements:*

a) For speeds less than 45 mph, with only one lane of traffic, the barrier is not expected to deflect more than 1.25 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 1.75 ft.

b) For speeds between 45 and 65 mph, with only one lane of traffic, the barrier is not expected to deflect more than 1.5 ft. For roadways with more than one lane of traffic, the barrier could deflect as much as 2 ft.

c) For speeds greater than 65 mph or conditions different from the crash tests used for calibration of the model, or for a more precise deflection calculation, one may directly consult with the design charts and tables.

# TRANSPORTATION RESEARCH DIGEST

## ARIZONA TRANSPORTATION INSTITUTE

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

**Improved Load Rating of Reinforced Concrete Slab Bridges** by David V. Jauregui, Alicia Licon-Lozano, and Kundan Kulkarni, Mew Mexico State University, Department of Civil Engineering, Box 30001, MSC 3CE, Las Cruces, NM 88003-8001 (NMDOT Research Bureau, 7500B Pan American Freeway NE, PO Box 94690, Albuquerque, NM 87199-4690) (Sep 2007)

### Highlights

- An AASHTO load rating analysis of Bridge 7270 was performed.

The largest vehicular live-load effects were produced by the design tandem in the positive moment regions and the HS20 design truck in the negative moment regions. The controlling legal truck for positive moment was the Type 3 while the Type 3S2 controlled for negative moment (except at one location).

Using the approximate method of analysis (i.e., the AASHTO equations for equivalent strip width), the lowest rating factors for positive moment were  $RF_{inv} = 1.03$  and  $RF_{opr} = 1.34$ . These ratings occurred close to midspan of the first (exterior) and fourth (interior) spans. For negative moment, the smallest ratings occurred at a rebar cutoff location and equaled  $RF_{inv} = 0.84$ ,  $RF_{opr} = 1.08$ , and  $RF_{legal} = 1.13$ .

Based on the rating factors obtained from approximate analysis, Bridge 7270 has a safe load capacity for AASHTO legal loads and state legal loads having only minor variations from the AASHTO loads.

The measured tensile strains under the test truck loads plus the estimated dead load strains exceeded the concrete cracking strain at several locations in the positive and negative moment regions. These results confirmed that the concrete was cracked and thus, implied that the slab was not a gross section.

In the positive moment regions, the experimental neutral axis locations varied

across the slab width but overall lied about halfway between the theoretical limits based on uncracked and cracked section behavior. In the negative moment regions, the experimental neutral axis positions also varied and fit within the theoretical bounds but more towards an uncracked section.

The experimental neutral axis depths did not vary significantly under the 5-yard and 10-yard dump trucks, indicating that the slab had about the same stiffness under both loads. On the whole, the neutral axis evaluation supported the use of an intermediate section modulus for computing the experimental bending moments of the slab.

Bridge 7270 was modeled as a prismatic, concrete slab with linear-elastic and homogeneous material properties. Finite element moments in the slab determined under the 5-yard and 10-yard dump trucks fit between the experimental  $M_{cr}$  and  $M_{gr}$  moments (derived from measured tensile strains) which represent the limits of cracked and gross section behavior.

At the midspan and pier sections of the first span, the finite element moments approximated the  $M_{av}$  (i.e., the average of  $M_{cr}$  and  $M_{gr}$ ) moments. In the second span, the finite element moments agreed best with the  $M_{cr}$  moments at midspan and the  $M_{gr}$  moments at the pier. Overall, the experimental moments (determined using the average section modulus) agreed reasonably well with the analytical moments from a baseline finite element model

which considered only the concrete slab superstructure.

The diagnostic test results did not reveal any sort of inadvertent behavior (e.g., edge member participation, unintended continuity) that could further improve the behavior of this particular bridge beyond that captured by the baseline model. Yet there may be cases where the load distribution may be more favorable than that determined by a baseline model. For example, slab bridges having Jersey barriers joined continuously along the edge (rather than discretely connected metal rails) may benefit from the stiffness contribution of the edge members; however, such type of behavior should be verified through load testing before it is included in the refined analysis.

In the positive and negative moment regions, the critical transverse position of the design vehicles (for one lane loaded) was the one with the nearest wheel line located a distance of 2 ft. from the edge of the rail. For multiple loaded lanes (i.e., two and three lanes), the critical configuration happened with the lanes positioned right next to the rail and no horizontal separation between the lanes.

Under design loading and including the multiple presence factors, the largest slab moments from finite element analysis were produced by two loaded lanes for positive moment and one loaded lane for negative moment. The smallest moments were produced by three loaded lanes.

The critical equivalent widths from refined analysis were based on different load cases; two loaded lanes controlled in the positive moment regions and one loaded lane controlled in the negative moment regions. On the other hand, the controlling case from approximate analysis was "more than one lane loaded" for both positive and negative moment.

The equivalent widths obtained by refined analysis were greater than those determined using the AASHTO approximate method of analysis. The refined widths were 26.1 % and 13.1 % larger at the first midspan and first pier, respectively. At the midspan and pier locations of the second span, the refined widths were 22.1 % and 11.1 % greater. This comparison indicated that the approximate widths were conservative, particularly for positive moment.

The increase in the equivalent strip widths obtained from refined analysis signifies a decrease in live-load effects, which in turn proportionally increases the rating factors. That is, the rating factors increased by the same percent increase in the equivalent widths. As a result of the higher level evaluation, the lowest inventory and operating rating factors improved from 0.84 to 0.93 and 1.08 to 1.20 (an increase of 11 %), respectively. The factors increased by just 11% (rather than over 20%) since the rating was controlled by negative moment and not positive moment.

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

***Does Rail Transit Save Energy or Reduce Greenhouse Gas Emissions?*** by Randal O'Toole (Cato Institute, 1000 Massachusetts Avenue, N.W., Washington D.C. 20001-5403; Phone (202) 842-0200: <http://www.cato.org/pubs/pas/pa-615.pdf>) (April 14, 2008)

### **Highlights**

- ❑ Most rail transit lines use more energy per passenger mile than the average passenger automobile.
- ❑ Getting 1% of commuters to switch to hybrid-electric cars will cost less and do more to save energy than getting 1% to switch to public transit.

Far from protecting the environment, most rail transit lines use more energy per passenger mile, and many generate more greenhouse gases, than the average passenger automobile. Rail transit provides no guarantee that a city will save energy or meet greenhouse gas targets.

While most rail transit uses less energy than buses, rail transit does not operate in a vacuum: transit agencies supplement it with extensive feeder bus operations. Those feeder buses tend to have low ridership, so they have high energy costs and greenhouse gas emissions per passenger mile. The result is that, when new rail transit lines open, the transit systems as a whole can end up consuming more energy, per passenger mile, than they did before.

Even where rail transit operations save a little energy, the construction of rail transit lines consumes huge amounts of energy and emits large volumes of greenhouse gases. In most cases, many decades of energy savings would be needed to repay the energy cost of construction.

Rail transit attempts to improve the environment by changing people's behavior so

that they drive less. Such behavioral efforts have been far less successful than technical solutions to toxic air pollution and other environmental problems associated with automobiles.

Similarly, technical alternatives to rail transit can do far more to reduce energy use and CO<sub>2</sub> outputs than rail transit, at a far lower cost. Such alternatives include the following:

- Powering buses with hybrid-electric motors, biofuels, and—where it comes from non-fossil fuel sources—electricity;
- Concentrating bus service on heavily used routes and using smaller buses during off-peak periods and in areas with low demand for transit service;
- Building new roads, using variable toll systems, and coordinating traffic signals to relieve the highway congestion that wastes nearly 3 billion gallons of fuel each year;
- Encouraging people to purchase more fuel-efficient cars. Getting 1% of commuters to switch to hybrid-electric cars will cost less and do more to save energy than getting 1% to switch to public transit.

If oil is truly scarce, rising prices will lead people to buy more fuel-efficient cars. But states and locales that want to save even more energy and reduce greenhouse gas emissions will find the above alternatives far superior to rail transit.

**Transit's Share of Commuting (percent)**

	1970	1980	1990	2000	2006	Rail Began
Atlanta	10.4	9.1	5.9	4.1	4.4	1979
Baltimore	16.9	12.3	9.3	7.4	8.1	1983
Boston	18.2	13.5	12.7	12.5	12.3	1888
Buffalo	12.3	16.4	5.5	4.0	4.9	1986
Chicago	24.4	18.7	15.8	12.6	12.2	1892
Cleveland	14.0	11.5	6.8	5.0	4.6	1884
Dallas-Ft. Worth	5.7	4.0	2.7	2.2	2.1	1996
Denver-Boulder	4.6	6.6	4.8	5.1	5.3	1994
Houston	6.0	3.5	4.5	3.8	3.2	2004
Los Angeles	4.8	5.9	5.6	6.0	6.3	1988
Miami-Ft. Lauderdale	6.2	4.3	3.7	3.3	4.0	1984
Minneapolis-St. Paul	9.5	10.0	6.2	5.5	5.1	2004
New Orleans	21.5	11.5	8.3	7.1	2.9	1892
New York	39.0	30.7	29.3	28.9	30.8	1905
Philadelphia	23.0	15.1	12.4	10.1	9.8	1890
Pittsburgh	17.7	13.8	10.2	8.1	8.0	1890
Portland	7.0	9.8	6.7	7.7	7.6	1986
Sacramento	2.7	4.1	2.8	2.9	2.9	1987
Salt Lake City	2.3	5.5	3.5	3.6	4.2	1999
San Diego	4.8	3.5	3.5	3.6	3.3	1981
San Francisco-Oakland	16.0	16.8	14.5	14.3	13.1	1972
San Jose	2.4	3.1	3.1	3.6	3.6	1988
Seattle	6.6	9.1	7.1	7.9	8.1	2000
St. Louis	9.2	6.9	3.5	2.9	3.1	1994
Washington	17.6	16.7	15.6	13.7	16.9	1976

Sources: Census Bureau, *Decennial Census, 1970 through 2000*, and *American Community Survey for 2006* (Washington: Census Bureau).

# **TRANSPORTATION RESEARCH DIGEST**

## **ARIZONA TRANSPORTATION INSTITUTE**

e-mail [jsemmens@cox.net](mailto:jsemmens@cox.net)

MAY 2008

***Performance-Based Budgeting for North Carolina Public Transportation*** by Thomas J. Cook, Judson J. Lawrie, Institute for Transportation Research and Education North Carolina State University, Centennial Campus, Box 8601, Raleigh, NC 27695-8601 (North Carolina Department of Transportation Research and Analysis Group, 1 South Wilmington Street, Raleigh, North Carolina 27601) (Jun 2007)

### **Highlights**

- ❑ Few transit systems use formal performance-based budgeting.
- ❑ An approach to performance-based budgeting is recommended.

In order to better understand how North Carolina public transportation systems currently plan and budget, interviews were conducted with individuals from six representative transit agencies as well as from the North Carolina Department of Transportation/Public Transportation Division (NCDOT/PTD) about their planning, accounting, budgeting and performance measurement systems. In addition, various materials and documents were obtained and reviewed. Following is a summary of the questions that were explored.

#### *Are Planning or Goal-Setting Processes Used to Set a Direction at the Beginning of Each Year?*

There was a mixture of practices on this. Some transit system representatives described their planning/goal-setting/budgeting method as an integrated, continuous process of looking at needs, issues, problems, performance and finances, and then developing a budget accordingly. Others basically start with the current budget, determine if any additional funds will be available for new service, and then develop the budget for the following year.

#### *Do the Plans or Goals Include any Performance Measures?*

All of the transit systems consider performance in some manner. In particular, typical factors such as ridership and cost of service are commonly analyzed. Only a few systems use the more difficult and complex efficiency and effectiveness measures.

#### *Are the Plans or Goals Linked to the Budgeting Process?*

For the most part, those transit systems that conduct some kind of planning or goal-setting process before beginning the budget cycle use those plans and goals to formally or informally influence the budget development process.

#### *Does the Budget Document Include Any Performance Measures?*

None of the transit systems appear to incorporate any performance measures in their budget documents.

#### *What Accounting System is Used?*

Some of the transit systems use the NCDOT/PTD's Uniform Public Transportation Accounting System (UPTAS). Some of the systems use the MUNIS financial system utilized by many counties and municipalities, and then make manual adjustments as needed when submitting information to the NCDOT/PTD. One transit system that is a unit of a larger non-profit agency uses the accounting system of that agency.

### *What Kind of Performance Reporting is Performed During the Budget Year?*

Most of the monthly, quarterly or annual reporting involves only financial performance. Some reporting includes other performance information but it tends to be in the form of "outputs" such as ridership, service miles, etc., or information about such items as customer complaints and safety data.

### **Conclusions**

North Carolina transit systems use a variety of planning, goal-setting, performance measurement, budgeting and accounting systems and practices. They are also of greatly different size, are either urban or rural in nature, and may be a unit of city or county government. They also may be a public transportation authority or a non-profit agency. Finally, they may operate service directly, or through a contract operator. This suggests that a performance-based budgeting process designed for public transportation systems throughout the state will have to be adaptable to a great variety of system types and sizes.

Few transit systems in North Carolina use formal performance-based budgeting. In fact, this study only identified two systems that use some form of it— Charlotte Area Transit System (CATS) and the Triangle Transit Authority (TTA). This is not to say that it is not used by any other systems, only that the researchers were unable to locate any. Nor is it to say that only CATS and TTA use performance in their various management, planning and budgeting activities. Many if not all transit systems use performance in some way, formally or informally, as part of their ongoing management and operation of the systems.

There is a "next level" of performance-based budgeting (PBB) that would involve realigning accounting and financial reporting systems with the programs and services that are

the focus of performance measurement. This could even involve combining PBB with "program budgeting," the creation of accounting and financial reporting structures that allow information to be collected and aggregated across departmental boundaries. This is generally a substantial undertaking and may be appropriate for the larger, more complex transit systems after they have gained some experience with PBB. It is probably not a level that would be either necessary or feasible at smaller systems with limited staff and resources.

Finally, performance budgeting should be looked at as a process, not a new budget format. A performance-based budget may not look significantly different than a traditional line item budget; however, the process to develop the budget will be informed by the organization's performance.

### **Recommended Approach**

Create a mission statement and vision statement for the organization (or review the existing ones).

Develop long-term strategic goals that are "aligned" with the mission and vision.

For each strategic goal, develop more detailed and specific budget-year objectives for the upcoming budget year. These should include performance measures that will help gauge whether the objectives are being achieved.

Decide on the strategies, programs and/or actions that will be necessary to achieve the budget-year objectives.

Estimate the costs of the strategies, programs and actions and incorporate these costs in the proposed budget.

Once the budget year has started, report and monitor actual results (both financial and performance). If the results are not in line with what was expected or planned, make adjustments as necessary.