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AGING INFRASTRUCTURE

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In this issue of *The CIP Report,* we examine aging infrastructure and its impact on the security of our nation. The articles we feature this month analyze aging infrastructure issues within different sectors as well as overall areas that require attention.

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The first article provides an overview of the American Society of Civil Engineers' (ASCE) 2009 *Report Card for America's Infrastructure*. The second article comes from the American Association of State Highway and Transportation Officials (AASHTO) and provides an overview of their goals and current work. The third article focuses on a presentation from the Workshop on Aging Infrastructure held July 2009 at Columbia University.

We also feature a contribution from ASME Innovative Technologies Institute, LLC (ASME-ITI) on optimizing infrastructure investments. The next article discusses physical exams of aging buildings and the various issues that are involved with these buildings. Water infrastructure is another area featured in an article from the Water Environment Federation. The following article looks at the transportation sector, specifically the Washington Metropolitan Area Transit Authority (WMATA), and analyzes its critical funding needs. An article from New York University discusses infrastructure security and natural hazards. Lastly, *Legal Insights* discusses the Transportation Appropriations Act.

We hope you find this issue of *The CIP Report* informative and helpful. Thank you for your feedback and support.

Mick Kicklighter
Director, CIP
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America's Infrastructure

by Andrew W. Herrmann, PE, F.ASCE
ASCE 2010 Treasurer and Chair 2009 Report Card for America's Infrastructure

Our nation's infrastructure is plagued by aging systems and inadequate capacity. Earlier this year, the American Society of Civil Engineers (ASCE) released its 2009 *Report Card for America's Infrastructure*. The report found that the country's infrastructure rated a disappointing cumulative grade of "D," the same grade in the previous report card in 2005. This reflects little or no progress maintaining, repairing, and modernizing the nation's infrastructure over the last four years. In fact, while only one grade improved, that of the energy category, grades in three categories, aviation, roads, and transit, dropped.

Massive investment is needed at all levels of government to raise the infrastructure grades to an acceptable level. The Report Card shows a staggering deficit between the actual and needed investment levels. ASCE estimates the need for investment to be $2.2 trillion over the next five years, an increase of more than half a trillion dollars since 2005. Current spending projections are only $1.1 trillion over that same period, equal to just 50 percent of actual need.

Problems

While it is easy to become caught-up in large budget numbers and nationwide concerns, the problems of America's infrastructure affect the everyday lives of Americans in a concrete way. For example, transportation systems across the U.S. are suffering the effects of age and overuse. Failure to invest in an already over-stressed transportation infrastructure is having a tangible impact on Americans' way of life, including longer commute times, greater wear on vehicles, and increased safety concerns. Decaying transportation systems also have a significant impact on U.S. businesses, by delaying freight delivery, creating unpredictability in supply chains, and increasing shipping costs, which increases consumer costs and diminishes competitiveness.

One-third of America's major roads, a category which received a "D-" in the Report Card, are in poor or mediocre condition, and forty-five percent of major urban highways are congested. Americans are spending 4.2 billion hours a year stuck in traffic at a cost to the economy of $78 billion, or $710 per motorist. Congestion has become a critical challenge for the nation's highway systems, with wasted fuel climbing from 1.7 billion gallons in 1995 to 2.9 billion gallons in 2005.[1] Additionally, more than 26 percent of the nation's bridges are either structurally deficient or functionally obsolete, with the number of deficient bridges in urban areas rising.[2] With bridges remaining a "C" in the Report Card, an annual investment of $17 billion is needed to substantially improve conditions, compared to the $10.5 billion that is currently being spent. Together, roads and bridges need an investment of $930 billion over the next five years; however, there is a projected deficit of $594 billion.

In addition to roads and bridges, Americans increasingly depend on public transit systems for their transportation needs. Transit use increased 25 percent between 1995 and 2005, more than any other mode of transportation, but unfortunately, U.S. transit infrastructure only received a grade of "D" in the Report Card. Nearly half of American households do not

(Continued on Page 3)

[1] Texas Transportation Institute, *The 2007 Urban Mobility Report*.

[2] A structurally deficient bridge may be closed or restrict traffic in accordance with weight limits because of limited structural capacity. These bridges are not necessarily unsafe, but must post limits for speed and weight. A functionally obsolete bridge has older design feature and geometrics, and though also not necessarily unsafe, cannot accommodate current traffic volumes, vehicle sizes and weights.

ASCE *(Cont. from 2)*

have access to bus or rail transit, and only 25 percent have what they consider a "good option." The Federal Transit Administration estimates that $21.6 billion is needed annually to improve the system to good conditions. In 2008, federal contributions totaled $9.8 billion.

Another mode of transportation becoming increasingly popular, yet still suffering from condition and capacity issues, is the nation's rail system, which received a "C-" in this year's Report Card. As fuel efficiency becomes more important, the rail system will continue to be a viable option for both cargo and passenger travel. A freight train is three times as fuel efficient as a truck, and traveling by passenger rail uses 20 percent less energy per mile than traveling by car. To accommodate the increase in demand, an investment of more than $200 billion is needed through 2035.

Surface transportation is not the only form of transportation that is in need of attention. Both inland waterways and airports received poor grades in the Report Card, "D-" and "D," respectively. Airports continue to grapple with outdated systems that cause delays and waste money in fuel and time. In 2007, airlines incurred the second-worst on-time arrival record in history, with only 73 percent of flights arriving on time. A funding shortfall of more than $40 billion over the next five years will only serve to intensify the problem. Meanwhile, the nation's inland waterways also need major repair and updating. Of the 257 locks still in use on these waterways, 30 were built in the 1800s and another 92 are more than 60 years old, well past their design life of 50 years. The cost to replace the present system is estimated to be more than $125 billion.

While transportation may provide some of the most visible evidence of aging infrastructure, the management of water and environmental systems can also have a major effect on Americans' quality of life. Leaking pipes lose an estimated 7 billion gallons of clean drinking water every day. Aging facilities and an annual shortfall of $11 billion in spending earned the U.S. drinking water systems a grade of "D-." Similarly, wastewater treatment in the United States also received a grade of "D-." The physical condition of many of the nation's 16,000 wastewater treatment systems is poor due to a lack of investment in plants, equipment, and other capital improvements. Sanitary sewer overflows, caused by blocked or broken pipes, result in the release of as much as 10 billion gallons of raw sewage yearly, according to the EPA.[3] The U.S. drinking water and wastewater systems need a combined investment of $255 billion, but the projected spending is only $140 billion. If the nation fails to meet these needs, it risks reversing public health, environmental, and economic gains of the past three decades.

In addition to the problems with the nation's water systems, both dams and levees faired poorly in the Report Card with a "D" and "D-," respectively. Many dams have been determined to be deficient as a result of aging, deterioration, and lack of maintenance. There are more than 85,000 dams in the United States, and the average age is 51 years. The number of dams determined to be deficient has risen to more than 4,000 — including 1,819 that are classified as high hazard potential dams.[4] Over the past six years, for every deficient, high hazard potential dam repaired, nearly two more were declared deficient. Levees, which have received a great deal of attention in the last few years, received a nearly failing grade due to a lack of information about their reliability, their impact on life and safety issues, and the significant consequences of failure. More than 85 percent of the nation's estimated 100,000 miles of levees are locally owned and maintained. Rough estimates put the repair and rehabilitation cost at more than $100 billion.

While solid waste management received the Report Card's highest grade of "C+," it still faces numerous challenges. This grade is due in large part to the fact that more than a third of solid waste was

(Continued on Page 4)

[3] U.S. Environmental Protection Agency, *Clean Watersheds Needs Survey 2000 Report to Congress*, January 2004, www.epa.gov/owm/mtb/cwns/2000rtc/toc.htm.

[4] Association of State Dam Safety Officials, *Statistics on Dams and State Safety Regulation* (2007).

ASCE *(Cont. from 3)*

recycled or recovered, an increase of seven percent since 2000. However, per capita waste generation has remained generally constant over the last two decades, and the increasing volume of electronic waste creates potentially high levels of hazardous materials and heavy metals in the nation's landfills. Additionally, despite its potential for creating jobs and production revenue, brownfields redevelopment is underfunded — which is why hazardous waste received a "D." Federal funding for reclaiming the nation's worst toxic sites has declined to its lowest level in twenty years and 188 cities across the U.S. have brownfields[5] sites awaiting cleanup.

Solutions

The nation's infrastructure faces real problems that threaten our way of life if they are not addressed. These problems are solvable if we have the needed vision and leadership. Raising the grades on our infrastructure will require that we seek and adopt a wide range of structural and non-structural solutions, including technical advances, funding and regulatory changes, and changes in public behavior and support. In addition to the grades in the Report Card, ASCE also offers five key solutions to begin solving America's infrastructure crisis.

Increase Federal leadership in infrastructure.

During the 20th century, the federal government led the way in building our nation's greatest infrastructure systems. The New Deal programs, the Interstate Highway System, and the Clean Water Act are a few examples of that strong leadership. Unfortunately, federal leadership has since decreased, and the condition of the nation's infrastructure has suffered. America's infrastructure needs bold leadership and a compelling national vision, and that strong national vision must originate with strong federal leadership and be shared by all levels of government and the private sector.

Promote sustainability and resilience.

Infrastructure systems must be designed to protect the natural environment and withstand both natural and man-made hazards, using sustainable practices, to ensure that future generations can use and enjoy what is built today, as we have benefitted from past generations. Sustainability and resiliency must be an integral part of improving the nation's infrastructure, and both structural and non-structural methods must be applied to meet challenges. Additionally, research and development should be funded at the federal level to develop new, more efficient methods and materials for building and maintaining the nation's infrastructure.

Develop federal, regional, and state infrastructure plans.

Infrastructure investment at all levels must be prioritized and executed according to well conceived plans that both complement the national vision and focus on system-wide outputs. Goals of the plans should center on freight and passenger mobility, intermodality, water use, environmental stewardship, and encouraging resiliency and sustainability. These plans must reflect a better defined set of federal, state, local, and private sector roles and responsibilities, and instill better discipline for setting priorities and focusing funding to solve the most pressing problems. Additionally, they should complement broad national goals of economic growth and leadership, resource conservation, energy independence, and environmental stewardship.

Address life-cycle costs and ongoing maintenance.

As infrastructure is built or rehabilitated, life-cycle cost analysis should be performed for all systems to account for not only initial construction, but also operation, maintenance, environmental, safety, and other costs reasonably anticipated during the life of the project, such as recovery after disruption from natural or man-made hazards. Additionally, owners should be required to perform ongoing evaluations and maintenance to keep the system functioning at a safe and satisfactory level.

(Continued on Page 22)

[5] Brownfields sites are former industrial and commercial sites potentially containing hazardous waste.

American Association of State Highway and Transportation Officials (AASHTO): Working Toward Reviving our Aging Bridges and Structures

by Kelley Rehm, P.E.
Consultant for the AASHTO Bridges and Structures Program

AASHTO Overview

The American Association of State Highway and Transportation Officials (AASHTO) is a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. It represents all five transportation modes: air, highways, public transportation, rail, and water. Its primary goal is to foster the development, operation, and maintenance of an integrated national transportation system.

Membership in AASHTO is on an agency basis. All State Departments of Transportation (DOT) are active members, and several sub-state and federal transportation agencies in the United States, as well as many transportation agencies in other countries, belong to the Association as associate members. Membership is not extended to individuals or private sector entities.

Much of AASHTO's work is performed by committees comprised of member department personnel who serve voluntarily. The Association provides a forum for consideration of transportation issues and is frequently called upon by Congress to conduct surveys, provide data, and testify on transportation legislation. Through AASHTO's policy development activities, member departments often address federal programs and provide guidance.

For 2009 AASHTO has developed a Strategic Plan to include the following goals:

Goal 1: Re-establish transportation as a national priority.
Goal 2: Advocate and communicate to achieve AASHTO's goals.
Goal 3: Provide world class technical services.
Goal 4: Assist State DOTs with leadership and performance.

Vision: The American Association of State Highway and Transportation Officials is the voice for transportation and catalyst for organizational and technical excellence.

Mission: The American Association of State Highway and Transportation Officials advocates transportation-related policies and provides technical services to support states in their efforts to efficiently and safely move people and goods.

The Highway Subcommittee on Bridges and Structures (SCOBS), in conjunction with many other committees and subcommittees, is working hard to meet Goal 3. The primary intent of this goal is to ensure the continuation of AASHTO's world leadership role in the development of transportation standards and other technical services. This goal will focus on increasing the number of beneficiaries, ensuring continued state DOT participation in critical technical activities, expanding training opportunities for transportation agency professionals, and developing centers of excellence in safety, operations, finance, and freight transportation. As part of this goal, the SCOBS, along with the Subcommittee on Maintenance, is striving to provide technical expertise, research, and technical services in the area of PRESERVATION for our aging bridges and highway structures.

AASHTO Subcommittee on Bridges and Structures (SCOBS): Working Toward Preserving Our Aging Infrastructure

The AASHTO SCOBS is one of the many groups within AASHTO

(Continued on Page 6)

AASHTO *(Cont. from 5)*

making significant efforts to preserve our country's aging infrastructure, in particular, its bridges and structures. In 2006, a new technical committee, a subgroup of SCOBS, was formed with the designation of Bridge Preservation. This group works closely with the AASHTO Subcommittee on Maintenance in order to promote needed research and technical activities in the area of preservation of the nation's bridges. More information on this technical committee, as well as the other 19 technical committees under SCOBS, can be found at http://bridges.transportation.org.

After the tragic collapse of the I-35W Bridge in Minneapolis in 2006, much attention was focused on the condition of the nation's bridges and structures. As a result of the National Transportation Safety Board's (NTSB) investigation, several recommendations on the preservation of bridges were presented to AASHTO. Out of the six recommendations provided to AASHTO by NTSB, three of them dealt with inspection and preservation of existing bridges. SCOBS worked quickly to meet the recommendations of NTSB. At the annual meeting of SCOBS in July 2009, the Subcommittee approved amendments to the AASHTO *Manual for Bridge Evaluation* (MBE) and the AASHTO Guide to *Commonly Recognized Structural Elements* (CoRE) document that provided for more in-depth information on how to inspect and load rate gusset plates and connections. AASHTO also supports a Federal Highway Administration / National Cooperative Highway Research Program study that will provide even more in-depth understanding of gusset plates and their modes of deterioration.

SCOBS has also recently formed several working groups that will provide valuable information in the areas of bridge inspection and preservation. One of these working groups is preparing a proposal for providing for Element Level inspection within the Federal National Bridge Inspection System (NBIS). The current system is dependent on overall structure ratings such as Sufficiency Ratings and "Structurally Deficient" labels, which, as we have seen in the media, were never intended to be used by the general public and do not reflect the true condition or safety of a bridge. By incorporating element level inspection ratings, the system will reflect a clearer understanding of the condition and health of a bridge. The second working group recently has been assigned to look closely at truck size and weight issues to see how the changes in that industry are affecting highway structures.

AASHTO has also developed a technical service program centered on Transportation System Preservation. AASHTO has contracted with the National Center for Pavement Preservation (NCPP) to host the Transportation System Preservation Technical Services Program (TSP•2). The goals of the TSP•2 are to:

1. Provide a clearinghouse for comprehensive, up-to-date information on effective preservation technologies that enhance pavement and bridge performance and extend their useful service life;

2. Develop and administer a system preservation "Help Desk" to afford State highway agencies with a one-stop source for technical, training, and outreach services; and

3. Offer State highway agencies the means to exchange ideas, information, and best practices with one another.

A website serves as the focal point for TSP•2 information and activities. The website can be accessed at: http://www.tsp2.org. Access to the website is open to all State highway transportation personnel and other interested pavement and bridge practitioners. The TSP•2 website has several features designed to facilitate the exchange of preservation information. These include:

1. The TSP Preservation Research Roadmap;
2. A Bulletin Board and System (BBS), containing a wide range of preservation

(Continued on Page 23)

Intelligent Infrastructure: Securing Regional Sustainability Presented at the Department of Homeland Security's "Workshop on Aging Infrastructure" at Columbia University, July 2009

by James Carlini*
President, Carlini & Associates, Inc.

If a city and/or region want 21st century viability, new intelligent infrastructure and amenities are key to their future economic development and regional sustainability. There needs to be a solid "Platform for Commerce" to build upon. That platform provides broadband connectivity (multiple gigabit networks) and redundant power and distribution facilities to a multi-layer infrastructure which includes the more traditionally-defined layers like ports, roads, bridges, and railroads.

Why has this become so important? The three most important words in real estate have changed from "*Location, Location, Location*" to "*Location, Location, Connectivity*" in the last couple of years. Any planned commercial development must reflect this significant change in order to be competitive to attract first-rate tenants.

With Intelligent Business Campuses (IBCs) and Intelligent Industrial Parks (IIPs) under various stages of development and completion around the world, the way corporations and local government agencies view regional sustainability, job development, and retention as well as urban economic development, has changed. Those that do not see this fundamental shift will be left out of any real economic development and regional sustainability.

New design concepts need to be understood and applied to next generation industrial campuses as sophisticated tenants demand security, reliability, and redundancy to compete in the global marketplace of the 21st Century. As acknowledged in an earlier white paper, *Intelligent Business Campuses: Keys to Future Economic Development:*

Power and network planning have shifted to upfront Master Planning from being an afterthought after the corporate tenant moves in.

The primary challenge facing today's local and regional governments is to create a solid "platform for commerce" that companies and other organizations can build upon to expand their regional as well as global trade. This is a necessary foundation for any region and it insures the economic security of that region.

Traditional economic development in many American municipalities consisted of selecting a site, creating a TIF (Tax Increment Financing) district around it and then with a lot of fanfare, proclaiming that this area was "great for business and commerce". Hopefully, it would attract a higher caliber of development. Some TIF districts have been successful, but many recently created ones are still standing vacant as the initial hype has worn off, but no major developments have moved in.

Proclaiming a place is "great for business and commerce" is not the same as preparing it for business and commerce. Corporate site selection committees are getting more discerning. Whether they are looking at a self-contained campus or a site within a shared campus environment, corporations are getting more selective in what properties they will consider to build facilities on. These properties have to show pre-built infrastructure in order to gain in the rankings of possible sites to be included in a short list.

Infrastructure: 3,000 Years in the Making

A clear definition of what infrastructure consists of and what it supports is critical for today's strategic decision-making on tomorrow's long-term projects and economic development initiatives. Having a framework to refer to can only help structure discussions as well as clarify where security, power, and network connectivity priorities have to be focused.

Throughout the ages, trade routes were considered important to the regional sustainability of every civilization. From the Phoenicians

(Continued on Page 8)

Sustainability *(Cont. from 7)*

and Romans to the Chinese, to the more historically recent Europeans and the United States, trading goods and services was paramount to civilizations to thrive and survive. To put it in a historical perspective, Chart 1 (below) gives an overall view of the expansion of commerce and the seven layers of critical infrastructure that supported its growth and expansion throughout the last three thousand years.

To many people involved in infrastructure improvements, they fail to see the total picture or in this case, the total framework that provides for the platform for commerce. Each layer has significance and must be addressed when building new facilities as well as trying to retrofit existing facilities.

Critical Trade Routes Have Become Electronic

Throughout the last three Millennia, trade routes have been important to the expansion of trade, culture, and commerce. Now, those trade routes are also electronic and the need to include this layer is critical as it relates to global commerce and the digital world that we have created.

These electronic trade routes must have security woven into the fabric of this layer as billions, if not trillions, of dollars of securities and trade pass through it on a weekly basis. Many new and existing industrial parks have substandard protection when it comes to wireless networks and other communication media that can be compromised.

Just as expanding trade routes in the past meant overcoming natural obstacles, including water, land, and air, in our digital world — spam, viruses, and other electronic security impediments must be dealt with and defeated.

Most people have not yet equated broadband connectivity (network infrastructure) with the rest of the layers of critical infrastructure that have been recognized throughout centuries as needed for transportation and global commerce. The need to understand

(Continued on Page 9)

CHART 1: Critical Infrastructure Framework That Provides the "Platform for Commerce"

LAYER	LEVEL	DOMINANT INITIAL DRIVER OF IMPLEMENTATION IMPORTANCE
SPACE (FUTURE) (INTERPLANETARY)	(8)	JUST BEGINNING TO BE BUILT (|Space shuttles, space station, satellite networks| Future – mid-21st Century, 22nd Century? US, RUSSIA, JAPAN, CHINA?)
BROADBAND CONNECTIVITY NETWORK	7	CHINA, JAPAN, KOREA, NETHERLANDS (beginning 21st Century)
AIRPORTS	6	UNITED STATES, EUROPE (mid-20th Century)
POWER (GRIDS, NUCLEAR POWER)	5	UNITED STATES (beginning/ mid 20th Century)
TELEPHONE NETWORK (VOICE ONLY)	4	UNITED STATES (beginning/mid 20th Century)
RAILROADS	3	UNITED STATES (mid-1800s)
ROADS/BRIDGES	2	ROMAN EMPIRE (500BC- 476AD)
PORTS/ DOCKS/ WATER	1	PHOENICIANS (1200BC-900BC)

Source: JAMES CARLINI,

Sustainability *(Cont. from 8)*

how to maximize those electronic trade routes is critical to maximizing the economic viability of a region.

The Transportation of Information

The importance of the Internet is finally being recognized in this century by those that should have been rebuilding their copper "roadbed" of telephone network that they built in the United States decades ago. Just like single-lane dirt roads which evolved into the multi-lane superhighways of today, the single-function copper-based voice network has to be updated to a multi-channel, multi-gigabit network that can handle the explosive growth of video and other convergent applications. Just as you cannot drive fast on a dirt road, you cannot transport information fast on copper. At this point, copper should be replaced not only from a speed standpoint, but from an infrastructure security standpoint as well.

There have been several plans proposed by various groups to develop a national broadband strategy as well as its implementation. The major flaws in these plans are that their target speed is too low and they rely upon the embedded copper infrastructure. They are not setting the bar high enough within the planning stage. 100 Megabits per second is not what we should be aiming for as a standard speed.

Many people do not know how to convey speed of transmission or what it relates to in everyday life. This is part of the problem in trying to sell the importance of upgrading networks to a much faster broadband connectivity where new applications would be created. The chart at the bottom of this page is the "Speed Chart" which was developed to use as a tool to provide an example of the significant differences in delivery time of a 90-minute full motion video based on what type of network circuit was being used.

The Importance of Having a Solid Infrastructure

Regional sustainability will be based on having a solid "platform for commerce" which includes all the levels outlined in Chart 1. This is a global phenomenon as other countries have also implemented projects that adhere to this concept.

Unfortunately, many traditional organizations who are supposedly "experts" in infrastructure do not even include broadband connectivity as a layer within the total framework. Before any great action plan can be implemented, everyone has to be on the same page as understanding what makes up the infrastructure. We cannot have a 1950s approach on understanding, let alone creating and implementing, a strategy for re-building infrastructure.

(Continued on Page 24)

Speed Chart

Speed of Transmission
Downloading a 90-minute movie (1 gigabyte*)

Speed of Circuit (type)	Time Elapsed (rounded)
56 Kbps (dial-up)	426 hours (~17.7 days)
1.5 Mbps (DSL, cable, T-1)	15.91 hours
10 Mbps (wireless)	2.39 hours
1 Gbps (fiber to the curb)	8.59 seconds
10 Gbps (fiber to the house)	0.86 second

Source: James Carlini

*Gigabyte: a unit of information equal to 1 billon (actually 1,073,741,824) bytes (or 8,589,934,592 bits) or 1,024 megabytes (or 2 to the 30 power).

Optimizing Infrastructure Investments for the 21st Century

by James Creel
ASME Innovative Technologies Institute, LLC

Since the Northeast Blackout, Hurricane Katrina, and the collapse of the I-35W Bridge in Minneapolis, there has been a growing public awareness of aging infrastructures in the United States. ASCE recently assigned a grade of "D" to America's infrastructure along with an estimated $2.2 trillion needed to bring America's infrastructures in line with safety and capacity requirements.[1] Whether it is for roads, bridges, tunnels, rail lines, technological upgrades, "green" improvements, or just plain facility upkeep, hundreds of billions of dollars are being invested annually in various infrastructure projects across the country.[2]

It is reasonable to ask how the money will be invested, especially with the recent passage of the American Recovery and Reinvestment Act of 2009. What elevates one project over another? What criteria are used to prioritize investments? Are certain cities, states, or regions throughout the United States in greater need of these investments than others? Are proper risks and benefits weighed in an effort to optimize such investments? A blue ribbon commission, sponsored by the Center for Strategic and International Affairs, examined these questions and concluded that not only is America investing too little in aggregate, but America is investing in the wrong things. The commission found that we are poorly prepared to optimally allocate these massive funds.

This results in considerable opportunity losses as billions of dollars are potentially misspent. Elected leaders representing the interests of different states and districts can certainly tout the merits of one project over those of another. Highly paid lobbyists can do the same. The "stove-piped" nature of the allocation process from appropriations to breaking ground, earmarks, out-dated formulas, and block grants can distort from optimal investment.

What is missing is an objective, analytic approach that allows value, security, and resilience to be maximized relative to cost by the President, governors, and mayors.

ASME Innovative Technologies Institute, LLC (ASME-ITI), has convened a group of distinguished experts to address this immense national challenge. The ASME-ITI Working Group on Infrastructure Investment has produced a feasibility study of a methodology to guide how to invest taxpayer dollars wisely, strategically, and transparently. The report defines goals and necessary design requirements to allocate capital in a feasible manner according to systematically weighted national objectives. The process, developed by analogy with financial portfolio optimization, is summarized in the table on page 25.

The logic and some of the analytic tools of financial portfolio analysis contribute to a feasible approach for infrastructure portfolio optimization, with modifications to account for the differences between financial and infrastructure assets.

(Continued on Page 25)

[1] ASCE, http://www.infrastructurereportcard.org/, (accessed September 15, 2009).
[2] Peter R. Orszag, Director, Congressional Budget Office, "Investing in Infrastructure," Testimony before the Committee on finance, U.S. Senate, July 10, 2008.
[3] Center for Strategic and International Studies Commission on Public Infrastructure, Guiding Principles for Strengthening America's Infrastructure, 2006.

Physical Exam of Aging Buildings

by Peter A. Schkeeper, P.E.

Buildings provide both shelter and a quality of life for their occupants, whether as workplaces, houses of worship, or as homes for family living. Buildings also document the history of a culture. As buildings age, both materials as well as the quality of life within those buildings can deteriorate. This article will discuss the aging of buildings and the importance of Building Inspections to their preservation.

According to a report by Dr. C. Leonard Woolley, director of a joint expedition between the British Museum and the University of Pennsylvania Museum that was excavating in the region of Ur in lower Babylonia, the oldest building in the world that is still standing above ground is a small square temple, built by the Sumerian King Aannipadda, of Ur, about 4500B.C. There are buildings constructed during the Roman Empire, which I have personally visited, that are still being used. Within the United States, the Adobe buildings at Acomo Sky City, a National Trust Historic Site, are reported to have been in use for 1,000 years. The oldest buildings I have inspected are portions of residential buildings reported to date back to the 1600s, including one with a loose stone foundation. I have inspected many commercial and residential buildings that were constructed during the 1700s. Some are in great shape and many are being nursed along. With these buildings, issues often develop at the joints of sections added at different times with dissimilar materials. Deferred maintenance and temporary supplemental support are common practices that prevent a building from aging gracefully. How long a building can last depends upon many factors including the type of foundation, how it is sited, how roof and surface water runoff is managed, construction materials, air quality within the building, and the care afforded the building over the years. Older buildings have a romantic attraction and as with any romance, there are continual and increasing levels of maintenance that never go away.

There are numerous reasons to maintain an older building. A relatively recent environmental reason is that by maintaining older buildings, we do not release the carbon emissions that would result from demolishing the building. When a building becomes unsafe for habitation, then a crucial decisionmust be made: invest in its repair and restoration or destroy it.

Richard C. Diamond, Ph.D., a staff scientist at the Berkeley National Laboratory, issued a 2001 study entitled, "An Overview of the U.S. Building Stock." The following statement is extracted from Dr. Diamond's study, with his permission. While his 2001 study included a chart, a more current chart is shown in Figure 1.

Most commercial buildings, once constructed, are expected to last for decades or longer. New buildings are constructed each year and older buildings are demolished, but the commercial building stock at any point in time remains dominated by older buildings. More than 70 percent of buildings and total floor space in 1995 were constructed prior to 1980, and more than 50 percent of buildings and floor space, prior to 1970. (See Figure 1)

Data regarding the age of residential buildings was complied by the U.S. Census Bureau American Housing

(Continued on Page 12)

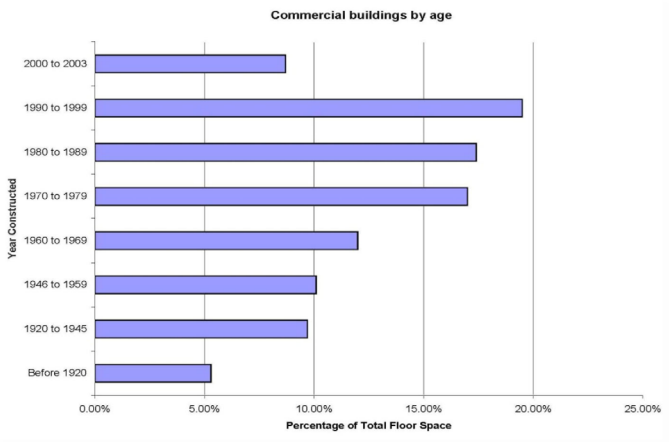

Figure 1: Source: Energy Information Administration

Inspections *(Cont. from 11)*

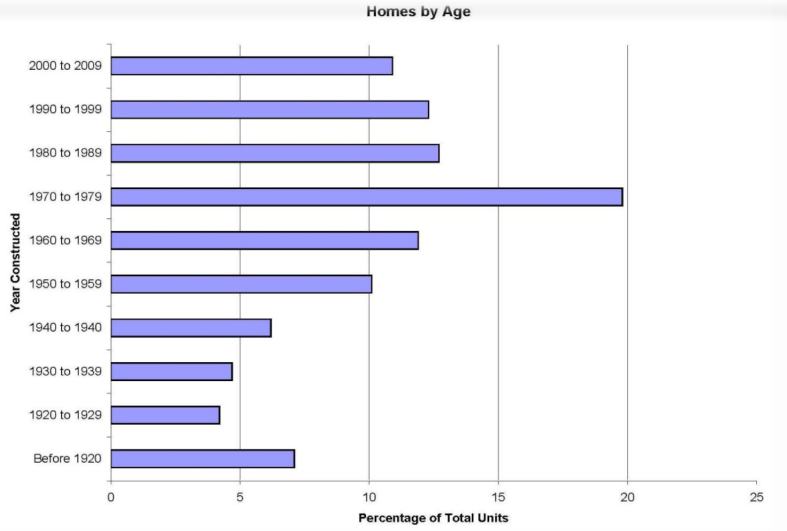

Figure 2: Source: American Housing Survey for the United States in 2007

Survey and is shown in Figure 2. Manufacturing, industrial, farm, and government buildings are not included in any of this data.

Taking Guidance from Building Codes

Building Codes have existed in one form or another for a very long period of time. The Code of Hammurabi, created in 1790 B.C., is generally accepted as the first building code (*If the house the builder built causes death to the owner then the builder is put to death*). Most modern codes have their roots embedded in the effort to reduce fires. Building codes are adopted or adapted by government jurisdictions, either by individual states or by local municipalities. Building Codes have expanded to all aspects of building construction. In the United States, the International Code Council has consolidated the most-used codes, many of which are adapted by states and major cities for their particular needs. Based on www.iccsafe.org, current ICC publications include the following:

- International Building Code®
- International Energy Conservation Code® Provisions®
- International Existing Building Code®
- International Fire Code®
- International Mechanical Code®
- ICC Performance Code™
- International Plumbing Code®
- International Private Sewage Disposal Code®
- International Property Maintenance Code®
- International Residential Code®
- International Wildland-Urban Interface Code®
- International Zoning Code®

In addition to the ICC codes, there are other code-writing organizations with codes that may be adapted or adopted by local or state jurisdictions. There are also many industry standards-writing organizations that are referenced within the codes or within material manufacturer's installation instructions. Manufacturer's installation instructions often contain requirements that are necessary to maintain their independent laboratory testing labeling requirements. Codes apply at the time a building is constructed and when there are modifications to a building. Some jurisdictions have adopted or adapted a property maintenance code that requires updating of the building. These codes are usually associated with periodic inspections. Typically, fire codes will have on-going applicability and be subject to periodic inspections. Thus older buildings that have not been updated continue to stand with construction and systems in effect at the time the building was constructed. Codes are not perfect but they do represent a consensus of current thinking for the minimum requirements. Code writing is a committee function with various interest groups participating in their development. Nothing prevents a building from being constructed and maintained to higher standards of care. Building inspections of existing buildings are typically not code inspections; however a good working knowledge of codes and standards will provide guidance for the Building Inspection Engineer.

Key Issues of Building Well Being

The well being of a building cannot be determined just by its age. Historic buildings that have been well cared for have lasted for

(Continued on Page 13)

Inspections *(Cont. from 12)*

centuries. New buildings can have serious or catastrophic flaws due to improper construction. Adverse conditions can develop within buildings that seem to take on a life of their own, such as mold. The well being of a building is important, and issues critical to well being, identified by Building Inspection Engineers, can be prioritized as follows:

• Life Safety – Life safety is a preeminent requirement for any building and would be the first priority for repair whenever a building issue develops that could threaten life. Examples include falling facades of taller buildings, balcony failure, fire hazard, and elevator or escalator problems. Even interior air quality considerations can reach the level of Life Safety, as has been demonstrated with Legionnaires' Disease.

• Building Structural Integrity – Building structural stability is not always visually apparent yet often a visual indicator will alert the experienced building inspection engineer that investigation is necessary. One example of a structural issue that is not always obvious is corroding reinforcing steel within reinforced concrete structural support members.

• Water Intrusion – Water intrusion can take on many forms starting with rain water entry through the building envelope including the roof and exterior walls. Condensation at or within the building envelope is yet another source of water intrusion into the building. Ground water and plumbing leaks are additional sources of water.

• Building Functionality – Necessary Building Functions include a building's electrical, plumbing, lighting, heating, and air conditioning systems.

• Energy Efficiency – Energy efficiency has a significant impact on the cost of operating a building and has increased in social responsibility.

• Maintenance Issues – Maintenance Issues include maintaining proper surface conditions on the exterior and interior of the building and routinely maintaining building systems. Deferred maintenance is a major cause of building deterioration. Most maintenance issues can be anticipated and planned for, and preventive maintenance is more cost effective and less disruptive to building operations than waiting for failure.

• Comfort Issues – Comfort Issues include air conditioning and automatic functions such as automatic lighting or automatic toilet flushing.

Building Inspection Engineering

Building Inspection Engineering involves many areas of knowledge. Its growing importance as a discipline over the past 50 years is demonstrated by the number of Professional Engineers and Registered Architects now obtaining Board Certification as Building Inspection Engineers.

A Building Inspection Engineer must possess a broad range of knowledge to function as an effective diagnostician. Board Certification provides evidence of competency to inspect buildings, their systems, structural weaknesses and strengths, and to ensure the safety and health of the building's occupants. The 23 major topics that require demonstrated knowledge and documented experience in order to obtain Board Certification as a Building Inspection Engineer include:

- History of building and construction, including historic preservation
- Building materials
- Construction detailing and techniques
- Structural analysis and theory of structures
- Thermal systems
- Surveying engineering
- Timber and wood frame structures
- Steel structures
- Concrete and masonry structures
- Plumbing/waste management
- Life safety
- Building electrical systems
- Integrated building system design
- Geotechnical engineering
- Building mechanical systems (e.g. vertical transportation)
- Site features, including security
- Building codes and standards, including ADA compliance
- Engineering economics (e.g. cost estimation, financial

(Continued on Page 22)

The Future for Sustainable Water Infrastructure

by Lorraine Loken*
Senior Manager Public Communications, Water Environment Federation

For more than a decade, water infrastructure investment has languished. The gap in funding ($40-150 billion)[1] has deepened as infrastructure deteriorates, creating dramatic scenes of public horror. From cars being swept down the Potomac River last December to massive sink holes swallowing trucks in Manhattan[2] and Fire Engines in Los Angeles[3] to flood waters contaminating public buildings with *Escherichia coli* (E. coli) in New Jersey,[4] collapsing water infrastructure is seizing the public's attention.

Just as the Cuyahoga River going up in flames 40 years ago spurred the Clean Water Act, the Water Sector is hopeful that we may be on a threshold toward political action for sustainable water infrastructure. Experts warn that if we do not take action soon, an entire generation of progress under the Clean Water Act and Safe Water Drinking Act is at risk. At stake, is a dangerous tipping point to a new era, or should we say, old, where water systems become unstable in their ability to deliver, kills fish, and drinking water alerts become an everyday occurrence.

The American Recovery and Reinvestment Act (ARRA) provided a shot in the arm for wastewater and drinking water with funding of $4 billion and $2 billion respectively. However, everyone agrees a one-year increase is not a long term funding strategy. That is why the Water Sector is making a concerted effort to plant seeds toward sustainable infrastructure and funding. While public attention is focused on health care and climate change, the water industry considers their options. The dialogue will escalate in October when water and wastewater leaders meet at the Water Environment Federation (WEF) Technical Exhibition and Conference (WEFTEC®) in Orlando, to debate the future for sustainable water infrastructure. Four 2009 reports have been released to inform the discussion:

- The Aspen Institute, *Sustainable Water Systems: Step One — Redefining the Nation's Infrastructure Challenge*
- American Water Works Association, *Federal Water Infrastructure Bank*
- U.S. Government Accountability Office (GAO), *Clean Water Infrastructure: A Variety of Issues Need to Be Considered When Designing a Clean Water Trust Fund*
- Water Environment Research Foundation, *Strategic Asset Management and Communication Report on Public Communication – Perceptions and Early Communications Tools*

Redefining the Nation's Infrastructure Challenge

The Aspen Institute's *Sustainable Water Systems: Step One — Redefining the Nation's Infrastructure Challenge* seeks to reframe the issue. Rather than focus on the gap in funding, it defines infrastructure needs in sustainability terms. It expands the definition of water infrastructure to include all natural infrastructures that contribute to water quality and supply such as rivers, lakes, streams, groundwater aquifers, floodplains, floodways, wetlands, and watersheds. Embracing this approach, we are directed to pursue

(Continued on Page 15)

[1] U.S. EPA, The Clean Water and Drinking Water Infrastructure Gap Analysis (Washington, D.C.) 2002.
[2] NY1 News, February 2, 2009, "Oil Truck Falls into Manhattan Sinkhole," http://www.ny1.com/Default.aspx?ArID=93652, accessed 9/8/09.
[3] Associated Press, September 6, 2009, "Water Main Break Causes Flooding in Los Angeles," http://www.google.com/hostednews/ap/article/ALeqM5geDUvZfc7dzGJd8oa6hV7msLnuEwD9AHV0NO0 accessed 9/8/09.
[4] Environmental Expert.com, September 2, 2009, http://www.environmental-expert.com/resultEachPressRelease.aspx?cid=21001&codi=61638&level=0, accessed 9/8/2009.

Sustainable Water *(Cont. from 14)*

green infrastructure, low-impact development, land conservation, and better management practices for agriculture.

A "Sustainable Path" is articulated in this report to define the ideal situation in which all financial and natural resource costs are managed optimally for safe and reliable water services. Twenty elements were developed covering the full depth and scope of management issues from Public Outreach & Stakeholder Involvement to Energy Management. Several elements mirror the U.S. Environmental Protection Agency's (EPA) *10 Attributes of Effectively Managed Water Sector Utilities* from 2007. The redefinition was born in the paradigm shift toward watershed management that has taken place over the past decade. The report's recommendations promote a holistic approach toward integrated watershed management.

Although the experts were able to reach consensus on what sustainable infrastructure looks like, the "how to" was not an easy agreement. Both the Aspen Institute's report and the U.S. EPA's Attributes emphasize full-cost pricing. They argue that pricing structures which incorporate the full cost to ratepayers lead to market efficiencies in conservation and better environmental decisions. This has become a tension point within the Water Sector as large utilities, some with near crisis needs and high risk scenarios, seek urgent answers that will not break their ratepayers' pocketbooks.

National Infrastructure Bank

Another option for sustainable infrastructure was introduced by the American Water Works Association. The American Water Works Association commissioned a report, *Federal Water Infrastructure Bank*, to determine the efficacy of a National Infrastructure Bank. It is a bank-like financing mechanism with elements of existing programs such as the State Revolving Fund (SRF). Unsuccessful so far, several similar bills have already moved through Congress to establish the funding modeled after the Federal Deposit Insurance Corporation. Its major advantage to other proposals is that theoretically it poses little cost to the federal government.

The Bank's two-pronged approach would provide financial assistance for large water infrastructure projects and reduce the cost of leveraging SRF programs. It would provide direct financing through loans or loan guarantees to larger projects at interest rates at or below the U.S. Treasury Bond rate. The Bank could also purchase or guarantee SRF bonds, lowering their interest rates and allowing SRF programs to make more loans and increase subsidies to communities.

Lending to communities at the Treasury bond rate could save millions of dollars of financing costs. As Bank financing would be in the form of loans and loan guarantees, the main federal budgetary impact would be in the form of additional subsidies provided to reduce interest rates below the Treasury bond rate for communities and SRF programs.

Clean Water Trust Fund

The report, *Clean Water Infrastructure: A Variety of Issues Need to Be Considered When Designing a Clean Water Trust Fund*, published by the GAO, was written to inform Congress about another option. Rep. Earl Blumenauer (D – Ore.) introduced the bipartisan Water Protection and Reinvestment Act in July. It would create a Clean Water Trust Fund to provide a stable and sustainable source of funding for upgrades to wastewater treatment infrastructure.

Currently, local utilities shoulder 97% of investment needs for infrastructure, an estimated $60 billion per year.[5] Many larger utilities argue that looming challenges associated with aging systems, emerging issues, and climate change — droughts, increased storm intensity, sea-level rise, and carbon emissions reduction — are certain to increase needed changes and federal mandates. In addition, the transition to more innovative technologies and approaches such as outlined in The Aspen Institute report will require capital investment to implement. These challenges are pressing at the same time that municipal access to the bond market has become less certain. Without a stable source of funding such as the Transportation

(Continued on Page 26)

[5] Kirk, Ken, "Solving the Funding Gap…the Road to a Sustainable Federal-State-Local Partnership" WEFTEC proceedings, Alexandria, Va., 2009.

The Washington Region's Continuing Transportation Funding Shortfall

by John Swanson, Senior Transportation Planner
Metropolitan Washington Council of Governments

For quite some time, in good times and in bad, the story has basically been the same: the Washington region is facing an ongoing transportation funding shortfall. Revenues are simply not keeping up with needs. The region is growing at a rapid pace, and new people and new jobs are creating new transportation demands. In addition, the existing transportation system needs urgent attention. Our Metro transit system and Interstate highways are no longer new. Maintenance and rehabilitation expenses were expected to soak up the vast majority — at least 70 percent — of future transportation revenues.

For more than a decade, the National Capital Region Transportation Planning Board (TPB) has been shining a spotlight on the funding shortfall. In 2000, the TPB's long-range transportation plan highlighted the far-reaching extent of the financial squeeze, noting that the region needed an increase of 50 percent to meet the region's transportation needs. Since that time, the list of unfunded needs has grown. The short-term funding picture is even bleaker. A TPB analysis in 2004, called "Time to Act", found that available funding would meet less than half of the region's critical transportation needs between 2005 and 2010.

Metro's Needs are Critical

The funding needs of the Washington Metropolitan Area Transit Authority (WMATA) are particularly critical. The Metro system, once shiny and new, is showing its age. An increasingly larger portion of funds is now dedicated to maintenance and rehabilitation. In 2004, following the release of TPB's "Time to Act" report, the WMATA board approved a funding scheme called "Metro Matters", which committed $3.3 billion over six years from state and local governments to purchase new buses and rail cars and fund basic infrastructure investments. Even at the time, it was clear that "Metro Matters" was a stop-gap solution.

In October 2008, Congress passed legislation authorizing $1.5 billion in federal funding over the next ten years. U.S. Representative Tom Davis of Virginia introduced the legislation in 2005. This bill stipulates that federal dollars are contingent upon Maryland, Virginia, and D.C. providing one-for-one matching dollars, and requires management changes, including the permanent establishment of an inspector general position and expansion of the WMATA board to include federal representatives. In total, the Davis legislation will provide an infusion of $3 billion over ten years, which will be used to support Metro's capital program, including the purchase of rail cars and buses, repair of leaky tunnels, and deteriorating station platforms, and other investments that can improve system performance on a daily basis. WMATA estimates it needs to purchase more than 300 railcars to replace the original, deteriorating ones. The funding under the Davis legislation only applies to capital and preventive maintenance expenses on existing WMATA systems, and may not be used to increase the mileage of the rail system.

A boost of $3 billion will go a long way toward addressing Metro's funding uncertainties, but it only represents a portion of anticipated needs. In October 2008, as Congress was wrapping up the funding bill, Metro General Manager John B. Catoe Jr. announced that the system needs more than $11 billion over 10 years — approximately double the rate of capital investment spending each year since 2002 — to maintain and improve its services.

Recent short-term funding prospects present new opportunities: the passage of the American Recovery and Reinvestment Act (ARRA) in

(Continued on Page 17)

Funding Shortfall *(Cont. from 16)*

February 2009 prompted Metro to identify "shovel-ready" capital projects eligible for federal funding. While this funding will provide short-term assistance, Metro continues to face budget shortfalls to the tune of $176 million — or 13 percent of Metro's operating budget — for FY2010. According to Metro Board Chairman Jim Graham, these conditions will require Metro to "do more with less." It is evident that daunting challenges remain.

Tolls Are a Growing Funding Source

Another development in recent years has been the changing attitude toward tolls. Just over a decade ago, a proposal to finance the new Woodrow Wilson Bridge with tolls was not politically acceptable. Today, three out of the five most expensive projects planned for the next six years are toll projects — Virginia's two HOT lanes projects (on the I-495 Beltway and I-95/395) and Maryland's Intercounty Connector. In addition, tolls from the Dulles Toll Road are a key component of funding for the Metrorail extension to Dulles Airport, which is currently under construction. The TPB's 2006 long-range financial analysis found that tolls and private sources can be expected to provide seven percent of anticipated revenues between now and 2030. A similar analysis in 2003 found that toll and private money accounted for just one percent of forecasted revenues.

We can expect more toll lane projects in the future. Transportation funding continues to be tight and congestion is rapidly getting worse. The TPB has taken a lead in looking at pricing policies, including toll lanes. In 2003, the TPB convened more than 200 elected officials, community leaders, planners, and academics for a conference that explored innovative pricing strategies and helped to galvanize regional interest in tolling as a solution to the region's perpetual transportation funding shortfall.

New electronic toll-collection technologies and a new sense of public support have made toll lanes more viable. A TPB scenario analysis, released in 2008, analyzed the potential effects of widespread road pricing in the Washington region. The study "Evaluating Alternative Scenarios for a Network of Variably Priced Highway Lanes in the Metropolitan Washington Region" outlined several different scenarios for adding new priced lanes, pricing existing highways, and enhancing bus services on tolled lanes. The study was funded by the Federal Highway Administration of the U.S. Department of Transportation.

The Shortfall Continues

Despite additional funding for Metro and the increased use of tolls, the transportation funding shortfall continues to grow. A 2006 TPB financial analysis found that although transportation revenues have actually increased since 2003 (the 2005 federal transportation reauthorization legislation — SAFETEA-LU — provided a major boost), the shortfall has still increased. This is in large part due to the construction costs that have eaten up much of the gain in revenue. During the years 2004-2006, nationwide construction expenditures jumped about 28 percent, compared to an increase of just 17 percent over the eight years prior to 2004. These rises were linked to increasing global demand for concrete, asphalt, and other materials. Several efforts to raise revenues in Virginia have been stymied. In November 2002, voters rejected a referendum that would have increased the sales tax by a half cent to raise revenue for transportation projects. In February 2008, the Virginia Supreme Court invalidated a package of taxes and fees that the Northern Virginia Transportation Authority (NVTA) planned to use for transportation priorities. The Court ruled that the NVTA could not raise and spend such revenues because it is not a directly elected body.

As the nation headed into recession in 2008, state and local governments faced severe budget crises that undermined transportation funding even further. The new Obama administration offered relief through an infrastructure stimulus package, approved in February 2009, which provided $700 million for transportation in the Washington region. These funds will largely be spent on deferred maintenance and rehabilitation projects.

Looking Toward Systemic Change

Short-term funding infusions are

(Continued on Page 24)

Infrastructure Age, Security, and Natural Hazards

by Rae Zimmerman, Carlos E. Restrepo and Jeffrey S. Simonoff
New York University

Infrastructure comprises essential services for diverse needs and customers. It encompasses energy, transportation, communications, water supply, and environmental protection, among others. It is also faced with a wide variety of threats, increasingly from natural hazards, terrorism, and day to day failures that can result in devastating accidents. One intuitively attractive indicator of condition and need is infrastructure age. Yet, it is a complicated concept to define. The age of infrastructure facilities, in terms of construction year, can be dramatically affected by rehabilitation, retrofits, and maintenance. Moreover, age has a complicated relationship with many other factors that affect performance such as environmental stresses, usage, design, operations and maintenance practices, and dependencies and interdependencies among infrastructures. Few barometers of infrastructure condition have been able to cull out age. The ASCE (2009) report card assigns infrastructure an average of "D", and age is difficult to separate out in this characterization.

Over the past few decades, infrastructure facilities and their services have been faced with escalating hazards and threats. Simonoff, Restrepo, Zimmerman and Naphtali (2008) noted increased federally declared disasters at a rate of 2.7% per year from 1990 to 2005, and three quarters of the top 12 hurricanes, i.e., with the highest dollar damage, have occurred since 2000 (Blake, Rappaport, and Landsea 2007). Terrorist attacks on transit are noteworthy throughout Europe as the Mineta Institute has identified, summarized by Zimmerman and Restrepo (2009), and attacks such as the Madrid and London bombings since September 11, 2001 have been spectacular. Electric power facilities have experienced similar attacks in countries outside of the U.S. (Simonoff, Restrepo and Zimmerman 2007). If age does contribute to vulnerability by means of weakening the condition of facilities so they cannot withstand the impact of these events, it will become an increasing problem in the face of these rising trends.

A number of observations point to associations between age and infrastructure condition both directly and indirectly. For bridges, the U.S. Department of Transportation Federal Highway Administration (FHWA) National Bridge Inventory measures age (as year built) and also performance. In New York State (NYS) alone, the proportion of bridges rated in the inventory as structurally deteriorated and functionally obsolete declined with decreasing age. For hazardous liquid pipelines, which transport crude oil, gasoline, and related products, Restrepo, Simonoff and Zimmerman (2009: 40) found that 12% of accidents between 2002 and 2005 were attributed to internal and external corrosion, a potentially age-related condition, and a quarter of natural gas transmission incidents were also due to these factors (Simonoff, Restrepo and Zimmerman in preparation). For dams, the National Inventory of Dams assigns three hazard levels: high, significant, and low. High hazard dams are defined as those whose failure may potentially cause losses in human life, property and infrastructure; significant hazard dams have a lower likelihood of affecting those factors; and low hazard dams are those whose failure can be expected to damage agricultural land and roads. Hazard ranking increases with age. For example, in NYS low hazard dams have a mean age of 66 years whereas high hazard dams have a mean of 84 years. Water main breaks routinely occur in older water distribution lines (Cooper 2009), although Cooper (2009) and a U.S. EPA study (2002) found environmental factors as significant. Leakage rates or lost water is an alternative measure of damage, and has, according to U.S. EPA (2007) and U.S. Geological Survey, accounted for 1.7 trillion gallons of lost water.

(Continued on Page 28)

Bridge Diagnostics

by Jeffrey L. Schulz, P.E. Chief Testing Engineer,
Bridge Diagnostics Incorporated

Aging infrastructure poses a serious challenge to policy-makers. It also presents a serious logistical problem, as someone needs to provide the services needed to keep aging infrastructure functional and to identify problems before they endanger the safety of those who use this infrastructure on a daily basis. Bridge Diagnostics Incorporated (BDI) is a Colorado company that has been testing bridge infrastructure since 1989, conducting hundreds of field tests in that time. In addition, BDI manufactures equipment specifically designed for bridge testing. This article will explain how bridge testing works and what it does to protect bridge infrastructure from aging-related harm.

In what has often been compared to an EKG for people, BDI performs "live load testing" on all types of structures, most often, highway bridges. The basic goal of each of these tests is to gain a more accurate picture of how the structures are actually behaving under heavy load. An example of how this is useful is the common experience of encountering an "Oversized Load" while traveling. Companies moving these large loads must register them first with the state Department of Transportation (DOT) to ensure that they can cross the bridges safely. It can be very expensive if it is determined that a bridge cannot handle the load and must then be re-routed. In addition, issues such as political pressure and/or security considerations are often involved in the decision to allow certain loads to cross, indicating that factors other than the structure's ability to handle the load can also come into play.

Political considerations aside, in order to determine if the load can cross the bridge safely, the engineer must compare two basic quantities: the applied load (weight and axle configuration of the vehicle) and the capacity of the structural members (how much can the bridge hold without being overstressed). Assumptions must be made by the engineer to arrive at both quantities such as how much of the overload is carried by a particular beam or the strength of the concrete in the girders. Guidelines for determining these quantities are spelled out in the applicable AASHTO design codes. However, in the above-described situation, where the load may be approaching a critical level of the structure's capacity, a load test can provide a more accurate estimate of how the load is being distributed around the structure. This kind of information can often allow the bridge owner to feel more comfortable about allowing the heavy load to cross the structure since the decision will be based on a more accurate analysis. In general, bridges carry load more efficiently than assumed during a simple analysis. This means that often heavier loads can cross quite safely, although this is not always the case.

The photo below and on page 20 illustrate a typical test. Military installations all over the country must transport heavy loads, in this case, an M1 tank. Bridges nearby the installations will typically be owned by the county or state and there will be questions regarding how well these structures can handle these heavy loads whilst

(Continued on Page 20)

Diagnositics *(Cont. from 19)*

crossing them on a frequent basis. These particular tests determined that the bridges and vehicles were distributing the load better than expected.

BDI has been involved in load testing for over 400 structures around the U.S. and the world, the vast majority of which have been determined to be in adequate condition to carry the specified loads. There have only been a few structures in which we have recommended immediate remedial action. This experience, however, does not necessarily translate into being able to make a broad statement about the structures that have not been tested. This sample is mostly limited to a family of structures that are generally in favorable condition and in which the owner would like to keep the structure in service. In cases where a visual inspection indicates significant deterioration, BDI will often recommended that rather than spending time and effort on testing, the resources should be dedicated to repairs instead since, no matter what the test results, one of the end recommendations would be to go ahead and perform repairs anyway.

The basic testing process involves the installation of very sensitive strain and deflection sensors on the bridge's primary structural members as seen in the photo below and on page 27. Access to the bridge is usually supplied with a manlift or scaffolding and the sensors are attached at pre-determined locations. Then, a vehicle that has been weighed at the local scales crosses the bridge at approximately 5 mph and data is recorded on all sensors at approximately 40 samples per second. A typical data graph is shown on page 27. The truck crossing is repeated multiple times and at multiple lateral truck locations to capture the entire behavior of the bridge and to ensure good data quality.

After the test is completed, all of the instrumentation is removed. Due to the specialized equipment that has been developed by BDI, a typical bridge can be ready for testing in less than one day. Alternative testing techniques usually require much longer setup and are therefore are more expensive.

Once back at the office, a computer model of the bridge is developed and is loaded exactly the same way that the actual bridge was loaded in the field. Now, a direct comparison can be made between what the actual bridge is doing and what the computer model is predicting it should do. The next step we follow is to modify certain components of the computer model until its response matches that of the actual structure. This is done in a very systematic way and follows general engineering principles. The end

(Continued on Page 27)

Legal Insights

Transportation Appropriations Act

by Joseph Maltby, J.D., Research Associate

The Transportation Appropriations Act for the 2009 – 2010 fiscal year is currently winding its way through Congress. The bill has already reached conference between the House of Representatives and the Senate, where differences between the two versions are being ironed out through negotiation and amendments. The present version of the bill does contain some funding for initiatives related to aging infrastructure and infrastructure improvements.

$1.1 billion is being set aside for surface transportation capital infrastructure. These funds will be distributed as discretionary grants to state and local governments and independent transit agencies. Funds will be awarded competitively to projects which will have a significant impact on a metropolitan area, a region, or the nation as a whole. Projects are encouraged to relate in some fashion to the construction of roads, bridges, freight rail, or mass transit. The funds are required to be distributed in an equitable fashion between urban and rural communities, with no less than $250 million going to rural areas, as opposed to the funds being divided purely by need or population. Funds are also required to be spread among a variety of transportation modes. No individual grant may be larger than $300 million, no more than 2.5 percent of the funds may be distributed to any individual state, and any project must include at least 20 percent in matching funds from the grant recipient, though this cost-sharing rule may be relaxed for rural projects. Regulations governing the grant program will follow the bill's eventual passage.

Additionally, the Office of Transportation Planning, Research, and Development is slated to receive $8.2 million for operational expenses, funding research activities, and grants. The Federal Railroad Administration is slated to receive $25 million for rail line relocation and improvement on top of railroad obligations it authorizes the Treasury Department to issue. The transit agency for the District of Columbia and surrounding metro area has been designated to receive $150 million for its operations, but must obtain specific approval from the Secretary of Transportation for any capital or preventative maintenance projects.

These funds do not come without some strings attached. Highway projects using federal aid are required to purchase their materials from an American supplier or receive a waiver from the Secretary of Transportation. The general public is given 15 days to comment on the waiver before it can be enacted. There are also some rules clearly being included to satisfy particular constituencies. Federal funds also may not be used for any tolled highway within the state of Texas unless the highway charged a toll before the project began. Amtrak may not use any federal funds for its operation if it prohibits the transportation of secure firearms. The definition of "secure" is laid out in some detail. A large portion of the funds being made available to the D.C. transit authority are being designated for safety system improvements, which is not surprising considering the recent incidents on their trains.

These amounts are small compared to the total size of the bill. This suggests aging infrastructure has lessened as a priority as public attention has moved onto other issues and as time has elapsed since any major disasters associated with aging infrastructure. Indeed, the D.C. transit agency train crash is recent enough to merit a large pool of funding. In addition, funding is constrained by requirements that placate specific contingencies

(Continued on Page 29)

ASCE *(Cont. from 4)*

Increase and improve infrastructure investment from all stakeholders.

While great strides can be made with sustainable development and ongoing maintenance, significant funds must be invested to make necessary long-term improvements. All levels of government, owners, and users must renew their commitment to infrastructure investments in all categories. All available financing options must be explored and debated.

Conclusion

With a cumulative grade of "D" for 15 of the nation's critical infrastructure systems, the 2009 *Report Card for America's Infrastructure* demonstrates that the condition of our nation's infrastructure continues to be below average, and in some cases, is slipping toward failure. That same infrastructure has a direct impact on our personal and economic health and its condition is endangering our nation's future prosperity. While the 2009 American Reinvestment and Recovery Act did address some areas of immediate need, it only represents a down payment on the larger, systemic problems our infrastructure faces.

A healthy infrastructure will enable us to remain a strong and prosperous nation, but only if we move forward with vision, leadership, and community involvement and support. With perseverance and a common goal, we can work together to rebuild our once great infrastructure. ❖

Inspections *(Cont. from 13)*

analysis)
- Investigative methods and forensics
- Environmental issues
- Written communication for building inspection engineers
- Standards of practice
- Professional practice/ethics

Cursory building and home inspections are often done for real estate transactions to identify visual material physical deficiencies. There are various "standards" for home inspection and numerous states have licensed home inspectors with regulations that are more descriptive than evaluative in nature. Commercial and industrial real estate transaction inspections are often done to meet the guidelines established by The American Society of Testing and Materials (ASTM). Even property condition assessments that follow the guidelines established by ASTM E2018 may not be adequate for older buildings that need to be evaluated for preservation purposes. The U.S. Department of Housing and Urban Development has created a Residential Rehabilitation Inspection Guide that was published as part of its PATH program (Partnership for Advancing Technology in Housing). The American Society of Civil Engineers has crafted a standard SEI/ASCE 11-99 titled "Guideline for Structural Condition Assessment of Existing Buildings" that is more thorough in its requirements for evaluations pertaining to preservation, rehabilitation, and strengthening of existing buildings.

The initial evaluation by a Building Inspection Engineer includes document review and a visual condition assessment with photo documentation. Field testing using a variety of non-destructive instruments is common. Laboratory testing may be needed, and a team of specialized individuals may also be needed for very specific evaluations.

Older, larger, and more unique buildings, particularly buildings with historic or sophisticated systems, require higher levels of engineering and building science knowledge to assess their condition and identify potential corrective actions. ❖

More information about Building Inspection Engineers and Board Certified Building Inspection Engineers can be found at http://nabie.org.

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AASHTO *(Cont. from 6)*

related areas;
3. LISTSERV email mailing list enrollment and new list requests;
4. A Help Desk assistance request system;
5. An on-line System Preservation Technical Library;
6. An Event Calendar; and
7. A Preservation News Archive.

All of these programs through AASHTO help to maintain our aging infrastructure and help to provide safe reliable transportation facilities for years to come. ❖

For more information on AASHTO, its publications, committees, and programs, please visit www.transportation.org.

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Standing Committee on Planning
- Census Transportation Planning Products Program (CTPP)
- Subcommittee on Asset Management

Standing Committee on Public Transportation
- Multi-State Technical Assistance Program (MTAP)

Standing Committee on Rail Transportation
Standing Committee on Highways
- Subcommittee on Bridges and Structures
- Subcommittee on Construction
- Subcommittee on Design
- Subcommittee on Highway Transport
- Subcommittee on Maintenance
- Subcommittee on Materials
- Subcommittee on Right of Way and Utilities
- Subcommittee on Traffic Engineering
  - National Committee on Uniform Traffic Control Devices
- Subcommittee on Systems Operation and Management
- Joint AASHTO/ACEC Committee
- NTPEP Oversight Committee
- Special Committee on International Activity Coordination
- Special Committee on U.S. Route Numbering
- Special Committee on Wireless Technology
- Technology Implementation Group
- Value Engineering Technical Committee

Standing Committee on Research
- Research Advisory Committee

Standing Committee on Water Transportation
Standing Committee on Performance Management
Standing Committee on Highway Traffic Safety

Funding Shortfall *(Cont. from 17)*

not enough; more systemic long-term change is needed. The upcoming authorization of the federal transportation legislation offers an opportunity to restructure the nation's transportation policy and to substantially increase funding levels over the long term. Although the new legislation is due by September 30, 2009, the date when the current SAFETEA-LU legislation expires, Congress will likely extend the current legislation for several months before taking up a new bill

In September 2008, the TPB approved a set of policy principles calling for more funding, more attention to metropolitan-level challenges, and more balance among transportation modes. According to Ron Kirby, Director of Transportation Planning for the TPB, the policy principles "reflect the growing consensus across the nation that the current structure of federal transportation funding is ill- suited to addressing pressing needs for system maintenance, new infrastructure, and the increasingly urgent problems of congestion, rising energy costs, and global warming."

In order to tackle these problems, the funding shortfall must be solved. Chris Zimmerman, Arlington County Board Member, said it was important to "clearly advocate for raising the gas tax, and call for authorization to occur on time so that additional funding is not delayed."

Empowering metropolitan-level planning and decision making is also essential. "I think there is a real opportunity presented by this bill" said Tim Lovain, former Alexandria City Council Member. "There's the very real possibility that this authorization will redirect a substantial share of resources to metropolitan regions." ❖

Sustainability *(Cont. from 9)*

As pointed out during an Illinois House of Representatives computer technology committee meeting in 2007:

We are beyond the "Digital Divide" and are now in the "Digital Desert" where all levels of the economic strata are affected by a lack of broadband connectivity. The three most critical issues facing Illinois are Job Erosion, Network Infrastructure, and Education. (James Carlini, 2007)

As they say, if we do not heed the mistakes made in the past, we are condemned to repeat them in the future. We cannot afford to let any portion of the United States lag behind in this restructuring of the infrastructure.

Understanding what infrastructure consists of today, how it is a multi-layered platform, and how it is a platform for commerce that must be secure, can only help decision makers prioritize projects and understand their full impact on the stabilization of the regional economy. ❖

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Investments *(Cont. from 10)*

Four existing analytic methodologies (right-hand column) must be integrated to realize the approach while meeting all design specifications, demonstrating the feasibility of the method.

Additional work to integrate the methods and to field test the integrated approach must be done for the approach to bring much needed discipline to the jumbled and often inconsistent procedures used to make these critical investment decisions.

Spending money is easy. Accounting for it, managing it, and getting a reasonable return on the investment are, however, more demanding challenges. Planners and decision makers at all levels need sound and objective measures to determine proper and optimal courses of action. Ignoring these issues will simply repeat the failing grades our nation has earned on its infrastructure disbursements in the recent past. Failure to change the decision-making status quo will only result in a continued decline in the vital underpinning of our economy, competitiveness, and quality of life. But time is of the essence. For the United States to capture the full benefit of these investments this approach must be completed quickly and correctly — the first time — or the opportunity will be lost. ❖

For a copy of ASME-ITI's feasibility study on optimizing infrastructure investments, please email James Creel at **creelj@asme.org**.

Table. Financial Portfolio Optimization Provides the Framework for Infrastructure Portfolio Optimization

Process for Financial Assets	Process for Infrastructure Assets	Required Tools
1. Develop strategic goals and plan. Define: a. Strategic and operational objectives & their relative priorities; b. Constraints, e.g., budget total, geographic "balance," product lines, etc. c. Valuation metrics to measure objectives and constraints.	1. Same	Analytic Hierarchy Process (AHP)
2. Value existing portfolio relatives to strategic and operational objectives – gap analysis of value, risk: existing dependencies – from owner's perspective	2. Same, except from *both* owner's and public's perspectives "dual perspective," below.	Regional Input-Output Model OR Regional Systems/Economics Model
3. Assess new financial investment opportunities individually – full value, risk, performance relative to objectives	3. Same, but dual perspective with full multi-attribute value, risk, resilience, etc. – public *and* owner	Engineering-Economics Model
4. Estimate correlations among existing & new assets or with market as whole (covariance or "beta")	4. Same, but estimate *physical interdependencies* among existing & new assets – unintended consequences, cascades & systemic failures	Regional Input-Output Model OR Regional Systems/Economics Model
5. Optimize investment portfolio – efficient frontier; *maximize* value at acceptable risk level, within budget & other private constraints (performance, "balance," lines of business, etc.)	5. Same, but set aside investments private investors will make; then *maximize* multi-attribute value at acceptable risk level, within budget & other constraints (distributional balance, equity, etc.)	Portfolio Optimizer, either integrated with AHP OR Specially adapted to examine virtually all investment combinations
6. Examine constrained, optimal portfolios – owner's perspective only – Select portfolio, invest, manage & evaluate performance for next iteration.	6. Same, but Examine constrained optimal portfolios – *public's* perspective only – Select portfolio, invest, manage & evaluate performance for next iteration.	Sensitivity analysis using any or all of the above tools

Sustainable Water *(Cont. from 15)*

Sector has through the gasoline tax, utilities reason that they will face challenges they cannot realistically meet to achieve their mission to protect public health and the environment.

Funding for the CWTF would be targeted and prioritized to pollutant sources that are causing the largest problems. The GAO report looked at funds that could be administered and used; what activities should be eligible; and, what type of financial assistance should be provided. They researched potential revenue streams from taxes on five industries:

1. Beverages
2. Fertilizers and pesticides
3. Flushable products, including soaps, detergents, cooking oils, and toiletries
4. Pharmaceuticals
5. Water appliances and plumbing fixtures

Of course, none of these will be an easy sell, each having its own arguments against new taxes as well as lobbyists on Capitol Hill. Neither did the GAO report look at secondary impacts of a particular tax.

The Constant Theme — Public Outreach

No matter what different approaches these options offer there is one common theme that runs throughout: public awareness and appreciation is an important component to insure any sustainable future for water infrastructure.

The ARRA was an enormous boost, but for those who did not have their shovels ready, it may make the coming reality of needs even more of a public understanding dilemma. The average American may wonder why, despite federal funds spent on infrastructure, their rates are on a routine incline as water utilities make new requests. Public opposition to price hikes may make rate increases even less politically palatable than they are currently. Given the enormous funding requests and the competing needs in a faltering economy, politicians and water boards will not pursue long term needs unless the public is supportive. Citizens must understand the vital role water services play in their community for public health, the environment, and as the basis for a successful economy.

In a report by the Water Environment Research Foundation to be published later this month, *Strategic Asset Management and Communication Report on Public Communication – Perceptions and Early Communications Tools*, researchers determined that public outreach, in itself, will not drive asset management. According to their findings, however, elected and appointed officials agreed that public outreach and education is needed to support the decisions necessary for infrastructure sustainability.

Having understood this several years ago, WEF created a public education initiative to provide communications tools called, *Water Is Life, and Infrastructure Makes It Happen*™. Municipalities and local organizations have access to free, downloadable, and customizable outreach materials that contain thought compelling slogans and eye-catching graphics to grab the publics' attention. WEF's goal has been to provide utilities a communications strategy and encourage them to work in local coalitions for water infrastructure. The approach relies on stakeholders working together using consistent messaging. The partnership strengthens their voice to engage the public and make their case. Local leaders are empowered to take necessary steps to support water infrastructure.

Will sustainable infrastructure funding get buried, pushed aside for fear of the ever increasing deficit and tax burdens? Or, can we once and for all realize the critical nature of water infrastructure to U.S. public health, the environment and as a foundation component of the economy? Combined, the four reports summarized here will inform and help elevate the debate within the water and finance sector for sustainable infrastructure investment. ❖

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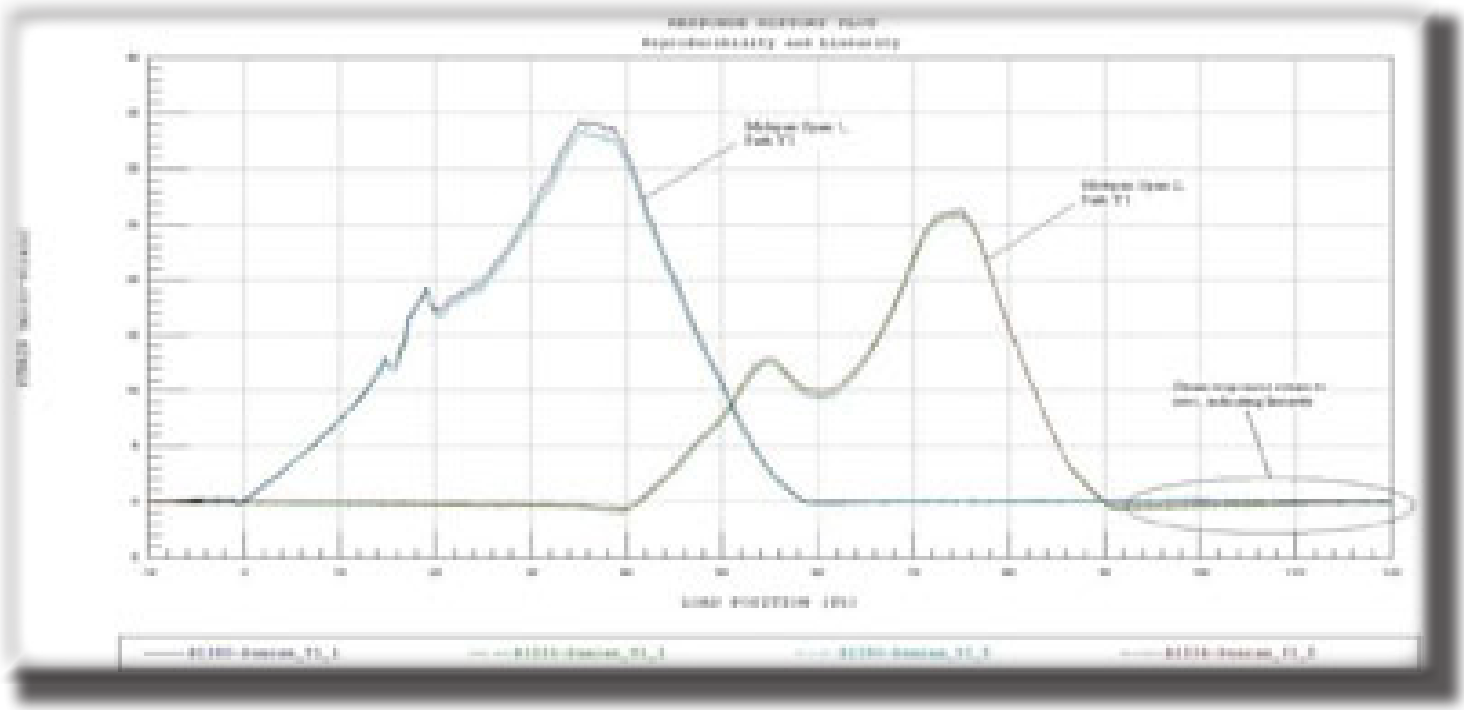
Diagnositics *(Cont. from 20)*

result is an accurate model that behaves like the actual bridge, and can confidently predict the behavior of the actual bridge under very heavy loads.

The typical results are that the bridge has more capacity and better distribution than originally assumed since things like sidewalks and guardrails actually carry some of the load. It should be noted that the testing and analysis procedures used for these investigations have been developed and refined by BDI over the last 20 years. The primary focus of these procedures has been to be able to implement them quickly and efficiently, therefore allowing them to be completed for a very reasonable cost.

With regards to aging infrastructure, as described above, the bridges that our particular firm has dealt with have been predominantly in adequate condition. Again, perhaps because of the types of structure we are involved with, we are not seeing a totally accurate view in whether or not there is any particular danger to the travelling public. The best source for this type of information would come from the state DOTs directly as they have detailed Bridge Management Systems that are basically databases on the condition of their bridges; most of the data there will be from their visual inspections that they must conduct every two years.

BDI is familiar with a variety of structural evaluation technologies. For more information on BDI's field testing and analysis services, please visit our website at http://www.bridgetest.com/index.html. ❖



Security *(Cont. from 18)*

Equally compelling as age-related failures are the catastrophic failures of relatively new infrastructure from factors such as lack of redundancy and flexibility that might otherwise have reduced the likelihood of failure and its consequences. Over two dozen bridge collapses tracked by the National Transportation Safety Board occurred among bridges that were not among the oldest. For example, bridges collapsed that were built during the 1950s and 1960s with prevailing non-redundant design. The Mianus Bridge, constructed in 1958, collapsed in 1983 in part due to maintenance problems. Similarly, the collapse in 1987 of the Schoharie Creek Bridge, which opened in 1954, was attributed to structural elements that contributed to susceptibility to bridge scour that ultimately undermined the bridge supports.

In addition to design and construction, environmental factors can decrease the lifetime and vulnerability of infrastructure. Examples are freeze-thaw cycles, undermining of structural support due to soil erosion and failure to replace soil after construction, electric currents, and vibration. Dependencies and interdependencies among infrastructures, which can be either spatial or functional, have dramatically altered the vulnerability of infrastructure. The rates at which different infrastructures recover from their dependency on other infrastructure is highly variable as the 2003 U.S.-Canada Blackout showed (Zimmerman and Restrepo 2006).

Thus age of infrastructure is one of a number of factors that affects infrastructure performance and its susceptibility to catastrophic failures, contributing to them and relating to them in a complicated way. Although age is commonly used as a surrogate for vulnerability, research on exactly how consistently it is defined and how it relates to environmental factors, design and construction practices, and interdependencies is critical. Moreover, if age does affect infrastructure condition, research is needed on how this affects the ability of infrastructure to withstand terrorist attacks and natural hazards. Finally, on a positive note, new innovations in planning and design can override effects that age can have on infrastructure lifetime estimates and resiliency needs, such as: using innovative materials that can resist heat, corrosive effects of water inundation, and physical impacts; redundant designs, avoidance of single point failure points, and flexible services to compensate for whatever negative affects may occur; and green technologies for resilience that may not be as age sensitive or can be more easily upgraded.

This paper is based on "The Age of Infrastructure in a Time of Security and Natural Hazards," by R. Zimmerman, C.E. Restrepo and J.S. Simonoff of New York University at the Aging Infrastructures Workshop sponsored by the United States Department of Homeland Security Science and Technology Directorate and Columbia University on July 21, 2009. This research was supported Cooper, M. (2009) Old by the United States Department of Homeland Security through the Center for Catastrophe Preparedness and Response at New York University, Grant number 2004-GTTX-0001, for the project "Public Infrastructure Support for Protective Emergency Services," by the United States Department of Homeland Security through the Center for Risk and Economic

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(Continued on Page 29)

Legal Insights *(Cont. from 21)*

and by earmarks to pet projects of specific congressional officials. A larger constraint is the requirement to spend funds across geographic areas regardless of need or of the respective populations served by an improvement, but this rural-urban divide is an essential characteristic of U.S. political system. Without this requirement and a demand to spend funds across all 50 states, an appropriations bill would never pass the Senate. The ultimate conclusion that can be drawn from the bill as it exists now is that some progress will continue to be made at the federal level on the aging infrastructure problem, but a solution is still far away. ❖

Security *(Cont. from 28)*

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