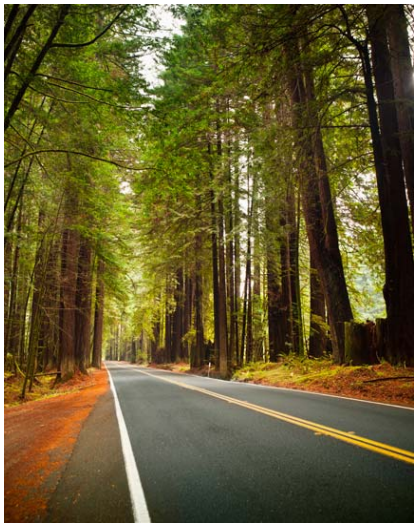
Beyond Ratings

Potential Cost Savings of Sustainability Practices

The Sustainable Highways Initiative

The Federal Highway Administration's (FHWA) Sustainable Highways Initiative supports programs and activities that facilitate balanced decision-making among environmental, economic and social values — the triple bottom line. Sustainability goes beyond being "green". A sustainable highway should satisfy life cycle functional requirements of societal development and economic growth while reducing negative impacts to the environment and consumption of natural resources. The sustainability of a highway should be assessed and considered from conception through construction and in maintenance and operations. A sustainable approach seeks to meet all of these needs while hitting economic targets for cost-effectiveness. FHWA has conducted a research pilot study to identify the potential cost savings associated with implementing sustainability practices. By exploring the ways that transportation agencies and system users benefit from incorporating sustainability in highway development, this research helps to illustrate how a full range of transportation practices contributes to the triple bottom line.



INVEST

INVEST is FHWA's web-based self-evaluation tool for assessing sustainability over the life cycle of a transportation project or program. INVEST provides a suite of best practices that can deliver a range of benefits to transportation agencies, highway users, regional and local economies, the environment and social welfare.

This tool connects sustainability principles with action by providing a system for rating specific transportation practices during three phases in the life of transportation infrastructure: System's Planning (SP), Project Development (PD) and Operations and Maintenance (OM). By providing a means to measure sustainability specifically for transportation, INVEST helps stakeholders in the industry go above and beyond facilitating an objective approach to assess processes and identify improvement opportunities, thereby encouraging the implementation of sustainable practices.

Beyond Ratings: The Value of Sustainability Practices

It can be difficult to capture the true value of sustainability. Benefits of the triple bottom line can be realized in several ways including cost savings, healthier environments, time savings to users and agencies as well as improved quality of life. In an effort to better quantify the economic benefits of sustainability while also highlighting the environmental and social benefits of such practices, FHWA used this study to go beyond rating the sustainability of transportation projects and programs and explore building a business case for implementing some practices of the INVEST tool. Six representative practices were selected and

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studied to find real world examples of costs savings. These practices were explored to provided sufficient information to present triple bottom line benefits in tangible and comparable metrics (e.g., time saved, costs saved in dollar value, etc.).

To help inform decisions about the use of sustainable transportation practices FHWA has generated dollar equivalents to estimate benefits and cost savings of specific practices that have been implemented by transportation agencies. These savings or benefits were classified into agency savings, economic benefits (to the users), environmental benefits and social benefits.

Agency Cost Savings: generate direct savings to agency's capital, operations, maintenance and service costs and budgets.

Economic Benefits or Savings for Users: generate economic benefits and savings to the users of the infrastructure by improving or enhancing mobility and efficiency (e.g., travel time) to-and-from centers of economy.

Environmental Benefits or Savings: generate environmental benefits or savings by reducing impact or enhancing the environment and ecology.

Social Equity Benefits or Savings: generate social equity or savings by reducing impact or enhancing factors such as safety, security, and accessibility.

Findings

The findings of this exploratory reserch have been summarized in a narrative for each selected practice. These narratives describe the goal of the sustainability practice, the sustainability linkage and the potential triple bottom line cost savings. The basis for potential savings is supported by specific examples from agency experiences. Additionally, a list of tools and references was developed for each practice that can provide supplementary information to transportation agencies and decision makers seeking to adopt similar practices.

SP-6	**Safety Planning:** State agencies can save tens of millions of dollars by reducing and saving on the emergency response, property damage, administrative, legal, and liability costs of crashes.
SP-9	**Travel Demand Management (TDM):** TDM helps manage congestion and parking demand more efficiently, which can save state agencies tens of millions of dollars by reducing the need for additional roadway capacity.
PD-14	**ITS for System Operations:** State agencies can save tens of millions of dollars by implementing ITS for system operations and reducing the need for additional major capital investment and operational costs created by congestion.
PD-20	**Recycle Materials:** State agencies can save, at the least, millions of dollars by saving 10-50 percent of their annual paving costs.
OM-8	**Bridge Management System (BMS):** State agencies can save tens of millions of dollars by extending the useful service-life of bridges through more efficient maintenance.
OM-12	**Road Weather Management Program (RWMP):** State agencies can save tens of millions of dollars each year by implementing a RWMP, which can reduce their winter maintenance costs by 10-15 percent.

SP-6

Safety Planning

Goal

Agency integrates quantitative measures of safety into the transportation planning process, across all modes and jurisdictions.

Sustainability Linkage

Reducing fatal and serious injuries due to traffic crashes contributes to the social and economic triple bottom line principles by reducing the impacts associated with personal and public property damage, injury, and loss of life.

Crashes are also a major source of nonrecurring congestion, which, in some places, is estimated to account for half of all congestion.[1] Thus reducing crashes also tends to improve mobility with benefits across the Triple Bottom Line (TBL). The process of reducing crashes starts with systematic, collaborative, data-driven planning.

Potential TBL Cost Savings*

$$ - DOTs can save on the cost of emergency response, property damage, administrative, legal, and liability costs of crashes.

$$$ - Highway users can save millions of dollars in crash (property damage), travel delay, and workplace productivity costs.

$$ - Reducing crashes can prevent adverse environmental impact costs (added fuel usage and air quality emissions caused by congestion).

$$$$ - Safety planning can save people's lives and enhance quality of life .

*Order of magnitude dollar equivalent potential savings for planning and implementation of highway safety measures: $~1M, $$~10M, $$$~100M, $$$$~1B

Basis for Savings

The U.S. Department of Transportation (USDOT) National Highway Traffic Safety Administration (NHTSA) reported 33,561 fatalities, 2.36 million injuries, and 9.9 million vehicles were involved in motor vehicle crashes in the United States in 2012[2] with total TBL costs approaching $1 trillion.[3] Additional information is available from the FHWA Operations Benefit/Cost Analysis Desk Reference.[4]

Comprehensive, collaborative, data-driven safety planning is essential, not only to reduce the economic and social costs associated with these motor vehicle crashes, but most importantly to help save people's lives.

Safety planning to reduce crashes is the first step to prevent property damage, emergency response, litigation, and liability costs associated with crashes.[5] Capacity needs may also be reduced through reduction of crash induced delays.[6]

Crash reduction improves system reliability resulting in increased productivity and efficiency for users.[7] NHTSA estimated that the total pure economic cost of motor vehicle crashes in the U.S. in 2010 was about $277 billion.[8]

Crash reduction lowers vehicle emissions released by idling traffic[9] as a result of congestion, and avoids petroleum and toxic spills from commercial vehicle crashes.[10] NHTSA estimates that adverse environmental impact costs of crashes in 2010 were $28 billion.[11]

According to NHTSA the societal costs of motor vehicle crashes in the U.S. reflected as impacts to quality of life factors exceeded $590 billion in 2010.[12]

Agency Experience

Washington State Department of Transportation (WSDOT) conducted an INVEST pilot study that evaluated three corridor studies and found that the SP-6 criteria could be used to effectively integrate quantitative safety planning and considerations into these projects.[13] California DOT's Highway Safety Improvement Program (HSIP)[14] helped reduce the number of fatal collisions (19.6 percent) and number of persons injured (18.8 percent) at 95 highway locations.[15]

Transportation Safety Planning (TSP)

The mission of TSP is to reduce transportation fatalities and serious injuries by supporting comprehensive, system-wide, multimodal, data-driven, and proactive regional and statewide transportation planning processes that integrate safety into surface transportation decision-making. TSP involves processes that yield the following products: Strategic Highway Safety Plans (SHSP), safety provisions in the Statewide Transportation Improvement Programs (STIP) and Transportation Improvement Programs (TIP), and long-range transportation (20-year) plans.

Comprehensive and Collaborative

Starting with Federal law that requires state and metropolitan transportation planning processes to be consistent with the SHSPs, TSP supports comprehensive, system-wide, multimodal proactive planning processes to protect motorized and non-motorized users including pedestrians, vehicle occupants, bicyclists, motorcyclists, older users, and children.

State Departments of Transportation (DOTs) and Metropolitan Planning Organizations (MPOs) play the leading roles in TSP. However, to make the greatest impact a broad range of other stakeholders should be engaged and involved,[16] including:

- ✓ State, Local, and Tribal Transportation Agencies
- ✓ Emergency Medical Services
- ✓ Local Law Enforcement
- ✓ Transit Agencies
- ✓ State Agencies
- ✓ Federal Agencies
- ✓ Trade Associations
- ✓ Highway Safety Advocates
- ✓ Private sector entities

Data Driven

TSP work is based on a scientific approach that includes collection and maintenance of safety data, data analysis, project development, and monitoring.

Analysis tools[17] include:

- ✓ The Highway Safety Manual (HSM)
- ✓ Crash Modification Factors (CMF)
- ✓ Interactive Highway Safety Design Model (IHSDM)
- ✓ Safety Analyst to identify safety improvement needs and cost-effectiveness
- ✓ Systemic Safety Project Selection Tool to consider risk as well as crash history.
- ✓ Highway Performance Monitoring System (HPMS) Viewer and Geographic Information System (GIS) Tools
- ✓ PlanSafe to incorporate sociodemographic data
- ✓ U.S. Road Assessment Program (usRAP) benchmarking safety performance
- ✓ Pedestrian and Bicycle Crash Analysis Tool (PBCAT)
- ✓ Bicycle Countermeasure Selection System – BIKESAFE
- ✓ Pedestrian Safety Guide and Countermeasure Selection System – PEDSAFE
- ✓ Interchange Safety Analysis Tool (ISAT).
- ✓ Surrogate Safety Assessment Model (SSAM) to assess design alternatives using traffic simulation models

Notes on Valuation

The range in agency cost savings realized through TSP implementation can be expected to vary across states due to:

- ✓ Current crash rates
- ✓ Highway congestion
- ✓ Stakeholder collaboration
- ✓ Degree of system maturity

Individual Assessments

States are encouraged to review the following references, and to consult the FHWA INVEST Subject Matter Expert, Robert.Ritter@dot.gov for additional working materials in assessing their own unique situations and/or if they have information that could assist others on this topic.

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SP-9

Travel Demand Management

Goal

Reduce vehicle travel demand throughout the system.

Sustainability Linkage

Travel Demand Management (TDM) provides multiple sustainability benefits, including environmental (reduced energy consumption and related emissions), social (improved awareness of available travel choices), and economic (reduced costs of travel and congestion to economy).

TDM strategies aimed at maximizing traveler choices include education and outreach programs; incentivizing non-auto trips; ridesharing; parking, road, and vehicle pricing; pedestrian-friendly land use, and employer trip reduction programs (e.g., transit benefits, trip-end facilities, parking cash-out programs, teleworking, etc.). These measures are most effective in urban areas as this is where most congestion occurs and thus the benefits of reduced automobile travel may be most effectively realized.

Potential TBL Cost Savings*

$$ - Reduced congestion and parking demand can reduce the need for additional roadway capacity.

$$$ - Congestion reduction improves reliability, enhancing overall mobility.

$$ - Reduced greenhouse gas and principal pollutant emissions lessens environmental impact.

$$ - Traffic reductions and expanded transportation options can improve safety, health, and access.

*Order of magnitude dollar equivalent potential savings: $~1M, $$~10M, $$$~100M

Basis for Savings

Implementation of TDM strategies such as congestion pricing, policy changes, high-capacity rapid transit, parking management, transportation-efficient development, and others[1] can:

Reduce the need for billions of dollars in additional roadway capacity and associated maintenance, and maximize returns on existing infrastructure by implementing TDM measures that improve system-wide travel times, reliability, and access.[2]

Improve mobility and reliability by at least a few percent, reducing the hundreds of millions of dollars in costs related to person miles of travel and delay due to congested urban traffic for the public at large. Commuters and individuals who ride public transportation in urban areas can save almost $800 per month.[3]

Improve air quality by reducing emissions from single-occupancy vehicles (SOV) by several percent and preserve green space by reducing the amount of land needed for roads and parking facilities.[4]

Improve safety and access by at least a few percent reduces the tens of millions of dollars in costs associated with a lack of transportation options and the avoidable costs of traffic congestion, including crashes.[5]

Agency Experience

As a result of applying INVEST to Corridor Studies and the SR 520 Bridge Project in Washington State, the Washington State Department of Transportation (WSDOT) integrated TDM strategies into planning and programming that resulted in improved performance, measures, and guidelines.[6]

WSDOT reports significant successes with TDM throughout the years, including the removal of 28,000 vehicles from Washington roadways every weekday morning and an annual reduction of 62 million vehicle miles traveled (VMT) statewide. This reduction in VMT prevented 27,490 metric tons of greenhouse gases from being emitted and three million gallons of fuel from being consumed. Between 1990 and 2000 the City of Bellevue, WA, successfully reduced the SOV commute rate in downtown Bellevue by 30 percent by implementing TDM strategies.[7]

Figure 1: State Route 520 Bridge in Seattle, Washington (Source: Ramanathan)

Commuter Ridesharing

Ridesharing is a traditional TDM practice that strives to make long-term reductions in SOV trips in order to help meet air quality goals, increase system-wide efficiency, and improve travel time reliability. Other key benefits of ridesharing, carpooling, or vanpooling include user affordability, avoidance of costly car related expenses, time savings, reduced congestion, commuter tax benefits, and reduced greenhouse gas emissions and fuel consumption.[8]

A commuting cost calculator from the state of New Jersey estimates the following cost savings for carpools of various sizes:[9]

	Estimated Savings per Days of Carpool Use in a Week ($)				
Mode	1 Day	2 Days	3 Days	4 Days	5 Days
Carpool-2	6.11	12.22	18.33	24.44	30.55
Carpool-3	8.14	16.28	24.42	32.56	40.70
Carpool-4	9.16	18.32	27.48	36.64	45.80

Similarly the table below summarizes the CO_2 emissions from SOV commuting in the U.S. (lbs):[10]

Estimated CO_2 Emissions Savings per Typical SOV (lbs.)			
Daily	Weekly	Monthly	Yearly
23.3	116.5	456.6	5,587

In Los Angeles County, the ridesharing program reduced the cost per trip by $2.80 while the cost per person placed into a new ridesharing arrangement was $0.82 per day.[11]

Value/Congestion Pricing

Congestion pricing, a type of road pricing also known as value pricing, shifts travel time and reduces vehicle travel on a particular roadway depending on different factors such as congestion, location, and traffic volume levels.[12] The table below summarizes road pricing benefits on a rating scale from 3 (very beneficial) to -3 (very harmful). A score of 0 indicates no or mixed impacts.

Strategy[13]	Revenue Generation	Congestion Reduction	Pollution Reduction	Increased Safety
Road Toll (fixed rates)	3	2	1	1
Congestion Pricing (time-variable)	2	3	2	1
HOT Lanes	1	2	1	0
Cordon Fees	2	3	1	1
Distance-based Fees	3	2	2	2
Pay-As-You Drive Insurance	0	2	2	3
Road Space Rationing	0	3	1	1

Notes on Valuation

The range in the benefit-cost ratios and agency cost savings potential from TDM can be expected to vary across states due to:

- Highway congestion
- Availability of transit
- Willingness of employers to participate
- Degree of existing TDM system maturity

Individual Assessments

States are encouraged to review the FHWA Office of Operations publication titled *Integrating Demand Management into the Transportation Planning Process: A Desk Reference*[11] to assess the potential policy objectives as well as the scope of TDM in the planning process, and to consult the FHWA Invest Subject Matter Expert, egan.smith@dot.gov for additional working materials in assessing their own unique situations and/or if they have information that could assist others on this topic. States are also encouraged to review the FHWA Office of Operations *Operation Benefit/Cost Analysis Desk Reference*[14] and to consult with jim.hunt@dot.gov with questions relating to this material.

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PD-14

ITS for System Operations

Goal

Improve the efficiency of transportation systems without adding infrastructure capacity in order to reduce emissions and energy use, and improve economic and social needs.

Sustainability Linkage

Intelligent Transportation Systems (ITS) applications support all of the triple bottom line principles by improving mobility, reducing congestion, and improving safety while avoiding environmentally—and economically—costly capacity increases.

ITS can be used to influence and induce changes in trip making (e.g., route, mode, and time of travel), which helps shift demand to where and when capacity may be available, improving overall system utilization and efficiency. Compared to roadway widening and other capacity increasing alternatives, which take longer to implement due to high initial costs and environmental considerations, ITS and management/operations strategies can be implemented much faster and require relatively lower up-front costs. This allows economic benefits to be realized sooner, enhancing the overall economic value of these investments. Taken as a whole, Transportation Systems Management and Operations (TSM&O) and its associated ITS elements can offer significant economic, environmental, and social benefits without the impacts and expense of additional paving.

Potential TBL Cost Savings*

$$ - DOTs can save by avoiding expensive capacity investments.

$$$ - User benefits from reduced congestion/ improved reliability.

$ - Greenhouse gas and pollutant emissions as well as traditional capacity impacts avoided.

$$ - Improved safety, mobility, and emergency response.

**Order of magnitude dollar equivalent potential savings: $~1M, $$~10M, $$$~100M*

Basis for Savings

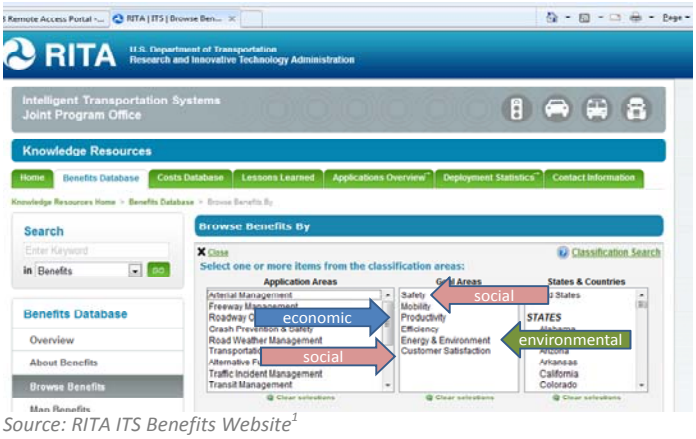
As detailed on the Research and Innovative Technology Administration's (RITA) ITS website, the application of ITS technology to transportation can yield a myriad of low-cost, high-value benefits across the triple bottom line. An extensive database of ITS benefits and costs is available through the links provided in this section.[i]

ITS investments can produce dramatic improvements for a small fraction of the costs needed to build additional travel/turn lanes. For more information visit RITA's online ITS cost database.

Reducing vehicle miles traveled (VMT) improves mobility by providing smoother, safer travel conditions, which can result in fewer crashes and resulting delays for improved system reliability. For more information visit RITA's online ITS database for economic benefits.

Reduce emissions generated by traffic backups attendant to poor travel conditions by tens of percentage points. For more information visit RITA's online ITS database for environmental benefits.

Improve safety and access associated with otherwise avoidable cost of crashes. Do so by providing safer travel conditions on a more reliable system for personal vehicles, buses, and commercial and emergency users. For more information visit RITA's online ITS database for social benefits.

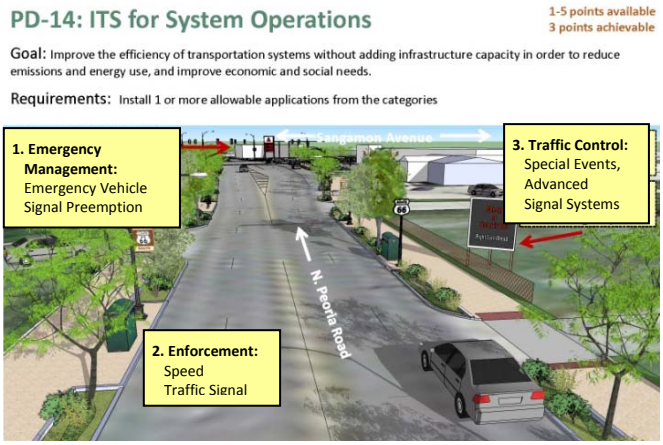


Source: RITA ITS Benefits Website[i]

i The database is derived from reported before and after results of ITS deployments throughout the country. Although it can serve as a useful source to estimate the range of benefits that could be expected for a particular ITS application, caution should be exercised in assuming similar results for your implementation. More advanced analysis, modeling, and simulation should be considered to estimate the impacts of specific ITS strategies utilized in particular settings.

Agency Experience

An INVEST case study by the Springfield Sangamon County Regional Planning Commission (SSRPC) employed ITS practices for emergency signal preemption, speed enforcement, and special event signage:[2]



Source: INVEST Case Study Springfield Sangamon County Regional Planning Commission (SSRPC)[3]

Other ITS applications include Arterial Management, Freeway Management Crash Prevention & Safety, Road Weather Management, Transit Management, Traffic Incident Management, Emergency Management, Information Management, Commercial Vehicle Operations, and Intermodal Freight. Each of these applications typically provides several techniques to improve efficiencies.

For instance, one of the many successful techniques is observed with the application of a real-time, decentralized traffic signal system pilot test developed by the Robotics Institute at Carnegie Mellon University called SURTRAC (Scalable Urban Traffic Control) in the East Liberty area of Pittsburgh, PA. In this pilot program the significant triple bottom line benefits of a relatively modest investment are listed below:

Arterial Management > Traffic Control > Adaptive Signal Control

	PERCENT IMPROVEMENT[4]				
Period	Travel Time	Vehicle Speed	Number of Stops	Wait Time	Emissions, Fuel Consumption
AM Rush	30%	34%	29%	48%	24%
Mid-day	33%	49%	53%	50%	29%
PM Rush	23%	27%	9%	36%	18%
Evening	18%	28%	35%	28%	14%
Overall	26%	34%	31%	41%	21%

Assumed values used to calculate benefit estimates for the nine pilot intersections are displayed in the following table:

Parameter	Value[5]		
Value of Traveler Time	12.75 ($/hour)		21.25 ($/hour)
Value Occupancy	1.59		1
Vehicle Split	98%		2%
Gas Unit Price	3.48 ($/gallon)		3.48 ($/gallon)
	CO	NOx	VOC
Pollutant Unit Price	0.0063 ($/kg)	1.28 ($/kg)	1.28 ($/kg)

Based on the previous assumptions and 261 weekdays of annual use, benefit estimates for the nine test intersections were estimated to be approximately $7,184 daily and $1,875,127 annually. If SURTRAC were to be implemented throughout all the intersections in the City of Pittsburgh, citywide benefits would be estimated to be over $125 million annually. It is also estimated that the benefit-cost ratio would be about 20:1 after five years of operation due to the negligible operational costs associated with SURTRAC's decentralized nature. Even after assuming a cost of $50,000 per intersection for technology upgrades, return on investment is realized after three months of operation.

Notes on Valuation

The range in the benefit-cost ratios and agency cost savings potential can be expected to vary across states due to:

- ✓ Highway congestion
- ✓ Labor and material costs
- ✓ Degree of system maturity

FHWA Office of Operations provides resources to help evaluate the benefit and costs of operational improvements including ITS. These resources include the Tool for Operations Benefit Cost Analysis (TOPS-BC)[6] and other relevant publications.[7,8]

Individual Assessments

States are encouraged to review the FHWA Office of Operations *Operation Benefit/Cost Desk Reference*[9] and the references shown below, and to consult the FHWA INVEST Subject Matter Expert (SME), Jim.Hunt@dot.gov, for additional working materials in assessing their own unique situations and/or if they have information that could assist others on this topic. In addition, Paul.Pisano@dot.gov is the SME for ITS applications related to road weather management.

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PD-20

Recycle Materials

Goal

Reduce lifecycle impacts from extraction, production, and transportation of virgin materials through recycling.

Sustainability Linkage

Recycling materials supports the environmental and economic principles of the triple bottom line by reducing the consumption of raw materials, reducing landfill waste, and encouraging cost savings. Some savings accrue to the traveling public because recycling pavements in place can reduce traffic disruption. However, the main benefits associated with recycling involve the avoidance of mining, processing, delivery, and disposal impacts.

Potential TBL Cost Savings*

$$ - DOTs can save 10-50 percent of their paving costs.

$ - Highway users can save travel time from reduced construction delay.

$ - Environmental impacts of mining and land filling can be avoided.

$ - Agencies set a good example and provide safety benefits.

*Order of magnitude Triple Bottom Line (TBL) dollar equivalent potential savings: $~1M, $$~10M, $$$~100M

Basis for Savings

The majority of available agency cost savings information related to the recycling of transportation facility constituents involves the use of Reclaimed Asphalt Pavement (RAP), Recycled Concrete Aggregate (RCA), and/or in-place construction recycling methods.

As the resource base for virgin materials diminishes over time, the best materials available for reconstruction are often found in existing pavements. In addition to reducing waste, recycling pavements can lead to the use of best available materials while minimizing transportation, land fill, and mining impacts.[1]

Recycling of pavement materials can result in shorter construction times and less trucking of construction materials, thus minimizing traffic disruptions and associated costs on the traveling public.[2]

Recycling pavement materials reduce the amount of construction trucking required to complete a project, thus reducing related energy use, emissions, and traffic congestion.[3] It also reduces the environmental impacts associated with the mining of virgin materials by leaving these resources available for future generations along and scarce landfill capacity.[4]

Citizens who expect their government to be sensitive to the needs of future generations are not only well served by the direct dollar savings generated by the recycling practice, but also benefit from the example and precedent set by public agencies establishing practices that encourage the wise reuse of existing resources.

Agency Experience

According to the Ohio Department of Transportation (ODOT) Cleveland Inner Belt (George V. Voinovich) Bridge INVEST Case Study, nearly all of the materials from the closed Inner Belt Bridge in Cleveland will be recycled or reused.[5]

Reclaimed Asphalt Pavement and Recycled Concrete Aggregate

RAP has been extensively used for decades in pavement construction across the country. According to a recent study jointly conducted by National Asphalt Pavement Association (NAPA) and FHWA, the 2012 construction season used more than 68.3 million tons of RAP and 1.86 million tons of Recycled Asphalt Shingles (RAS) in pavements across the U.S., saving taxpayers more than $2.2 billion.[6] Based on recent survey results, the NAPA estimated savings at $600 per ton for asphalt binder, assuming five percent liquid asphalt in RAP, is $2.04 billion. The estimated savings at $600 per ton for asphalt binder, assuming conservative asphalt content for the RAS, is $228 million.[7]

% RAP	% Savings[8 9 1011]
10	8
20	14 - 15
25	14 - 20
30	21
40	28
50	30 - 40

Savings associated with different percentages of RAP content have been reported by various researchers as a percent of total pavement cost.

Performance of RAP has also proven to be good. An FHWA survey of states found that over a 17-year period, the performance of recycled Hot Mix Asphalt (HMA), designed and controlled during production, is similar to or could even improve upon the properties of conventional HMA. In the 1970s WSDOT built two projects using 70 percent RAP that had service lives of 16 years in comparison to control sections (no RAP) that lasted 10 years.[12] Although greater usage of RAP is desirable, it must be noted that there are less obvious factors that the use of higher percentage RAP may affect. Based on available resources, environment, and site conditions, the percentage of RAP use that provides an optimal level of cost savings and performance could differ on a case-by-case basis.[13]

The American Concrete Pavement Association (ACPA) reports that RCA byproducts (e.g., crushed concrete pavement used as aggregate) varied in price from $1 to over $16 per ton, and resulted in as much as $4 per ton of savings per square-yard of Portland Cement Concrete (PCC). Some estimate savings as high as $5 million on a single project by using RCA.[14] Other technologies such as roller compacted concrete pavement (RCCP)[15] and composite pavements, particularly HMA over PCC[16] and two-lift concrete pavements,[17] can also use recycled materials and generate cost savings.

In-Place Pavement Recycling

Methods of In-Place Pavement recycling include Cold In-Place Recycling (CIR), Hot In-Place Recycling (HIR), and Full Depth Reclamation (FDR). In-place pavement methods can substantially reduce transportation costs associated with hauling aggregate by using the material already in place. FHWA reports initial savings for CIR in lieu of conventional construction methods of 6 to 67 percent; 20 to 30 percent range savings were most commonly reported by state DOTs.[18] Similarly, FHWA research suggests that the use of HIR methods can generate cost savings over conventional construction methods in a range of 17 to 50 percent, with the 15 to 25 percent range of savings being most commonly reported by state DOTs.[19] With Full Depth Reclamation (FDR) costs are typically reduced by 25 to 50 percent and waste production is minimal compared to conventional treatments.[20]

Recycling Minor Structural Elements

Anecdotal information suggests that at least 90 percent of the minor structural highway elements including existing luminaries, signal poles, and sign structures can be relocated, reused, or recycled at considerable savings. For instance, North Park Road, Jackson Lake Lodge to Leek's Marina Project relocated and reused over 90 percent of minor structural elements.[21] However, documented research on agencies experience recycling minor structural elements is lacking due to its "business as usual" nature.

Notes on Valuation

In general the savings to be realized through recycling of materials will depend on:

- ✓ Availability of virgin materials
- ✓ Local markets
- ✓ Available technologies

Individual Assessments

States are encouraged to access the following references and to consult the FHWA Invest Subject Matter Expert, Gina.Ahlstrom@dot.gov for additional working materials in assessing their own unique situations and/or if they have information that could assist others on this topic.

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OM-8

Bridge Management System[i]

Goal

Leverage a Bridge Management System (BMS) to balance activities that extend the life and function of bridges with impacts to the human and natural environment.

Sustainability Linkage

Maintaining and using a BMS supports the environmental and economic principles by optimizing the management of bridge structures, including preservation, restoration, and replacement, to maximize their lifetimes. This reduces costs, the environmental impacts of construction, and raw material usage.

Potential Triple Bottom Line (TBL) Cost Savings*

$$ - DOTs can save by extending the useful service-life of bridges through more efficient maintenance.

$$ - System users benefit from reduced traffic congestion and reliability costs due to bridge postings and closures.

$ - Less frequent and shorter construction reduces emissions released from congestion/ detours associated with bridge closures.

$$$ - Safety/access costs avoided due to bridge closures.

*Order of magnitude dollar equivalent potential savings: $~1M, $$~10M, $$$~100M

Figure 1: AASHTOWare Bridge Management Software Logo

[i] Strictly speaking, a bridge management system is a planning and analysis tool that helps inform the larger process of bridge management which includes all the managerial functions of an agency necessary for policy analysis, planning, programming, budgeting, and project decisions for bridges. As used here the terms bridge management and bridge management system are basically synonymous.

Basis for Savings

Bridge management helps agencies identify bridge preservation and improvement activities that provide the maximum cost benefit for minimum given level of investment.[1] Improvements in preservation, restoration, and replacement of bridge structures through bridge management can:

Reduce life cycle costs by enabling agencies to spend their money where it is most effective on projects regarding preventative maintenance repair, rehabilitation, or replacement by utilizing a life cycle approach.[2]

Generate road-user benefits in terms of reduced travel time, vehicle operation, and accident-related costs as the result of bridge reconstruction.[3] With billions worth of travel benefits that could be affected, user costs due to traffic delays and lost productivity are often more than 10 times the direct cost of maintenance, repair, and rehabilitation.[4]

Reduce environmental impacts caused by fuel consumption and CO_2 emissions by decreasing traffic congestion and detour vehicle miles traveled through avoidance of long-term bridge closures.

Improve safety and access by at least a few percent of the tens of millions of dollars associated with the avoidable cost of crashes by avoiding the traffic impacts associated with major reconstruction projects, thus providing safer travel conditions on a more reliable system for personal vehicles, buses, and commercial and emergency users.

Agency Experience

BMS information can help agencies make balanced, rational, defensible, and cost-effective decisions[5] that together with prudent bridge management investments can increase the fraction of bridges within a network that are in fair or good condition and significantly reduce life cycle costs, while conferring other benefits across the triple bottom line.

Idaho, Michigan, and Virginia were successful in using bridge management to improve the structural health of their bridges. Idaho has increased the percentage of bridges in good condition from 67 percent in 2006 to 73 percent in 2010. Michigan increased its percentage of good and fair bridges from 79 percent in 1998 to 92 percent in 2011, and Virginia increased its percentage of fair and good bridges from 90 percent in 2000 to 92 percent in that same year.[6]

North Carolina Department of Transportation

In the 1980s North Carolina State University (NCSU) developed OPBRIDGE, a BMS program.[7] In 1988, OPBRIDGE calculated an annual user cost of $566 million due to detours and accidents on NCDOT bridges. In 1993 the NCDOT bridge management budget was increased from $100 million to $150 million, resulting in user costs savings of approximately $245 million and a total cost savings over $300 million.[8]

Agency	Initial Investment	Additional Investment	Annual Cost Savings
NCDOT	$40-60 million	$100 million	> $300 million

More recently, NCDOT has been able to use their BMS to help implement cost-efficient low-impact bridge replacement designs that have decreased replacement time by as much as four years and typically shrink project costs by 25 percent, while supporting water quality goals.[9]

Oregon Department of Transportation

Financial projections from a statewide bridge improvement study in Oregon indicated that substandard bridges would cause a potential loss to Oregon's economy of some $123 billion in lost production and 88,000 lost jobs in the next 25 years unless steps were taken to improve the state's bridges.[10] Subsequent investments informed by ODOT's BMS reduced bridge deficiency percentage from 33 to 23 percent since 2004 according to a 2012 report. These results indicated a continuing upward trend in fair and good bridges that began in 2007.[11]

Florida Department of Transportation

FDOT has implemented and customized the bridge management software Pontis (which is now known as AASHTOWare BrM). FDOT's BMS identified improvement projects that had the most benefit for FDOT:[12]

Improvement Project[13]	Average Annual User Benefit	Type of Saving
Bridge Widening	$1.2 million	Estimated as savings in accident costs
Bridge Raising	$14,000	Estimated as savings in truck detour costs
Bridge Strengthening	$93,000	Estimated as savings in truck detour costs

Notes on Valuation

The range in the benefit-cost ratios and agency cost savings potential can be expected to vary across states due to:

- Climate variation and de-icing needs
- Highway congestion
- Labor and material costs
- Degree of management system maturity
- Type and condition of bridges
- Level of investments, strategies, and policies

Individual Assessments

States are encouraged to access the following references and to consult the FHWA Invest BMS Subject Matter Expert, Derek.Constable@dot.gov, for additional working materials in assessing their own unique situations and/or if they have information that could assist others on this topic.

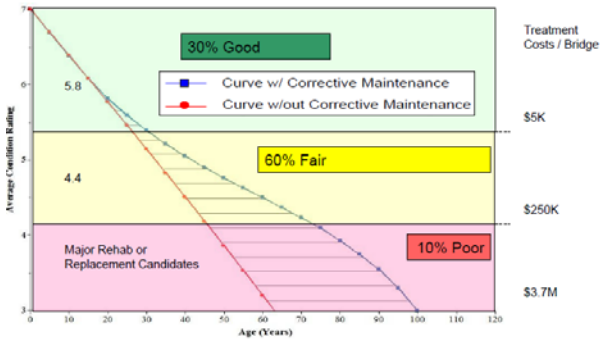

Figure 2: Bridge Service Life Extension Through Effective Maintenance[14]

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OM-12

Road Weather Management Program

Goal

Plan, implement, and monitor a road weather management program (RWMP), including snow and ice control, to reduce environmental impacts with continued or better levels of service.

Sustainability Linkage

Implementing an effective and efficient road weather management program supports all of the triple bottom line principles by improving safety, increasing mobility, reducing delay and traffic interruptions, increasing productivity of the labor force, and reducing impacts of materials (e.g., salt) used for management on infrastructure and the environment.

With the effective use of technology, RWMP's can inform managers on the deployment of response resources on highway weather events more efficiently. These efficiencies save treatment costs while improving mobility, avoiding environmental impacts (e.g., salt impact), and reducing crashes.

Potential TBL Cost Savings*

$$ - DOTs can save 10 to 25 percent of their winter maintenance costs.

$$$ - Highway users can save millions of dollars in travel delay.

$ - Salt impacts can be reduced by 10 to 20 percent.

$$$ - Safety/access benefits can also go well into the millions.

*Order of magnitude dollar equivalent potential savings: $~1M, $$~10M, $$$~100M

Basis for Savings

Typically RWMP's can address impacts to transportation systems across the country from all types of weather events. However, principal among these is the use of RWMP's for snow and ice control on highway systems. Enhanced use of technology in snow and ice control to both monitor and predict deterioration of travel conditions (RWIS – Road Weather Information Systems), as well as recommend event and site specific treatment plans (MDSS - Maintenance Decision Support Systems) can:

Save agencies several percent of the tens of millions of dollars spent on snow and ice control by reducing unnecessary deployment of labor (e.g., drivers), equipment (e.g., trucks), and materials (e.g., salt) to treat highways during marginal snow and ice conditions.

Improve mobility by at least a few percent of the hundreds of millions of dollars related to vehicle miles of travel during storms by providing smoother and safer travel conditions, thus avoiding crashes and delays, while improving system reliability.

Reduce environmental impacts caused by salt and other deicing chemicals (environmental damage and vehicle/infrastructure corrosion), and reduce emissions from traffic backups (attendant to poor travel conditions) and unneeded treatment miles logged by trucks, which translate to at least a few percent of the millions of dollars of savings.

Improve safety and access by at least a few percent of the tens of millions of dollars associated with the avoidable cost of crashes by providing safer travel conditions on a more reliable system for personal vehicles and buses as well as commercial and emergency users.

Agency Experience

An INVEST Case Study Report by the Utah Department of Transportation (DOT) concluded, "[u]sing the proper amount of material (salt, red salt, etc.) is vital to keeping the roads safe during storms. Excess use wastes resources (material and money) as well as introducing more salt to the environment (…) Although each storm is unique, guidelines regarding best practices (including type and amount of material; use of brine; time between plow passes; etc.) are available and should be implemented."[1]

RWIS-based Programs

A study performed on the Wisconsin DOT's Wisconsin's Winter Weather System documented that this RWIS-based program achieved "savings of up to four hours per person for each significant storm (a value of around $144,000/storm)."[2]

A separate report from the Utah DOT states that its RWIS-based program provided a benefit-cost ratio of approximately 11.0 and estimated the potential value of savings to range from 11 to 25 percent of its winter maintenance costs.[3]

Reports of RWIS savings from other DOTs are listed below:

Agency	Cost Savings (%)	Benefit-Cost Ratio
Iowa DOT[4]	5.6	1.8
Michigan DOT[5]	19.5 to 50	2.8 to 7.0
Nevada DOT[6]	6.5	3.2
Utah DOT[7]	11.0 to 25.0	11.0

These numbers are consistent with those reported in the NCHRP 20-7 (117) report, which suggests that an RWIS-based program can reduce approximately 10 to 20 percent of an agency's snow and ice control budget.[8]

MDSS-based Programs

The Indiana Department of Transportation (DOT) implemented MDSS-based RWMP throughout the state between 2008 and 2009 and reports a 38.6 percent savings to agency winter maintenance costs on an annual basis. This translates to a benefit-cost ratio of over 25.0.[9]

Reports of this and other MDSS savings are listed below:

Agency	Cost Savings (%)	Benefit-Cost Ratio
City/County of Denver[10]	2.0	1.3
Colorado DOT[11]	10.9	0.9
Indiana DOT[12]	38.6	25.0
Minnesota DOT[13]	6.6	1.6
New Hampshire DOT[14]	4.7	1.1

Notes on Valuation

The range in the benefit-cost ratios and agency cost savings potential can be expected to vary across states due to:

- ✓ Climate variation
- ✓ Highway congestion
- ✓ Labor and material costs
- ✓ Degree of system maturity

Individual Assessments

States are encouraged to access the following references and to consult the Federal Highway Administration (FHWA) INVEST Subject Matter Expert, Paul.Pisano@dot.gov, for additional working materials in assessing their own unique situations and/or if they have information that could assist others on this topic.

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Sustainability in Action

Although a pilot effort, this study provided an important first step to further communicate and expand the benefits of incorporating sustainability practices into transportation programs and projects. It is important to note that Potential savings will vary due to factors such as program size, geography, climate and levels of congestion. By tying the benefits that these sustainability practices generate across the triple bottom line to a "dollar equivalent" value, this research effort starts to close the gap between the concept of sustainability and the practical application and results that they bring to daily functions of local, regional and state transportation agencies. In other words, this pilot effort has taken an initial step to translate sustainability into the language of currency and dollar-values, which organizations understand and identify with as important factors to accomplishing their strategic and business goals.

Learn More

To learn more about FHWA's Sustainable Highways Initiative, INVEST and this research effort, please visit: **www.sustainablehighways.dot.gov**

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