Risk-Based Transportation Asset Management:

Managing Risks to Networks, Corridors, and Critical Structures

REPORT 4: MANAGING RISKS TO CRITICAL ASSETS

U.S. Department of Transportation
Federal Highway Administration

MARCH 2013

Notice

Quality Assurance Statement

NOTE FROM THE DIRECTOR

The Federal Highway Administration (FHWA) continuously seeks innovative ways to improve the management of the nation's highway infrastructure. The Office of Asset Management offers this series of reports on risk management as another means by which transportation agencies can better understand and manage their highway assets.

The use of risk management among U.S. transportation agencies largely is limited to managing risk at the project level generally focused during construction. Risk management at the project level helps to identify threats and opportunities to projects' cost, scope and schedule. However, we at the FHWA along with our partners at state and local transportation agencies recognize the growing need for a better understanding of risk management at program and organizational levels.

Today, the leading international transportation, banking and insurance organizations have explored the benefits of risk management at the program and enterprise level and use it as a tool to protect their investments. Based on those practices, the Office of Asset Management is offering this series of reports on how risk management can be scaled up to asset management programs, and to the entire enterprise of a transportation agency.

It's important for highway agency officials to consider incorporating risk management in the decision-making process for several reasons. First, they have seen the benefits of risk management at the project level. Second, they have heard from their international colleagues that risk management can pay dividends when used at the broader program and enterprise level, particularly when agencies don't have enough funding to address their priorities. Third, managing risk is an integral step in following a comprehensive asset management framework as described in the *AASHTO Asset Management Guide—A Focus on Implementation.* Finally, the U.S. Congress has proposed that states develop "risk-based transportation asset management plans." These factors convinced the Office of Asset Management to offer this series of reports.

We believe you will find these reports helpful as you develop your asset management program and make investment decisions. This series of reports will help the transportation agencies to meet the increasingly complex challenges involved in making decisions and communicating them effectively to the public.

Sincerely,

Butch Wlaschin
Director of the Office of Asset Management

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Introduction

Transportation asset management (TAM) enters a new risk-based era with the enactment of the Moving Ahead for Progress in the 21st Century Act, also known as MAP-21. The legislation requires a risk-and-performance based asset management plan for bridges and pavements on the National Highway System (NHS). MAP-21 also requires development of a national freight network that consists of critical corridors, facilities and connectors.

As transportation agencies develop their asset management plans, it is likely that they will stratify their risks based upon the importance of the key networks, corridors and facilities. This report, the fourth in a series of five reports on risk management, examines how agencies may apply risk-based asset management practices to key networks, corridors and facilities, particularly ones moving freight. The first three reports covered an overview of risk management, multi-level management of risks and achievement of policy objectives through risk management.

Risk and Its Management

As these earlier reports have defined, risk is the positive or negative effect of uncertainty or variability upon agency objectives. This internationally recognized definition broadens the consideration of risks to be more than only threats. The implication of this broader definition is that risk management can be applied not only to threats but also to opportunities created by uncertainty, variability or change as they relate to the achievement of *all* organizational objectives. Risks to the achievement of agency goals, reaching performance targets, meeting public expectations, satisfying customers or achieving acceptable condition and performance on key highway networks, corridors or individual assets could also be managed.

Building from this broad definition of risk, these reports use the definition of risk management as, the cultures, processes and structures that are directed towards the effective management of potential opportunities and threats. Interim Federal Highway Administration (FHWA) guidance notes that transportation agencies should consider managing risk as part of the strategic and systematic process of operating, maintaining, and improving physical assets and managing their highway network with a focus on the program and agency level. FHWA also encourages states to continue addressing risk at the project level.

Risk Management: A Common Idea, A New Application

The formal terminology of a risk-based approach to managing assets on networks and corridors may be new to some U.S. transportation agency officials. However, many aspects of its practice will be familiar. Highway agencies have long practiced functional classification. That is the classifying or stratifying of highway routes by their importance to key transportation objectives, such as connecting major population centers, moving freight, serving as evacuation routes, serving key ports or linking economic generators. Routes of lesser criticality have lower classifications, lower design standards and often receive less investment.

Functional classification is a form of risk management. Failures on major routes create greater risk of failure to key organizational or public objectives, such as providing connectivity, ensuring safe transportation, moving freight or providing access to key facilities during emergencies. The greater volumes on major networks such as the NHS create greater opportunities to improve travel times, reduce freight costs or improve economic competitiveness. Highway agencies have for decades understood and developed their

transportation programs around a hierarchical classification of key routes. They just have not called it a risk-based approach to managing networks, or the corridors within them.

The requirements of MAP-21 and risk-based asset management provide a new opportunity for DOTs to explain their decisions and demonstrate to the public and policy makers that they are responsible stewards of scarce resources. A risk-based approach to managing corridors and networks can allow DOTs to make the case for the difficult tradeoffs so many are forced to accept because of insufficient revenue to maintain the entire system adequately. When resources are limited, it provides them an opportunity to convey to policy makers and to the public the logic and reasoning behind the need to accept lower levels of service on lesser used roads in return for preserving performance and minimizing risks to more important ones. Such strategies typically represent a well thought-out and methodical approach to decision-making. They demonstrate the strategic best use of limited resources to preserve condition and performance on key routes, as opposed to spreading limited funds equally across the network and accepting a statewide drop in highway condition and performance.

Risk Management: Tradeoffs, Transparency to Preserve Critical Networks

A few examples below illustrate existing practices of risk management, trade-offs and the transparency in the use of these practices, where an agency is able to communicate with and obtain buy-in from policy makers and the public on how it is making key decisions in the prioritization and use of public resources for the management of its assets.

North Carolina DOT: A Tiered Approach to Managing Risks
Actions by the North Carolina DOT are an example of a risk-based approach to managing networks and the assets

within them. The DOT is responsible for over 79,000 miles of roads that include most of the public road system in the state including most local roads. The DOT works closely with local officials and for many years put special emphasis upon local needs. However, the DOT realized that sustaining a high level of condition on local roads was coming at the expense of the more heavily travelled NHS.

The demand for resources from all segments of the road network necessitated a risk-based approach to decision-making that could assist the agency in making tradeoffs. While developing the Statewide, Long-Range Multimodal Transportation Plan, the agency categorized the highway network in three tiers. Shown in Figure 1 are the Statewide (Interstate/NHS), Regional (NC/Lower importance U.S.) and Sub-regional (Secondary and Municipal Routes) based on their function and level of importance to different constituencies at the state, regional and sub-regional level.

Just based on the vehicle miles traveled (VMT), the failures of the higher functional classes create a greater impact on a

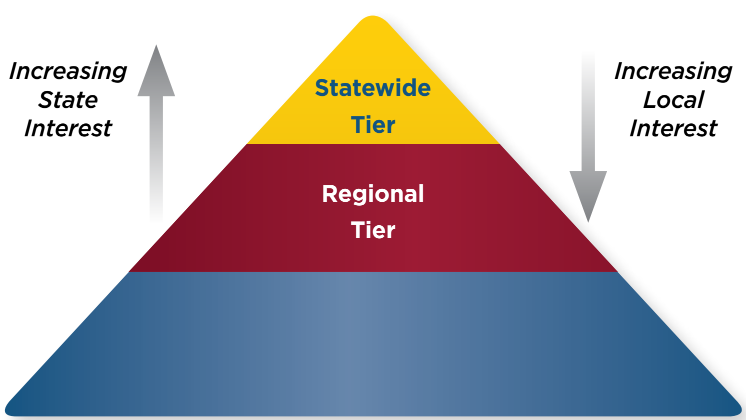

Figure 1. *NCDOT's risk-based approach to categorizing its highway network.* (SOURCE: NCDOT)

larger section of the user community. This categorization allows the agency to gauge the relative risk of asset degradation or failure upon its population and economy. By communicating this categorization, the agency is able to explain to the public and the stakeholders that it is acting responsibly when it gives higher priority to the higher classification roads and ensures that they are maintained so as to have a lower risk of failure. It demonstrates that the agency is keeping public safety, economic growth and other public concerns at the forefront of its decision-making. Having the three tiers makes it easier for the agency to communicate the impact of risks to the state, region or sub-region to policy makers and the public. This provides the appropriate perspective and helps the agency gain the needed support when it has to make difficult investment trade-offs.

The North Carolina DOT has set higher targets for bridges on the high-volume Interstates when compared to the Primary or Secondary systems. Table 1 shows that with limited resources, achieving targets for the higher volume systems such as the Interstates means accepting lower performance on the lower volume systems. Using a risk management approach to making tradeoffs, the agency can demonstrate responsible decision making to its stakeholders.

Utah DOT: Risk Management and Trade-Offs

An example from the Utah DOT illustrates a similar decision-making and trade-off process. Figure 2 (see page 6) shows the number of miles of pavement in overall "Good" condition reducing while those with "Poor" and "Fair" condition increasing over the years. This trend, caused by insufficient pavement budgets, forced the Utah DOT to take a risk-based approach to setting higher condition targets for its major networks, at the conscious expense of its lower functional classes.

		INTERSTATE		PRIMARY		SECONDARY	
Bridge Components	Measure	2010 Target	State Average Score	2010 Targets	State Average Score	2010 Target	State Average Score
Decks (Concrete)	% >= 6	85	85	80	79	75	84
Superstructure (Concrete)	% >= 6	90	81	85	60	80	65
Superstructure (Steel)	% >= 6	90	89	85	82	80	81
Superstructure (Timber)	% >= 6	90	NA	85	43	80	69
Substructure (Timber)	% >= 6	90	NA	85	40	80	42
Substructure (Concrete Pile)	% >= 6	90	80	85	75	80	81
Substructure (Steel Pile)	% >= 6	90	91	85	84	80	81
Substructure (Concrete Piers)	% >= 6	90	91	85	81	80	81
NBIS Culverts	% >= 6	85	86	85	86	85	89
Non-NBIS Culverts	Good	80	84	80	74	80	56
Overhead Sign Structures	Good	95	95	95	93	95	88

Table 1. *NCDOT sets higher targets and sustains higher conditions on the higher functional classes.* (SOURCE: NCDOT)

Figure 3 (see page 8) shows the impact of budgets (illustrated by the green bars) not increasing from 2013 to 2030. The chart also shows that ensuring the Overall Condition Index (OCI) of the NHS in Utah does not drop below 75 by 2030 will mean letting the Non-NHS pavement conditions drop to below 50.

The red trend line in Figure 3 represents pavement conditions on the Interstate Highway System and the light blue line, the conditions on the NHS through 2030. Using **risk-based investments,** the Utah DOT is sustaining pavement conditions

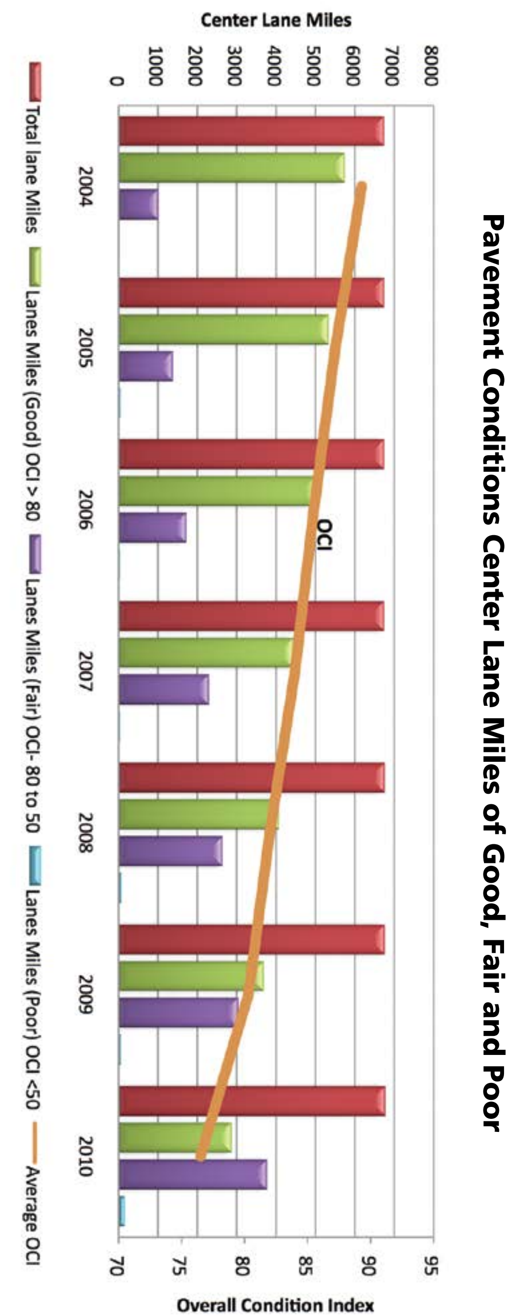

Figure 2. *Pavement Condition trend in Utah.* (SOURCE: UTAH DOT)

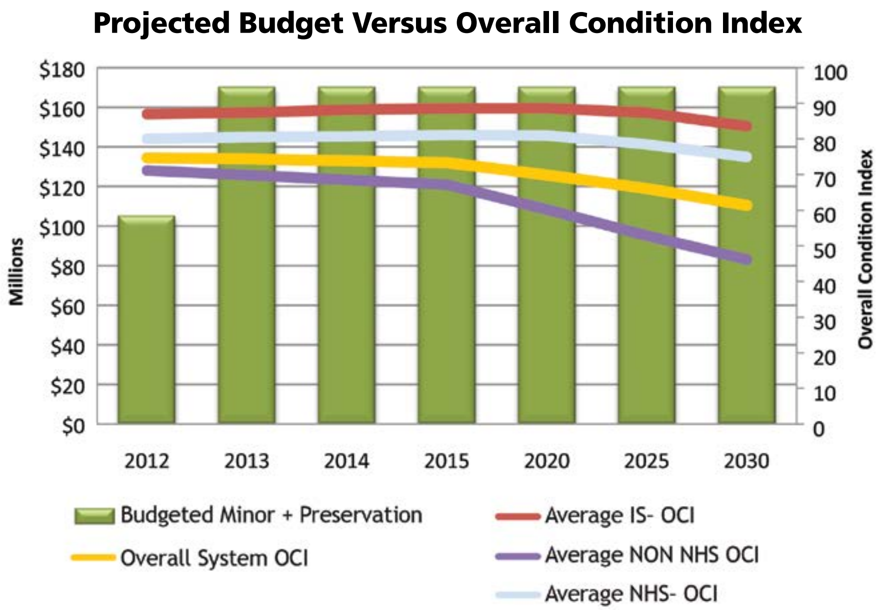

Figure 3. *Projected budgets and Overall Condition Index of pavements in Utah.* (SOURCE: UTAH DOT)

on its higher functional classification networks. However, it is clearly articulating to the public and policy makers that the tradeoff to sustaining those routes with the projected funds means accepting lower conditions on the non-NHS ones. The condition of the non-NHS routes, shown in the purple trend line, show substantial declines from 2015 through 2030 if pavement budgets remain static as predicted by the green bars.

Minnesota DOT: Risk-Based Pavement Investment Strategy with Public Input

The Minnesota DOT used an explicit risk-based analysis paired with public comment to identify a risk-based pavement investment strategy as seen in Figure 4. The rising red line shows that the miles of pavement in poor condition would rise significantly from 2010 to 2034 based upon current investment levels. Although the department's target

was to have no more than 2 percent of its pavements in poor condition, its pavement forecasts predicted that the percentage of poor condition pavements would rise to more than 40 percent by 2034 based upon its currently available investment. It realized that it could not afford to achieve its targets and it ***engaged the public in a risk-based analysis.*** Based on focus groups and public comment, the DOT determined that the public would accept up to 10 percent of the lane miles in poor condition. The department then identified a risk tolerance of having between 5 percent and 10 percent of its pavements in poor condition as illustrated by the green band. Then, based upon higher investment levels, it is now forecasting the actual poor pavement conditions to fluctuate between 5 and 10 percent of its inventory through 2034. This analysis showed that the department was initially too conservative in attempting to maintain no more than 2 percent of its pavements in poor condition.

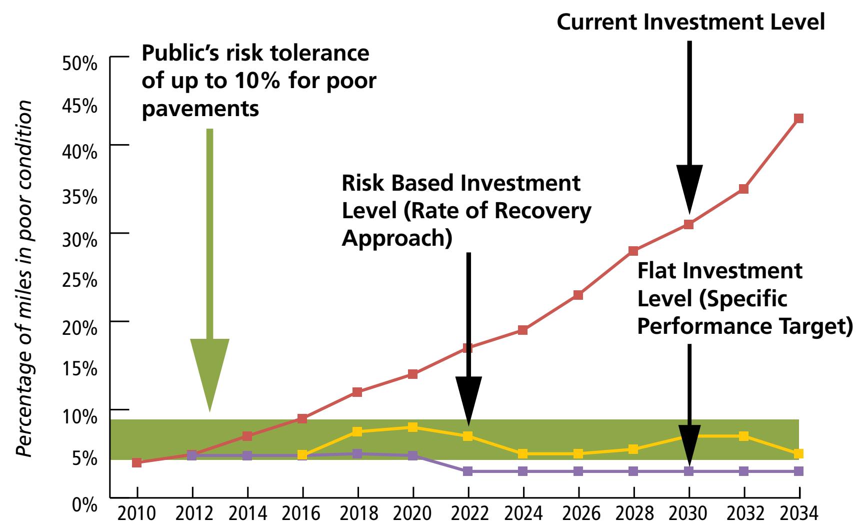

Figure 4. *Minnesota DOT's use of risk-based tradeoffs to set a "risk appetite" acceptable to the public.*
(SOURCE: MINNESOTA DOT)

Effective communication with the public indicated their willingness to accept a lower standard, allowing the department to set a lower target, yet meet public expectation. The exercise illustrated that the "risk appetite" for the public was for up to 10 percent of the pavements to be in poor condition. This also allowed the agency to give the necessary focus and priority to the critical segments of corridors and higher classification roads while meeting the public expectation and tolerance for risk.

VicRoads: The "Impaired Asset List" a Tool for Risk Management

This type of risk-based asset investment decision is taken to another level in the Australian State of Victoria. VicRoads, the state's highway agency, has been emphasizing risk management for more than a decade. The VicRoads report titled, "Stitch in Time-Five years of successful maintenance in Victoria", notes that, *"Road users expect better conditions on busy roads."* VicRoads' risk-based budgeting process invests more in more heavily travelled and economically important routes and accepts lower conditions on the lesser ones. It is unable to keep all roads in sound condition and must accept a certain percentage of the low-volume pavements to fall below acceptable levels. Once a pavement deteriorates and still cannot be repaired because of budget constraints, the roadway is formally added to an ***impaired asset list.*** This listing allows it to be signed as an impaired road, the speed limit is reduced and the drivers are informed of its impaired condition. This formal designation not only notifies state budget authorities that the department has made a risk-based decision to post the pavement as impaired, it also protects the department from legal liability should crashes occur due to poor pavement conditions. Although agency officials prefer not to post roads as being impaired, the ability to do so allows them to re-direct scarce funds to higher-volume and more economically critical routes.

These examples illustrate that a risk-based approach is already being practiced by several state transportation agencies nationwide. Hence formalizing the approach consistent with MAP-21 requirements does not involve embarking on an entirely new compliance program; rather it involves formalizing the existing practices into a holistic approach for the state. In doing so, it becomes important to examine how the transportation assets or groupings of assets within a state can be prioritized to meet national and state agency objectives in an optimal manner.

The Disproportionate Importance of Key Corridors, Networks and Facilities

A primary objective of transportation agencies in the United States has long been to provide the infrastructure assets and operational support necessary to efficiently and safely move people and goods across the nation by providing the connectivity necessary for economic growth while protecting the environment for future generations.

A risk-based asset management approach to moving people and goods focuses on evaluating the networks, corridors and facilities that create the greatest threats to and opportunities for achieving goals of mobility and safety. It also considers risks to the achievement of an agency's freight or economic-development objectives.

Some systems, corridors and facilities illustrate the disproportionate economic importance of a few key high-risk assets. Because of their high use, any failure of assets or degradation of service along these networks, or the unavailability of network segments for any length of time, can cause major impacts to the safety and movement of people and goods.

To illustrate, the National Highway System comprises 4 percent of the public road miles but carries about

DEFINITIONS

Across countries and industries, the terms used to define risk vary. The following descriptions define the terms used to refer to the various kinds of risk in this report.

ENTERPRISE RISK

This report uses the term enterprise risk to refer to all levels of risk being managed by a state department of transportation.

AGENCY RISK

This report refers to agency risk as the highest level of risk within an organization that affects a DOT's ability to accomplish its mission and achieve its strategic goals and objectives.

PROGRAM RISK

Program risks are ones that could affect the achievement of program objectives. Programs generally are defined as collections of related projects or on-going efforts to ensure achievement of specific organizational objectives.

PROJECT RISK

Project risks are those that effect the successful accomplishment of project objectives.

75 percent of the nation's truck freight (Figure 5). The Interstate Highway System, which is a subset of the NHS, comprises 1.5 percent of all public roads but carries 47 percent of all combination trucks, and 22 percent of all single-unit trucks. The I-95 Corridor serves 10 percent of the nation's landmass but 37 percent of its population. The Marquette Interchange in Milwaukee handles an estimated 30 percent by value of all of Wisconsin's truck freight. The

top 10 container ports handle 78 percent of the nation's container volume out of 86 container ports nationally. Two sister ports, Los Angeles and Long Beach, handle 33 percent of all national container imports and exports.[i] Any loss of serviceability or issues within these key assets creates disproportionate economic impacts, thus making them high-risk facilities. Effective access to and from these ports are critical to the movement of goods and have major impact on the US economy.

Besides assigning priority to assets on high priority highways, transportation agencies often also consider other highly significant non-NHS routes that carry lower volumes of traffic. Segments of these routes may be critical to national security or to the regional and sub-regional needs of the state. Some serve the unique needs of connecting economic hubs and regions in the state that are important

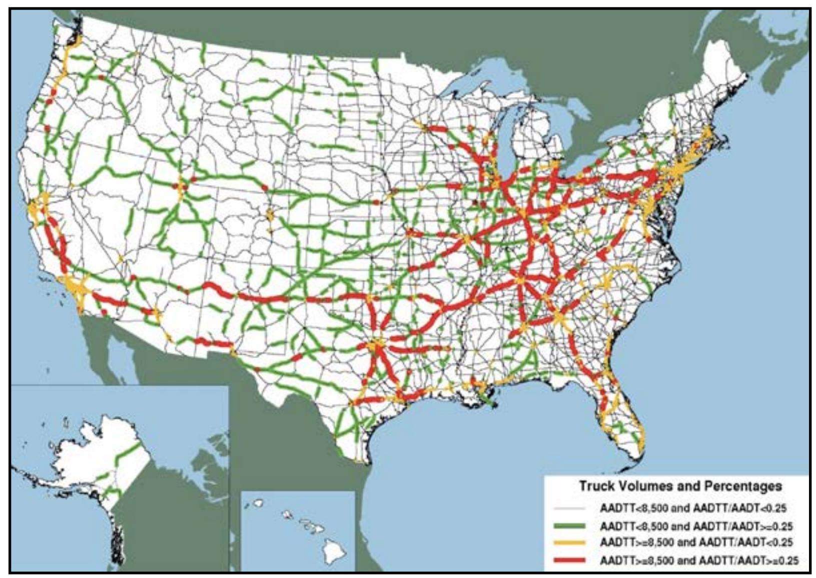

Figure 5. *Annual Average Daily Truck Traffic on the NHS.* (SOURCE: U.S. DOT, FHWA, OFFICE OF FREIGHT MANAGEMENT AND OPERATIONS, FREIGHT ANALYSIS FRAMEWORK, VERSION 3.1 2010)

local economic generators. Others serve as important evacuation routes, provide connectivity to defense facilities, provide non-redundant access routes to locations and serve the safety needs, such as, being the only bridge providing connectivity out of a community or section of the state. An example of one may be the famous Highway 1 and its bridges and causeways connecting the Florida Keys with the mainland. On a smaller scale, the Mauckport Bridge connecting Mauckport, Indiana, with Brandenburg, Kentucky, is the only Ohio River crossing in a 60-mile long section of the river. Any risk to that structure creates serious consequences to those rural communities' access and economy.

The Economic Risks to Corridors and Networks

Approximately 12.6 billion tons of freight move across the nation's roadways every year.[ii] With cheaper goods competing for market share, minimizing the delivered cost of goods has become more important, resulting in a lack of appetite to stock inventories and a move towards adoption of "Just in Time" practices. Delays are therefore costly. According to FHWA, the 2,110 freight bottlenecks on highways throughout the United States cause more than 243 million hours of delay to truckers annually. A conservative estimate puts the annual costs to truckers at $6.5 billion per year.[iii] Also, with the continuously increasing cost of fuel, the public has less appetite to be stuck in traffic for long periods. The FHWA "Freight Story" (USDOT FHWA 2008)[iv] notes that Just-in-Time inventory is hampered by congestion and the resulting reduction in reliability and increase in travel times. These delays have an impact on the U.S. economy. Thus, reliable, available and well-functioning roadway networks are important to the efficient movement of freight, a factor critical to keeping cost of products low.

The "Freight Story" estimates that even with growth in air-freight, maritime, and rail services, about 29 percent

of the urban NHS will be congested, with an additional 13 percent approaching congestion, during peak periods in 2020. By comparison, 10 percent of the urban NHS was congested in 1998. By functional class, urban Interstates are and will continue to be the most traveled segments, with congestion reaching 53 percent in 2020.[v] These projections of the peak congestion on the NHS are shown in Figure 6.

It is evident that even within the important NHS, certain urban segments will continue to see higher congestion over the next decade and will become ever more critical to the nation's economy. Hence, loss of asset availability and degradation of services on the nation's highway network clearly presents a risk to safety, mobility, convenience and commerce, all of which are important national goals.

Key transportation corridors, networks and critical facilities will therefore constitute a logical priority as a transportation agency assesses where within the network of assets it manages, the impacts to the economy, safety and key national or regional priorities are most likely to be felt.

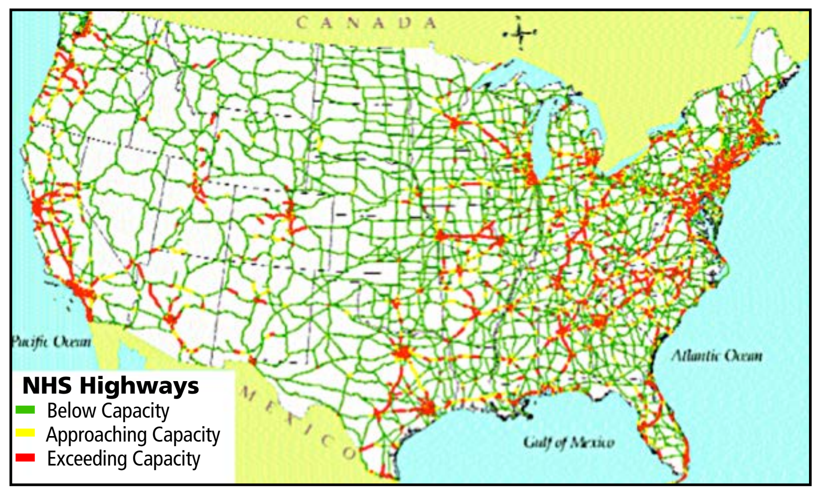

Figure 6. *Projected Peak Congestion on the National Highway System in 2020.*

The Steps for Risk Management of Networks and Corridors

Establishing the Context

The first step in risk management is to establish the context for the organization and the objectives it seeks to achieve. The risks to be prioritized are those most likely to create uncertainty regarding achievement of the organization's objectives.

The International Organization for Standardization (ISO) and other bodies provide the general framework for risk management as illustrated in Figure 7. For transportation asset management, the national goals in MAP-21 combined with state goals and targets provide the context surrounding the management of transportation assets identified in the first step.

Ensuring sound asset conditions allow a network, corridor or facility to achieve its intended objective. That may include public safety, movement of people and freight, national security, moving goods, state or local connectivity, or for achieving environmental or social objectives. Irrespective of the reason, establishing the context helps the prioritization that will be necessary in the risk management process.

Identification of Risks

The second step in the process will involve identifying and prioritizing the major assets and the risks to them. Some of the major assets will be readily identifiable, such as the components of the Interstate Highway System. However, others such as the most at-risk assets on NHS intermodal connectors may be less apparent. As part of the corridor planning effort, an inventory of key assets will be necessary.

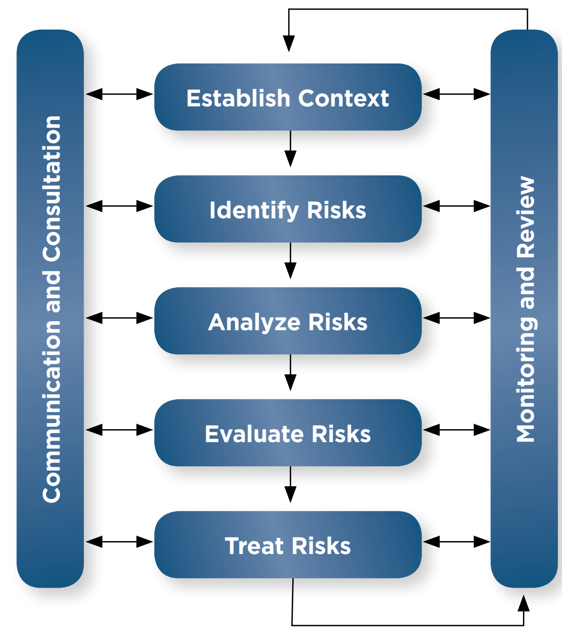

Figure 7. *ISO's risk management framework.*

Once those assets are inventoried, the possible risks to them can be identified. These risks could be possible threats such as increasing traffic loadings, or climatic, seismic or geologic threats. They could also include organizational risks (such as weak internal management systems) or financial risks (such as increasing costs, decreasing revenues and resulting budget constraints).

Risk identification could be based on the probability of asset failure or degradation of performance and the resulting impact to the objectives or goals of the specific network or corridor. The expected impact and the agency's risk tolerance can be factored into determining the type and immediacy of the treatment.

Analysis and Evaluation of Risks

Analysis of risks involves identifying the possible likelihood of a risk or event occurring. The condition and performance of the high priority assets in the network or corridor, in conjunction with the responses can be useful in evaluating the severity of the risk. The following is a sample of some of the questions that may be used in the analysis:

- Are there fracture-critical, non-redundant structures?
- Do the road segments have bridges that are prone to scour or hydrological events?
- Are the road segments subject to seismic events?
- Are there slopes or retaining wall failures possible in geologically unstable areas?
- Are the traffic control devices and Intelligent Transportation Systems subject to regular preventive maintenance to ensure functionality?
- Is there regular maintenance and inspection of tunnels, their lighting, ventilation and emergency notification systems?
- Is the facility subject to flooding, storm surges, and severe winter storm events?

Risks Due to Gradual Failure

Risks to assets may be caused by gradual failures or gradual degradation of asset performance. These can be caused by a lack of sound preservation practices, inadequate asset inventories, a lack of management systems or weak asset management policies to ensure sound long-term performance for the lowest possible lifecycle costs. Examples of such risk include:

- Loss of pavement friction caused by aggregate polishing, flushing, rutting and resulting ponding of water;
- Loss of lane delineation through degradation of lane markings;
- Loss of functionality of key safety devices such as guardrail, crash attenuators and cable barrier through deterioration, such as guardrail post rotting, block deterioration, rust or crashes;
- Potholes and pavement rutting and cracking;
- Degradation of shoulders, leading to drop offs and roadway department crashes;
- Loss of reflectivity or visibility of regulatory and advisory signs;
- Failure of drainage systems to remove water from roadway surfaces;
- Weakening of parapets from rust or concrete spalling;
- Structures can pose a risk of lost structural integrity if key components such as expansion joints, bearings, rockers, and drainage devices are allowed to fail which accelerates bridge degradation;
- Mechanically Stabilized Earth walls degrade if drainage erodes the internal structural fill;
- Failure to seal bridge decks risks loss of deck integrity;
- Poorly maintained components such as wing walls and riprap can risk the performance of a structure during storm events.

Risks of Increased Economic Cost

Risks to a network or corridor can also be considered from a perspective of sustaining it in fully functioning and good condition at the lowest possible life-cycle cost to preserve its long-term value. A sound pavement that is properly maintained has more value for society than a structurally poor pavement. A risk management perspective is to apply proactive preservation and maintenance strategies to sustain the performance and condition of the assets for the longest period economically possible.

The Rhode Island Department of Transportation struggled for more than a decade to reduce its high number of bridge deficiencies. It has replaced several high-value structures and has recently adopted its first bridge preservation program for its Interstate Highway System bridges. While it would like to have a statewide preservation program, it has taken a risk-based approach to applying limited preservation funds to ensure the long-term value and performance of its most critical structures, those on its interstate highways.

Prioritization of Environmental Considerations

A network or corridor's assets can be prioritized by their criticality to the successful functioning of the corridor or by additional social objectives important to the state. For instance, risks could be assessed by their likelihood of violating social or environmental requirements. Examples include:

- Adverse noise or localized air quality impacts on minority and low-income populations in violation of environmental justice objectives;
- Failure of retention and detention ponds that create excessive runoff that erode streams and water ways;

- Failure of water quality best management practice devices that lead to increased "first flush" of roadway pollutants into water ways;
- Failure to maintain hydrology in created wetlands that violate environmental document or water-quality permit standards;
- Drainage practices that violate water-quality or habitat requirements;
- Failure to manage salt storage or garage facilities that lead to excess salt runoff or the improper runoff of controlled materials from maintenance facilities.

In the advanced risk management practices of the highway agencies in Victoria, Queensland and New South Wales, Australia, the risk of violating environmental requirements is viewed as a significant agency risk that is carefully monitored. Likewise, for U.S. highway agencies whose facilities impact sensitive resources or populations, the identification of environmental or social risks can serve to highlight the agency's sensitivity to sound stewardship.

Treatment of Risks

The final step in the risk-management process is the identification of how to treat the identified risks. The "five Ts" of ***treat, tolerate, terminate, transfer or take advantage of,*** provide the menu of choices for each risk.

The comprehensive evaluation of all risks allows the holistic mitigation of risks to the network or corridor, rather than the mitigation of risks to individual assets or groups of assets within them. While trade-offs may be made at the functional class level as described earlier, agencies may also decide to make trade-offs between assets ***within*** a corridor, so as to focus first on those assets that are most critical. This approach will facilitate a holistic approach to mitigation.

Examples of Risk Management of Corridors

Agencies may choose to further prioritize networks by putting additional weight to certain especially important corridors within the networks. As they prioritize their routes that serve critical industries or supply chains, ones that are particularly important for emergency evacuations or which carry disproportionately large volumes, they may choose to place additional weight upon certain network links or corridors.

Published data illustrating holistic risk management of corridors is limited. However, in addition to the examples illustrated previously, several more examples of risk management of corridors are available and have been included here. These examples illustrate how agencies have implemented formal plans that address several of the strategies discussed in this report.

Risk Management in Michigan DOT

Loss of Asset Value—A Risk Analysis

A very important example of using asset inventories and management systems to help analyze and prevent risks to the transportation system can be seen in the analysis and reports provided by the Michigan Transportation Asset Management Council (TAMC), a legislated council with representatives from agencies responsible for managing or funding roads. The TAMC coordinates the collection, analysis and reporting of data on asset conditions and investments to Legislature and the State Transportation Commission.

Figure 8 shows the TAMC analysis of the 2010 Pavement Condition on the Federal Aid system. It indicates that a third (over 20,810 lane miles) of the system is in poor condition. Figure 9 shows the trend of "poor" pavement conditions increasing over the years. The TAMC report[vi] discussed this trend of increase in poor pavements as having a significant economic and financial impact. The report also urges action to ensure that this trend be reversed, as returning poor roads to good condition costs four to five times more than maintaining a road in fair condition.

2010 Pavement Condition *(Federal Aid)*

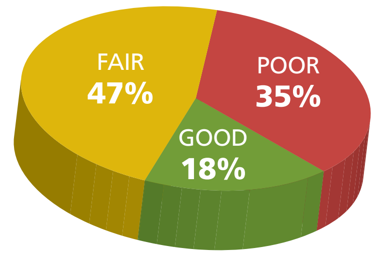

Figure 8. *Pavement Condition on Federal Aid System.*
(SOURCE: TAMC 2010 PASER DATA COLLECTION)

Discussing the lane miles in poor condition the report notes that the dramatic decline is resulting in need for structural improvements. From 2004 to 2010 the percent of lanes needing structural improvements has doubled to 34.8 percent. The TAMC discussing the transportation funding crisis notes that the Michigan's Transportation Fund's (MTF) total gross revenue levels have declined as shown in Figure 10. Because of a reduction of $200 million in reduced gas tax revenues dedicated to roads and bridges over the last seven years, without additional funding, the system conditions will continue to decline. Additionally, without state match, federal gas tax collected in Michigan would be lost to other states.

Michigan DOT and the TAMC are using the asset data, condition and analysis information to present the case of the

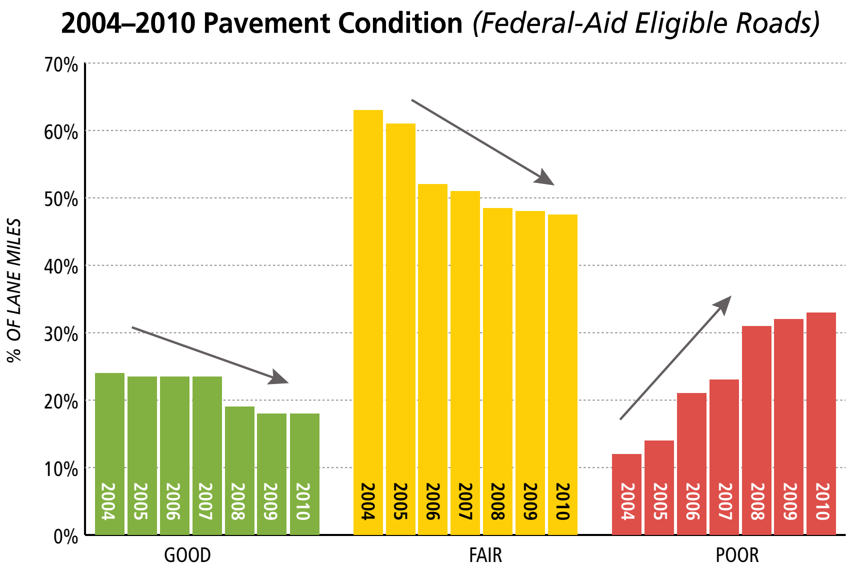

Figure 9. *Pavement Condition Trends.* (SOURCE: MDOT)

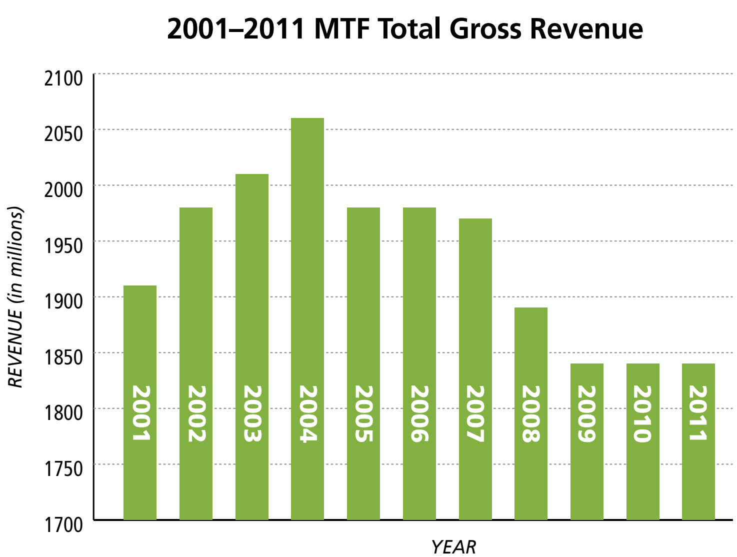

Figure 10. *MTF-Total Gross Revenue Level.* (SOURCE: MDOT)

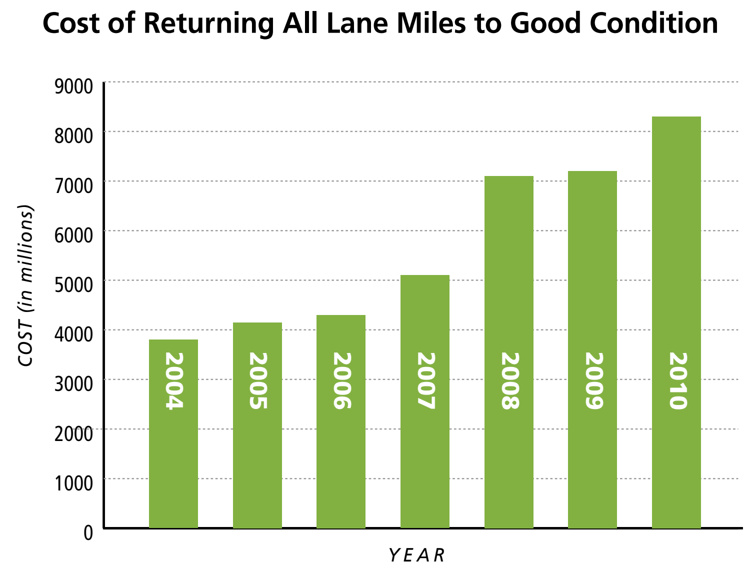

Figure 11. *Cost of Returning All Lane Miles to Good Condition.* (SOURCE: MDOT)

impending financial and economic risk that needs to be averted. The analysis in Figure 11 shows the cost of deterioration almost doubling from 2004 to 2010 and highlights the risk of loss in value of the road assets without immediate injection of funds to address system needs. In presenting this analysis, the TAMC is emphasizing the impact of deterioration, and the need for funds and good asset management practices to help prevent the risk of such loss in value.

Risk Management of I-94 Corridor

Over the last several years Michigan DOT has been dealing with the insufficiency of funds to address degradation of aging transportation infrastructure assets. The agency continuously analyzes the degree and impact of risks to assets as it makes trade-off decisions. Such trade-offs mean minimizing the risks to the more heavily traveled and highest priority roads. One such example can be seen in the risk management of the heavily traveled I-94 corridor.

In September 2010, to manage the risk of safety and reliability in travel through the I-94 corridor and to promote economic vitality of the region, Michigan DOT established the ***I-94 Corridor Operations Partnership.*** The partnership also had the objective of coordinating activities to provide a high quality transportation system and travel experience. As part of this effort, the agency is investing approximately $51 million in Wayne and Macomb counties to do resurfacing, repairs and other extensive improvements to bridges, overpasses, pavements, ramps and other roadway assets such as lighting. In addition, the agency is also implementing several operational strategies.

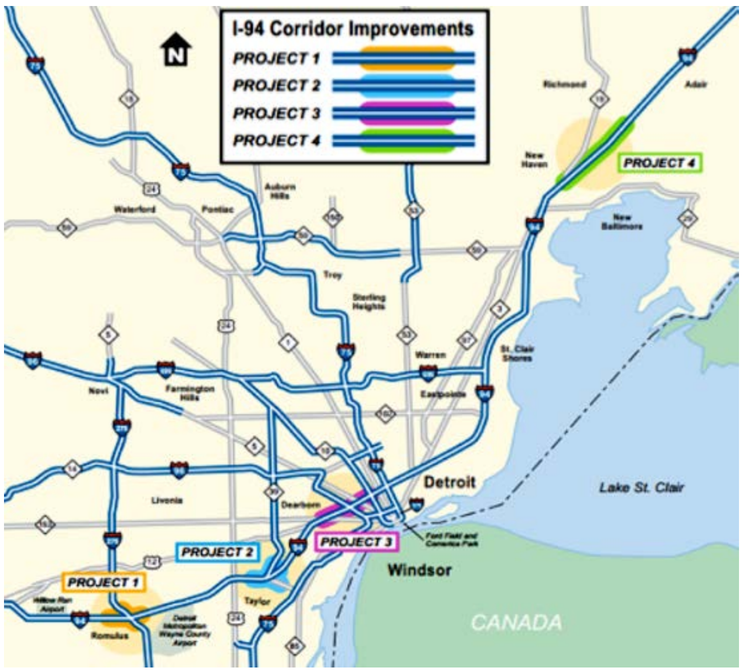

Figure 12. *Michigan DOT's I-94 Corridor improvement projects.*
(SOURCE: MDOT)

The MDOT goals for this corridor include:

1. To improve work zone standards, implementation, and coordination so that customers' experiences traveling through the corridor are consistent and reliable.

2. Improve work zone operations and manage delays so that customers' needs for reliable and realistic travel times are achieved.

3. Improve customer communication—information to the motorists and feedback from them to ensure the motoring public has quality and timely information to guide their travel decisions and to ensure that MDOT is accurately and consistently meeting or exceeding customers' needs and expectations.

Managing risks to multiple assets and operations to ensure the safety and reliability of the corridor requires extensive planning. It also requires coordination among multiple state and local agencies. All project work on the corridor is closely coordinated and monitored. To ensure safety and reliability of travel on the corridor, travel delays are closely tracked and treatments are implemented to keep delays below the established Corridor Delay Threshold. Other examples of risk management of the corridor include:

- Detailed procedures for lane closures;
- Providing minimum travel width (11 feet minimum) during construction on the corridor;
- Providing additional flexible or other delineators when paved shoulders (2-feet minimum) cannot be obtained.

The agency also has strategies for maintenance of traffic on the corridor. Work zone operations, incident management and messaging in the corridor are managed actively.

Enhanced Mile Markers are installed throughout the corridor to improve incident identification and emergency response. By identifying the potential asset and operational risks, the agency has been able to successfully implement strategies to minimize delays and improve the safety and reliability of travel on the corridor. These strategies involve establishing allowable limits for travel time delays (TTD) through the I-94 corridor within the state and then monitoring the TTDs over segments of the corridor by ensuring that the predicted delays (in a worst case scenario) are kept below the allowable limits. The TTDs are kept within allowable limits through a combination of revising (i) specific project implementation schedules and (ii) traffic maintenance strategies.

Figure 13 shows the three segments of the I-94 corridor (each segment containing several projects), the allowable TTDs for each segment and the predicted TTDs for each segment. It is seen that while the predicted TTDs are well below the allowable limits for the first segment, the values in the

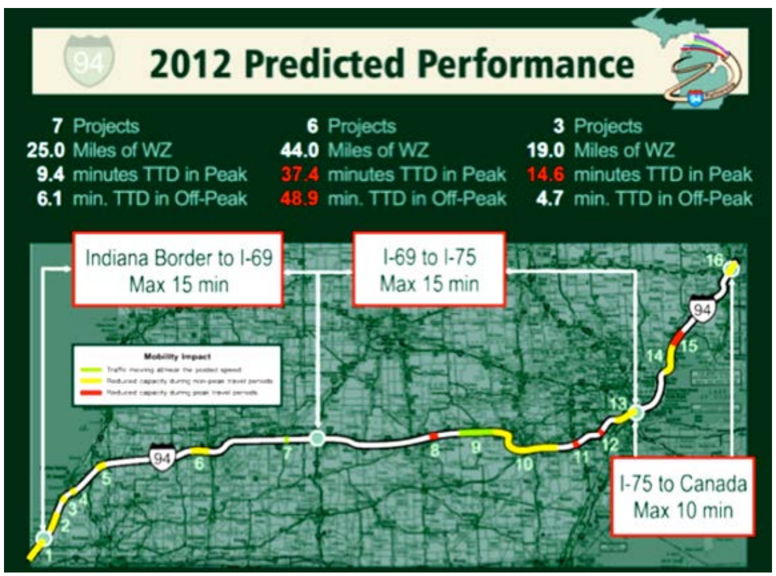

Figure 13. *Predicted and allowable TTDs for various segments of the Michigan I-94 Corridor.* (SOURCE: MDOT)

second and third segments exceed the allowable limits for either peak or off-peak periods, necessitating an implementation of one or a combination of the strategies listed previously to keep the TTDs within allowable limits.

This is one example of how the DOT applied risk-based management strategies to invest and manage the performance and condition of an important corridor segments on I-94.

Risk Management in Florida DOT

Risk Management of the Strategically Important I-95 Corridor

In Florida, the I-95 corridor is considered a critical transportation facility, providing for the movement of people and goods along the east coast of Florida.[vii] Half of the 32 Fortune 1000 companies in Florida are located along the I-95 corridor. Hence managing the risks to this corridor is a high priority for the DOT. The I-95 corridor is part of the Strategic Intermodal System that serves facilities including major airports, intermodal freight-rail terminals, passenger terminals, seaports and a spaceport.

The Florida House Bill 1021 required that the DOT, in consultation with several other agencies within whose jurisdictional areas the I-95 corridor lies, work to *"complete a study of transportation alternatives for the travel corridor parallel to Interstate 95 which takes into account the* ***transportation, emergency management, homeland security, and economic development*** *needs of the state."* The study was to identify "cost-effective measures that may be implemented to alleviate congestion on Interstate-95, facilitate emergency and security responses, and foster economic development." Also, the Florida Administrative Code requires the twelve I-95 Corridor counties to develop a Comprehensive Emergency Management Plan that implements a framework to deal with emergencies and disasters.

The I-95 corridor is heavily used, so the impact of asset failures or other risks can be significant. Law enforcement officers perform traffic enforcement along the entire corridor, monitoring speed and movement of trucks and other vehicles to minimize crashes and incidents.

Risk Management for the DOT includes being prepared to address hazardous materials incidents and manage large volumes of traffic during emergencies. It requires that during emergencies, in the event that the I-95 corridor is damaged or impassable, alternate routes are available and usable. This means managing the performance and condition of these alternate routes throughout the year. The 2010, I-95 study of alternatives also illustrated that alternative transportation routes and modal choices need to be considered by 2035 to accommodate the growing demand. It states that *"I-95 even at build-out, will not be operating at acceptable levels" and "parallel facilities may be facing a similar outlook."*

As part of this process, Florida DOT is implementing many capacity improvements, lane management, developing or augmenting alternate routes and managing the current capacity innovatively. Multiple studies have been completed and additional studies of various segments of the I-95 are currently in process.

One of the strategies being used by the DOT involves innovative lower cost options such as converting two existing HOV lanes to two express lanes. This will extend the 95 Express from Golden Glades Interchanges in Miami-Dade County to Broward Boulevard in Broward County. Variable priced tolling that adjusts to congestion levels and encourages carpooling and travel during non-peak hours is used on 95-Express. The construction will cost approximately $106 million and will include reconstruction of pavements, work on inside and outside shoulders, work at the Ives Dairy

Interchange, widening bridges, installing noise walls at specific locations and various ITS work.

Various alternatives for approximately 13.5 miles of I-95 between State Road 816 (Oakland Park Boulevard) in Broward County and State Road 808 (Glades Road) in Palm Beach County are currently being studied.

The I-95 project along the Treasure Coast, shown in Figure 14 includes over $160 million dollars of projects that involved adding lanes in each direction, adding noise walls, widening bridges, milling and resurfacing existing pavements, upgrading multiple interchanges, reconstructing ramps, upgrading signals, minor widening and adding new lights throughout the corridor segment.

The Florida DOT example illustrates the strategic approach taken by the DOT to identify, evaluate and develop plans to manage current and future risks to the I-95 corridor. This has resulted in the understanding that long-term risk management

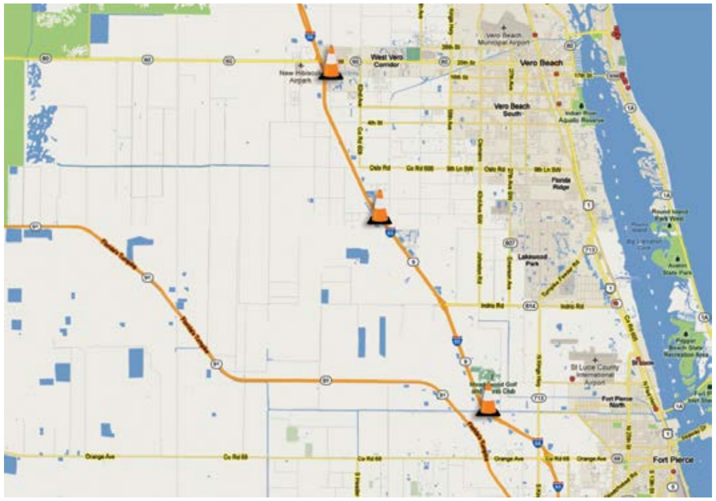

Figure 14. *The I-95 Treasure Coast highway in Florida.*
(SOURCE: GOOGLE)

will have to consider not just increasing the capacity of I-95 where possible and those of parallel facilities, but also ensuring that alternative routes and other modal choices become readily available.

Managing Risks Due to Hurricanes

Risk management of corridors and other heavily used roads in Florida include both operational and non-operational strategies. Several risk mitigation strategies relating to roadway assets were used by the Florida DOT in 2004, when in a span of seven weeks, the state was hit by four hurricanes. The agency later studied its response to the events and refined the risk mitigation strategies used to minimize the impact of such events in the future.

The risk mitigation included ensuring that the transportation assets are in good condition and do not fail during a natural event. It also included planning for mobilizing other assets and implementing operational strategies to minimize safety risks to the public. These strategies included suspending tolling and facilitating the exit and entry of traffic on toll roads, deploying portable message signs to clearly mark detour routes, having emergency contracts for repair and cleanup, deploying generators to every major intersection, redesigning the traffic signal control cabinets at intersections for generator connection, use of stop control where generator power is not available, use of light emitting diode signal heads and revising the wind speed criteria for critical signs and miscellaneous structures.

Management Systems Aiding Proactive Risk Management of High Priority Assets

Proactive management of risks to assets is one of the highest priorities in FDOT. The Florida DOT uses an in-house management system called "Florida's Analysis System for Targets" to track pavement conditions. The DOT uses over 35 years of historical pavement condition data to predict future

pavement performance at a system level. Using available data, the agency analyzed and studied the impact and relationship of several variables including truck volume, average daily traffic, geographic location, asphalt thickness, and surface type to performance. Using the analysis, the agency determined the variables that had the greatest correlation to pavement performance and used it to develop reliable pavement deterioration models. Statistical analysis revealed that the geographic district where the roadway was located, along with the surface type (open vs. dense) were the most reliable factors in predicting future pavement performance. There are separate graphs for open and dense graded pavements. The statewide performance is simply an aggregation of these graphs. By knowing the performance characteristics of each district, FDOT can apply an expected performance curve to each individual roadway.

Figure 15 (see next page) shows the pavement deterioration curves by district for cracks on dense graded surfaces. Similar deteriorations curves are generated for open-grade surfaces as well for other factors such as smoothness and rutting. The predicted risk to the pavements based on the analysis enables the DOT to make financial decisions and to accurately allocate funds based on expected future needs. For example, if District 1 is projected to have 10% of the statewide deficiencies in 2016, it will be allocated 10% of the total statewide resurfacing monies for that year. The agency process takes three years to get from the point where a project is initially identified as a resurfacing candidate until it is let for construction. The process is detailed and all resurfacing greater than ½ mile in length goes through design and construction. The reason for this is that the agency views the resurfacing projects as the opportunity to systematically upgrade its corridors. The resurfacing projects involve not only making improvements to the roadway surface, they also upgrade the roadway geometry, operational characteristics, signing, signals, drainage, and safety.

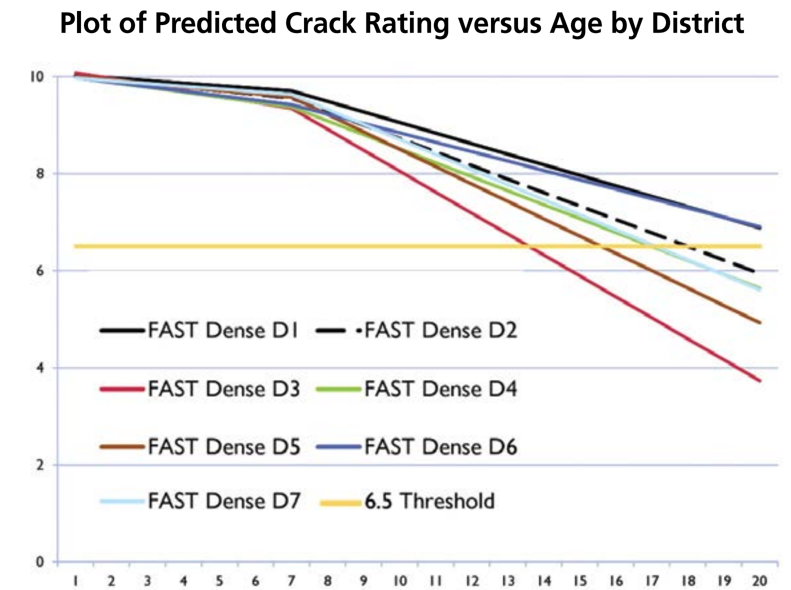

Figure 15. *Predicted Crack Rating by District for Dense Graded Surfaces.* (SOURCE: FDOT)

In general, the agency uses Resurfacing, Rehabilitation and Reconstruction (3R) projects to upgrade the entire corridor. These upgrades are not intended to meet new construction criteria, or to give a community all of the bells and whistles. The upgrades included are typically necessary to maintain what the agency considers to be the minimum level of safety and function. Once a 3R project has touched a particular segment of roadway, there is a very good chance that FDOT will not make significant improvements to that roadway again until the next 3R project comes along. The driving factor in when to perform one of these projects is the condition of the pavement.

The agency has invested heavily in asset management and in collecting and managing its pavement condition data. The analysis of the historical data enables the agency to make funding decisions about pavement preservation activities

five years into the future. Because of the amount of engineering work that goes into a typical resurfacing project, the projects are actually identified and selected three years in advance and have a longer planning cycle than may be common in other DOTs.

Figure 16 shows how predicted future pavement performance is used to make funding decisions. The green line shows the DOTs statutory requirement—to keep a minimum of 80% of the state's pavements meeting the Department's minimum standards. In May of 2012, over 90% of the state's pavements met FDOT's minimum standards. The current policy (in May 2012), shown in blue, was to resurface 5.5% of the state's highways annually. That policy was predicted to result in performance that would exceed 93% by 2020 and remain at a level below 95% through 2035. The analysis indicated to the upper management that the DOT was over-preserving the system and the effort on resurfacing be

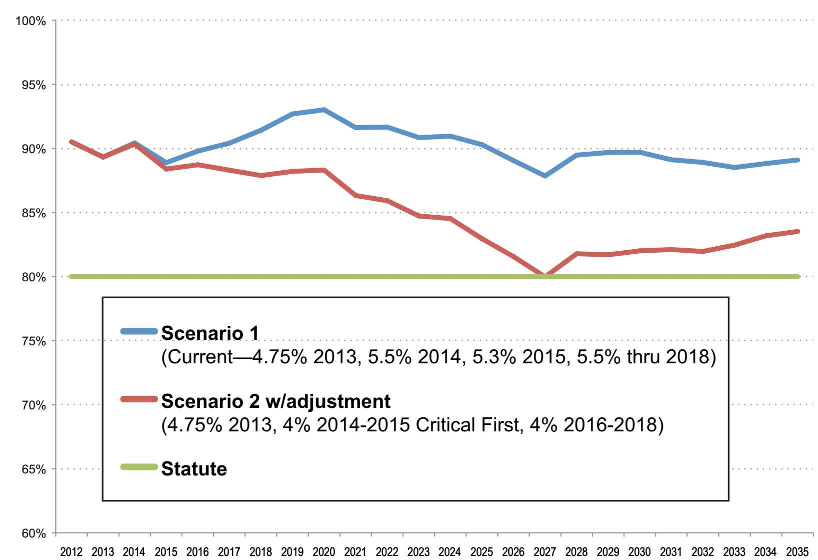

Figure 16. *Forecasted Scenarios of Pavement Performance* (SOURCE FDOT).

lowered a bit. This resulted in a decision to resurface 4.0% of the system annually through 2018, with a return to 5.5% in 2019 (revised policy, shown in red). The agency is currently pursuing this revised policy that is projected to bring the system performance back below 85% by 2023. Agency leadership reviews the risks to the performance and condition of the system regularly and re-evaluates strategies to make strategic decisions.

Risk Management in Washington DOT

Risk Management—A Routine Tool for Efficient and Effective Action

Washington DOT (WSDOT) is another DOT that is actively implementing risk-based asset management practices. With limited resources at their disposal agency personnel are focused on managing their risks "efficiently and effectively". Figure 17, shows the agency's tracking of the Gas tax purchasing power declining over time. As one of the lead DOTs implementing risk-based asset management, WSDOT has

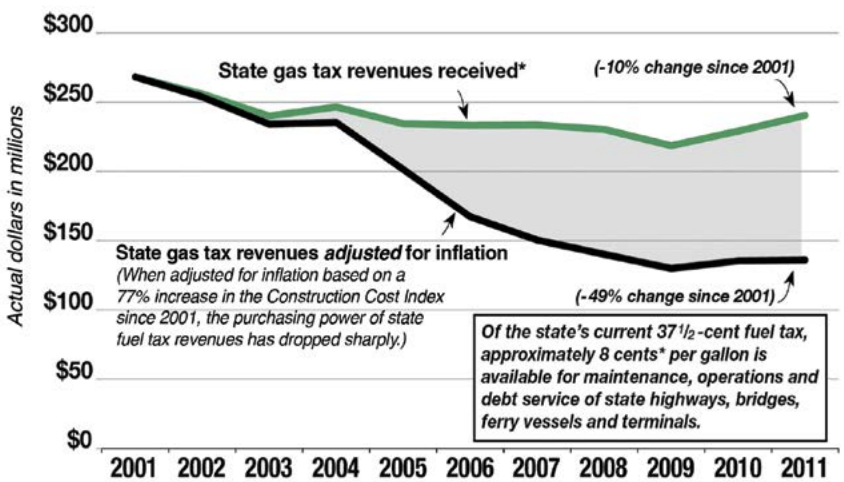

Figure 17. *Gas Tax purchasing power declines over time.* (SOURCE: WSDOT).

been educating agency personnel, its policy makers and the public for many years on how decisions relating to one program or subprogram can affect those in other programs. With limited resources, investing more in one program would mean a reduction in others. This situation inherently requires the DOT to prioritize and manage risks across all programs effectively. With aging infrastructure, natural disasters and the need for economic growth vying for limited resources, risk-based decisions have become routine for the DOT.

Decision Making to Minimize Risk of Catastrophic Failures

To effectively manage its infrastructure assets with the limited funds available, WSDOT tracks and forecasts potential risks to assets. Based on the classification, age, conditions, performance and projected risk to assets, the agency develops and implements various strategies. Figure 18 shows an example of the projected risk of catastrophic failure over

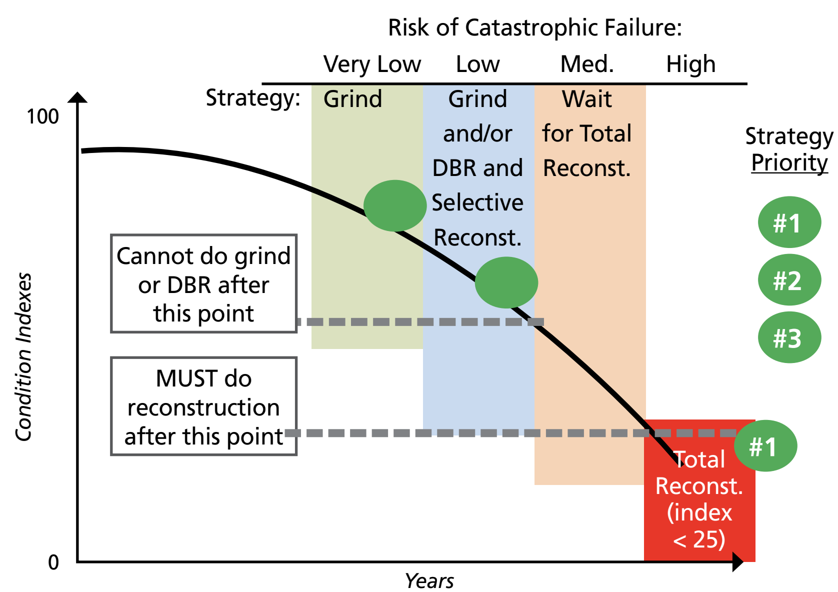

Figure-18. *Risks of Catastrophic Failure for Concrete Pavements.* (SOURCE: WSDOT) the years for concrete pavements and the strategies that the agency deploys for the different levels of risks. The agency has also strategically used crack sealing and lower cost preservation options such as chip sealing on lower classification roads without compromising on asset performance.

Managing Risks to High Priority Corridors

An example of the WSDOT's approach to managing risks to high priority corridors can be seen in the creation of "Lifeline Seismic Routes". WSDOT has programs that cost effectively address seismic risks and risks relating to, scours, concrete deck, and other major repairs. To address seismic risks, WSDOT, in collaboration with other state and federal agencies, is tracking "Peak Ground Acceleration Contours" associated with earthquakes. With limited available funds and the resultant inability to address all seismic risks at one time, WSDOT has created a ***lifeline set*** of routes that will provide ***emergency response in the highest ground motion acceleration zone*** (see Figure 19). Bridges on routes have been

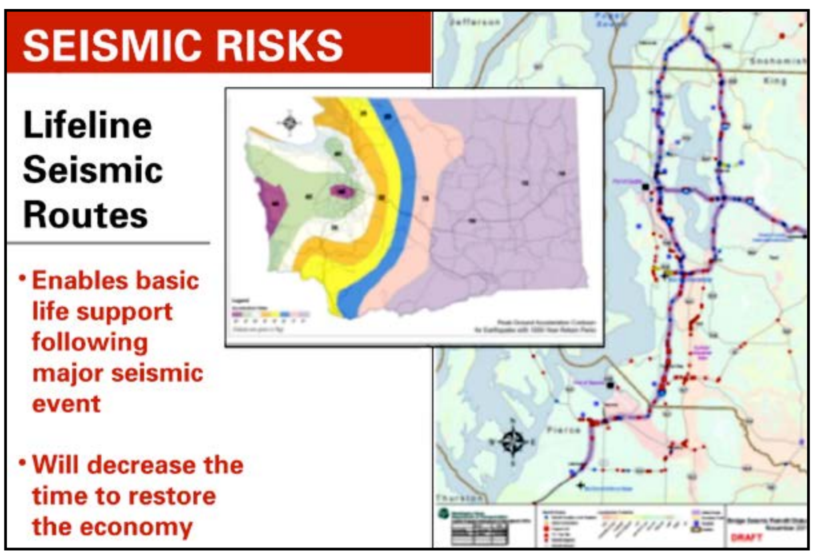

Figure-19. *Lifeline Seismic Routes.* (SOURCE: WSDOT)

categorized based on Average Daily Traffic. WSDOT has detailed plans that consider route recovery time based on whether the bridge carried state route traffic, or carried traffic over the state route. The plan gives higher priority to bridges that carry state route traffic as against those that carry traffic over the state route. According to the WSDOT's Seismic Prioritization Plan, 2013-2015, "WSDOT's *disaster response plan includes provisions for receiving emergency supplies/personnel at Joint Base Lewis-McChord Air Force Base near Tacoma, Seattle International Airport and/or Paine Air Field in Everett, and transporting them throughout the region via the Lifeline Route on Interstate-5 and Interstate 405.* WSDOT further divided the interstate routes into segments between major junction points in order to determine the cost to retrofit each segment and identify the most cost effective path between McChord Air Force Base and Paine Field. *Thus, retrofitting Interstate-5 & Interstate 405 bridges between McChord Air Force Base and Paine Air Field is a top priority for the bridge seismic retrofit program.*"

Risk of Financial Loss and Economic Impact Due to Natural Disasters

Washington DOT also understands the financial risks and economic impacts that the loss or unavailability of infrastructure assets can have on the business in the state. The state of Washington has historically been experiencing other natural disasters such as floods and avalanches. These have led to closures of the I-5 and I-90 corridors within the state and caused moderate to severe impacts to businesses in the region as can be observed in Figures 20 and 21 (see next page).

To minimize future impacts from similar occurrences, the agency has established detailed risk management and mitigation strategies that are implemented during events. After such closures occur, the DOT studies the effectiveness of the strategies implemented with the intent to improve and refine

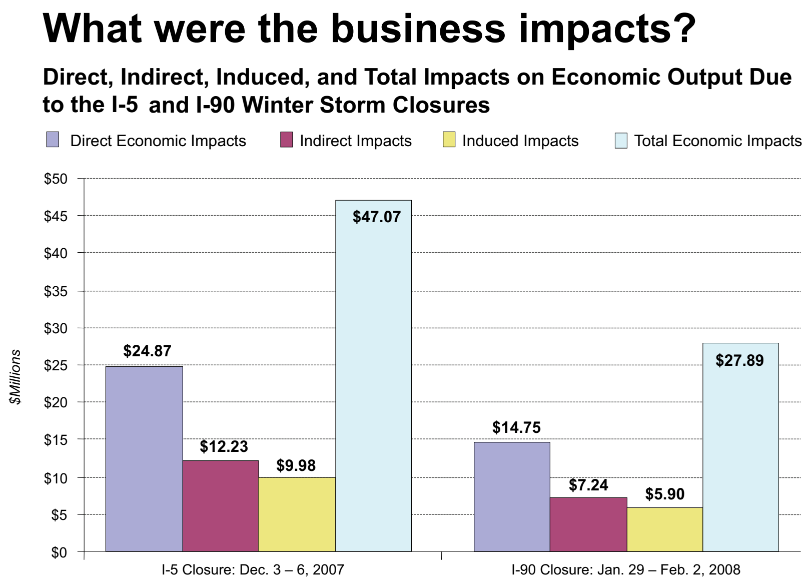

Figure 20. *Business impacts from 1-5 and I-90 winter storm closures in the 2007-2008 season.* (SOURCE: WSDOT)

them. One such study was done after the closure of Interstate 5, south of the Ports of Seattle and Tacoma, near Chehalis, Washington in December 2007 due to flooding. Several feet of water overtopped the interstate for five days and resulted in the stoppage of all passenger and freight movement. The flooding was caused by a series of significant weather systems that also closed all East-West corridors through the Cascade Mountains including the I-90 corridor in December 2007 due to heavy snowfall and avalanches.

The agency developed a detailed detour plan that is implemented in the event that I-5 has to be closed because of rain, snow or other reasons. To address the closure of the eastern side of the state on I-90 in the vicinity of the Snoqualmie Pass, the DOT identified a vision for additional lanes to be added, segments of the roadway to be moved away from the steep avalanche slopes and lengthening the area for vehicles to chain up.

Additional risk management strategies identified as a result of this study included the need to provide safe parking to truck drivers stranded due to storms and other natural events. These drivers are mandatorily required to rest for 10 hours after 11 hours of driving. This strategy ensures that when stranded drivers are unable to find parking, they do not park along shoulders and freeway ramps causing safety risks.

WSDOT is working with multiple agencies to develop a long-term vision for the I-90 corridor along a 15-mile stretch between Hyak and Easton. The Environmental Impact Statement that resulted from this effort outlines improvements needed to meet projected traffic demands, improve

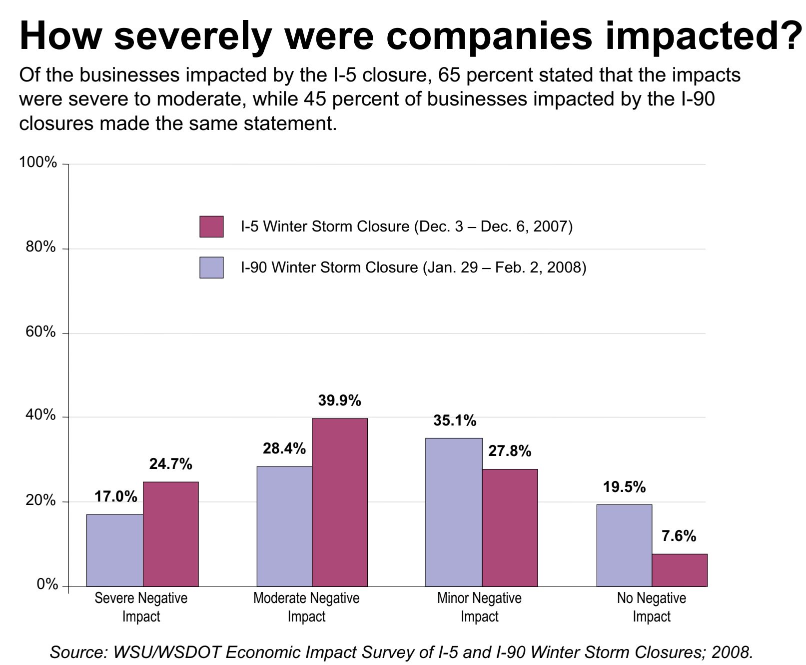

Figure 21. *Severity of business impacts from 2007-2008 winter storm closures on 1-5 and I-90.* (SOURCE: WSDOT)

public safety, and meet identified project needs for this stretch of the I-90 corridor.

WSDOT anticipates that when all improvements are completed, travelers will experience a safer and more efficient six-lane freeway. Closures resulting from avalanches and rock slides will be minimized and a new pavement designed to last 50 years will provide a smoother ride. Further, by installing new bridges and culverts, WSDOT will reconnect wildlife habitat on both sides, thereby protecting both wildlife and the traveling public.

While applying performance management to all its assets and operations, WSDOT uses risk-based management approaches to identify the network locations that are below the performance goals established by the Legislature. Considering the risks, the agency then uses lower cost preservation and maintenance strategies to improve or maintain the performance of existing assets while still addressing congestion and economic development issues for which all lower cost alternatives have been exhausted.

The DOT has a holistic corridor risk management plan that address critical asset condition and performance needs. These also address capacity and operational strategies that present risks to corridors. Risk management has become a routine activity for WSDOT.

Conclusions

The national experience demonstrates that the risk-based asset management of transportation corridors can be a valuable tool for transportation agencies nationwide. It provides transportation agencies a mechanism to positively impact the safety, condition and performance of a larger number of assets and the traveling public in a strategic and holistic manner while enabling the optimal utilization of

increasingly limited resources. Several conclusions can be drawn from this experience. These include:

- Networks, corridors or segments of corridors primarily involve prioritized functional classes of assets such as the National Highway System or heavily used roads that serve a majority of the traveling public nationwide. They also involve other critical transportation assets, such as, evacuation routes, non-redundant access routes, connectivity to defense facilities or other important assets critical to national security or connections between economic hubs within a region. Risk management of such a grouping of assets allows transportation agencies a means to facilitate the improvement of safety, condition and service level of a larger number of assets in a manner that maximizes the positive impact to users.

- Risk management of networks and corridors provides an opportunity to implement the strategic best use of resources, thus maximizing the outcome from limited resources in tough economic times. In the current difficult global economic climate, governments and DOTs are reeling under the burden of ageing infrastructure and ballooning operational service level requirements. These necessitate increasing amounts of investments to meet the safety needs and expectations of the traveling public and various stakeholders including businesses. At the same time, agencies are being challenged by declining tax revenues. This imbalance has forced governments and agencies to find creative solutions to optimize the use of resources. Risk management at the corridor level expands the logic to apply to a larger and more critical grouping of assets and thus provides one means to receive *"the biggest bang for the buck".*

- When optimizing with limited resources, transportation agencies will need to make trade-offs. Making trade-offs can result in having to accept lower performance levels on lesser-used assets. However, transportation agencies are keen to ensure this does not mean a universal reduction in performance standards to unacceptable levels. Instead it can represent a risk-based shifting of priorities, whereby the lesser used assets still maintain an acceptable, though lower, level of service while the condition and performance of major networks and corridors are preserved.

- A formalized process for the risk management of assets at the corridor level allows transportation agencies to communicate to the public, policy makers and other stakeholders that the strategies being implemented by them represent a well-thought out and methodical approach to decision-making and demonstrate that they are responsible stewards of the region's transportation assets.

ENDNOTES

[i] U.S. Army Corps of Engineers U.S. Waterborne Container Traffic by Port/Waterway in 2007

[ii] FHWA Freight Facts and Figures, Tables 2-1 and 2-1M. Weight of Shipments by Transportation Mode: 2007, 2010, and 2040, accessed at http://www.ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/11factsfigures/table2_1.htm, Nov. 12, 2012

[iii] FHWA, Freight Operations and Management, The Freight Story 2008, accessed at http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/costs.htm

[iv] The Freight Story, FHWA, accessed http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/demands.htm

[v] http://ops.fhwa.dot.gov/freight/publications/fhwaop03004/congest.htm

[vi] Transportation Asset Management Council, "Michigan Roads and Bridges 2010 Annual Report"

[vii] I-95 Transportation Alternatives Study, dated June 2010

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FHWA-HIF-13-017